Index

Abstract....4
Introduction....6
Chapter 1 Energy policies....8
1.1. The European Union Framework.... 15
Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC [OJ L315 p.1].... 15
Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast).... 56
Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC.... 88
1.2. The Italian Framework of the Energy Laws in the building sector.... 100
D.Lgs. 28/11.... 100
Legislative Decree No 192 of 19 August 2005, Presidential Decree No 59 of 2 April 2009, Decree of the Ministry of Economic Development of 26 June 2009.... 102
1.3. The technical laws.... 105
The ISO 13153:2012 "Framework for the design process for energy savings single family residential and small commercial buildings.... 105
The UNI TS 11300-1/2 3-4.... 106
Chapter 2 State of the art....108
2.1. Net Zero Energy Buildings: a look at the definitions.... 108
2.2. Discussion of new net zero approach.... 115
2.3. Criteria to define a Net Zero Energy Building.... 129
2.4. Net ZEB balance.... 134
2.4.1 Framework for Net ZEB definitions.... 135
Chapter 3 A review of the existing case studies....156
3.1. The influence of the climate.... 156
3.2. Examples.... 158
3.3. The energy targets: passive solar energy concepts.... 271
Chapter 4 How to achieve the Net Zero Energy goal....276
4.1. Energy Efficiency as a starting base.... 276
4.2. Energetic targets.... 281
4.3.Target Groups For Indicators....282

4.3.1 Audience interested in quantitative indicators....................................... 283
4.3.2 Review of LMGI indicators.. 285
Chapter 5 From a Net Zero CO_2 Emission Home to a Net Zero Energy Home: an Italian case study, the Leaf House 290
5.1. Site and Climate 296
5.2. Building Envelope 297
5.3. Thermal Plant.. 300
5.4. The monitoring System.. 311
5.4.1 The Leaf Monitoring and Building Automation System........................ 321
Chapter 6 How to cover the Gap between Production and Consumption.....................324
6.1. The building energy performances 324
6.2. The dynamic simulations: TRNSYS.. 327
6.3. The building model: Type 56 and TRNBUILD ambient.............................. 345
6.4. Calibration of the model 374
6.5. Results.. 379
6.6. Single day analysis... 387
Chapter 7 Different Scenarios to achieve the Net Zero Energy target 408
7.1. Scenario 1: More efficient photovoltaic modules... 411
7.2. Scenario 2: A more efficient GHP 412
7.3. Scenario 3: A different Thermal plant layout 413
7.4. Scenario 4: Combining different retrofit hypothesis 414
Chapter 8 Conclusions...416
Annex I The IEA/ECBS/Task 40 Programme..419
Annex II The BUI file created by TRNBUILD...427
References 446
Chapter 1 446
Chapter 2 446
Chapter 3 449
Chapter 4 450
Chapter 7 450

Ringraziamenti

Tutto il lavoro illustrato nelle pagine che seguono è stato svolto grazie ai preziosi insegnamenti e alle opportunità di studio e di analisi fornitemi dai Docenti del Dipartimento di Energia, Ingegneria dell'Informazione e Modelli Matematici (DEIM) dell'Università degli Studi di Palermo: Prof. Maurizio Cellura e Prof. Valerio Lo Brano.

Un particolare e sentito ringraziamento è rivolto al Prof. Maurizio Cellura per avermi trasmesso, nel corso degli anni di Dottorato, la metodologia di lavoro, la rapidità e la capacità di affrontare problematiche diverse nonché per avermi dato l'opportunità di sviluppare un tema di ricerca di valenza scientifica internazionale in seno al Programma Energy Conservation in Building Systems/Annex52 Solar Heating and Cooling/Task 40, nell'ambito del quale sono stati presentati i risultati ottenuti durante gli anni di svolgimento del Dottorato.

Ringrazio altresì il Prof. Valerio Lo Brano, tutor didattico all'attività di ricerca, per aver fornito suggerimenti critici sul lavoro di tesi e per il supporto scientifico all'analisi dei dati e allo sviluppo del modello di simulazione del sistema edificio-impianto.

Inoltre intendo sottolineare la collaborazione intrapresa tra il DEIM ed il Gruppo Loccioni rappresentato dall'ing. Davide Nardi Cesarini in seno al programma Energy Conservation in Building Systems/Annex52 Solar Heating and Cooling/Task 40, nell'ambito del quale l'edificio di proprietà del suddetto Gruppo è stato reso disponibile come caso studio.

Desidero inoltre ringraziare la mia famiglia per il supporto e la pazienza mostrate.

Abstract

In the last years the concept of Net Zero Energy Building (NZEB) has been developing and spreading in the scientific community. The work presented in this thesis has been largely developed in the context of the International Energy Agency (IEA) joint Programme Solar Heating and Cooling (SHC) Task40 and Energy Conservation in Buildings and Community Systems (ECBCS) Annex52: Towards Net Zero Energy Solar Buildings.

It is known that the energy consumption in Europe for residential and commercial buildings is around 40 % of the total production. It is then extremely important to optimize both the implementation of energy efficiency measures and the usage of renewable resources that can be harvested on site. When energy efficiency measures are successfully combined with on-site renewable energy sources, and the energy consumption is equal (or nearly) to the energy production, then the output achieved can be referred to as “near net zero energy “or “net zero-energy building”. In Chapter 2 a description of the main typologies of NZEB is carried out, revealing that the most important ones are the following: site-ZEB and source-ZEB depending on where the energy balance is calculated. After a brief description of the NZEB most common definitions and classifications many examples have been examined, analyzing their features in relation to the climate in which they are, in order to show different solutions and approaches to the problem of reaching net zero energy balances (Chapter 3).

In this thesis an Italian case-study has been examined: the Leaf House (LH) located in Ancona, Italy. The Leaf House is one of the best case studies of the IEA/SHC/ECBS/Task 40 Programme, in terms of thermo-physical characteristics of the building envelope, thermal plant, building automation system and energy monitoring.

In Chapter 5 the Leaf House case-study is described in detail as well as the model implemented into the TRNSYS software (Chapter 6), reproducing the energy production system, the thermal features of the building and comparing simulated with monitored data. Particular attention has to be paid to the Leaf House monitoring system, which allows the assessment of the building energy balance.

A careful analysis of monitored data brings to search some improving strategies to reach the zero energy target. After the simulation of the real building systems (through the software TRNSYS-Chapter 6), several scenarios have been investigated to improve energy performances of the building. Moreover the implemented model has been properly calibrated. The study proposes a detailed analysis of the case-study in order to show the possible energy savings that an NZEB can achieve in comparison with a non-net zero energy building. The re-design options are then proposed and the results evaluated by TRNSYS are described in detail.

The monitored situation shows an energy consumption of 37 MWh for the year 2009; although around 6 MWh are wasted in the monitoring equipment the energy production is lower than this value.

A simple solution, to reach the NZEB status is moving towards a higher production: e.g. the substitution of the PV panels with higher efficient others. In this way the energy balance reaches “zero” during the year.

Nevertheless the problem can be solved otherwise, reducing the energy needs. In this direction, the Geothermal Heat Pump and its energy needs have been analyzed in detail. It has been verified that the COP of the machine is way lower than the declared 4.6 and that an effective 4.6 COP could lead to significant energy savings.

The idea of reaching higher efficiencies led to the proposal of a different plant scheme with the exclusion of a heat exchanger to reduce as much as possible energy losses. While it is possible to obtain the NZEB status simply making a substitution of the PV panels, the investigation on further energy savings has been continued.

Finally the Italian case study allow to identify the strategies to improve the energy performances of the a *Near Net Zero Energy* building to reach the NZEB target. It represents also an Italian reference for others who wish to build NZEBs in the Italian context.

At last two annexes to this work are shown, the first shows objectives and activities of the Task 40 ECBS Programme while the second shows the Building description file created into TRNBUILD environment, in order to describe the Leaf House building envelope features.

Introduction

The topic of Zero Energy Buildings (ZEBs) has received increasing attention in recent years, until becoming part of both EU and US policies on energy efficiency in buildings. In the recast of the EU Directive on Energy Performance of Buildings (EPBD) it is specified that by the end of 2020 all new buildings shall be "nearly zero energy buildings" [1]. For the Building Technologies Program of the US Department Of Energy (DOE), the strategic goal is to achieve "*marketable zero energy homes in 2020 and commercial zero energy buildings in 2025"* [2]. However, despite the emphasis on the goals the definitions remains generic and are not yet standardized. The EPBD, for example, states that "nearly zero energy building means a building that has a very high energy performance" and that "The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby". The term Net ZEB refers to buildings that are connected to the energy infrastructure. While the concept of Net ZEBs is understood, an internationally agreed definition is still lacking. It is recognized that different definitions are possible, in order to be consistent with the purposes and political targets that lay behind the promotion of Net ZEBs. A harmonized framework for describing the relevant characteristics of Net ZEBs in a series of criteria has been presented. For each criterion different options are available on how to deal with that specific characteristic. Evaluation of the criteria and selection of the related options becomes a methodology for elaborating sound Net ZEB definitions in a formal, systematic and comprehensive way. This can create the basis for legislations and action plans to effectively achieve the political targets.

The common denominator for the different possible Net ZEB definitions in the harmonized framework is the balance between delivered and feed-in energy and associated credits. The general pathway to achieve a Net ZEB consists of two steps: first, reduce energy demand by means of energy efficiency measures. Second, generate electricity, or other energy carriers, by means of energy supply options to get enough credits to achieve the balance.

Additionally, other indicators than the mere balance over a period of time may be desirable, in order to add qualified information on the overall "goodness of design" of a

Net ZEB. In existing literature an example of such additional information is given by a hierarchy of supply options. In the work of the IEA Task40/Annex 52 this qualified information is added by means of temporal energy match indices. Finally, the monitoring procedure is viewed as an integral part of the definition.

Chapter 1 Energy policies

Goals for Energy Efficiency Improvements

In its National Energy Efficiency Action Plan (NEEAP), 2007, Italy was required to demonstrate to the European Commission how the Government intends to reach its indicative 9.6% energy savings target by 2016. The Plan took into account measures already adopted under Law no.296/2006 (the 2007 Finance Act) and other measures already implemented in 2006 and 2007. The plan addresses industrial, residential, tertiary and transport sectors, and the main measures included: white certificates, fiscal measures to encourage energy efficiency of buildings, transport, biofuels, domestic electrical appliances, lighting, industrial motors.

The Italian Law No 99/2009 provided for the publication of an Extraordinary Plan for Energy Saving and Efficiency. The plan envisaged the improved coordination among central and local administrations, promotion of sustainable construction and refurbishment of buildings, provisions for stimulating the supply of energy services, incentives for micro and small co-generation systems, mechanisms apt to boost the demand of white and green certificates, encouraging auto-productions of energy in SMEs [3].

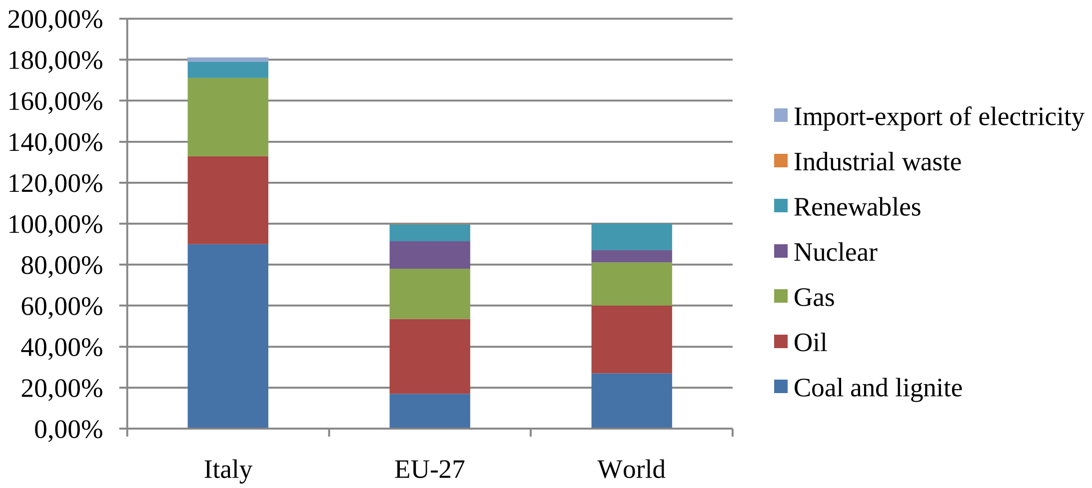


Figure 1 Primary energy consumption – Year 2009

If compared to other EU Member States, Italy's energy need is characterized by more vulnerable supplies, higher dependence on hydrocarbons (oil and gas), a limited carbon contribution and the total lack of electronuclear generation.

The primary energy demand, in 2010, was on the order of 185.3 Mtep, i.e., 2.7% higher than in 2009. The increase in primary energy demand is a clear evidence that the decrease trend of primary consumptions in the previous four years has inverted, although the 2010 value is far from the 197.8 Mtep peak achieved in 2005.

In 2010, the final energy consumption was 137.5 Mtep, 3.6% higher than 2009. Such increase is due to: higher consumption in the industrial sector (+5.5%); increased non-energy (+12.9%) and civil uses (+4.1%).

The distribution of energy uses among various sectors (Figure XX) shows a strong incidence of the civil sector, with an increase from 30.8% in 2004 to 35.0% in 2010, followed by transports (31.0%) and industry (23%) [4].

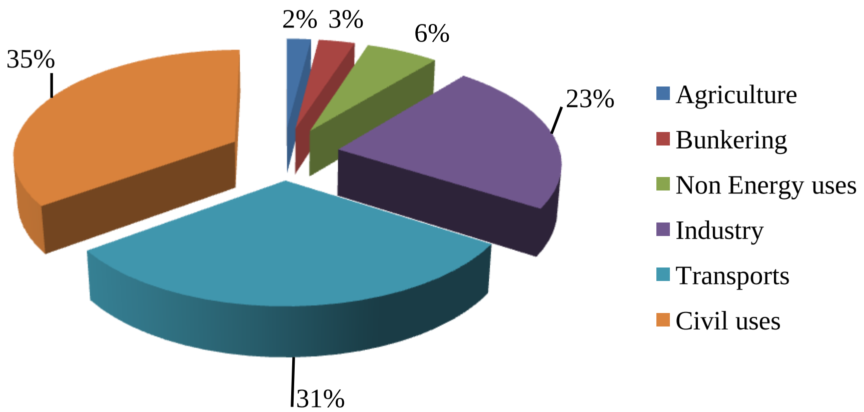


Figure 2 Final energy uses per sector - Year 2010

The consumption trend in the final use sectors shows a 6.6% increase in total consumption in 2001-2005 and a 6.2% decrease in 2006-2010, with a mean annual decrease rate of ca. 1.25%. Along with the severe consumption contraction in the industrial sector, such decrease stems from the economic crisis and the effects of measures aimed at promoting and incentivizing energy efficiency, but also from a slight consumption decrease in transports, which offsets the consumption increase in the civil sector [5].

Traditionally, Italy is one of the most energy-efficient countries among the industrialized ones: the final energy consumption per capita of 2.4 tep/capita is actually one of the lowest among the countries with similar industrial development (2.7 tep/capita EU average per capita consumption, Figure 3).

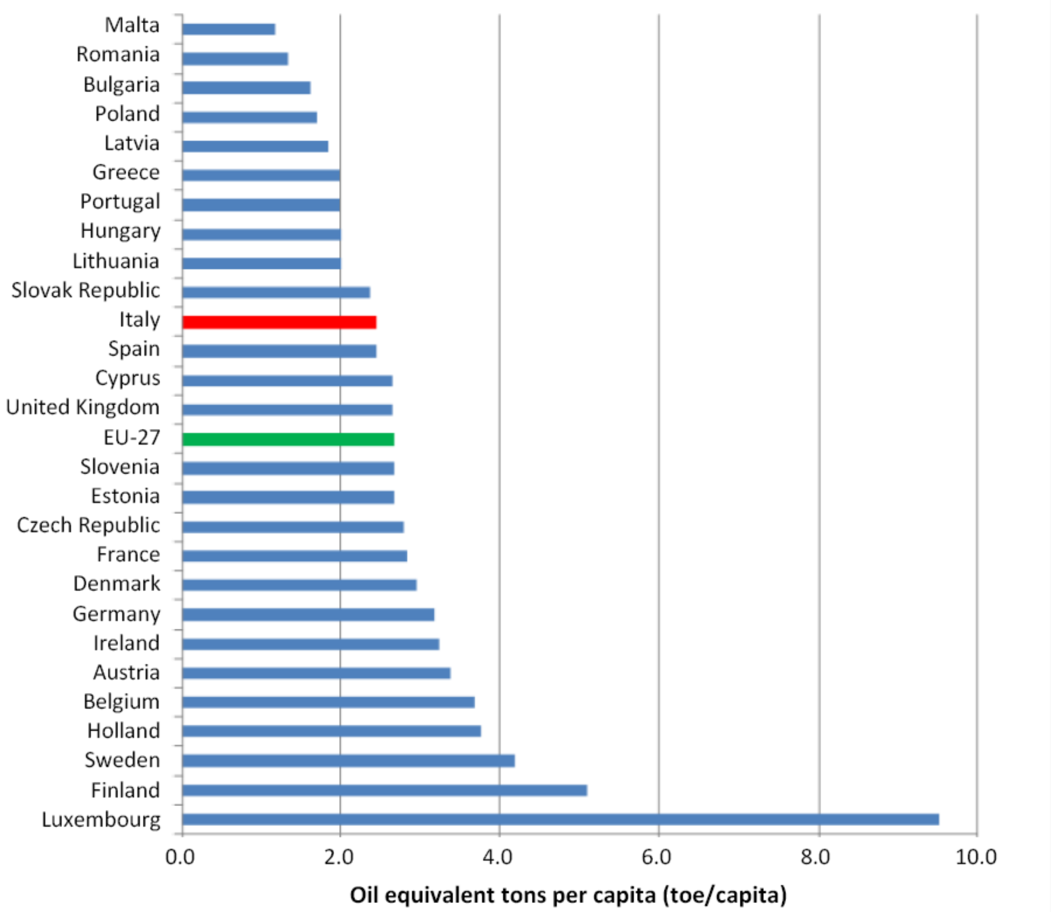


Figure 3 Final energy consumption per capita – Year 2009

In 2010, the primary energy intensity – i.e., the quantity of energy consumed to produce one GDP unit – was 151.3 tep/M€00 (Tep per M€ concatenated, reference year: 2000) (Figure 4).

Between 1990 and 2005, albeit with a fluctuating trend, such an indicator recorded a neglectable variation, whereas in 2006-2009 it showed a continuous decreasing trend resulting in a definite reduction (6%) following a severe decrease in the primary energy demand (-8.8%), exceeding the GDP contraction (-3.0%). The 2010 data show a trend inversion, with an increase in primary energy higher than GDP's and the consequent increase in primary intensity (+1.4%).

The final energy intensity and primary intensity have similar trends (Figure 4). In 2010, a value of 114.6 tep/M€00 was recorded, with an increase of 2.3% compared to 2009, whereas in 1990-2010 the overall decrease was 5.4%. Between 1990 and 2010, Italy showed a decrease both in primary and in final energy intensity, with a mean annual decrease rate of 0.30% for primary intensity and 0.27% for final intensity [6].

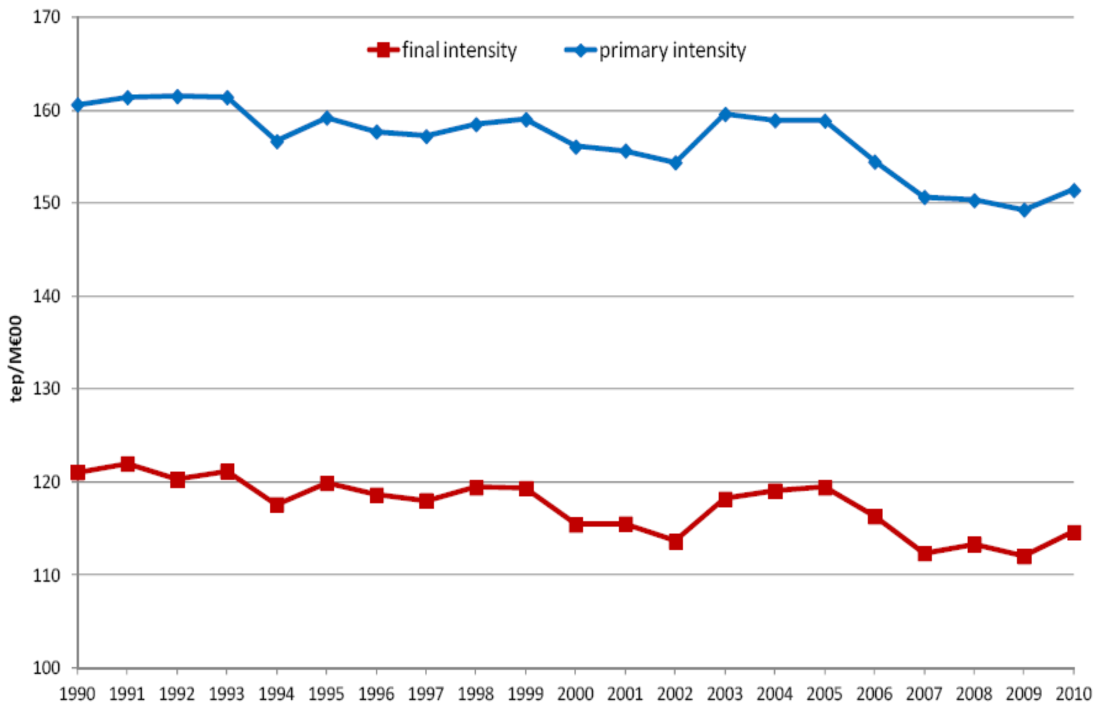


Figure 4 Primary and final energy intensities in 1990-2010 (tep/M€00)

CO_2 emissions per unit of GDP (CO_2 intensity) decreased twice as fast as the total energy intensity over the period 1990-2009 due to substitutions of oil and coal by gas (1% per year compared with 0.4% per year).

As a result of efficiency improvements, the fuel switch in thermal generation and the spread of renewables, the average CO_2 emission factor for power generation has fallen by about 25% since 1990, to less than 450g CO_2 / kWh in 2009.

On July 27, 2011, at the State-Regions Conference, the second Italian Action Plan for Energy Efficiency (2nd PAEE) was approved. The Italian Action Plan for Energy Efficiency 2011 is required by Directive 32/06 as an information tool for the European Commission on Member States programs and performance relating to energy efficiency.

Overall results

As shown in Figure 3, Italy has one of the lowest levels of energy consumption per capita among countries of comparable industrial development. The first PAEE was approved in 2007, before the transposition of the Directive, and expected to reach a savings target for 2016 of 9%, in line with the guidelines of the Directive, and an interim target of 3% for 2010.

The results achieved in the first period (2007/2010) are positive. The goal was exceeded by 33.8%. At the intermediate target of 2010 savings of 47,711 GWh/year was achieved instead of the expected 35,658 GWh/year. The contribution of the residential sector has been relevant to the achievement of the overall result. Some areas for improvement are the tertiary sector and transport.

The PAEE 2011 retains the target of 9% (126,540 GWh/year) reduction in energy consumption by 2016, the general approach and the methodology for calculating the target. With the extension to 2020, the PAEE 2011 aims to link policies on renewables with energy efficiency policies. In fact, energy efficiency is a key objective of the Climate-Energy Package, and the National Action Plan for Renewable includes assumptions regarding the efficiency. Since PAEE 2011 expected to achieve a saving of 184,672 GWh/year for 2020, the NAP includes an additional savings of 12 MTEP (140,000GWh/year).

According to Directive 2009/28/EC, in 2020, 17% of Italy’s final energy consumption must be covered by renewable sources. Taking the efficient scenario as a reference point, this means that in 2020 the final consumption of renewable energy must be 22.62 mtoe.

ENEA-UTEE is responsible for delivering the Regional Energy Balances (BERs) as well as the National EE Indicators. BERs provide data on the supply and consumption of coal, oil, gas, electricity, heat, renewables and waste, for all the 20 Italian Regions. Therefore, BERs represent a fundamental tool to monitor the achievement of the objectives related to the energy consumption covered by RES in the frame of the Burden Sharing and to support Regions in their decision making process.

The instruments to improve energy efficiency, already in force or enabled in 2007-2010, are included in one of the following categories:

- Legislative/Normative Instruments.
- The commonest forms of normative instruments used in Italy are the Minimum Energy Performance Standards and urban instruments.
- Training and Public Awareness.
- Measures to increase knowledge, awareness and training among stakeholders or users.
- Financial Incentives and Subsidies.
- Measures encouraging or fostering given activities, behaviors or investments by using financial and fiscal instruments. These include incentives for renewable energy, discounts for high-efficiency domestic appliances, subsidies, subsidized loans and forms of financing. In addition, fiscal incentives are provided, such as tax exemptions, reductions and/or credits to purchase or install given services and goods.
- Strategic Processes.
- Those processes aimed at developing and implementing policies. They are generally related to strategic planning documents and strategies for policy development.
- R&TD. Government investment policies or support to investments in technology research, development and demonstration.
- Tradable Permits.
- Three types of instruments: Emissions Trading System (ETS), white certificates (WCs) derived from energy saving or obligations and green certification systems

based on the obligation to produce or purchase a minimum amount of renewable energy (mainly electric power).

In the following paragraphs the European and the Italian framework of laws about the energy efficiency in the building sector are shown.

1.1. The European Union Framework

Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC [OJ L315 p.1]

Chronological framework

On 25 October 2012, the EU adopted the Directive 2012/27/EU on energy efficiency.

This Directive establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date. It lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.

On 16 January 2012, the EU adopted the Delegated Regulation (EU) No 244/2012 supplementing Directive 2010/31/EU on the energy performance of buildings. Article 5 of the Directive 2010/31/EU required the EC) to establish a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. To obtain the input from experts into the development of this methodology framework, the EC organised two expert meetings.

On 19 May 2010, the EU adopted the Energy Performance of Buildings Directive 2010/31/EU (EPBD) which isthe main legislative instrument to reduce the energy consumption of buildings. Under this Directive, Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of building energy performance and require the regular inspection of boilers and air conditioning systems in buildings. Moreover, the Directive requires Member States to ensure that by 2021 all new buildings are so-called 'nearly zero-energy buildings.

The Directive 2012/27/EU on energy efficiency of buildings takes into account that:

(1) The Union is facing unprecedented challenges resulting from increased dependence on energy imports and scarce energy resources, and the need to limit climate change and to overcome the economic crisis. Energy efficiency is a valuable means to address these challenges. It improves the Union’s security of supply by reducing primary energy consumption and decreasing energy imports. It helps to reduce greenhouse gas emissions in a cost- effective way and thereby to mitigate climate change.

(2) The Conclusions of the European Council of 8 and 9 March 2007 emphasised the need to increase energy efficiency in the Union to achieve the objective of saving 20 % of the Union’s primary energy consumption by 2020 compared to projections. The conclusions of the European Council of 4 February 2011 emphasised that the 2020 20 % energy efficiency target as agreed by the June 2010 European Council, which is presently not on track, must be delivered. Projections made in 2007 showed a primary energy consumption in 2020 of 1 842 Mtoe. A 20 % reduction results in 1 474 Mtoe in 2020, i.e. a reduction of 368 Mtoe as compared to projections.

(3) The Conclusions of the European Council of 17 June 2010 confirmed the energy efficiency target as one of the headline targets of the Union’s new strategy for jobs and smart, sustainable and inclusive growth (‘Europe 2020 Strategy’). Under this process and in order to implement this objective at national level, Member States are required to set national targets in close dialogue with the Commission and to indicate, in their National Reform Programmes, how they intend to achieve them.

(4) The Commission Communication of 10 November 2010 on Energy 2020 places energy efficiency at the core of the Union energy strategy for 2020 and outlines the need for a new energy efficiency strategy that will enable all Member States to decouple energy use from economic growth.

(5) In its resolution of 15 December 2010 on the Revision of the Energy Efficiency Action Plan, the European Parliament called on the Commission to include in its revised Energy Efficiency Action Plan measures to close the gap to reach the overall Union energy efficiency objective in 2020.

(6) One of the initiatives of the Europe 2020 Strategy is the flagship resource-efficient Europe adopted by the Commission on 26 January 2011. This identifies energy

efficiency as a major element in ensuring the sustainability of the use of energy resources.

(7) The Conclusions of the European Council of 4 February 2011 acknowledged that the Union energy efficiency target is not on track and that determined action is required to tap the considerable potential for higher energy savings in buildings, transport, products and processes. Those conclusions also provide that the implementation of the Union energy efficiency target will be reviewed by 2013 and further measures considered if necessary.

(8) On 8 March 2011, the Commission adopted its Communication on an Energy Efficiency Plan 2011. The Communication confirmed that the Union is not on track to achieve its energy efficiency target. This is despite the progress in national energy efficiency policies outlined in the first National Energy Efficiency Action Plans submitted by Member States in fulfilment of the requirements of Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services. Initial analysis of the second Action Plans confirms that the Union is not on track. To remedy that, the Energy Efficiency Plan 2011 spelled out a series of energy efficiency policies and measures covering the full energy chain, including energy generation, transmission and distribution; the leading role of the public sector in energy efficiency; buildings and appliances; industry; and the need to empower final customers to manage their energy consumption. Energy efficiency in the transport sector was considered in parallel in the White Paper on Transport, adopted on 28 March 2011. In particular, Initiative 26 of the White Paper calls for appropriate standards for CO_2 emissions of vehicles in all modes, where necessary supplemented by requirements on energy efficiency to address all types of propulsion systems.

(9) On 8 March 2011, the Commission also adopted a Roadmap for moving to a competitive low carbon economy in 2050, identifying the need from this perspective for more focus on energy efficiency.

(10) In this context it is necessary to update the Union’s legal framework for energy efficiency with a Directive pursuing the overall objective of the energy efficiency target of saving 20 % of the Union’s primary energy consumption by 2020, and of making

further energy efficiency improvements after 2020. To that end, this Directive should establish a common framework to promote energy efficiency within the Union and lay down specific actions to implement some of the proposals included in the Energy Efficiency Plan 2011 and achieve the significant unrealised energy saving potentials it identifies.

(10) In this context it is necessary to update the Union's legal framework for energy efficiency with a Directive pursuing the overall objective of the energy efficiency target of saving 20 % of the Union's primary energy consumption by 2020, and of making further energy efficiency improvements after 2020. To that end, this Directive should establish a common framework to promote energy efficiency within the Union and lay down specific actions to implement some of the proposals included in the Energy Efficiency Plan 2011 and achieve the significant unrealised energy saving potentials it identifies.

(11) Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (requires the Commission to assess and report by 2012 on the progress of the Union and its Member States towards the objective of reducing energy consumption by 20 % by 2020 compared to projections. It also states that, to help Member States meet the Union's greenhouse gas emission reduction commitments, the Commission should propose, by 31 December 2012, strengthened or new measures to accelerate energy efficiency improvements. This Directive responds to this requirement. It also contributes to meeting the goals set out in the Roadmap for moving to a competitive low carbon economy in 2050, in particular by reducing greenhouse gas emissions from the energy sector, and to achieving zero emission electricity production by 2050.

(12) An integrated approach has to be taken to tap all the existing energy saving potential, encompassing savings in the energy supply and the end-use sectors. At the same time, the provisions of Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on promotion of cogeneration based on a useful heat demand in the internal energy market and Directive 2006/32/EC should be strengthened.

(13) It would be preferable for the 20 % energy efficiency target to be achieved as a result of the cumulative implementation of specific national and European measures promoting energy efficiency in different fields. Member States should be required to set indicative national energy efficiency targets, schemes and programmes. These targets and the individual efforts of each Member State should be evaluated by the Commission, alongside data on the progress made, to assess the likelihood of achieving the overall Union target and the extent to which the individual efforts are sufficient to meet the common goal. The Commission should therefore closely monitor the implementation of national energy efficiency programmes through its revised legislative framework and within the Europe 2020 process. When setting the indicative national energy efficiency targets, Member States should be able to take into account national circumstances affecting primary energy consumption such as remaining cost-effective energy- saving potential, changes in energy imports and exports, development of all sources of renewable energies, nuclear energy, carbon capture and storage, and early action. When undertaking modelling exercises, the Commission should consult Member States on model assumptions and draft model results in a timely and transparent manner. Improved modelling of the impact of energy efficiency measures and of the stock and performance of technologies is needed.

(14) Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources (1) states that Cyprus and Malta, due to their insular and peripheral character, rely on aviation as a mode of transport, which is essential for their citizens and their economy. As a result, Cyprus and Malta have a gross final consumption of energy in national air transport which is disproportionately high, i.e. more than three times the Community average in 2005, and are thus disproportionately affected by the current technological and regulatory constraints.

(15) The total volume of public spending is equivalent to 19 % of the Union's gross domestic product. For this reason the public sector constitutes an important driver to stimulate market transformation towards more efficient products, buildings and services, as well as to trigger behavioural changes in energy consumption by citizens and enterprises. Furthermore, decreasing energy consumption through energy efficiency improvement measures can free up public resources for other purposes. Public bodies at

national, regional and local level should fulfil an exemplary role as regards energy efficiency.

(15) The total volume of public spending is equivalent to 19 % of the Union's gross domestic product. For this reason the public sector constitutes an important driver to stimulate market transformation towards more efficient products, buildings and services, as well as to trigger behavioural changes in energy consumption by citizens and enterprises. Furthermore, decreasing energy consumption through energy efficiency improvement measures can free up public resources for other purposes. Public bodies at national, regional and local level should fulfil an exemplary role as regards energy efficiency.

(16) Bearing in mind that the Council conclusions of 10 June 2011 on the Energy Efficiency Plan 2011 stressed that buildings represent 40 % of the Union's final energy consumption, and in order to capture the growth and employment opportunities in the skilled trades and construction sectors, as well as in the production of construction products and in professional activities such as architecture, consultancy and engineering, Member States should establish a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock. That strategy should address cost-effective deep renovations which lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels leading to a very high energy performance. Such deep renovations could also be carried out in stages.

(17) The rate of building renovation needs to be increased, as the existing building stock represents the single biggest potential sector for energy savings. Moreover, buildings are crucial to achieving the Union objective of reducing greenhouse gas emissions by 80-95 % by 2050 compared to 1990. Buildings owned by public bodies account for a considerable share of the building stock and have high visibility in public life. It is therefore appropriate to set an annual rate of renovation of buildings owned and occupied by central government on the territory of a Member State to upgrade their energy performance. This renovation rate should be without prejudice to the obligations with regard to nearly-zero energy buildings set in Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of

buildings (2). The obligation to renovate central government buildings in this Directive complements that Directive, which requires Member States to ensure that when existing buildings undergo major renovation their energy performance is upgraded so that they meet minimum energy performance requirements. It should be possible for Member States to take alternative cost-efficient measures to achieve an equivalent improvement of the energy performance of the buildings within their central government estate. The obligation to renovate floor area of central government buildings should apply to the administrative departments whose competence extends over the whole territory of a Member State. When in a given Member State and for a given competence no such relevant administrative department exists that covers the whole territory, the obligation should apply to those administrative departments whose competences cover collectively the whole territory.

(18) A number of municipalities and other public bodies in the Member States have already put into place integrated approaches to energy saving and energy supply, for example via sustainable energy action plans, such as those developed under the Covenant of Mayors initiative, and integrated urban approaches which go beyond individual interventions in buildings or transport modes. Member States should encourage municipalities and other public bodies to adopt integrated and sustainable energy efficiency plans with clear objectives, to involve citizens in their development and implementation and to adequately inform them about their content and progress in achieving objectives. Such plans can yield considerable energy savings, especially if they are implemented by energy management systems that allow the public bodies concerned to better manage their energy consumption. Exchange of experience between cities, towns and other public bodies should be encouraged with respect to the more innovative experiences.

(20) An assessment of the possibility of establishing a 'white certificate' scheme at Union level has shown that, in the current situation, such a system would create excessive administrative costs and that there is a risk that energy savings would be concentrated in a number of Member States and not introduced across the Union. The objective of such a Union-level scheme could be better achieved, at least at this stage, by means of national energy efficiency obligation schemes for energy utilities or other alternative policy measures that achieve the same amount of energy savings. It is

appropriate for the level of ambition of such schemes to be established in a common framework at Union level while providing significant flexibility to Member States to take fully into account the national organisation of market actors, the scheme at Union level has shown that, in the current situation, such a system would create excessive administrative costs and that there is a risk that energy savings would be concentrated in a number of Member States and not introduced across the Union. The objective of such a Union-level scheme could be better achieved, at least at this stage, by means of national energy efficiency obligation schemes for energy utilities or other alternative policy measures that achieve the same amount of energy savings. It is appropriate for the level of ambition of such schemes to be established in a common framework at Union level while providing significant flexibility to Member States to take fully into account the national organisation of market actors, the specific context of the energy sector and final customers' habits. The common framework should give energy utilities the option of offering energy services to all final customers, not only to those to whom they sell energy. This increases competition in the energy market because energy utilities can differentiate their product by providing complementary energy services. The common framework should allow Member States to include requirements in their national scheme that pursue a social aim, in particular in order to ensure that vulnerable customers have access to the benefits of higher energy efficiency. Member States should determine, on the basis of objective and non-discriminatory criteria, which energy distributors or retail energy sales companies should be obliged to achieve the end-use energy savings target laid down in this Directive. Member States should in particular be allowed not to impose this obligation on small energy distributors, small retail energy sales companies and small energy sectors to avoid disproportionate administrative burdens. The Commission Communication of 25 June 2008 sets out principles that should be taken into account by Member States that decide to abstain from applying this possibility. As a means of supporting national energy efficiency initiatives, obligated parties under national energy efficiency obligation schemes could fulfil their obligations by contributing annually to an Energy Efficiency National Fund an amount that is equal to the investments required under the scheme.

(21) Given the over-arching imperative of restoring sustainability to public finances and of fiscal consolidation, in the implementation of particular measures falling within the

scope of this Directive, due regard should be accorded to the cost-effectiveness at Member State level of implementing energy efficiency measures on the basis of an appropriate level of analysis and evaluation.

(22) The requirement to achieve savings of the annual energy sales to final customers relative to what energy sales would have been does not constitute a cap on sales or energy consumption. Member States should be able to exclude all or part of the sales of energy, by volume, used in industrial activities listed in Annex I to Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community (1) for the calculation of the energy sales to final customers, as it is recognised that certain sectors or subsectors within these activities may be exposed to a significant risk of carbon leakage. It is appropriate that Member States are aware of the costs of schemes in order to be able to accurately assess the costs of measures.

(23) Without prejudice to the requirements in Article 7 and with a view to limiting the administrative burden, each Member State may group all individual policy measures to implement Article 7 into a comprehensive national energy efficiency programme.

(24) To tap the energy savings potential in certain market segments where energy audits are generally not offered commercially (such as small and medium-sized enterprises (SMEs)), Member States should develop programmes to encourage SMEs to undergo energy audits. Energy audits should be mandatory and regular for large enterprises, as energy savings can be significant. Energy audits should take into account relevant European or International Standards, such as EN ISO 50001 (Energy Management Systems), or EN 16247-1 (Energy Audits), or, if including an energy audit, EN ISO 14000 (Environmental Management Systems) and thus be also in line with the provisions of Annex VI to this Directive as such provisions do not go beyond the requirements of these relevant standards. A specific European standard on energy audits is currently under development.

(25) Where energy audits are carried out by in-house experts, the necessary independence would require these experts not to be directly engaged in the activity audited.

(26) When designing energy efficiency improvement measures, account should be taken of efficiency gains and savings obtained through the widespread application of cost-

effective technological innovations such as smart meters. Where smart meters have been installed, they should not be used by companies for unjustified back billing.

(27) In relation to electricity, and in accordance with Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity, where the roll-out of smart meters is assessed positively, at least 80 % of consumers should be equipped with intelligent metering systems by 2020. In relation to gas, and in accordance with Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas, where the roll-out of intelligent metering systems is assessed positively, Member States or any competent authority they designate, should prepare a timetable for the implementation of intelligent metering systems.

(28) Use of individual meters or heat cost allocators for measuring individual consumption of heating in multi- apartment buildings supplied by district heating or common central heating is beneficial when final customers have a means to control their own individual consumption. Therefore, their use makes sense only in buildings where radiators are equipped with thermostatic radiator valves.

(29) In some multi-apartment buildings supplied by district heating or common central heating, the use of accurate individual heat meters would be technically complicated and costly due to the fact that the hot water used for heating enters and leaves the apartments at several points. It can be assumed that individual metering of heat consumption in multi-apartment buildings is, nevertheless, technically possible when the installation of individual meters would not require changing the existing in- house piping for hot water heating in the building. In such buildings, measurements of individual heat consumption can then be carried out by means of individual heat cost allocators installed on each radiator.

(30) Directive 2006/32/EC requires Member States to ensure that final customers are provided with competitively priced individual meters that accurately reflect their actual energy consumption and provide information on actual time of use. In most cases, this requirement is subject to the conditions that it should be technically possible, financially reasonable, and proportionate in relation to the potential energy savings. When a connection is made in a new building or a building undergoes major renovations, as defined in Directive 2010/31/EU, such individual meters should, however, always be

provided. Directive 2006/32/EC also requires that clear billing based on actual consumption should be provided frequently enough to enable consumers to regulate their own energy use.

(31) Directives 2009/72/EC and 2009/73/EC require Member States to ensure the implementation of intelligent metering systems to assist the active participation of consumers in the electricity and gas supply markets. As regards electricity, where the roll-out of smart meters is found to be cost-effective, at least 80 % of consumers must be equipped with intelligent metering systems by 2020. As regards natural gas, no deadline is given but the preparation of a timetable is required. Those Directives also state that final customers must be properly informed of actual electricity/gas consumption and costs frequently enough to enable them to regulate their own consumption.

(32) The impact of the provisions on metering and billing in Directives 2006/32/EC, 2009/72/EC and 2009/73/EC on energy saving has been limited. In many parts of the Union, these provisions have not led to customers receiving up-to-date information about their energy consumption, or billing based on actual consumption at a frequency which studies show is needed to enable customers to regulate their energy use. In the sectors of space heating and hot water in multi-apartment buildings the insufficient clarity of these provisions has also led to numerous complaints from citizens.

(32) The impact of the provisions on metering and billing in Directives 2006/32/EC, 2009/72/EC and 2009/73/EC on energy saving has been limited. In many parts of the Union, these provisions have not led to customers receiving up-to-date information about their energy consumption, or billing based on actual consumption at a frequency which studies show is needed to enable customers to regulate their energy use. In the sectors of space heating and hot water in multi-apartment buildings the insufficient clarity of these provisions has also led to numerous complaints from citizens.

(34) When designing energy efficiency improvement measures, Member States should take due account of the need to ensure the correct functioning of the internal market and the coherent implementation of the acquis, in accordance with the Treaty on the Functioning of the European Union.

New electricity generation installations and existing installations which are substantially refurbished or whose permit or licence is updated should, subject to a cost-benefit analysis showing a cost-benefit surplus, be equipped with high-efficiency cogeneration units to recover waste heat stemming from the production of electricity. This waste heat could then be transported where it is needed through district heating networks. The events that trigger a requirement for authorisation criteria to be applied will generally be events that also trigger requirements for permits under Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions and for authorisation under Directive 2009/72/EC.

(36) It may be appropriate for nuclear power installations, or electricity generation installations that are intended to make use of geological storage permitted under Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide (2), to be located in places where the recovery of waste heat through high-efficiency cogeneration or by supplying a district heating or cooling network is not cost-effective. Member States should therefore be able to exempt those installations from the obligation to carry out a cost-benefit analysis for providing the installation with equipment allowing the recovery of waste heat by means of a high-efficiency cogeneration unit. It should also be possible to exempt peak-load and back-up electricity generation installations which are planned to operate under 1 500 operating hours per year as a rolling average over a period of five years from the requirement to also provide heat.

(37) It is appropriate for Member States to encourage the introduction of measures and procedures to promote cogeneration installations with a total rated thermal input of less than 20 MW in order to encourage distributed energy generation.

(38) High-efficiency cogeneration should be defined by the energy savings obtained by combined production instead of separate production of heat and electricity. The definitions of cogeneration and high-efficiency cogeneration used in Union legislation should be without prejudice to the use of different definitions in national legislation for purposes other than those of the Union legislation in question. To maximise energy savings and avoid energy saving opportunities being missed, the greatest attention should be paid to the operating conditions of cogeneration units.

(39) To increase transparency for the final customer to be able to choose between electricity from cogeneration and electricity produced by other techniques, the origin of high-efficiency cogeneration should be guaranteed on the basis of harmonised efficiency reference values. Guarantee of origin schemes do not by themselves imply a right to benefit from national support mechanisms. It is important that all forms of electricity produced from high-efficiency cogeneration can be covered by guarantees of origin. Guarantees of origin should be distinguished from exchangeable certificates.
(40) The specific structure of the cogeneration and district heating and cooling sectors, which include many small and medium-sized producers, should be taken into account, especially when reviewing the administrative procedures for obtaining permission to construct cogeneration capacity or associated networks, in application of the 'Think Small First' principle.
(41) Most Union businesses are SMEs. They represent an enormous energy saving potential for the Union. To help them adopt energy efficiency measures, Member States should establish a favourable framework aimed at providing SMEs with technical assistance and targeted information.
(42) Directive 2010/75/EU includes energy efficiency among the criteria for determining the Best Available Techniques that should serve as a reference for setting the permit conditions for installations within its scope, including combustion installations with a total rated thermal input of 50 MW or more. However, that Directive gives Member States the option not to impose requirements relating to energy efficiency on combustion units or other units emitting carbon dioxide on the site, for the activities listed in Annex I to Directive 2003/87/EC. Member States could include information on energy efficiency levels in their reporting under Directive 2010/75/EU.

(43) Member States should establish, on the basis of objective, transparent and non-discriminatory criteria, rules governing the bearing and sharing of costs of grid connections and grid reinforcements and for technical adaptations needed to integrate new producers of electricity produced from high-efficiency cogeneration, taking into account guidelines and codes developed in accordance with Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and Regulation (EC)

No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks. Producers of electricity generated from high-efficiency cogeneration should be allowed to issue a call for tender for the connection work. Access to the grid system for electricity produced from high-efficiency cogeneration, especially for small scale and micro-cogeneration units, should be facilitated. In accordance with Article 3 of Directive 2009/72/EC and Article 3(2) of Directive 2009/73/EC, Member States may impose public service obligations, including in relation to energy efficiency, on undertakings operating in the electricity and gas sectors.

(44) Demand response is an important instrument for improving energy efficiency, since it significantly increases the opportunities for consumers or third parties nominated by them to take action on consumption and billing information and thus provides a mechanism to reduce or shift consumption, resulting in energy savings in both final consumption and, through the more optimal use of networks and generation assets, in energy generation, transmission and distribution.

(45) Demand response can be based on final customers' responses to price signals or on building automation. Conditions for, and access to, demand response should be improved, including for small final consumers. Taking into account the continuing deployment of smart grids, Member States should therefore ensure that national energy regulatory authorities are able to ensure that network tariffs and regulations incentivise improvements in energy efficiency and support dynamic pricing for demand response measures by final customers. Market integration and equal market entry opportunities for demand-side resources (supply and consumer loads) alongside generation should be pursued. In addition, Member States should ensure that national energy regulatory authorities take an integrated approach encompassing potential savings in the energy supply and the end-use sectors.

(46) A sufficient number of reliable professionals competent in the field of energy efficiency should be available to ensure the effective and timely implementation of this Directive, for instance as regards compliance with the requirements on energy audits and implementation of energy efficiency obligation schemes. Member States should

therefore put in place certification schemes for the providers of energy services, energy audits and other energy efficiency improvement measures.

(47) It is necessary to continue developing the market for energy services to ensure the availability of both the demand for and the supply of energy services. Transparency, for example by means of lists of energy services providers, can contribute to this. Model contracts, exchange of best practice and guidelines, in particular for energy performance contracting, can also help stimulate demand. As in other forms of third-party financing arrangements, in an energy performance contract the beneficiary of the energy service avoids investment costs by using part of the financial value of energy savings to repay the investment fully or partially carried out by a third party.

(48) There is a need to identify and remove regulatory and non-regulatory barriers to the use of energy performance contracting and other third-party financing arrangements for energy savings. These barriers include accounting rules and practices that prevent capital investments and annual financial savings resulting from energy efficiency improvement measures from being adequately reflected in the accounts for the whole life of the investment. Obstacles to the renovating of the existing building stock based on a split of incentives between the different actors concerned should also be tackled at national level.

(49) Member States and regions should be encouraged to make full use of the Structural Funds and the Cohesion Fund to trigger investments in energy efficiency improvement measures. Investment in energy efficiency has the potential to contribute to economic growth, employment, innovation and a reduction in fuel poverty in households, and therefore makes a positive contribution to economic, social and territorial cohesion. Potential areas for funding include energy efficiency measures in public buildings and housing, and providing new skills to promote employment in the energy efficiency sector.

(50) Member States should encourage the use of financing facilities to further the objectives of this Directive. Such financing facilities could include financial contributions and fines from non-fulfilment of certain provisions of this Directive; resources allocated to energy efficiency under Article 10(3) of Directive 2003/87/EC; resources allocated to energy efficiency in the multiannual financial framework, in

particular cohesion, structural and rural development funds, and dedicated European financial instruments, such as the European Energy Efficiency Fund.

(51) Financing facilities could be based, where applicable, on resources allocated to energy efficiency from Union project bonds; resources allocated to energy efficiency from the European Investment Bank and other European financial institutions, in particular the European Bank for Reconstruction and Development and the Council of Europe Development Bank; resources leveraged in financial institutions; national resources, including through the creation of regulatory and fiscal frameworks encouraging the implementation of energy efficiency initiatives and programmes; revenues from annual emission allocations under Decision No 406/2009/EC.

(52) The financing facilities could in particular use those contributions, resources and revenues to enable and encourage private capital investment, in particular drawing on institutional investors, while using criteria ensuring the achievement of both environmental and social objectives for the granting of funds; make use of innovative financing mechanisms (e.g. loan guarantees for private capital, loan guarantees to foster energy performance contracting, grants, subsidised loans and dedicated credit lines, third party financing systems) that reduce the risks of energy efficiency projects and allow for cost-effective renovations even among low and medium revenue households; be linked to programmes or agencies which will aggregate and assess the quality of energy saving projects, provide technical assistance, promote the energy services market and help to generate consumer demand for energy services.

(53) The financing facilities could also provide appropriate resources to support training and certification programmes which improve and accredit skills for energy efficiency; provide resources for research on and demonstration and acceleration of uptake of small-scale and micro- technologies to generate energy and the optimisation of the connections of those generators to the grid; be linked to programmes undertaking action to promote energy efficiency in all dwellings to prevent energy poverty and stimulate landlords letting dwellings to render their property as energy-efficient as possible; provide appropriate resources to support social dialogue and standard-setting aiming at improving energy efficiency and ensuring good working conditions and health and safety at work.

(54) Available Union financial instruments and innovative financing mechanisms should be used to give practical effect to the objective of improving the energy performance of public bodies' buildings. In that respect, Member States may use their revenues from annual emission allocations under Decision No 406/2009/EC in the development of such mechanisms on a voluntary basis and taking into account national budgetary rules.

(55) In the implementation of the 20 % energy efficiency target, the Commission will have to monitor the impact of new measures on Directive 2003/87/EC establishing the Union's emissions trading scheme (ETS) in order to maintain the incentives in the emissions trading system rewarding low carbon investments and preparing the ETS sectors for the innovations needed in the future. It will need to monitor the impact on those industry sectors which are exposed to a significant risk of carbon leakage as determined in Commission Decision 2010/2/EU of 24 December 2009 determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage (1), in order to ensure that this Directive promotes and does not impede the development of these sectors.

(56) Directive 2006/32/EC requires Member States to adopt, and aim to achieve, an overall national indicative energy savings target of 9 % by 2016, to be reached by deploying energy services and other energy efficiency improvement measures. That Directive states that the second Energy Efficiency Plan adopted by the Member States shall be followed, as appropriate and where necessary, by Commission proposals for additional measures, including extending the period of application of targets. If a report concludes that insufficient progress has been made towards achieving the indicative national targets laid down by that Directive, these proposals are to address the level and nature of the targets. The impact assessment accompanying this Directive finds that the Member States are on track to achieve the 9 % target, which is substantially less ambitious than the subsequently adopted 20 % energy saving target for 2020, and therefore there is no need to address the level of the targets.

(57) The Intelligent Energy Europe Programme established by Decision No 1639/2006/EC of the European Parliament and of the Council of 24 October 2006

establishing a Competitiveness and Innovation Framework Programme (2007 to 2013) has been instrumental in creating an enabling environment for the proper implementation of the Union's sustainable energy policies, by removing market barriers such as insufficient awareness and capacity of market actors and institutions, national technical or administrative barriers to the proper functioning of the internal energy market or underdeveloped labour markets to match the low-carbon economy challenge. Many of those barriers are still relevant.

(58) In order to tap the considerable energy-saving potential of energy-related products, the implementation of Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products and Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products should be accelerated and widened. Priority should be given to products offering the highest energy-saving potential as identified by the Ecodesign Working Plan and the revision, where appropriate, of existing measures.

(59) In order to clarify the conditions under which Member States can set energy performance requirements under Directive 2010/31/EU whilst respecting Directive 2009/125/EC and its implementing measures, Directive 2009/125/EC should be amended accordingly.

(60) Since the objective of this Directive, namely to achieve the Union's energy efficiency target of 20 % by 2020 and pave the way towards further energy efficiency improvements beyond 2020, cannot be sufficiently achieved by the Member States without taking additional energy efficiency measures, and can be better achieved at Union level, the Union may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty on European Union. In accordance with the principle of proportionality, as set out in that Article, this Directive does not go beyond what is necessary in order to achieve that objective.

(61) In order to permit adaptation to technical progress and changes in the distribution of energy sources, the power to adopt acts in accordance with Article 290 of the Treaty on the Functioning of the European Union should be delegated to the Commission in

respect of the review of the harmonised efficiency reference values laid down on the basis of Directive 2004/8/EC and in respect of the values, calculation methods, default primary energy coefficient and requirements in the Annexes to this Directive. It is of particular importance that the Commission carry out appropriate consultations during its preparatory work, including at expert level. The Commission, when preparing and drawing up delegated acts, should ensure a simultaneous, timely and appropriate transmission of relevant documents to the European Parliament and the Council.

(62) In order to ensure uniform conditions for the implementation of this Directive, implementing powers should be conferred on the Commission. Those powers should be exercised in accordance with Regulation (EU) No 182/2011 of the European Parliament and of the Council of 16 February 2011 laying down the rules and general principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers.

(63) All substantive provisions of Directives 2004/8/EC and 2006/32/EC should be repealed, except Article 4(1) to (4) of, and Annexes I, III and IV to Directive 2006/32/EC. Those latter provisions should continue to apply until the deadline for the achievement of the 9 % target. Article 9(1) and (2) of Directive 2010/30/EU, which provides for an obligation for Member States only to endeavour to procure products having the highest energy efficiency class, should be deleted.

(64) The obligation to transpose this Directive into national law should be limited to those provisions that represent a substantive change as compared with Directives 2004/8/EC and 2006/32/EC. The obligation to transpose the provisions which are unchanged arises under those Directives.

(65) This Directive should be without prejudice to the obligations of the Member States relating to the time limits for transposition into national law and application of Directives 2004/8/EC and 2006/32/EC.

(66) In accordance with the Joint Political Declaration of Member States and the Commission on explanatory documents of 28 September 2011, Member States have undertaken to accompany, in justified cases, the notification of their transposition measures with one or more documents explaining the relationship between the

components of a directive and the corresponding parts of national transposition instruments.

Article 1 Explains the Subject matter and scope of the Directive, specifying that:

1. The Directive establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date. It lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.
2. The requirements laid down in this Directive are minimum requirements and shall not prevent any Member State from maintaining or introducing more stringent measures. Such measures shall be compatible with Union law. Where national legislation provides for more stringent measures, the Member State shall notify such legislation to the Commission.

Article 2 shows the main definitions used in the Directive, that are the following:

(1) 'energy' means all forms of energy products, combustible fuels, heat, renewable energy, electricity, or any other form of energy, as defined in Article 2(d) of Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics
(2) 'primary energy consumption' means gross inland consumption, excluding non-energy uses;
(3) 'final energy consumption' means all energy supplied to industry, transport, households, services and agriculture. It excludes deliveries to the energy transformation sector and the energy industries themselves;
(4) 'energy efficiency' means the ratio of output of performance, service, goods or energy, to input of energy;
(5) 'energy savings' means an amount of saved energy determined by measuring and/or estimating consumption before and after implementation of an energy efficiency

improvement measure, whilst ensuring normalisation for external conditions that affect energy consumption;

(6) ‘energy efficiency improvement’ means an increase in energy efficiency as a result of technological, behavioural and/or economic changes;

(7) ‘energy service’ means the physical benefit, utility or good derived from a combination of energy with energy-efficient technology or with action, which may include the operations,

maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to result in verifiable and measurable or estimable energy efficiency improvement or primary energy savings;

(8) ‘public bodies’ means ‘contracting authorities’ as defined in Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts;

(9) ‘central government’ means all administrative departments whose competence extends over the whole territory of a Member State;

(10) ‘total useful floor area’ means the floor area of a building or part of a building, where energy is used to condition the indoor climate;

(11) ‘energy management system’ means a set of interrelated or interacting elements of a plan which sets an energy efficiency objective and a strategy to achieve that objective;

(12) ‘European standard’ means a standard adopted by the European Committee for Standardisation, the European Committee for Electrotechnical Standardisation or the European Telecommunications Standards Institute and made available for public use;

(13) ‘international standard’ means a standard adopted by the International Standardisation Organisation and made available to the public;

(14) ‘obligated party’ means an energy distributor or retail energy sales company that is bound by the national energy efficiency obligation schemes referred to in Article 7;

(15) ‘entrusted party’ means a legal entity with delegated power from a government or other public body to develop, manage or operate a financing scheme on behalf of the government or other public body;

(16) ‘participating party’ means an enterprise or public body that has committed itself to reaching certain objectives under a voluntary agreement, or is covered by a national regulatory policy instrument;

(17) ‘implementing public authority’ means a body governed by public law which is responsible for the carrying out or monitoring of energy or carbon taxation, financial schemes and instruments, fiscal incentives, standards and norms, energy labelling schemes, training or education;

(18) ‘policy measure’ means a regulatory, financial, fiscal, voluntary or information provision instrument formally established and implemented in a Member State to create a supportive framework, requirement or incentive for market actors to provide and purchase energy services and to undertake other energy efficiency improvement measures;

(19) ‘individual action’ means an action that leads to verifiable, and measurable or estimable, energy efficiency improvements and is undertaken as a result of a policy measure;

(20) ‘energy distributor’ means a natural or legal person, including a distribution system operator, responsible for transporting energy with a view to its delivery to final customers or to distribution stations that sell energy to final customers;

(21) ‘distribution system operator’ means ‘distribution system operator’ as defined in Directive 2009/72/EC and Directive 2009/73/EC respectively;

(22) ‘retail energy sales company’ means a natural or legal person who sells energy to final customers;

(23) ‘final customer’ means a natural or legal person who purchases energy for own end use;

(24) ‘energy service provider’ means a natural or legal person who delivers energy services or other energy efficiency improvement measures in a final customer’s facility or premises;

(25) ‘energy audit’ means a systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings;

(26) ‘small and medium-sized enterprises’ or ‘SMEs’ means enterprises as defined in Title I of the Annex to Commission Recommendation 2003/361/EC of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises (1); the category of micro, small and medium-sized enterprises is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million;

(27) ‘energy performance contracting’ means a contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial savings;

(28) ‘smart metering system’ or ‘intelligent metering system’ means an electronic system that can measure energy consumption, providing more information than a conventional meter, and can transmit and receive data using a form of electronic communication;

(29) ‘transmission system operator’ means ‘transmission system operator’ as defined in Directive 2009/72/EC and Directive 2009/73/EC respectively;

(30) ‘cogeneration’ means the simultaneous generation in one process of thermal energy and electrical or mechanical energy;

(31) ‘economically justifiable demand’ means demand that does not exceed the needs for heating or cooling and which would otherwise be satisfied at market conditions by energy generation processes other than cogeneration;

(32) ‘useful heat’ means heat produced in a cogeneration process to satisfy economically justifiable demand for heating or cooling;

(33) ‘electricity from cogeneration’ means electricity generated in a process linked to the production of useful heat and calculated in accordance with the methodology laid down in Annex I;

(34) ‘high-efficiency cogeneration’ means cogeneration meeting the criteria laid down in Annex II;

(35) ‘overall efficiency’ means the annual sum of electricity and mechanical energy production and useful heat output divided by the fuel input used for heat produced in a cogeneration process and gross electricity and mechanical energy production;

(36) ‘power-to-heat ratio’ means the ratio of electricity from cogeneration to useful heat when operating in full cogeneration mode using operational data of the specific unit;

(37) ‘cogeneration unit’ means a unit that is able to operate in cogeneration mode;

(38) ‘small-scale cogeneration unit’ means a cogeneration unit with installed capacity below 1 MW e ;

(39) ‘micro-cogeneration unit’ means a cogeneration unit with a maximum capacity below 50 kW e ;

(40) ‘plot ratio’ means the ratio of the building floor area to the land area in a given territory;

(41) ‘efficient district heating and cooling’ means a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat;

(42) ‘efficient heating and cooling’ means a heating and cooling option that, compared to a baseline scenario reflecting a business-as-usual situation, measurably reduces the input of primary energy needed to supply one unit of delivered energy within a relevant system boundary in a cost- effective way, as assessed in the cost-benefit analysis referred to in this Directive, taking into account the energy required for extraction, conversion, transport and distribution;

(43) ‘efficient individual heating and cooling’ means an individual heating and cooling supply option that, compared to efficient district heating and cooling, measurably reduces the input of non-renewable primary energy needed to supply one unit of delivered energy within a relevant system boundary or requires the same input of non-renewable primary energy but at a lower cost, taking into account the energy required for extraction, conversion, transport and distribution;

(44) ‘substantial refurbishment’ means a refurbishment whose cost exceeds 50 % of the investment cost for a new comparable unit;

(45) ‘aggregator’ means a demand service provider that combines multiple short-duration consumer loads for sale or auction in organised energy markets.

Article 3 shows the Energy efficiency targets that are the following:

1. Each Member State shall set an indicative national energy efficiency target, based on either primary or final energy consumption, primary or final energy savings, or energy intensity. Member States shall notify those targets to the Commission in accordance with Article 24and Annex XIV Part 1. When doing so, they shall also express those targets in terms of an absolute level of primary energy consumption and final energy consumption in 2020 and shall explain how, and on the basis of which data, this has been calculated.
When setting those targets, Member States shall take into account:
(a) that the Union’s 2020 energy consumption has to be no more than 1 474 Mtoe of primary energy or no more than 1 078 Mtoe of final energy;
(b) the measures provided for in this Directive;
(c) the measures adopted to reach the national energy saving targets adopted pursuant to Article 4(1) of Directive 2006/32/EC; and
(d) other measures to promote energy efficiency within Member States and at Union level.

When setting those targets, Member States may also take into account national circumstances affecting primary energy consumption, such as:
(a) remaining cost-effective energy-saving potential;
(b) GDP evolution and forecast;
(c) changes of energy imports and exports;
(d) development of all sources of renewable energies, nuclear energy, carbon capture and storage; and
(e) early action.
2. By 30 June 2014, the Commission shall assess progress achieved and whether the Union is likely to achieve energy consumption of no more than 1 474 Mtoe of primary energy and/or no more than 1 078 Mtoe of final energy in 2020.
3. In carrying out the review referred to in paragraph 2, the Commission shall:
(a) sum the national indicative energy efficiency targets reported by Member States;
(b) assess whether the sum of those targets can be considered a reliable guide to whether the Union as a whole is on track, taking into account the evaluation of the first annual

report in accordance with Article 24(1), and the evaluation of the National Energy Efficiency Action Plans in accordance with Article 24(2);

(c) take into account complementary analysis arising from:

(i) an assessment of progress in energy consumption, and in energy consumption in relation to economic activity, at Union level, including progress in the efficiency of energy supply in Member States that have based their national indicative targets on final energy consumption or final energy savings, including progress due to these Member States' compliance with Chapter III of this Directive;

(ii) results from modelling exercises in relation to future trends in energy consumption at Union level;

(d) compare the results under points (a) to (c) with the quantity of energy consumption that would be needed to achieve energy consumption of no more than 1 474 Mtoe of primary energy and/or no more than 1 078 Mtoe of final energy in 2020.

Article 4 explains how the Building renovation has to be made:

Member States shall establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private. This strategy shall encompass:

(a) an overview of the national building stock based, as appropriate, on statistical sampling;

(b) identification of cost-effective approaches to renovations relevant to the building type and climatic zone;

(c) policies and measures to stimulate cost-effective deep renovations of buildings, including staged deep renovations;

(d) a forward-looking perspective to guide investment decisions of individuals, the construction industry and financial institutions;

(e) an evidence-based estimate of expected energy savings and wider benefits.

A first version of the strategy shall be published by 30 April 2014 and updated every three years thereafter and submitted to the Commission as part of the National Energy Efficiency Action Plans.

Article 5 shows the Exemplary role of public bodies' buildings

1. Without prejudice to Article 7 of Directive 2010/31/EU, each Member State shall ensure that, as from 1 January 2014, 3 % of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements that it has set in application of Article 4 of Directive 2010/31/EU.

The 3 % rate shall be calculated on the total floor area of buildings with a total useful floor area over 500 m 2 owned and occupied by the central government of the Member State concerned that, on 1 January of each year, do not meet the national minimum energy performance requirements set in application of Article 4 of Directive 2010/31/EU. That threshold shall be lowered to 250 m^2 as of 9 July 2015.

Where a Member State requires that the obligation to renovate each year 3 % of the total floor area extends to floor area owned and occupied by administrative departments at a level below central government, the 3 % rate shall be calculated on the total floor area of buildings with a total useful floor area over 500 m^2 and, as of 9 July 2015, over 250 m^2 owned and occupied by central government and by these administrative departments of the Member State concerned that, on 1 January of each year, do not meet the national minimum energy performance requirements set in application of Article 4 of Directive 2010/31/EU.

When implementing measures for the comprehensive renovation of central government buildings in accordance with the first subparagraph, Member States may choose to consider the building as a whole, including the building envelope, equipment, operation and maintenance.

Member States shall require that central government buildings with the poorest energy performance be a priority for energy efficiency measures, where cost-effective and technically feasible.

2. Member States may decide not to set or apply the requirements referred to in paragraph 1 to the following categories of buildings:

(a) buildings officially protected as part of a designated environment, or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance;

(b) buildings owned by the armed forces or central government and serving national defence purposes, apart from single living quarters or office buildings for the armed forces and other staff employed by national defence authorities;

(c) buildings used as places of worship and for religious activities.

3. If a Member State renovates more than 3 % of the total floor area of central government buildings in a given year, it may count the excess towards the annual renovation rate of any of the three previous or following years.

4. Member States may count towards the annual renovation rate of central government buildings new buildings occupied and owned as replacements for specific central government buildings demolished in any of the two previous years, or buildings that have been sold, demolished or taken out of use in any of the two previous years due to more intensive use of other buildings.

5. For the purposes of paragraph 1, by 31 December 2013, Member States shall establish and make publicly available an inventory of heated and/or cooled central government buildings with a total useful floor area over 500 m^2 and, as of 9 July 2015, over 250 m^2 , excluding buildings exempted on the basis of paragraph 2. The inventory shall contain the following data:

(a) the floor area in m^2 ; and

(b) the energy performance of each building or relevant energy data.

6. Without prejudice to Article 7 of Directive 2010/31/EU, Member States may opt for an alternative approach to paragraphs 1 to 5 of this Article, whereby they take other cost- effective measures, including deep renovations and measures for behavioural change of occupants, to achieve, by 2020, an amount of energy savings in eligible buildings owned and occupied by their central government that is at least equivalent to that required in paragraph 1, reported on an annual basis.

For the purpose of the alternative approach, Member States may estimate the energy savings that paragraphs 1 to 4 would generate by using appropriate standard values for the energy consumption of reference central government buildings before and after renovation and according to estimates of the surface of their stock. The categories of reference central government buildings shall be representative of the stock of such buildings.

Member States opting for the alternative approach shall notify to the Commission, by 31 December 2013, the alternative measures that they plan to adopt, showing how they would achieve an equivalent improvement in the energy performance of the buildings within the central government estate.

7. Member States shall encourage public bodies, including at regional and local level, and social housing bodies governed by public law, with due regard for their respective competences and administrative set-up, to:

(a) adopt an energy efficiency plan, freestanding or as part of a broader climate or environmental plan, containing specific energy saving and efficiency objectives and actions, with a view to following the exemplary role of central government buildings laid down in paragraphs 1, 5 and 6;

(b) put in place an energy management system, including energy audits, as part of the implementation of their plan;

(c) use, where appropriate, energy service companies, and energy performance contracting to finance renovations and implement plans to maintain or improve energy efficiency in the long term.

Article 6 is about Purchasing by public bodies

1. Member States shall ensure that central governments purchase only products, services and buildings with high energy-efficiency performance, insofar as that is consistent with cost-effectiveness, economical feasibility, wider sustainability, technical suitability, as well as sufficient competition, as referred to in Annex III.

The obligation set out in the first subparagraph shall apply to contracts for the purchase of products, services and buildings by public bodies in so far as such contracts have a value equal to or greater than the thresholds laid down in Article 7 of Directive 2004/18/EC.

2. The obligation referred to in paragraph 1 shall apply to the contracts of the armed forces only to the extent that its application does not cause any conflict with the nature and primary aim of the activities of the armed forces. The obligation shall not apply to contracts for the supply of military equipment as defined by Directive 2009/81/EC of

the European Parliament and of the Council of 13 July 2009 on the coordination of procedures for the award of certain works contracts, supply contracts and service contracts by contracting authorities or entities in the fields of defence and security (1).

3. Member States shall encourage public bodies, including at regional and local levels, with due regard to their respective competences and administrative set-up, to follow the exemplary role of their central governments to purchase only products, services and buildings with high energy-efficiency performance. Member States shall encourage public bodies, when tendering service contracts with significant energy content, to assess the possibility of concluding long- term energy performance contracts that provide long-term energy savings.

4. Without prejudice to paragraph 1, when purchasing a product package covered as a whole by a delegated act adopted under Directive 2010/30/EU, Member States may require that the aggregate energy efficiency shall take priority over the energy efficiency of individual products within that package, by purchasing the product package that complies with the criterion of belonging to the highest energy efficiency class.

Article 7 speaks about the Energy efficiency obligation schemes

1. Each Member State shall set up an energy efficiency obligation scheme. That scheme shall ensure that energy distributors and/or retail energy sales companies that are designated as obligated parties under paragraph 4 operating in each Member State’s territory achieve a cumulative end-use energy savings target by 31 December 2020, without prejudice to paragraph 2.

That target shall be at least equivalent to achieving new savings each year from 1 January 2014 to 31 December 2020 of 1,5 % of the annual energy sales to final customers of all energy distributors or all retail energy sales companies by volume, averaged over the most recent three-year period prior to 1 January 2013. The sales of energy, by volume, used in transport may be partially or fully excluded from this calculation.

Member States shall decide how the calculated quantity of new savings referred to in the second subparagraph is to be phased over the period.

2. Subject to paragraph 3, each Member State may:

(a) carry out the calculation required by the second subparagraph of paragraph 1 using values of 1 % in 2014 and 2015; 1,25 % in 2016 and 2017; and 1,5 % in 2018, 2019 and 2020;
(b) exclude from the calculation all or part of the sales, by volume, of energy used in industrial activities listed in Annex I to Directive 2003/87/EC;
(c) allow energy savings achieved in the energy transformation, distribution and transmission sectors, including efficient district heating and cooling infrastructure, as a result of the implementation of the requirements set out in Article 14(4), point (b) of Article 14(5) and Article 15(1) to (6) and (9) to be counted towards the amount of energy savings required under paragraph 1; and
(d) count energy savings resulting from individual actions newly implemented since 31 December 2008 that continue to have an impact in 2020 and that can be measured and verified, towards the amount of energy savings referred to in paragraph 1.
3. The application of paragraph 2 shall not lead to a reduction of more than 25 % of the amount of energy savings referred to in paragraph 1. Member States making use of paragraph 2 shall notify that fact to the Commission by 5 June 2014, including the elements listed under paragraph 2 to be applied and a calculation showing their impact on the amount of energy savings referred to in paragraph 1.
4. Without prejudice to the calculation of energy savings for the target in accordance with the second subparagraph of paragraph 1, each Member State shall, for the purposes of the first subparagraph of paragraph 1, designate, on the basis of objective and non-discriminatory criteria, obligated parties amongst energy distributors and/or retail energy sales companies operating in its territory and may include transport fuel distributors or transport fuel retailers operating in its territory. The amount of energy savings to fulfil the obligation shall be achieved by the obligated parties among final customers, designated, as appropriate, by the Member State, independently of the calculation made pursuant to paragraph 1, or, if Member States so decide, through certified savings stemming from other parties as described in point (b) of paragraph 7.
5. Member States shall express the amount of energy savings required of each obligated party in terms of either final or primary energy consumption. The method chosen for expressing the required amount of energy savings shall also be used for calculating the

savings claimed by obligated parties. The conversion factors set out in Annex IV shall apply.

6. Member States shall ensure that the savings stemming from paragraphs 1, 2 and 9 of this Article and Article 20(6) are calculated in accordance with points (1) and (2) of Annex V. They shall put in place measurement, control and verification systems under which at least a statistically significant proportion and representative sample of the energy efficiency improvement measures put in place by the obligated parties is verified. That measurement, control and verification shall be conducted independently of the obligated parties.

7. Within the energy efficiency obligation scheme, Member States may:

(a) include requirements with a social aim in the saving obligations they impose, including by requiring a share of energy efficiency measures to be implemented as a priority in households affected by energy poverty or in social housing;

(b) permit obligated parties to count towards their obligation certified energy savings achieved by energy service providers or other third parties, including when obligated parties promote measures through other State-approved bodies or through public authorities that may or may not involve formal partnerships and may be in combination with other sources of finance. Where Member States so permit, they shall ensure that an approval process is in place which is clear, transparent and open to all market actors, and which aims at minimising the costs of certification;

(c) allow obligated parties to count savings obtained in a given year as if they had instead been obtained in any of the four previous or three following years.

8. Once a year, Member States shall publish the energy savings achieved by each obligated party, or each sub-category of obligated party, and in total under the scheme.

Member States shall ensure that obligated parties provide on request:

(a) aggregated statistical information on their final customers (identifying significant changes to previously submitted information); and

(b) current information on final customers' consumption, including, where applicable, load profiles, customer segmentation and geographical location of customers, while preserving the integrity and confidentiality of private or commercially sensitive information in compliance with applicable Union law.

Such a request shall be made not more than once a year.

9. As an alternative to setting up an energy efficiency obligation scheme under paragraph 1, Member States may opt to take other policy measures to achieve energy savings among final customers, provided those policy measures meet the criteria set out in paragraphs 10 and 11. The annual amount of new energy savings achieved through this approach shall be equivalent to the amount of new energy savings required by paragraphs 1, 2 and 3. Provided that equivalence is maintained, Member States may combine obligation schemes with alternative policy measures, including national energy efficiency programmes.

The policy measures referred to in the first subparagraph may include, but are not restricted to, the following policy measures or combinations thereof:

(a) energy or CO_2 taxes that have the effect of reducing end-use energy consumption;

(b) financing schemes and instruments or fiscal incentives that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption;

(c) regulations or voluntary agreements that lead to the application of energy-efficient technology or techniques and have the effect of reducing end-use energy consumption;

(d) standards and norms that aim at improving the energy efficiency of products and services, including buildings and vehicles, except where these are mandatory and applicable in Member States under Union law;

(e) energy labelling schemes, with the exception of those that are mandatory and applicable in the Member States under Union law;

(f) training and education, including energy advisory programmes, that lead to the application of energy- efficient technology or techniques and have the effect of reducing end-use energy consumption.

Member States shall notify to the Commission, by 5 December 2013, the policy measures that they plan to adopt for the purposes of the first subparagraph and Article 20(6), following the framework provided in point 4 of Annex V, and showing how they would achieve the required amount of savings. In the case of the policy measures referred to in the second subparagraph and in Article 20(6), this notification shall demonstrate how the criteria in paragraph 10 are met. In the case of policy measures other than those referred to in the second subparagraph or in Article 20(6), Member

States shall explain how an equivalent level of savings, monitoring and verification is achieved. The Commission may make suggestions for modifications in the three months following notification.

10. Without prejudice to paragraph 11, the criteria for the policy measures taken pursuant to the second subparagraph of paragraph 9 and Article 20(6) shall be as follows:

(a) the policy measures provide for at least two intermediate periods by 31 December 2020 and lead to the achievement of the level of ambition set out in paragraph 1;
(b) the responsibility of each entrusted party, participating party or implementing public authority, whichever is relevant, is defined;
(c) the energy savings that are to be achieved are determined in a transparent manner;
(d) the amount of energy savings required or to be achieved by the policy measure are expressed in either final or primary energy consumption, using the conversion factors set out in Annex IV;
(e) energy savings are calculated using the methods and principles provided in points (1) and (2) of Annex V;
(f) energy savings are calculated using the methods and principles provided in point 3 of Annex V;
(g) an annual report of the energy savings achieved is provided by participating parties unless not feasible and made publicly available;
(h) monitoring of the results is ensured and appropriate measures are envisaged if the progress is not satisfactory;
(i) a control system is put in place that also includes independent verification of a statistically significant proportion of the energy efficiency improvement measures; and
(j) data on the annual trend of energy savings are published annually.
11. Member States shall ensure that the taxes referred to in point (a) of the second subparagraph of paragraph 9 comply with the criteria listed in points (a), (b), (c), (d), (f), (h) and (j) of paragraph 10.
Member States shall ensure that the regulations and voluntary agreements referred to in point (c) of the second subparagraph of paragraph 9 comply with the criteria listed in points (a), (b), (c), (d), (e), (g), (h), (i) and (j) of paragraph 10.

Member States shall ensure that the other policy measures referred to in the second subparagraph of paragraph 9 and the Energy Efficiency National Funds referred to in Article 20(6) comply with the criteria listed in points (a), (b), (c), (d), (e), (h), (i) and (j) of paragraph 10.

12. Member States shall ensure that when the impact of policy measures or individual actions overlaps, no double counting of energy savings is made.

Article 8 is about Energy audits and energy management systems:

1. Member States shall promote the availability to all final customers of high quality energy audits which are cost-effective and:

(a) carried out in an independent manner by qualified and/or accredited experts according to qualification criteria; or

(b) implemented and supervised by independent authorities under national legislation.

The energy audits referred to in the first subparagraph may be carried out by in-house experts or energy auditors provided that the Member State concerned has put in place a scheme to assure and check their quality, including, if appropriate, an annual random selection of at least a statistically significant percentage of all the energy audits they carry out.

For the purpose of guaranteeing the high quality of the energy audits and energy management systems, Member States shall establish transparent and non-discriminatory minimum criteria for energy audits based on Annex VI.

Energy audits shall not include clauses preventing the findings of the audit from being transferred to any qualified/accredited energy service provider, on condition that the customer does not object.

2. Member States shall develop programmes to encourage SMEs to undergo energy audits and the subsequent implementation of the recommendations from these audits.

On the basis of transparent and non-discriminatory criteria and without prejudice to Union State aid law, Member States may set up support schemes for SMEs, including if they have concluded voluntary agreements, to cover costs of an energy audit and of the implementation of highly cost-effective recommendations from the energy audits, if the proposed measures are implemented.

Member States shall bring to the attention of SMEs, including through their respective representative intermediary organisations, concrete examples of how energy management systems could help their businesses. The Commission shall assist Member States by supporting the exchange of best practices in this domain.

3. Member States shall also develop programmes to raise awareness among households about the benefits of such audits through appropriate advice services.

Member States shall encourage training programmes for the qualification of energy auditors in order to facilitate sufficient availability of experts.

4. Member States shall ensure that enterprises that are not SMEs are subject to an energy audit carried out in an independent and cost-effective manner by qualified and/or accredited experts or implemented and supervised by independent authorities under national legislation by 5 December 2015 and at least every four years from the date of the previous energy audit.

5. Energy audits shall be considered as fulfilling the requirements of paragraph 4 when they are carried out in an independent manner, on the basis of minimum criteria based on Annex VI, and implemented under voluntary agreements concluded between organisations of stakeholders and an appointed body and supervised by the Member State concerned, or other bodies to which the competent authorities have delegated the responsibility concerned, or by the Commission.

Access of market participants offering energy services shall be based on transparent and non-discriminatory criteria.

6. Enterprises that are not SMEs and that are implementing an energy or environmental management system - certified by an independent body according to the relevant European or International Standards - shall be exempted from the requirements of paragraph 4, provided that Member States ensure that the management system concerned includes an energy audit on the basis of the minimum criteria based on Annex VI.

7. Energy audits may stand alone or be part of a broader environmental audit. Member States may require that an assessment of the technical and economic feasibility of connection to an existing or planned district heating or cooling network shall be part of the energy audit.

Without prejudice to Union State aid law, Member States may implement incentive and support schemes for the implementation
of recommendations from energy audits and similar measures.

Article 9 speaks about Metering

1. Member States shall ensure that, in so far as it is technically
possible, financially reasonable and proportionate in relation to the potential energy savings, final customers for electricity, natural gas, district heating, district cooling and domestic hot water are provided with competitively priced individual
meters that accurately reflect the final customer's actual energy consumption and that provide information on actual time of use.
Such a competitively priced individual meter shall always be provided when:
(a) an existing meter is replaced, unless this is technically impossible or not cost-effective in relation to the estimated potential savings in the long term;
(b) a new connection is made in a new building or a building undergoes major renovations, as set out in Directive 2010/31/EU.
2. Where, and to the extent that, Member States implement intelligent metering systems and roll out smart meters for natural gas and/or electricity in accordance with Directives 2009/72/EC and 2009/73/EC:
(a) they shall ensure that the metering systems provide to final customers information on actual time of use and that the objectives of energy efficiency and benefits for final customers are fully taken into account when establishing the minimum functionalities of the meters and the obligations imposed on market participants;
(b) they shall ensure the security of the smart meters and data communication, and the privacy of final customers, in compliance with relevant Union data protection and privacy legislation;
(c) in the case of electricity and at the request of the final customer, they shall require meter operators to ensure that the meter or meters can account for electricity put into the grid from the final customer's premises;
(d) they shall ensure that if final customers request it, metering data on their electricity input and off-take is made available to them or to a third party acting on behalf of the

final customer in an easily understandable format that they can use to compare deals on a like-for-like basis;

(e) they shall require that appropriate advice and information be given to customers at the time of installation of smart meters, in particular about their full potential with regard to meter reading management and the monitoring of energy consumption.

3. Where heating and cooling or hot water are supplied to a building from a district heating network or from a central source servicing multiple buildings, a heat or hot water meter shall be installed at the heating exchanger or point of delivery.

In multi-apartment and multi-purpose buildings with a central heating/cooling source or supplied from a district heating network or from a central source serving multiple buildings, individual consumption meters shall also be installed by 31 December 2016 to measure the consumption of heat or cooling or hot water for each unit where technically feasible and cost-efficient. Where the use of individual meters is not technically feasible or not cost-efficient, to measure heating, individual heat cost allocators shall be used for measuring heat consumption at each radiator, unless it is shown by the Member State in question that the installation of such heat cost allocators would not be cost-efficient. In those cases, alternative cost-efficient methods of heat consumption measurement may be considered.

Where multi-apartment buildings are supplied from district heating or cooling, or where own common heating or cooling systems for such buildings are prevalent, Member States may introduce transparent rules on the allocation of the cost of thermal or hot water consumption in such buildings to ensure transparency and accuracy of accounting for individual consumption. Where appropriate, such rules shall include guidelines on the way to allocate costs for heat and/or hot water that is used as follows:

(a) hot water for domestic needs;

(b) heat radiated from the building installation and for the purpose of heating the common areas (where staircases and corridors are equipped with radiators);

(c) for the purpose of heating apartments.

Article 10 explains the Billing information

1. Where final customers do not have smart meters as referred to in Directives 2009/72/EC and 2009/73/EC, Member States shall ensure, by 31 December 2014, that

billing information is accurate and based on actual consumption, in accordance with point 1.1 of Annex VII, for all the sectors covered by this Directive, including energy distributors, distribution system operators and retail energy sales companies, where this is technically possible and economically justified.

This obligation may be fulfilled by a system of regular self- reading by the final customers whereby they communicate readings from their meter to the energy supplier. Only when the final customer has not provided a meter reading for a given billing interval shall billing be based on estimated consumption or a flat rate.

2. Meters installed in accordance with Directives 2009/72/EC and 2009/73/EC shall enable accurate billing information based on actual consumption. Member States shall ensure that final customers have the possibility of easy access to complementary information on historical consumption allowing detailed self- checks.

Complementary information on historical consumption shall include:

(a) cumulative data for at least the three previous years or the period since the start of the supply contract if this is shorter. The data shall correspond to the intervals for which frequent billing information has been produced; and

(b) detailed data according to the time of use for any day, week, month and year. These data shall be made available to the final customer via the internet or the meter interface for the period of at least the previous 24 months or the period since the start of the supply contract if this is shorter.

3. Independently of whether smart meters have been installed or not, Member States:

(a) shall require that, to the extent that information on the energy billing and historical consumption of final customers is available, it be made available, at the request of the final customer, to an energy service provider designated by the final customer;

(b) shall ensure that final customers are offered the option of electronic billing information and bills and that they receive, on request, a clear and understandable explanation of how their bill was derived, especially where bills are not based on actual consumption;

(c) shall ensure that appropriate information is made available with the bill to provide final customers with a comprehensive account of current energy costs, in accordance with Annex VII;

(d) may lay down that, at the request of the final customer, the information contained in these bills shall not be considered to constitute a request for payment. In such cases, Member States shall ensure that suppliers of energy sources offer flexible arrangements for actual payments;
(e) shall require that information and estimates for energy costs are provided to consumers on demand in a timely manner and in an easily understandable format enabling consumers to compare deals on a like-for-like basis.

Article 11 is about cost of access to metering and billing information

1. Member States shall ensure that final customers receive all their bills and billing information for energy consumption free of charge and that final customers also have access to their consumption data in an appropriate way and free of charge.

2. Notwithstanding paragraph 1, the distribution of costs of billing information for the individual consumption of heating and cooling in multi-apartment and multi-purpose buildings pursuant to Article 9(3) shall be carried out on a non-profit basis. Costs resulting from the assignment of this task to a third party, such as a service provider or the local energy supplier, covering the measuring, allocation and accounting for actual individual consumption in such buildings, may be passed onto the final customers to the extent that such costs are reasonable.

Article 12 shows the Consumer information and empowering programme

1. Member States shall take appropriate measures to promote and facilitate an efficient use of energy by small energy customers, including domestic customers. These measures may be part of a national strategy.

2. For the purposes of paragraph 1, these measures shall include one or more of the elements listed under point (a) or (b):

(a) a range of instruments and policies to promote behavioural change which may include:
(i) fiscal incentives;
(ii) access to finance, grants or subsidies;

(iii) information provision;

(iv) exemplary projects;

(v) workplace activities;

(b) ways and means to engage consumers and consumer organisations during the possible roll-out of smart meters through communication of:

(i) cost-effective and easy-to-achieve changes in energy use;

(ii) information on energy efficiency measures.

Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)

Revision of Directive 2002/91/EC

The Directive 2010/31/EU was adopted after experiencing the implementation of the first EPBD Directive 2002/91/EC in the Member States and following a proposal from the Commission in 2008 which was based on a detailed impact assessment. The aim of this revision was to clarify and simplify certain provisions, extend the scope, make some more effective, and provide for the leading role of the public sector.

The Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings takes into account that:

(1) Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings (4) has been amended (5). Since further substantive amendments are to be made, it should be recast in the interests of clarity.
(2) An efficient, prudent, rational and sustainable utilization of energy applies, inter alia, to oil products, natural gas and solid fuels, which are essential sources of energy, but also the leading sources of carbon dioxide emissions.
(3)Buildings account for 40 % of total energy consumption in the Union. The sector is expanding, which is bound to increase its energy consumption. Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the Union’s energy dependency and greenhouse gas emissions. Together with an increased use of energy from renewable sources, measures taken to reduce energy consumption in the Union would allow the Union to comply with the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), and to honour both its long term commitment to maintain the global temperature rise below 2 °C, and its commitment to reduce, by 2020, overall greenhouse gas emissions by at least 20 % below 1990 levels, and by 30 % in the event of an international agreement being reached. Reduced energy consumption and an increased use of energy from renewable sources also have an

important part to play in promoting security of energy supply, technological developments and in creating opportunities for employment and regional development, in particular in rural areas.

(4) Management of energy demand is an important tool enabling the Union to influence the global energy market and hence the security of energy supply in the medium and long term.

(5) The European Council of March 2007 emphasised the need to increase energy efficiency in the Union so as to achieve the objective of reducing by 20 % the Union's energy consumption by 2020 and called for a thorough and rapid implementation of the priorities established in the Commission Communication entitled 'Action plan for energy efficiency: realising the potential'. That action plan identified the significant potential for cost-effective energy savings in the buildings sector. The European Parliament, in its resolution of 31 January 2008, called for the strengthening of the provisions of Directive 2002/91/EC, and has called at various times, on the latest occasion in its resolution of 3 February 2009 on the Second Strategic Energy Review, for the 20 % energy efficiency target in 2020 to be made binding. Moreover, Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020, sets national binding targets for CO_2 reduction for which energy efficiency in the building sector will be crucial, and Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources provides for the promotion of energy efficiency in the context of a binding target for energy from renewable sources accounting for 20 % of total Union energy consumption by 2020.

(6) The European Council of March 2007 reaffirmed the Union's commitment to the Union-wide development of energy from renewable sources by endorsing a mandatory target of a 20 % share of energy from renewable sources by 2020. Directive 2009/28/EC establishes a common framework for the promotion of energy from renewable sources.

(7) It is necessary to lay down more concrete actions with a view to achieving the great unrealised potential for energy savings in buildings and reducing the large differences between Member States' results in this sector.

(8) Measures to improve further the energy performance of buildings should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness. These measures should not affect other requirements concerning buildings such as accessibility, safety and the intended use of the building.

(9) The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level. That includes, in addition to thermal characteristics, other factors that play an increasingly important role such as heating and air-conditioning installations, application of energy from renewable sources, passive heating and cooling elements, shading, indoor air-quality, adequate natural light and design of the building. The methodology for calculating energy performance should be based not only on the season in which heating is required, but should cover the annual energy performance of a building. That methodology should take into account existing European standards.

(10) It is the sole responsibility of Member States to set minimum requirements for the energy performance of buildings and building elements. Those requirements should be set with a view to achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the lifecycle of the building, without prejudice to the right of Member States to set minimum requirements which are more energy efficient than cost-optimal energy efficiency levels. Provision should be made for the possibility for Member States to review regularly their minimum energy performance requirements for buildings in the light of technical progress.

(11) The objective of cost-effective or cost-optimal energy efficiency levels may, in certain circumstances, for example in the light of climatic differences, justify the setting by Member States of cost-effective or cost- optimal requirements for building elements that would in practice limit the installation of building products that comply with standards set by Union legislation, provided that such requirements do not constitute an unjustifiable market barrier.

(12) When setting energy performance requirements for technical building systems, Member States should use, where available and appropriate, harmonised instruments, in particular testing and calculation methods and energy efficiency classes developed under measures implementing Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign

requirements for energy-related products (1) and Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy- related products (2), with a view to ensuring coherence with related initiatives and minimise, to the extent possible, potential fragmentation of the market.

(13) This Directive is without prejudice to Articles 107 and 108 of the Treaty on the Functioning of the European Union (TFEU). The term 'incentive' used in this Directive should not therefore be interpreted as constituting State aid.

(14) The Commission should lay down a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements. Member States should use this framework to compare the results with the minimum energy performance requirements which they have adopted. Should significant discrepancies, i.e. exceeding 15 %, exist between the calculated cost-optimal levels of minimum energy performance requirements and the minimum energy performance requirements in force, Member States should justify the difference or plan appropriate steps to reduce the discrepancy. The estimated economic lifecycle of a building or building element should be determined by Member States, taking into account current practices and experience in defining typical economic lifecycles. The results of this comparison and the data used to reach these results should be regularly reported to the Commission. These reports should enable the Commission to assess and report on the progress of Member States in reaching cost-optimal levels of minimum energy performance requirements.

(15) Buildings have an impact on long-term energy consumption. Given the long renovation cycle for existing buildings, new, and existing buildings that are subject to major renovation, should therefore meet minimum energy performance requirements adapted to the local climate. As the application of alternative energy supply systems is not generally explored to its full potential, alternative energy supply systems should be considered for new buildings, regardless of their size, pursuant to the principle of first ensuring that energy needs for heating and cooling are reduced to cost- optimal levels.

(16) Major renovations of existing buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance. For reasons of cost-effectiveness, it should be possible to limit the minimum energy performance

requirements to the renovated parts that are most relevant for the energy performance of the building. Member States should be able to choose to define a 'major renovation' either in terms of a percentage of the surface of the building envelope or in terms of the value of the building. If a Member State decides to define a major renovation in terms of the value of the building, values such as the actuarial value, or the current value based on the cost of reconstruction, excluding the value of the land upon which the building is situated, could be used.

(17) Measures are needed to increase the number of buildings which not only fulfil current minimum energy performance requirements, but are also more energy efficient, thereby reducing both energy consumption and carbon dioxide emissions. For this purpose Member States should draw up national plans for increasing the number of nearly zero-energy buildings and regularly report such plans to the Commission.

(18) Union financial instruments and other measures are being put into place or adapted with the aim of stimulating energy efficiency-related measures. Such financial instruments at Union level include, inter alia, Regulation (EC) No 1080/2006 of the European Parliament and of the Council of 5 July 2006 on the European Regional Development Fund, amended to allow increased investments in energy efficiency in housing; the public- private partnership on a 'European energy-efficient buildings' initiative to promote green technologies and the development of energy-efficient systems and materials in new and renovated buildings; the EC- European Investment Bank (EIB) initiative 'EU sustainable energy financing initiative' which aims to enable, inter alia, investments for energy efficiency and the EIB-led 'Marguerite Fund': the 2020 European Fund for Energy, Climate Change and Infrastructure; Council Directive 2009/47/EC of 5 May 2009 amending Directive 2006/112/EC as regards reduced rates of value added tax, structural and cohesion funds instrument Jeremie (Joint European Resources for micro to medium enterprises); the Energy Efficiency Finance Facility; the Competitiveness and Innovation Framework Programme including the Intelligent Energy Europe II Programme focused specifically on removing market barriers related to energy efficiency and energy from renewable sources through for example the technical assistance facility ELENA (European Local Energy Assistance); the Covenant of Mayors; the Entrepreneurship and Innovation programme; the ICT Policy Support Programme 2010, and the Seventh Research Framework Programme. The European

Bank for Reconstruction and Development also provides funding with the aim of stimulating energy-efficiency-related measures.

(19) Union financial instruments should be used to give practical effect to the objectives of this Directive, without however substituting national measures. In particular, they should be used for providing appropriate and innovative means of financing to catalyse investment in energy efficiency measures. They could play an important role in the development of national, regional and local energy efficiency funds, instruments, or mechanisms, which deliver such financing possibilities to private property owners, to small and medium-sized enterprises and to energy efficiency service companies.

(20) In order to provide the Commission with adequate information, Member States should draw up lists of existing and proposed measures, including those of a financial nature, other than those required by this Directive, which promote the objectives of this Directive. The existing and proposed measures listed by Member States may include, in particular, measures that aim to reduce existing legal and market barriers and encourage investments and/or other activities to increase the energy efficiency of new and existing buildings, thus potentially contributing to reducing energy poverty. Such measures could include, but should not be limited to, free or subsidised technical assistance and advice, direct subsidies, subsidised loan schemes or low interest loans, grant schemes and loan guarantee schemes. The public authorities and other institutions which provide those measures of a financial nature could link the application of such measures to the indicated energy performance and the recommendations from energy performance certificates.

(21) In order to limit the reporting burden on Member States it should be possible to integrate the reports required by this Directive into the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services. The public sector in each Member State should lead the way in the field of energy performance of buildings, and therefore the national plans should set more ambitious targets for the buildings occupied by public authorities.

(22) The prospective buyer and tenant of a building or building unit should, in the energy performance certificate, be given correct information about the energy performance of the building and practical advice on improving such performance.

Information campaigns may serve to further encourage owners and tenants to improve the energy performance of their building or building unit. Owners and tenants of commercial buildings should also be encouraged to exchange information regarding actual energy consumption, in order to ensure that all the data are available to make informed decisions about necessary improvements. The energy performance certificate should also provide information about the actual impact of heating and cooling on the energy needs of the building, on its primary energy consumption and on its carbon dioxide emissions.

(23) Public authorities should lead by example and should endeavour to implement the recommendations included in the energy performance certificate. Member States should include within their national plans measures to support public authorities to become early adopters of energy efficiency improvements and to implement the recommendations included in the energy performance certificate as soon as feasible.

(24) Buildings occupied by public authorities and buildings frequently visited by the public should set an example by showing that environmental and energy considerations are being taken into account and therefore those buildings should be subject to energy certification on a regular basis. The dissemination to the public of information on energy performance should be enhanced by clearly displaying these energy performance certificates, in particular in buildings of a certain size which are occupied by public authorities or which are frequently visited by the public, such as shops and shopping centres, supermarkets, restaurants, theatres, banks and hotels.

(25) Recent years have seen a rise in the number of air-conditioning systems in European countries. This creates considerable problems at peak load times, increasing the cost of electricity and disrupting the energy balance. Priority should be given to strategies which enhance the thermal performance of buildings during the summer period. To that end, there should be focus on measures which avoid overheating, such as shading and sufficient thermal capacity in the building construction, and further development and application of passive cooling techniques, primarily those that improve indoor climatic conditions and the micro- climate around buildings.

(26) Regular maintenance and inspection of heating and air- conditioning systems by qualified personnel contributes to maintaining their correct adjustment in accordance with the product specification and in that way ensures optimal performance from an

environmental, safety and energy point of view. An independent assessment of the entire heating and air-conditioning system should occur at regular intervals during its lifecycle in particular before its replacement or upgrading. In order to minimise the administrative burden on building owners and tenants, Member States should endeavour to combine inspections and certifications as far as possible.

(27) A common approach to the energy performance certification of buildings and to the inspection of heating and air-conditioning systems, carried out by qualified and/or accredited experts, whose independence is to be guaranteed on the basis of objective criteria, will contribute to a level playing field as regards efforts made in Member States to energy saving in the buildings sector and will introduce transparency for prospective owners or users with regard to energy performance in the Union property market. In order to ensure the quality of energy performance certificates and of the inspection of heating and air-conditioning systems throughout the Union, an independent control mechanism should be established in each Member State.

(28) Since local and regional authorities are critical for the successful implementation of this Directive, they should be consulted and involved, as and when appropriate in accordance with applicable national legislation, on planning issues, the development of programmes to provide information, training and awareness-raising, and on the implementation of this Directive at national or regional level. Such consultations may also serve to promote the provision of adequate guidance to local planners and building inspectors to carry out the necessary tasks. Furthermore, Member States should enable and encourage architects and planners to properly consider the optimal combination of improvements in energy efficiency, use of energy from renewable sources and use of district heating and cooling when planning, designing, building and renovating industrial or residential areas.

(29) Installers and builders are critical for the successful implementation of this Directive. Therefore, an adequate number of installers and builders should, through training and other measures, have the appropriate level of competence for the installation and integration of the energy efficient and renewable energy technology required.

(30) Member States should take account of Directive 2005/36/EC of the European Parliament and of the Council of 7 September 2005 on the recognition of professional

qualifications with regard to the mutual recognition of professional experts which are addressed by this Directive, and the Commission should continue its activities under the Intelligent Energy Europe Programme on guidelines and recommendations for standards for the training of such professional experts.

(31) In order to enhance the transparency of energy performance in the Union's non-residential property market, uniform conditions for a voluntary common certification scheme for the energy performance of non-residential buildings should be established. In accordance with Article 291 TFEU, rules and general principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers shall be laid down in advance by a regulation adopted in accordance with the ordinary legislative procedure. Pending the adoption of that new regulation, Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission (2) continues to apply, with the exception of the regulatory procedure with scrutiny, which is not applicable.

(31) The Commission should be empowered to adopt delegated acts in accordance with Article 290 TFEU in respect of the adaptation to technical progress of certain parts of the general framework set out in Annex I, and in respect of the establishment of a methodology framework for calculating cost-optimal levels of minimum energy performance requirements. It is of particular importance that the Commission carry out appropriate consultations during its preparatory work, including at expert level.

(32) Since the objective of this Directive, namely of enhancing the energy performance of buildings, cannot be sufficiently achieved by the Member States, due to the complexity of the buildings sector and the inability of the national housing markets to adequately address the challenges of energy efficiency, and can by the reason of the scale and the effects of the action be better achieved at Union level, the Union may adopt measures, in accordance with the principle of subsidiarity as set out in Article 5 of the Treaty on European Union. In accordance with the principles of proportionality, as set out in that Article, this Directive does not go beyond what is necessary in order to achieve that objective.

(33) The obligation to transpose this Directive into national law should be confined to those provisions which represent a substantive change as compared with Directive

2002/91/EC. The obligation to transpose the provisions which are unchanged arises under that Directive.

(34) This Directive should be without prejudice to the obligations of the Member States relating to the time limits for transposition into national law and application of the Directive 2002/91/EC.

(35) In accordance with point 34 of the Interinstitutional Agreement on better law-making, Member States are encouraged to draw up, for themselves and in the interest of the Union, their own tables, illustrating, as far as possible, the correlation between this Directive and the transposition measures, and to make them public,

This Directive promotes the improvement of the energy performance of buildings within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness.

This Directive lays down requirements as regards:

a. the common general framework for a methodology for calculating the integrated energy performance of buildings and building units;
b. the application of minimum requirements to the energy performance of new buildings and new building units;
c. the application of minimum requirements to the energy performance of:
d. existing buildings, building units and building elements that are subject to major renovation;
e. building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are retrofitted or replaced; and
f. technical building systems whenever they are installed, replaced or upgraded;
g. national plans for increasing the number of nearly zero- energy buildings;
h. energy certification of buildings or building units;
i. regular inspection of heating and air-conditioning systems in buildings; and
j. independent control systems for energy performance certificates and inspection reports.

The requirements laid down in this Directive are minimum requirements and shall not prevent any Member State from maintaining or introducing more stringent measures.

Such measures shall be compatible with the Treaty on the Functioning of the European Union. They shall be notified to the Commission.

In the Article 2 the Directive describe some definition pointing out the attention to the Net Zero Energy Building, following the main definitions will be exposed:

- ‘building’ means a roofed construction having walls, for which energy is used to condition the indoor climate;
- ‘nearly zero-energy building’ means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;
- ‘technical building system’ means technical equipment for the heating, cooling, ventilation, hot water, lighting or for a combination thereof, of a building or building unit;
- ‘energy performance of a building’ means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting;
- ‘primary energy’ means energy from renewable and non- renewable sources which has not undergone any conversion or transformation process;
- ‘energy from renewable sources’ means energy from renewable non-fossil sources, namely wind, solar, aerothermal, geothermal, hydrothermal and ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases;
- ‘building envelope’ means the integrated elements of a building which separate its interior from the outdoor environment;
- ‘building unit’ means a section, floor or apartment within a building which is designed or altered to be used separately;
- ‘building element’ means a technical building system or an element of the building envelope;
- ‘major renovation’ means the renovation of a building where:

(a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated; or

(b) more than 25 % of the surface of the building envelope undergoes renovation;

Member States may choose to apply option (a) or (b).

- ‘European standard’ means a standard adopted by the European Committee for Electrotechnical Standardisation or the European Telecommunications Standards Institute and made available for public use;
- ‘energy performance certificate’ means a certificate recognized by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit, calculated according to a methodology adopted in accordance with Article 3;
- ‘cogeneration’ means simultaneous generation in one process of thermal energy and electrical and/or mechanical energy;
- ‘cost-optimal level’ means the energy performance level which leads to the lowest cost during the estimated economic lifecycle, where:

i) the lowest cost is determined taking into account energy-related investment costs, maintenance and operating costs (including energy costs and savings, the category of building concerned, earnings from energy produced), where applicable, and disposal costs, where applicable; and

ii) the estimated economic lifecycle is determined by each Member State. It refers to the remaining estimated economic lifecycle of a building where energy performance requirements are set for the building as a whole, or to the estimated economic lifecycle of a building element where energy performance requirements are set for building elements.

The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive;

- ‘air-conditioning system’ means a combination of the components required to provide a form of indoor air treatment, by which temperature is controlled or can be lowered;

- ‘boiler’ means the combined boiler body-burner unit, designed to transmit to fluids the heat released from burning;
- ‘effective rated output’ means the maximum calorific output, expressed in kW, specified and guaranteed by the manufacturer as being deliverable during continuous operation while complying with the useful efficiency indicated by the manufacturer;
- ‘heat pump’ means a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings;
- ‘district heating’ or ‘district cooling’ means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling.

In the Article 3 the Directive underlines that the adoption of a methodology for calculating the energy performance of buildings have to be created.

Member States shall apply a methodology for calculating the energy performance of buildings in accordance with the common general framework set out in Annex I.

In the Article 4 the minimum energy performance requirements has been set, in particular:

- Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels. The energy performance shall be calculated in accordance with the methodology referred to in Article 3. Cost-optimal levels shall be calculated in accordance with the comparative methodology framework referred to in Article 5 once the framework is in place.
- Member States shall take the necessary measures to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to

achieving cost-optimal levels. When setting requirements, Member States may differentiate between new and existing buildings and between different categories of buildings. These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building. A Member State shall not be required to set minimum energy performance requirements which are not cost-effective over the estimated economic lifecycle. Minimum energy performance requirements shall be reviewed at regular intervals which shall not be longer than five years and, if necessary, shall be updated in order to reflect technical progress in the building sector.

- Member States may decide not to set or apply the requirements referred to in paragraph 1 to the following categories of buildings:
  a. buildings officially protected as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance;
  b. buildings used as places of worship and for religious activities;EN 18.6.2010 Official Journal of the European Union L 153/19 (c) temporary buildings with a time of use of two years or less, industrial sites, workshops and non-residential agricultural buildings with low energy demand and non-residential agricultural buildings which are in use by a sector covered by a national sectoral agreement on energy performance;
  c. residential buildings which are used or intended to be used for either less than four months of the year or, alternatively, for a limited annual time of use and with an expected energy consumption of less than 25 % of what would be the result of all-year use;
  d. stand-alone buildings with a total useful floor area of less than 50 m 2 .

Article 5 shows the calculation of cost-optimal levels of minimum energy performance requirements:

- The Commission shall establish by means of delegated acts in accordance with Articles 23, 24 and 25 by 30 June 2011 a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements. The comparative methodology framework shall be established in accordance with Annex III and shall differentiate between new and existing buildings and between different categories of buildings.
- Member States shall calculate cost-optimal levels of minimum energy performance requirements using the comparative methodology framework established in accordance with paragraph 1 and relevant parameters, such as climatic conditions and the practical accessibility of energy infrastructure, and compare the results of this calculation with the minimum energy performance requirements in force. Member States shall report to the Commission all input data and assumptions used for those calculations and the results of those calculations. The report may be included in the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC. Member States shall submit those reports to the Commission at regular intervals, which shall not be longer than five years. The first report shall be submitted by 30 June 2012.
- If the result of the comparison performed in accordance with paragraph 2 shows that the minimum energy performance requirements in force are significantly less energy efficient than cost-optimal levels of minimum energy performance requirements, the Member State concerned shall justify this difference in writing to the Commission in the report referred to in paragraph 2, accompanied, to the extent that the gap cannot be justified, by a plan outlining appropriate steps to significantly reduce the gap by the next review of the energy performance requirements as referred to in Article 4(1). The Commission shall publish a report on the progress of the Member States in reaching cost-optimal levels of minimum energy performance requirements.

In the Article 6 the measures that have to be applied to new buildings was shown:

- Member States shall take the necessary measures to ensure that new buildings meet the minimum energy performance requirements set in accordance with Article 4. For new buildings, Member States shall ensure that, before construction starts, the technical, environmental and economic feasibility of high-efficiency alternative systems such as those listed below, if available, is considered and taken into account:

a. decentralised energy supply systems based on energy from renewable sources;
b. cogeneration;
c. district or block heating or cooling, particularly where it is based entirely or partially on energy from renewable sources;
d. heat pumps.

- Member States shall ensure that the analysis of alternative systems referred to in paragraph 1 is documented and available for verification purposes. That analysis of alternative systems may be carried out for individual buildings or for groups of similar buildings or for common typologies of buildings in the same area. As far as collective heating and cooling systems are concerned, the analysis may be carried out for all buildings connected to the system in the same area.

Article 7 explains the measures about existing buildings, in particular:

1. Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements set in accordance with Article 4 in so far as this is technically, functionally and economically feasible. Those requirements shall be applied to the renovated building or building unit as a whole. Additionally or alternatively, requirements may be applied to the renovated building elements.

2.Member States shall in addition take the necessary measures to ensure that when a building element that forms part of the building envelope and has a significant impact on the energy performance of the building envelope, is retrofitted or replaced, the energy performance of the building element meets minimum energy performance requirements in so far as this is technically, functionally and economically feasible.

3.Member States shall determine these minimum energy performance requirements in accordance with Article 4.

4.Member States shall encourage, in relation to buildings undergoing major renovation, the consideration and taking into account of high-efficiency alternative systems, as referred to in Article 6(1), in so far as this is technically, functionally and economically feasible.

Article 8 specifies what the Member states have to do about the technical building systems:

1.Member States shall, for the purpose of optimizing the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings. System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.

2.The system requirements shall cover at least the following:

- heating systems;
- hot water systems;
- air-conditioning systems;
- large ventilation systems;
- or a combination of such systems.

3.Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation, whilst ensuring that this encouragement is in line with point 2 of Annex I to Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity (1). Member States may furthermore encourage, where appropriate, the installation of active control systems such as automation, control and monitoring systems that aim to save energy.

Article 9 gives the deadlines to apply the concept of Net Zero Energy Building, in particular it explains that:

1. Member States shall ensure that:

(a) by 31 December 2020, all new buildings are nearly zero- energy buildings; and

(b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

Member States shall draw up national plans for increasing the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building.

2. Member States shall furthermore, following the leading example of the public sector, develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings, and inform the Commission thereof in their national plans referred to in paragraph 1.

3. The national plans shall include, inter alia, the following elements:

(a) the Member State's detailed application in practice of the definition of nearly zero-energy buildings, reflecting their national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m^2 per year. Primary energy factors used for the determination of the primary energy use may be based on national or regional yearly average values and may take into account relevant European standards;

(b) intermediate targets for improving the energy performance of new buildings, by 2015, with a view to preparing the implementation of paragraph 1;

(c) information on the policies and financial or other measures adopted in the context of paragraphs 1 and 2 for the promotion of nearly zero-energy buildings, including details of national requirements and measures concerning the use of energy from renewable sources in new buildings and existing buildings undergoing major renovation in the context of Article 13(4) of Directive 2009/28/EC and Articles 6 and 7 of this Directive.

4. The Commission shall evaluate the national plans referred to in paragraph 1, notably the adequacy of the measures envisaged by the Member State in relation to the objectives of this Directive. The Commission, taking due account of the principle of subsidiarity, may request further specific information regarding the requirements set out in paragraphs 1, 2 and 3. In that case, the Member State concerned shall submit the requested information or propose amendments within nine months following the request

from the Commission. Following its evaluation, the Commission may issue a recommendation.

5. The Commission shall by 31 December 2012 and every three years thereafter publish a report on the progress of Member States in increasing the number of nearly zero-energy buildings. On the basis of that report the Commission shall develop an action plan and, if necessary, propose measures to increase the number of those buildings and encourage best practices as regards the cost-effective transformation of existing buildings into nearly zero-energy buildings.

6. Member States may decide not to apply the requirements set out in points (a) and (b) of paragraph 1 in specific and justifiable cases where the cost-benefit analysis over the economic lifecycle of the building in question is negative. Member States shall inform the Commission of the principles of the relevant legislative regimes.

Article 10 shows the financial incentives and market barriers

1. In view of the importance of providing appropriate financing and other instruments to catalyze the energy performance of buildings and the transition to nearly zero- energy buildings, Member States shall take appropriate steps to consider the most relevant such instruments in the light of national circumstances.

2. Member States shall draw up, by 30 June 2011, a list of existing and, if appropriate, proposed measures and instruments including those of a financial nature, other than those required by this Directive, which promote the objectives of this Directive.

Member States shall update this list every three years. Member States shall communicate these lists to the Commission, which they may do by including them in the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC.

3. The Commission shall examine the effectiveness of the listed existing and proposed measures referred to in paragraph 2 as well as of relevant Union instruments, in supporting the implementation of this Directive. On the basis of that examination, and taking due account of the principle of subsidiarity, the Commission may provide advice or recommendations as regards specific national schemes and coordination with Union and international financial institutions. The Commission may include its examination

and possible advice or recommendations in its report on the National Energy Efficiency Plans referred to in Article 14(5) of Directive 2006/32/EC.

4. The Commission shall, where appropriate, assist upon request Member States in setting up national or regional financial support programmes with the aim of increasing energy efficiency in buildings, especially of existing buildings, by supporting the exchange of best practice between the responsible national or regional authorities or bodies.

5. In order to improve financing in support of the implementation of this Directive and taking due account of the principle of subsidiarity, the Commission shall, preferably by 2011, present an analysis on, in particular:

(a) the effectiveness, the appropriateness of the level, and the actual amount used, of structural funds and framework programmes that were used for increasing energy efficiency in buildings, especially in housing;

(b) the effectiveness of the use of funds from the EIB and other public finance institutions;

(c) the coordination of Union and national funding and other forms of support that can act as a leverage for stimulating investments in energy efficiency and the adequacy of such funds for achieving Union objectives.

On the basis of that analysis, and in accordance with the multiannual financial framework, the Commission may subsequently submit, if it considers this appropriate, proposals with respect to Union instruments to the European Parliament and the Council.

6. Member States shall take account of the cost-optimal levels of energy performance when providing incentives for the construction or major renovation of buildings.

7. The provisions of this Directive shall not prevent Member States from providing incentives for new buildings, renovations or building elements which go beyond the cost-optimal levels.

Article 11 introduces the Energy performance certificates

1. Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building and reference values such as

minimum energy performance requirements in order to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance.

The energy performance certificate may include additional information such as the annual energy consumption for non- residential buildings and the percentage of energy from renewable sources in the total energy consumption.

2. The energy performance certificate shall include recommendations for the cost-optimal or cost-effective improvement of the energy performance of a building or building unit, unless there is no reasonable potential for such improvement compared to the energy performance requirements in force.

The recommendations included in the energy performance certificate shall cover:

(a) measures carried out in connection with a major renovation of the building envelope or technical building system(s); and

(b) measures for individual building elements independent of a major renovation of the building envelope or technical building system(s).

3. The recommendations included in the energy performance certificate shall be technically feasible for the specific building and may provide an estimate for the range of payback periods or cost-benefits over its economic lifecycle.

4. The energy performance certificate shall provide an indication as to where the owner or tenant can receive more detailed information, including as regards the cost-effectiveness of the recommendations made in the energy performance certificate. The evaluation of cost effectiveness shall be based on a set of standard conditions, such as the assessment of energy savings and underlying energy prices and a preliminary cost forecast. In addition, it shall contain information on the steps to be taken to implement the recommendations. Other information on related topics, such as energy audits or incentives of a financial or other nature and financing possibilities may also be provided to the owner or tenant.

5. Subject to national rules, Member States shall encourage public authorities to take into account the leading role which they should play in the field of energy performance of buildings, inter alia, by implementing the recommendations included in the energy performance certificate issued for buildings owned by them within its validity period.

6. Certification for building units may be based:

(a) on a common certification of the whole building; or

(b) on the assessment of another representative building unit with the same energy-relevant characteristics in the same building.

7. Certification for single-family houses may be based on the assessment of another representative building of similar design and size with a similar actual energy performance quality if such correspondence can be guaranteed by the expert issuing the energy performance certificate.

8. The validity of the energy performance certificate shall not exceed 10 years.

9. The Commission shall, by 2011, in consultation with the relevant sectors, adopt a voluntary common European Union certification scheme for the energy performance of non-residential buildings. That measure shall be adopted in accordance with the advisory procedure referred to in Article 26 (2). Member States are encouraged to recognize or use the scheme, or use part thereof by adapting it to national circumstances.

Article 12 introduces the issue of energy performance certificates

1. Member States shall ensure that an energy performance certificate is issued for:

(a) buildings or building units which are constructed, sold or rented out to a new tenant; and

(b) buildings where a total useful floor area over 500 m 2 is occupied by a public authority and frequently visited by the public. On 9 July 2015, this threshold of 500 m 2 shall be lowered to 250 m 2 .

The requirement to issue an energy performance certificate does not apply where a certificate, issued in accordance with either Directive 2002/91/EC or this Directive, for the building or building unit concerned is available and valid.

2. Member States shall require that, when buildings or building units are constructed, sold or rented out, the energy performance certificate or a copy thereof is shown to the prospective new tenant or buyer and handed over to the buyer or new tenant.

3. Where a building is sold or rented out in advance of construction, Member States may require the seller to provide an assessment of its future energy performance, as a derogation from paragraphs 1 and 2; in this case, the energy performance certificate shall be issued at the latest once the building has been constructed.

4. Member States shall require that when:

— buildings having an energy performance certificate,

— building units in a building having an energy performance certificate, and

— building units having an energy performance certificate,

are offered for sale or for rent, the energy performance indicator of the energy performance certificate of the building or the building unit, as applicable, is stated in the advertisements in commercial media.

5. The provisions of this Article shall be implemented in accordance with applicable national rules on joint ownership or common property.

6. Member States may exclude the categories of buildings referred to in Article 4(2) from the application of paragraphs 1, 2, 4 and 5 of this Article.

7. The possible effects of energy performance certificates in terms of legal proceedings, if any, shall be decided in accordance with national rules.

Article 13 speaks about the display of energy performance certificates

1. Member States shall take measures to ensure that where a total useful floor area over 500 m 2 of a building for which an energy performance certificate has been issued in accordance with Article 12(1) is occupied by public authorities and frequently visited by the public, the energy performance certificate is displayed in a prominent place clearly visible to the public.

On 9 July 2015, this threshold of 500 m 2 shall be lowered to 250 m 2 .

2. Member States shall require that where a total useful floor area over 500 m 2 of a building for which an energy performance certificate has been issued in accordance with Article 12(1) is frequently visited by the public, the energy performance certificate is displayed in a prominent place clearly visible to the public.

3. The provisions of this Article do not include an obligation to display the recommendations included in the energy performance certificate.

Article 14 is about the inspection of heating systems

1. Member States shall lay down the necessary measures to establish a regular inspection of the accessible parts of systems used for heating buildings, such as the heat generator, control system and circulation pump(s), with boilers of an effective rated output for space heating purposes of more than 20 kW. That inspection shall include an

assessment of the boiler efficiency and the boiler sizing compared with the heating requirements of the building. The assessment of the boiler sizing does not have to be repeated as long as no changes were made to the heating system or as regards the heating requirements of the building in the meantime.

Member States may reduce the frequency of such inspections or lighten them as appropriate, where an electronic monitoring and control system is in place.

2. Member States may set different inspection frequencies depending on the type and effective rated output of the heating system whilst taking into account the costs of the inspection of the heating system and the estimated energy cost savings that may result from the inspection.

3. Heating systems with boilers of an effective rated output of more than 100 kW shall be inspected at least every two years.

For gas boilers, this period may be extended to four years.

4. As an alternative to paragraphs 1, 2 and 3 Member States may opt to take measures to ensure the provision of advice to users concerning the replacement of boilers, other modifications to the heating system and alternative solutions to assess the efficiency and appropriate size of the boiler. The overall impact of this approach shall be equivalent to that arising from the provisions set out in paragraphs 1, 2 and 3.

Where Member States choose to apply the measures referred to in the first subparagraph, they shall submit to the Commission a report on the equivalence of those measures to measures referred to in paragraphs 1, 2 and 3 of this Article by 30 June 2011 at the latest. Member States shall submit these reports to the Commission every three years. The reports may be included in the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC.

5. After receiving the national report from a Member State about the application of the option as described in paragraph 4, the Commission may request further specific information regarding the requirements and equivalence of the measures set out in that paragraph. In that case, the Member State concerned shall present the requested information or propose amendments within nine months.

Article 15 treats the inspection of air-conditioning systems

1. Member States shall lay down the necessary measures to establish a regular inspection of the accessible parts of air-conditioning systems of an effective rated output of more than 12 kW. The inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. The assessment of the sizing does not have to be repeated as long as no changes were made to this air-conditioning system or as regards the cooling requirements of the building in the meantime.

Member States may reduce the frequency of such inspections or lighten them, as appropriate, where an electronic monitoring and control system is in place.

2. The Member States may set different inspection frequencies depending on the type and effective rated output of the air-conditioning system, whilst taking into account the costs of the inspection of the air-conditioning system and the estimated energy cost savings that may result from the inspection.

3. In laying down the measures referred to in paragraphs 1 and 2 of this Article, Member States shall, as far as is economically and technically feasible, ensure that inspections are carried out in accordance with the inspection of heating systems and other technical systems referred to in Article 14 of this Directive and the inspection of leakages referred to in Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases (1).

4. As an alternative to paragraphs 1, 2 and 3 Member States may opt to take measures to ensure the provision of advice to users on the replacement of air-conditioning systems or on other modifications to the air-conditioning system which may include inspections to assess the efficiency and appropriate size of the air-conditioning system. The overall impact of this approach shall be equivalent to that arising from the provisions set out in paragraphs 1, 2 and 3.

Where Member States apply the measures referred to in the first subparagraph, they shall, by 30 June 2011 at the latest, submit to the Commission a report on the equivalence of those measures to the measures referred to in paragraphs 1, 2 and 3 of this Article. Member States shall submit these reports to the Commission every three years. The reports may be included in the Energy Efficiency Action Plans referred to in Article 14(2) of Directive 2006/32/EC.

5. After receiving the national report from a Member State about the application of the option as described in paragraph 4, the Commission may request further specific information regarding the requirements and equivalence of the measures set in that paragraph. In this case, the Member State concerned shall present the requested information or propose amendments within nine months.

Article 16 introduces the reports on the inspection of heating and air-conditioning systems

1. An inspection report shall be issued after each inspection of a heating or air-conditioning system. The inspection report shall contain the result of the inspection performed in accordance with Article 14 or 15 and include recommendations for the cost-effective improvement of the energy performance of the inspected system.

The recommendations may be based on a comparison of the energy performance of the system inspected with that of the best available feasible system and a system of similar type for which all relevant components achieve the level of energy performance required by the applicable legislation.

2. The inspection report shall be handed over to the owner or tenant of the building.

Article 17 speaks about Independent experts

Member States shall ensure that the energy performance certification of buildings and the inspection of heating systems and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts, whether operating in a self-employed capacity or employed by public bodies or private enterprises.

Experts shall be accredited taking into account their competence.

Member States shall make available to the public information on training and accreditations. Member States shall ensure that either regularly updated lists of qualified and/or accredited experts or regularly updated lists of accredited companies which offer the services of such experts are made available to the public.

Article 18 treats the Independent control system

1. Member States shall ensure that independent control systems for energy performance certificates and reports on the inspection of heating and air-conditioning systems are established in accordance with Annex II. Member States may establish separate systems

for the control of energy performance certificates and for the control of reports on the inspection of heating and air-conditioning systems.

2. The Member States may delegate the responsibilities for implementing the independent control systems.

Where the Member States decide to do so, they shall ensure that the independent control systems are implemented in compliance with Annex II.

3. Member States shall require the energy performance certificates and the inspection reports referred to in paragraph 1 to be made available to the competent authorities or bodies on request.

Article 19 specifies that the Commission, assisted by the Committee established by Article 26, shall evaluate this Directive by 1 January 2017 at the latest, in the light of the experience gained and progress made during its application, and, if necessary, make proposals.

Article 20 informs that

1. Member States shall take the necessary measures to inform the owners or tenants of buildings or building units of the different methods and practices that serve to enhance energy performance.

2. Member States shall in particular provide information to the owners or tenants of buildings on energy performance certificates and inspection reports, their purpose and objectives, on cost-effective ways to improve the energy performance of the building and, where appropriate, on financial instruments available to improve the energy performance of the building.

At the request of the Member States, the Commission shall assist Member States in staging information campaigns for the purposes of paragraph 1 and the first subparagraph of this paragraph, which may be dealt with in Union programmes.

3. Member States shall ensure that guidance and training are made available for those responsible for implementing this Directive. Such guidance and training shall address the importance of improving energy performance, and shall enable consideration of the optimal combination of improvements in energy efficiency, use of energy from renewable sources and use of district heating and cooling when planning, designing, building and renovating industrial or residential areas.

4. The Commission is invited to continuously improve its information services, in particular the website that has been set up as a European portal for energy efficiency in buildings directed towards citizens, professionals and authorities, in order to assist Member States in their information and awareness- raising efforts. Information displayed on this website might include links to relevant European Union and national, regional and local legislation, links to Europa websites that display the National Energy Efficiency Action Plans, links to available financial instruments, as well as best practice examples at national, regional and local level. In the context of the European Regional Development Fund, the Commission shall continue and further intensify its information services with the aim of facilitating the use of available funds by providing assistance and information to interested stakeholders, including national, regional and local authorities, on funding possibilities, taking into account the latest changes in the regulatory framework.

Article 21 specifies that in order to facilitate the effective implementation of the Directive, Member States shall consult the stakeholders involved, including local and regional authorities, in accordance with the national legislation applicable and as relevant. Such consultation is of particular importance for the application of Articles 9 and 20.

Article 22 is about the Adaptation of Annex I to technical progress

The Commission shall adapt points 3 and 4 of Annex I to technical progress by means of delegated acts in accordance with Articles 23, 24 and 25.

Article 28 explains the timestep that Member States have to respect in the adoption ot the Directive

1. Member States shall adopt and publish, by 9 July 2012 at the latest, the laws, regulations and administrative provisions necessary to comply with Articles 2 to 18, and with Articles 20 and 27.

They shall apply those provisions as far as Articles 2, 3, 9, 11, 12, 13, 17, 18, 20 and 27 are concerned, from 9 January 2013 at the latest.

They shall apply those provisions as far as Articles 4, 5, 6, 7, 8, 14, 15 and 16 are concerned, to buildings occupied by the public authorities from 9 January 2013 at the latest and to other buildings from 9 July 2013 at the latest.

They may defer the application of Article 12(1) and (2) to single building units that are rented out, until 31 December 2015. This shall however not result in fewer certificates being issued than would have been the case under the application of the Directive 2002/91/EC in the Member State concerned.

When Member States adopt measures, they shall contain a reference to this Directive or be accompanied by such a reference on the occasion of their official publication. They shall also include a statement that references in existing laws, regulations and administrative provisions to Directive 2002/91/EC shall be construed as references to this Directive. Member States shall determine how such reference is to be made and how that statement is to be formulated.

2. Member States shall communicate to the Commission the text of the main provisions of national law which they adopt in the field covered by this Directive.

Article 29 Repeal

Directive 2002/91/EC, as amended by the Regulation indicated in Annex IV, Part A, is hereby repealed with effect from 1 February 2012, without prejudice to the obligations of the Member States relating to the time limit for transposition into national law and application of the Directive set out in Annex IV, Part B.

References to Directive 2002/91/EC shall be construed as references to this Directive and shall be read in accordance with the correlation table in Annex V.

ANNEX I

Common general framework for the calculation of energy performance of buildings

(referred to in Article 3)

1. The energy performance of a building shall be determined on the basis of the calculated or actual annual energy that is consumed in order to meet the different needs associated with its typical use and shall reflect the heating energy needs and cooling energy needs (energy needed to avoid overheating) to maintain the envisaged temperature conditions of the building, and domestic hot water needs.

2. The energy performance of a building shall be expressed in a transparent manner and shall include an energy performance indicator and a numeric indicator of primary energy use, based on primary energy factors per energy carrier, which may be based on national or regional annual weighted averages or a specific value for on- site production.

The methodology for calculating the energy performance of buildings should take into account European standards and shall be consistent with relevant Union legislation, including Directive 2009/28/EC.

3. The methodology shall be laid down taking into consideration at least the following aspects:

(a) the following actual thermal characteristics of the building including its internal partitions:

(i) thermal capacity;

(ii) insulation;

(iii) passive heating;

(iv) cooling elements; and

(v) thermal bridges;

(b) heating installation and hot water supply, including their insulation characteristics;

(c) air-conditioning installations;

(d) natural and mechanical ventilation which may include air-tightness;

(e) built-in lighting installation (mainly in the non-residential sector);

(f) the design, positioning and orientation of the building, including outdoor climate;

(g) passive solar systems and solar protection;

(h) indoor climatic conditions, including the designed indoor climate;

(i) internal loads.

4. The positive influence of the following aspects shall, where relevant in the calculation, be taken into account:

(a) local solar exposure conditions, active solar systems and other heating and electricity systems based on energy from renewable sources;

(b) electricity produced by cogeneration;

(c) district or block heating and cooling systems;

(d) natural lighting.

5. For the purpose of the calculation buildings should be adequately classified into the following categories:

(a) single-family houses of different types;

(b) apartment blocks;

(c) offices;

(d) educational buildings;

(e) hospitals;

(f) hotels and restaurants;

(g) sports facilities;

(h) wholesale and retail trade services buildings;

(i) other types of energy-consuming buildings.

ANNEX II

Independent control systems for energy performance certificates and inspection reports

1. The competent authorities or bodies to which the competent authorities have delegated the responsibility for implementing the independent control system shall make a random selection of at least a statistically significant percentage of all the energy performance certificates issued annually and subject those certificates to verification.

The verification shall be based on the options indicated below or on equivalent measures:

(a) validity check of the input data of the building used to issue the energy performance certificate and the results stated in the certificate;

(b) check of the input data and verification of the results of the energy performance certificate, including the recommendations made;

(c) full check of the input data of the building used to issue the energy performance certificate, full verification of the results stated in the certificate, including the recommendations made, and on-site visit of the building, if possible, to check correspondence between specifications given in the energy performance certificate and the building certified.

2. The competent authorities or bodies to which the competent authorities have delegated the responsibility for implementing the independent control system shall make a random selection of at least a statistically significant percentage of all the inspection reports issued annually and subject those reports to verification.

ANNEX III

Comparative methodology framework to identify cost-optimal levels of energy performance requirements for buildings and building elements

The comparative methodology framework shall enable Member States to determine the energy performance of buildings and building elements and the economic aspects of measures relating to the energy performance, and to link them with a view to identifying the cost-optimal level.

The comparative methodology framework shall be accompanied by guidelines outlining how to apply this framework in the calculation of cost-optimal performance levels.

The comparative methodology framework shall allow for taking into account use patterns, outdoor climate conditions, investment costs, building category, maintenance and operating costs (including energy costs and savings), earnings from energy produced, where applicable, and disposal costs, where applicable. It should be based on relevant European standards relating to this Directive.

The Commission shall also provide:

— guidelines to accompany the comparative methodology framework; these guidelines will serve to enable the Member States to undertake the steps listed below,

— information on estimated long-term energy price developments.

For the application of the comparative methodology framework by Member States, general conditions, expressed by parameters, shall be laid down at Member State level.

The comparative methodology framework shall require Member States to:

— define reference buildings that are characterised by and representative of their functionality and geographic location, including indoor and outdoor climate conditions. The reference buildings shall cover residential and non-residential buildings, both new and existing ones,

— define energy efficiency measures to be assessed for the reference buildings. These may be measures for individual buildings as a whole, for individual building elements, or for a combination of building elements,

— assess the final and primary energy need of the reference buildings and the reference buildings with the defined energy efficiency measures applied,

— calculate the costs (i.e. the net present value) of the energy efficiency measures (as referred to in the second indent) during the expected economic lifecycle applied to the reference buildings (as referred to in the first indent) by applying the comparative methodology framework principles.

By calculating the costs of the energy efficiency measures during the expected economic lifecycle, the cost-effectiveness of different levels of minimum energy performance requirements is assessed by the Member States. This will allow the determination of cost-optimal levels of energy performance requirements.

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC

Directive 2002/91/EC Of The European Parliament and of the Council of 16 December 2002 on the energy performance of buildings takes into account that:

(1) Article 6 of the Treaty requires environmental protection requirements to be integrated into the definition and implementation of Community policies and actions.
(2) The natural resources, to the prudent and rational utilisation of which Article 174 of the Treaty refers, include oil products, natural gas and solid fuels, which are essential sources of energy but also the leading sources of carbon dioxide emissions.
(3) Increased energy efficiency constitutes an important part of the package of policies and measures needed to comply with the Kyoto Protocol and should appear in any policy package to meet further commitments.
(4) Demand management of energy is an important tool enabling the Community to influence the global energy market and hence the security of energy supply in the medium and long term.
(5) In its conclusions of 30 May 2000 and of 5 December 2000, the Council endorsed the Commission's action plan on energy efficiency and requested specific measures in the building sector.
(6) The residential and tertiary sector, the major part of which is buildings, accounts for more than 40 % of final energy consumption in the Community and is expanding, a trend which is bound to increase its energy consumption and hence also its carbon dioxide emissions.

(7) Council Directive 93/76/EEC of 13 September 1993 to limit carbon dioxide emissions by improving energy efficiency (SAVE) (5), which requires Member States to develop, implement and report on programmes in the field of energy efficiency in the building sector, is now starting to show some important benefits. However, a complementary legal instrument is needed to lay down more concrete actions with a view to achieving the great unrealised potential for energy savings and reducing the large differences between Member States' results in this sector.

(8) Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (6) requires construction works and their heating, cooling and ventilation installations to be designed and built in such a way that the amount of energy required in use will be low, having regard to the climatic conditions of the location and the occupants.

(9) The measures further to improve the energy performance of buildings should take into account climatic and local conditions as well as indoor climate environment and cost-effectiveness. They should not contravene other essential requirements concerning buildings such as accessibility, prudence and the intended use of the building.

(10) The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at regional level, that includes, in addition to thermal insulation other factors that play an increasingly important role such as heating and air-conditioning installations, application of renewable energy sources and design of the building. A common approach to this process, carried out by qualified and/or accredited experts, whose independence is to be guaranteed on the basis of objective criteria, will contribute to a level playing field as regards efforts made in Member States to energy saving in the buildings sector and will introduce transparency for prospective owners or users with regard to the energy performance in the Community property market.

(11) The Commission intends further to develop standards such as EN 832 and prEN 13790, also including consideration of air-conditioning systems and lighting.

(12) Buildings will have an impact on long-term energy consumption and new buildings should therefore meet minimum energy performance requirements tailored to the local climate. Best practice should in this respect be geared to the optimum use of factors

relevant to enhancing energy performance. As the application of alternative energy supply systems is generally not explored to its full potential, the technical, environmental and economic feasibility of alternative energy supply systems should be considered; this can be carried out once, by the Member State, through a study which produces a list of energy conservation measures, for average local market conditions, meeting cost-effectiveness criteria. Before construction starts, specific studies may be requested if the measure, or measures, are deemed feasible.

(13) Major renovations of existing buildings above a certain size should be regarded as an opportunity to take cost effective measures to enhance energy performance.

Major renovations are cases such as those where the total cost of the renovation related to the building shell and/or energy installations such as heating, hot water supply, air-conditioning, ventilation and lighting is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated, or those where more than 25 % of the building shell undergoes renovation.

(14) However, the improvement of the overall energy performance of an existing building does not necessarily mean a total renovation of the building but could be confined to those parts that are most relevant for the energy performance of the building and are cost-effective.

(15) Renovation requirements for existing buildings should not be incompatible with the intended function, quality or character of the building. It should be possible to recover additional costs involved in such renovation within a reasonable period of time in relation to the expected technical lifetime of the investment by accrued energy savings.

(16) The certification process may be supported by programmes to facilitate equal access to improved

energy performance; based upon agreements between organisations of stakeholders and a body appointed by the Member States; carried out by energy service companies which agree to commit themselves to undertake the identified investments. The schemes adopted should be supervised and followed up by Member States, which should also facilitate the use of incentive systems. To the extent possible, the certificate should describe the actual energy-performance situation of the building and may be revised accordingly. Public authority buildings and buildings frequently visited by the public should set an example by taking environmental and energy considerations into account and therefore should be subject to energy certification on a regular basis. The dissemination to the public of this information on energy performance should be enhanced by clearly displaying these energy certificates. Moreover, the displaying of officially recommended indoor temperatures, together with the actual measured temperature, should discourage the misuse of heating, air-conditioning and ventilation systems. This should contribute to avoiding unnecessary use of energy and to safeguarding comfortable indoor climatic conditions (thermal comfort) in relation to the outside temperature.

(17) Member States may also employ other means/measures, not provided for in this Directive, to encourage enhanced energy performance. Member States should encourage good energy management, taking into account the intensity of use of buildings.

(18) Recent years have seen a rise in the number of air-conditioning systems in southern European countries. This creates considerable problems at peak load times, increasing the cost of electricity and disrupting the energy balance in those countries. Priority should be given to strategies which enhance the thermal performance of buildings during the summer period. To this end there should be further development of passive cooling techniques, primarily those that improve indoor climatic conditions and the microclimate around buildings.

(19) Regular maintenance of boilers and of air-conditioning systems by qualified personnel contributes to maintaining their correct adjustment in accordance with the product specification and in that way will ensure optimal performance from an environmental, safety and energy point of view. An independent assessment of the total heating installation is appropriate whenever replacement could be considered on the basis of cost-effectiveness.

(20) The billing, to occupants of buildings, of the costs of heating, air-conditioning and hot water, calculated in proportion to actual consumption, could contribute towards energy saving in the residential sector. Occupants should be enabled to regulate their own consumption of heat and hot water, in so far as such measures are cost effective.

(21) In accordance with the principles of subsidiarity and proportionality as set out in Article 5 of the Treaty, general principles providing for a system of energy performance requirements and its objectives should be established at Community level, but the

detailed implementation should be left to Member States, thus allowing each Member State to choose the regime which corresponds best to its particular situation. This Directive confines itself to the minimum required in order to achieve those objectives and does not go beyond what is necessary for that purpose.

(22) Provision should be made for the possibility of rapidly adapting the methodology of calculation and of Member States regularly reviewing minimum requirements in the field of energy performance of buildings with regard to technical progress, inter alia, as concerns the insulation properties (or quality) of the construction material, and to future developments in standardization.

(23) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission (1).

Article 1 explains the objectives:

The objective of this Directive is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. This Directive lays down requirements as regards:

(a) the general framework for a methodology of calculation of the integrated energy performance of buildings;

(b) the application of minimum requirements on the energy performance of new buildings;

(c) the application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation;

(d) energy certification of buildings; and

(e) regular inspection of boilers and of air-conditioning systems in buildings and in addition an assessment of the heating installation in which the boilers are more than 15 years old.

Article 2 specifies the following definitions:

1. ‘building’: a roofed construction having walls, for which energy is used to condition the indoor climate; a building may refer to the building as a whole or parts thereof that have been designed or altered to be used separately;

2. ‘energy performance of a building’: the amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building, which may include, inter alia, heating, hot water heating, cooling, ventilation and lighting. This amount shall be reflected in one or more numeric indicators which have been calculated, taking into account insulation, technical and installation characteristics, design and positioning in relation to climatic aspects, solar exposure and influence of neighbouring structures, own-energy generation and other factors, including indoor climate, that influence the energy demand;
3. ‘energy performance certificate of a building’: a certificate recognised by the Member State or a legal person designated by it, which includes the energy performance of a building calculated according to a methodology based on the general framework set out in the Annex;
4. ‘CHP’ (combined heat and power): the simultaneous conversion of primary fuels into mechanical or electrical and thermal energy, meeting certain quality criteria of energy efficiency;
5. ‘air-conditioning system’: a combination of all components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity and air cleanliness;
6. ‘boiler’: the combined boiler body and burner-unit designed to transmit to water the heat released from combustion;
7. ‘effective rated output (expressed in kW)’: the maximum calorific output specified and guaranteed by the manufacturer as being deliverable during continuous operation while complying with the useful efficiency indicated by the manufacturer;
8. ‘heat pump’: a device or installation that extracts heat at low temperature from air, water or earth and supplies the heat to the building.

Article 3 explain the methodology that has to be adopted

Member States shall apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of the general framework set out in the Annex. Parts 1 and 2 of this framework shall be adapted to technical progress in accordance with the procedure referred to in Article 14(2), taking into account standards or norms applied in Member State legislation. This methodology shall be set at national or regional level. The energy performance of a building shall be expressed in a transparent manner and may include a CO2 emission indicator.

Article 4 specifies the setting of energy performance requirements

1. Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings are set, based on the methodology referred to in Article 3. When setting requirements, Member States may differentiate between new and existing buildings and different categories of buildings. These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building. These requirements shall be reviewed at regular intervals which should not be longer than five years and, if necessary, updated in order to reflect technical progress in the building sector.

2. The energy performance requirements shall be applied in accordance with Articles 5 and 6.

3. Member States may decide not to set or apply the requirements referred to in paragraph 1 for the following categories of buildings:

— buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance,
— buildings used as places of worship and for religious activities,
— temporary buildings with a planned time of use of two years or less, industrial sites, workshops and non-residential agricultural buildings with low energy demand and nonresidential agricultural buildings which are in use by a sector covered by a national sectoral agreement on energy performance,
— residential buildings which are intended to be used less than four months of the year,
— stand-alone buildings with a total useful floor area of less than 50 m^2.

Article 5 defines the measures that Member States have to adopt in the new buildings

Member States shall take the necessary measures to ensure that new buildings meet the minimum energy performance requirements referred to in Article 4.

For new buildings with a total useful floor area over 1 000 m2, Member States shall ensure that the technical, environmental and economic feasibility of alternative systems such as:

— decentralised energy supply systems based on renewable energy,
— CHP,
— district or block heating or cooling, if available,
— heat pumps, under certain conditions, is considered and is taken into account before construction starts.

Article 6 defines the measures that Member States have to adopt in the existing buildings.

Member States shall take the necessary measures to ensure that when buildings with a total useful floor area over 1 000 m2 undergo major renovation, their energy performance is upgraded in order to meet minimum requirements in so far as this is technically, functionally and economically feasible.

Member States shall derive these minimum energy performance requirements on the basis of the energy performance requirements set for buildings in accordance with Article 4. The requirements may be set either for the renovated building as a whole or for the renovated systems or components when these are part of a renovation to be carried out within a limited time period, with the abovementioned objective of improving the overall energy performance of the building.

Article 7 defines the measures that Member States have to adopt in the Energy performance certificate

1. Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the

prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years.

Certification for apartments or units designed for separate use in blocks may be based:

— on a common certification of the whole building for blocks with a common heating system, or
— on the assessment of another representative apartment in the same block.

Member States may exclude the categories referred to in Article 4(3) from the application of this paragraph.

2. The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance.

The objective of the certificates shall be limited to the provision of information and any effects of these certificates in terms of legal proceedings or otherwise shall be decided in accordance with national rules.

3. Member States shall take measures to ensure that for buildings with a total useful floor area over 1 000 m2 occupied by public authorities and by institutions providing public services to a large number of persons and therefore frequently visited by these persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public.

The range of recommended and current indoor temperatures and, when appropriate, other relevant climatic factors may also be clearly displayed.

Article 8 treats the theme of the inspection of boilers

With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall either:

(a) lay down the necessary measures to establish a regular inspection of boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 kW to 100 kW. Such inspection may also be applied to boilers using other fuels. Boilers of an effective rated output of more than 100 kW shall be inspected at least every two years. For gas boilers, this period may be extended to four years.

For heating installations with boilers of an effective rated output of more than 20 kW which are older than 15 years, Member States shall lay down the necessary measures to establish a one-off inspection of the whole heating installation. On the basis of this inspection, which shall include an assessment of the boiler efficiency and the boiler sizing compared to the heating requirements of the building, the experts shall provide advice to the users on the replacement of the boilers, other modifications to the heating system and on alternative solutions; or (b) take steps to ensure the provision of advice to the users on the replacement of boilers, other modifications to the heating system and on alternative solutions which may include inspections to assess the efficiency and appropriate size of the boiler. The overall impact of this approach should be broadly equivalent to that arising from the provisions set out in (a). Member States that choose this option shall submit a report on the equivalence of their approach to the Commission every two years.

Article 9 regards the inspection of air-conditioning systems

With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of airconditioning systems of an effective rated output of more than 12 kW.

This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvement or replacement of the air-conditioning system and on alternative solutions.

Article 10 introduces the requirements of the independent experts

Member States shall ensure that the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts, whether operating as sole traders or employed by public or private enterprise bodies.

Article 15 Transposition

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive at the latest on 4 January 2006. They shall forthwith inform the Commission thereof. When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. Member States shall determine how such reference is to be made.

2. Member States may, because of lack of qualified and/or accredited experts, have an additional period of three years to apply fully the provisions of Articles 7, 8 and 9. When making use of this option, Member States shall notify the Commission, providing the appropriate justification together with a time schedule with respect to the further implementation of this Directive.

ANNEX I

General framework for the calculation of energy performance of buildings (Article 3)

1. The methodology of calculation of energy performances of buildings shall include at least the following aspects:

(a) thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include
air-tightness;
(b) heating installation and hot water supply, including their insulation characteristics;
(c) air-conditioning installation;
(d) ventilation;
(e) built-in lighting installation (mainly the non-residential sector);

(f) position and orientation of buildings, including outdoor climate;

(g) passive solar systems and solar protection;

(h) natural ventilation;

(i) indoor climatic conditions, including the designed indoor climate.

2. The positive influence of the following aspects shall, where relevant in this calculation, be taken into account:

(a) active solar systems and other heating and electricity systems based on renewable energy sources;

(b) electricity produced by CHP;

(c) district or block heating and cooling systems;

(d) natural lighting.

3. For the purpose of this calculation buildings should be adequately classified into categories such as:

(a) single-family houses of different types;

(b) apartment blocks;

(c) offices;

(d) education buildings;

(e) hospitals;

(f) hotels and restaurants

1.2. The Italian Framework of the Energy Laws in the building sector

D.Lgs. 28/11

This decree, pursuant to Directive 2009/28/CE and in accordance with the criteria established by the law of 4th June 2010 no. 96, defines the tools, mechanisms, incentives and institutional, financial and legal framework necessary for achieving the objectives on the overall share of energy from renewable sources in gross final consumption of energy and the share of energy from renewable sources in transport, up to 2020. This decree also lays down rules relating to statistical transfers between member states, joint projects between member states and with third party countries, guarantees of origin, administrative procedures, information and training, as well as access to the electricity grid for renewable energy and it establishes sustainability criteria for biofuels and bioliquids.

Article 3 establishes the following national targets:

1. The overall ratio of energy from renewable sources to the final energy consumption to be achieved in 2020 is 17 percent.

2. Within the objective set out in paragraph 1, the ratio of energy from renewable sources in all forms of transport will in 2020 have to be at least 10 per cent of the final consumption of energy in the transport sector in that year.

The objectives set out in paragraphs 1 and 2 are pursued through a progression over time consistent with the guidelines of the national action plans for renewable energy prepared in accordance to Article 4 of Directive 2009/28/CE.

4. The calculation methods of the objectives established by paragraphs 1, 2 and 3 are shown in annex 1.

Article 11 introduces a requirement for the integration of renewable energy sources in new buildings and in existing buildings subject to major renovation.

1. Projects for new buildings and major renovation projects of existing buildings will require the use of renewable sources to cover the consumption of heat, electricity and cooling, in accordance with the minimum principles of integration and the starting dates referred to in annex 3. [..]

4. Renewable Energy Plants installed to reach the conditions set out in annex 3 of the decree have access to government incentives for the promotion of renewable energy sources, limited to the amount in excess of that required for compliance with those obligations. For such plants, it is still possible to have access to guarantee and rotation funds[..].

6. In air quality plans under current legislation, regions and the autonomous provinces may require that the values set out in annex 3 should be ensured, in whole or in part, by applying use of renewable energy sources other than biomass burning, where this is necessary to ensure the process of achieving and maintaining the values of air quality related to particulate matter (PM10 and PM2.5) and polycyclic aromatic hydrocarbons (PAHs).

7.The obligations under regional or municipal legislation are adapted to the provisions of this article within 180 days from the date of entry into force of this decree. After expiry of the said period, the provisions of this article are to be applied.

Article 12 introduces measures of simplification.

1..Projects of new buildings and major renovation of existing buildings that can ensure coverage of the consumption of heat, electricity and cooling of more than 30 percent compared with the minimum requirements set out in annex 3, shall, at the time of issuance of the building certificate, benefit of a 5 per cent volume bonus, subject to compliance with the rules on minimum distances between buildings and minimum protection distances of roadways, in the cases covered and governed by the municipal planning. [..]

Legislative Decree No 192 of 19 August 2005, Presidential Decree No 59 of 2 April 2009, Decree of the Ministry of Economic Development of 26 June 2009

Directive 2002/91/EC for increasing **the energy efficiency of buildings** was transposed by the Italian Government by means of Legislative Decree No 192 of 19 August 2005, coming into force on 8 October 2005. By means of this provision a regulatory framework was established within which the Regions can carry out their duties, develop the specifics and take advantage of their climatic and socio-economic circumstances. The Decree, the part concerning winter heating already being in force, lays down implementing provisions. To date the following implementation standards have been issued: Presidential Decree No 59 of 2 April 2009 and the Decree of the Ministry of Economic Development of 26 June 2009 on national guidelines for the energy performance certification of buildings. Compared with the preceding legislative framework on the matter, Legislative Decree 192/2005 and its implementing provisions (DPR 59/09 and Ministerial Decree 26 June 2009) present some new criteria, including the following:

- They set minimum mandatory requirements for Primary Energy Needs22 for winter heating and for the energy needs of the building envelope in connection with summer air conditioning for all new constructions and for total refurbishments of large sized buildings (1.000 m^2 or more of useable floor area), with a phased-in application over 2006-2008-2010;
- They specify higher levels of thermal insulation for the building envelope and minimum requirements for buildings that are undergoing refurbishments (without limit to size or amount) with the same phased application as the preceding point;
- They call for energy certification;
- They promote the use of higher efficiency plant and equipment, (for example: heat pumps, three- or four-star gas boilers, for new buildings and refurbishments);
- They rationalise the checks on heating systems, updating the frequency of performance inspections to help contain consumption;

- They require, in the case of new constructions and the installation of new plants or the refurbishment of existing plants, that 50 % of the annual primary energy need for domestic hot water be met with the use of renewable energy sources (20 % for buildings in old town centres);
- They lay down a process of monitoring and comparison aimed at the harmonisation of legislation with the regions and autonomous provinces.

Table 1.Energy savings resulting from the transposition of Directive 2002/91/EC and the implementation of Legislative Decree 192/05 (FEC) [7]

Actions	2005	2006	2007	2008	2009	2010	Totals 2007-2010
Residential sector	186	877	847	849	721	646	4.126
Non residential sector	-	1.144	858	858	572	572	4.004
Replacement of heat generators	-	2.306	2.321	2.089	2.086	2.086	10.889
Maintenance of heat generators (Constant, non-cumulative annual figure)	-	5.288	5.288	5.288	5.288	5.288	5.288
Totals	186	9.615	9.314	9.084	8.667	8.592	24.307

Note: the data in relation to the non-residential sector, replacement of heat generators and maintenance of heat generators for 2010 are the same as those for 2009 because they are still being processed, since applications for authorisation for the incentive may be amended until September 2011.

Tax allowances (55%) for the energy upgrading of existing buildings is in force since 1 January 2007, this is a financial incentive consisting of an allowance against the taxable income of individuals (IRPEF) or companies (IRES), set up on the basis of Law No 296 of 27 December 2006 (Finance Act 2007) et seq. In particular, the energy upgrading works on existing buildings provided for in paragraphs 344, 345, 346 and 347 of Article 1 of Law No 296 of 27 December 2006, supplemented and modified by subsequent regulatory provisions, allow for: the overall energy upgrading of the building; works on the horizontal and vertical opaque structures and the transparent structures, inclusive of frame and glass; the installation of solar panels for the production of hot water; the replacement of winter heating systems with systems equipped with condensation boilers or, alternatively, with systems equipped with high-efficiency heat pumps, i.e. low-temperature geothermal systems.

- This form of incentive can be accumulated with certain White Certificate schedules laid down by the Ministerial Decrees of 20 July 2004.
- Table 2 provides a detailed analysis of the actions carried out, resulting in an energy saving in terms of final energy (Final Energy Consumption) of 5.204 GWh/year, of which more than 40 % was derived from the use of efficient heating systems.

Table 2. Energy savings [GWh/year] achieved through the granting of tax allowances (55%) for the energy upgrading of existing buildings (FEC) [6]

Actions	**2007**	**2008**	**2009**	**2010**	**Totals 2007-2010**
Insulation of opaque envelope	54	218	199	108	579
Replacement of doors and windows	177	350	297	173	997
Installation of solar heating panels for hot water	135	394	247	195	971
Use of efficient heating systems	370	837	705	420	2.332
Balanced flues and wood fired boilers	51	160	40	74	325
Totals	787	1.959	1.488	970	5.204

1.3. The technical laws

The ISO 13153:2012 “Framework for the design process for energy savings single family residential and small commercial buildings

ISO Technical Committee (TC) 205, Building environment design, developed new International Standard – ISO 13153:2012, Framework of the design process for energy-saving single-family residential and small commercial buildings – that provides framework for effective consideration of energy-saving approaches to building of residences and small commercial buildings during various design process stages. Standard also includes 3 annexes intended to facilitate effective usage.

Energy consumption in buildings – including climate control, appliances, lighting, and other installed equipment – represents nearly 40% of the world’s total energy use. In recent years, rising living expenses and environmental concerns have driven many homeowners to seek new ways to cut down on their household energy use. In response, International Organization for Standardization (ISO) Technical Committee (TC) 205, Building environment design, has developed a new International Standard, ISO 13153:2012, Framework of the design process for energy-saving single-family residential and small commercial buildings, that provides a framework for effective consideration of energy-saving approaches to the building of residences and small commercial buildings during the different stages of the design process.

Under ISO 13153, the predicted reduction of energy consumption in a given residence is used to determine an “energy consumption ratio,” allowing for meaningful comparisons of actual energy use and potential energy savings between different design approaches. The standard is applicable to the heating, cooling, and lighting systems of new buildings, as well as hot water, ventilation, and other relevant sources of energy consumption. As part of a growing group of ISO standards for energy efficiency in buildings, ISO 13153 is expected to assist designers in making effective, informed decisions about the use of various energy-saving technologies in light of the specific design conditions and environmental circumstances affecting each individual residence or commercial structure.

ISO 13153 also includes three annexes, which are intended to make it easier to make effective use of the standard. The annexes provide examples of energy-saving elemental technologies and specification options; design guidelines, including details on energy consumption ratios for elemental technologies; and notes on the experimental estimation of systems, based on actual conditions of usage.

The UNI TS 11300-1/2 3-4

UNI TS 11300 Part 1: Evaluation of energy need for space heating and cooling

The technical specification defines the procedures for the national implementation of UNI EN ISO 13790:2008, with reference to the monthly method for calculating the thermal energy needs for heating and cooling.

The technical specification addresses all the conditions for the applications of the UNI EN ISO 13790:2008: design rating, energy assessment of the building needs through the calculation in standard conditions (asset rating), or in particular climatic and operating conditions (tailored rating).

UNI TS 11300 Part 2: Evaluation of primary energy need and of system efficiencies for space heating and domestic hot water production

The technical specification provides data and methods for the determination of:
- the demand for domestic hot water needs in terms of thermal energy;
- electricity demand for auxiliary systems of heating systems and for the production of domestic hot water
- the primary energy needs for winter heating and for the production of domestic hot water.

The technical specification have to be applied to designed system (or renovated) or to existing systems:
- for heating only;
- mixed or combined, for heating and for domestic hot water production
- only for the production of hot water for sanitary use.

UNI TS 11300 Part 3: Evaluation of primary energy and system efficiencies for space cooling

The technical specification provides data and methods for the determination of:
- efficiency and energy needs for cooling systems
- the primary energy needs for cooling systems.

The technical specification have to be applied only to fixed cooling systems with electrical chillers or absorption ones.

The technical specification have to be applied only to new projects or retrofitted ones or to existing systems:
- for cooling only
- for air conditioning in summer.

The technical specification doesn't need application to the individual components of summer air conditioning systems which refer to specific product standards.

Chapter 2 State of the art

2.1. Net Zero Energy Buildings: a look at the definitions

Energy Use in buildings worldwide accounts for over 40% of primary energy use and 24% of greenhouse gas emissions. Several International Energy Agency (IEA) countries have adopted a vision of so-called 'net zero energy buildings' as a long-term goal of their energy policies. However, what is missing is a clear definition and international agreement on the measures of building performance that could inform 'zero energy' building policies, programs and industry adoption around the world.

In general, there is a plurality of approaches in defining what a ZEB is. Relevant work can be found in literature on the survey and comparison of case studies and existing and proposed definitions [1 – 5]. It emerges from these analyses that little agreement exists on a common definition that is based on scientific analysis. Recurrent issues concern the metric (i.e. primary energy, carbon emissions, etc.) and the items to be considered in the balance (i.e. energy use in the operation of a building, energy embodied in materials and technical installations, etc.). In turn, the different definitions end up suggesting different optimal design strategies, influencing the choices on insulation levels, HVAC system performance, PV or cogeneration system dimensioning, etc.

The term ZEB is used commercially without a clear understanding and countries are enacting policies and national targets based on the concept without a clear definition in place. Commercial definitions may be partial or biased in their scope, for example including only some loads in the balance, or allowing for energy inefficient buildings to achieve the status of ZEB thanks to oversized PV systems, but without applying any energy saving measure. For these reasons such definitions are not suitable as a basis for regulations and national policies. Furthermore, in order to be environmentally friendly in a broader view ZEBs should be designed – to the extent that is in the control of the designers – in a way that do not put additional stress on the energy supply grids.

Indeed, the focus of this thesis is on buildings that are connected to an energy infrastructure, i.e. electricity grid, district heating and cooling system, gas pipe network, biomass and biofuels distribution networks, and not on autonomous buildings. To this respect the term Net ZEB can be used to refer to buildings that are connected to the energy infrastructure, while the term ZEB is more general and may include as well autonomous buildings. The wording 'Net' underlines the fact that there is a balance between energy taken from and supplied back to the energy grids over a period of time, nominally a year. Net ZEBs are the focus of this thesis.

The work done so far in the IEA Task40/Annex 52 [5], including the comparison of calculation methodologies adopted or suggested by the participating institutes in their home countries, has confirmed that the idea of Net ZEB is understood conceptually. Conceptually, it is understood that a Net ZEB is a building with greatly reduced energy demand that can be balanced by an equivalent on-site generation of electricity, or other energy carriers, from renewable sources. It is also understood that the definition may affect significantly the way buildings are designed to achieve the goal. What is missing is a formal, comprehensive framework that considers all the relevant aspects characterising a Net ZEB definition. This paper builds upon concepts found literature and expands the analysis identifying a series of criteria that characterise a sound Net ZEB definition.

It is difficult to find a building, which can be named the first Zero Energy/Emission Building (ZEB). One of the reasons could be that maybe ZEB is not a new concept for a building. Over the decades, in many articles different ZEB's were described and evaluated, however almost for each project the ZEB either was defined differently or no exact definition was used. Able, (1994) raised the issue of lack of common understanding for low-energy buildings, but it could also refer to any building concept "*An analysis of discussions and papers about low-energy buildings, as well as different low-energy building projects, indicates that the ideas behind demonstration projects are often based on a few fundamental conditions. Usually, however, these conditions are not accounted for explicitly but, nevertheless, they do exist. This can lead to misunderstandings and conclusions which can be misleading.*" Recently, the lack of common understanding and common definition for ZEB became noticeable and the world wide discussion has begun. There are many studies available, in which authors tried to propose different definitions for ZEB depending on: - how the zero energy goal is achieved - what is the building – grid interaction - unequal energy qualities in the energy balance - what are the project boundaries for the balance. The main objective of this Chapter is to give an overview of studies performed on ZEB. The studies include different definitions of ZEB, empirical and experimental investigation of ZEB concept, and detailed description of the energy efficient technologies, active and passive utilization of renewable energy sources. With such a broad range of topics for studies, in this chapter main focus will be put on wide diversity among ZEB's definitions. Based on differences and similarities of the definitions various approaches for defining ZEB are proposed.

There are many studies dedicated to Zero Energy Building, in which authors emphasize the lack of common understanding of what should be equal to "Zero". In the report, written in 2006 by Torcellini, et al., authors use the general definition for ZEB given by The U.S. Department of Energy (DOE) Building Technologies Program: *"A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies."* However they also point out clearly undefined "zero": *"Despite the excitement over the phrase "zero energy," we lack a common definition, or even a common understanding, of what it means."*

Furthermore, the definition of Zero Energy Building can be constructed in several ways, depending on the project goals, intentions of the investor, concern about the climate changes and greenhouse gas emissions or finally the energy costs. Taking into consideration all the above mentioned scenarios in the following advantages and disadvantages of four most commonly used definitions were pointed out:

• ***Net Zero Site Energy****: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.*

• ***Net Zero Source Energy:*** *A source ZEB produces at least as much energy as it uses in year, when accounted for at the source. Source energy refers to the primary energy* *used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to source conversion multipliers.*

• ***Net Zero Energy Costs:*** *In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.*

• ***Net Zero Energy Emissions:*** *A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources.*

Table 3 ZEB Definition Summary [6]

Definition	Pluses	Minuses	Other Issues
Site ZEB	• Easy to implement. • Verifiable through on-site measurements. • Conservative approach to achieving ZEB. • No externalities affect performance, can track success over time. • Easy for the building community to understand and communicate. • Encourages energy- efficient building designs.	Requires more PV export to offset natural gas. • Does not consider all utility costs (can have a low load factor). • Not able to equate fuel types. • Does not account for non-energy differences between fuel types (supply availability, pollution).	
Source ZEB	• Able to equate energy value of fuel types used at the site. • Better model for impact on national energy system. • Easier ZEB to reach.	Does not account for nonenergy differences between fuel types (supply availability, pollution). • Source calculations too broad (do not account for regional or daily variations in electricity generation heat rates). • Source energy use accounting and fuel switching can have a larger impact than efficiency technologies. • Does not consider all energy costs (can have a low load factor).	Need to develop site-to source conversion factors, which require significant amounts of information to define.
Cost ZEB	• Easy to implement and measure. • Market forces result in a good balance between fuel types. • Allows for demand-responsive control • Verifiable from utility bills.	• May not reflect impact to national grid for demand, as extra PV generation can be more valuable for reducing demand with on-site storage than exporting to the grid. • Requires net-metering agreements such that exported electricity can offset energy and nonenergy charges. • Highly volatile energy rates make for difficult tracking over time.	• Offsetting monthly service and infrastructure charges require going beyond ZEB. • Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates.
Emission ZEB	• Better model for green power. • Accounts for nonenergy differences between fuel types (pollution, greenhouse gases). • Easier ZEB to reach.		• Need appropriate emission factors.

Torcellini, et al. (2006) [6] mention that in all definitions grid connectivity is accessible, however the definitions also apply for grid independent structures. Finally, in the paper

Torcellini, et al. conclude: "*Consistent ZEB definitions are needed for those who research, fund, design, and evaluate ZEBs.*"

Mertz, et al. (2007) distinguish two definitions for ZEB: a net-zero energy building or a net-zero CO2 (CO2 neutral) building. They are the result of resource limitation and environmental impact, respectively. Mertz, et al. (2007) describe a net-zero energy home *"… as a home, that over the course of year, generates the same amount of energy as it consumes. A net-zero energy home could generate energy through photovoltaic panels, a wind turbine, or a biogas generator. The net-zero energy home consider in this paper uses photovoltaic panels (PV) to offset electricity purchased from the grid." "In a CO2 neutral home, no CO2 is added to the atmosphere due to the operation of the building. This could be accomplished by purchasing tradable renewable certificates (TRC's) generated by solar, wind, or biogas. It could also be accomplished by purchasing CO2 credits on a carbon trading market form some who has CO2 credits to sell. In addition, the home could generate all of its energy on-site like a net-zero energy home".* Mertz, et al. (2007) mention for the first time the possibility for a building to be a part of the CO2 credits exchange market. Moreover, by the last statement in the definition for net-zero CO_2 building authors indicates, that net-zero energy building is at the same time a CO_2 neutral home, however CO_2 neutral home does not necessarily have to be a net-zero energy home.

In the International Energy Agency (IEA) report written by Jens Laustsen in 2008, the issue of different interpretation the ZEB definition is further discussed. Laustsen, (2008) gives the general definition for ZEB: "*Zero Energy Buildings do not use fossil fuels but only get all their required energy from solar energy and other renewable energy sources"* however, at the same time emphasize its weak points by saying: "*Compared to the passive house standards there is no exact definition for the way to construct or obtain a zero energy building. In principle this can be a traditional building, which is supplied with very large solar collector and solar photo voltage systems. If these systems deliver more energy over a year than the use in the building it is a zero net energy building."* When focusing on the issue of what zero refers to Lausten, (2008), similarly as Mertz, et al. (2007), mentions two definition:

• ***Zero Net Energy Buildings*** *are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid.*

• ***Zero Carbon Buildings*** *are buildings that over a year do not use energy that entails carbon dioxide emission. Over the year, these buildings are carbon neutral or positive in the term that they produce enough CO2 free energy to supply themselves with energy. Zero Carbon Buildings differ from Zero Energy Building in the way that they can use for instance electricity produced by CO2 free sources, such as large windmills, nuclear power and PV solar systems which are not integrated in the buildings or at the construction site.*

2.2. Discussion of new net zero approach

The Zero Energy/Emission Building is a complex concept thus the development of one ZEB definition applicable for all case is not a simple task, there are many approaches to the ZEB definition and each of them spotlights different aspects of ZEB. Those issues have served to create a list of the main topics, which should be considered, when developing a new net ZEB definition. First and probably the most important is the issue of the balance:

• what are the units of the balance (final energy; primary energy; exergy; energy costs or maybe CO_2 emission)

• which energy demands are in the balance: only the energy needed for operating the building, or also the energy use connected with occupants behaviour (cooking, appliances, lighting etc.) is included?

• if the embodied energy in the construction should be accounted in the balance?

When looking at the general practice for calculating the energy use of a building, the most commonly used unit is the primary energy. This unit allows taking into consideration the difference in the generation and distribution of 1 kW of electricity and 1kW of heat or natural gas and thus express better the actual building energy use. Using the energy costs could make it almost impossible to design a building, which would be a ZEB through its entire lifetime. Since the energy prices not only differ between counties but also change in time and moreover the relative difference between prices of different fuels may vary over time. So a building could be ZEB only at the time when it is designed. Final energy is the easiest unit to implement and understand, but on the other hand quality of the different kinds of energy if fully neglected. CO2 emission could be also a unit, but for a second definition of Zero Emission Building. The second question regarding the energy demands should not be difficult to answer, because if a building is named zero energy building, then zero should refers to both demands at the same time.

In order to evaluate total building environmental impact embodied energy should be taken into account in the balance. However, it can significantly difficult and extend calculations especially in early design phase, when many values are yet unknown.

Another question for the discussion is to distinguish between off-grid and on-grid ZEB and if net zero approach is only focus on grid connected cases or not? From the literature review it can be noticed that the word ‘net’ is more often used in the definitions for grid connected ZEB to emphasize the interaction with the utility grid. Assuming, that net zero approach includes only on-grid ZEB, in the developed definition the regulations of the building-grid interaction should be well described, since this connection ought to be beneficial for both sides. Unfortunately, the studies describe mostly how positive it is from the building neglecting the gird situation.

Furthermore, one more topic for the discussion is the requirements, if the ZEB definition should include specific requirements it terms of:

• maximum allowed energy use,

• minimum indoor environment quality (temperature and IAQ)

• type and application of renewable energy sources?

In number of publications devoted to ZEB, similar path to achieve ZEB can be noticed. Firstly, the reduction of energy demand using energy efficient technologies and afterwards utilization of renewable energy sources (RES) to supply remaining energy. This is the most logical approach to reach ZEB. Nevertheless, as Laustsen, (2008) points out: “*In principle this can be a traditional building, which is supplied with very large solar collector and solar photo voltage systems. If these systems deliver more energy over a year than the use in the building it is a zero net energy building.”* In order to avoid and eliminate this kind of ZEB a fixed value of maximum allowed energy use could be a good solution.

In the literature the topic of indoor environment quality is almost fully neglected in the ZEB definitions, though it is an important issue. On the one hand it would be very beneficial from general point of view, that all ZEB would use the same values. It would be much easier to evaluate and compare ZEB between each other. On the other hand, giving so detailed criteria in the ZEB definition could significantly limit its usefulness in many cases. Since, different values can be used depending on building type, country, applied standard and local climate conditions. A good solution could be a guidance or suggestion which standards or values should be used.

In prevailing ZEB cases described in the literature solar energy (solar thermal and photo voltaic – PV) is mostly common used Renewable Energy Source (RES). It follows from the fact that, firstly it can be easily implemented in the building construction (no extra space besides building footprint is needed) and secondly it is the best developed RES technology for small-scale application. However, there are cases, in which another RES than solar energy would be more beneficial or easier to use, so why the ZEB definition should impose a certain type of RES? When the above mentioned questions, mostly related to general ZEB definition, are answered, then comes the matter if this one general definition is enough to include all cases? Focusing only on a single building brings already difficulties. There are different buildings types, which have different purpose and requirements and this diversity may not be covered by one definition. Thus, while developing the ZEB definition it should be considered that maybe it will be more suitable to develop separate definition for residential and non residential buildings. The same issue appears when taking into consideration a single building and a community situation. Is one general definition sufficient for a building and at the same a group of buildings? Finally, a question of different climates and thus different design criteria can be posed, if it is feasible to design and construct ZEB all over the world according to the same definition? Those topics are the key issues/questions, which should be solved while developing a new ZEB definition.

Finally, these are the key points, which should be included in the definition.

• Primary energy – units of the balance.

• Total energy demand = for operating the building + associated with occupancy.

• Fixed maximum energy use.

• Distinguish between residential and non-residential

• Application all types of renewable energy sources.

• Regulations of the grid-building interaction.

The following are a number of main important topics for the discussion of ZEB definitions.

Energy focus

Total energy demand in the building is a sum of thermal (heating, cooling) demand and electricity demand (appliances, lighting), however many studies focus only on one neglecting the other. This issue is raised by Able, (1994): "*Many low-energy building projects seem to have been based on the idea 'decrease heat supply at any cost'. In some cases, this has resulted in 'zero-energy buildings' which, it is true, do not need any heat supply but do, instead, indirectly need electricity, e.g., to operate the heat pump included in the system.*"

In the seventies and eighties, when large part of energy use in the buildings was mostly due to the heating (space heating and domestic hot water) in publications devoted to Zero Energy Building, in the definitions only heat was accounted in the zero. Esbensen, et al. (1977) describe an experimental ZEB house in Denmark and point out: "*With energy conservation arrangements, such as high-insulated constructions, heatrecovery equipments and a solar heating system, the Zero Energy House is dimensioned to be self-sufficient in space heating and hot-water supply during normal climatic conditions in Denmark. Energy supply for the electric installations in the house is taken from the municipal mains.*"

Saitoh, (1984) and Saitoh, et al. (1985) in their studies present a Natural Energy Autonomous House in Japan. According to authors: "*... a multi-purpose natural energy autonomous house will meet almost all the energy demands for space heating and cooling as well as supply of hot water for standard Japanese house in 10-15 years. For this purpose, solar energy, the natural underground coldness and sky radiation cooling are utilized.*" On the other hand, in number of papers total energy demand of a building is fully dominated by electricity demand, thus in the ZEB definition only electricity is considered. One of the reasons for this situation is simply the lack of district heating in many countries, however this issue is not commonly mention in the definition, which makes it imprecise.

Gilijamse, (1995): "A zero energy house is defined here as a house in which no fossil fuels are consumed, and the annual electricity consumption equals annual electricity production. Unlike the autarkic situation, the electricity grid acts as a virtual buffer with annually balanced delivers and returns”

Parker, et al.(2001): “During times of peak demand, a Zero Energy Home generates more power than it uses, thereby reducing power demand on the utility provider. During times of power outage, the home generates its own power, allowing the homeowner essential energy security. In a Florida study, a prototype Zero Energy Home outperforms a conventional model by providing almost all of its own power needs throughout the year” Iqbal, (2003): “Zero energy home is the term used for a home that optimally combines commercially available renewable energy technology with the state of the art energy efficiency construction techniques. In a zero energy home no fossil fuels are consumed and its annual electricity consumption equals annual electricity production. A zero energy home may or may not be grid connected” Nevertheless, in the scientific publications do exist ZEB definitions including both heating and electricity demand in total energy demand.

In the NREL report “The Potential Impact of Zero Energy Homes” from 2006, authors use as basis for the ZEB description the definition given by The U.S. Department of Energy (DOE) Building Technologies Program: “a net zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies.” and later extend it by saying:”A Zero Energy Home combines state-of-the-art, highly energy-efficient designs and equipment with on-site renewable energy generation (which typically includes a solar hot water production system and a rooftop photovoltaic, or PV, system) to return as much energy to the utility as it takes on an annual basis. Zero Energy Homes are designed to perform well, be comfortable, require only standard maintenance, and look no different from an ordinary home.”

According to Lausten, (2008), “Zero Net Energy Buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid." Voss, (1996): "…Its entire energy demand for heating, domestic hot water, electricity and cooking is supplied solely by solar energy."

In some ZEB projects focus not only on the operating energy demand but also on energy embodied in the building construction and materials. One of example of such a project can be BedZED - neutral carbon eco-community near London. Morbitzer, (2008) points out: "…where possible, BedZED is built from natural, recycled or reclaimed materials. All the wood used has been approved to be sourced from sustainable resources, and construction materials were selected for their low embodied energy and were sourced within 35-mile radius of the site if possible." Another example is a Rivendale NetZero Project ("Project Profile: Riverdale NetZero Project—Edmonton, Alberta", 2008) in which, except energy efficient technologies and renewable energy production, resource conservation is taken into consideration: "Sustainable, regional materials are used extensively in the building. The decorative exterior window trim is made from salvaged, clear cedar bevel siding. The glulam beams in the living room are recycled from a liquor store. The hardwood flooring is recycled from a school gymnasium. Other flooring is Marmoleum, cork and sustainably manufactured tile. The building envelope is constructed primarily of locally grown spruce. Most of the insulation is made of recycled newspaper."

Energy Supply system

In the prevailing literature is the strict distinguish, between off-grid ZEB and on-grid ZEB. The main difference between those two approaches is that, the off-grid ZEB does not have any connection to the utility grid, thus it does not purchase energy from the external sources and the boundaries for the balance calculations are within the building. In other words the building offset all required energy by producing energy from RES. As the on-grid ZEB is also energy producing building, but there is a possibility for both purchasing energy from the gird and feeding it back to the grid. This division is also noticeable in the ZEB definitions. The off-grid ZEB commonly also called autonomous or self-sufficient building has been reported in many publications: Stahl, et al. (1994), Voss, et al. (1996), Kramer, (2007), Platell, et al. (2007), however there is no clear definition of off-grid ZEB. The authors usually set the goals for the projects, which indirectly can be understood as the ZEB definition, or give the definition which can be used exclusively for described study case. Stahl, et al. (1994): "*The goals of the project can be summarized as follows:*

• use of solar energy to replace other, environmentally damaging energy carriers

• demonstration of new concepts of solar architecture integrated into an energetically optimized structure

• utilization of advanced technologies for energy conservation

• demonstration of new solar energy systems.

The intention of the project is to show the technical potential of solar energy to replace all environmentally damaging energy carriers in a dwelling. Kramer, et al. (2007): "... objective is to demonstrate solar-hydrogen energy system that allows the building to operate without any connection to the electrical grid." Voss, et al. (1996): "The Fraunhofer Institute for Solar Energy Systems has built an energy self-sufficient solar house (SSSH) in Freiburg, Germany. Its entire energy demand for heating, domestic hot water, electricity and cooking is supplied solely by solar energy. The combination of state-of-the-art energy-saving technologies with highly efficient solar systems minimizes the mismatch between the solar radiation input and the building energy demand in winter. The remaining seasonal energy storage is accomplished by electrolysis of water during summer with electricity from a photovoltaic generator."

Nevertheless, there are studies, in which clear definition for the off-grid ZEB is given. According to the report written by Laustsen in 2008 for International Energy Agency (IEA) (Laustsen, 2008): *"Zero Stand Alone Buildings are buildings that do not require connection to the grid or only as a backup. Stand alone buildings can autonomously supply themselves with energy, as they have the capacity to store energy for night-time or wintertime use."* Iqbal, (2003): "*Zero energy home is the term used for a home that optimally combines commercially available renewable energy technology with the state of the art energy efficiency construction techniques. In a zero energy home no fossil fuels are consumed and its annual electricity consumption equals annual electricity production… An off-grid zero energy home has an arrangement for large energy* *storage usually in the form of batteries. In an off-grid zero energy home, depending upon the battery storage, a part of the load may be un-served.*

Similar, as for the off-grid ZEB, there are publications, describing the on-grid ZEB projects, however not including a clear definition of on-grid ZEB. Naturally, somewhere in the paper is mentioned that ZEB is exchanging energy with the utility grid, nevertheless it is not obvious from the beginning.

According to Rosta, et al. (2008): "*Ideally, a ZEH produces as much energy as it consumes in a year's time".* The definition is not saying much about the building and its interaction with the grid, however later in the paper can be read that: "*Accounting for the electric energy generated by the PV system on the ZEH, and defining electric energy used by the utility grid as positive and electric energy used by the grid as negative, a plot of the net electric energy usage of the houses is obtained"* which indicates, that there is building-grid interaction.

Noguchi, et al. (2008): *"In this paper, a net zero-energy home (NZEH) is defined as a house that consumes as much energy as it produces over a year"* and after few pages authors describe: "*The BIPV/T system is an on-grid application accompanied with an inverter for the AC/DC conversion. The system allows for redirection of the locally generated electricity surpluses to the grid.*"

The studies with clear grid-connected ZEB definition belong to: Gilijamse, (1995), Parker, et al. (2001), Iqbal, (2003), Laustsen, (2008). Gilijamse, (1995): "*A zero energy house is defined here as a house in which no fossil fuels are consumed, and the annual electricity consumption equals annual electricity production. Unlike the autarkic situation, the electricity grid acts as a virtual buffer with annually balanced delivers and returns"*

Parker, et al. (2001): "*During times of peak demand, a Zero Energy Home generates more power than it uses, thereby reducing power demand on the utility provider. During times of power outage, the home generates its own power, allowing the homeowner essential energy security. In a Florida study, a prototype Zero Energy Home outperforms a conventional model by providing almost all of its own power needs* *throughout the year."* Iqbal, (2003): "*Zero energy home is the term used for a home that optimally combines commercially available renewable energy technology with the state of the art energy efficiency construction techniques. In a zero energy home no fossil fuels are consumed and its annual electricity consumption equals annual electricity production… A grid-connected zero energy home may generate more power than it uses supplying excess generated power to the grid. During times of power outage, using the energy stored in batteries, a grid-connected zero energy home can generate its own power, allowing the homeowner essential energy security. A zero net energy home is designed and constructed to generate all of the energy it requires through a combination of energy efficiency and renewable energy generation technologies."*

Laustsen, (2008): "*Zero Net Energy Buildings are buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids. Seen in these terms they do not need any fossil fuel for heating, cooling, lighting or other energy uses although they sometimes draw energy from the grid"* The issue of large storage, energy losses either in storing or converting energy and oversized renewable resources in autonomous ZEB compared to grid-connected ZEB become a public discussion. Torcellini, et al. (2006) indicate: "*A ZEB typically uses traditional energy sources such as the electric and natural gas utilities when on-site generation does not meet the loads. When the on-site generation is greater than the building's loads, excess electricity is exported to the utility grid. By using the grid to account for the energy balance, excess production can offset later energy use. Achieving a ZEB without the grid would be very difficult, as the current generation of storage technologies is limited. Despite the electric energy independence of off-grid buildings, they usually rely on outside energy sources such as propane (and other fuels) for cooking, space heating, water heating, and backup generators. Off-grid buildings cannot feed their excess energy production back onto the grid to offset other energy uses. As a result, the energy production from renewable resources must be oversized. In many cases (especially during the summer), excess generated energy cannot be used.*

According to Voss, (2008): "*While the energy systems used in off-grid buildings have to be over-dimensioned, especial in term of storage, in order to provide energy at all times [Goetzberger 1994], in grid-connected projects the goal is simply to have the total* *amount of energy consumed in the building over the course of year offset by the total amount produces…. The connection to the power grid therefore plays a decisive role as a sort of storage battery for electricity, especially in Europe across seasons"*

Single or Community

If one building can be ZEB, then crating a zero energy community should be just a matter of combining those building into communities, villages or even towns. However, should also the definition for one ZEB be multiplied by the number of the buildings creating the community or should zero energy community have a separate definition. In the scientific publications the prevailing definitions are focus only on one building/house/home only Laustsen, (2008) in the ZEB definitions uses plural: "*Zero Net Energy Buildings are buildings… Zero Carbon Buildings are buildings…etc"* Though, later in the paper author indicates "*Compared to the passive house standards there is no exact definition for the way to construct or obtain a zero energy building."* Nevertheless, few case studies ZEB communities are described. The best know eco community also called the largest UK eco village is the Beddington Zero Energy Development (BedZED). "*BedZED has been designed to address environmental, social and economic needs. It brings together a number of proven methods – most of which are not particularly high tech - for reducing energy, water and car use. Crucially, it produces affordable, attractive and environmentally responsible housing and workspace*". According to General Information Report 89, (2002): "*BedZED's zero-carbon 'total energy strategy' is achieved via:*

• *energy-efficient design of the buildings – reducing heat losses and utilising solar gain, to the point where it is feasible to eliminate conventional central heating systems altogether*

• *energy-efficient and hot-water-saving appliances to reduce demand – this sets the capacity for the CHP system*

• *use of renewable energy sources – wood-fuelled CHP (trees absorb CO2 as they grow, and return it to the atmosphere when burnt); PV power integrated into the sunspace roofs means that BedZED will become a net exporter of renewable energy*

• *a green transport plan minimising residents' use of fossil-fuel cars and the need to commute to work."*

Finally Morbitzer, (2008) emphasizes:"*...a strength of BedZED is certainly the variety of environmental issues it addresses. It does not only focus on energy demands of a building, but also by considering aspects such as transport energy, embodied energy, water consumption, ecology, or social housing".*

Not exactly the ZEB community is defined by Clark, et al.(2008), though in the paper authors describe the agile sustainable communities with this words: "*Agile sustainable communities are primarily the result of different infrastructures that interact together or in tandem... Agile means that within a geo-political city, state or region, the local communities generate their energy from local on-site renewable power resources such as solar, water, waste, wind, geothermal, and biomass, etc. These renewable energy supplies can also be backed by storage technologies, the central grid or other means so that the community always has power or a firm base load."*

Bağcı, (2008), based on the studies introduces a new term of zero energy island and explains it as:*" In the context of this study, the focus was on production of electrical energy only. Analog to the existing term ZEB (Zero Energy Building), a new term ''Zero Energy Island'' is introduced to name the same concept for islands."*

Building type

The ZEB definitions can be also divided according to the building type. In the prevailing literature there is almost no difference between the ZEB definition for a commercial building and a residential building. Commonly in the publications three phrases are used: zero energy building, zero energy house and zero energy home. As the first term is the most broad one and includes both residential and commercial building, the two others typically are used for the residences.

Generally, there is this tendency, when the scientific studies of zero energy concept are not devoted to one, specific study case (building) the authors tend to use the phrase zero energy building: Torcellini,et al. (2006), Kilkis, (2006),Voss, (2008), Laustsen, (2008).

The U.S. Department of Energy (DOE) Building Technologies Program (NREL, 2006) uses one ZEB definition for both building types "*a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies*."

Though, when the paper is dedicated to an exact type of building, usually the residence, phrase zero energy house exchangeable with zero energy home is employed in the definition: Esbensen, et al. (1977), Parker, et al. (2001), Gilijamse, (1995), Iqbal, (2003), Mertz, et al. (2007), Rosta, et al, (2008), Noguchi, et al. (2008), Pogharian, et al. (2008).

In the Griffith, et al. (2006) the technical potential to achieve ZEB for commercial building is investigated, though the authors do not create any special ZEB definition, Griffith, et al. use the net-site ZEB definition described by Torcellini, et al. (2006): "*For this research, we used a net site energy definition. A net site ZEB produces as much energy annually as it uses when accounted for at the site (natural gas energy use is offset with on-site electricity generation at a 1:1 ratio)."[7]*

Application of renewable energy sources.

Good ZEB definition should also indicates, what is the supply-side of the renewable energy sources. According to Torcellini, et al. (2006) there are two options: on-site supply or off-site supply. Within the on-site supply authors distinguish building footprint and building site separately. Within the off-site supply the building either uses RES available off-site to produce energy on-site, or purchase off-site RES. Tocellini, et al. (2006) propose a ranking of preferred application of renewable energy sources:

Table 4 ZEB Renewable Energy Supply Option Hierarchy Torcellini, et al (2006)

Option Number	ZEB Supply – Side Options	Examples
0	Reduce site energy use through low energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc
On-Site Supply Options		
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building
Off-Site Supply Options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat.
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered.

Torcellini, et al. (2006) indicate: "Rooftop PV and solar water heating are the most applicable supply-side technologies for widespread application of ZEBs. Other supply-side technologies such as parking lot-based wind or PV systems may be available for limited applications. Renewable energy resources from outside the boundary of the building site could arguably also be used to achieve a ZEB. This approach may achieve a building with net zero energy consumption, but it is not the same as one that generates the energy on site and should be classified as such. We will use the term "off-site ZEB" for buildings that use renewable energy from sources outside the boundaries of the building site." "A good ZEB definition should first encourage energy efficiency, and then use renewable energy sources available on site. A building that buys all its energy from a wind farm or other central location has little incentive to reduce building loads, which is why we refer to this as an off-site ZEB. Efficiency measures or energy conversion devices such as daylighting or combined heat and power devices cannot be considered on-site production in the ZEB context. Fuel cells and microturbines do not generate energy; rather they typically transform purchased fossil fuels into heat and electricity. Passive solar heating and daylighting are demand-side technologies and are considered efficiency measures. Energy efficiency is usually available for the life of the building; however, efficiency measures must have good persistence and should be "checked" to make sure they continue to save energy. It is almost always easier to save energy than to produce energy."

Type of renewable sources

The main concept of zero energy building is the independence of fossil fuels, thus the utilization of the renewable energy sources. By renewable energy sources can be understood: solar thermal, solar photovoltaic (PV), biomass and wind or wave energy. In the prevailing literature ZEB definitions are not focus on one particular renewable technology. According to ASHRE (Kilkis, 2007): *"ZEB is a building, which on annual basis, uses no more energy than is provided by the building on-site renewable energy sources".* The U.S. Department of Energy (DOE) Building Technologies Program (NREL, 2006) defines ZEB as: "*a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies*."

Torcellini, et al. (2006) in ZEB definitions do not spotlight specific renewable source, however in the paper authors emphasize that: "*Rooftop PV and solar water heating are the most applicable supply-side technologies for widespread application of ZEBs."* Laustsen, (2008) includes in the ZEB definition all RES, however emphasizes solar energy: "*Zero Energy Buildings are buildings that do not use fossil fuels but only get all their required energy from solar energy and other renewable energy sources."*

Mertz, et al. (2007) distinguish three RES: *"A net-zero energy home could generate energy through photovoltaic panels, a wind turbine, or a biogas generator"* Iqbal, (2003): "*Zero energy home is the term used for a home that optimally combines commercially available renewable energy technology with the state of the art energy efficiency construction techniques. In a zero energy home no fossil fuels are consumed…"* Nevertheless, among the studies can be noticed that most commonly applied technologies in the ZEB projects are solar thermal and photovoltaic: Esbensen, et al. (1977), Saitoh, (1984), Saitoh, et al. (1985), Stahl, et al. (1995), Voss, et al. (1996), Gilijamse, (1995)Karmer, (2007), Mertz, et al. (2007), Parker, et al. (2001), Rosta, et al. (2008), ”Riverdale NetZero Project-Edmontom, Alberta”, (2008), Noguchi, et al. (2008) etc. Charron, (2005) gives even a definition for zero energy solar homes: "*Homes that utilise solar thermal and solar photovoltaic (PV) technologies to generate as much energy as their yearly load are referred to as net-Zero Energy Solar Homes (ZESH).”*

Other renewable energy sources are not as popular as solar energy, though there are studies describing ZEB projects in which biomass and wind or wave energy are taken into consideration as a possible RES.

2.3. Criteria to define a Net Zero Energy Building

The topic of zero energy buildings (ZEBs) has received increasing attention in recent years, until becoming part of the energy policy in several countries. In the recast of the EU Directive on Energy Performance of Buildings (EPBD) it is specified that by the end of 2020 all new buildings shall be “nearly zero energy buildings” [8]. For the Building Technologies Program of the US Department of Energy (DOE), the strategic goal is to achieve “marketable zero energy homes in 2020 and commercial zero energy buildings in 2025” [9]. However, despite the emphasis on the goals the definitions remains in most cases generic and are not yet standardized. A more structured definition, even though limited in scope to new residential buildings, is the one of ‘zero carbon homes’ in the UK, where there is a political target to build all new homes as zero carbon by 2016. The zero carbon definition has undergone a lengthy process that started in 2006 and was still subject to revisions in 2011 [10,4]. Otherwise, the term ZEB is used commercially without a clear understanding and countries are enacting policies and national targets based on the concept without a clear definition in place. Commercial definitions may be partial or biased in their scope, for example including only thermal or only electrical needs in the balance, or allowing for energy inefficient buildings to achieve the status of ZEB thanks to oversized PV systems, but without applying relevant energy saving measures. For these reasons such definitions are not suitable as a basis for regulations and national policies. Relevant work can be found in literature on existing and proposed definitions [12–20] and survey and comparison of existing case studies [21,22]. Furthermore, an international effort on the subject is ongoing in the International Energy Agency (IEA) joint Solar Heating and Cooling (SHC) Task40 and Energy Conservation in Buildings and Community systems (ECBCS) Annex52 titled "Towards Net Zero Energy Solar Buildings" [23]. It emerges from these analyses that little agreement exists on a common definition that is based on scientific analysis. There is a conceptual understanding of a ZEB as an energy efficient building able to generate electricity, or other energy carriers, from renewable sources in order to compensate for its energy demand. Therefore, it is implicit that there is a focus on buildings that are connected to an energy infrastructure and not on autonomous buildings. To this respect the term Net ZEB can be used to refer to buildings that are connected to the energy infrastructure, while the term ZEB is more general and may as well include autonomous buildings. The wording 'Net' underlines the fact that there is a balance between energy taken from and supplied back to the energy grids over a period of time, nominally a year.

As discussed in [22] the Net ZEB approach is one strategy towards climate neutral buildings, in addition to others based on energy efficient buildings combined with almost carbon neutral grid supply. Net ZEBs are designed to overcome the limitation given by a non 100% 'green' grid infrastructure. Exploiting local renewable energy sources (RES) on-site and exporting surplus energy from on-site generation to utility grids is part of the strategy to increase the share of renewable energy within the grids, thereby reducing resource consumption and associated carbon emissions. On the other hand, especially for the power grid, wide diffusion of distributed generation may give rise to some problems such as power stability and quality in today's grid structures, mainly at local distribution grid level. Development of "smart grids" is ongoing to fully benefit from distributed generation with respect to reducing the grids primary energy and carbon emission factors, as well as operation costs. Within a least-cost planning approach, on-site options have to be compared with measures at the grid level, which take advantage of the economy of scale and equalization of local peaks. However, it is clear that the mere satisfaction of an annual balance is not in itself a guarantee that the building is designed in a way that minimizes its (energy use related) environmental impact. In particular, Net ZEBs should be designed – to the extent that is in the control of the designers – to work in synergy with the grids and not to put additional stress on their functioning. Considering the interaction between buildings and energy grids also leads to consider that every country, or regional area, has different challenges to face with respect to the energy infrastructure, on top of different climate and building traditions. Therefore every country has the need to adapt the Net ZEB definition to its own specific conditions, e.g. defining the primary energy or carbon emission conversion factors for the various energy carriers, establishing requirements on energy efficiency or prioritizing certain supply technologies. What is missing is a formal, comprehensive and consistent framework that considers all the relevant aspects characterising Net ZEBs and allow each country to define a consistent (and comparable with others) Net ZEB definition in accordance with the country's political targets and specific conditions. The frame-work described in this thesys builds upon concepts found literature and further developed in the context of the joint IEA (International Energy Agency) SHC (Solar Heating and Cooling programme) Task40 and ECBCS (Energy Conservation in Buildings and Community Systems) Annex52: Towards Net Zero Energy Solar Buildings [23]. Table 5 shows a list of nomenclature used in this paragraph.

Table 5 Nomenclature.

CHP Combined heat and power	fload Load match index
COP Coefficient of performance	g, G Generation, generation weighted
DHW Domestic hot water	gm Net monthly generation, annual total
DSM Demand side management	Gm, Net monthly generation weighted
HVAC Heating, ventilation and air conditioning	i Energy carrier
Net ZEB(s) Net zero energy building(s)	l, L Load, load weighted lm Net monthly load, annual total Lm
RES Renewable energy sources	Net monthly load weighted m Month
STD Standard deviation	max Maximum
d, D Delivered, delivered weighted	min Minimum
e, E Exported, exported weighted	t Time interval
fgrid Grid interaction index	w Weighting factor

Terminology and Net ZEB balance concept

The sketch shown in Fig. 5 gives an overview of relevant terminology addressing the energy use in buildings and the connection between buildings and energy grids.

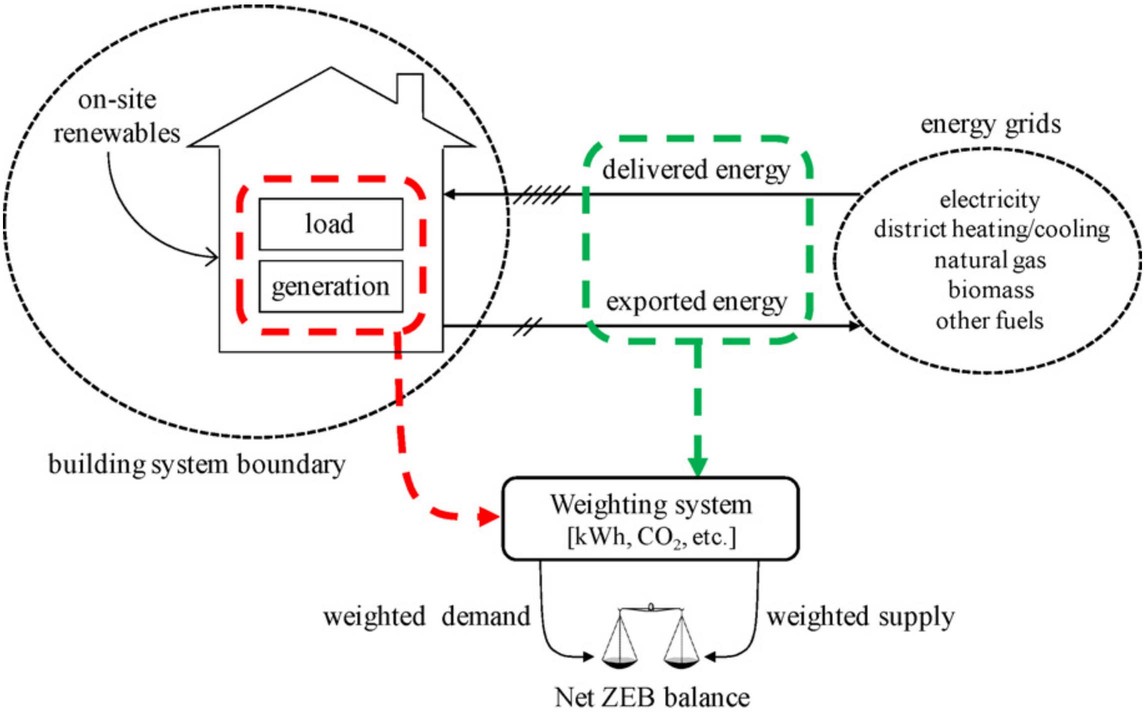


Figure 5 Sketch of connection between buildings and energy grids showing relevant terminology.

Following each term present in Fig. 5 is shortly explained.

1. Building system boundary

The boundary at which to compare energy flows flowing in and out the system. It includes:

•Physical boundary: can encompass a single building or a group of buildings; determines whether renewable resources are ‘on-site’ or ‘off-site’. •

•Balance boundary: determines which energy uses (e.g. heating, cooling, ventilation, hot water, lighting, appliances) are included in the balance.

2. Energy grids (or simply ‘grids’)

The supply system of energy carriers such as electricity, natural gas, thermal networks for district heating/cooling, biomass and other fuels. A grid may be a two-way grid, delivering energy to a building and occasionally receiving energy back from it. This is normally the case for electricity grid and thermal networks.

3. Delivered energy

Energy flowing from the grids to buildings, specified per each energy carrier in (kWh/y) or (kWh/m^{2}y). This is the energy imported by the building. However, it is established praxis in many countries to name this quantity ‘delivered energy’, see for example [24].

4. Exported energy

Energy flowing from buildings to the grids, specified per each energy carrier in (kWh/y) or (kWh/m^{2}y).

5. Load Building’s energy demand, specified per each energy carrier in (kWh/y) or (kWh/m^{2}y).

The load may not coincide with delivered energy due to self-consumption of energy generated on-site.

6. Generation Building’s energy generation, specified per each energy carrier in (kWh/y) or (kWh/m^{2}y).

The generation may not coincide with exported energy due to self-consumption of energy generated on-site. N.B. Design calculations to convert building energy needs, such as for heating, cooling, ventilation, hot water, lighting, appliances, into the demand for certain energy carriers (here ‘loads’), accounting for system efficiencies and interactions are not covered in this paper; nor are calculations to determine on-site generation or pos-sible self-consumption patterns. Readers are encouraged to refer to their relevant national methodologies and regulations for guidance.

7. Weighting system

A weighting system converts the physical units into other metrics, for example accounting for the energy used (or emissions released) to extract, generate, and deliver the energy. Weighting factors may also reflect political preferences rather than purely scientific or engineering considerations.

8. Weighted demand

The sum of all delivered energy (or load), obtained summing all energy carriers each multiplied by its respective weighting factor.

9. Weighted supply

The sum of all exported energy (or generation), obtained sum-ming all energy carriers each multiplied by its respective weighting factor.

2.4. Net ZEB balance

A condition that is satisfied when weighted supply meets or exceeds weighted demand over a period of time, nominally a year. The net zero energy balance can be determined either from the balance between delivered and exported energy or between load and generation. The former choice is named import/export balance and the latter load/generation balance. A third option is possible, using monthly net values of load and generation and it is named monthly net balance. The Net ZEB balance is calculated as in Eq. (1):

$$\text{Net ZEB balance} : |\text{weighted supply}| - |\text{weighted demand}| = 0 \quad (1)$$

where absolute values are used simply to avoid confusion on whether supply or demand is consider as positive. The Net ZEB balance can be represented graphically as in Fig. 6, plotting the weighted demand on the x-axis and the weighted supply on the y-axis.

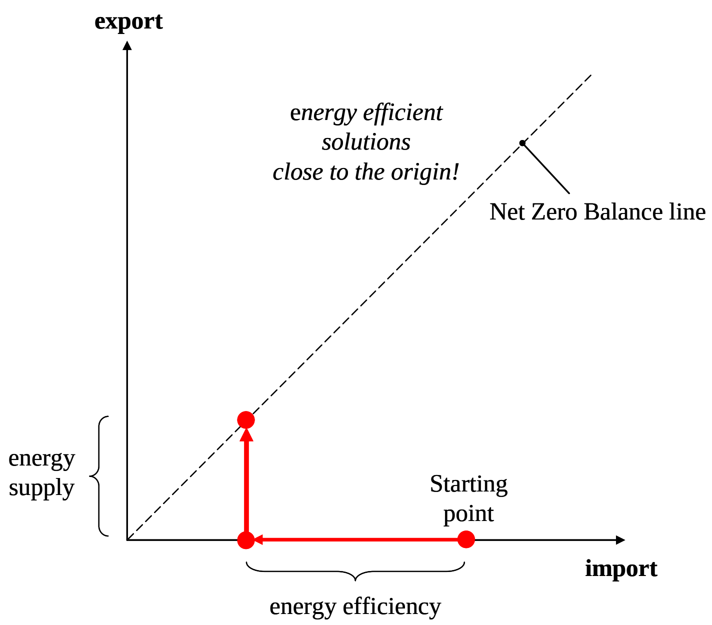


Figure 6 Graph representing the net ZEB balance concept

The reference building may represent the performance of a new building built according to the minimum requirements of the national building code or the performance of an existing building prior to renovation work. Starting from such reference case, the pathway to a Net ZEB is given by the balance of two actions:

(1) reduce energy demand (x-axis) by means of energy efficiency measures;
(2) generate electricity as well as thermal energy carriers by means of energy supply options to get enough credits (y-axis) to achieve the balance. In most circumstances major energy efficiency measures are needed as on-site energy generation options are limited, e.g. by suitable surface areas for solar systems, especially in high-rise buildings.

In most circumstances major energy efficiency measures are needed as on-site energy generation options are limited, e.g. by suitable surface areas for solar systems, especially in high-rise buildings.

2.4.1 Framework for Net ZEB definitions

The balance of Eq. 1 represents the core concept of a Net ZEB definition. In order to use such formula in practice several aspects have to be evaluated and some explicit choice made, e.g. the metrics adopted for weighting and comparing the different energy carriers. Additionally, other features than the mere balance over a period of time may be desirable in characterizing Net ZEBs. These aspects are described and analyzed in a series of five criteria and sub-criteria, and for each criterion different options are available. Evaluation of the criteria and selection of the related options becomes a methodology for elaborating Net ZEB definitions in a systematic, comprehensive and consistent way. The Net ZEB definition framework is organized in the following criteria and sub-criteria:

1. Building system boundary

1.1 Physical boundary

1.2 Balance boundary

1.3 Boundary conditions

2. Weighting system

2.1 Metrics

2.2 Symmetry

2.3 Time dependent accounting

3. Net ZEB balance

3.1 Balancing period

3.2 Type of balance

3.3 Energy efficiency

3.4 Energy supply

4. Temporal energy match characteristics

4.1 Load matching

4.2 Grid interaction

5. Measurement and verification

1 Building system boundary

Defining the building system boundary is necessary to identify what energy flows cross the boundary. The building system boundary can be seen as a combination of a physical and a balance boundary. Only energy flows that cross the system boundary, i.e. both physical and balance boundaries, are considered for the Net ZEB balance. This means, for example, that if a definition excludes plug-loads from the balance boundary, the electricity used for plug-loads is not to be counted. With design data this is not a problem. With monitoring data though, it represents a complication because the power meter normally does not discern between the different power uses. A Net ZEB definition that does not include all operational energy services poses a challenge on building performance verification because it requires a more sophisticated measurement system, see criterion 5: Measurement and verification.

1.1 Physical boundary

The physical boundary may be on a single building or on a cluster of buildings. In this thesys the focus is mainly on single buildings, but the same framework would apply equally well to clusters of building. It is important to note though that a cluster of buildings implies a synergy between several buildings which are not necessarily Net ZEB as singles but as a whole. The physical boundary is useful to identify so called ‘on-site’ generation systems; so that if a system is within the boundary it is considered on-site, otherwise it is ‘off-site’. As analyzed later in criterion 3.4: Net ZEB balance –

Energy supply, off-site supply options may or may not be accepted for calculating the balance, or may be given different priorities. As an example, one may think of a PV system installed on the parking lot, detached from the main building. If the boundary is taken on the building's physical footprint such system would then be regarded as off-site. If the boundary instead is set on the building's property or if the power meter is taken as the physical boundary, then the PV system would be on-site. Furthermore, the physical boundary can be used to address the property issue of RES installations. On one hand RES installations or investments not on the building site may be accountable in the balance if financed by the building owner/constructor, as in the UK zero carbon home definition, see [25,26] and further discussion on allowable solutions in criterion 3.4: Net ZEB balance – Energy supply.

On the other hand, a RES installation on the building site may not be considered accountable for the building balance if it is property of a third party, e.g. if the roof space has been rented to an investor (utility company, ESCO, etc.) who owns the PV system and runs it independently.

It has to be specified which two-way grids are available at the physical boundary. A two-way grid is a grid that can deliver energy to and also receive energy back from the building(s). Without a two-way grid it is not possible to define a Net ZEB. The power grid is normally available as two-way grid. Other two-way grids may be local thermal networks, such as district heating/cooling networks. Specific conditions are normally required by the grid operators in order to accept exported energy, such as on frequency and voltage tolerances (power grid) or temperature levels (thermal network).

1.2 Balance boundary

The balance boundary defines which energy uses are considered for the Net ZEB balance. Operational energy uses typically include heating, cooling, ventilation, domestic hot water, fixed lighting and plug-loads. National and commercial standards on energy performance may consider different combinations of them. Other energy uses may be included in the balance, even though they are typically not considered in building energy performance codes and standards. This may include treatment of rain water or charging of electric vehicles. Electric vehicles are not a building related energy use but charging their batteries may be used as a way to optimize the interaction with the grid (see criterion 4.2: Temporal energy match characteristics – Grid interaction). Other energy uses that do not occur in the operational phase, but in the life cycle of a building may be considered, such as embodied energy/emissions in materials and technical installations. More energy efficient and energy producing buildings are likely to deploy more materials (e.g. insulation) and technical installations (e.g. PV system) including materials whose manufacturing is energy intensive. Consequently, the importance of embodied energy/emissions increases and including it into the balance broadens the scope of Net ZEBs as environmental friendly and sustainable buildings. Embodied energy/emissions should be annualized for proper accounting in addition to operational energy use; this implies making assumption on the life time of the building and its components. Likewise, also energy used for erection and demolition of the building could be considered, even though their relative importance is generally low and it may be justifiable to neglect it [27].

1.3 Boundary conditions

A consistent Net ZEB definition should allow a meaningful comparison between similar buildings in similar climates, as well as between the expected performance of a building from its design data and the measured performance revealed by monitoring data, see criterion 5: Measurement and verification. It is important to understand if any deviation from expected values is attributable to technical operating or design mistakes, or if it is simply due to different conditions of use. For this purpose it is necessary to explicitly specify a set of boundary conditions: functionality, space effectiveness, climate and comfort. The functionality describes what type of uses the building is designed for, such as residential, office, school or hospital. In case of multi-functional buildings it is necessary to specify how the floor area is distributed between the different functions. The space effectiveness can be expressed in terms of people/m^2 or, consequently, of energy use per person. Variations from expected functionality and/or space effectiveness are important and should be taken into consideration before comparing the expected performance with the monitored one. For example, higher/lower people density causes different energy demand. The reference climate and the comfort standards used in design also need to be specified. Variations from expected out-door climate and/or indoor comfort conditions are important and should be taken into consideration before comparing the expected performance with the monitored one. For example, hotter/colder years or different temperature settings cause different energy demand.

2 Weighting system

The weighting system converts the physical units of different energy carriers into a uniform metrics, hence allowing the evaluation of the entire energy chain, including the properties of natural energy sources, conversion processes, transmission and distribution grids. Choosing a common balance metrics also allows taking into account the so-called fuel switching effect, e.g. when export of PV electricity during summer compensates for imported biomass or fossil fuels in winter.

2.1 Metrics

In [12] four types of metrics are considered: site energy, source energy, energy cost, and carbon emissions related to energy use. Advantages and disadvantages of each choice are discussed and it is shown how the choice would affect the required PV installed capacity. Other possible metrics are the non-renewable part of primary energy, exergy [13], environmental credits and politically/strategically decided factors. The choice of the metrics, especially with political factors, will affect the relative value of energy carriers, hence favouring the choice of certain carriers over others and influencing the required (electricity) generation capacity. For an analysis of the details and the implications for design of each choice reference is made to the mentioned literature [12–20]. Quantification of proper conversion factors is not an easy task, especially for electricity and thermal networks as it depends on several considerations, e.g. the mix of energy sources within certain geographical boundaries (international, national, regional or local), average or marginal production, present or expected future values and so on. There are no correct conversion factors in absolute terms. Rather, different conversion factors are possible, depending on the scope and the assumptions of the analysis. This leads to the fact that ‘politically corrected’ weighting factors may be adopted in order to find a compromise agreement. Furthermore, ‘political factors’ (or ‘strategic factors’) may be used in order to include considerations not directly connected with the conversion of primary sources into energy carriers. Political factors can be used to promote or discourage the adoption of certain technologies and energy carriers. For example biomass and biofuels, in case of carbon emissions as the metrics, would have a very low conversion factor making it an attractive solution. However, availability of biomass is not infinite and it needs to be used also for other non-energy purposes such as food production. Hence, even in regions of abundant local availability it may be desirable to ‘politically’ increase the conversion factor in order to reduce the attractiveness of biomass and favour other solutions, e.g. solar systems.

2.2 Symmetry

Each two-way energy carrier (e.g. electricity) can be weighted symmetrically, using the same weighting factors for both delivered and exported quantities, or asymmetrically, using different factors. The rationale behind symmetric weighting is that the energy exported to the grids will avoid an equivalent generation some-where else in the grid. Hence the exported energy has a substitution value, which is equal to the average weighting factor for that grid. This is a valid approach as long as the energy generated on-site does not have any negative effect on the balance or if that effect is accounted for somewhere else. First example: with on-site cogeneration the negative effect is the increase of purchased fuel because of the reduced thermal efficiency. The delivered energy entering the physical boundary is increased, therefore accounting for the negative effect and the exported electricity can be fully credited for its substitution value. Second example: with on-site PV generation the negative effect is the increase in embodied energy. If the balance boundary does include embodied energy of the PV system, then the total demand to be balanced off is increased, accounting for the negative effect and the exported electricity can be fully credited for its substitution value. Asymmetric weighting may be used to account for the negative effect of on-site generation if that is not accounted for somewhere else in the balance. For example, in the above case with PV system, if embodied energy is not part of the boundary balance then each kWh of exported electricity should not be fully credited because it did cost something – in energetic terms – to produce it. Rather than omitting this aspect, it is possible to associate a negative value to the kWh generated (in terms of the adopted metrics, such as primary energy or emissions) and credit the exported kWh net of it, i.e. the substitution value minus the negative effect value. This way it is possible to give different weighting factors to different generation technologies generating the same carrier, e.g. PV and cogeneration in the same building, hence valuing their different properties, possibly in combination with political factors as discussed in criterion 2.1: Weighting system – Metrics. The drawback is that each system should then be equipped with a separate meter, at least in theory. Similarly, also delivered energy may have different weighting factors for the same carrier, as for example in the case of a portion of purchased electricity being covered by green certificates. However, the main rationale behind asymmetric weighting is that energy demand and supply do not have the same value, hence delivered and exported energy should be weighted differently in order to reflect this principle. Two situations are possible:

- Delivered energy is weighted higher: This takes into account the cost and losses on the grids side associated with transportation and storage of exported energy (and in case of electricity also possible earthing of feed-in power) as in the German tariff system since 2009 [28]. This option may serve the purpose of reducing exchange with the grids–hence promoting self-consumption of on-site generation–in a scenario of wide diffusion of energy consuming and producing buildings;
- Exported energy is weighted higher: This option may serve the purpose of promoting technology diffusion in a scenario of early technology adoption, e.g. the early PV feed-in tariffs adopted in Germany, Italy, Spain and other countries, where feed-in electricity is paid two to three times higher than what delivered electricity is charged for (here the asymmetric metrics is the energy cost).

2.3. Time dependent accounting

Due to the complexity of the energy infrastructure, it is often feasible to estimate the weighting factors only as average values for a period of time. This is a static accounting, and it typically applies to primary energy and carbon emission factors. Electricity, for example, may be evaluated for large regions while district heating/cooling or biomass may be evaluated at local scale, according to the actual availability of resources in the area. In any case the evaluation of weighting factors should be updated at regular intervals to reflect the development of the grids. To this respect it is possible to consider different scenarios on the possible evolution of weighting factors [29] where the European electricity grid is analyzed towards 2050. In the evaluation of electricity and district heating/cooling weighting factors it is also important to distinguish between average and marginal production and specify which choice is made. It is also possible to evaluate weighting factors on hourly basis, therefore leading to a dynamic accounting. As an intermediate option a quasi-static accounting would have seasonal/monthly average values and/or daily bands for base/peak load. For energy prices it is already quite common to have seasonal or hourly fluctuating prices, while for other metrics such as primary energy and carbon emissions this is not the standard praxis today but it may become more common in future. Examples of this are given by the hourly energy emission factors for electricity generation in the US [30] and the power demand tracking in real time of the power grid in Spain [31]. Dynamic and quasi-static accounting would help, at least in theory, the design of buildings that optimize their interaction with the grids. The Time-Dependent Valuation of saving [32] is such an example. However, including dynamic accounting in the Net ZEB balance would considerably increase the complexity of calculations and the assumptions on future time dependent pat-terns. It is rather preferable, in the authors' opinion, to calculate the Net ZEB balance with static or quasi-static values and then use, in addition, dynamic values to address the temporal energy match characteristics, see criterion 4: Temporal energy match characteristics.

3 Net ZEB balance

The balance of Eq. (1) may be calculated in different ways, depending for example on the quantities that are of interest or available and the period over which to calculate the balance. Furthermore, policy makers must decide whether or not to enforce minimum energy efficiency requirements and/or a hierarchy of renewable energy supply options.

3.1 Balancing period

A proper time span for calculating the balance is assumed, often implicitly, to be a year. An yearly balance is suitable to cover all the operation settings with respect to the meteorological conditions, succession of the seasons in particular. Selection of shorter time spans, such as seasonal or monthly balance, could be highly demanding from the design point of view, in terms of energy efficiency measures and supply systems, in order to reach the target in critical time, such as winter time. On the other hand, a much wider time span, on the order of decades, could be selected to assess the balance along the entire building's life cycle including embodied energy. Nevertheless, as noted in criterion 1.2: Building system boundary – Balance boundary, embodied energy can be annualized and counted in addition to operational energy uses. It is therefore held that the balance is calculated on a yearly basis.

3.2 Type of balance

The core principle for Net ZEBs is the balance between weighted demand and weighted supply, generically described in Eq. (1). Delivered and exported energy quantities can be used to calculate the balance when monitoring a building. Alternatively, estimates of delivered and exported energy may be available in design phase, depending on the ability to estimate self-consumption of energy carriers generated on-site. In these cases an import/export balance is calculated as in Eq. (2)

$$\sum_i g_i \times w_{e,i} - \sum_i l_i \times w_{d,i} = G - L \geq 0 \quad (2)$$

where e and d stands for exported and delivered, respectively; w stands for weighting factor and i for energy carrier. E and D stands for weighted exported and delivered energy, respectively; see also Table 5 on nomenclature. However, most building codes do not require design calculations to estimate self-consumption, consequently lacking the estimations of delivered and exported amounts [17]. Such approaches perform like generation and load systems did not interact, basically because missing normative data on end users temporal consumption patterns (e.g. for lighting, electrical appliances, cooking, hot water use). Thereby, in most common cases only generation and load values are available and a load/generation balance is calculated as in Eq. (3):

$$\sum_i g_i \times w_{e,i} - \sum_i l_i \times w_{d,i} = G - L \geq 0 \quad (3)$$

where g and l stands for generation and load, respectively; w stands for weighting factor and i for energy carrier. G and L stands for weighted generation and load, respectively; see also Table 5 on nomenclature. It is worth noting that overlooking the interactions between generation systems and loads as in the generation balance is equivalent to assume that, per each carrier, the load is entirely satisfied by delivered energy while the generation is entirely fed into the grid. Alternatively, a balance may be calculated based on monthly net values. For each energy carrier, generation and load occurring in the same month are assumed to balance each other off; only the monthly residuals are summed up to form the annual totals. This can be seen either as a load/generation balance performed on monthly values or, equivalently, as a special case of import/export balance where a “virtual monthly self-consumption” pattern is assumed. Such procedure has been proposed in the framework of the German building energy code, see [19,21], where it is thought with focus on electricity; the same procedure though may be applied also to thermal carriers. This approach may be regarded as monthly net balance, calculated as in Eq. (6), substituting Eqs. (4) and (5):

$$g_{m,i} = \sum_m \max[0, g_i(m) - l_i(m)] \quad (4)$$

$$l_{m,i} = \sum_m \max[0, g_i(m) - l_i(m)] \quad (5)$$

$$g_{m,i} \times w_{e,i} - \sum_i l_{m,i} \times w_{d,i} = G_m - L_m \geq 0 \quad (6)$$

where g and l stands for generation and load, respectively, and m stands for the month; w stands for weighting factor and i for energy carrier. Gm and Lm stands for the total weighted monthly net generation and load, respectively; see also Table 5 on nomenclature. The three balances are coherent with each other2 but differ by the amount of on-site energy generation which is self-consumed, or ‘virtually’ assumed as self-consumed, as shown in Fig. 7. Graphically, the load/generation balance gives the points for weighted demand and supply most far away from the origin; while with import/export balance and monthly net balance the points get closer to the origin as a consequence of the self-consumption and virtual monthly self-consumption, respectively. The import/export balance is expected to be always in between the two other, due to the fact that there usually is some amount of self-consumption but hardly more than the virtual monthly self-consumption, which can be regarded as an upper limit as long as seasonal energy storage is not considered. It is worth noting that self-consumption of energy generated on-site can be seen as either an efficiency measure or as a supply measure depending on the type of balance adopted. In case of load/generation balance self-consumption is seen as part of the overall generation and is visualized in the graph as moving the weighted supply point up along the y-axis. However, in case of import/export balance self-consumption is seen as a reduction of the load, visualized in the balance graph by moving the weighted demand point closer to the origin, along the x-axis3. This is consistent with the implicit viewpoint of the two balances. In the load/generation balance the building is seen independently, so that energy generated, whether self-consumed or not, does not affect the efficiency of the building as such. In the import/export balance the building is seen in connection with the grids, so that self-consumption does reduce the amount of energy exchanged, in this sense improving the efficiency of the system building-grids. Each type of balance has pros and cons. The import/export balance gives the most complete information, showing the interaction with the grids but it is the most difficult to obtain in design phase because it requires estimates of self-consumption patterns and detailed simulation (preferably with hourly or sub-hourly resolution). The load/generation balance is the most suit to be seamlessly integrated in existing building codes that are only oriented at calculating the loads. In facts, it is only necessary to add one step: calculation of the generation. The drawback is that it completely overlooks the interaction with the grids. The monthly net balance has the advantage of being simple to implement while not completely overlooking the interaction with the grids. On one hand it only needs monthly values of generation and load and does not require either detailed simulations or self-consumption estimates. On the other hand while the virtual monthly self-consumption is a coarse approximation, it still provides some information on the seasonal interaction with the grids. The higher the monthly net generation (or load), the higher the seasonal unbalance of energy exchanged with the grids.

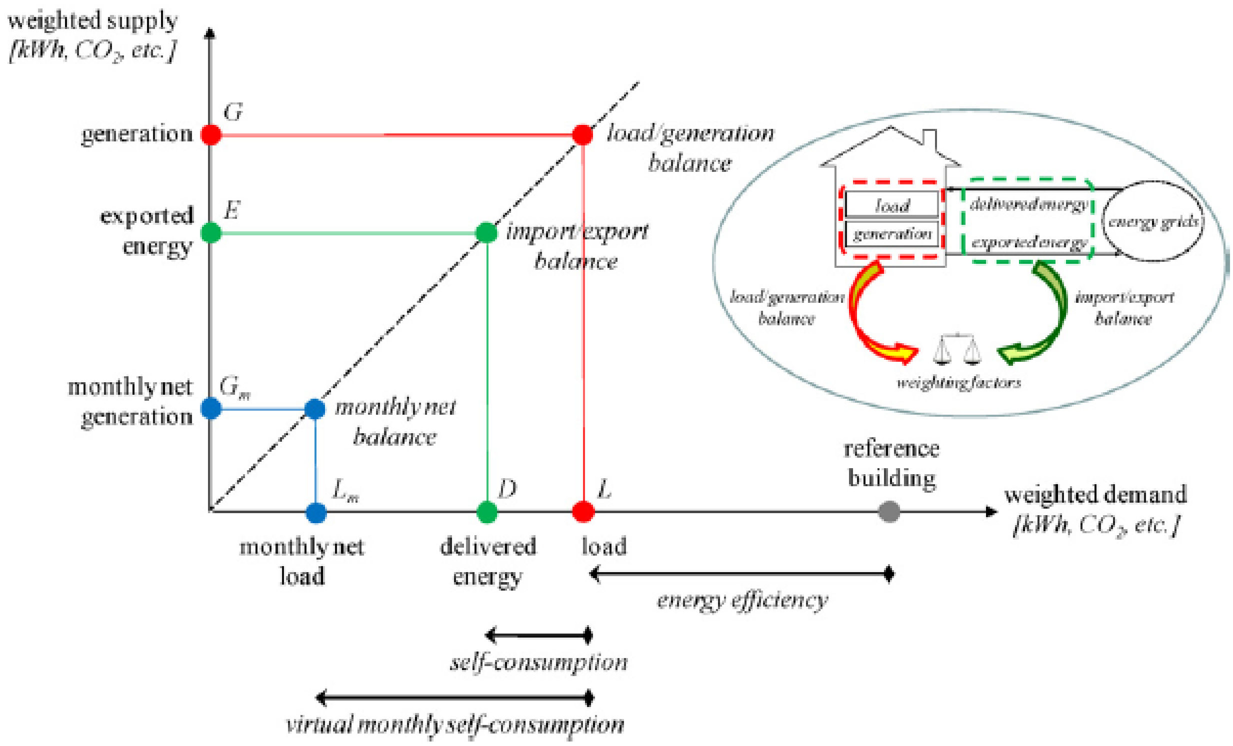


Figure 7 Graphical represntation of the three types of balance: import/export balance beetween weighted exported and delivered Energy, load/genertation balance between weighted generation and load, and monthly net balance between weicghted montly net values of generation and load

3.3 Energy efficiency

A Net ZEB definition may set mandatory minimum requirements on energy efficiency. Such requirements may be either prescriptive or performance requirements, or a combination of the two. Prescriptive requirements apply to properties of envelope components (e.g. U-values of walls and windows, air-tightness in pressurization test) and of HVAC systems (e.g. specific fan power, COP of heat pumps), while performance requirements apply to energy needs (e.g. for heating, cooling, lighting) or total (weighted) primary energy demand. See [33] for an overview of prescriptive and performance based energy efficiency requirements adopted in existing national or commercial certification systems. Mandatory requirements on energy efficiency may be determined on the basis of cost-optimality considerations as in the plans of the EPBD [15]; such methodology is still under development for the time being, see [41–43]. Alternatively, mandatory efficiency targets could simply require a demand reduction (e.g. 50%) compared to a reference building of the same category (e.g. detached house, office, school). In absence of explicit requirements on energy efficiency it is left to the designers to find the cost-optimal balance between energy efficiency measures and supply options, eventually considering embodied energy too, if in the balance boundary. However, the analysis of a large number of already existing Net ZEBs underlines the priority of energy efficiency as the path to success [22].

Restrictions on the use of some energy carriers, such as oil, can be a direct requirement of a Net ZEB definition or a consequence of the assigned weighting factor, e.g. assigning a ‘politically’ or ‘strategically’ high value to oil would reduce its attractiveness.

3.4 Energy supply

A Net ZEB definition may set mandatory requirements on energy supply. A straightforward requirement is proposed in [37] by setting a threshold for the minimum share of renewable energy that has to be used for covering the building’s energy demand. Alternatively, energy supply options may be categorized in different ways and a Net ZEB definition may set a mandatory hierarchy of renewable energy supply options. This prioritization is meant to add an additional dimension to the energy balance itself. Typically, distinction is made at least between ‘on-site’ and ‘off-site’; see [12,17,25,26]. For using a hierarchy of options a clear and unambiguous definition of what is on-site and off-site (and any further distinction) has to be stated in criterion 1: Building system boundary – Physical boundary. In [12] the renewable energy supply options are prioritized on the basis of three principles:

(1) emissions-free and reduced transportation, transmission, and conversion losses;

(2) availability over the lifetime of the building;

(3) highly scalable, widely available, and have high replication potential for future Net ZEBs.

These principles lead to a hierarchy of supply options where resources within the building footprint or on-site (e.g. PV and CHP) are given priority over off-site supply options, (e.g. import of biofuel for cogeneration or purchase of green electricity). Reasons for supporting such a hierarchy are extensively discussed in the report. In [17] a similar categorization of supply options is given according to their distance from the building, even though no hierarchy of preferences is expressed. However, it is worth mentioning that the meaning of off-site varies depending on whether the focus is on the origin of the fuel [12] or on the location of the actual generation system [17]. Another example of classification and hierarchy is given by the "Zero Carbon Home" policy under development in the UK (only for new residential buildings), see [25,26]. In the Zero Carbon Home approach offsetting carbon emissions is achieved in two steps, named: "carbon compliance" and "allowable solutions". Carbon compliance is a mix of mandatory energy efficiency measures and a selection of on-site options (e.g. PV and connection to thermal grids) to be implemented as first priority. Allowable solutions is a set of further supply options, including extended on-site options, near-site and off-site options; where the meaning of such words is again different than in [12,17]. One of the more contentious topics is likely be how to account for 'soft' renewable generation options ('soft' as opposed to 'hard' = physical generation of energy carriers). For example, the allowable solutions in the Zero Carbon Home definition in the UK include investment (through a national investment fund) in low- and zero-carbon energy projects off-site. These include investments in the local energy infrastructure and financing energy efficient renovation of buildings in the area. Another area that requires further thought by policy makers, if renewable energy supply is to be prioritized, is defining 'supply-side' renewable generation separately from 'demand-side' generation. As defined in [12], supply-side renewable energy can be commoditized, exported, and sold like electricity or hot water for district systems, while demand-side renewable are only available in connection with reducing building energy demand on-site. Examples of demand-side generation include CHP systems, ground source heat pumps, and passive solar systems. Restrictions on the use of some supply option, such crediting of electricity from gas fired CHP, can be a direct requirement of a Net ZEB definition or a consequence of the assigned weighting factor. For example, assigning a 'politically' or 'strategically' low value to electricity generated by gas fired CHP would reduce the attractiveness of such a choice. However, it should be considered that in areas with poor performance of the grid (high share of fossil fuels and high carbon emission in the generation mix) it may be reasonable to allow solutions that make a very efficient use of natural gas, such as gas fired CHP, especially if the gas grid is already in place.

4 Temporal energy match characteristics

Beside an annual energy or emission balance Net ZEBs are characterized by their different ability to match the load and to work beneficially with respect to the needs of the local grid infrastructure. Suitable indicators can be used to express characteristics of a Net ZEB such as the temporal match between a building's load and its energy generation, load matching, and the temporal match of import/export of energy with respect to the grid needs, grid interaction [38,39]. Such indicators are useful to show differences and similarities between alternative design solutions. The indicators are intended as assessment tools only: there is no inherent positive or negative value associated with them, e.g. increasing the load match may or may not be appropriate depending on the circumstances on the grid side. Load matching and grid interaction calculation have to be per-formed for each energy carrier separately. The calculation of such indicators needs energy data in a time resolution of months for studying the seasonal effects, and hourly or sub-hourly resolution for studying peak load effects. Target groups for this form of Net ZEB characterization are the building owners and designers, community and urban planners as well as the local grid operators in the context of "smart buildings" and "smart grids".

4.1 Load matching

The temporal match between load and generation for an energy carrier gives a first insight on a building's ability to work in synergy with the grid. When there is a poor correlation between load and generation, e.g. load mainly in winter and generation mainly in summer, the building will more heavily rely on the grid. If load and generation are more correlated, the building will most likely have higher chances for fine tuning self-consumption, storage and export of energy in response to signals from the grid, see criterion 4.2: Grid interaction. Load matching can be addressed in design by separate calculations or simulations on load and generation, without need to know or estimate self-consumption. For this reason indicators of load matching fit well for being used in combination with a load/generation balance, see criterion 3.2: Net ZEB balance – Type of balance. Suitable indicators for load matching are proposed under different wordings and summarized with a review in [39]. The most common wording for solar systems applied to buildings is the so-called "solar fraction". Generalizing the term to any form of generation leads to the load match index [38] in the form of Eq. (7):

$$f_{load,i} = \frac{1}{N} \times \sum_{year} \min\left[1, \frac{g_i(t)}{l_i(t)}\right] \quad (7)$$

where g and l stands for generation and load, respectively; i stands for energy carrier and t is the time interval used, e.g. hour, day or month. N stands for the number of data samples, i.e. 12 for monthly time interval and 8760 for hourly time interval, respectively. See also Table 5 on nomenclature.

Load match calculation is sensitive to the time resolution considered, as investigated in [38] for three existing buildings in Portugal, USA and Germany respectively, and in [40] by simulations for dwellings in high latitude climates. In that study, based on 10 min data resolution not more than 28% of the annual load can be matched although the annual yield fully balances the annual demand. Analyzing the load match at the monthly level, instead, gives a matching of 67%. Also the load considered, naturally, affects load match calculations. Simulations of a Belgian dwelling [41] report that considering 1 min data resolution 42% of the household electrical demand was instantaneously matched, while the fraction decreases to 29% when including the demand for space heating and DHW via heat pump. The reason is that the (electrically driven) heat pump increases the electric load in times with low solar power availability. When calculated on monthly values the load match index provides basically the same kind of information as the monthly net balance, see criterion 3.2: Net ZEB balance – Type of balance. In this case though, the higher the load match index, the lower the seasonal unbalance of energy exchanged with the grid. The load match index is, however, a finer indicator than the monthly net balance because it looks at one energy carrier at a time and is not distorted by the weighting.

4.2 Grid interaction

To assess the exchange of energy between a Net ZEB and a grid versus the grid's needs one must know at least the import/export profile from the building. The other half information must come from the grid's side, e.g. in terms of base/peak load, hourly price or carbon emission factor. The grid interaction can be addressed based on metering or simulation data of delivered and exported quantities. Therefore, indicators of grid interaction fit well for being used in combination with an import/export balance, see criterion Net ZEB balance-Type of balance. Such data have to consider the entire load, including user related loads such as plug loads even if excluded from the balance boundary, as the grid stress can only be addressed by a full balance approach, see criterion 1.2: Building system boundary – Balance boundary. Several indicators have been proposed to analyze the interaction between buildings and grids, with a viewpoint from either the building or the grid perspective [39]. As an example, an index from the viewpoint of the building is considered here: the grid interaction index [38]. The grid interaction index represents the variability (standard deviation) of the energy flow (net export) within a year, normalized on the highest absolute value. The net export from the building is defined as the difference between exported and delivered energy within a given time interval. The grid interaction index is calculated as in Eq. (8):

$$f_{grid,i} = STD\left[\frac{e_i(t)-d_i(t)}{\left|\max\left[e_i(t)-d_i(t)\right]\right|}\right] \quad (8)$$

where e and d stands for exported and delivered, respectively; i stands for energy carrier and t is the time interval used, e.g. hour, day or month. See also Table 5 on nomenclature. As for load matching, also the grid interaction index is sensitive to the time resolution considered.

An important characteristic from the viewpoint of the grids is the grid interaction flexibility [39] of a Net ZEB, understood as the ability to respond to signals from the grid (smart grids), e.g. price signals, and consequently adjust load (DSM), generation (e.g. CHP) and storage control strategies in order to serve the grid needs together with the building needs, and/or adjust to favourable market prices for energy exports or imports. Therefore, to be meaningful the grid interaction flexibility has to be evaluated with a time resolution of an hour or preferably even lower. What is actually in the hands of designers is to design the building and its energy systems to enhance grid interaction flexibility. The flexibility could be quantified using suitable indicator(s) evaluated in two opposite extreme situations. An extreme situation is an export priority strategy (maximum energy export): the generation system export energy to the grids regardless of the building's load or storage possibilities. The opposite extreme situation is a load matching priority strategy (maximum load match): control strategies for storage system, load shifting and generation modulation, where possible, provide maximized self-consumption of the generated energy. The difference between the two values tells how flexible a building is in terms of grid interaction. One important design strategy may be to enhance the grid interaction flexibility: the higher the flexibility, the better the building will be able to adapt to signals from the grid. It is worth noting that for building designer to design Net ZEBs with high grid interaction flexibility, it is necessary to have data on end users temporal consumption patterns, e.g. for lighting, electrical appliances, cooking, hot water use. Such data should be statistically representative for the type of building in analysis (i.e. residential, office, school, etc.) or better such data should be even normative. In the same way as weather data are standardized to provide designers with a reference climate, user profile data may be standardized to offer designers a reference temporal consumption pattern (with hourly and seasonal variations) for each type of building. Furthermore, evaluation of different strategies for the control of load, generation and storage need the support of advanced dynamic simulations tools.

5 Measurement and verification

The establishment of building performance targets at policy level necessarily leads to the development of energy rating systems, i.e. methodologies for the evaluation of the building energy performance. Ratings can be calculated ratings when based on calculations, or measured (or operational) ratings when based on actual metering [42]. Within this perspective, it is questioned whether the Net ZEB target should be a calculated or a measured rating. A measured rating would enable the verification of claimed Net ZEBs, the effectiveness and robustness of the design solutions applied, and at last the actual achievement of the energy policy targets. To check that a building is in compliance with the Net ZEB definition applied, a proper measurement and verification (M&V) process is required [43]. Such process is strictly dependent on the options selected for each criteria of the definition and on the features of the building to be assessed. As a minimum, As comfort is a mandatory requirement in buildings, an M&V protocol should also check the indoor environmental quality (IEQ). The complexity can then increase significantly due to the large number of sensors likely required in several locations within a building. Nevertheless, to warrantee indoor comfort is always the first priority in building design and the risk of designing Net ZEBs with poor IEQ shall be avoided; IEQ measurements would help to this respect. Furthermore it would help explaining possible deviations from the expected energy performance – in relation to the expected operating conditions criterion 1.3: Building system boundary – Boundary conditions – and point out relevant optimization measures. Clearly, the completeness and complexity of a Net ZEB definition is reflected in the M&V process in terms of feasibility and affordability. It is worth noting that only the energy uses included in the balance boundary, see criterion 1.2: Building sys-tem boundary – Balance boundary, contribute to define the Net ZEB balance. As a consequence, the exclusion of an energy use from the balance boundary, e.g. the electricity use for plug-loads, would require the installations of a separate meter–or possibly several–in addition those located at the interface with the grids (on the physical boundaries). This means moving from a whole building monitoring approach to sub-metering [44–46], increasing the complexity of the monitoring system and jeopardizing the verifiability of the definition. For an easily verifiable definition, hence, it would be preferable to have all the energy carriers crossing the physical boundary included in the balance boundary as well. Furthermore, in order to implement a measured rating for Net ZEBs it is necessary to specify the required validity over time and over variable boundary conditions. How long a claimed Net ZEB shall comply with the definition? What happens if in the selected time span, changes in boundary conditions occur, such as variation in the climate, occupancy, building uses? It is therefore necessary to define:

• The time span over which the measured rating shall satisfy the Net ZEB balance;

• Tolerances on the balance and required comfort conditions;

• Parametric analysis approaches to show the relationship between the balance and influencing variables, such as comfort, climate, building use, occupancy, user behaviour. an M&V protocol for Net ZEBs should enable the assessment of the import/export balance, as this is the core of the Net ZEB concept. Eventually, an M&V process could aim at evaluating also the temporal match characteristics, such as the load match or grid interaction indices. This requires setting the time resolution and selecting the duration of measurements, sampling and recording time.

Finally while the concept of zero energy buildings is generally under-stood, an internationally agreed definition is still lacking. It is recognized that different definitions are possible, in order to be consistent with the purposes and political targets that lay behind the promotion of Net ZEBs. A framework for describing the relevant characteristics of Net ZEBs in a series of five criteria and relative sub-criteria has been presented. For each criterion different options are available on how to deal with that specific characteristic. Evaluation of the criteria and selection of the related options becomes a methodology for elaborating Net ZEB definitions in a systematic, comprehensive and consistent way. This can create the basis for legislations and action plans to effectively achieve the political targets. The common denominator for the different possible Net ZEB definitions in the presented framework is the balance between weighted demand and supply. The balance may be calculated in different ways, depending on the quantities that are of interest and available. An import/export balance focuses on the energy flows exchanged between the building and the grids; it applies in monitoring or in design when estimates of self-consumption are available. A simpler load/generation balance focuses on the gross load and generation quantities disregarding their interplay; it applies in design when estimates of self-consumption are not available. A third type of balance is the monthly net balance that can be seen as a combination of the other two; monthly generation and load (for each energy carrier) are assumed to balance each other off and only the monthly residuals are summed up to form the annual totals. The choice of a proper balance metrics and weighting system should depend on targets in the political agenda and not being driven solely by feasibility of Net ZEB projects or minimization of investment cost; even though this may be a major target itself. However, it is important that authorities and competent national bodies and legislators are fully aware of the effect of the weighting factors when deciding upon the metrics to adopt for the Net ZEB definition they want to set in place. Important aspects in the framework are the criteria on energy efficiency and energy supply. While the pathway to a Net ZEB is given by the balance of the two actions–energy efficiency and energy supply–experience from a large number of already existing Net ZEBs underlines the priority of energy efficiency as the path to success [22]. Minimum energy efficiency requirements may be enforced in a Net ZEB definition. Likewise, a hierarchy of energy supply options may also be enforced. Net ZEBs are characterized by more than the mere weighted balance over a period of time. In this paper the authors pro-pose a characterization based on two aspects of temporal energy match: load matching, the ability to match the building's own load, and grid interaction, the ability to work beneficially with respect to the needs of the local grid infrastructure. These aspects are evaluated separately per each energy carrier exchanged with the grids, no weighting is applied. For the load matching an indicator is proposed, the load match index, able to express the seasonal unbalance of energy exchanged with a grid. For the grid interaction the concept of grid interaction flexibility is introduced, which may be estimated in design phase by simulating different strategies for the control of load, generation and storage systems. The indicators presented address the topics but need to be further developed. However, there is a need to work with a time resolution of hours or even lower in order to address issues such as energy price fluctuation and grids' peak load. To this respect building designers need information on end users temporal consumption patterns, better if from normative data, and the support of advanced dynamic simulations tools. Finally, it is argued that only a measured rating would enable the verification of claimed Net ZEBs, the effectiveness and robustness of the design solutions applied, and at last the actual achievement of the energy policy targets. Therefore, a measurement and verification (M&V) process is required and its completeness and complexity will dependent on the options selected for the definition criteria. It is stressed that for an easily verifiable Net ZEB definition it is preferable to include all operational energy uses in the balance boundary. Specification of other boundary conditions, such as reference climate, comfort, functionality and space effectiveness, are also necessary in order assess possible deviations from the calculated to the measured balance.

Chapter 3 A review of the existing case studies

The main NZEBs guide-lines have been described, classifications and definitions have been clarified as they are developing in the scientific backgrounds. Before starting an in-depth analysis on the Italian case-study that is the main subject of this work, it is however useful to observe some parameters that could influence the study of a NZEB.

This section will deal with some interesting case-studies chosen for their relevance and acknowledged level of interest. The case studies be described will be presented in a schematic form to underline their main characteristics.

3.1. The influence of the climate

In this paragraph many different case study buildings were described using a schematic approach, they were divided by climate and their main characteristic will be underlined. This work examines the case study buildings established for the NZEB Task 40/Annex 52 research subtask C: Advanced Building Design, Technologies and Engineering.

Figure 8 describes the stats for the buildings that have criteria for inclusion as case studies.

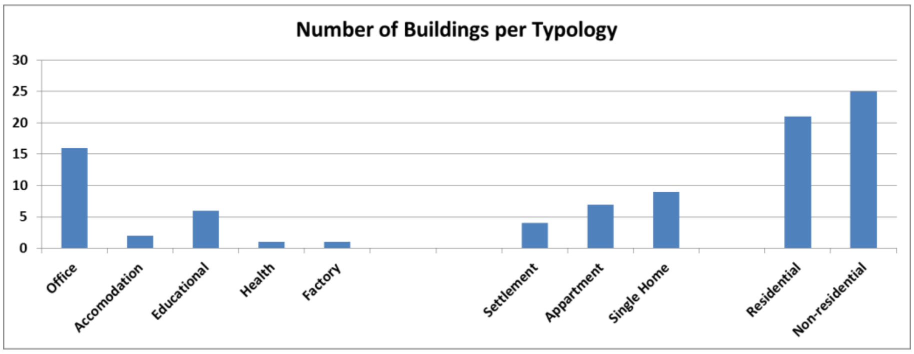


Figure 8 Number of case study buildings per typologies

We will have enough 'Office' buildings to perhaps be able to generalise our results. We should have some general things we can say about single family homes, but we certainly do not have enough numerically to be able to draw conclusions.

If we look at this data from the point of view of climate, the potential for statistically valid generalizations seems very low, when we recall that each stack of 10 to 19 buildings in these groups can be broken down further into the above – energy dominant – building types:

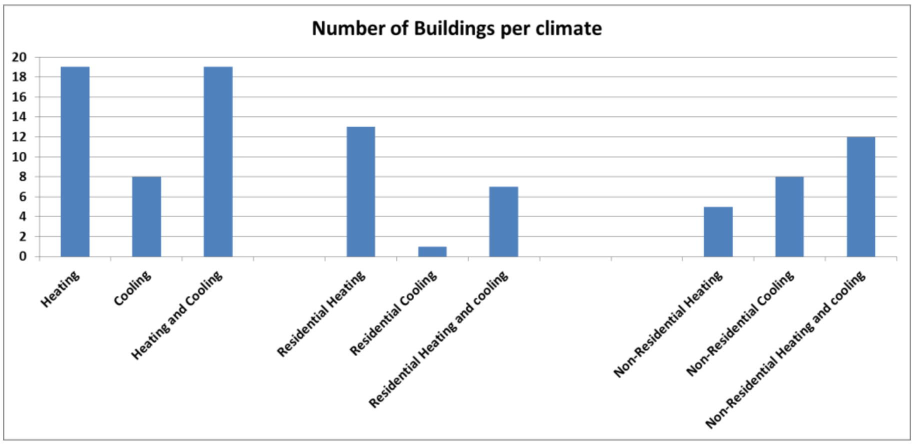


Figure 9 Number of buildings per climate

There is certainly no case to be made to have more than three distinct climate types – heating dominated, cooling dominated and mixed.

If we then look to divide up our data (Figure 10) even further into the actual headings under which we might create 'solution sets' the following breakdown appears:

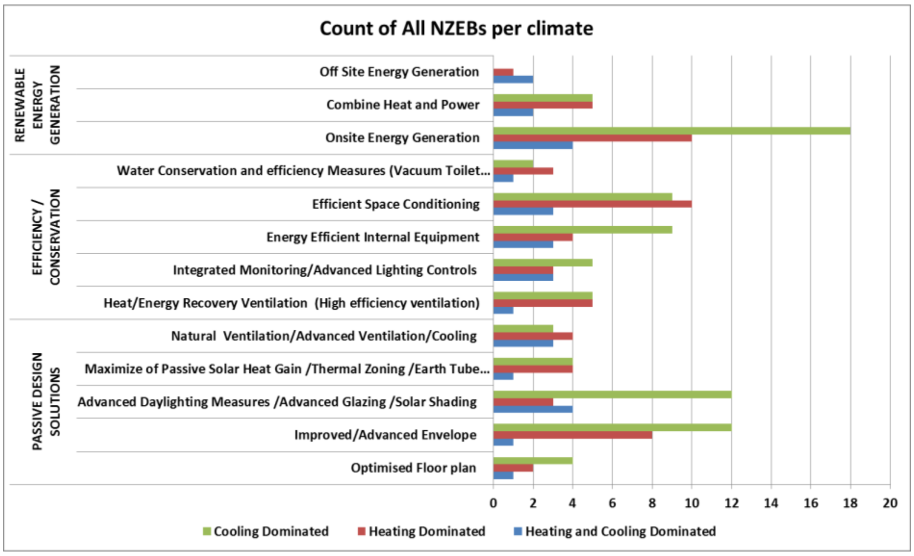


Figure 10 Count of All NZEBs per climate

The have been amalgamated in the above diagram. Natural Ventilation / Advanced Ventilation / and Cooling for example have been grouped as one design feature class.

Similarly Advanced Daylighting Measures / Advanced Glazing / Solar Shading are grouped. The primary purpose is to group into sufficient numbers of buildings to be able to draw conclusions about 'solution sets'. The secondary purpose is to group the solution sets into design ideas or approaches: the groupings are intended to be the identification of a design issue that a solution set might explore where the solutions within the set might be say Natural Ventilation and Advanced Ventilation and Cooling.

A second reason for grouping is to see whether at this higher level there is a discernible pattern to the types of system that would enable us to observe any missing headings / classes of building design feature.

3.2. Examples

Case study buildings´solutions set to the theory [1]

In the following pages a description of the case study building studied in the IEA/T40 Programm will be presented, the study shows that passive approaches have a crucial importance in these cases:

PIXEL Building (Australia)

- Native grass roof garden and cantilevered wetland reed beds to provide shading to exterior of building
- All concrete used in the building is a very low carbon design with approximately 50% less embodied carbon that traditional concrete of the same strength
- Sunshade system
- Under floor displacement air distribution

SolarCompany office building (Belgium)

- Solar shading
- Roof extraction with intelligent flow pattern
- Ground-air heatexchanger
- High efficiency heat-recovery in the ventilation unit

Abondance Montreal - Le Soleil (Canada)

- GeoExchange system: In heating mode, the GeoExchange system collects energy in the ground

- Heat recovery from shower drains using a greywater heat recovery heat exchanger
- Passive solar heat from windows
- Super energy-efficient building envelope(Airtight, with soy-based polyurethane foam insulation.)
- thermal mass
- The installation of the panels creates a pergola to shade the accessible roof terrace.

Natural Resources Canada's Material Testing Laboratory (Canada)

- innovative shading and daylighting and selective glazing
- Displacement ventilation system using exhaust air as a supplement to fume hood supply air
- Solar ventilation air preheating
- Transfer of office exhaust air to laboratory and process fume hood supply air

EnergyFlexFamily (Denmark)

- Building envelope without cold bridges
- Combination of heat pumps, ventilation systems, solar heat

ELITHIS TOWER (France) -

- All the computers are switched off at night, housework is done by day - thus avoiding to lighten entire floorplates
- Management of the protagonists of the project to reach solutions and not to impose
- Solar shield calculated in function of the sun path and the surrounding buildings to have the advantages of the sun (daylighting, heat) without the drawbacks (over-heat, glare effect)
- Triple flow ventilation

GREEN OFFICE BUILDING (France)

- Privileging passive rather than active design (outside insulation, triple glazing, natural night ventilation)

PRIMARY SCHOOL LIMEIL BREVANNES (France)

- Windows in the south facade (daylighting)

- Playground on the roof
- Privileging passive rather than active design : cross natural ventilation, nightventilation during summer season
- High thermal mass ; high exterior insulation ; triple glazing

Solon SE headquarters (Germany)

- Water pipes were integrated into the concrete fabric of the building to achieve energy-saving temperature regulation in a process known as concrete core temperature control
- The triple-glazed windows provide highly effective thermal insulation with external shade elements with blades and sun protection glass affording optimal protection from the sun
- Importance was attached to natural ventilation via windows. - Day light control - Open space offices –everybody can choose his working space every day anew and is able to control the light, heat, ventilation and so on
- Use of heat from production hall beside

Solvis (Germany)

- Highly insulated timber construction with high mass for heat storage
- Vacuum insulation in façade of office building
- Increased daylight utilization
- Optimization of the relation of building volume and thermal envelope
- Combination of construction and fixation of solar active elements
- A basic ventilation and night cooling by a mechanical exhaust air system improves the aerial quality in the office tract. This happens in the hall about controlled ventilation with heat recovery.

Little Greenie (New Zealand)

- Combination of large areas on the north facade for increased daylighting and low energy LED lighting sources
- Building has an improved envelope with high insulation values (walls, roof, and floor), high thermal mass, double glazing, and minimal thermal bridging. There are no electric heating sources, only under floor radiant heating (in the concrete slab) that is supplied from the solar hot water system.

Meridian Building (New Zealand)

- The building uses a combination of large areas on the facade for increased daylighting
- The building has an advanced envelope with a double facade, high thermal mass,and facade specific solar shading to lower heat gains from the large perimeter windows.

SOLAR XXI (Portugal)

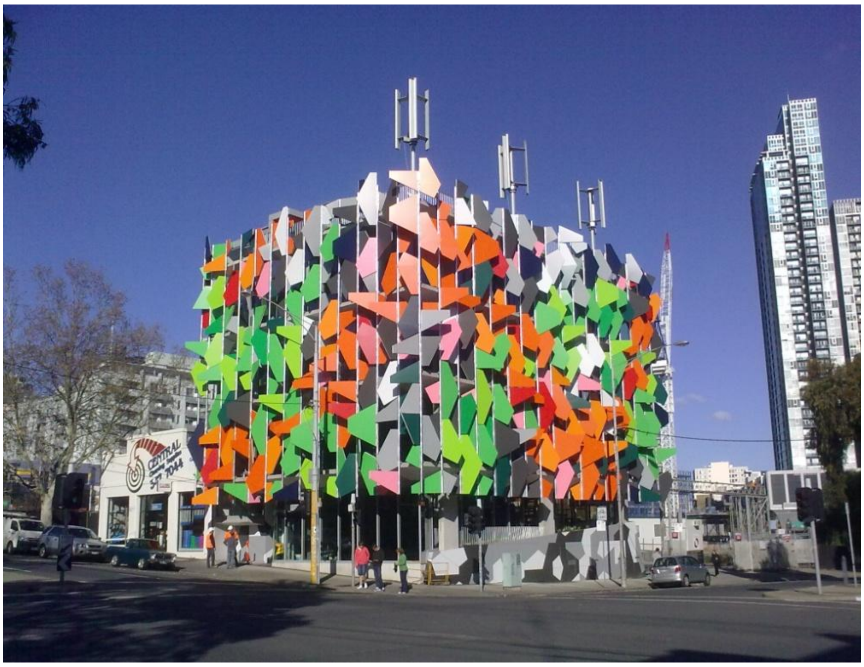
- Large glazing area (south oriented windows are protected with venetian blinds)
- Skylight in the central hall of the building (nat.lightening+nat. ventilation by stack effect)
- translucent adjustable vents on all doors connecting the rooms to the circulation area
- Passive cooling system-earth tube array
- BIPV-T-building integrated PV (façade) with heat recovery system

Research Support Facility (USA)

- Natural Ventilation
- Radiant Heating and Cooling Ceiling Slab
- Daylighting
- Thermal Mass
- Green IT
- Evaporative Cooled Data Center
- Campus woodchip boiler
- Chilled Water Storage
- 6" Interior Concrete Thermal Mass
- Bid Build Procurement
- Complete system integration
- Strict Plug Load Control
- Energy driven design
- Cost Effective, Large Scale ZEB

In the following pages the case studies analyzed by Task 40 members will be presented in a schematic form to underline their main characteristics.

Heating and Cooling dominated areas

Project name**PIXEL** Building	
Status	*Base building construction completed13th July 2010, fitout construction underway.*
Location Country; city	Australia, Melbourne
Latitude/ Longitude	- *Latitude 37°48'16.63" south* - *Longitude 144°1'743.20" east*
Climate Challenge	*Building must deal with both Winter & Summer*in a very changeable climate
Picture	
Building type	*Non-Residential – Commercial Office Building*
Engineer	Umow Lai
Architect	Studio 505
Area (m^2)	1,000 m² Gross Floor Area
Energy produced (kWh/m2.year)	- *Data below are estimates as the project is being measured now* - *PV SUPPLY: 91kWh/m2/year* - *Wind 15,282kWhrs / 1,000 so 15.2 kWhrs/m2 year* - *Fixed PV 3,509kWhrs / 1000m² so 3.5 kWhrs/m2 year* - *Tracking PV 6,853 kWhrs / 1000m² so 6.8 kWhrs/m2 year* - *Bio-gas 1,490 kWhrs / 1000m² so 1.5 kWhrs/m2 year*
Energy consumed (kWh/m2.year)	- *Base building uses 7,290 kWhrsElectricty and 28,780 kWhrs of Natural Gas* - *Fitout uses 19,537 kWhrs of Electrcity* - *All end uses 55,6070 kWhrs / 1000m² so 55.6kWhrs/m2 year*
Web site with publicly available building information	www.pixelbuilding.com.au

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***At least 12 months of monitored data will be available by mid 2012*** *At Pixel the following data is to be monitored:* - *Sub-hourly measurements of Room Temp, Slab Temp and RH in all spaces;* - *Sub-hourly measurements of Slab Temp in all spaces;* - *Lighting levels in all office spaces;* - *External wind direction, wind speed, global and direct solar radiation, temperature, humidity and rainfall.* - *Power and Energy for all end uses;* - *Biogas production;* - *Wind and solar renewable energy production;* - *Rain water, mains water and greywater consumption for all end uses;* - *portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;)*
Energy performance < 50% building standard	***Pixel building's average kWh/m2/yr:*** *Standard Melbourne office tenancy energy consumption is 111 kWhrs/m2/ year** *Standard Melbourne base building energy consumption is 167 kwhrs/m2/ year** *Therefore Standard Melbourne office energy consumption is 278 kwhrs/m2/ year* *Pixel energy consumption is 55.6kWhrs/m2 year* *(* based on surveys conducted by the Sustainable Energy Authority of Victoria in 2000)*

Innovative solution set	***Whole building mixture of different technologies:*** - *Building has been designed to be carbon neutral* - *Chilled structure and gas fired absorption chillers* - *Building is water balanced – with rainwater captured at roof garden, treated and reticulated so that all water is used three times before discharge to atmosphere or waste* - *Native grass roof garden and cantilevered wetland reed beds to provide shading to exterior of building* - *All concrete used in the building is a very low carbon design with approximately 50% less embodied carbon that traditional concrete of the same strength*
Innovative technologies	***Individual technologies that are new / interesting:*** - *100% Fresh Air with plate heat exchanger at roof level* - *Under floor displacement air distribution* - *Chiller uses ammonia as refrigerant gas* - *Pixel features the first use of innovative new micro wind turbine generation* - *Fixed and tracking PV arrays* - *Vaccuum toilet technology* - *Anerobicdigestor on site with methane gas "farmed" and used a fuel source for central hot water* - *Xeriscape roof garden that re-introduces native Victorian grassland species that were once endemic to the location* - *Sunshade system designed to reduce both thermal load form the facade and glare from the office area* - *Individual addressable dimming on the office lighting* - *LED lighting to all non-office areas of the building*
Energy supply / integration of RE	***Integration questions about Renewables:*** - *3No. Wind turbines designed for turbulent wind environments and to operate at peak output concurrent with the average wind speed of Melbourne(15,282kWhrs per year)* - *3No. Tracking PV arrays, 18 panels total (6,853 kWhrs per year)* - *2No. Fixed Roof Mounted PV array, 12 panels total (3,509 kWhrs per year)* - *Anerobicdigestor on site with methane gas "farmed" and used a fuel source for central hot water (1,490 kWhrs per year)*

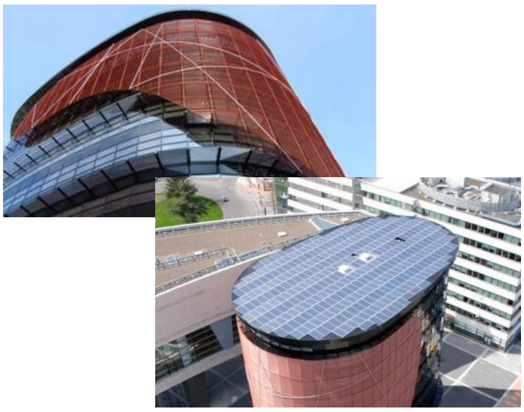
Match Index? addressed	*The building has been designed to be carbon neutral and so measurements are made based on greenhouse gas intensity of the energy sources. For grid electricity the intensity in Melbourne is 1.34 kg CO_2e/kWhr and for natural as it is 0.2134 kg CO_2e/kWhr. This results in a renewable energy supply equivalent to 34,676 kg CO_2e and a demand of 15,812 kg CO_2e for the base building. Importantly the renewable energy is mostly in the form of electricity which is in high demand on summer days (for power supply to air condition buildings) at which time the RE on Pixel is at maximum output.*
Lessons learned	- *Client is part of STC team and is extensively documenting the lessons with grant funds provided by the state government.* - *Australian Government's science agency, CSIRO, are undertaking an independent review of the carbon status of the building with a paper on alternative options that might have been explored* - *Melbourne University have been involved in the testing and certification of the wind turbines* - *RMIT University haveundertakeng an independent and peered review of the carbon embodied in the concrete* - *Melbourne University have been commissioned for the design of the roof garden (including growing media, membranes and native grasses. They have also designed the wetland reed beds and, via a research commission, have established a vegetation mix to re-introduce the grassland that typified Melbourne prior to European settlement.* - *Architect is prepared to answer questions on the process.* - *Umow Lai, the engineering team are interested to participate in examination of the building performance including what they would do to improve performance for future projects.*
Indoor environment data	- *PoE Surveys will be carried out with occupants of the building.* - *Temperatures, Humidity and equipment operating parameters will all be recorded)* - *Quarterly tuning of the building will be conducted during the first year of operation to review and refine the performance of the building. The building will be recommissioned to include any identified adjustments at the conclusion of the first year of operation.*

Abondance Montreal – Le Soleil	
Status	1. already operational 2. commissioned (first phase done but a second phase will be done in a few months) Two units are occupied (July 2009 and May 2010) and the third is an office/showroom (it will change soon).
Location Country; city	Canada, Montreal
Latitude/ Longitude	- Latitude 45.30N - Longitude 73.35W
Climate Challenge	1. Building must deal with Both Winter & Summer
Picture	
Building type	Residential
Engineer	Pageau Morel et Associés
Architect	Studio MMA Atelier d'architecture
Area (m^2)	436,6 m^2 (96.5 m^2 per unit, plus basement and stairway as common areas)
Energy produced (kWh/m^2year)	114,3 kWh/m^2year
Energy consumed (kWh/m^2year)	68,1 kWh/m^2year

Web site with publicly available building information	http://www.ecocite.com/fr/AbondanceAcceuil_fr.html http://www.innomagazine.com/img/magazine/INNO_4.pdf http://www.cmmtq.org/Image_usager/Documents/imb/imbvol24no7_septembre2009.pdf http://www.cmhc-schl.gc.ca/fr/prin/dedu/maeq/abso/
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	- **The building will exceed netzero, and be energy positive.** - **Architecturally the building works** - **The building has been designed for climate change (2030)** - **The project is affordable** - **The project is repeatable** - **The design is market ready** - **Expect to be better than modelling results**
Monitoring mandatory	- *Date collection plan produced (document available in French)* - *Report available every month with data (until October 2012)* - *Passive heat and building envelop aren't monitored* - *Meter for solar hot water used (Kamstrup Ultraflow 65-T-CDAD-510 and o Kamstrup Multical 601)* - *Multifunction meter for electricity used (Itron Sentinel)* - *Meter for ambient temperature* - *Meter for geothermal energy (every 15 minutes)*
Energy performance < 50% building standard	*Average = 150; building = 68 kWh/m2/yr*
Innovative solution set (by this we mean...	- *Combination of passive and active solar (PV, Solar water and geoExchange)*
Innovative technologies	- Solar Electricity: The building will generate has much electricity as it consumes. - GeoExchange system: In heating mode, the GeoExchange system collects energy in the ground. - Solar Domestic Hot water: Solar thermal collectors will be used to heat domestic hot water. - Solar thermal vacuum tubes for domestic hot water. - Pre-heating of domestic hot water using the heat pump de-superheaters - Heat recovery from shower drains using a greywater heat recovery heat exchanger. - Passive solar heat from windows stored in the building's thermal mass. - Super energy-efficient building envelope. (Airtight, with soy-based polyurethane foam insulation.)
Energy supply / integration of RE	- *The installation of the panels creates a pergola to shade the accessible roof terrace.*
Match Index? addressed	Supply>Demand on yearly basis. The excess heat will be sold.
Lessons learned	- *The systems are oversized to be sure to be net zero.* - *Structural architecture was difficult to design (PV load). It was difficult to get the right information.*
Indoor environment data	- *Temperature will be recorded*

SolarCompany office building	
Status	3. already operational (monitoring started but not yet fully implemented, scheduled for October 2010)
Location Country; city	BE - 3550 Heusden-Zolder
Latitude/ Longitude	- Latitude N51.04112 - Longitude E5.32985
Climate Challenge	2. Building must deal with both winter & summer (heating dominated climate, but usually high internal gains in offices present a challenge for summer comfort)
Picture	
Building type	Non-Residential: small office building with different zones
Engineer	Cenergie, ...
Architect	Bert Schellekens
Area (m^2)	582
Energy produced (kWh/m^2year)	-
Energy consumed (kWh/m^2year)	- 11 for heating (PHPP calculation)

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	
Monitoring mandatory	***12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** - *Minute by minute measurements of Temp and RH in all spaces;* - *Power and Energy for all end uses;* - *portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;* - *some detailed measurements for air-flow are planned to better assess the effect of night-ventilation on summer-comfort*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *(PH-standard with 11Kwh/m2a for heating)*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies:*** *e.g.* - *Solar shading, roof extraction with intelligent flow pattern including server-room, low internal gains.* - *intelligent control for optimal performance of whole building and best use of different technologies* - *Zoning*
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* ***(by this we mean...*** - *ground-coupled heat-pump, ground-air heatexchanger, high efficiency heat-recovery in the ventilation unit, ...*
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV on the roof* - *PV integrated in the facade*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** *to be determined based on monitoring*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Building owner is a company that is importing, distributing and installing PV and HVAC. They want to use their office-building as a test- and reference-case.* - *Cenergie (energy consultants) share some of the office-space. They did some of the simulations and will be involved in the monitoring.*
Indoor environment data	***Replace example with your data:*** *eg* -

Project name ***ELITHIS TOWER***	
Status	4. already operational
Location Country; city	Dijon, Bourgogne, FRANCE
Latitude/ Longitude	- Latitude 47°N - Longitude 5°E
Climate Challenge	3. Building must deal with Both Winter & Summer
Picture	 
Building type	Non-Residential
Engineer	Elithis Ingénierie
Architect	Jean-Marie Charpentier
Area (m^2)	5 000 m²
Energy produced (kWh/m^2year)	- *PV SUPPLY (560 m²): 16 kWh/m2/yr - measured during the first year of use* - *Wood pellet boiler (10 m^3/y)*
Energy consumed (kWh/m^2year)	- 65 kWh_{PE}/m².y (primary energy / during the conception phase) - 98 kWh_{PE}/m².y (primary energy / measured during the first year of use) - *Including ALL end uses (not just space conditioning);* - *Note: 35% (design phase) and 56% (POE) of this is the computing network.*
Web site with publicly available building information	http://www.tour-elithis.fr/index.php http://www.emporis.com/application/?nav=building&lng=3&id=1062736 http://www.jetsongreen.com/2009/10/positive-energy-elithis-tower-dijon.html

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	- *Energy meters for all end uses (heating, cooling, ventilation, pumps, elevator, lighting, office activities)* - *1600 sensors in the building*
Energy performance < 50% building standard	*Average = 550* $kWh_{PE}/m^2.y$ *Building* = 98 $kWh_{PE}/m^2.y$
Innovative solution set	- *The approach used to design the Elithis tower was to prioritize the energy saving and emissions of GHG before venturing towards technology (all the computers are switched off at night, housework is done by day - thus avoiding to lighten entire floorplates)* - *Management of the protagonists of the project to reach solutions and not to impose* - *Compactness of the building to avoid losses and inputs* - *Communication and involvement to reduce the human impact*
Innovative technologies	- *Solar shield calculated in function of the sun path and the surrounding buildings to have the advantages of the sun (daylighting, heat) without the drawbacks (over-heat, glare effect)* - *Triple flow ventilation*
Energy supply / integration of RE	- *PV on the flat roof*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis***
Lessons learned	- *Possibility to get the data (during the design stage and during the use of the building)* - *Elevators consume less than the stairs (due to lighting set off by presence detectors in the stairs)* - *7% of the area cause 50% of the lighting consumption (car park, stairs, entrance hall)* - *Pumps and auxiliary have a non-negligible consumption in the final balance* - *Wood pellet boiler : wrong choice because the combustion cycle hardly meet the low heat needs during mid seasons*
Indoor environment data	- *YES : 1600 sensors in the building* - *Building Management System*

Project name ***GREEN OFFICE BUILDING***	
Status	5. under construction
Location Country; city	Meudon, Ile de France, France
Latitude/ Longitude	- Latitude 48°N - Longitude 2°E
Climate Challenge	4. Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential:
Area (m^2)	20 000 m²
Energy produced (kWh/m^2year)	- *PV SUPPLY (4 000 m²): 64 kWh/m2/yr - estimate;* - *Cogeneration system with vegetable oil (local supply)*
Energy consumed (kWh/m^2year)	- Final energy : 40 (consumptions taken into account in the French Thermal regulation) + 22 (other consumptions : office activities, elevator, car park...)
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	- *Building Management System* - *Energy manager by store (bonus / penalty system)*
Energy performance < 50% building standard	*Average (French Thermal Regulation in 2005) = 160* *Building = 62*
Innovative solution set (by this we mean...	- *Diminution of the wideness of the buildings (14 m instead of 18m for a standard building), improves daylighting, ventilation...* - *Privileging passive rather than active design (outside insulation, triple glazing, natural night ventilation)*
Innovative technologies	- *Dual flow extracting system* - *Artificial lighting : direct and indirect with presence detectors and gradation* - *Hybrid ventilated window*
Energy supply / integration of RE	- *Cogeneration system with vegetable oil (local supply)* - *BIPV roof*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis***
Indoor environment data	- *Building Management System*

Project name ***PRIMARY SCHOOL LIMEIL BREVANNES***	
Status	6. already operational
Location Country; city	Limeil-Brévannes, Ile de France, France
Latitude/ Longitude	- Latitude 48°N - Longitude 2°E
Climate Challenge	5. Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential:
Architect	Lipa et Serge Goldstein
Area (m^2)	3 137 m²
Energy produced (kWh/m2.year)	- *PV SUPPLY (750 m²): kWh/m2/yr - estimate; still being measured* - *Thermal hot water : 30 m² / 1000 L storage*
Energy consumed (kWh/m2.year)	- *Building = 24,2 (final energy) / 60 (primary energy) including heating, hot water, kitchen, lighting, ventilation, others;*

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	- *Watt meters by type of use (heating, ventilation, hot water, kitchen, lighting, others & production)* - *Building Management System*
Energy performance < 50% building standard	*building = 24,2*
Innovative solution set (by this we mean...	- *Windows in the south facade (daylighting), no opening on the north facade* - *Playground on the roof (to avoid over-heat due to the tarmac around the school)* - *Privileging passive rather than active design*
Innovative technologies	-
Energy supply / integration of RE	- *PV panels as bardage in front of 21 mm of mineral wood*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis***
Lessons learned	- *Heat pump on water table : mud in the pump when the engine is off (during summer), needs to be on all year ie consumption that wasn't predicted*
Indoor environment data	- *Building Management System*

Project name ***Solon SE headquarters***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 12489 Berlin, Am Studio 16*
Latitude/ Longitude	*Latitude 52°25'40.30" north* *Longitude 13°32'43.90" east*
Climate Challenge	*Building Predominantly designed to deal with Summer and Winter*
Picture	
Building type	*Non-residential*
Engineer	*EGS-plan, Stuttgart*
Architect	*SFA Schulte-Frohlinde Architekten, Berlin*
Area (m^2)	*Office ca. 8.300 m² net floor area,* *Factory ca. 18.900 m² net floor area*
Energy produced (kWh/m2.year)	*Electricity (primary energy) – 8,09 kWh / m² net floor area per year* *(Measurements of CHP are missing)*
Energy consumed (kWh/m2.year)	*Primary energy – 75,00 kWh / m² net floor area per year*
Web site with publicly available building information	www.solon.com http://detailtopics.de/energie-nachhaltigkeit/projekte/projektauswahl/solon-headquarter/
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*Although architecture is an important factor, it is the everyday behaviour of people that can contribute the most to a good ecological balance. The architects worked closely with energy designer in evaluating the local conditions and the future use of the building. They wanted to cut energy consumption and CO² emissions to around one quarter of the values of a conventional office building.* *This has been achieved in terms of construction physics by an excellent building envelop and by focusing building services engineering on energy efficiency. Many individual elements contributed to their success*
Monitoring mandatory	*- high quality monitoring*
Energy performance < 50% building standard	*Average German standard = 190kWh/m²y; Solon headquarters = 25 kWh/m²y (standard only for heating)*
Innovative solution set	*- Water pipes were integrated into the concrete fabric of the building to achieve energy-saving temperature regulation in a process known as concrete core temperature control.* *- The triple-glazed windows provide highly effective thermal insulation with external shade elements with blades and sun protection glass affording optimal protection from the sun.* *- Importance was attached to natural ventilation via windows.* *- Day light control* *- Open space offices –everybody can choose his working space every day anew and is able to control the light, heat, ventilation and so on* *- Totally flexible building, everything works wireless* *- Use of heat from production hall beside* *- Investment in a biogas arrangement and a biogas powered CHPP with district heating grid* *- The green inner courtyards not only provide natural lighting but also prevent an excessive build-up of heat in the building during the summer. This, in turn, means less energy is used for cooling.*

Innovative technologies	*- ‚Solar filling station' supplies 10 electrical powered motor scooters for guests or employees* *- Autonomous energy shuttles: These mobile devices have of a capacity of 1 kW/h and are able to supply a completely equipped working desk for 10 hours. Over the night the shuttles are charged from stored solar power from the PV or favorable cheap night power. By these energy shuttles the work is possible at every place in the house, also on the roof, in the garden or in the courts.* *- LED lighting* *- The computer aided facility management system is equipped with an innovative control system – very few conventional light switches are still in use. The employees are able to adjust ventilation, heating and lighting on their own using computerized touchpanels, thus meeting their needs in an efficient and responsible way.*
Energy supply / integration of RE	*- Nice integrated PV on top of the building (a 210 kWp building-integrated photovoltaic system helps to further improve the headquarters' energy balance)* *- Renewable powered CHPP*
Match Index? addressed	*- See autonomous energy shuttles and ‚Solar filling station' for motor scooters* *- Lower mismatch because of CHPP and PV possible*
Lessons learned	*- Good contacts with monitoring team.* *- Very new building – only answers from employees and architecture critics*
Indoor environment data	*- Available*

Project name ***Solvis***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 38112 Braunschweig, Grotrian-Steinweg-Straße 12*
Latitude/ Longitude	*Latitude 52°19'4.73" north* *Longitude 10°29'24.13" east*
Climate Challenge	*Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential (factory with office wing)*
Engineer	*Solares Bauen (www.solares-bauen.de)*
Architect	*Architect Dietmar Riecks, Bochum (www.banz-riecks.de)*
Area (m^2)	*8215 m² net floor area (6715 m² factory and 1500 m² office)*
Energy produced (kWh/m^2year)	*Electricity (primary energy) – 29,22 kWh / m² net floor area per year (year 2004)* *Electricity (primary energy) – 57,83 kWh / m² net floor area per year (planned from 2005)*
Energy consumed (kWh/m^2year)	*Primary energy – 73,66 kWh / m² net floor area per year (year 2004)* *Primary energy – 57,22 kWh / m² net floor area per year (planned from 2005)* *(Production equipment is not included in the balance but extra electricity bought as green power)*
Web site with publicly available building information	www.enob.info/de/neubau/projekt/details/nullemissionsfabrik-solvis/ www.solvis.de www.solares-bauen.de/projekte/
Google Earth Reference	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The zero emission factory "Solvis" is unique in the planned size in the industrial sector. Also the high architectural quality guarantees a high attention with architects and planners for the project. Striking exterior sign is the outside steel construction of the production hall with its thermal solar collectors and PV modules. Special is in this industrial construction that it needs 80% less energy than conventional industrial arrangements. The low rest demand is covered with completely regenerative energy with solar thermal collectors, PV and the rape-oil powered CHPP.*
Monitoring mandatory	*- only low level monitoring*
Energy performance < 50% building standard	*Average German standard = 190kWh/m²y; Solvis = 28,9 kWh/m²y (standard only for heating)*
Innovative solution set	*- Highly insulated timber construction with high mass for heat storage* *- Vacuum insulation in façade of office building* *- Increased daylight utilization* *- Optimization of the relation of building volume and thermal envelope* *- Combination of construction and fixation of solar active elements* *- A basic ventilation and night cooling by a mechanical exhaust air system improves the aerial quality in the office tract. This happens in the hall about controlled ventilation with heat recovery.*
Innovative technologies	*- Solar collectors are connected with the sprinkler grid for thermal intermediate storage and as a radiation heater in the factory hall -cost-effective combination* *- Low energy HVAC and office equipment* *- Efficient lighting*
Energy supply / integration of RE	*- Active solar energy & biomass utilization with roof top installed PV and solar thermal collectors and a rape-oil powered CHPP*
Match Index? addressed	*- Lower mismatch because of CHPP coupled with solar thermal collectors*
Lessons learned	*- Very good contacts with architect and monitoring institute* *- The power consumption was too big in 2004. The balance should be reached by savings and a higher feed-in of BHKW power (in each case 135000 kWh of primary energy). An enlargement of the PV modules on the roof is not possible because of static reasons.* *- Architectural quality guarantees a high attention with architects*
Indoor environment data	*- Under investigation*

LAJON SCHOOL	
Status	In operation
Location Country; city	Lajon (BZ – Italy)
Latitude/ Longitude	- Latitude 46.37 N - Longitude 11.34 E
Climate Challenge	Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential: primary school
Engineer	Micheal Bergmeister
Architect	Johann Vonmetz
Area (m^2)	625
Energy produced (kWh/m^2year)	- PV SUPPLY: estimated yield of 16’471 kWh/a - PV SUPPLY: monitored yield of 17’859 kWh/a in 2007 and 18’175 kWh/a
Energy consumed (kWh/m^2year)	- Heating demand: 9 kWh/m²a (Energy certification CasaClima and PH have different values between 8 and 11 kWh/m²a) - Annual overall electricity demand: 5’690 kWh/a (design) - Average monitored electricity consumption: 4’584 kWh/a (monitored)
Web site with publicly available building information	No
Google Earth Reference?	No

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**Passive, all electrical education building with integrated RES supplying more than consumed.**
Monitoring mandatory	There is no monitoring system. Calculation are made based on bills.
Energy performance < 50% building standard	Referring standard for Bolzano Province is: - Heating demand less than 70 kWh/m²yr Presented building: - Design heating demand = 9 kWh/m²yr
Innovative solution set (by this we mean...	The energy concept is first of all based on the reduction of the energy demand toward a so called “passive house”. The compact building shape with an S/V ratio of 0.53 m-1 minimizes the outer scattering surfaces. Another structural solution maximizing the users’ comfort and reducing energy costs is given by a high thermal insulation of the external walls. Large windows let in light to naturally illuminate the interior spaces and venetian blinds protect from glaring sunlight conditions. While the south facing facade is characterised by an extensive glazed surfaces. All glazed surface are characterized by a low value of thermal transmittance. Also the main staircase is naturally lighted. A mechanical ventilation system with heat recovery assures high air quality and comfort for the students, whilst the air-air cross flow heat exchanger recovers energy from the exhaust air and delivers it to the incoming fresh air. of the building has been well demonstrated. The realization of an self-sufficient building has been obtained installing equipment with high efficiency rate (heat pump) and renewable energy sources (geothermal probes, solar thermal collectors and solar photovoltaic panels). Space heating with radiant floor supports the low energy approach allowing for reduced supply temperature.

Innovative technologies	Walls have been entirely covered with 20 cm of mineral foam panels, except for the roof where 24 cm wood fibre panels have been used. The mean U-value of the opaque surface is around 0.23 W/m²K. Big fenestration south (128 m², on a total surface of 150 m²). The glazed surface facing east is only 16 m² and windows facing north cover 36 m². Windows are triple coated panes filled with Argon and the window frames in oak – model Raicotherm 8 cm wide. The mean U-value of the transparent surface amounts to 0.78 W/m²K. Blower Door test results of 0.49 air changes per hour. Residual space heating and domestic hot water demands are covered by an electric heat pump – nominal power of 1.83 kWelectric and 8.3 kWthermal – operating with three ground probes (50 m deep) and by the heat produced from 18 m² of flat plate solar thermal collectors in the facade at first floor.
Energy supply / integration of RE	- *PV on the roof* - *ST collectors on south facade* - *Deep geothermal probes for ground source*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** *Yes*
Lessons learned	***Is data available on the design process?*** No
Indoor environment data	No

LEAF HOUSE	
Status	Already operational
Location Country; city	Italy, Angeli di Rosora
Latitude/ Longitude	- Latitude 43.47N - Longitude 13.7E
Climate Challenge	Building must deal with Both Winter & Summer
Picture	
Building type	Residential
Engineer	Luigi Trillini, Loccioni Group Team
Architect	Pacifico Ramazzotti
Area (m^2)	477
Energy produced (kWh/m2.year)	- *PV SUPPLY: 52.4 kWh/m2/yr - measured*
Energy consumed (kWh/m2.year)	- *Building = 77 including ALL end uses* - *Note: 15 kWh/m2/yr laboratory consumption* 11.5 *kWh/m2/yr heat pump inefficiency and bad management*
	-
Web site with publicly available building information	http://www.leafcommunity.com/index.php/info/leaf-house/?lang=en

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**The building is designed to be a demonstrating project for NZEBs, the owner is a company producing sensors. It is the best Italian case study in terms of monitored available data (it is a case study also for ST B)**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** - *Temp and RH values in all thermal zones stored every 10-15 minutes;* - *CO2 value in all apartments stored every 10-15 minutes;* - *Power and Energy for all end uses stored every 10-15 minutes;* - *Thermal Energy consumption for all the apartments stored every 10-15 minutes;* - *Plant functional parameters stored every 10-15 minutes;* - *External temperature, RH, radiance, wind speed and direction stored every 10-15 minutes*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr: 185*** *building = 52.4 (0.28% of the average)*
Innovative solution set	***Whole building mixture of different technologies:*** - *Geothermal heat pump;* - *Radiant floor* - *BIPV* - *Solar panels with thermal storage* - *Solar shields* - *Wall insulation* - *Ventilated roof* - *Efficient home appliances* - *Rain water collection*
Innovative technologies	***Individual technologies that are new / interesting:*** - *Preconditioning of fresh air in an underground duct;* - *Solar tubes* - *Flow rate of fresh air modulated with CO2 measures* - *Electrical load management*
Energy supply / integration of RE	***Integration questions about Renewables:*** - *monocrystalline PV* - *Geothermic probes*
Match Index? addressed	**…**
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Loccioni Group which is the owner is member of the Task 40.* - *Architecst and other technicians still work with Loccioni Group so are available to cooperate.*
Indoor environment data	***Replace example with your data:*** *eg* - *Occupants which are Loccioni Group Employees are ready to cooperate.* - *Comfort parameters monitored*

NATURALIA BAU	
Status	In operation
Location Country; city	Merano (BZ – Italy)
Latitude/ Longitude	- Latitude 46.66 N - Longitude 11.16E
Climate Challenge	Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential: Commercial store and offices
Architect	Dietmar Dejori
Area (m^2)	894
Energy produced (kWh/m^2year)	- PV SUPPLY: 16’496 kWh/yr(measured)
Energy consumed (kWh/m^2year)	- Heating demand: 8 kWh/m²a (Energy certification CasaClima) - Monitored total energy demand (electricity): 6729 kWh/a
Web site with publicly available building information	www.naturalia-bau.it/it/spezialthema/1-zero-emission.html
Google Earth Reference?	No

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**Passive all electrical office&retail building with PV field supplying more energy than consumed.** NZEB to heartily communicate the company (commercial) mission Exploitation of financial benefit due to PV production ("conto energia": feed in tariff incentive)
Monitoring mandatory	- Energy meter measuring heating and cooling production from the ground source heat pump - Electricity meters - C02 concentration as control parameter for ventilation system
Energy performance < 50% building standard	Referring standard for Bolzano Province is: - Heating demand less than 70 kWh/m^2yr Presented building: - Design heating demand = 7 kWh/m^2yr
Innovative solution set (by this we mean...	Natural materials Well insulated envelope Green roof Radiant floor and radiant walls Geothermal heat pumps powered by Photovoltaics Mechanical ventilation with heat recovery In detail: The new seat of Naturalia-Bau S.r.l. integrates passive house and eco sustainability concepts with an intensive use of renewable sources. In fact, on one hand the building features very high insulation of opaque envelope, large utilization of low environmental impact materials and very low U-value for the windows. The heat and cold distribution system includes floor and wall radiant panels which require a relatively low temperature. An air handling unit with heat recovery was also installed to reduce the heat and cold demand and to provide the inhabitants with high comfort. To reduce the energy consumption in summer, free cooling can be carried out or the only cold water coming from the probes can be used to cool down the air in the ventilation system. Hence, the ground source heat pump is switched on only in case a high internal comfort is missing.

Innovative technologies	The whole building is made of wood unless the foundation and the internal staircase (in concrete). Heating energy demand is strongly reduced thanks to the high level of insulation applied to the whole thermal envelope. Windows are characterized by triple glazing and high insulated wooden frames. A green roof has been also created. Walls are internally covered by clay. Heating distribution system is based on radiant walls and floors (first and third floor only) systems. Cooling load is covered by the mechanical ventilation system with heat recovery. Free cooling strategy are used in summer. The residual energy load is covered by heat pump (30W each) coupled with the geothermal probes (100 m deep). Often in summer the cooling load is simply covered thanks to the geothermal cooled water circulation. Two tanks assure heat or cold storage. Electric loads are covered by the PV system (20 kWp).
Energy supply / integration of RE	- *PV on the roof* - *Ground source heat pumps with deep geothermal wells*
Match Index? addressed	***Minimum requirement:Supply>Demand on yearly basis?****Yes*
Lessons learned	***Is data available on the design process?*** No
Indoor environment data	*none*

Polins	
Status	already operational
Location Country; city	Portogruaro (Venice) / Italy
Latitude/ Longitude	- Latitude: 45°46' - Longitude: 12° 50'
Climate Challenge	6. Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential: polifunctional building
Engineer	
Architect	Marco Acerbis
Area (m^2)	400 m^2
Energy produced (kWh/m^2year)	- 16,67 kWh/m^2year
Energy consumed (kWh/m^2year)	- about 34 kWh/m^2year
Web site with publicly available building information	www.marcoacerbis.com http://www.comune.portogruaro.ve.it/portal/it/progettualita/urbanistica/PoloInnovStrateg http://www.poloinnovazionestrategica.org/
Google Earth Reference?	http://maps.google.it/maps/place?cid=2581924085153073981&q=portogruaro+polins&hl=it&cd=8&cad=src:kml_balloon&ei=fZ6tTPmxHsmJ_gavl82FBg

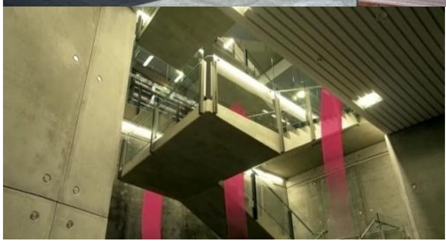
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	The first NZEB office in Italy, owned by a Municipality It is a beautiful building, representing a good example for the PV integration in buildings The use of PV as sunshading can be very common in Italy, where dealing with cooling is important (shaping an appropriate envelope)
Monitoring mandatory	*Yes, bills. For the rest: at the moment the building is not monitored (comfort), but may be it is going to be.*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** e.g. *Average = 105 kWh/m2/yr ; building = 25 kWh/m2/yr*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** *Eco sustainable materials* *Well insulated envelope* *Geothermal heat pumps powered by Photovoltaics* *Daylight control*
Innovative technologies	***Individual technologies that are new / interesting:*** *Geothermal heat pumps powered by Photovoltaics*
Energy supply / integration of RE	***Integration questions about Renewables:*** - *PV is an external sun-shading system. It suites the curved geometry of the building envelope. PV's shape is innovative, despite standard flat modules are used; this way the optimal balance between integration issues and performance issues has been got.*
Match Index? addressed	**…**
Lessons learned	***Is data available on the design process*** *Yes. The architect is collaborating with the Task 40 by answering questions, and he is also available for other needs we can have.*
Indoor environment data	***Replace example with your data:*** *eg* - …

Project name: Green Tomorrow	
Status	- *Construction completed August, 2009*
Location Country; city	- *Republic of Korea; Yongin, Gyeonggi*
Latitude/ Longitude	- *Latitude 37° 25' 74" north* - *Longitude 127° 16' 68" West*
Climate Challenge	- *Cold, dry winter and hot, humid summer*
Picture	
Building type	- Residential Building for exhibition
Engineer	- Commissioning Agent: Arup. - Electrical Engineer: Joyoung Eleccom - Energy Consultant: Samsung C & T - Environmental Building Consultant: Samsung C & T - LEED Consultant: Arup - Mechanical and Plumbing Engineer: Sebo Eng - Photovoltaic Contractor: S-Energy, Samsung SDI
Architect	- Architect: SAMOO Archtects - Contractor: Samsung C & T(Owner and contractor)
Area (m^2)	- 677 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 22.96 $kWh/m^2/yr$*
Energy consumed (kWh/m^2.year)	- *21.00 $kWh/m^2/yr$*
Web site with publicly available building information	http://www.greentomorrow.co.kr/
Google Earth Reference?	N/A

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Under monitoring by purpose of energy usage*
Energy performance < 50% building standard	- *ASHRAE 90.1-2004: 159 kWh/m^2/yr* - *Green Tomorrow: 21 kWh/m^2/yr*
Innovative solution set	- *Natural Ventilation* - *Ground Source Heat Pump* - *Daylighting* - *Earth Tube Pre-cooling* - *DC distribution* - *HEMS*
Innovative technologies	- *Vaccum Insulaton* - *Aerogel Insulation*
Energy supply / integration of RE	- *22.0 kWp Roof Mounted PV system* - *100Wp Window Shade Mounted PV system* - *18RT Geothermal heat pump system* - *3kWp Wind Turbine system*
Match Index? addressed	- *Energy Production: 22.96kWh/m^2/yr* - *Energy Consumption: 21.00 kWh/m^2/yr*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Yes (On design development, integration method etc.)*
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1* - *Meets Korean related Standard*

Project name: ***Little Greenie***	
Status	7. already operational 8. commissioned
Location Country; city	220 McShane Road, Wainui Bay, Golden Bay, New Zealand
Latitude/ Longitude	• Latitude 40S • Longitude 172E
Climate Challenge	7. Building must deal with Both Winter & Summer
Picture	  
Building type	Residential
Area (m^2)	Approx 100m^2
Energy produced (kWh/m^2year)	• *PV SUPPLY: At least 5kWh/m^2/yr. All generation is battery stored because it is not grid-tied.*
Energy consumed (kWh/m^2year)	• Building = *5kWh/m^2.yr (excluding water heating).* • Water heating is supplied by solar thermal collectors and furnace.
Web site with publicly available building information	http://goldenbayhideaway.co.nz/abodes/little_greenie
Google Earth Reference?	Wainui bay, Golden bay, New Zealand

WUPPERTAL MANDATORY CRITERIA	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** • *Minute by minute measurements of Temp and RH in all spaces;* • *Power and Energy for all end uses;* • *portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** • *New Zealand Average = 100kWh/m2.yr?;* • *Little Greenie = 5kWh/m^2.yr*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies:*** • *The general design technique employed is to minimise active systems and create a fully passive solar designed home.* • *This is achieved through a combination of large areas on the north facade for increased daylighting and low energy LED lighting sources.* • *As well the building has an improved envelope with high insulation values (walls, roof, and floor), high thermal mass, double glazing, and minimal thermal bridging. There are no electric heating sources, only under floor radiant heating (in the concrete slab) that is supplied from the solar hot water system.* • *This results in an all year round thermally comfortable home with minimal/no electric lighting during daylight hours.*
Innovative technologies	***Individual technologies that are new / interesting:*** • *Solar water heating* • *Under floor radiant heating* • *LED lighting* • *Double wall insulation* • *Adobe lined walls for increased thermal mass* • *Double glazed, thermally broken frames* • *Wood burner for extra water heating* • *Composting toilet*
Energy supply / integration of RE	***Integration questions about Renewables:*** • *Onsite/near site Photovoltaic panels with battery storage for off-the-grid energy supply.*
Match Index? addressed	• *Supply equals demand on a yearly, monthly and time-of-use interval.*
Lessons learned	• *Home Owner/Designer/Builder has indicated they are prepared to answer questions on the process.* • *The website go through the building process*
Indoor environment data	***Replace example with your data:*** • *May have POE surveys completed?* • *Temperature of full building is avaible (interior, ambient, in wall, under slab, in slab), Humidity, air velocity, black globe etc...*
	•

Project name: ***Meridian Building***	
Status	9. already operational 10. commissioned
Location Country; city	33 Custom House Quay, Wellington, New Zealand
Latitude/ Longitude	• Latitude 41S • Longitude 174E
Climate Challenge	8. Building must deal with Both Winter & Summer
Picture	   
Building type	Non-Residential
Engineer	BECA
Architect	Warren and Mahoney Architecture
Area (m^2)	Approx $100m^2$
Energy produced (kWh/m^2year)	• *All generation is 100% off-site renewable energy generation. It is grid-tied.*

Energy consumed (kWh/m^2year)	• Building = *60% less than a typical building of this typology*
Web site with publicly available building information	http://www.meridianbuilding.co.nz
Google Earth Reference?	Custom House Quay, Wellington, New Zealand

WUPPERTAL MANDATORY CRITERIA	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** • *Minute by minute measurements of Temp and RH in all spaces;* • *Power and Energy for all end uses;* • *portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** • *New Zealand Average = 150-160kWh/m2.yr?;* • *Meridian Building = 60% of typical building*
Innovative solution set	***Whole building mixture of different technologies:*** • *The building uses a combination of large areas on the facade for increased daylighting. The electric lighting is high efficiency T5 fluorescents lamps connected to a Digital Addressable Lighting Interface (DALI) to lower the lighting consumption.* • *The building has an advanced envelope with a double facade, high thermal mass, and facade specific solar shading to lower heat gains from the large perimeter windows. Whatever heating and cooling is needed mechanically is supplied by Active Chilled Beams.* • *The building uses low flow water fixtures and is coupled with solar hot water to lower water heating energy.*
Innovative technologies	***Individual technologies that are new / interesting:*** • *Active chilled beams* • *Double Facade* • *Solar Hot Water* • *Façade specific solar shading* • *High efficient T5 lamps* • *Digital Addressable Lighting Interface (DALI)* • *Low-flow water fixtures*
Energy supply / integration of RE	***Integration questions about Renewables:*** • *Offsite wind fields and hydro electric dams supple 100% renewable energy.*
Match Index? addressed	• *Zero at time-of-use due to offsite NZEB.*
Lessons learned	• *unsure?*
Indoor environment data	***Replace example with your data:*** • *May have POE surveys completed?* • *Temperature of full building is available (interior, ambient, in wall, under slab, in slab), Humidity, air velocity, black globe etc...*
	•

Project name: **SOLAR XXI**	
Status	already operational
Location Country; city	Portugal, Lisbon
Latitude/ Longitude	Latitude 38°46'20.27" north Longitude 9°10'39.83" west
Climate Challenge	Building must deal with Both Winter & Summer
Picture	
Building type	Non-Residential
Engineer	Helder Gonçalves
Architect	Pedro Cabrita, Isabel Diniz
Area (m^2)	1500 m^2
Energy produced (kWh/m^2year)	PV SUPPLY: 17.2kWh/m^2yr (measured-2007 data)
Energy consumed (kWh/m^2year)	Building Electric Energy Consumption: 22.13kWh/m^2yr; (2007 data) *Note: measured .* Building Global Energy Consumption: 36 kWh/m^2yr; (2007 data) *Note: measured+simulated .*
Web site with publicly available building information	www.lneg.pt
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION** *(**replace** example text in italics – example information from ENERPOS building La Reunion)*
Monitoring mandatory	-Minute by minute measurements of Temp and RH in all spaces; -Hourly total Electric consumption; -Portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Air velocity;
Energy performance < 50% building standard	Office buildings (standard value): 30 kgoe/m^{2}yr SOLAR XXI: 2.8 kgoe/m^{2}yr
Innovative solution set	Natural lightening/Natural ventilation strategies: -large glazing area (south oriented windows are protected with venetian blinds); - skylight in the central hall of the building (nat.lightening+nat. ventilation by stack effect); - translucent adjustable vents on all doors connecting the rooms to the circulation area (nat.lightening+nat.cross ventilation)
Innovative technologies	Passive cooling system-earth tube array (no active cooling system) BIPV-T-building integrated PV (façade) with heat recovery system
Energy supply / integration of RE	*-PV system integrated on the south building façade (BIPV-T)* *-PV system as a 'umbrella' shading the car-parking roof from the sun and also a strong architectural feature - making distinctive archi*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis***
Lessons learned	- *Client is part of STC team: has some lessons*
Indoor environment data	

ACCIONA	
Status	*already operational*
Location Country; city	*Spain, Egües, Navarra, Avenida de la Ciudad de la Innovación, 3*
Latitude/ Longitude	- *Latitude 42°48'56.69" N* - *Longitude 1°35'57.26"W*
Climate Challenge	*Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: offices*
Engineer	*Acciona Eficiencia Energética*
Architect	*Miguel Angel Garaikoetxea and Pedro Ansa*
Area (m^2)	*2591 m^2*
Energy produced (kWh/m^2year)	*According to simulation results:* - *PV= 52800 kWh* - *Solar thermal= 72000 kWh* - *Total energy produced= 124800 kWh = 48 kWh/m2.yr* *Also:* - *Biodiesel used=39500 kWh = 15 kWh/m2.yr*
Energy consumed (kWh/m^2year)	- *64 kWh/m2.yr* - *Simulated total energy use*
Web site with publicly available building information	http://www.pvdatabase.org/pdf/Acciona-Solar_Building_es.pdf
Google Earth Reference?	Spain_ACCIONA.kmz

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*First office building in Spain to be zero emissions. It combines a variety of technologies*
Monitoring mandatory	- *Data will be available*
Energy performance < 50% building standard	*Standard = 133 kWh/m2.yr* *Building = 64 kWh/m2.yr*
Innovative solution set (by this we mean...	- *Compact design,* - *South façade: shadings to allow solar gains in the winter but not in the summer, greenhouse for heat recovery* - *North, East, and West façaces: concrete for increased thermal inertia* - *Daylighting techniques*
Innovative technologies	- *Pre-cooling of fresh air with buried ducts* - *Air dumps in the curtain wall with automated control system for heat recovery*
Energy supply / integration of RE	- *PV= 50kWp* - *Solar thermal = 110kWp* - *2 absorption machines for cooling* - *Ground source heat pump* - *Bio-diesel boiler*
Match Index? addressed	- *Zero emission building* - *It produces 89% of its energy use, the 11% remaining being supplied with biodiesel (which is assumed carbon neutral)*
Lessons learned	- *Information will be available. The owner is keen to share data on his building*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

ARFRISOL_ALMERIA	
Status	*Already operational*
Location Country; city	Spain, Carrera Sacramento, S/N, Almeria
Latitude/ Longitude	- *Latitude 36°49'45.83" N* - *Longitude 2°24'18.57" W*
Climate Challenge	9. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office*
Engineer	
Architect	
Area (m^2)	*1070* m^2
Energy produced (kWh/m2.year)	- *Yet to be measured* - *PV = 9.3kWp* - *Solar thermal = 160* m^2 - *1 Absorption machines for cooling*
Energy consumed (kWh/m2.year)	- *Data not yet available*
Web site with publicly available building information	
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*(Applies to all ARFRISOL projects)* *The research project PSE-ARFRISOL aims to fostering energy efficiency in buildings by providing examples of actual buildings. Data and lessons learned obtained by monitoring these buildings will be used as tools for technology transfer to industry.* *The project involves a total of 5 buildings with the shared objective of reducing their heating and air conditioning loads by 80 to 90%. The 5 buildings share some passive and active strategies, but differ in others (depending on their location and building use).* *The project is led by the Spanish Ministry of Science and Innovation, and involves many private partners from the building industry.*
Monitoring mandatory	- *Data availability depends on the willingness of the Arfriol project stakeholders. It will likely be available by 2012 (we will probably know better in Graz)*
Energy performance < 50% building standard	- *Depends on the design building. This information will be available*
Innovative solution set (by this we mean...	- *Natural cross-ventilation* - *Different thermal inertia of walls depending on orientation*
Innovative technologies	- *Absorption machines*
Energy supply / integration of RE	- *The support for the PV system is used for shading the roof* - *See capacities above*
Match Index? Addressed	- *"Net zero" is not a target and, therefore, there is no NZEB definition applied.* - *The main goal is to substantially reduce the buildings' energy use (final energy)*
Lessons learned	- *The owner is a research center on energy and the environment, which is keen to provide data, comments, and lessons learned*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

ARFRISOL_ASTURIAS	
Status	- *Already operational*
Location Country; city	*Spain, San Pedro Anés, Siero (Asturias)*
Latitude/ Longitude	- *Latitude 43°25'24.19" N* - *Longitude 5°41'52.47" W*
Climate Challenge	10. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office*
Engineer	
Architect	
Area (m^2)	*1405 m^2*
Energy produced (kWh/m^2year)	- *Yet to be measured* - *PV = 4.1kWp* - *Solar thermal = 88 m^2* - *5 Absorption machines for cooling* - *Biomass boiler = 120 kW*
Energy consumed (kWh/m^2year)	- *Data not yet available*
Web site with publicly available building information	
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*(Applies to all ARFRISOL projects)* *The research project PSE-ARFRISOL aims to fostering energy efficiency in buildings by providing examples of actual buildings. Data and lessons learned obtained by monitoring these buildings will be used as tools for technology transfer to industry.* *The project involves a total of 5 buildings with the shared objective of reducing their heating and air conditioning loads by 80 to 90%. The 5 buildings share some passive and active strategies, but differ in others (depending on their location and building use).* *The project is led by the Spanish Ministry of Science and Innovation, and involves many private partners from the building industry.*
Monitoring mandatory	- *Data availability depends on the willingness of the Arfriol project stakeholders. It will likely be available by 2012 (we will probably know better in Graz)*
Energy performance < 50% building standard	- *Depends on the design building. This information will be available*
Innovative solution set	- *Different wall insulation depending on orientation* - *Greenhouse for heat recovery* - *Shading devices on windows* - *Natural cross-ventilation*
Innovative technologies	- *Absorption machines*
Energy supply / integration of RE	- *See capacities above*
Match Index? Addressed	- *"Net zero" is not a target and, therefore, there is no NZEB definition applied.* - *The main goal is to substantially reduce the buildings' energy use (final energy)*
Lessons learned	- *The owner is a research center on energy and the environment, which is keen to provide data, comments, and lessons learned*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

ARFRISOL_MADRID	
Status	*Already operational*
Location Country; city	*Spain, Madrid* *Avenida Complutense, 22*
Latitude/ Longitude	- *Latitude 40°27'5.04" N* - *Longitude 3°43'38.57"W*
Climate Challenge	11. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office*
Engineer	
Architect	
Area (m^2)	*2047 m^2*
Energy produced (kWh/m^2year)	- *Yet to be measured* - *PV = 5.7kWp* - *Solar thermal = 180 m^2* - *4 Absorption machines for cooling*
Energy consumed (kWh/m^2year)	- *Data not yet available*
Web site with publicly available building information	
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*(Applies to all ARFRISOL projects)* *The research project PSE-ARFRISOL aims to fostering energy efficiency in buildings by providing examples of actual buildings. Data and lessons learned obtained by monitoring these buildings will be used as tools for technology transfer to industry.* *The project involves a total of 5 buildings with the shared objective of reducing their heating and air conditioning loads by 80 to 90%. The 5 buildings share some passive and active strategies, but differ in others (depending on their location and building use).* *The project is led by the Spanish Ministry of Science and Innovation, and involves many private partners from the building industry.*
Monitoring mandatory	- *Data availability depends on the willingness of the Arfriol project stakeholders. It will likely be available by 2012 (we will probably know better in Graz)*
Energy performance < 50% building standard	- *Depends on the design building. This information will be available*
Innovative solution set (by this we mean...	- *Different glazing solutions and wall insulation depending on orientation* - *The support for the PV system is used for shading windows in the south façade*
Innovative technologies	- *Absorption machines* - *Lighting control to adjust to available light*
Energy supply / integration of RE	- *The support for the solar thermal system provides shade to the roof* - *See capacities above*
Match Index? Addressed	- *"Net zero" is not a target and, therefore, there is no NZEB definition applied.* - *The main goal is to substantially reduce the buildings' energy use (final energy)*
Lessons learned	- *The owner is a research center on energy and the environment, which is keen to provide data, comments, and lessons learned*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

ARFRISOL_PSA	
Status	*Already operational*
Location Country; city	*Spain, Tabernas, Paraje Retamares, S/N, Almeria*
Latitude/ Longitude	- *Latitude 37° 3'9.70"N* - *Longitude 2°23'24.24"W*
Climate Challenge	12. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office*
Engineer	
Architect	
Area (m^2)	*1115* m^2
Energy produced (kWh/m2.year)	- *Yet to be measured* - *PV = 8.1kWp* - *Solar thermal = 180* m^2 - *4 Absorption machines for cooling*
Energy consumed (kWh/m2.year)	- *Data not yet available*
Web site with publicly available building information	
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*(Applies to all ARFRISOL projects)* *The research project PSE-ARFRISOL aims to fostering energy efficiency in buildings by providing examples of actual buildings. Data and lessons learned obtained by monitoring these buildings will be used as tools for technology transfer to industry.* *The project involves a total of 5 buildings with the shared objective of reducing their heating and air conditioning loads by 80 to 90%. The 5 buildings share some passive and active strategies, but differ in others (depending on their location and building use).* *The project is led by the Spanish Ministry of Science and Innovation, and involves many private partners from the building industry.*
Monitoring mandatory	- *Data availability depends on the willingness of the Arfriol project stakeholders. It will likely be available by 2012 (we will probably know better in Graz)*
Energy performance < 50% building standard	- *Depends on the design building. This information will be available*
Innovative solution set (by this we mean...	- *Solar chimneys for natural ventilation* - *Different wall insulation depending on orientation*
Innovative technologies	- *Overnight cooling - radiant floor combined with convective panels on the roof* - *Pre-cooling of fresh air with buried ducts* - *Absorption machines*
Energy supply / integration of RE	- *The support for the solar thermal and the cooling systems provides shade to the roof* - *See capacities above*
Match Index? Addressed	- *"Net zero" is not a target and, therefore, there is no NZEB definition applied.* - *The main goal is to substantially reduce the buildings' energy use (final energy)*
Lessons learned	- *The owner is a research center on energy and the environment, which is keen to provide data, comments, and lessons learned*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

ARFRISOL_SORIA	
Status	*Already operational*
Location Country; city	*Spain, Soria* *Carretera Madrid-pamplona, KM 206, Cubo De La Solana*
Latitude/ Longitude	- *Latitude 41°39'11.44" N* - *Longitude 2°30'16.50" W*
Climate Challenge	13. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office*
Engineer	
Architect	
Area (m^2)	*1366 m^2*
Energy produced (kWh/m2.year)	- *Yet to be measured* - *PV = 7.5kWp* - *Solar thermal = 126 m^2* - *2 Biomass boilers = 100 + 48kW* - *5 Absorption machines for cooling*
Energy consumed (kWh/m^2year)	- *Data not yet available*
Web site with publicly available building information	
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*(Applies to all ARFRISOL projects)* *The research project PSE-ARFRISOL aims to fostering energy efficiency in buildings by providing examples of actual buildings. Data and lessons learned obtained by monitoring these buildings will be used as tools for technology transfer to industry.* *The project involves a total of 5 buildings with the shared objective of reducing their heating and air conditioning loads by 80 to 90%. The 5 buildings share some passive and active strategies, but differ in others (depending on their location and building use).* *The project is led by the Spanish Ministry of Science and Innovation, and involves many private partners from the building industry.*
Monitoring mandatory	- *Data availability depends on the willingness of the Arfriol project stakeholders. It will likely be available by 2012 (we will probably know better in Graz)*
Energy performance < 50% building standard	- *Depends on the design building. This information will be available*
Innovative solution set (by this we mean...	- *Different façade design, insulation, and thermal inertia depending on orientation* - *Natural cross-ventilation and solar chimneys*
Innovative technologies	- *Biomass boilers* - *Absorption machines*
Energy supply / integration of RE	- *The support for the solar thermal and the cooling systems provides shade to the roof* - *See capacities above*
Match Index? Addressed	- *100% renewable building (final energy). No fossil fuels are used in the building.*
Lessons learned	- *The owner is a research center on energy and the environment, which is keen to provide data, comments, and lessons learned*
Indoor environment data	- *Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

CIRCE Zaragoza	
Status	*Already operational (since June 2010)* *(renewable energy systems to be implemented in late 2010)*
Location Country; city	*Spain; Zaragoza* *Mariano Esquillor Gómez, 15, 50018*
Latitude/ Longitude	- *Latitude 41º41'N* - *Longitude 0º53'W*
Climate Challenge	14. *Building must deal with Both Winter & Summer*
Picture	
Building type	*Non-Residential: office, research center*
Engineer	*CIRCE*
Architect	*PETRA JEBENS ZIRKEL (http://www.jebens-architecture.eu/)*
Area (m^2)	*1743 m^2 (net floor area)*
Energy produced (kWh/m^2year)	- *By the end of this year, energy generation is expected to be 14.3 kWh/m2.year (solar PV + Solar thermal + small wind turbine).* - *This will soon be increased by adding a medium-size wind turbine and a biomass boiler*
Energy consumed (kWh/m^2year)	- *Total end use energy: 45.7 kWh/m2.year (Includes all energy uses)* - *(based on energy simulation)*
Web site with publicly available building information	*http://circe.cps.unizar.es/*
Google Earth Reference?	Spain_CIRCE.kmz *(The CIRCE building is not yet in the satellite image)*

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*This is the headquarters of CIRCE (research center which works on emission reduction). The building includes green construction concepts and technologies (natural materials and the like), and will be used as an example for technology transfer to companies and university students (University of Zaragoza)*
Monitoring mandatory	*Will be available* - *Power and Energy data* - *portable units to measure thermal comfort will be deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;*
Energy performance < 50% building standard	*Standard = 136.4 kWh/m2.year; building = 45.7 kWh/m2.year* *Both values based on energy simulation*
Innovative solution set (by this we mean...	- *Compact design* - *Barrier for the predominant wind* - *Solar chimney* - *Passive cooling tower* - *Shadings*
Innovative technologies	- *Radiant floor for both heating and cooling* - *Ground source heat pump* - *Greenhouse* - *Green roof*
Energy supply / integration of RE	- *PV* - *Wind turbine* - *Solar thermal* - *Biomass boiler (not yet)* - *Ground source heat pump*
Match Index? addressed	*Life cycle zero emissions building (LC-ZEB)*
Lessons learned	- *The building is owned and used by a research center which works on energy efficiency issues, and are keen to share their experience with the Task 40. Indeed, they attended the first meeting in Lisbon*
Indoor environment data	- *Will be assessed in the future by means of short term monitoring of temperature, relative humidity, air velocity, and available light*

LIMA (Low Impact Mediterranean Architecture)	
Status	*Under test*
Location Country; city	*Spain, Barcelona*
Latitude/ Longitude	*41°24'29.14"N* *2° 7'47.36"E*
Climate Challenge	*Building must deal with both Winter & Summer (Coastal Mediterranean Summer: warm and humid)*
Picture	
Building type	*Residential - prototype*
Engineer	*Several consulting and engineering companies involved, see http://www.saas.cat/index2.php?Idioma=Catalan&Seccion=LIMA&Opcion=Detalle&Proyecto=31*
Architect	*Joan Sabaté, Christoph Peters, Horacio Espeche - SaAS (www.saas.cat)*
Area (m^2)	*Prototype under test: single storey, 45 m^2* *Project: 4 storey building, 12 apartments of 75m^2 each*
Energy produced (kWh/m^2year)	*Prototype data:* *Solar thermal – 790 kWh/year -> 17.6 kWh/m2.year* *Solar photovoltaic – 1200 kWh/year -> 27 kWh/m2.year*

Energy consumed (kWh/m²year)	*Apartment (project):* • *Heating load of the apartment building: 2.3 kWh/m².yr (simulated with thermplan)* • *Cooling load of the apartment building: 9.2 kWh/m².yr (simulated with thermplan)* • *Hot water load: 20,5 kWh/m².yr* • *Lighting& appliances: 16,4 kWh/m².yr* *Prototype:* *There are no simulation results available for the house prototype. However, assuming that a house would have a 2-fold heating and cooling demand per m² because of its larger exterior wall area per m² of floor area:* • *Heating load: 4.6 kWh/m².yr* • *Cooling load: 18.4 kWh/m².yr* • *Hot water load: 20,5 kWh/m².yr* • *Lighting& appliances: 16,4 kWh/m².yr* *The solar thermal system provides heat for DHW and space heating. The prototype is equipped with an air condensed heat pump with an estimated 1.4 seasonal COP (the real project would have a ground source heat pump, but this could not be implemented in the prototype). Therefore, in terms of energy use:* • *Heating and DHW: (4.6+20.5-17.6)/1.4 = 5.4 kWh/m².yr* • *Cooling: 18.4/1.4 = 13.1 kWh/m².yr* • *Lighting& appliances: 16,4 kWh/m².yr* • *Total (electricity): 34.9 kWh/m².yr*
Web site with publicly available building information	*http://www.saas.cat/index2.php?Idioma=Catalan&Seccion=LIMA&Opcion=Detalle&Proyecto=31*
Google Earth Reference?	Spain_LIMA.kmz *(this is the location where the prototype building will be located for the year of monitoring)*

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*The project aims to show the economic and technological viability of drastically reducing the environmental impact of buildings in the Mediterranean Area, taking into account the whole lifecycle- construction and operation. It brings together research centers, universities and companies that are committed to a sustainable future. The objective is to generate a very low impact construction standard, capable of becoming a real alternative for the construction of housing, schools, and other buildings of similar dimensions, both in new construction and refurbishment.* *The test building is the first prototype of the LIMA initiative, which is a house. A first temporary office building with 160m^2 net floor area has been realised in Barcelona.*
Monitoring mandatory	- *High quality data will be available from more than 100 sensors and meters. The prototype will be tested under standardized conditions which means with automatically actuated internal loads (sensible and latent heat, electrical equipment, etc.) under real weather conditions and fixed comfort conditions.*
Energy performance < 50% building standard	- *Building energy use (electricity): Heating + cooling + ACS + Lighting (no appliances) = 20.5* - *Standard: Not calculated yet (but would be much larger than 41 kWh/m^2.yr)*
Innovative solution set (by this we mean...	- *Reducing heating and cooling loads through increased insulation, thermal mass and solar protections (ventilated façade, daylight transporting exterior Venetian blinds with automatic control)*
Innovative technologies	- *Heat recovery* - *High efficiency HVAC systems, equipment, appliances, and lighting* - *Radiant ceiling* - *Solar tubes for day lighting of interior spaces* - *Control systems for HVAC and lighting systems*
Energy supply / integration of RE	- *Solar thermal* - *Solar PV* - *Although not included in the prototype, the overall LIMA project (i.e., future LIMA buildings) may also include biomass*
Match Index? addressed	- *LIMA is not meant to be a NZEB, but rather a "low impact building" and therefore includes also the construction and maintenance energy and associated emissions, water management, comfort and indoor air quality aspects. It does not have an imposed energy balance to meet.* - *97% reduction of CO_{2eq} emissions during the building's 60 year life cycle (includes embodied energy)*
Lessons learned	- *Easy access to the design team responsible (SaAS). They are keen to share data and lessons learned*
Indoor environment data	- *Will be evaluated through continuous measurement of space temperature, relative humidity, air velocity, and available light*

Project name: Research Support Facility (RSF)	
Status	- Construction completed June 10, 2010 - Operation and occupancy began June 18, 2010
Location Country; city	- United States; Golden, Colorado
Latitude/ Longitude	- *Latitude 39° 44' 34.8" north* - *Longitude 105° 9' 10.8" West*
Climate Challenge	- Building must deal with Both Winter & Summer
Picture	
Building type	- Non-Residential Office Building
Engineer	- Civil Engineer: Martin/Martin, Inc. - Communications Engineer: Technology Plus Inc. - Daylighting Engineer: Architectural Energy Corporation - Electrical Lighting Engineer: RNL Design - MEP: Stantec Inc. - Structural Engineer: KL&A, Inc.
Architect	- Architect: RNL Design - Design-Builder: Haselden Construction
Area (m^2)	- 20,355.52 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 101 $kWh/m^2/yr$ - estimate; still being measured*
Energy consumed (kWh/m^2.year)	- *101 $kWh/m^2/yr$ including ALL end uses and prorated data center which serves RSF staff only*
Web site with publicly available building information	http://www.nrel.gov/sustainable_nrel/sustainable_buildings.html http://www.nrel.gov/features/20100414_green.html http://www.nrel.gov/features/20100301_windows.html http://www.nrel.gov/features/20091207_rsf.html http://www.nrel.gov/features/20091030_rsf.html http://www.nrel.gov/features/20090717_rsf.html http://www.nrel.gov/features/20090529_rsf.html
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Building Sub-metering*
Energy performance < 50% building standard	- *ASHRAE 90.1-2004: 165kWh/m²/yr* - *RSF: 101 kWh/m²/yr (Includes prorated data center)*
Innovative solution set (by this we mean...	- *Natural Ventilation* - *Radiant Heating and Cooling Ceiling Slab* - *Daylighting* - *Thermal Mass* - *Green IT* - *Evaporative Cooled Data Center* - *Campus woodchip boiler* - *Chilled Water Storage* - *6" Interior Concrete Thermal Mass* - *Bid Build Procurement* - *Complete system integration* - *Strict Plug Load Control* - *Energy driven design* - *Cost Effective, Large Scale ZEB*
Innovative technologies	-
Energy supply / integration of RE	- *480 kW Roof Mounted and 1080 kW Site Mounted PV system* - *Purchased wind energy*
Match Index? addressed	- *Energy Production: 101 kWh/m²/yr* - *Energy Consumption: 101 kWh/m²/yr (Includes prorated data center)*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Client is part of STC team: has some lessons. Architect has also indicated they are prepared to answer questions on the process.*
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1*

Cooling dominated areas

Project name ***ENERPOS Building***	
Status	11. already operational
Location Country; city	University Institute of Technology, Saint-Pierre, Reunion Island, France
Latitude/ Longitude	- Latitude 21S - Longitude 55.5E
Climate Challenge	15. Building Predominantly designed to deal with Summer
Picture	
Building type	Non-Residential
Engineer	INSET / Imageen
Architect	T. Faessel-Bohe
Area (m^2)	800 m² (net floor area) / 1 300 m² (gross area)
Energy produced (kWh/m2.year)	- *PV SUPPLY (370 m² / 49 kWc)* - *88 kWh/m²/yr - estimate; still being measured*
Energy consumed (kWh/m2.year)	- *Building = 30 including ALL end uses (not just space conditioning);* - *Note: 35% of this is the computing network*
	-
Web site with publicly available building information	http://lpbs.univ-reunion.fr/enerpos
Google Earth Reference?	
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	- *Minute by minute measurements of Temp and RH in all spaces;* - *Power and Energy for all end uses (minute by minute)*

	- *Portable units to measure thermal comfort has been deployed to provide short term assessment of Temp; RH; Illuminance; Air velocity; Radiant Temperature;*
Energy performance < 50% building standard	*Average = 150;* *Building = 30*
Innovative solution set	- *Combination of shading, daylighting and cross natural ventilation - where no one appears to compromise the other - by contrast with normal tropical practice where shading is more important than daylight: made possible in the end by appropriate technology (NOT high Tech Air conditioning) ceiling fans;* - *Privileging passive rather than active design* - *Information and education for the users*
Innovative technologies	- *No lighting - redesign of installed technology based on analysis of need;* - *Internal louvers provide 30% internal wall porosity to match external porosity and to facilitate cross natural ventilation and daylight of circulation areas* - *High efficient air ceiling fans*
Energy supply / integration of RE	- *PV is an external 'umbrella' shading the building roof from the sun and also a strong architectural feature - making distinctive architecture*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis***
Lessons learned	- *Client is part of STC team: has some lessons. Architect has also indicated they are prepared to answer questions on the process.* - *Also, Imageen, the engineering team are interested to paricipate in examination of what works and what they would not do again.*
Indoor environment data	- *PoE Surveys have been carried out. 1500 surveys for the two last hot seasons* - *Temperature and Humidity* - *Thermal parameters recorded during the comfort surveys*

Project name: Hawaii Gateway Energy Center	
Status	- *Construction completed January, 2005*
Location Country; city	- *United States; Kailua-Kona, Hawaii*
Latitude/ Longitude	- *Latitude 19° 44' 8" north* - *Longitude 156° 2' 56" West*
Climate Challenge	- *Building Predominantly designed to deal with Summer*
Picture	
Building type	- Non-Residential Office Building
Engineer	- Civil Engineer: RM Towill Corporation - Commissioning Agent: Engineering Economics, Inc. - Energy Consultant: Lincolne Scott, Inc. - Environmental Building Consultant: - LEED Consultant: ENSAR Group, Inc. (now RMI/ENSAR Built Environment) - MEP Engineer, Lighting: Lincolne Scott, Inc. - Structural Engineer: Libbey Heywood, Inc.
Architect	- Architect: Ferraro Choi And Associates, Ltd. - Contractor: Bolton, Inc.
Area (m^2)	- 334.45 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 98 $kWh/m^2/yr$*
Energy consumed (kWh/m^2.year)	- *87 $kWh/m^2/yr$*
Web site with publicly available building information	*http://www.ferrarochoi.com/sustainarch/nelha/index.html* *http://www.ferrarochoi.com/casestudies/Hawaii-Gateway-Energy-Center-CaseStudy/index_Hawaii-Gateway-Energy-Center-CaseStudy.html* *http://zeb.buildinggreen.com/overview.cfm?projectid=592*
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Building Sub-metering*
Energy performance < 50% building standard	- *ASHRAE 90.1-1999: 189 kWh/m²/yr* - *Hawaii Gateway Energy Center: 87 kWh/m²/yr*
Innovative solution set (by this we mean...	- *Natural Ventilation* - *Daylighting* - *Passive Thermal Chimneys* - *Sea Water Cooling*
Innovative technologies	-
Energy supply / integration of RE	- *20 kW Roof Mounted PV system*
Match Index? addressed	- *Energy Production: 98 kWh/m²/yr* - *Energy Consumption: 87 kWh/m²/yr*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* -
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1*

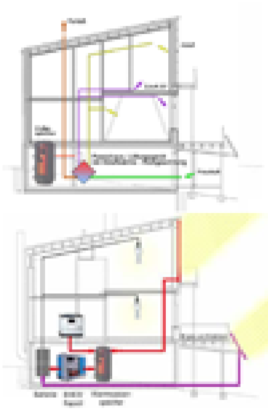
Project name: IDeAs Z^2 Design Facility	
Status	- Construction completed August, 2007
Location Country; city	- United States; San Jose, California
Latitude/ Longitude	- *Latitude 37° 20' 21.0" north* - *Longitude 121° 53' 38.0" West*
Climate Challenge	- *Building Predominantly designed to deal with Summer*
Picture	
Building type	- Non-Residential Office Building
Engineer	- Civil Engineer: Carroll Engineering - Electrical Engineer: Integrated Design Associates, Inc. - Mechanical Engineer: Johnson Controls - Mechanical Engineer: Rumsey Engineers, Inc. - Structural Engineer: Tipping-Mar + Associates
Architect	- Architect: EHDD Architecture - Contractor: Hillhouse Construction
Area (m^2)	- 669 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 82 $kWh/m^2/yr$*
Energy consumed (kWh/m^2.year)	- *81 $kWh/m^2/yr$*
Web site with publicly available building information	*http://www.ideasi.com/page16_a.html* *http://zeb.buildinggreen.com/overview.cfm?ProjectID=1346*
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Building Sub-metering*
Energy performance < 50% building standard	- *ASHRAE 90.1-1999: 203 kWh/m^2/yr* - *IdeAs Z^2 Design Facility: 81 kWh/m^2/yr*
Innovative solution set (by this we mean...	- *Daylighting* - *Ground Source Heat Pump* - *Reduced Plug Loads*
Innovative technologies	-
Energy supply / integration of RE	- *30 kW Roof Mounted PV system*
Match Index? addressed	- *Energy Production: 82 kWh/m^2/yr* - *Energy Consumption: 81 kWh/m^2/yr*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* -
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1*

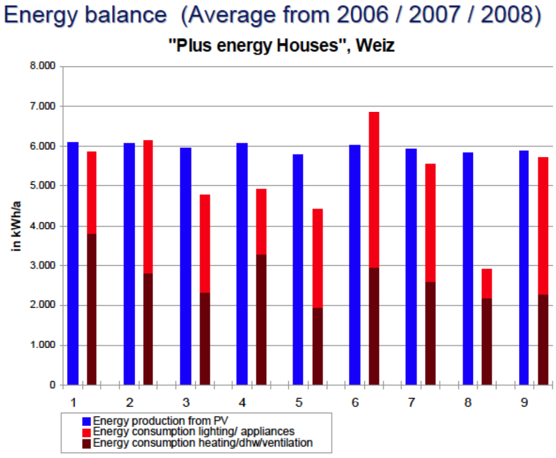
Heating dominated areas

Project name **SUNDAYS - Offices and Row-houses**	
Status	12. *commissioned*
Location Country; city	Austria; Gleisdorf
Latitude/ Longitude	- *Latitude 47°10'18 north* - *Longitude 15°71'66 east*
Climate Challenge	Heating Dominated
Picture	
Building type	*Non-Residential; Residential*
Engineer	Lieb Bau Weiz
Architect	Arch. DI Georg Reinberg
Area (m^2)	
Energy produced (kWh/m2.year)	Zero emission concept based on solar thermal, biomass, photovoltaics and wind energy// currently testing a protoyp of CHP- integrated in energy concept
Energy consumed (kWh/m2.year)	
Web site with publicly available building information	http://www.aee-intec.at
Google Earth Reference?	no

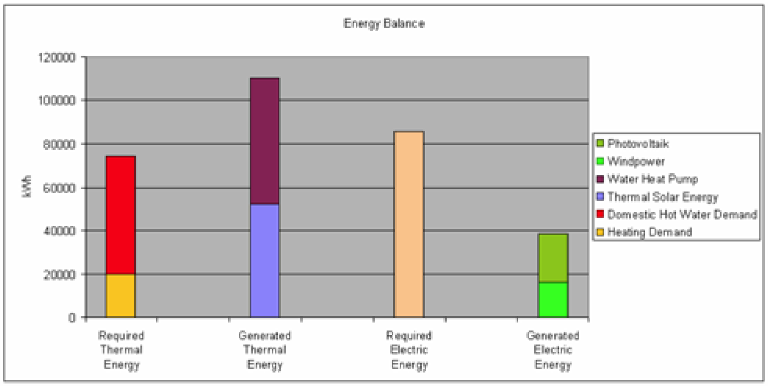
WUPPERTAL MANDATORY CRITERIA	
Monitoring mandatory	Excellent monitoring data available
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *e.g.* *Average for New buildings = 50; Building = 20;*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** - Advanced Thermal Insulation - Maximization of Passive Solar Heat Gain - Thermal Mass - Heavy Weight Constr. - Earth Tube Heat Exchanger - Heat-Buffer Rooms / Thermal zoning of Interior - PV; Solar Thermal Collectors facade integrated - Solar Thermal Domestic Hot Water - Solar Thermal Space Heating - Thermal Storage - Biogas / Biofuel CHP - Low Embodied Energy / Eff .Disassembling & Recyling of Building Materials
Innovative technologies	- solar thermal and biomass in a micro grid with other public buildings, photovoltaics and wind energy (public swimming pool,office building, labratory, row-houses, residential area, buidling of the fire brigade.. connected together to handle mismatch)
Energy supply / integration of RE	***Integration questions about Renewables:*** *PV and Solar Thermal Collectors are integrated into the south facade*
Match Index? addressed	surplus from photovoltaics supports public electricity grid// surplus of ST in summer delivered to public swimming pool)
Lessons learned	*Architect, Engineer and Owner have indicated that they are prepared to answer questions on the process.*
Indoor environment data	Excellent monitoring data, daily

Project name	**Schiestl-Schutzhütte - Hochschwab**
Status	*13. commissioned*
Location Country; city	Austria; Hochschwab
Latitude/ Longitude	- *Latitude 47°63'16 north* - *Longitude 15°17'80 east*
Climate Challenge	Heating Dominated
Picture	 
Building type	*Non-Residential (Alpine Refugee - Hotel)*
Engineer	Geischläger GmbH
Architect	Arch. DI Trebersburg / POS Architects
Area (m^2)	353m2
Energy produced (kWh/m^2year)	Big surplus of energy (for space heating) delivered to neighboured houses, because of high efficiency of the own building
Energy consumed (kWh/m^2year)	Domestic Hot Water: 0,7MWh/a Electricity Demand: 6570 kWh/a
Web site with publicly available building information	http://www.baunetzwissen.de/objektartikel/Haustechnik_Schiestl-Schutzhuette-am-Hochschwab-Steiermark_A_71708.html
Google Earth Reference?	no

WUPPERTAL MANDATORY CRITERIA	
Monitoring mandatory	monitoring data monthly till the last years
Energy performance < 50% building standard	*Average New Building= 50; building = 15;* passive house standard, 3 storage tanks supported by 64m2 ST, CHP, solid fuel heater//centralised ventilation system
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** - Advanced Thermal Insulation - Maximization of Passive Solar Heat Gain - Thermal Mass - Heavy Weight Constr. - Geothermal Heat Pump - Heat-Buffer Rooms / Thermal zoning of Interior - PV; Solar Thermal Collectors facade integrated - Solar Thermal Domestic Hot Water - Solar Thermal Space Heating - Thermal Storage - Mechanical Ventilation / Heat Recovery - Biogas / Biofuel CHP - Energy / Load Management - Waste Water Recycling - Low Embodied Energy / Eff .Disassembling & Recyling of Building Materials
Innovative technologies	example in a very hard climate area and building site, no grid-connection, self-sufficiend building
Energy supply / integration of RE	*PV and Solar Thermal Collectors are integrated into the south facade*
Match Index? addressed	No Grid Connection, Match Index addressed by storage tanks, batteries
Lessons learned	*Architect, Engineer and Owner have indicated that they are prepared to answer questions on the process.*
Indoor environment data	Excellent monitoring data, monthly

Project name ***Plus energy houses "Weiz"***	
Status	14. *commissioned*
Location Country; city	Austria; Weiz
Latitude/ Longitude	- *Latitude 47°21'67" north* - *Longitude 15°61'7" east*
Climate Challenge	Heating Dominated
Picture	 
Building type	*Residential*
Engineer	SG ELIN / TB Bierbaumer
Architect	Arch. DI Erwin Kaltenegger
Area (m^2)	9 Apartments/ Net area: Top 1: 105,5 m2 Top 2-9: 93,8 m2
Energy produced (kWh/m2.year)	energy-balance shows energy-gains in the annual balance - so called "plus energy houses" – see graph below.
Energy consumed (kWh/m2.year)	

Web site with publicly available building information	http://www.tanno.at
Google Earth Reference?	no
WUPPERTAL MANDATORY CRITERIA	
Monitoring mandatory	monthly basis
Energy performance < 50% building standard	*e.g. Average = 50; building = 15 kWh/m2a Net Floor Area*
Innovative solution set (by this we mean...	- Advanced Thermal Insulation - Maximization of Passive Solar Heat Gain - Thermal Mass - Heavy Weight Constr. - Natural Cross Ventilation / Night Cooling - Earth Tube Heat Exchanger - PV roof integrated - Air to Air Heat Pump - Heat Recovery / Mechanical Ventilation - Low Embodied Energy / Eff .Disassembling & Recyling of Building Materials
Innovative technologies	
Energy supply / integration of RE	*PV is integrated in the south facing Roof Area; Complete area 40 m2 per apartment* *Installed capacity per apartment 4,95 kWp*
Match Index? addressed	
Lessons learned	*Architect, Engineer and Owner have indicated that they are prepared to answer questions on the process.*
Indoor environment data	Not available

Project name **Zero Energy Hotel Vienna**	
Status	15. *commissioned*
Location Country; city	Austria; Vienna
Latitude/ Longitude	- *Latitude 48°10'19 north* - *Longitude 16°21'25 east*
Climate Challenge	Heating Dominated
Picture	
Building type	*Non-Residential*
Engineer	TB Heiling
Architect	Arch. DI Heinrich Trimmel
Area (m^2)	38 rooms
Energy produced (kWh/m^2year)	See below
Energy consumed (kWh/m^2year)	
Web site with publicly available building information	http://www.hotelstadthalle.at/en
Google Earth Reference?	no

WUPPERTAL MANDATORY CRITERIA	
Monitoring mandatory	monitoring data available
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *e.g. Average for New buildings = 50; Building = 15;*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** - Advanced Thermal Insulation - Thermal Mass - Heavy Weight Constr. - Earth Tube Heat Exchanger - Biofuel Biogas CHP - Windpower - PV facade integrated; PV roof integrated - Solar Thermal Domestic Hot Water - Solar Thermal Space Heating - Thermal Storage - Efficient HVAC Equipment - Biogas / Biofuel CHP - Energy / Load Management - Efficient Household Appliances - Heat Recovery
Innovative technologies	- Mixture of many different technologies to reach Zero
Energy supply / integration of RE	***Integration questions about Renewables:*** PV and Solar Thermal Collectors are integrated into the south façade an roof area, Windpowerplant on the roof
Match Index? addressed	No Information yet
Lessons learned	*Architect, Engineer and Owner have indicated that they are prepared to answer questions on the process.*
Indoor environment data	Good monitoring data

Project name ***Avalon Discovery III EQuilibrium™ House***	
Status	Commissioned (Occupied by a family)
Location Country; city	Canada; Red Deer, Alberta
Latitude/ Longitude	- Latitude 52° 11' N - Longitude 113° 54' W
Climate Challenge	16. Building Predominantly designed to deal with Winter
Picture	
Building type	Residential
Engineer	N/A
Architect	Avalon Master Builder, Calgary, Alberta (designer & builder)
Area (m^2)	243.8 m^2
Energy produced ($kWh/m^2 year$)	*PV SUPPLY: 43.4 + 14.0 solar hot water and space heat = 57.4 total – modelled, early results indicate somewhat less.*
Energy consumed ($kWh/m^2 year$)	- ***66.0 for all uses.***
	-
Web site with publicly available building information	www.cmhc-schl.gc.ca/en/inpr/su/eqho/eqho_007.cfm
Google Earth Reference?	Ironstone Drive & Issard Close, Red Deer, Alberta, Canada

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**Part of Canada Mortgage and Housing Corporation's EQuilibrium™ Housing Initiative. Modelled to surpass net-zero energy for all purposes, and to produce some net energy. Early results indicate it may achieve net-zero energy.**
Monitoring mandatory	***Monthly data will be collected for at least one year on energy used for space heat, hot water, lights & appliances and mechanical ventilation, and on energy generated by the PV and solar thermal system.***
Energy performance < 50% building standard	***There is no Canadian standard for kWh/m². Typical new houses in Alberta probably use close to 100. This house should use 9 or less.***
Innovative solution set (by this we mean...	***Whole building mixture of different technologies:*** - *Very well insulated and airtight envelope* - *Efficient heating equipment* - *Renewable energy.*
Innovative technologies	***Individual technologies that are new / interesting:*** - *Manually operable external shades on all windows. Can prevent overheating by passive solar, and add approximately RSI-0.5 to windows when closed.*
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV consists of integrated roof tiles.* - *Solar thermal collectors are vertically mounted and look like windows.*
Match Index? addressed	
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Designer/Builder can be contacted at* - *www.avalonmasterbuilder.com/*
Indoor environment data	- ***None planned***

Project name ***ÉcoTerra Home***	
Status	Already operational
Location Country; city	Eastman, Québec, Canada
Latitude/ Longitude	- Latitude 45.3°N - Longitude 72.3°W
Climate Challenge	Building Predominantly designed to deal with Winter
Picture	
Building type	Residential
Engineer	Andreas Athienitis Claude Agouri
Architect	Masa Noguchi
Area (m^2)	234 m^2 with basement (heated area)
Energy produced (kWh/m^2year)	**Assuming purchased energy* *TOTAL: 27.7 kWh/m²/yr* *BIPV/T electricity production: 14kWh/m²/yr – simulation* *BIPV/T thermal energy production: 13.7 kWh/m²/yr – simulation*
Energy consumed (kWh/m^2year)	**Assuming purchased energy* TOTAL: 37.5 kWh/m²/yr - Space heating: 9.5 kWh/m²/yr - Domestic hot water heating: 8.3 kWh/m²/yr - Lighting, appliances and exterior use electrical equipment: 17 kWh/m²/yr - Fans: 2.6 kWh/m2/yr
	-
Web site with publicly available building information	http://www.maisonalouette.com/french/ecoterra/041107/maison-ecoterra.htm
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** - *15 minute data interval for the DC and AC power, the solar radiation in the BIPV/T array plane, ambient temperature and wind velocity* - *More than 100 thermocouples measuring data at 5 min or 1 minute time interval for the BIPV/T room, the ground-source heat pump, the concrete slab and temperatures in different zones.* - *Data is available on water consumption, overall electricity production and consumption*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *Average national energy consumption: 250kWh/m^2/yr*
Innovative solution set (by this we mean...	- *Pre-engineered modular housing built in a factory (5 pieces) and assembled on-site* - *BIPV with heat recovery (BIPV/T) with the air used for domestic hot water heating, clothes drying and space heating (air circulated in a concrete slab in the basement)* -
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* ***(by this we mean...*** - *BIPV with heat recovery (BIPV/T) with the air used for domestic hot water heating, clothes drying and space heating (air circulated in a concrete slab in the basement* - *Passive solar design*
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *BIPV/T acts as the outer roofing material* - *Lower portion of the roof consists of regular roofing material, but was chosen to look like the a-Si BIPV/T system used for the upper portion of the roof*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** Building energy simulations showed that demand will be slightly greater than the supply
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Integrated design process was followed* - *Data on the design process is available*
Indoor environment data	***Replace example with your data:*** *eg* - *Temperature recorded*

Project name ***Riverdale NetZero Project***	
Status	Commissioned (Occupied by a family)
Location Country; city	Canada; Edmonton, Alberta
Latitude/ Longitude	- Latitude 53° 34’ N - Longitude 113° 31’ W
Climate Challenge	17. Building Predominantly designed to deal with Winter
Picture	
Building type	Residential
Engineer	Howell-Mayhew Engineering (solar energy systems)
Architect	Habitat Studio & Workshop Ltd., Edmonton , Alberta (designer & builder)
Area (m^2)	234 m^2 (for each half of the duplex)
Energy produced (kWh/m^2year)	*PV SUPPLY: 30.6 + 11.8 solar hot water and space heat = 42.4 total (for each half) – modelled, early results indicate somewhat less.*
Energy consumed (kWh/m^2year)	- ***38.5 for all uses (for each half).***
	-
Web site with publicly available building information	www.cmhc-schl.gc.ca/en/inpr/su/eqho/eqho_007.cfm
Google Earth Reference?	9924 - 87 Street, Edmonton , Alberta, Canada

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**Part of Canada Mortgage and Housing Corporation's EQuilibrium™ Housing Initiative. Modelled to surpass net-zero energy for all purposes, and to produce some net energy. Early results indicate it will come close to net-zero energy.**
Monitoring mandatory	***Monthly data will be collected for at least one year on energy used for space heat, hot water, lights & appliances and mechanical ventilation, and on energy generated by the PV and solar thermal system.***
Energy performance < 50% building standard	***There is no Canadian standard for kWh/m^2. Typical new houses in Alberta probably use close to 100. This house should use 4 or less.***
Innovative solution set (by this we mean...	***Whole building mixture of different technologies:*** - *Very well insulated and airtight envelope* - *Efficient heating equipment* - *Renewable energy.*
Innovative technologies	***Individual technologies that are new / interesting:*** - Double-stud wall system with a 406 mm cavity filled with blown-in cellulose insulation - North windows are argon filled, quadruple-glazed, with three soft low-e coatings - 22 m^2 of solar thermal collectors, water storage tanks of 300 L &17,000 L
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *Solar thermal collectors are vertical to avoid snow cover and maximize winter collection.*
Match Index? addressed	
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Designer/Builder can be contacted at* - *www.habitat-studio.com/*
Indoor environment data	- ***None planned***

Project name: ***BOLIG+***	
Status	under final design
Location Country; city	DENMARK, Aalborg
Latitude/ Longitude	- Latitude: 57°03’35” N - Longitude: 9°54’49” E
Climate Challenge	Building Predominantly designed to deal with Winter
Picture	
Building type	Residential
Engineer	Esbensen Consulting Engineers A/S
Architect	Arrkitema architects
Area (m^2)	7000 m² (heated gross floor area)
Energy produced (kWh/m^2year)	- *PV SUPPLY: 60.47 kWh/m2/yr – estimate* - Solar thermal supply: 7.28 *kWh/m2/yr – estimate*
Energy consumed (kWh/m^2year)	- *Building = 60.47 kWh/m²/yr including ALL end uses (not just space conditioning;*
	-
Web site with publicly available building information	www.boligplus.org
Google Earth Reference?	-

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	This building will be the first Danish example of an energy neutral block of flats, which includes the resident's use of electricity. Furthermore it is required that exergy remains unchanged over the year.
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** - *will not be available – construction works starts in 2011* - *detailed measurements will be performed !*
Energy performance < 50% building standard	*Requirement for this building type and soze = 70; building = 13.4 kWh/m²/yr*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** - *Combination of mechanical (winter) and cross natural ventilation;* - *Intelligent control of electricity consumption* - *Architectural means to help residents reduce electricity consumption, i.e. dryer cabinets on the balconies to minimise use of dryers* - *Natural gas cookers replacing electrical* - *Ground source heat pump* - *Combined thermal and electrical solar collectors (PV/T)* - *Utilisation of daylight* - *Privileging passive rather than active design.*
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* ***(by this we mean...*** - *See above.*
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV and PV/T is being used to provide electricity and domestic hot water during summer. A ground source heat pump is being used to provide space heating for the building.* - *Low energy lighting is being used in the buildings common areas and its immediate surroundings.* - *Architectural design is targeted at meeting the requirements for an energy neutral building.*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** - *Yes*: "*BOLIG+ an energy neutral multifamily building*"
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Engineering team is part of STC team - has some lessons.* - *Architect has also indicated they are prepared to answer questions on the process.*
Indoor environment data	***Replace example with your data:*** - *One of the rules for the project contest was a good and healthy indoor climate, and it will be measures (physical measurements and interviews/questionnaires) when the building is occupied.* - *Temperature and Humidity data will berecorded.*

Project name ***Blaue Heimat***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 69121 Heidelberg, Karl-Philipp-Fohr-Straße 4-10.*
Latitude/ Longitude	*Latitude 49°25'49.87" north* *Longitude 8°40'50.06" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	*Solares Bauen (www.solares-bauen.de)*
Architect	*Gerstner Architekten, Heidelberg*
Area (m^2)	*3374 m² net floor area*
Energy produced (kWh/m2.year)	*Primary energy – 98,20 kWh / m² net floor area per year (maybe more because of the wind park participation)*
Energy consumed (kWh/m2.year)	*Primary energy – 98,20 kWh / m² net floor area per year*
Web site with publicly available building information	www.zero-haus.de/kenndaten.html www.solares-bauen.de/projekte/
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The project Blaue Heimat as the first apartment house reached the zeroHaus standard and this in spite of the renovation background. A participation in a wind park the surroundings of Heidelberg were vital, nevertheless, on this occasion.*
Monitoring mandatory	*- Monitoring data available*
Energy performance < 50% building standard	*Average German standard = 190kWh/m²y; Blaue Heimat < 12 kWh/m²y (standard only for heating)*
Innovative solution set	*- Redeveloped on basis of a differentiated costs / use consideration - energetically and a living space enlargement* *- Energy savings with better lighting, switchable plug strips and power saving appliances (all achieved about integrating and informing of the users)* *- Dry rooms were equipped with an efficient ventilation and all dishwashers and washing machines have a separate hot-water connection*
Innovative technologies	*- ventilation system with heat recovery specially for renovated buildings*
Energy supply / integration of RE	*- PV-plant on the inclined roof* *- (Bio-)gas powered CHPP* *- Participation /investment during construction phase) in a wind park near Heidelberg*
Match Index? addressed	*- potentially lower mismatch because of CHPP*
Lessons learned	*- Good contacts with engineer team.*
Indoor environment data	*- Under investigation*

Project name ***Haus der Zukunft***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 93049 Regensburg, Rennweg*
Latitude/ Longitude	*Latitude 49°0' 46.36" north* *Longitude 12°2' 17.22" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	*Markus Staudigl - General Solar Systems Deutschland GmbH* *Developer: SONNENkRAFT + Fraunhofer ISE + University of Applied Sciences Regensburg + fabi Architekten*
Architect	*Stephan Fabi, Fabi Architekten*
Area (m^2)	*175 m² net floor area*
Energy produced (kWh/m2.year)	*End energy (only electricity) – kWh / 20,50 m² net floor area per year*
Energy consumed (kWh/m2.year)	*End energy (only electricity) – kWh / 18,00 m² net floor area per year*
Web site with publicly available building information	www.fabi-architekten.de/projekte/hausderzukunft_plus.html www.activehouse.info/cases/house-future www.solaranlagen-portal.de/wordpress/sonnenkraft-haus-der-zukunft-eingeweiht
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The building concept and construction started with the question of what a future without a need for fossil fuels in architectural structures would be like. The target is a house designed for the future, which will set the building standards for 2020. Besides passive house technology, a new, more highly developed building concept will lead the way into the future. This building concept is not only based on energy efficiency, but, more importantly, on solar energy production.* *The place where a person lives should be a good fit for that person. The modern way of life changes very quickly. Therefore, the rooms should be able to be easily altered in order to fulfil new needs of the homeowner. The house should be comfortable, low maintenance, and a place of tranquillity in this increasingly fast-paced world.* *The house is designed to suit people's needs so that the occupants feel comfortable.*
Monitoring mandatory	*- Monitoring should be available*
Energy performance < 50% building standard	*Average German standard = 160kWh/m²y; Haus der Zukunft = 7,00 kWh/m²y (standard only for heating)*
Innovative solution set	*- The Building draught is based not only on energy conservation but rather on solar power production* *- Contains the formative connection of technology and architecture to a homogeneous whole and a high degree of flexibility of the envelope to be able to update uncomplicatly new technologies* *- The mechanical cross ventilation and the natural ventilation from the lower level up to the roof ensures optimal air exchange and provides for well-being.* *- The building services engineering, control system, and construction mesh with the architecture of the house to create one homogenous unit. The building offers a high degree of flexibility so that the latest technology can be integrated at any time.*

Innovative technologies	*- Modern furnishing with energy-efficient appliances* *- A compact EIB-controlled building service system regulates the passive use of solar energy from the south and west in winter and automatically shades the southern surface of the glass during the summer. In order to avoid making the system overly technical and to make it possible for the homeowner to choose a more conventional lifestyle, the automatic regulation system can be turned off.*
Energy supply / integration of RE	*- Fully integrated PV and solar thermal collectors* *- heat pump*
Match Index? addressed	*- All electric home, only electricity is used for heat pumps – this is produced by PV-elements* *-Only use of electricity, no source changing* *- The building form follows the path of the sun and allows the optimum active use of solar energy over day time. The inclination corners of the wall and roof surfaces are adapted to the respective adjustment and kind of utilization (solar thermal collectors or photovoltaic) ideally.*
Lessons learned	*- Under investigation, very new project* *- The draught is moved in several European countries, independently of each other. The results stand in the direct comparison.*
Indoor environment data	*- Data should be available* *- A fully-automatic sun protection and natural ventilation are actuated by an intelligent control system with sensors to measure temperature, CO2 and humidity in connection with a weather station. This intelligent control system ensures that the inhabitants' needs with regard to well-being, comfort and indoor environment will be met.*

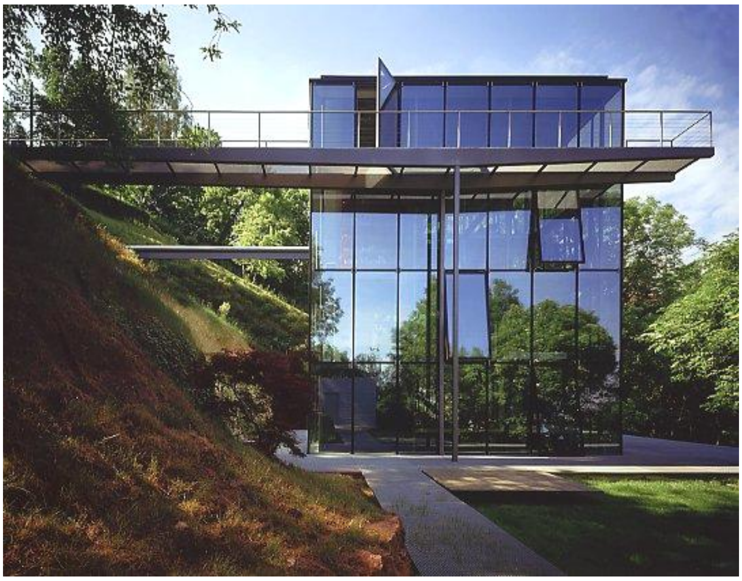
Project name ***Kleehäuser Freiburg***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 79100 Freiburg, Paul-Klee Str. 6-8*
Latitude/ Longitude	*Latitude 47°58'36.47" north* *Longitude 7°49'18.93" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	*Solares Bauen (www.solares-bauen.de)*
Architect	*Common & Gies Architekten – Freiburg (www.giesarchitekten.de)*
Area (m^2)	*3508m² net floor area*
Energy produced (kWh/m2.year)	*Electricity (primary energy) – 118,70 kWh / m² net floor area per year* *Electricity (primary energy) – 296745 kWh / year*
Energy consumed (kWh/m2.year)	*Primary energy – 73,70 kWh / m² net floor area per year* *Primary energy - 274407 kWh / year*
Web site with publicly available building information	www.kleehaeuser.de www.solares-bauen.de/projekte/#22
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The Kleehäuser were build in an assembly and in a common and cost-efficient construction. The common (construction, financing and use) is always in the foreground. A lot is used collectively (e.g. integrated holiday flats and a guestroom...). The wish for individually formable plans originated from the assembly in a higher structure. This was allowed and, beyond it, leaves open many freedoms (flexibility, changeability, barrier free design). All parties were build in high residential quality (space height, passive house standard) and the greatest possible individuality. The excellent access to a variety of services and public transportation options is given and can be reached on foot.* *The whole primary power demand is less than 500 watts per inhabitant, the regenerative cash ratio is at more than 100%*
Monitoring mandatory	*- only low level monitoring with energy meters*
Energy performance < 50% building standard	*Average German standard = 210kWh/m²y; Kleehäuser = 15kWh/m²y (standard only for heating)*
Innovative solution set	*- The 2000 W Society was the primary consideration in the concept (Whole primary power demand is less than 500 watts per inhabitant)* *- New strategies with a wind fonds (attendance 18.000 EUR) in the wind arrangement Saint Peter in the Schwarzwald (corresponds to approx. 240,000 kWh of primary energy per year)* *- communal wash and dryroom with communal washing machines with warm water tabs, communal deep freezes* *- Fixed sun shading* *- Passive house concept* *- privileging energy efficiency rather than active design*
Innovative technologies	*- Power-saving lifts* *- energy efficient outside lighting* *- Small and own district heating grid with heat from a small CHPP* *- CHP* ***and*** *solar thermal collectors* *- Low energy HVAC and appliances*
Energy supply / integration of RE	*- PV on top of the roof* *- Solar thermal collectors* *- Wind energy without need of architectural integration*
Match Index? addressed	*- Lower mismatch because of CHPP and solar thermal collectors and the wind arrangement off-site*
Lessons learned	*- Very good contacts with architect and one owner. Hence good information about the user acceptance and architectural considerations and decision process*
Indoor environment data	*- Maybe*

Project name ***Plus energy settlement Freiburg***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 79100 Freiburg, Elly Heuss Knapp Str.*
Latitude/ Longitude	*Latitude 47°58'29.73" north* *Longitude 7°49'46.88" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	
Architect	*Rolf Disch - Büro für Solararchitektur (Office of Solar Architecture)*
Area (m^2)	*7890m² net floor area*
Energy produced (kWh/m2.year)	*Primary energy - 113,95 kWh / m² net floor area per year* *Primary energy - 924.134,50 kWh / year* *End energy – 43,00 kWh / m² net floor area per year* *End energy - 348.730,00 / year*
Energy consumed (kWh/m2.year)	*Primary energy - 70,65 kWh / m² net floor area per year* *Primary energy - 572.971,50 kWh / year*
Web site with publicly available building information	http://iea40.buildinggreen.com/overview.cfm?projectid=1336 www.solarsiedlung.de/
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The Plus-Energy Settlement in Freiburg is a fixture of the community, the city and the region. It exemplifies the use of regenerative energy and provides its inhabitants with the social benefits of a housing community offering a high, ecologically conscious standard of living.* *In the Solar Community at Schlierberg, natural resources were a primary consideration in the overall construction concept, the choice of materials, and the water and energy systems. Inhabitants are encouraged to be creative with the aesthetics of their living spaces, and incidental living costs and expenses are kept low through convenient access to ecological mobility by public transport, by bike or on foot.*
Monitoring mandatory	*- only low level monitoring with energy metering* *- Monitoring of the project's energy performance was done by University Wuppertal (www.btga.uni-wuppertal.de) in 2007 and 2008* *- Minute by minute measurements of some terrace houses* *- Monthly power and heat measurements (consumption and production) for all end uses of more than 20 terrace houses* *- Partial measurements of indoor comfort data (humidity, temperature...)*
Energy performance < 50% building standard	*Average standard = 210kWh/m²y; Plus energy settlement= 14,1kWh/m²y (standard only for heating)*
Innovative solution set	*- New marketing and financing strategies with „Solarfonds"* *- Integrated planning aiming towards plus energy - Consequent urban planning, building and window orientation / sizing (All the terraced houses face south, and the distance between the rows of houses is designed to prevent obstruction of natural light during the winter)* *- Fixed sun shading with PV-overhang* *- Combination of Ideas from „Solar buildings" and „Passive houses"* *- privileging passive rather than active design* *- Natural resources were a primary consideration in the overall concept, the choice of materials and the energy systems*
Innovative technologies	*- District heating grid with heat from partly renewable powered CHPP* *- Fully integrated PV-system in the roofs* *- Decentral ventilation systems with heat recovery*
Energy supply / integration of RE	*- 3.150 m² PV roofs, fully integrated in architectural concept* *- PV as an external shading for south facing windows* *- renewable powered CHP with district heating grid*

Match Index? addressed	- *seasonal mismatch PV yield/electricity demand, PV yield has to overcome primary energy use for heating (low due to passive house concept and biomass use)* *- Car-sharing program offers the chance to include mismatch ideas*
Lessons learned	*- Very good contacts with architect and some owners. Hence good information about problems and changes (The application of the wood-based CHP was not as successful as initially hoped. Some buildings don´t reach the plus energy aim. But the settlement compensates this so that the settlement can function only as a whole. As urban areas can present difficulties in optimizing solar energy use, the site was assessed during predesign to maximize solar energy capacity. The settlement design was initially developed for a larger area and planned to address a wider variety of sustainability initiatives, including mobility and water use. Due to difficulties with financing and market acceptance, the size and scope of the project were adapted.)*
Indoor environment data	*- Temperature and Humidity data of 4 buildings recorded*

Project name ***R128 – Haus Sobek***	
Status	*already operational*
Location Country; postal code; city; street	*Germany, 70180 Stuttgart, Römerstr. 128*
Latitude/ Longitude	*Latitude 48°45'23.44" north* *Longitude 9°10'28.35" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	*Transsolar Energietechnik GmbH, Dipl.-Ing. Matthias Schuler, Stuttgart* *WSGreen Technologies by Architect Werner Sobeck (www.wernersobek.de)*
Architect	*Prof. Dr. Werner Sobeck, Stuttgart (www.wernersobek.de)*
Area (m^2)	*250 m² net floor area*
Energy produced (kWh/m^2year)	*Primary energy (electricity) – 37,65 kWh / m² net floor area per year*
Energy consumed (kWh/m^2year)	*Primary energy (electricity) – ca. 24,00 kWh / m² net floor area per year*

Web site with publicly available building information	www.wernersobek.com
Google Earth Reference?	*Not yet*
WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*The single family house R128 is developed as a CO2-free building. The house is built up from steel construction elements and with recyclable materials.* *There are no light switches, door handles, window clutches or armatures, because all processes are steered over sensors. Besides, most functions can be accessed by phone or internet. The house is contactable, controllable and monitorable by a computer system.* *Without technology this house would be only one greenhouse!*
Monitoring mandatory	*- Monitoring data should be available*
Energy performance < 50% building standard	*Average German standard = 160kWh/m²y; R128 = 15,00 (?) kWh/m²y (standard only for heating)*
Innovative solution set	*- Whole façade is glazed- works as a parody* *- lightweight construction, no vertical dividing walls -nearly no thermal mass* *- Increased daylight utilization* *- Build with recyclable materials* *- All processes are steered over sensors (oral and haptic)*
Innovative technologies	*- Low energy HVAC and office equipment, efficient lighting* *- New gas fillings in the disc space of the glass, new glasses (u-value of the building envelope should lie around 0.4)* *- Solar energy irradiated by the facade is absorbed about water flowed cover elements and connect to a heat accumulator supplied from which the building can also be heated in winter*
Energy supply / integration of RE	*- PV on top of building and on top of a small building with energy meters*
Match Index? addressed	*- Only electricity is used for heat pumps – this is produced by PV-elements ->low mismatch level* *- Only use of electricity, no source changing*
Lessons learned	*- Architectural quality guarantees a high attention in the architecture scene* *- Contacts to Architect and engineers*
Indoor environment data	*- Available*

Project name *Solar decathlon house Madrid 2010, Team Wuppertal*	
Status	*under construction*
Location Country; postal code; city; street	*Germany, 42285 Wuppertal, Haspeler Str. 27 (will change in July 2010)* *Construction site: Germany, 27619 Schiffdorf-Sellstedt, Schiffdorfer Str. 10a*
Latitude/ Longitude	*Latitude 51°15'32.27" north (will change in July 2010)* *Longitude 7° 9'58.75" east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	*University of Wuppertal, Fraunhofer Institute (Students + Prof. Karsten Voss)*
Architect	*University of Wuppertal (Students + Prof. Annet Joppien)*
Area (m^2)	*74 m² net floor area*
Energy produced (kWh/m^2year)	*End energy (only electricity) – 129,26 kWh / m² net floor area per year*
Energy consumed (kWh/m^2year)	*End energy (only electricity) – 56,67 kWh / m² net floor area per year*
Web site with publicly available building information	*www.sdeurope.uni-wuppertal.de*
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	
Monitoring mandatory	*- Monitoring data will be available*
Energy performance < 50% building standard	*Average German standard = 160kWh/m²y; Solar decathlon house = 10 kWh/m²y (standard only for heating)*
Innovative solution set	*- Flexible home* *- Flexible energy & architectural concept*
Innovative technologies	*- Best practice appliances and technical equipment* *- Full LED lighting* *- Indirect adiabatic cooling* *- PCM with passive cooling*
Energy supply / integration of RE	*- PV on top of the building and on south façade (architectural and design integration – change of polycrystalline and monocrystalline cells)* *- Solar thermal collectors (evacuated tube collectors) in south facing façade*
Match Index? addressed	*- All electric home, only electricity is used for heat pumps – this is produced by PV-elements* *- Battery backup system to use more self produced solar power (even during night time)* *-Energy management system* *-Only use of electricity, no source changing*
Lessons learned	*- Hard work to have success at the solar decathlon competition*
Indoor environment data	*- Data will be available*

Project name ***WWF headquarters***	
Status	*already operational*
Location Country; postal code; city; street	*Netherlands, 3708 JB Zeist, Driebergseweg 10*
Latitude/ Longitude	*Latitude 52°04'30 north* *Longitude 05°14'51 east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Non residential – Office building*
Engineer	*ARUP*
Architect	*RAU architects*
Area (m^2)	*3770 m² net floor area*
Energy produced (kWh/m^2year)	*Primary energy – kWh / m² net floor area per year*
Energy consumed (kWh/m^2year)	*Primary energy – kWh / m² net floor area per year*
Web site with publicly available building information	www.rau.nl/
Google Earth Reference?	*Not yet*

WUPPERTAL MANDATORY CRITERIA Why is this building an STC CASE?	*RAU architects transformed a former 1950's agricultural laboratory into the first CO2-neutral and (almost entirely) self-sustaining office in the Netherlands.*
Monitoring mandatory	*- unknown*
Energy performance < 50% building standard	*Average Dutch standard = kWh/m²y; WWF headquarters < kWh/m²y*
Innovative solution set	*- Natural materials have replaced bare concrete* *- Natural ventilation and the use of natural materials offer a balanced and healthy indoor environment* *- Cool ground water is used for cooling the building before flushing toilets* *- The surplus of warmth in the summer is stored in a water reservoir in the ground and used for heating the building during winter. Likewise, cooling energy is stored underground during winter months and is used for cooling in summer.* *- Energy and construction materials were saved by keeping the concrete skeleton of the former laboratory. All used wood is FSC-certified. The doormat is made of old car tires, the flooring is made from recycled carpets. All used materials are child labour free.* *- daylight penetrate deep into the building*
Innovative technologies	*- Triple glazing and wooden lamellas in front of the large windows ensure efficient isolation and heat resistance (Wooden lamellas placed all around the façade protect the building from overheating - High-energy summer sunlight can enter the building only indirectly, whereas low-energy winter sunlight can pass through the lamellas unhindered).* *- Mud is used as a thermal buffer inside the building. Embedded in the mud just below the surface is a mesh of fine capillary tubes covering large areas of the ceiling. The building is heated and cooled by pumping warm or cold water through the tubes.*
Energy supply /integration of RE	*- Solar cells on the roof generate electrical energy and solar thermal collectors are used for heating up water*
Match Index? addressed	-
Lessons learned	-
Indoor environment data	-

BENASQUE - CCBPP	
Status	*already operational*
Location Country; city	*Benasque, Spain*
Latitude/ Longitude	- *42°36'12.37"N* - *0°31'26.04"E*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Non-Residential: Convention center*
Engineer	*Lluís Durat, Aiguasol*
Architect	*Isabel Pascual, Bernardo Fernández*
Area (m^2)	*1550*
Energy produced (kWh/m2.year)	*PV**:** 7985 kWhe/yr* *Biomass: 36 kWh/m2.yr*
Energy consumed (kWh/m2.year)	- *Heating: 36 kWh/m2.yr (100% biomass) (no cooling)* - *Electricity: 39 kWh/m2.yr*
Web site with publicly available building information	*http://benasque.org/*
Google Earth Reference?	Spain_Benasque.kmz

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	*The Centro de Ciencias de Benasque Pedro Pascual (CCBPP) is a facility for hosting scientific meetings. It is located in Benasque, a mountain village sitting in the Pyrenees at 1150m above sea. The challenge of CCBPP is to achieve very high energy efficiency performance while keeping the look of a mountain village building. The cold weather in Benasque is an additional challenge for the reduced energy use of the CCBPP.* *Since the CCBPP hosts scientific meetings and conferences, it is a convenient building to perform tests and to display results of energy studies*
Monitoring mandatory	*Will be available*
Energy performance < 50% building standard	*Heating loads based on simulation (TRNSYS) are 22 kWh/m2.yr, while the reference building (also simulated heating load) is 41 kWh/m2.yr* *No data on the reference building electrical use is (currently) available*
Innovative solution set (by this we mean...	- *Vertical shading in windows* - *Extensive use of daylight* - *Natural ventilation, with no active cooling required*
Innovative technologies	- *Automatic controls for natural ventilation* - *Lighting energy use is reduced through sensors of available light, extensive zoning of the spaces, and high efficiency fixtures*
Energy supply / integration of RE	*PV and biomass*
Match Index? addressed	*This building is not meant to be a NZEB. However, it is a low energy building with biomass as the solely heating source. There is some electricity generation with PV, and the remaining is from a hydroelectric source, which makes it a zero emission building*
Lessons learned	*Owners, architects and engineers are keen to collaborate with the project sharing their data and lessons learned with this building*
Indoor environment data	*Could be evaluated through short term measurement of space temperature, relative humidity, air velocity, and available light*

Kraftwerk B	
Status	**DELETE NOT APPLICABLE:** *already operational (year of construction 2009)*
Location Country; city	Bennau, Switzerland
Latitude/ Longitude	***REPLACE example with your data (try to be as exact as possible –google data are quite well for this):*** e.g. - *Latitude* 47° 7′ *north* - *Longitude* 8° 47′ *east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	amena ag, planforum, Schwyz, Switzerland
Architect	grab architekten, Altendorf, Switzerland
Area (m^2)	1380
Energy produced (kWh/m^2year)	- *PV SUPPLY: 122.5 kWh/m2/yr - estimate; still being measured* - *Solar ther.: 205.4 kWh/m2/yr*
Energy consumed (kWh/m^2year)	- *45 (heating/DHW/overall electricity)*
Web site with publicly available building information	*http://www.solaragentur.ch/dokumente/G-09-08-20%20Bennau.pdf*

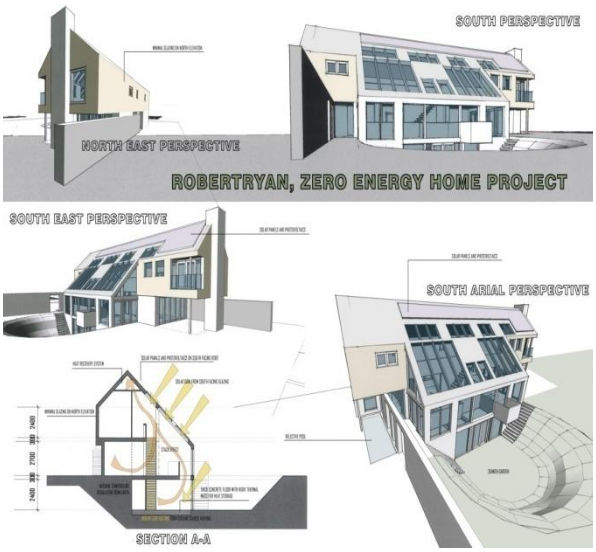
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION** ***(replace*** *example text in italics – example information from ENERPOS building La Reunion)*
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** *e.g.* - *monitoring is not mandatory* - *monitoring of consumption and PV-Production*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *30 (weighted limit for MINERGIE®-P standard);* *building = -30.4*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** *e.g.* - *excellent building envelope* - *50% window area on the southwest façade for passive energy use* - *less thermal bridges (no balconies, no canopies, etc.)* - *mechanical ventilation* - *low efficient household appliance* - *air/water heat pump* - *single small wood ofen in each apartments* - *PV and thermal solar* - *external shading*
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* **(by this we mean...** - *thermal solar integrated in the south west facade* - *3 different hot water storage tanks* - *surplus of DHW (preheating of the DHW for the neighbours)* - *surplus of electricity (export to the grid)* - use of waste heat of the waste water for preheating of the DHW - rain water use for toilets, washing machine and garden watering
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV on the roof* - *thermal solar integrated in the south west façade*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** *Yes*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Yearly balance is positive* - *concept works*
Indoor environment data	- *NO*

Marché International, Kemptthal	
Status	*already operational (year of construction 2007)*
Location Country; city	Kemptthal, Switzerland
Latitude/ Longitude	***REPLACE example with your data (try to be as exact as possible – google data are quite well for this):*** e.g. - *Latitude* 47° 27' 0 *north* - *Longitude* 8° 41' 60 *east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Non Residential*
Engineer	Naef Energietechnik, Zürich, Switzerland
Architect	kämpfen für architektur, Zürich, Switzerland
Area (m^2)	1516
Energy produced (kWh/m^2year)	- *PV SUPPLY: 26.4 kWh/m2/yr - estimate; still being measured*
Energy consumed (kWh/m^2year)	- *26.4 (heating/DHW/overall electricity)*
Web site with publicly available building information	*http://www.solaragentur.ch/dokumente//M-07-10-16%20Marche%20International.pdf?PHPSESSID=335c845582724ea4f7c615aebe2014cf*

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION** *(**replace** example text in italics – example information from ENERPOS building La Reunion)*
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** *e.g.* *monitoring is not mandatory* - *monitoring of consumption and PV-Production*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *25 (weighted limit for MINERGIE®-P standard);* *building = -35.6*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** *e.g.* - *excellent building envelope* - *balconies on the south facade against overheating* - *south façade: 50% windows, 50% GlassX – Elements ("PCM-transparent-façade": increase of thermal comfort, glare protection)* - *mechanical ventilation (ground-to-air heat exchanger)* - *low efficient appliance and lighting systems* - *sole/water heat pump for heating and cooling*
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* ***(by this we mean...*** - 12 m2 hydroponics on each floor to regulated the humidity
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV on the roof*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** *Yes*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Yearly balance is positive* - *concept works*
Indoor environment data	- *NO*

Riehen	
Status	*already operational (year of construction 2007)*
Location Country; city	Riehen, Switzerland
Latitude/ Longitude	- *Latitude* *47° 35′ 7.08″ north* - *Longitude* *7° 39′ 0″ east*
Climate Challenge	*Building Predominantly designed to deal with Winter*
Picture	
Building type	*Residential*
Engineer	Building technology: Otmar Spescha, Ingenieurbüro für energieeffizientes Bauen, Schwyz, Switzerland
Architect	Werner Setz, Setz Architektur, Rupperswil, Switzerland
Area (m^2)	315
Energy produced (kWh/m^2year)	- *PV SUPPLY: 9.2 kWh/m2/yr - estimate; still being measured* - *Solar ther.: 49.5 kWh/m2/yr*
Energy consumed (kWh/m^2year)	- *42.3 (heating/DHW/overall electricity)*
Web site with publicly available building information	*http://www.solaragentur.ch/dokumente//Riehen_1.pdf*
Google Earth Reference?	
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION** ***(replace*** *example text in italics – example information from ENERPOS building La Reunion)*
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data;*** *e.g.*

	- *monitoring is not mandatory* - *monitoring of consumption and PV-Production*
Energy performance < 50% building standard	***List the country standard and your building's average kWh/m2/yr:*** *30 (weighted limit for MINERGIE®-P standard);* *building = 17.8*
Innovative solution set (by this we mean...	***Whole building mixture of different technologies: (by this we mean...*** *e.g.* - *excellent building envelope* - *mechanical ventilation (coupled with heat pump)* - *low efficient household appliance* - *sole/water heat pump* - *PV and thermal solar* - *external shading* - *construction based on CO_2 reducted materials* - *national wood is used for the facade*
Innovative technologies	***Individual technologies that are new / interesting:*** *e.g.* ***(by this we mean...*** - *passive energy use though large windows to the south* - *small windows to the north side (low heat loss)* - *day light optimization with large windows*
Energy supply / integration of RE	***Integration questions about Renewables:*** *eg* - *PV an thermal solar on the roof*
Match Index? addressed	***Minimum requirement: Supply>Demand on yearly basis?*** *Yes*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* - *Yearly balance is positive* - *concept works*
Indoor environment data	- ***NO***

Project name : ROBERTRYAN Zero-energy House	
Status	Design stage(construction to be completed by mid 2011)
Location Country; city	West Kilbride North Ayrshire, Scotland United Kingdom
Latitude/ Longitude	- Latitude 55.74 N - Longitude 4.86 W
Climate Challenge	Building Predominantly designed to deal with Winter
Picture	
Building type	Residential
Engineer	TBC
Architect	TBC + MEARU, Mackintosh School of Architecture
Area (m^2)	259.2 m^2
Energy produced ($kWh/m^2/year$)	- PV/Thermal (air): connected to a heat recovery system 32.16 $kW/m^2/year$ (8333kWh/year) - Hybrid solar thermal mass system (solar input: 1161.47kWh/year) - Wood pellet boiler - More detail analysis on REs will be carried

Energy consumed (kWh/m^2/ year)	- 32.00 kWh/m2/ year (8294.33 kWh/yr) including solar input - 27.52 kWh/m2/ year (7132.86 kWh/year) excluding solar input
Web site with publicly available building information	N/A
Google Earth Reference?	http://maps.google.co.uk/maps?ll=55.689882,-4.847944&z=14&t=h&hl=en-GB
WUPPERTAL MANDATORY CRITERIA	**INFORMATION**
Monitoring mandatory	To be conducted from mid 2011
Energy performance < 50% building standard	
Innovative solution set	**Whole building mixture of different technologies:** e.g. - South facing long facade of the building is considered to get maximum advantage of Solar gain - Passive design decisions in terms of dimension, placement of openings, materials and functional organization at design stage - Use of Panel system for building also gives guidelines for the dimension of the spaces proportionate to the panel dimensions. - Compaction of the volumes to reduce the heat loss and reduce the material use and hence, reducing the project cost - Sloping roof with the of 30˚ - Building a basement to make the internal area naturally insulated - Placement of the heat producing spaces like kitchen on north side to utilize the heat produced - Ratio of the openings on each facade of the building varies to achieve natural light and ventilation; large openings on south facade to achieve solar heat and day lighting, while, less openings on east, west and north facades to reduce heat losses - Triple glazing windows filled with argon gas and low emissivity coating for drastic reduction of fabric heat loss through windows. - Thermal capacity and insulation quality of different materials - High thermal performance using insulation that achieves U-values of 0.15W/m^{2}K for walls and 0.1 W/m^{2}K in floors and ensures air-tightness at approx. 0.8 air-changes per hour that reduces ventilation loss. - Incorporating landscaping into design to reduce CO_2 and to maintain rain water run-off, creating a pleasant surrounding - Balanced heat recovery system that recycles preheated indoor air over 75%. - PV and/or solar thermal grow space that allows for the growth of rooftop solar panels.

Innovative technologies	**Individual technologies that are new / interesting:** e.g. - PV/T heat recovery system - Hybrid solar thermal mass system - Wood pellet boiler - Energy-efficient appliances and lighting. - All above is under review at the current design stage
Energy supply / integration of RE	**Integration questions about Renewable:** e.g. - BIPV connected to heat recovery system - Hybrid solar thermal mass where a solar thermal collector is connected to internal thermal mass
Match Index? addressed	To be analyzed at PoE survey stage
Lessons learned	**Is data available on the design process?** e.g. - Significance of organisational design decision making - Visualisation of design choices and prediction of potential energy usage
Indoor environment data	To be analyzed at PoE survey stage

Project name: Aldo Leopold Legacy Center	
Status	- *Construction completed April, 2007*
Location Country; city	- *United States; Baraboo, Wisconsin*
Latitude/ Longitude	- *Latitude 43° 29' 20" north* - *Longitude 89° 43' 27" West*
Climate Challenge	- *Building Predominantly designed to deal with Winter*
Picture	
Building type	- Non-Residential Office Building
Engineer	- Commissioning Agent: Supersymmetry USA, Inc. - Electrical Engineer: Powrtek Engineering, Inc. - Energy Consultant: Thermal Energy Systems Specialists, LLC - Environmental Building Consultant: University of Wisconsin-Milwaukee School of Architecture - LEED Consultant: The Boldt Company - Mechanical and Plumbing Engineer: Matrix Mechanical Solutions, LLC - Photovoltaic Contractor: H & H Group, Inc. - Structural Engineer: KompGilomen Engineering, Inc.
Architect	- Architect: The Kubala Washatko Architects, Inc. - Contractor: The Boldt Company
Area (m^2)	- 1105.55 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 55 $kWh/m^2/yr$*
Energy consumed (kWh/m^2.year)	- *49 $kWh/m^2/yr$*
Web site with publicly available building information	*http://www.aldoleopold.org/legacycenter/* *http://zeb.buildinggreen.com/overview.cfm?ProjectID=946* *http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab028737.pdf* *http://www.aldoleopold.org/LandEthicCampaign/earth%20tubes.pdf* *http://www.architecture.uwaterloo.ca/faculty_projects/terri/carbon-aia/case/leopold/leopold.html*

Google Earth Reference?	
WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Building Sub-metering*
Energy performance < 50% building standard	- *ASHRAE 90.1-2004: 159 kWh/m^2/yr* - *Aldo Leopold Legacy Center: 49 kWh/m^2/yr*
Innovative solution set (by this we mean...	- *Natural Ventilation* - *Ground Source Heat Pump* - *Daylighting* - *Earth Tube Air Storage*
Innovative technologies	-
Energy supply / integration of RE	- *39.6 kW Roof Mounted PV system*
Match Index? addressed	- *Energy Production: 55 kWh/m^2/yr* - *Energy Consumption: 49 kWh/m^2/yr*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* -
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1*

Project name: Oberlin College Lewis Center	
Status	- Construction completed January, 2000
Location Country; city	- United States; Oberlin, Ohio
Latitude/ Longitude	- *Latitude 41° 17' 34.8" north* - *Longitude 82° 13' 1.2" West*
Climate Challenge	- *Building Predominantly designed to deal with Winter*
Picture	
Building type	- Non-Residential Educational Building
Engineer	- Civil Engineer: CT Consultants, Inc. - MEP: Lev Zetlin Associates - Structural Engineer: Lev Zetlin Associates
Architect	- Architect: William McDonough + Partners - Contractor: Mosser Construction, Inc.
Area (m^2)	- 1263.48 m^2
Energy produced (kWh/m^2.year)	- *PV SUPPLY: 115 $kWh/m^2/yr$*
Energy consumed (kWh/m^2.year)	- *102 $kWh/m^2/yr$*
Web site with publicly available building information	*http://www.oberlin.edu/ajlc/ajlcHome.html* *http://zeb.buildinggreen.com/overview.cfm?projectid=18* *http://www.nrel.gov/buildings/pdfs/36273.pdf* *http://www.nrel.gov/docs/fy03osti/31516.pdf* *http://www.nrel.gov/docs/fy05osti/33180.pdf*
Google Earth Reference?	

WUPPERTAL MANDATORY CRITERIA why is this building an STC CASE?	**INFORMATION**
Monitoring mandatory	***Need 12 months of monitored data by mid 2012*** ***Amount and detail of monitored data*** - *Building Sub-metering*
Energy performance < 50% building standard	- *ASHRAE 90.1-2001: 170kWh/m^2/yr* - *Oberlin: 102 kWh/m^2/yr*
Innovative solution set (by this we mean...	- *Natural Ventilation* - *Daylighting* - *Thermal Mass* - *Ground Source Heat Pump*
Innovative technologies	-
Energy supply / integration of RE	- *60 kW Roof Mounted and 100 kW Site Mounted PV system*
Match Index? addressed	- *Energy Production: 115 kWh/m^2/yr* - *Energy Consumption: 102 kWh/m^2/yr*
Lessons learned	***Is data available on the design process? i.e can we access the design team to understand what lessons were learned.*** *e.g.:* -
Indoor environment data	- *Meets ASHRAE Standard 55* - *Meets ASHRAE Standard 62.1*

3.3. The energy targets: passive solar energy concepts

Passive solar energy systems constitute one of most important parameter of the matrix of solutions set of the Net Zero Energy Solar Buildings.

Passive solar energy concepts described in this chapter fall into three broad categories depending of the solar use and consist in four separate components (Fig.11).

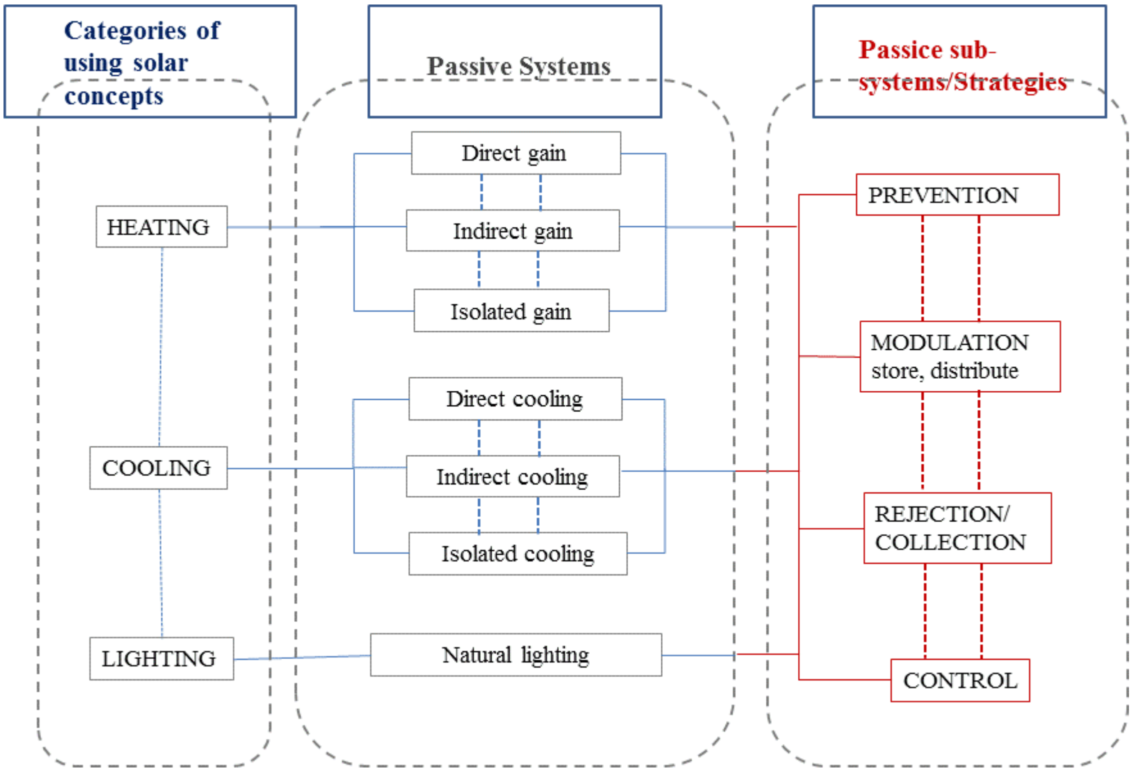


Figure 11 Scheme of the Passive concepts

The first two categories use the solar energy for the building thermal needs (heating and cooling energy use). The third one, use the energy from the sun to directly impact the building lighting needs. A list of some different passive concepts will be considered in this paragraph. The ones listed in the Figure11 are appropriate in a wide range of climates and building types.

The passive concepts used for heating/cooling the building usually consists of four separate components: *prevention,modulation, rejection/collection and control*, the others concepts (daylighting) that use the solar energy to light the building usually consists only in three components: *prevention, modulation, and rejection/collection*.

Passive Heating

Passive heating concepts use heat from the sun to offset winter heating needs. Passive systems are characterized by their direct interaction between the building structure and the environment.

Collection

The purpose of the collection subsystem is to allow sunlight into the building to heat the space and, if appropriate, to heat the storage mass. The collection subsystem may include windows, skylights, or some other type of solar aperture. The storage subsystem usually includes parts of the floor or interior walls of the building. The size, shape and the distribution of the solar apertures affects the quantity of heating energy available to offset auxiliary heating energy needs.

Modulation-Storage

The purpose of the storage subsystem is to store the collected solar heat for later use. Stored energy is released from the storage mass and distributed throughout the building to offset heating energy use. The size of the storage subsystem affects the quantity of heat stored and the time delay between initial collection and final use of energy.

Modulation-Distribution

Distribution is accomplished by arranging the functional spaces of the building such that those that need heat are closest to the storage subsystem. The size, shape, and location of rooms in the building impact the optimum distribution of the heat throughout the building. Heat distribution is accomplished by a combination of radiation and convection. Heat is radiated and convected from the storage system into the rooms, being heated after the collected solar energy has passed through the storage system. Heat is convected through the air, warming it, and thereby warming the inside room.

Control

The passive heating systems of buildings can´t be controlled in the same fashion of an HVAC system. Control in passive buildings is achieved by altering the position of the shading devices and by changing the way the ventilation is processed. Some advanced passive buildings may also be equipped with thermostats and thermal fluxmeters to control fans and shading devices.

Passive solar heating systems are often categorized by the relationship between the solar system and the building, that is, whether or not the solar system is part of a room being heated, part of the building, or totally separate from the building. Using this reasoning, there are three categories of passive solar heating systems:

Table 6 Passive solar heating systems

direct gain systems - collection, modulation (storage, distribution)
There exist two types of direct gain heating systems: a direct gain without *storage* that represents a system that does not include any additional interior mass in the building (except the structural components: walls, ceilings, floors) and a direct gain with storage that includes additional internal mass to extend the storage capacity.
indirect gain systems - collection, modulation (storage, distribution)
Indirect gain places the collection and the modulation (storage) components of the solar thermal system very close to each other as part of the same element. Solar heat is *collected* and *stored* in the exterior wall or on the roof and can be *distributed* to the living space (in some applications) when the building element (wall or roof) integrates a recovery system that allow the heated air between element components…enter and circulate into the room to offset the immediate heating energy needs. The Trombe wall and other similar types of walls such as BIPV-T, are typical indirect gain systems.
isolated gain systems - collection, modulation (storage)
Isolated gain passive heating systems isolate the *collection* and *storage* subsystems from the building. One special category of an isolated gain system is a sunspace. A sunspace combines some features of the direct gain systems with the others of indirect gain systems. A sunspace is a room attached to or integrated with to the exterior of a building in which the inside temperature is allowed to rise and fall outside the thermal comfort zone. The space can be inhabited, thus acting like a direct gain system.

Passive Cooling

Passive cooling systems have the same basic components as passive heating systems, but work in a different manner. Whereas the purpose of the passive heating is to draw heat into the building, the purpose of a passive cooling is to prevent, remove or reject the heat from the building.

Prevention

The purpose of the prevention systems is to avoid heat loss (as passive heating component) and to avoid overheating (as passive cooling component). Thermal insulation prevents building heat loss by creating a barrier between the warm air inside the building and the cold air outside it. This also works in reverse when it is desirable to keep the cool air inside. The external shading devices (overhangs, screens), the most effective method of shading can reduce or prevent overheating on the building south oriented spaces.

Rejection

The rejection of the building heat gain from the external environment can be achieved by facilitating heat loss to the following natural sources of cooling: air movement, cooling breezes, evaporation and earth coupling. One of the most successful cooling strategies in order to reduce the internal loads of the building, by means of heat rejection is natural ventilation. Natural ventilation relies on the natural airflow and breezes to reduce the need for mechanical cooling when the building is occupied. The ventilation coupled to an earth tube system that use the earth as the cold source, reduce the building overheating by pre-cooling ventilation air and evacuation, rejection.

As the passive heating systems, there are three categories of passive cooling systems (Table 7) which can prevent or disperse the heat surplus by radiation to the sky, convection to the air and conduction to the ground:

Table 7 Categories of passive cooling systems

direct cooling systems - prevention, rejection
- shading and advanced glazing - natural ventilation (night ventilation, cross natural ventilation, thermal chimney - evaporative cooling - envelope techniques (advanced thermal insulation, green roofs..) - night-sky radiation
indirect cooling systems - rejection
- night-sky radiative cooling - earth tube cooling system - ventilation of the thermal storage elements
isolated cooling systems
- separated cooling spaces ……

Natural lighting

Natural lighting is the use of natural light from the sky as a supplement for electric lighting in buildings. Traditional natural lighting systems differ in one major respect from passive heating systems: they use the sun (the sky) as a source of light and avoid letting direct sunlight into a building. Since light from the sky is used in lieu of direct sunlight, natural lighting systems function quite well on overcast, partly cloudy, or clear days. Natural lighting is an instantaneous use of the light from the sky. Therefore, natural lighting systems consist of collection and distribution components and do not include a storage component like passive heating systems. However, much like solar thermal strategies, natural lighting systems are categorized according to the type of collection system used. Thus, there are three basic types of natural lighting systems:

(1) sidelighting

(2) toplighting

(3) coredaylighting

Daylighting is the most effective passive solar strategy in almost all commercial building types because it reduces two major energy uses in these buildings: electric lighting and cooling.

Chapter 4 How to achieve the Net Zero Energy goal

4.1. Energy Efficiency as a starting base

Components of solar houses, passive houses or whole passive house concepts are a basis for the energy efficiency in many built examples. Approximately one third of the worldwide recognized Net ZEBs use this idea and lower the energy demand of the buildings in all typologies equally by nearly 60% in comparison to standard buildings which were built according to current building directives. This calls for very good insulation, use of passive solar heat gains and a high compactness. The average surface to volume ratio is around 0.6 in the residential sector and around 0.3 in the non residential sector. On the average, a maximum height of three stories is present in the residential sector and fewer stories in the office building sector. The latter is due to the strong cost pressure of this more energy intensive real estate sector.

Some measures promote in addition to a reduced energy demand also the user comfort. Mechanical ventilation systems, partially with heat recovery, advanced day lighting or solar shading devices are used nearly as often as solar-thermal domestic hot water processing or power saving HVAC technology. The latter reduces both the heat demand and electricity demand. In an international scope, this is only partially grasped by construction specifications or energy directives. Also, the load of e.g. household appliances or office equipment is not illustrated in these regulations, however, it is present in most of the Net ZEB balances. A restriction on partial sectors of the consumption prevents the continuous examination in practice and extracts essential parts of the consumption from its necessary optimization. The consumption should be measured furthermore with renunciation of oversized meter equipment. The annual measurability of energy consumption is an excellent aspect of the net zero energy principle. By including the electricity consumption, the need to reduce the electrical demands is evident. Nevertheless, it is obvious that this is hard to achieve in practice. Sparing equipment in offices or flats, as well as LED lighting, have been realized only in cases in which users and owners are the same authority. In this consumption sector, further savings potential is present.

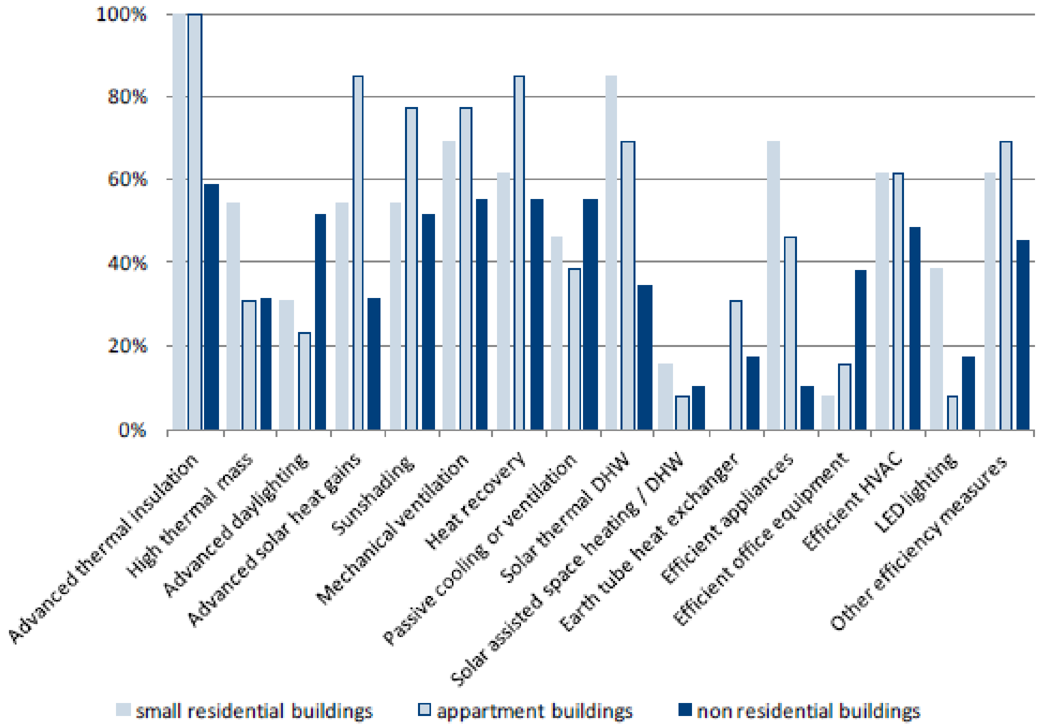


Figure 12 Pool of single measures concerning energy conservation

Beside the passive house concept, a big pool of single measures concerning energy conservation can be found (figure 12). Isolated measures are combined in integral draughts due to special exigencies. Besides, not all these measures have direct influence on the architecture of the buildings. The objection that efficient material and technologies are often not compatible to original design draughts is valid only partially. A great variety in possibilities can be found in the yet built projects.

On-Site Energy Generating Technologies

On the way to Net ZEBs efficiency measures are even as important as the cover of remaining energy demands with renewable energy sources and technologies. Figure 13 illustrates that a reduced consumption requires less on-site energy generation. Beside economic advantages, this offers bigger architectural options. An almost unavoidable tool on the way to equalized energy balanced buildings is the on-site generation of electricity with photovoltaics. Nevertheless, this has a great impact on the design and the appearance of the building because of the need for big coherent surfaces in non shaded southern orientations (northern orientations in the southern hemisphere). The more energy is needed to be generated, the greater the significance of the PV expanse and its aesthetical influence.

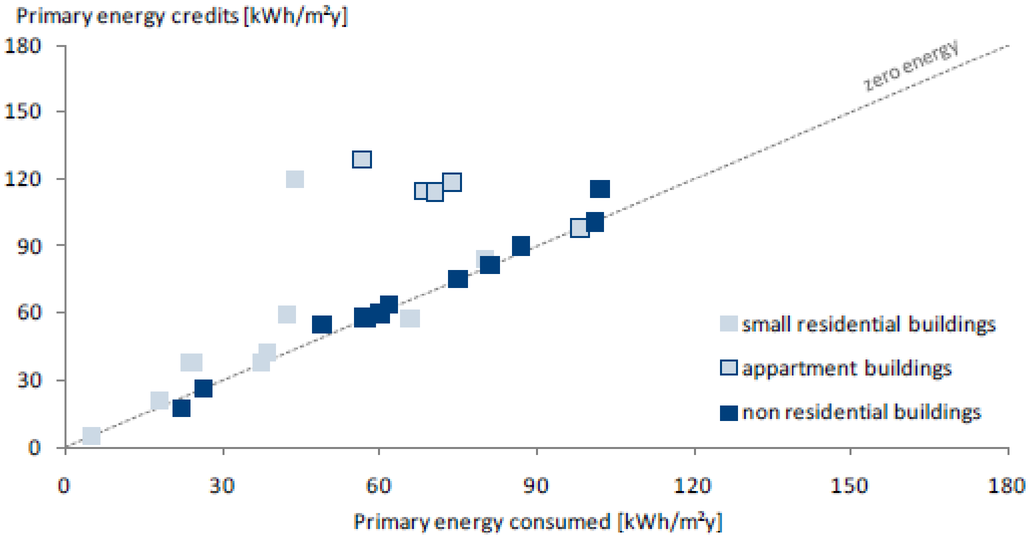


Figure 13 Compendium of primary energy consumption and credit generation

Not utilized potentials (see above), improved equipment in the view of the electrical needs, a rising amount of grid connected renewable energy sources and an improvement of PV technology available on the market as well as other systems (e.g. heat pumps, biomass CHP) will allow a reduction of necessary PV surfaces. The chronological analysis in figure 14 shows a decrease of the PV areas per m² net floor area in the still short history of zero energy buildings. This observation can be supported in spite of the increase of PV surfaces by office buildings. For some years they use less external credits and increasingly PV due to its risen efficiency. The increase in the sector of apartment buildings results from the plus energy aim and the very huge PV surface at the Plus-energy-Settlement in Freiburg.

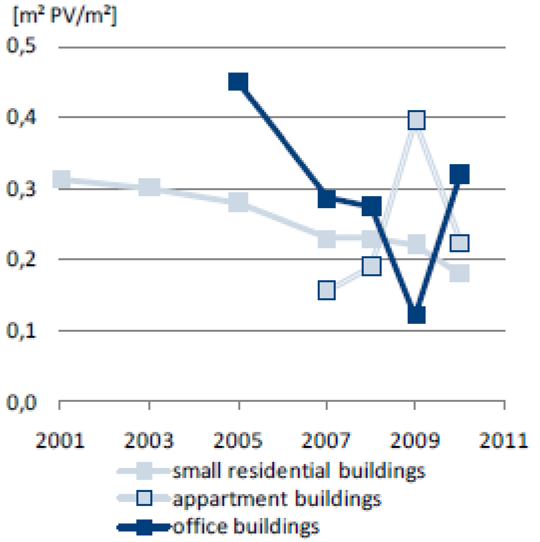


Figure 14 Development of PV per building floor area

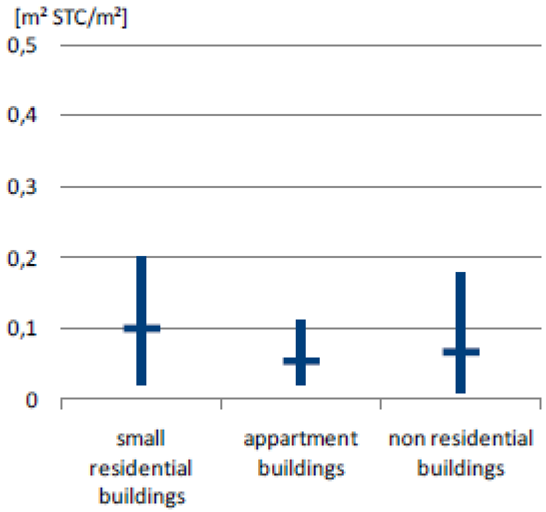


Figure 15 Area of solar thermal collectors per building

Solar thermal systems are used as a demand reduction technology as long as heat is not fed into local grids. Due to the non grid connected operation of most solar thermal systems their smaller size offers more integration potential. In the sectors of bigger residential complexes and non residential buildings, solar collectors are substituted by combined heat and power (CHP) plants. The use of gas or even biomass with CHP opens an economically higher attraction and can supply bigger utilities with small district heating grids more steadily.

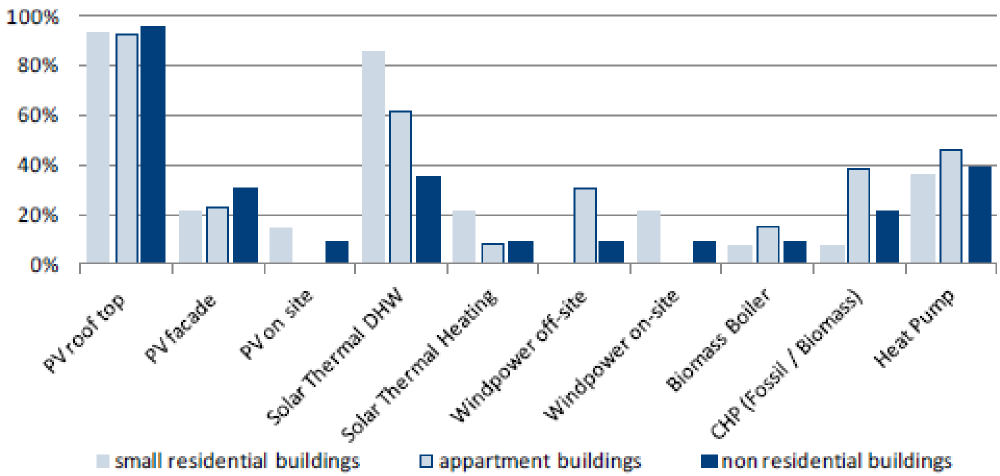


Figure 16 Technologies applied in different building typologies

In the last couple of years, the number of zero energy buildings with heat pumps increase. The improved technology, decreasing investment cost [1], the surrender of a second base fee and no need to store fuels in the buildings or to build chimneys make this technology attractive. The use of electricity as the only energy source simplifies the measurement of necessary balance data.

For on-site Net ZEBs the use of solar energy is essential. While the availability of biomass from sustainable sources is limited, solar energy is an infinitely available energy source. The potential of this inexhaustible energy source is used building integrated as well as on-site and is the basis for the equalized energy balance. The lasting and day chronologically independent energy source wind can rarely be used in the building sector. Some projects used small wind turbines. But, these arrangements (still) do not have the potential to compensate the whole demands of the respective buildings. Low wind speeds in urban areas and the noise problems prohibit the use in larger scale. The investment or participation in big wind parks or off-site wind turbines, as well as the inclusion of the generated electricity in the energy balances, is often used at energy intensive buildings or renovation projects. Within their available or badly orientated roof surfaces, not enough energy can be generated with PV to compensate the consumed energy. In renovation projects more technical equipment is pursued in general which often encloses CHP plants. This also applies to factories. However, the potential of biomass can seldom be exhausted. Pellet or wood waste fired CHP plants are hardly used in the scope of buildings. Rape oil powered CHPP are a used alternative in spite of known discussions. Building related water power generation (e.g. micro-hydro) currently has no role in all known buildings.

Finally the biggest challenge for all zero energy projects is the best fit of energy saving design and technology combined with renewable energy utilization, primarily on site. These challenges are especially huge if a renovation project has the aim of being a net zero energy building. Besides, factors like actor and stimulation play rather subordinated, climatic and typological peculiarities a bigger role.

In the area of small residential buildings passive house and low energy house concepts are combined with solar thermal systems, heat pumps and photovoltaics. The use of energy efficient HVAC-technology and power saving household appliances can be identified here more often than in other typologies. However, big residential projects use at least energy efficient HVAC-technology and compensate reduced energy demands by passive house principles combined with CHP and PV systems. In the non residential sector the solutions are a little more extensive. The aimed efficiency in typologies except residential buildings is also achieved more and more by passive house ideas and the use of mechanical ventilation at least in heating dominated countries. The higher electricity loads and the mostly unfavourable relation of solar suitable surfaces on the roof or facade to the building floor area are compensated by on- and off-site CHP (only in some cases with biomass), as well as participation in external wind turbines or even "green" power supply.

Recently, detached buildings have originated increasingly in suburban and urban areas. Narrow sites in dense city areas, as well as strict building regulations or development plans, often limit the active and passive use of solar energy. Within the EU goals, the nearly net zero energy building regulations may be frightening. Future electric mobility options may lead to concepts of running cars with on-site generated electricity [2]. Electric cars may be considered as part of the building energy load such as appliances and their batteries considered as part of the short term electric storage capacity for the building energy system. Also comprehensive life cycle assessments in addition to the comparison of operation energy and generation could acquire a greater significance [3].

4.2. Energetic targets

Although several alternative definitions exist, a “Net-Zero Energy Building” can be succinctly described as a grid-connected building that generates as much energy as it consumes over a year. The “net-zero” balance is attained by applying energy conservation and efficiency measures and by incorporating renewable energy systems. While based on annual balances, a complete description of a net-zero building requires examining the system at smaller time-scales. This assessment should address: (a) the relationship between power generation and building loads and (b) the resulting interaction with the power grid. This paragraph presents and categorizes quantitative indicators suitable to describe both aspects of the building’s performance. These indicators are easily quantifiable and could complement the output variables of existing building simulation tools. The indicators and examples presented here deal only with electric generation and loads.

4.3. Target Groups For Indicators

This paragraph presents quantitative indicators that can be used to described load matching and grid interaction (LMGI) conditions in net-zero or near net-zero buildings. *Load matching* refers to how the local energy generation compares with the building load; *grid interaction* refers to the energy exchange between the building and a power grid. These are independent, but intimately related issues.

Net-zero energy buildings do not exist in isolation. Despite the multiple definitions of net-zero building [4], the wording "*net*-zero" implies an interaction with a surrounding energy grid. It is expected that the accounting of the selected metric (e.g., primary energy) over a relatively long period (typically a year), will yield a net balance close to zero.

The "net-zero" concept is convenient and practical. However, it is insufficient to describe the energy performance of a building and its potential role as an active element in the energy network. If the building-grid interaction at smaller time-scales is not considered, net-zero energy buildings could have a detrimental impact on the performance of the grid at high penetration levels. For example, they may contribute to increasing peak loads, thus requiring additional generation and transmission capacity from utilities. They may also increase voltage variation in local distribution grids, a factor that needs to be taken into account when operating or designing grids.

To illustrate this point, net-zero homes in high latitudes usually have net energy consumption in winter, and net energy generation in summer. In absence of other measures, net ZEBs will contribute to the burden carried by the power grid, while producing energy when the grid does not require it. If a net-zero building draws power during peak times, from the point of view of the grid there will be little difference between a net-zero building and a conventional one. If the issues of load matching and grid interaction are not properly addressed, net-zero energy buildings might prove ineffective or even counterproductive to their final goals, namely energy conservation, promotion of renewable energy sources, and global reduction of GHG emissions.

In view of these considerations, the issues of load matching and grid interaction have become part of the discussions of the IEA activity Task 40/Annex 52 “Towards Net Zero Energy Solar Buildings” (IEA, 2008). Several definitions, criteria and quantitative indicators for load matching and grid interaction were recently presented [5]. Quantitative indicators can be used to evaluate the impact of advanced control and energy storage strategies, such as batteries or thermal energy storage (TES) devices. The expected gradual adoption of “smart grid” features, and “smart meters” in advanced buildings, implies that new opportunities will be available for information exchange between buildings and the grid. It will be possible for the building to respond dynamically to price signals from the grid, and to take demand response actions. Load management is of foremost interest for utilities and could help in popularizing net-zero energy designs.

The indicators presented herein deal with buildings using electricity as their sole energy carrier. Electricity is the main priority in this analysis, since the technical challenges of storing electric energy highlight the relevance of the building-grid interaction. However, most of these indicators may also be applicable to buildings using other energy carriers (e.g., buildings connected to a district heating system, district cooling).

The indicators presented here are intended only as assessment tools: there is no inherent positive or negative value associated with them. For this reason, it is useful the use of the term “mismatch” (used in some indicators), which may have a negative connotation. Matching the building’s load with PV generation may or may not be appropriate depending on the circumstances.

4.3.1 Audience interested in quantitative indicators

In the following paragraph the different target audiences that will be interested in different kinds of quantitative indicators are shown. The level of detail, the time resolution and technical complexity of the indicators must be adapted to the needs of different groups. The following potential target audiences have been identified:

Building designers and owners

When developing a net-zero energy building, quantitative *load matching* indicators may guide the design team in comparing different design/project scenarios and selecting equipment. In particular, they could be useful in sizing energy storage devices and HVAC components. Load match indicators may also serve to assess the vulnerability of the building to natural catastrophes, weather events or a grid breakdown.

Building owners or operators could also use *grid interaction* indicators to better take advantage of time-of-use (TOU) electricity rates or feed-in tariffs (FIT) [6]. Indicators developed based on daily and hourly data may be of interest for this target audience, since energy storage in a building is usually possible only for periods of about one day or perhaps a few days.

Community designers and urban planners

LMGI indicators need not be limited to a single building: they could also be used to describe the performance of building clusters or larger communities. In this sense, LMGI indicators can work as descriptors of a generalized energy system. Building groups or communities may include centralized storage or district heating systems that could help in managing the load of the community over long periods. Designers of such a system could benefit from *load matching* indicators with low time resolution (for instance, seasonal solar fraction).

Grid operators at a local distribution level

Operators of distribution grids at medium or low voltage (a few hundred to a few thousand volts) are interested in the load distribution on the grid, especially peak powers, because these are influential on losses and voltage profiles. Therefore, *grid indicators* with very high temporal resolution (i.e., time scales of at least hours), may help them in assessing and design the operation limits of the grid. For example, these indicators may help to improve voltage regulation in the case of high penetration rates of PV systems [7]. Indicators based on probability and statistical information could be useful for operators of distribution grids.

Grid operators at a national or regional level

Operators of national energy grids are familiarized with economic dispatch and planning the operation of generation plants and transmission lines based on expected loads. *Grid indicators* with low temporal resolution (daily or longer) are useful for this target group, as they could be used to assess the impact of net-zero energy buildings in the grid. Aggregated *grid indicators* at hourly resolution will help to manage national grids and to increase the penetration of renewables in the electric power system, especially if high daily peak/baseload ratios occur.

4.3.2 Review of LMGI indicators

When these two concepts (load matching and grid interaction indicators) are mentioned in the literature, it is not always obvious what the differences between them are. The main distinction made is that load matching indicators measure the degree of overlap between generation and load profiles (e.g. the percentage of load covered by on-site generation over a period of time) whereas grid interaction indicators take aspects of the unmatched parts of generation or load profiles into account (e.g. peak powers delivered to the electricity distribution grid).

Another important distinction to make regards the information needed for evaluation of the indicators is that some indicators use only the on-site load and generation profiles, while others also use additional information such as energy market prices or information on a whole set of buildings in an area. Given their lower dependency on data, it is evident that indicators of the former type are easier to both evaluate and generalise, while the latter type becomes more specific in both time and place.

Table 8 shows a categorisation of the indicators, or types of indicators, found in the available literature. A short summary of the findings is given below.

Table 8 Summary of LMGI indicators.

		Indicator category	
		Load matching	Grid interaction
Data requirements	On-site load and generation	**I** Load match index[1] Solar fraction[2] Cover factor[4] Self-consumption factor[7] Loss-of-load probability (LOLP)[4]	**II** Grid interaction index[1] Capacity factor[4] Peak power indicators[4] Grid citizenship tool[8]
	Additional data	**III** Mismatch compensation factor[5] Market matching[3]	**IV** Profile addition indicators[3] Coincidence factor[6]

[1]Voss et al. (2010), [2]Widén et al. (2009), [3]Widén and Wäckelgård (2010), [4]Verbruggen et al. (2011), [5]Lund et al. (2011), [6]Willis and Scott (2000), [7]Castillo-Cagigal et al. (2010), [8]Colson and Nehrir (2009).

Category I

This category encompasses load matching indicators that do not need any additional information besides the load and generation profiles. The first four, namely the *load match index*, the *solar fraction*, the *cover factor* and the *self-consumption factor*, contain essentially the same information; the fraction of the load covered by on-site generation.

The actual concept of a ‘solar fraction’ is of course only applicable for on-site solar technologies, while the two others are more general. These three indicators are, as an example, well suited for describing how much of the demand can be saved by on-site energy supply and how much energy must be bought from the grid by the building owner. The fifth indicator, the *loss-of-load probability* (LOLP) index, instead shows how *often* the on-site supply is not enough to cover the demand.

Category II

This category collects indicators that can be used to show different aspects of the grid interaction of a building, without any need for additional data besides load and generation profiles. The *grid interaction index* shows the variability of the amount of purchased or delivered energy for a given time resolution, normalised by the highest absolute value.

The *capacity factor*, as formulated by Verbruggen et al. (2011) [8], shows the total energy exchange with the grid divided by the exchange that would have occurred at nominal connection capacity, i.e. a measure of the utilisation of the grid connection.

Another aspect to be considered is the distribution of power peaks for delivered or demanded energy. These are called *peak power indicators* here and could simply be the maximum peak power or the time duration or mean value of the highest peaks. For grid connections and distribution grids with a large number of buildings that are both net users and exporters of energy, the latter indicators could provide basic information for dimensioning and design. Colson and Nehrir (2009) [9] introduced a qualitative tool, namely the *microgrid citizenship tool*, based on key microgrid characteristics of nominal generation capacity, installed storage, and load. The concept of the tool can be adapted to grid- connected buildings. The tool is composed of three ratios: the *component ratio (CR)* offers a qualitative scale (from -1 to +1) for the degree of generation to load; the *storage ratio (SR)* gives a measure of how well the installed generation is supported by its own storage; and the *intermitency ratio (IR)* is intended to give a qualitative indication as to how “dependable” the microgrid (building) is at supplying power.

Category III

This category contains indicators that use additional data to show aspects of load matching that cannot be shown with only load and generation data. The *mismatch* *compensation factor* (MMCF) is the quotient between the on-site generation capacity that meets the annual demand and the capacity that compensates for the mismatch (i.e. the capacity that makes total generated electricity worth as much as demanded electricity on an annual basis). A MMCF > 1 means that the system that compensates for the mismatch is smaller than the system that gives a net zero energy balance because generated electricity is, on average, worth more than demanded electricity [10]. The *market matching* indicator is similar to the MMCF and shows the difference between the market value of bought and delivered energy [11].

The main advantage of these indicators is that they can value the load matching of the building from the electricity market's viewpoint. If there is a need for electricity on the market, the MMCF will be greater than 1 and the market matching index positive, indicating that the "mismatch" in the building is generally positive from the system's point of view. Electricity market prices for the studied location are an important additional piece of information needed to evaluate these indicators.

Category IV

Although there may be a need for electricity on the whole market when the building overproduces, there may also be unfavourable consequences of electricity overproduction levels in the local distribution grid. Category IV lists a few indicators for identifying such situations. The *profile addition indicators* are evaluated for the aggregate load of a local distribution grid to show the effect on the margin of adding a NZEB profile. The actual indicator evaluated could, for example, be one of those listed in category II. This approach needs information about the aggregate load on the studied grid. The *coincidence factor* is, in general, the fraction between the observed peak of a customer group and the sum of the individual peaks of each customer. It shows the degree of random coincidence between individual peaks and the degree of smoothing when aggregating a large number of buildings. For a grid company, a typical coincidence factor for different types of NZEBs would probably be interesting, as it can be used to size grid components [12]. This indicator needs a set of NZEB grid interaction profiles to be evaluated. The *covering index* is the ratio between the available conventional power in the system and the peak power demand. This indicator is of interest for energy operators at national level [13].

All of these indicators attempt to summarise a large dataset of generation and load profiles (and possibly additional information) into one or a small set of numbers. Another approach is to visualise a larger range of values, for example showing the variability in the grid interaction, in graphs. Some examples are *sequence graphs* that show profiles in sequence, time step by time step, *cumulative graphs* that show cumulative generation and load time step by time step to show the temporal asymmetry, and *duration curves* that sort data in decreasing order. Various numerical indicators can be determined from the duration curve.

Although the usefulness of each indicator depends on the final objective, LMGI indicators could add significant value to the output of building performance simulation tools, and give a more complete picture of net-zero energy buildings.

Although there are no “good” or “bad” values, LMGI indicators enable assessing of the effect of load management strategies (storage, predictive control, orientation, demand response, etc.). In consequence, they can be used to gauge the *flexibility* of a building’s design to respond to variable generation, loads and grid conditions. [14]

Chapter 5 From a Net Zero CO_2 Emission Home to a Net Zero Energy Home: an Italian case study, the Leaf House

In this chapter the case study building will be shown, starting from the design phase and explaining the main features of the building: the Leaf House (LH).

The initial goal of the design was to develop a carbon neutral house, but during the design stage the NZEB concept was added. This house is an application of new concepts of the architectural design: comfort, sustainability, energy and economy.

It was also built as a laboratory where new sustainable technologies are studied and further developed; indeed in the building there is a monitoring system able to record data about the quality of the air, the humidity, the CO_2 level by means of several sensors that are installed in all the rooms of the six apartments. In the following a detailed description of the building envelope, the technologies, and the energy saving of the LH is shown. In the carbon neutral house energy is entirely produced by renewable sources without CO_2 emissions.

In the following paragraphs the main features of the LH will be presented.

Energy saving measures

1.Design

The first step for the energy saving and towards the CO_2 emissions reduction is the design carried out following the idea and the philosophy of the rural buildings which have never had any constant and rich energy sources. The nature of the ground, the sun and wind exposure, the presence of vegetation, the level of humidity represent some of the factors affecting self-sustainable settlements in every moment and in every place. The Leaf House inspiring model is the rural house of Marche region agricultural tradition with its farm, an autonomous and sustainable microcosm where every resource was exploited and nothing wasted.

2.Insulation

The thermal insulation is the most efficient measurement for reducing the energy needs. A kWh which has been not consumed has a much higher environmental value respect to a kWh produced even in the most renewable way; this is the real task of insulation, that is not to waste energy. If in winter the inner heat disperses less quickly towards outside and if in summer the outer heat finds it more difficult to heat the house, it will be easier to maintain the temperatures required.
The walls structure is composed of an external layer of Polystyrene of 18 cm with a factor λ of 0,036, it insulates more or less just like a thickness of about 1,5 m of bricks. Remarkable is also the attention paid to heat bridges: fixtures, rolling shutters, windows, doors and the relative structures must guarantee the maximum insulation. It is not only possible to benefit of the thermal insulation but also of the acoustic one up to 43 dB.

3.Thermal Distribution

It is from the floor the heat (or cool) diffuses to the dwellings with a series of advantages in terms of comfort: rooms without radiators, possibility to freely organize the spaces, smaller dusts circulation, lower structures humidity. The radiating floor returns advantages in terms of energy: it is possible to reach the same result of a normal radiator at a lower temperature. In the Leaf House floors are both in wood and terracotta, natural and comfortable materials.

4.Air Treatment

In the Leaf House to change air in the rooms, an air treatment unit has been installed (ATU). Different sensors measure the temperatures, the presence of carbon dioxide and the humidity activate the air circulation improving the function usually carried out by open windows. Anyway, if windows open, the air system will automatically stop to avoid energy wastes. ATU is provided with batteries for the heat exchange: before being introduced into flats the outer air is heated in winter and cooled in summer thus exchanging thermal energy with the water produced by the heat pump. The thermal energy recover avoids the inner air heat or cool dispersion before the expulsion, to avoid thermal wastes. The outer air is also naturally pre-conditioned through an underground path of about 10 m before getting to the ATU.

5.Water Collection System And Treatment

In the Leaf House rain water is collected in a tank digged under the garden and reused for domestic purposes and for irrigation, thus reducing the water total consumptions of the 50%. The water is also pre-treated in the kitchens to make it completely pure and drinkable (in the sink there is a three-way valve: hot, cold, drinkable). This means not to buy anymore water in bottles with its load of CO_2 and the encumbrance of empties and their relative disposal.

Clean energy production

1.Geothermal Heat Pump

In the Leaf House the heat and cold generation is carried out by the geothermal heat pump exchanging with the ground through three vertical probes of 100 m. each. This solution is used both for cooling and for heating thus avoiding the use of boiler and conditioner. The heat pump is able to transfer heat from a lower temperature body to a higher temperature body exclusively using electric energy.

In the most summer days it is not even necessary to have any heat pump, since the water automatically cools by passing through the underground probes.

The choice of the heat pump has been done taking into account to the high declared efficiency (the declared Coefficient of Performance is 4,6, the monitored one is lower than the previous value), moreover there where two positive additional factors: on one side the nature of the ground, rich of water, enables the thermal exchange and on the other the adoption of a floor radiating heating and conditioning system to maintain relatively low temperatures of the heat carrier in winter (less than 40°C) and relatively high in summer (more than 17°C).

Clean energy production

1.Photovoltaic system

The heat pump uses electric energy for the temperature difference necessary for the heating. Such energy, together with the one used for the rest of the occupancies, is freely offered by the Sun through the photovoltaic system covering all the surface of the Leaf House roof facing the South (150m^2. for a production of 20 kWp). The plant is perfectly integrated in the layer and allows the access to the highest rates according to the Energy Account.

2.Thermal solar panels and immediate hot water

The Leaf House does not only extract from the Sun the electric energy but also uses this renewable pure and free source to heat the water through thermal solar collectors integrated in the building. They integrate or completely replace (according to the season) the heat pump in the production of domestic hot water and integration to the heating and, thanks to the inertial storage, they guarantee the comfort in every moment of the day. Moreover, thanks to a circulation system, the hot water immediately gets to the uses thus avoiding water wastes.

Clean energy production

1.Solar Tubes

In the rear part of the house facing the North the sunlight arrives carried by solar tubes: a similar solution to the mirrors systems already used by the ancient Egyptians. The home automation system modulates the lighting according to the natural light available.

Technology integration

1.Building Automation

The technological power plant is the heart of the Leaf House. Here all the energy management and production systems are integrated together with the most advanced home automation, testing and automation systems. In the Leaf House there are more than 1000 sensors and checks for the different systems inside which alarm systems, intrusion detection monitoring and the remote house testing are integrated. The Leaf House dwellers can use the most advanced technologies, both from the point of view of usability and of tests. In order to drastically reduce the electric consumption in the Leaf House flats, it is possible to use low consumption electronic appliances such as liquid crystal TV sets and laptops instead of PC. All the electronic appliances are equipped with automatic systems for the standby testing. The interface for the Leaf House dwellers is possible for every flat through a display showing, or from where it is possible to recall, all the immediate and stored consumption data.

Technology integration

1.Information Technology

The Leaf House is in communication with the rest of the Leaf Community and the rest of the world through the most innovative technologies implemented by LOCCIONI I CONNECTING. A WiMax bandwidth wireless connection (it is the first cell installed in Marche Region when the Ministry assigned the frequencies) allows to manage moving, web conference, unified communication, safety and videosurveillance services. The inner wi-fi coverage, through a specific control and management system, allows to configure the wireless cover on the single flats in an intelligent, personal and flexible way (each flat manages its network independently from the others). The Unified Communication system allows the phone occupancies centralized testing and the completely free management inside the Leaf Community of the phone and communication traffic. The Web-ex web conference services allow the Leaf Workers to work in remote in a very efficient way. The switching architecture separates the flat networks in a safe and performing way and at the same time it provides the leading structure for the LOCCIONI I CONNECTING building automation (operating on IP protocol), completely integrated with the safety and videosurveillance systems. The IPATCH wiring allows the network infrastructure centralized and remote management and completes the Leaf Network.

2.Home Appliances

Every apartment in the Leaf House is supplied with a special Green Set, made of the most water and energy efficient appliances. The overall energy and water savings this set is able to generate reaches up to 30% compared to the most efficient similar set in the market of only two years ago. This results in every appliance being able to use just the necessary quantity of energy and water to perform their task in an optimal way, always delivering perfect results. Dishwashers and washing machines make extensive use of hot water; they are fitted with a hot water fill system drawn directly from the house's pipes, making a very limited use of their internal resistance, at the origin of their high energy consumption.

3.Lighting

Artificial light is as much of a necessity for indoor environments as it is for outdoor environments. It not only allows us to carry out the routine tasks associated with everyday living, even during the night or when natural light is in short supply, but also increases the quality of the spaces involved, thereby guaranteeing improved safety conditions.

The need for high-quality light is now combined with the demand for reduced energy consumption (and thus reduced CO_2 emissions). In the Leaf House there are a range of lighting fixtures which utilize the most advanced technology, for use in carbon neutral homes. These solutions use highly energy-efficient light sources, high-performance optics and electronic components which are capable of connecting the systems to electrical installation control and management devices. The use of lighting fixtures with low heat emission levels (fluorescent lamps and LEDs) also reduces the amount of energy required to operate air conditioning systems.

5.1. Site and Climate

Climate encompasses the statistics of temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological elemental measurements in a given region over long periods. Climate can be contrasted to weather, which is the present condition of these elements and their variations over shorter periods. A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere.[1] The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The most commonly used classification scheme was originally developed by Wladimir Köppen. The Köppen classification depends on average monthly values of temperature and precipitation. The most commonly used form of the Köppen classification has five primary types labeled A through E (Figure 17). These primary types are A, tropical; B, dry; C, mild mid-latitude; D, cold mid-latitude; and E, polar. The five primary classifications can be further divided into secondary classifications such as rain forest, monsoon, tropical savanna, humid subtropical, humid continental, oceanic climate, Mediterranean climate, steppe, subarctic climate, tundra, polar ice cap, and desert.

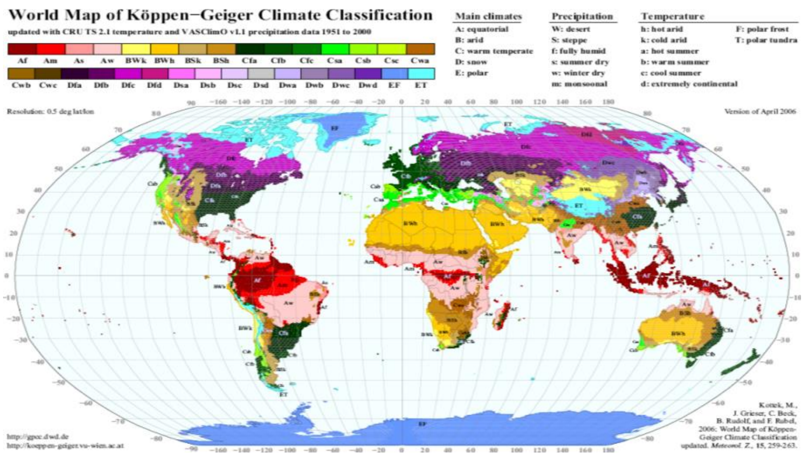


Figure 17 Koppen Classification

The Mediterranean climate regime resembles the climate of the lands in the Mediterranean Basin, parts of western North America, parts of Western and South Australia, in southwestern South Africa and in parts of central Chile. The climate is characterized by hot, dry summers and cool, wet winters.

The Leaf house is located in Angeli di Rosora, Ancona, Italy; the building is south oriented (latitude 43°28'43.16 N, longitude 13°04'03.65 E), the altitude is 130 m. The site is characterized by a moderate climate, in detail:

- minimum annual temperature is -5°C;
- maximum annual temperature is 37°C;
- mean annual humidity is 67%;
- mean annual horizontal solar radiation is 302 W/m2.

5.2. Building Envelope

The building is characterized by a rectangular shape and is composed of six flats with an inner symmetrical division. Its net conditioned floor area is 477 m^2. Four apartments are occupied by two people each while two apartments are only occasionally occupied. In figure 17 the layout of the LH ground floor flat is shown. The building is composed by three levels; every one contain a couple of twin flats. The ground and the first floor flats measure 85.39 m^2 each. (Figure 18)

Figure 18 Ground floor layout of the Leaf House and an image of the buuilding

To maximize the solar radiation gain, the ratio of the lengths of the south and east facades was set to 1.34.

For each façade the ratio of glazing area over the gross wall surface is:

South: 23,9%;

East: 6%;

West: 6%;

North 10%

The southern façade presents external fixed overhangs used as shading elements.

The house is the result of the application of new architectural design concepts dealing with the needs of comfort, sustainability, energy and economy. It was built according to the recent requirements of the energy Italian law and integrating different sources of renewable energy. The envelope is described in the following paragraph:

Walls

Plaster 2 cm, Light weight brick 30 cm, Cement plastering 1,5 cm, Polystyrene 18 cm and Plaster 2cm;

Roof

Plasterboard 3cm, Vapor barrier 0.1 cm, Wood fiber (170 kg/m^3), Rock wool10 cm, sheath 0.1 cm, Air space and Pinewood 2 cm;

Floor

Terracotta tiles2 cm, concrete subfloor 5 cm, polyurethane foam4 cm, Background lean concrete5 cm, Bitumen0.5 cm, Concrete 20 cm, air cavity19 cm, rock fragments11.5 cm.

Dividing floors between apartments are insulated enough (Global R value 3.09 m^2 °C/W in addition to the insulation of the radiating floors) to expect a negligible thermal impact of radiating floors on underneath flats.

Table 9 lists the calculated transmittance values of opaque structures.

Table 9- External structures average U values

External structures	Calculated U value of the structures
	[W/(m^{2}K)]
Vertical structures	0.150
Horizontal floor	0.300
Sloping roof	0.250

The LH envelope was built according the instructions of the Italian Legislative Decree (LD) 311/2006 and its implementation standards (e.g. Ministerial Decree March 11th 2008). This law defines the limits for the thermal transmittance of the walls and of the glazing components. Table 10 shows the comparison between the global transmittance limit (U values) imposed by the law and the calculated transmittance value of the opaque structures.

Table 10 Comparison between the U value limits imposed by the Ministerial Decree March 11th 2008 and the calculated U value of the structures

External structures	Limits for the global transmittance value (MD March 11th 2008)	Calculated U value of the structures	Percentage reduction
	[W/(m^{2}K)]	[W/(m^{2}K)]	[%]
Opaque vertical structures	0.364	0.150	-58%
Opaque horizontal floor	0.312	0.300	-3.8%
Opaque sloping roof	0.351	0.250	-32%

The basement of the building was properly insulated by 0.04 m of Polyurethane (The thermal resistance is 2.45 m^{2}K/W. Particular attention is paid to the thermal insulation of the thermal bridges. In the Leaf House, windows guarantee the maximum insulation according to the Italian Legislative Decree 311/2006 and the Ministerial Decree of March 11th 2008 and subsequent amendments and additions. The windows are made of a double panel insulated glazing (U=1.1 W/(m^{2}K) with a 6 mm external glass, 14 mm gap filled with argon and4 mm internal glass; the average global window U-value is 1.40 W/(m^{2}K). The Solar Heat Gain Coefficient (SHGC) is 0.6. The window frames are made of a triple pane of wood, thermal foam and aluminum. The LH has a monitoring system that records the energy and environmental data of all rooms of the six apartments.

5.3. Thermal Plant

The technological power plant represent the Leaf House heart and brain integrating the best available technologies. Heat is produced here and the information on the different flats, together with the operative functions are here conveyed. Signals come to the brain control panel (Figure 19) managing the procedures to satisfy the Leaf House needs.

In a mixed push-pull system it manages:

- The thermal energy production by the heat pump (Figure 20);
- The electropumps and electrovalves operation on the collectors system (Figure 21) for the thermal energy distribution to the flats and to the different elements of the power plant itself;
- Accumulators (Figure 22);
- Fully automatic ventilation carried out by the air treatment unit (Figure 23)

The brain control panel manages the thermal plant in order to satisfy the buildings heating and cooling needs.

Heating and cooling is provided by means of radiant floors.

For example as shown in the following images it manages the temperature of the water circulating in the radiant floor.

Figure 19 The brain control panel

Figure 20 The LH Geothermal Heat Pump

Figure 21 electropumps and electrovalves operation on the collectors system

Figure 22Accumulators

Figure 23 Air Treatment Unit

By many temperature drills the right operating condition is maintained in the radiating floor. Figure 24 describes the temperature of different drills present in the collectors which feed the apartments.

Figure 24 Monitored temperatures by the Brain Control Panel

In the LH the heat and cold generation is carried out by a geothermal heat pump (GHP) that exchanges with the ground through three vertical probes (100 m). The Ground Source Heat Pump provides hot water for heating and cold water for cooling.

In each flat of the LH there is a radiant floor supplied by the GHP. During the summer season, the cooling system uses free cooling provided by a ground coupled heat exchanger.

The water circulating in the radiant floor in the winter is maintained at a low temperature, the temperature in each room is controlled by regulating the flow of hot water through each tubing loop. This system reduces the energy consumption of the heating system: in the first period of monitoring, the energy needed for heating was 27 $kWht/m^2$ per year while the same for cooling was 20 $kWht/m^2$ per year (monitored data year 2009).

During the summer season the cooling system uses the natural cooling provided by a ground coupled heat exchanger.

The electropumps and electrovalves operation on the collectors system (Figure 20) for the thermal energy distribution to the flats and to the different elements of the power plant itself.

Ventilation is mechanical, with heat recovery. Fresh air, before being treated, goes through an underground pipe; it is preheated in cold winter days and pre-cooled it in summer. By means of a CO2 sensor, the presence of occupants is detected and, when the dwelling is empty, ventilation rate is reduced and – consequently – the energy required by the ventilation fan. The efficiency of the heat recovery system is 80%.

The installed Air Treatment Unit (ATU-Figure 22) is linked to the geothermal heat pump. The thermal energy recovered avoids the inner air heat or cool dispersion before the expulsion, and avoids thermal waste. The outer air is also naturally pre-conditioned through an underground duct of about 10 m before getting to the ATU.

The aim of the mechanical ventilation system is to guarantee a high quality of the air in the building. For this reason a different sensor system has been installed. This system measures the presence of carbon dioxide and humidity and it activates the air circulation improving the function usually carried out by opening the windows.

When the CO_2 level increases due to the presence of people in the apartment, the fresh air flow is increased through managing the variable air volume devices in the air duct. In detail the mechanical ventilation is 0.2 volumes/h at the temperature of 20 °C.

The ATU is provided of a heat recovery system which has an efficiency of 80%. Furthermore, the mechanical ventilation system stops if the windows are opened by the occupants.

In every flat of LH there is a radiant floor fed by a GHP. The electric energy needs of the heat pump are covered by the energy produced on site by the photovoltaic panels covering the roof facing the south.

In the Leaf house there are seven flat plane solar thermal collectors (2.6 m^2 each). Domestic hot water is provided by this solar system, and integrated by the heat pump. Moreover, thanks to a recirculation system, the hot water immediately gets to the users thus avoiding water wastes. An indirect active system is used: a pump is employed to circulate a Heat Transfer Fluid (HTF) between the collector and a storage tank using a heat exchanger. The solar thermal collectors are also used as solar shields for the windows of the first floor. The solar thermal collectors produced about 4,227 kWht per year .

In the rear part of the house facing the North the sunlight arrives carried by solar tubes. The home automation system modulates the lighting according to the natural light available.

The rain water is collected in a tank buried under the garden and reused for WC and irrigation, thus reducing the water total consumptions of the 69%. The drinkable water is supplied by the public utility and the tap is provided by a three-way valve to supply hot, cold and sparkling water. This fact avoids buying water in bottles, with its load of CO_2 and the encumbrance of empties and their relative disposal.

Finally the LH energy system includes seven sub-systems (Figure 25):

- The solar collector system;
- The geothermal probes and the heat pump;
- The air handling unit (AHU);
- The auxiliary boiler;
- The photovoltaic system;
- The radiating floors.

Figure 25 Systems and subsystems the LH is divided in

The solar collector system

Seven solar thermal collectors (2.6 m^2 each) integrate, or completely replace (according to the season), the heat pump in the production of domestic hot water. A recirculation system allows the occupants to immediately get hot water reducing water wastes. The heat is transferred from the solar collectors to the coil of the storage tank by means of a glycol-water mixture. A pump drives the fluid back to the collectors. The difference between the outlet water temperature of the solar panels and the water inside the storage tank is less than 10 degrees; otherwise the pump is turned off (Figure 26).

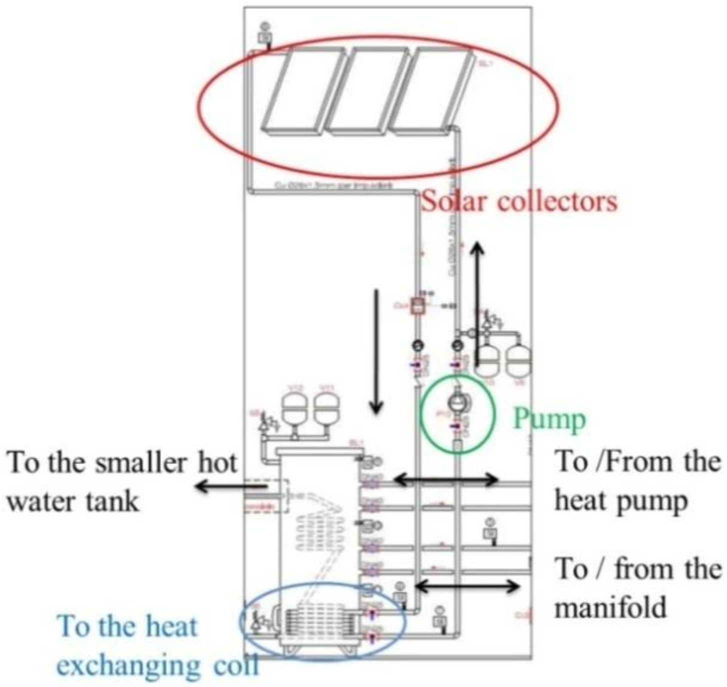


Figure 26 Scheme of the solar collector system

The geothermal probes and the heat pump

Figure 27 represents a simplified scheme of the geothermal probes and the heat pump. The officially declared COP of the GHP is 4.6, lower than the measured value during the first year of monitoring. The efficiency reduction is probably due to:

- the non-optimal use of thermal devices;
- the anomalous electrical absorption of the compressor respect to the declared data(7-8 % higher);
- a mis-management of the ignition system characterized by too fast cycles.

The geothermal circuit, which regularly supplies the heat pump, during the summer season is connected to the free-cooling heat exchanger.

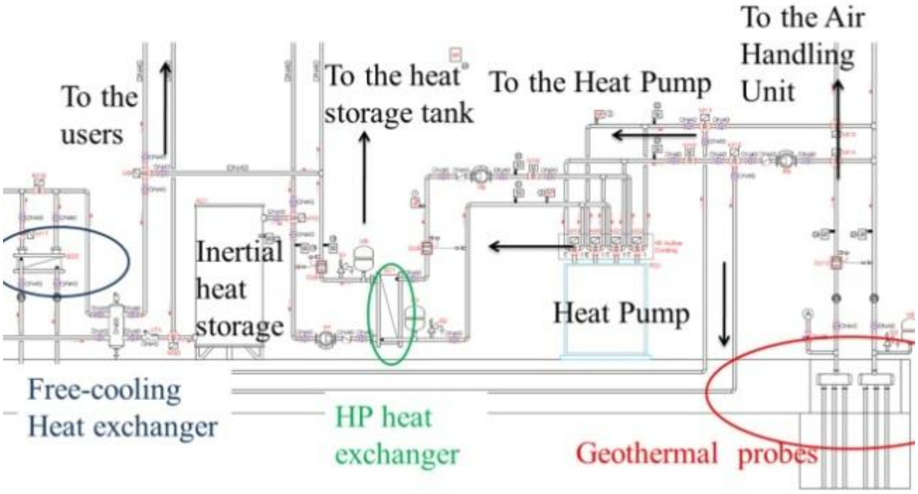


Figure 27 Schematic representation of the GHP system

The air handling unit (AHU)

As previously described, to exchange air in the rooms an ATU has been installed. Before introducing air into flats, the outer air is heated in winter and cooled in summer exchanging thermal energy with the water produced by the heat pump (Figure 28). To avoid thermal wastes, the thermal energy is extracted from the inner air before the expulsion. The outer air is also naturally pre-conditioned through an underground path of about 10 m before getting to the AHU.

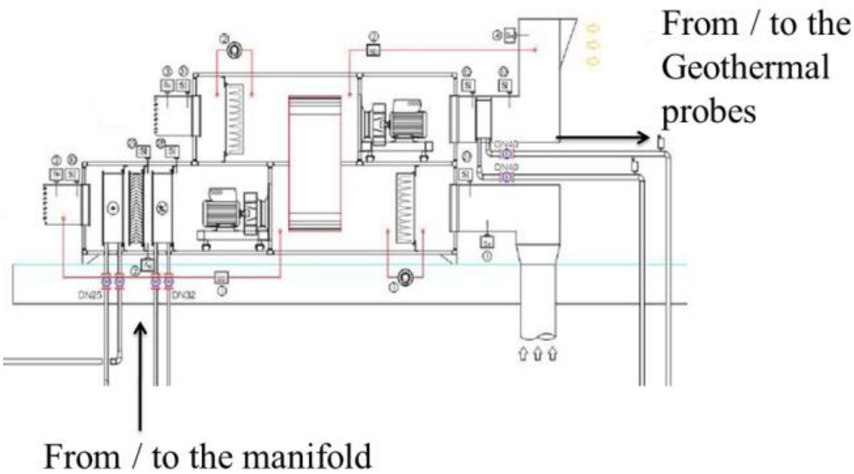


Figure 28 Scheme of the ATU

The auxiliary boiler

An auxiliary boiler is used to heat the fluid when the target temperature is not reached by the other systems. In figure 29 it is possible to see the position of the boiler respect to the other plants.

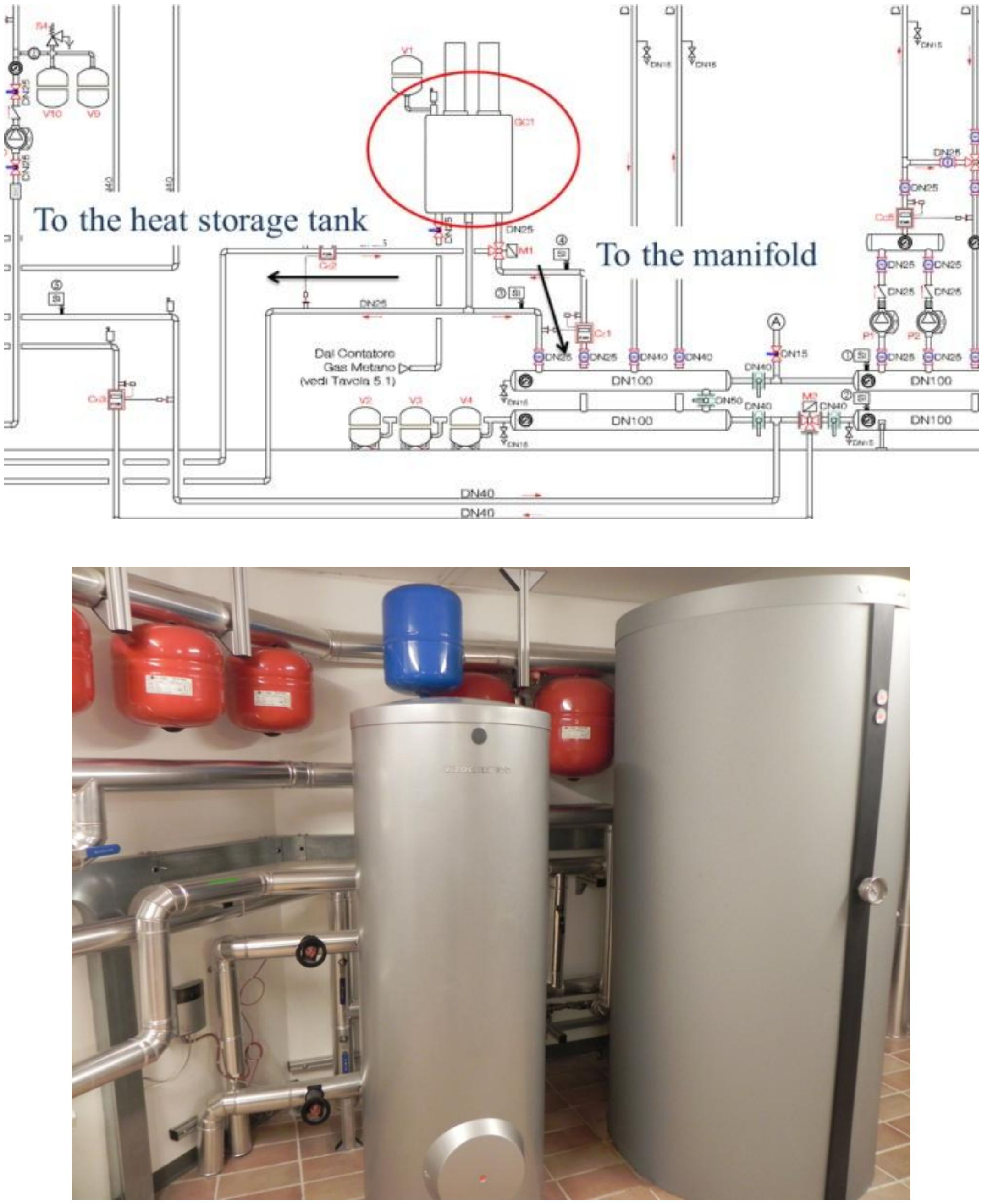


Figure 29 Immages of the Auxiliary boiler

The photovoltaic system

A grid-connected PV system characterized by a 20 kW nominal power generates electricity for the LH. The PV field , which is composed by 115 panels, covers the entire roof surface ($150m^2$), facing the south.

The panels are arranged in nine strings and are connected to three inverters. The nominal declared efficiency of the PV panels is 12%.

Figure 30 The DC/AC photovoltaic converters

The radiant floors

In each flat there is a radiant floor fed by the GHP. The temperature in the rooms is controlled by a regulation system that is able to check the hot water flow through each tubing loop. Zoning valves and thermostats permit to reduce the energy consumption. During the summer season, excluding the hottest days, the cooling system uses the natural cooling provided by a ground coupled heat exchanger.

In winter, the water that circulates in the tubing has a temperature of 25-28°C.

5.4. The monitoring System

According to the definition, a NZEB should fulfill the requirements not only considering the design data but also during the real operation condition. For this reason a structured monitoring procedure is needed. Moreover the evaluation of additional parameters has to be considered such as comfort parameters (temperature, relative humidity, air speed, radiant temperature, CO_2 level). The monitoring equipment should also provide data to calculate match indexes to understand which is the impact of the building on the grid.

The objective of this paragraph is to analyze the state of the art about sensors and transducers useful to calculate the energy balance of the building and other parameters and to understand how they can be integrated in a data acquisition system. The monitoring and building automation system has been developed by Loccioni Group, it uses an innovative approach based on the so called Leaf Framework (figure 31). The Leaf Framework is a software platform between the system devices and the logic level which includes graphical user interfaces, building automation algorithms, business intelligence tools and databases. In other words it behaves like a software gateway between different devices and systems.

Figure 31 Leaf frame work interface

More than 1,200 sensors and actuators have been integrated with drivers which allow communication between devices and systems by means of different protocols. The sensors are classified in three main groups: apartment sensors (CO_2, air temperature and humidity sensors, electricity and thermal energy meters),mechanical plant sensors (temperature sensors, thermal energy meters, water flow meters, etc.) and weather station sensors. All data are normalized and stored in a database. The Leaf framework allows the building automation system to use all the available strategies with energy efficiency algorithms. For example the HVAC system stops if windows are open. The inlet temperature of the water in the radiant floor is regulated according to the external temperature. The air flow rate is regulated according to the CO_2 level in each apartment. The LH is considered as a laboratory whose stored data are analyzed using business intelligence tools and used to test predictive algorithms.

The experience made by Loccioni Group with the Leaf Framework will be presented underlining the advantage and disadvantages of this method.

Energy monitoring

Overall building Energy Balance

The monitoring system should consider all the loads included in the balance. The boundary to be considered is the overall building. The building can be fed by three different categories of sources:

- the grid (electricity)
- fuel supplier (natural gas)
- District Heating/Cooling (thermal energy)

In the energy balance also the on-site production from renewable energy sources should be considered:

- Hydro power (electricity)
- Wind power (electricity)
- PV (electricity)

- Ground source (thermal energy)

Heating system performance monitoring

Monitoring the performance of an element of the heating plant can be useful for several reasons:

- Comparing the performance data provided by the manufacturer with the operational data
- Fault prevention oriented data analysis
- Performance improvement through parameters setting

For heat/cool generators monitoring the performance means calculating the real efficiency/COP. This calculation needs different data acquisition according to the type of heat/cool generator.

For example calculating the COP of a air condensing heat pump requires the installation of a Multimeter to measure the electrical energy consumed by the machine and an energy meter to measure the thermal energy produced by the heat pump. To compare the measured data with the data reported in the data sheet provided by the manufacturer also a temperature sensor is needed to measure the condensing operative air temperature.

The same considerations can be done for a water condensing heat pump. In this case a second energy meter is useful to monitor the thermal stress affecting the probes and the annual energy balance between heat and cool delivered to the ground.

Monitoring the performance of a gas boiler requires an energy meter to measure the thermal energy produced and a gas flow meter to calculate the amount of fuel burned by the boiler.

Often a boiler has two different output: one for heating and one for domestic hot water. In this case two energy meters are needed. This consideration can be applied clearly also to heat pumps provided with two outputs.

Other elements which need to be monitored are heat exchangers. Their efficiency tends to decrease because of furring and/or corrosion and water leakage. Data collected by energy meter installed before and after the heat exchanger can provide useful information for programming maintenance actions.

Also solar collectors can be monitored to calculate their efficiency and to understand if the choice of the number of collectors was correct. In this case an energy meter is needed to measured the energy transferred from the solar system to the storage system. A Broadcasting station can allow to monitor the operating condition of the collectors.

Excluding fuels all the other measurement can be reduced to measures of thermal energy end electricity. For this reason it can be useful analyzing the state of the art about transducers that can be used to measure thermal energy and electrical energy.

Thermal Energy monitoring

In Table 11 a list of some devices that can be used to measure thermal energy is presented. All this devices include a flow measuring part, two temperature sensors and a calculator. The flow meter measuring principle can be based on ultrasound or on magnetic induction.

Table 11 Thermal energy meter

Manufacturer	Model	Accuracy (Power)	Protocol
Siemens	2WR6	+/-3%	M-bus, Pulse
Brunata	HG-Q	+/-2% Class 2 EN1434	Modbus, M-bus, LON
Danfoss	Sonometer 1000	+/-2% Class 2 EN1434	RF, Modbus, Mbus
Metrima	SVMF531	+/-3%	Pulse, M-bus
Hydrometer	773	+/-2% Class 2 EN1434	RF, Modbus, M-bus

Here are some important features that have to be considered in the choice of an energy meter:

- Range

- Accuracy
- Compliance with norms (EN 1434 in Europe)
- Availability of an eprom for data backup
- Output (T_{in}, T_{out}, Flow, Power, Energy)
- Possible use in heating and cooling (two variables needed)
- Protocol used for communication

Electrical energy monitoring

In Table 12 a list of some devices that can be used to measure electrical energy is presented. Multimeters measure voltage and current and calculate power. Some of them measure just current while voltage is a fixed value set during configuration.

Table 12 Multimeter

Manufacturer	**Model**	**Accuracy (Power)**	**Protocol**
Siemens	SENTRON PAC3100	+/- 1%	Modbus
Schneider	PM9C	+/-2%	Modbus
Camille Bauer	U1281		M-bus, L-bus, LON
Socomec	Diris A20	+/-0.4%	Jbus/Modbus

Here are some important features that have to be considered in the choice of a multimeter:

- Grid voltage
- Grid frequency
- Peak load
- Number of phase (1 residential building, 3 non residential building)
- Range
- Accuracy
- Compliance with norms (EN 61036 in Europe)
- Output (Voltage, Current, power factor, Power Energy)

- Protocol used for communication

Notice that all the multimeters and the energy meters communicate in M-bus or in Modbus. These communication protocols where born for specific application.

Modbus is a serial communication protocol published by Modicon in 1979. It became a de facto standard communication protocol for connecting industrial electronic devices. Modbus allows the communication between approximately 240 devices connected to the same network and it is often used to connect a supervisory unit (typically a computer) with remote terminal unit in SCADA systems (Supervisory Control And Data Acquisition). There are two main serial Modbus versions and unfortunately a Modbus RTU device can't communicate with a Modbus ASCII device.

M-bus (Meterbus) was developed to fill the need for a system for the networking and remote reading of utility meters (gas, electricity). M-bus is a master-slave system: typically a computer interrogates the meter connected with a two wire cable.

The Leaf House case study

The Leaf House heating plant design team had a lot of interest in the monitoring system. The monitoring strategies described in the previous paragraph were applied with the aim of collecting data useful to understand the energy performance of the heating plant.

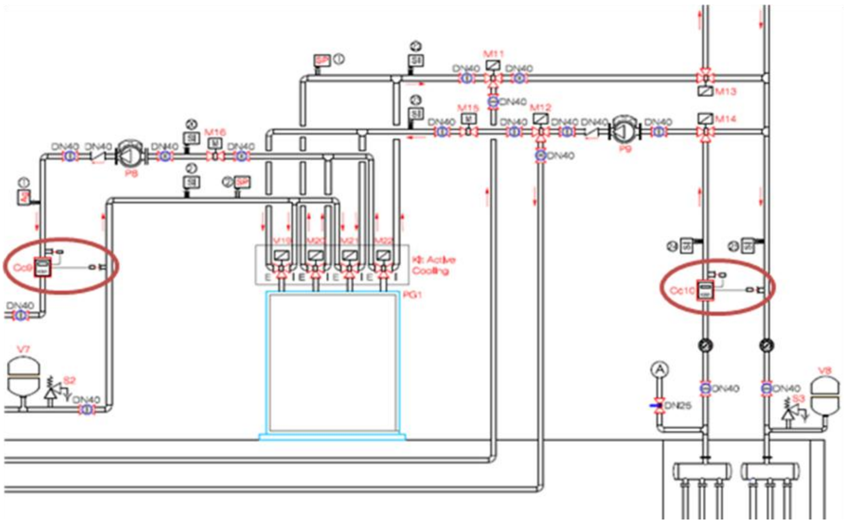


Figure 32 Heating plant scheme (P&IDs)

The heat pump performance is monitored using two energy meters Brunata HG-Q. The number 9 measures the amount of energy produced by the heat pump, while the number 10 measure the heat delivered to the ground. Both the energy meters are combined meter for heating and cooling and they are calibrated to work with glycol.

The monitoring system is completed by a Multimeter installed in the power panel. The data collected allowed to find out a consumption higher than the consumption declared by the manufacturer (7%).

The energy meter number 10 allows to calculate the annual balance between heat and cool dissipated by the probes.

Table 13 Heat and cool dissipated by the probes, measured by energy meter 10

	Heat	**Cool**	**Balance**
Energy [kWh]	16,673	14,405	2,268

The Energy Meter number 9 (combined with number 10) can be used also to calculate the performance of the heat exchanger which separates the part of the plant filled with water from the part filled with glycol. The number 9 measures the energy delivered from the heat pump to the heat exchanger (glycol circuit) while the number 8 measures the energy delivered from the heat exchanger to the final users (water circuit).

The performance of the heat exchanger is similar to what is expected to be.

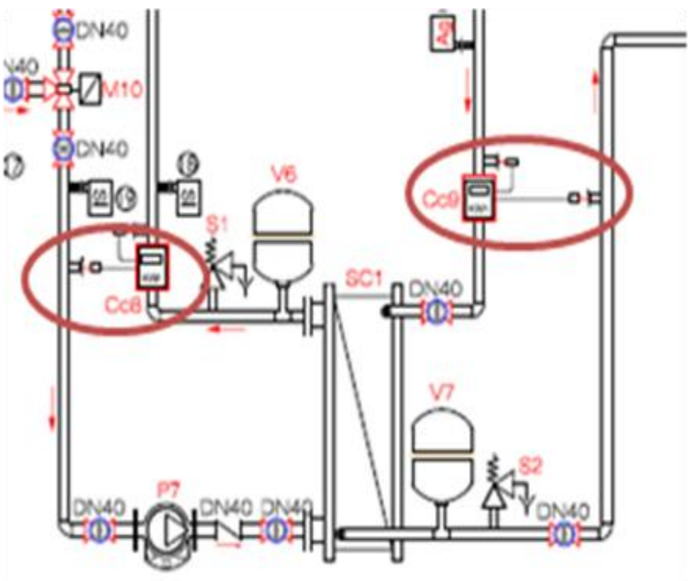


Figure 33 Position of Energy Meter number 8 and 9

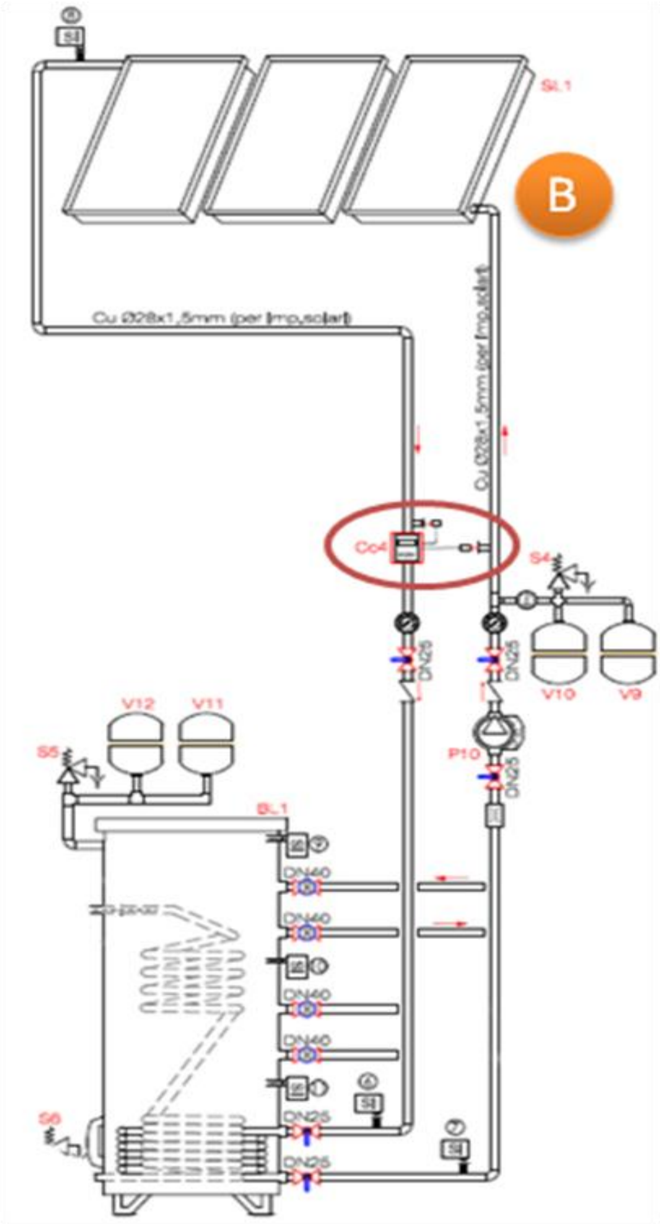


Figure 34 Position of Energy meter number 4

Also the energy provided by the solar collectors is monitored: an energy meter (Number 4) measures the energy delivered from the solar collectors to the energy storage system. An onsite broadcasting station allows to monitor the performance of the solar system. The data collected confirmed the data provided by the manufacturer. Comparing the production and the consumption of hot water an oversizing of the solar system was discovered.

Comfort parameter monitoring

A monitoring system designed to monitor the comfort in a building should be provided of a Thermal Comfort Meter (Fanger Meter) which integrates all the instrumentation necessary to calculate PWM and PDD indexes.

Anyway it's impossible to install this instrumentation for all the lifetime of a occupied building because it is an expansive instrumentation for researchers. On the contrary some parameters can be monitored with cheap and permanent building automation instrumentation.

Dry bulb temperature, relative humidity and CO_2 level are the parameters we have to focus on.

The cheapest transducers are the analog ones. They can be active or passive sensors that have a voltage (0-10V) or current output (4-20mA). There are also other devices available to communicate in standard or proprietary protocols and they are used in building managed by a Building Automation System.

Temperature

Most of the temperature sensors used for comfort monitoring of building are NTC (negative temperature coefficient) thermistor. A thermistor is a resistor whose resistance varies significantly with temperature; particularly the resistance of an NTC thermistor decreases when the temperature increases. Table 13 shows the Leaf House temperature sensors.

Table 14 Temperature sensors

Manufacturer	**Model**	**Accuracy (Power)**	**Protocol**
Schneider	STR100	+/-2%	Analog
Mamac System	TE-205-EU-12	+/-3%	Analog
Honeywell	TR21		Analog, LONworks

NTC are very cheap, they have a good accuracy and they don't need to be calibrated very often. These characteristics make them suitable to be used in monitoring application.

Relative Humidity

Table 15 Relative Humidity sensors

Manufacturer	Model	Accuracy (Power)	Protocol
Schneider	SHR100	+/-2%	Analog
Mamac System	HU-225-3-VDC	+/-2%	Analog
Honeywell	H7625A1008	+/-2%	Analog

They are usually active sensors. The sensing element is a thin film capacitor whose capacity changes with the relative humidity.

CO_2

Table 16 CO_2 sensors

Manufacturer	Model	Accuracy (Power)	Protocol
Schneider	SCR100	+/-5%	Analog
Vaisala	GMW115	+/-3%	Analog
Honeywell	AQS51	+/-5%	Analog

Most of CO_2 transducers are NDIR (non dispersive infrared) sensors. The gas concentration is measured by its absorption of a specific wavelength in the infrared.

The Leaf House Case Study

In each apartment of the Leaf House there are a CO_2 sensor, a humidity sensor and some air temperature sensors (one for each room).

The SenseAir CO_2 sensors are a NDIR (non dispersive infrared) sensors. The amount of CO_2 in the apartment is not only an important parameter for the quality of the air but it is also used for the regulation of the mechanical ventilation: the flow of the inlet air is increased if the CO_2 level in the apartment increases.

The temperature and humidity sensors are made by E+E Elektronik Ges.m.b.H. (model EE10). They measure the humidity in the apartment and the dry bulb temperature in each room. These values are compared to the values set by the tenants to set the regulation of the HVAC system.

Monitoring system and Building Automation System

In new buildings or retrofit ones sometimes the installation of a completely new monitoring system can be avoided: some sensors are usually already installed and they can be integrated with new sensors in the monitoring system avoiding waste of money, space and cable management. For example in almost all houses utility revenue meter are installed. They usually measure the global amount of energy absorbed by a building or a flat.

Also PV plant are often provided of meters to calculate the total amount of energy produced by the plant to grant to the owner the amount of incentives due by the government.

In many buildings comfort sensors are mandatory to provide a feedback value for HVAC management. For example temperature sensors are used to regulate heating and cooling, relative humidity to regulate dehumidifier and $C0_2$ to regulate the flow rate provided by mechanical ventilation system. Moreover all these sensors are already installed in building with a Building Automation system. Unfortunately integrating these sensors is not so easy because they can belong to different subsystems and communicate with different protocols. Using hardware gateway to transform information from one protocol to another can be quite expensive. In the following chapter a possible solution will be presented.

5.4.1 The Leaf Monitoring and Building Automation System

The Leaf Framework is a system developed by Loccioni Group Building Automation Team with the aim to develop a system able to interface and coordinate all the sensors and the subsystems found in the building.

The main characteristic of this solution is the implementation of a wrapper for each subsystem named driver. The driver is a software code that allows the communication between the field device and the supervisor which can be a PC or a PLC (Programmable Logic Computer).

The result of this architecture is a middleware application which implements the communication interfaces and makes the abstraction of subsystems possible.

This software platform guarantees the fundamental requirements of reusability, modularity and expandability.

The Model Driven Architecture (MDA) paradigm has been employed for software implementation. This software design methodology allows to split modeling from the realization of applicative components. This strategy allows the separation between model and technology.

The post processing algorithms, the data mining activity and the Business Intelligence operation that can be applied on data become independent from the field devices.

Each interface component of domotic standards is identified as a plug-in (Figure 35). The framework plugin architecture allows a seamless integration of new hardware by just implementing a new access driver to the physical device. This methodology makes a quick integration of new possible functionalities and does not require any modification to already tested and correctly running software.

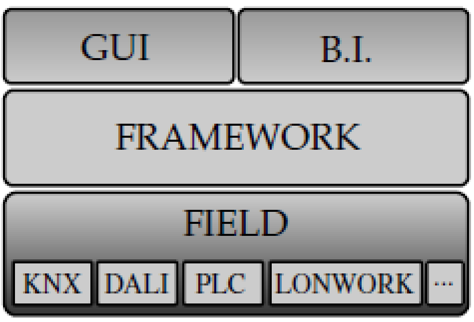


Figure 35 Separation of field device from abstraction level

The most innovative characteristic of the Leaf Framework can be summarized in the following points:

- The framework create a field for each information. Moreover virtual channel can be created aggregating data according to mathematical logics without the need of post processing
- Plugins can be dynamically added with a simple configuration
- The channels can be configured both for polling or for event driven data management

As said before this architecture can be used not just for monitoring but also for Building Automation purposes. The same Framework can integrate both sensors and actuators allowing the implementation of complex algorithms for HVAC management, lighting control, safety and security system management etc.

Chapter 6 How to cover the Gap between Production and Consumption

6.1. The building energy performances

In the Leaf House energy comes from the Building Integrated Photovoltaic plant, covering a surface of 150 m^2, it produces during the first year of monitoring 25 651 kWh_e (1 295 KWh/kW_p according to the estimated production in that place). In the following, the results of the first year of monitoring are going to presented. The design team made predictions on production and consumptions to be comparable values. As the following data confirm, they are not (Table 17).

The photovoltaic system produced 25,651 kWh during the monitored year.

Table 17 Monthly energy consumption vs production

Month	PV production [kW_e]	Global Building consumptions [kW_e]
Jan-2009	715	3237,3
Feb-2009	1394	2257,0
Mar-2009	2347	2987,8
Apr-2009	2262	2396,1
May-2009	3375	2911,0
June-2009	2879	3259,8
July-2009	3499	4354,5
Aug-2009	3140	4111,9
Sept-2009	2329	2868,3
Oct-2009	1847	2436,0
Nov-2009	1185	2817,1
Dec-2009	679	3401,8
TOT	**25.651**	**37.038,7**

The following figure (Figure 36) shows the previous yearly data trend.

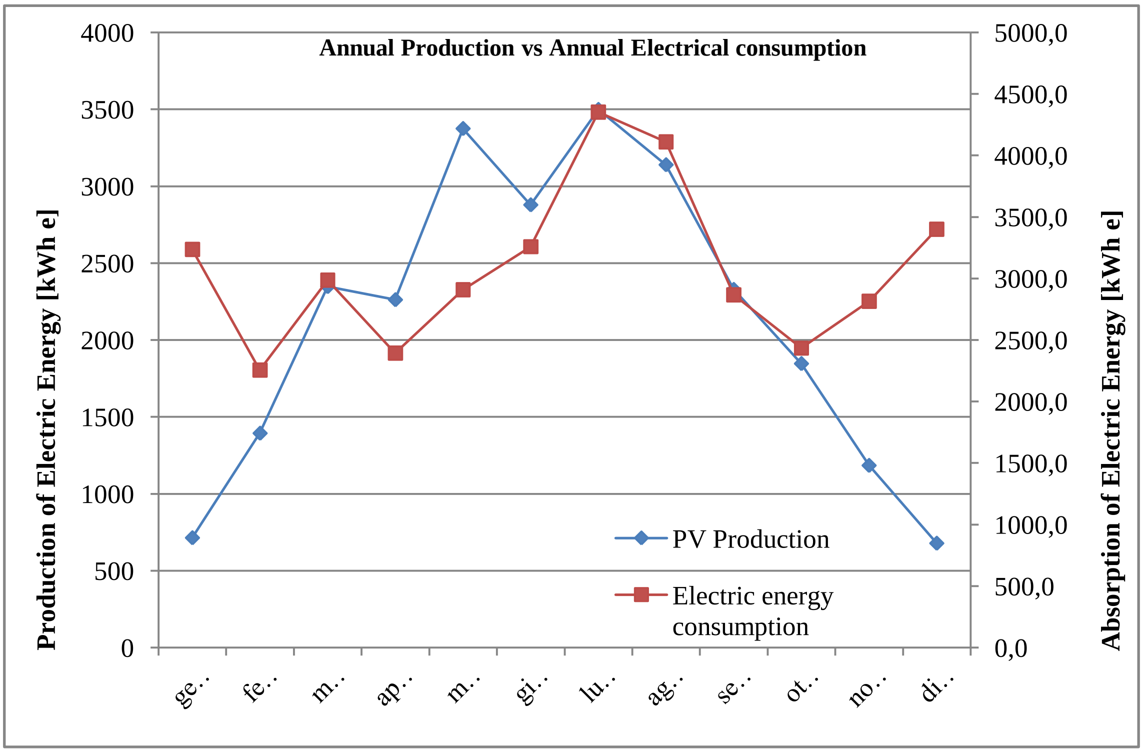


Figure 36 Annual trend of electric energy consumption vs PV prodution

In Table 18 the main consumption of each flat is shown, the first column shows the consumption of the Thermal plant (TP).

Table 18 Global Energy consumption divided per flat including the Thermal Plant (TP)

	TP [kW_e]	Flat1 [kW_e]	Flat2 [kW_e]	Flat3 [kW_e]	Flat4 [kW_e]	Flat5 [kW_e]	Flat6 [kW_e]
Jan-2009	2737,2	35,2	28,0	87,0	100,5	39,8	100,5
Feb-2009	1697,0	141,5	61,0	102,9	100,0	46,0	100,0
Mar-2009	2317,5	143,2	96,7	115,8	104,0	53,2	104,0
Apr-2009	1793,8	151,2	98,6	99,4	87,5	51,3	87,5
May-2009	2090,3	192,5	149,9	99,8	99,0	111,4	99,0
June-2009	1887,9	156,0	285,5	100,7	372,3	255,7	372,3
July-2009	2746,5	206,1	320,0	114,8	423,7	278,8	423,7
Aug-2009	2729,0	201,2	281,2	91,9	354,2	247,2	354,2
Sept-2009	2125,2	203,4	120,4	117,1	93,8	59,6	93,8
Oct-2009	1770,6	162,9	106,6	141,6	83,0	65,4	83,0
Nov-2009	2074,5	162,7	124,1	165,3	100,3	78,8	100,3
Dec-2009	2690,3	121,6	84,6	158,0	105,9	56,8	105,9
TOT [kW_e]	**26659,8**	**1877,4**	**1756,5**	**1394,2**	**2024,1**	**1343,9**	**2024,1**

Table 19 Energy consumption of the TP divided in DHW,Cooling,Heating

	DHW	Cooling	Heating
Jan-2009	135,7	2424,0	916,8
Feb-2009	90,8	1791,6	759,8
Mar-2009	111,2	2114,6	910,1
Apr-2009	163,6	430,9	589,1
May-2009	211,9	454,2	483,0
June-2009	230,2	1501,8	737,4
July-2009	226,1	2215,0	623,3
Aug-2009	198,6	1960,6	758,6
Sept-2009	184,4	1254,9	794,0
Oct-2009	136,1	180,3	829,0
Nov-2009	105,8	630,4	851,9
Dec-2009	71,2	727,8	855,2
Tot	**1865,7**	**15686,0**	**9108,1**

Thermal collectors provided 4,227 kWh_t satisfying 63% of domestic hot water needs. Analyzing the monitored data, the electricity consumption for the heating and cooling energy only provided by the GHP was calculated and was 5.3 MWh during the heating season and 2.6 MWh during the cooling season.

A first analysis of monitored data shows as the building is only close to reach the NZEB target.

Table 20 Electric energy production and consumption (data collected in 2009)

ENERGY	MWh	%
Production	25.65	87.72
Consumption	30.38	100.00
Production - Consumption	**-4.73**	**-12.28**

To increase the value of the Production/Consumption ratioit is required a redesign of the building-equipment system: redesign hypotheses to reach the NZEB target will be described in the following paragraphs.

The energy balance of the building shows that the total consumption is about 37,000 kWhe per year while the energy yield due to the PV production is 25 650 kWhe per year. Indeed the energy consumptions of the laboratory is about 6,700 kWhe per year. Consequently the energy gap not covered by the PV system is 4,650 kWhe.

To assess how to reduce the energy gap between consumption and production a dynamic model of the building and its thermal systems has been created. The model, which was built into TRNSYS (version 16.1) environment, has a complex geometry. For this reason some simplifications were assumed:

- The tank used in the production of domestic hot water was not considered because of the complexity of the double tank configuration,
- Some recirculating nodes of the piping system were eliminated,
- The air treatment unit was implemented directly in the TRNBuild, so it does not appear in the TRNSYS scheme.

A detailed description of the TRNBUILD model and of the TRNSYS STUDIO model will be shown in paragraphs 6.2 and 6.3.

6.2. The dynamic simulations: TRNSYS

The LH building plant system has been simulated using the software TRNSYS Studio.

TRNSYS is a complete and extensible simulation environment for the transient simulation of systems, including multi-zone buildings. It is used by engineers and researchers around the world to validate new energy concepts, from simple domestic hot water systems to the design and simulation of buildings and their equipment, including control strategies, occupant behavior, alternative energy systems (wind, solar, photovoltaic, hydrogen systems), etc.

One of the key factors in TRNSYS' success over the last 25 years is its open, modular structure. The source code of the kernel as well as the component models is delivered to the end users. This simplifies extending existing models to make them fit the user's specific needs.

TRNSYS consists of a suite of programs: The TRNSYS simulation Studio, the simulation engine (TRNDll.dll) and its executable (TRNExe.exe), the Building input data visual interface (TRNBuild.exe), and the Editor used to create stand-alone redistributable programs known as TRNSED applications (TRNEdit.exe).

The DLL-based architecture allows users and third-party developers to easily add custom component models, using all common programming languages (C, C++, PASCAL, FORTRAN, etc.). In addition, TRNSYS can be easily connected to many other applications, for pre- or post-processing or through interactive calls during the simulation (e.g. Microsoft Excel, Matlab, COMIS, etc.). TRNSYS applications include:

- Solar systems (solar thermal and PV)
- Low energy buildings and HVAC systems with advanced design features (natural ventilation, slab heating/cooling, double façade, etc.)
- Renewable energy systems
- Cogeneration, fuel cells
- Anything that requires dynamic simulation.

A TRNSYS project is typically setup by connecting components graphically in the Simulation Studio. Each Type of component is described by a mathematical model in the TRNSYS simulation engine and has a set of matching Proforma's in the Simulation Studio The Proforma has a black-box description of a component: inputs, outputs, parameters, etc.

TRNSYS components are often referred to as Types (e.g. Type 1 is the solar collector). The Multizone building model is known as Type 56.

The Simulation Studio generates a text input file for the TRNSYS simulation engine. That input file is referred to as the deck file.

The LH building plant system has been simulated by the TRNSYS software, for testing the reliability of the software by the comparison with real data .

The following plant scheme (Figure 37) describes with a sufficient degree of precision the heat plant existing in the LH. The storage tank on the left is reached by different lines coming from the isolated solar circuit, the inlet cold water, and from the heat pump heat exchanger. During summer , two different diverting valves close the heat pump glycol circuit on a free-cooling heat exchanger , directly connected with the users collectors, to ensure summer cooling for the water circulating in the radiating floors and for the air treatment unit.

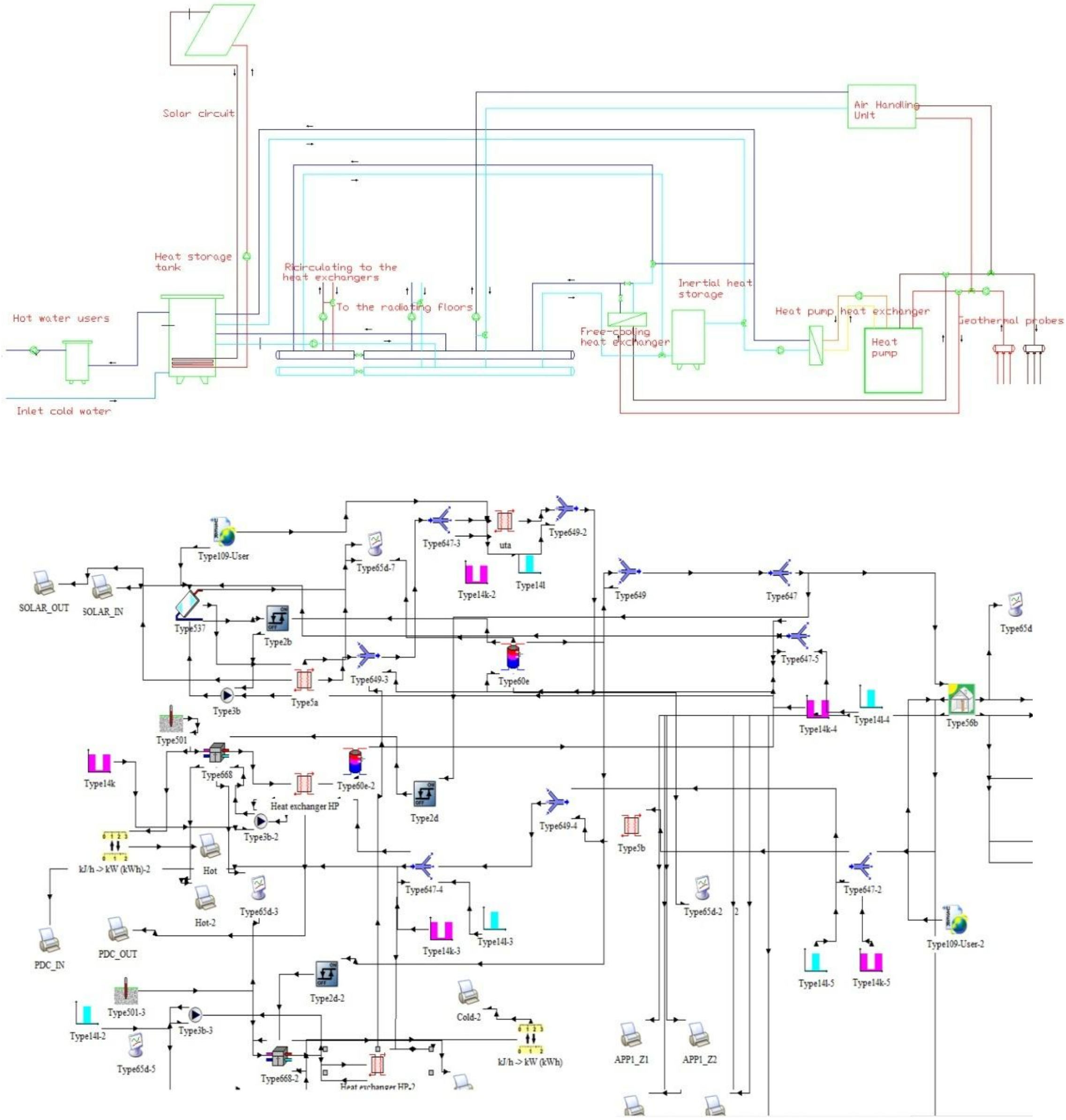


Figure 37 The Leaf House plant and the Trnsys simulation studio model

In order to simplify the operating scheme the following assumptions were adopted :

- The smaller tank used in the production of domestic hot water has been eliminated,
- The domestic hot water production has not been evaluated,
- Some recirculating nodes have been eliminated,
- The air treatment unit has been implemented directly in the TRNBuild, so it will not appear in the TRNSYS scheme,

- Modified configuration of the solar heat exchanger (This topic will be dealt with later).

A global scheme of the simplified HVAC system follows, together with a global scheme of the TRNSYS simulation is shown in figure 43.

In the simulation Studio environment an output manager from where you control which variables are integrated, printed and/or plotted, and a log/error manager that allows you to study in detail what happened during a simulation is present.

The TRNSYS Simulation Engine

The simulation engine is programmed in Fortran and the source is distributed (see the \SourceCode directory). The engine is compiled into a Windows Dynamic Link Library (DLL), TRNDll. The TRNSYS kernel reads all the information on the simulation (which components are used and how they are connected) in the TRNSYS input file, known as the deck file (*.dck). It also opens additional input files (e.g. weather data) and creates output files.

The simulation engine is called by an executable program, TRNExe, which also implements the online plotter, a very useful tool that allows you to view dozens of output variables during a simulation.

A TRNSYS project consists of components (e.g. a solar collector, a data reader, a printer) linked together.

User can check a component's configuration by double-clicking its icon. This will open a window with multiple tabs. When the window is opened, the foremost tab shows a list of parameters and their value (the solar collector parameters are shown in Figure 38). You can see additional information about the parameters by clicking the "More" button.

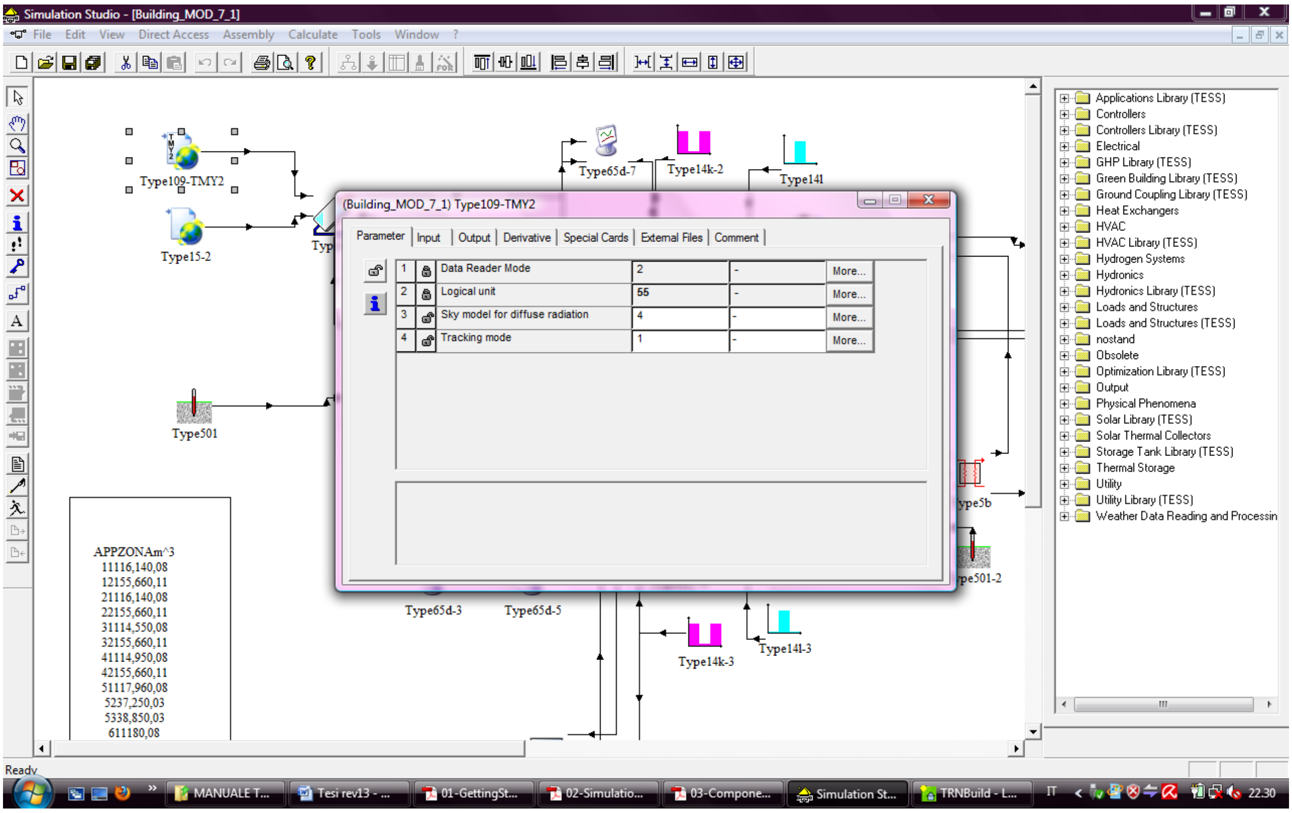


Figure 38 Example of properties of a specific Type

You can explore the different tabs to view the component's inputs, outputs and derivatives (if any – derivatives are capacitive variables of the component, e.g. nodes representing a given amount of water in a storage tank).

If user double-click on a link between two components, is will be opened a new window that lists all input-output connections inside that link. Figure 39 shows the link between Type 109 (weather data reading and processing) and Type 1b (solar collector)

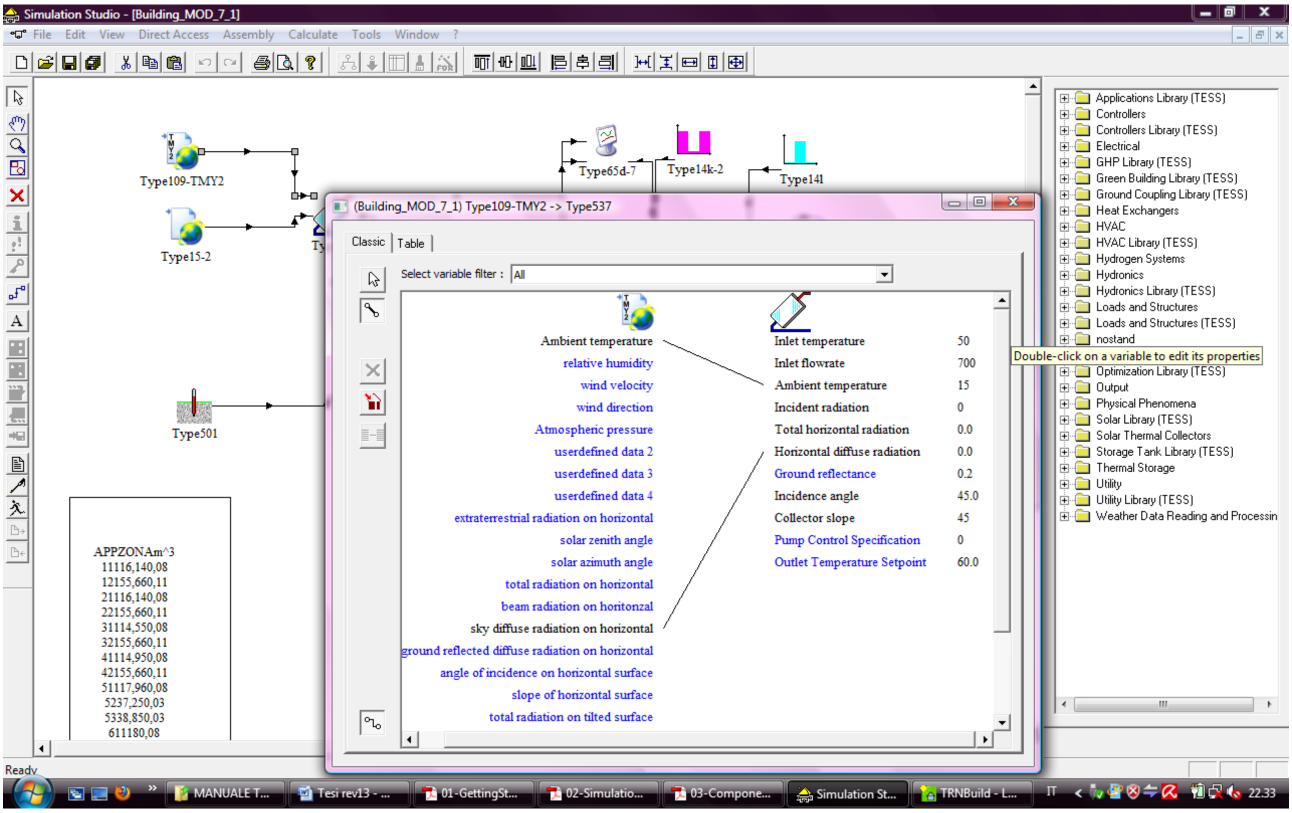


Figure 39 Example of connection window

In this thesis the results of different analysis will be shown, first the weather data for the 2009 have been directly implemented into TRNSYS in order to compare simulated to monitored data, as TRNSYS data files are made of average data collected for decades; second two different models have been developed to describe both the photovoltaic system and the HVAC one.

The first model is composed of types representing a simple and clear description of the real PV system: the weather type collects the temperature, radiation, wind speed, etc, data that have been imported to TRNSYS and works as an input for the solar photovoltaic panel type. The raw power produced is then directed to an inverter and to a large number of integrators and printers that allow the simulation data to be collected.

The HVAC system is far more complex. The subsystems described in the simulated model are:

- Heat pump circuit and geothermal probes,
- Free cooling,

- Solar system,
- Type 56.

The first two elements of the list are connected too, because the geothermal probes are the core element of the free cooling circuit. They are not however described at the same time to have a clear distinction of the cooling and heating system working in the Leaf House.

Every system and sub-system will be described in the following pages.

The PV model

The photovoltaic system in the leaf house is built around 115 panels, granting a power of 20 kW and a monitored production of 25 MWh during 2009. A quick summary of the single module\cell main characteristics is following.

Table 21 PV panels technical data

Power	175 W
V	36,4 V
I	4,67 A
Open circuit V	43,5 V
Short-circuit I	5,2 A
Cell efficiency	16%
Cell module	13,30%
Module dimensions	1560 x 808 mm
Thickness	50 mm
Weight	15,1 kg
Cell type	Monocrystalline
Cell dimensions	150x150 mm

The panels are arranged in nine strings, two of whom composed of twelve panels while the other composed of thirteen panels. Three inverters are connected to the system, receiving the whole current produced by the PV panels and transforming it into alternate current. The PV panels system is grid-connected (Figure 40).

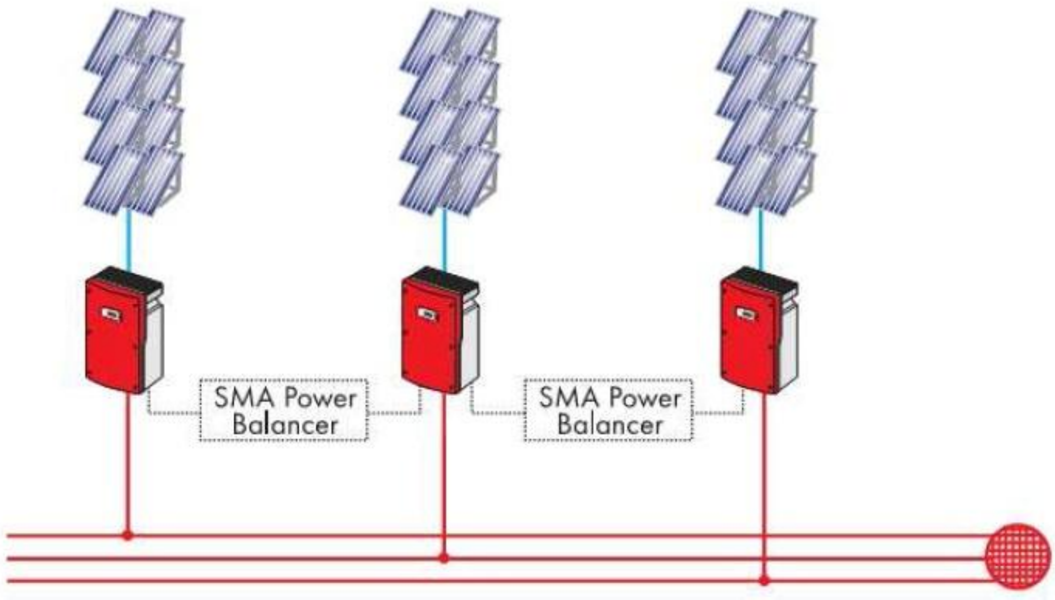


Figure 40 PV system scheme

Due to the nature of the lines, composed of a heterogeneous number of panels two different models of inverter are used in the leaf house, whose main characteristics are summarized in the following table 22.

Table 22 Inverter technical data

		Sunny Mini Central 6000 TL	Sunny Mini Central 7000 TL
IN	**Max Power**	6200 W	7200 W
	Max V	700 V	700 V
	V Range, MPPT	333-500 V	333-500 V
	I max IN	19 A	22 A
OUT	**Max Power**	6000 W	7000 W
	I max out	27 A	31 A
	V	220-240 V	220-240 V
	cos φ	1	1
	Max efficiency	98%	98%

The PV model has been implemented into TRNSYS with no substantial changes according to the real layout of the plant. The simulation has been run simulating each group of strings connected to each inverter and with the assumption of connecting all of them to an ideal inverter obtaining results absolutely close between each other. The predefined monocrystalline photovoltaic panel type has been set up to resemble as much as possible the real one using the data already presented in tabs before. The type 48 however, used for the simulation of the inverters, is not much customizable, thus leading to a one-only input as an overall efficiency, excluding obviously the raw power coming from the panels. It is, in fact, the only type TRNSYS possesses to represent PV systems that are not connected to a battery storage. It has been set up an average efficiency of the inverter system of 95 % for the simulation.

The climatic data reader (type 109) is connected to the PV panels (type 94), in order for the type to elaborate a value of raw power, connected afterwards to the inverter (type 48).

The simulating graph has been added (figure 41). It is possible to evaluate the producing trend, during the different months of the year.

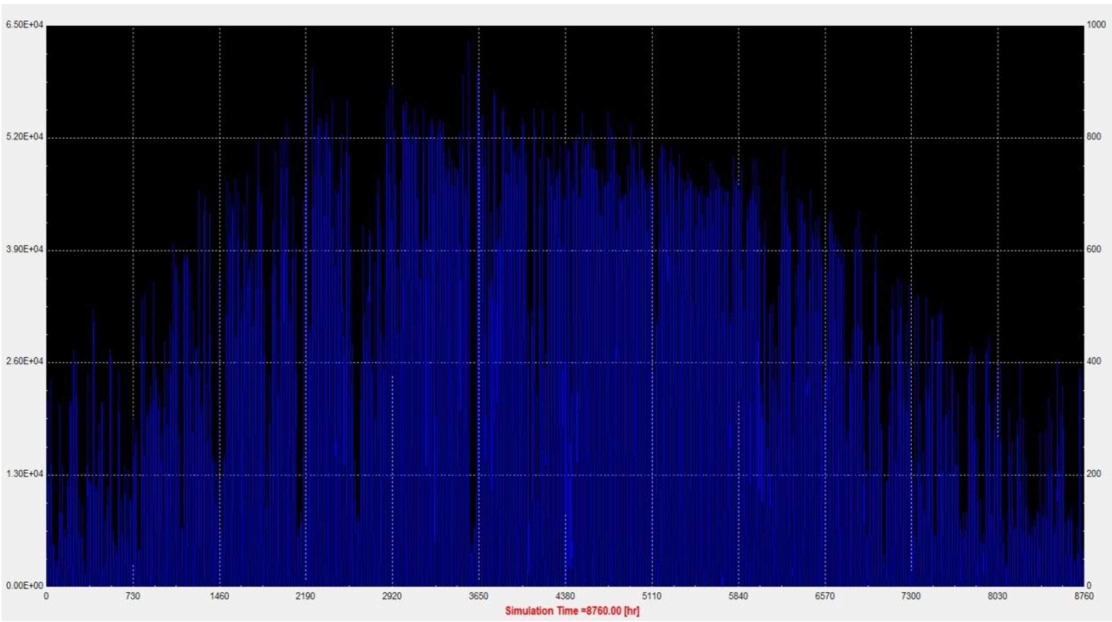


Figure 41 Trnsys output exemple

The same analysis on the same plant has been conducted with the PVSYST software (Figure 42), specifically designed to study and describe photovoltaic systems and plants.

Every configuration of existing string has been simulated in detail, describing as well in detail the inverters, power losses and the influences of shadows in the production.

Table 23 PV layout description

PV Module	Shuco-Si-mono	SPV 175 SMG-S
Array 1	12 modules in series	2 strings in parallel
Array 2	13 modules in series	3 strings in parallel
Array 3	13 modules in series	4 strings in parallel
Total arrays global power	20 kWp	
Total modules	115	

Table 24 DC/AC converters

Inverters	Sunny mini central 6000TL	Sunny mini central 7000TL
Array 1	Operating voltage: 335-500 V Nominal power 6kW AC	
Array 1		Operating voltage: 335-500 V Nominal power 7kW AC
Array 1		Operating voltage: 335-500 V Nominal power 7kW AC

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	5.7°		
Near Shadings	Linear shadings			
PV Field Orientation	tilt	22°	azimuth	0°
PV modules	Model	SPV 175 SMG-S	Pnom	175 Wp
PV Array	Nb. of modules	115	Pnom total	**20 kWp**
Inverter	Model	Sunny Mini Central 6000 TL	Pnom	6.0 kW ac
Inverter	Model	Sunny Mini Central 7000 TL	Pnom	7.0 kW ac
Inverter pack	Nb. of units	3.0	Pnom total	**20 kW ac**
User's needs	Unlimited load (grid)			

Perspective of the PV-field and surrounding shading scene

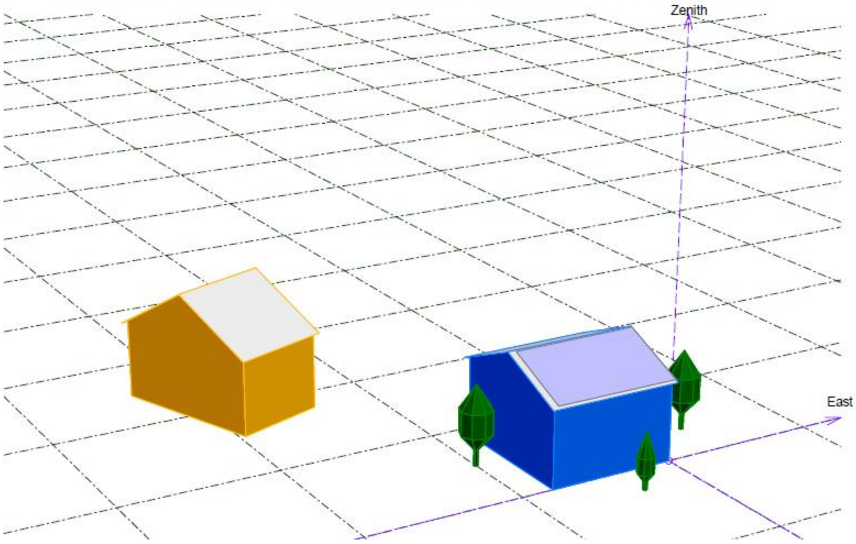


Figure 42 Screenshot of the PV system in PVSYTS

Main system parameters	System type	**Grid-Connected**		
Horizon	Average Height	5.7°		
Near Shadings	Linear shadings			
PV Field Orientation	tilt	22°	azimuth	0°
PV modules	Model	SPV 175 SMG-S	Pnom	175 Wp
PV Array	Nb. of modules	115	Pnom total	**20 kWp**
Inverter	Model	Sunny Mini Central 6000 TL	Pnom	6.0 kW ac
Inverter	Model	Sunny Mini Central 7000 TL	Pnom	7.0 kW ac
Inverter pack	Nb. of units	3.0	Pnom total	**20 kW ac**
User's needs	Unlimited load (grid)			
Main simulation results				
System Production	**Produced Energy**	**24.16 MWh/year**	Specific prod.	1200 kWh/kWp/year
	Performance Ratio PR	78.7 %		

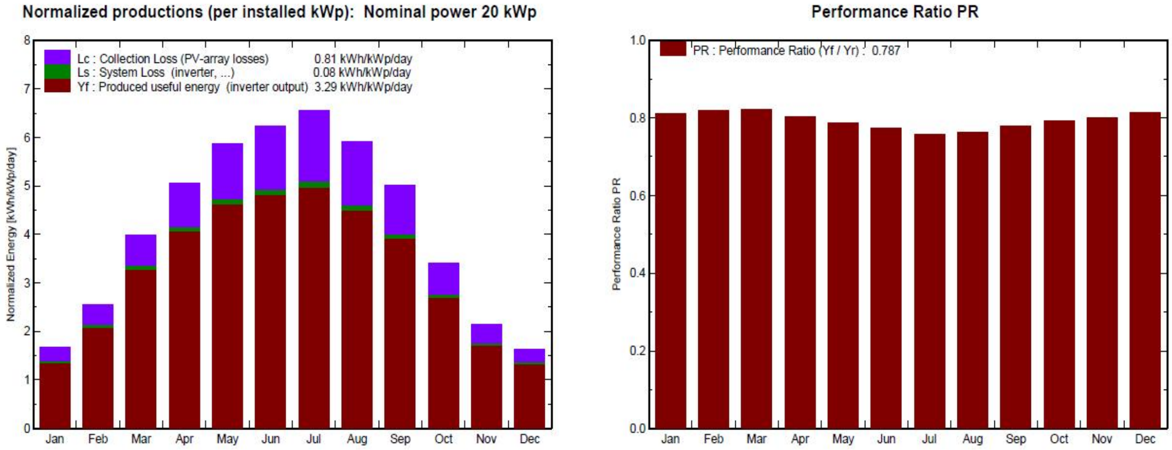


Figure 43 Screenshot of the power output in PVSYST

The HVAC system

In order to make the operating scheme simpler, the following assumptions were adopted:

- The smaller tank used in the production of domestic hot water has been eliminated,
- Some recirculating nodes have been eliminated,
- The air treatment unit has been implemented directly in the TRNBuild,
- Modified configuration of the solar heat exchanger (This topic will be dealt with later).

A global scheme of the simplified HVAC system follows (Figure 44), together with a global scheme of the TRNSYS simulation (Figure 45 and Figure 46).

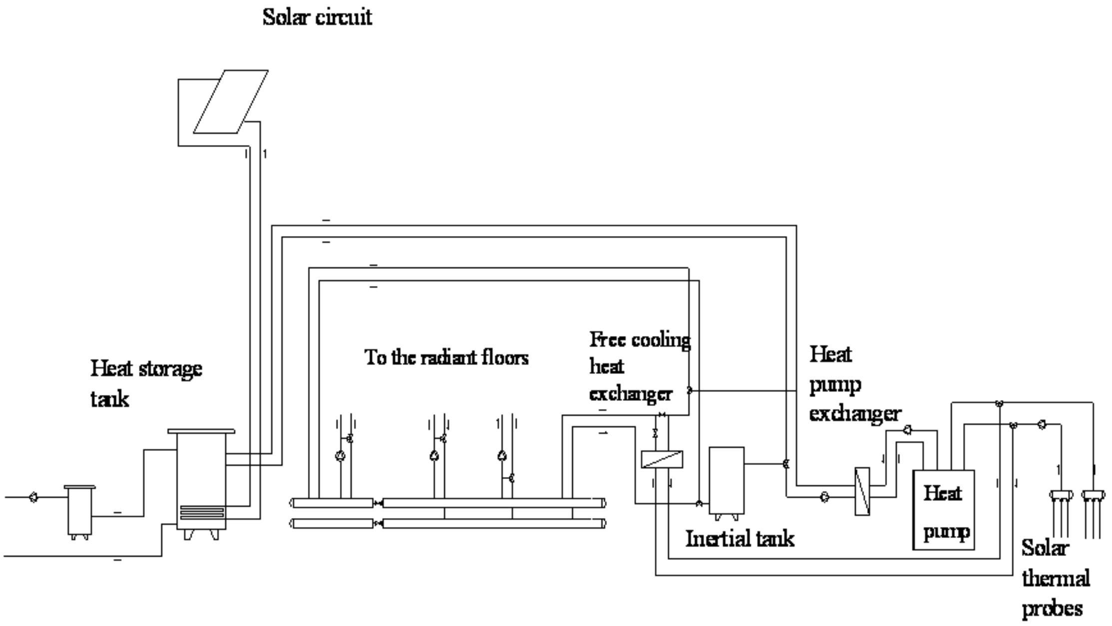


Figure 44 LH Plant scheme

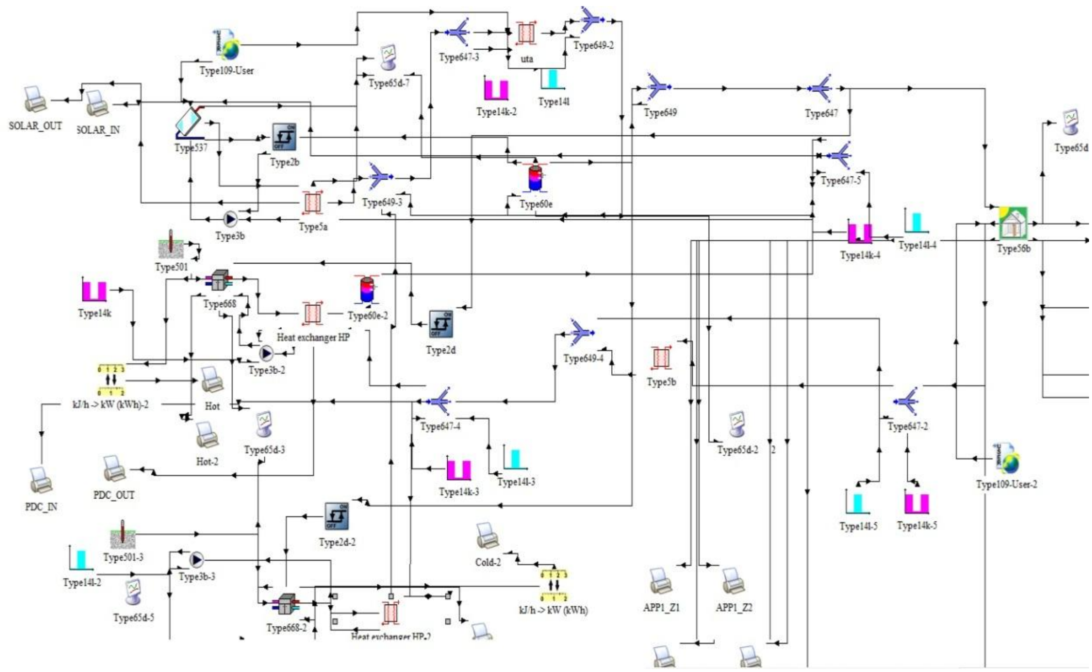


Figure 45 HVAC Trnsys model

Geothermal probes and heat pump

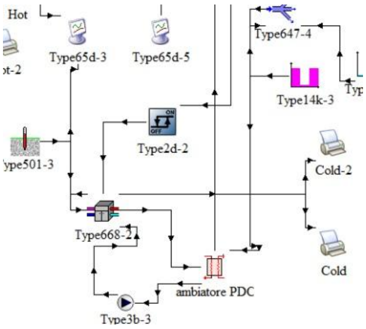


Figure 46 Heat pump TRNSYS sub-system

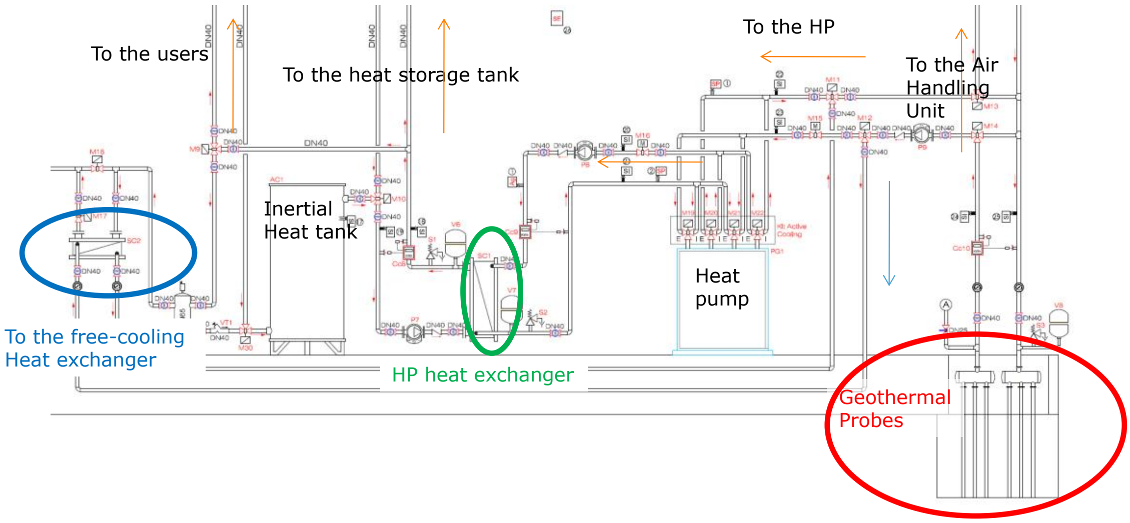


Figure 47 Geothermal probes and HP sub-system

During the cold season, the stream, coming back from the radiating floors, reaches first the heat pump heat exchanger connected on the hot side to a closed circuit with a pump and the heat pump itself.

The heat pump heating control works under the condition of a limit of temperature: the temperature of the fluid leaving the storage tank must not be higher than 26 degrees °C, because that fluid stream has to move into the radiating floor.

The heat pump is connected to a closed geothermal circuit that provides both the heating and the free-cooling when needed.

The small inertial tank connected to this circuit has been reproduced in the scheme in order to obtain better overall performances.

The COP of the GHP officially declared by the manufacturer is 4,6; a lower value of the COP was measured during the first year . This is probably due to:

1. the occupants' behaviour due to their use of the dehumidifier etc;
2. the anomalous electrical absorption of the compressor respect to the declared data (7-8% higher);
3. mismanagement of the ignition system characterized by too fast cycles.

Free cooling

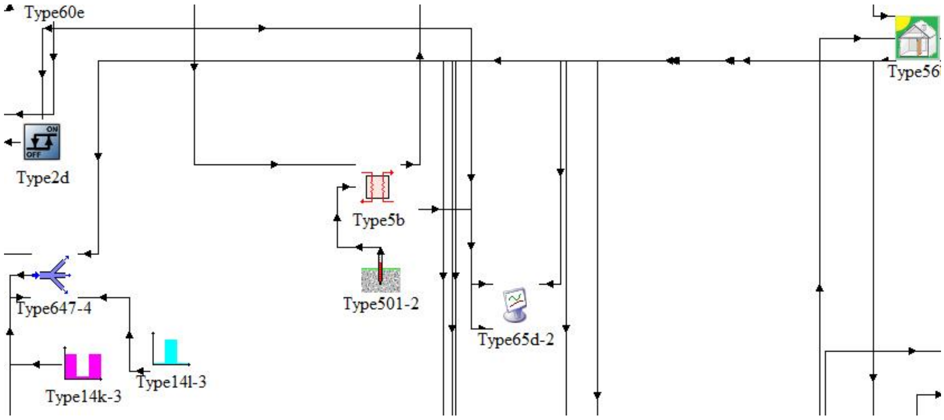


Figure 48 Free-cooling TRNSYS sub-system

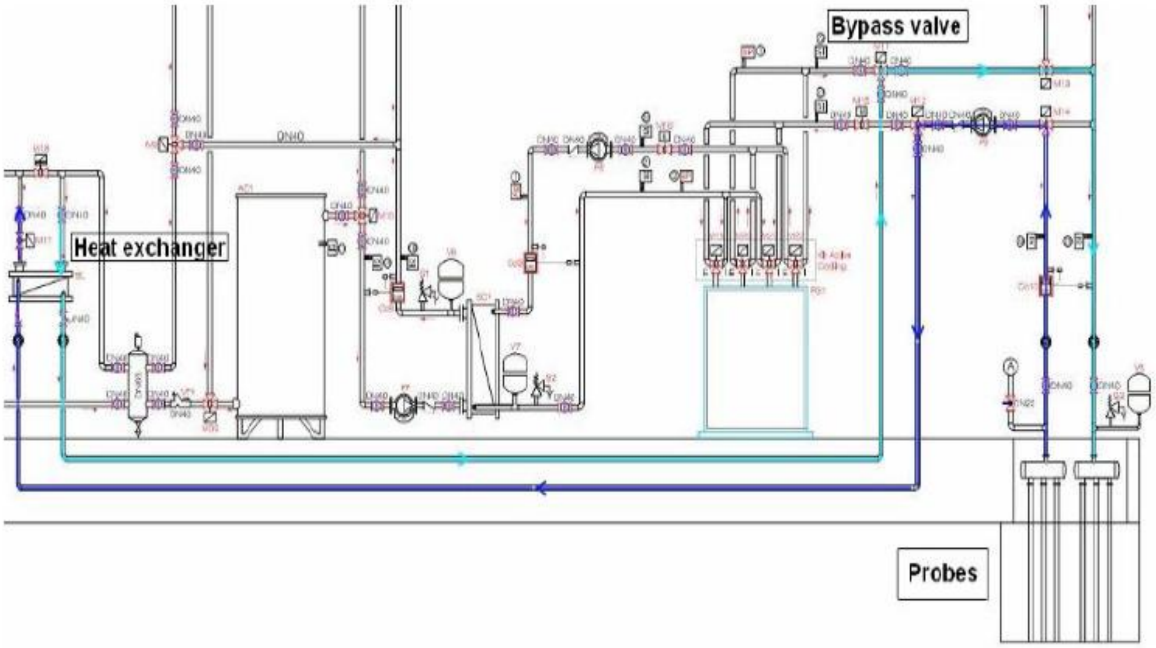


Figure 49 Detail of the free-cooling system

During the cooling season the simulated plant works quite differently. The whole system part that works with the solar circuit is completely bypassed through the use of diverting valves that assign the fluid to different lines according to the season of the year. Coming from the type 56, the fluid is directed to a geothermal heat exchanger that works exchanging heat directly with the ground thanks to a secondary circuit of glycol water and to the heat pump, this time working as a cooler for the working fluid. The LH heat pump in cooling mode is activated manually. The heat pump simulated control system is set up in order to start working when the temperature on the main line returning back to the radiant floors, reaches 20°C.

The type 647 is a diverting valve that, according to the hour of simulation leads the fluid towards the HVAC system or to the ground heat exchanger (type 5b).

Types 14k and 14l are two 0-1 functions, that are used to express the fraction of fluid exiting from the valve.

Solar system

The solar system is composed of panels Schuco Sol S, for a total area of nearly 19 m^2, whose main characteristics are summarized in Table 25.

Table 25 Solar panels – Technical data

Dimensions	2152x1252x93mm
Area	2,69 m^2
Weight	55 kg
Efficiency η0	80,80%
Coefficients of thermal dispersion	k_1=3,518 W/m^2K
	k_2 = 0,012 W/m^2K
Coefficient of absorption α	95%
Coefficient of emissivity ε	5%

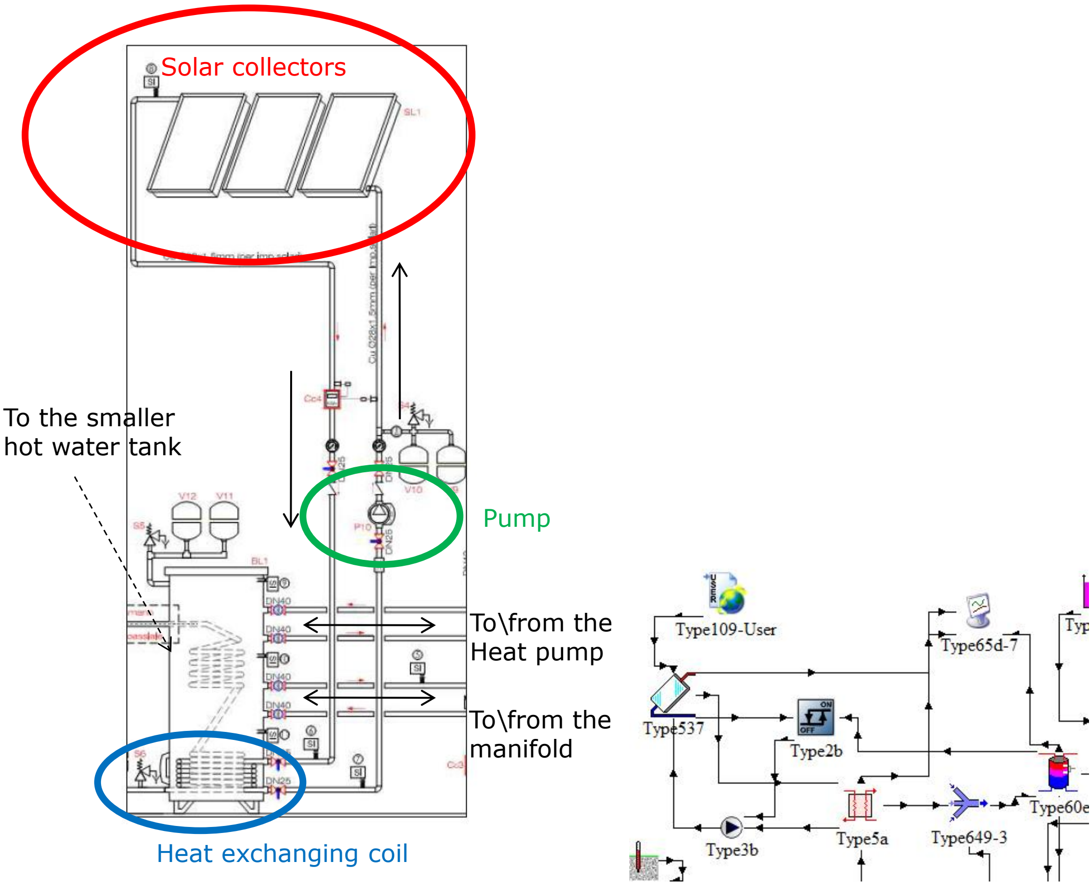


Figure 50 Solar sub-system

The solar circuit is composed of the panels type (537), connected to the weather data type (109-user), specifically created starting from the data collected for the zone in 2009. There were some missing data though, replaced by average data calculated from the closest days. The solar circuit is closed on a heat exchanger where glycol water exchanges heat with the cold flux. The pump in the solar circuit (type3b) works until the temperature condition is met : the difference between the temperature at the exit node of the solar panels and the one inside the storage tank must be at least 10 degrees: Type 2b is used as a differential thermostat. The heated stream is then directed into the storage tank and from there into the heating floors line.

Type 5a heat exchanger is not a real component of the plant : it was necessary to split the heat exchange in the storage tank, between the solar line and the stored water, in two different steps, because of some type 534 problems, that led to simulation undesired difficulties. This process has been made while always comparing simulation results to the monitored data.

6.3. The building model: Type 56 and TRNBUILD ambient

The Type 56 is the core of the model: it represents physically the house, the flats, the connection between them and the interactions between the house and the surrounding environment.

This component models the thermal behavior of a building divided into different thermal zones. In order to use this component, a separate pre-processing program must first be executed. The TRNBUILD program reads in and processes a file containing the building description and generates two files that will be used by the TYPE 56 component during a TRNSYS simulation. The file containing the building description processed by TRNBUILD can be generated by the user with any text editor or with the interactive program TRNBUILD (see Annex II). The first parameter is the FORTRAN logical unit for the data file with the building data (*.BUI). The Data is taken from the Program Window library. The second parameter is set to 1 if time-dependent convective heat transfer coefficients are used (for example in combination with floor panel heating systems). The third parameter gives the weighting factor between air and mean surface temperature for the calculation of an operative room temperature. Other optional parameters give FORTRAN logical unit numbers for the standard output files generated by TYPE 56. The inputs and outputs of TYPE 56 depend upon the building description and options within the TRNBUILD program. TRNBUILD generates an information file describing the outputs and required inputs of TYPE 56.

There are two ways to model the equipment for heating, cooling, humidification, and dehumidification. The two methods are similar to the "energy rate" and "temperature level" control modes available in the TYPE 12 and 19 load models. With the "energy rate" method, a simplified model of the air conditioning equipment is implemented within the TYPE 56 component. The user specifies the set temperatures for heating and cooling, set points for humidity control, and maximum cooling and heating rates. These specifications can be different for each zone of the building. If the user desires a more detailed model of the heating and cooling equipment, a "temperature level" approach is required. In this case, separate components are required to model the heating and/or cooling equipment. The outputs from the TYPE 56 zones can be used as inputs to the equipment models, which in turn produce heating and cooling inputs to the TYPE 56 zones.

Building model description

In this thesis, a dynamic building simulation is carried out within TRNSYS using the TYPE 56 component in which the thermal behavior of buildings can be calculated very precisely. To simulate the thermal behavior, TYPE 56 requires a great deal of building data (geometrical data, wall construction data, etc.) and other data (radiation, ambient temperature, humidity, building schedules, etc.) which influence the building. The data for a calculation are first assembled and then defined for the TRNSYS simulation.

The steps to create the model are the follows:
1. Divide the building into thermal zones and determine the geometry from plans.
2. Enter the data (wall and window areas, ventilation, infiltration, etc.) with the preprocessor TRNBUILD.
3. Create a TRNSYS input file (see Annex II) which describes the system to be simulated including the location of the building data for TYPE 56 with the preprocessor TRNSYS STUDIO.

In the TRNBuild simulation each flat has been divided in the following zones taking into account also the presence of the temperature sensors:

- two symmetrical zones for the ground and first floor apartments (Figure 51): Zone 1 (red area), Zone 2 (blue area);
- three symmetrical zones for the second floor flat (Figure 52-53): Zone 1 (blue area), Zone 2 (red area) and Zone 3 (white area).

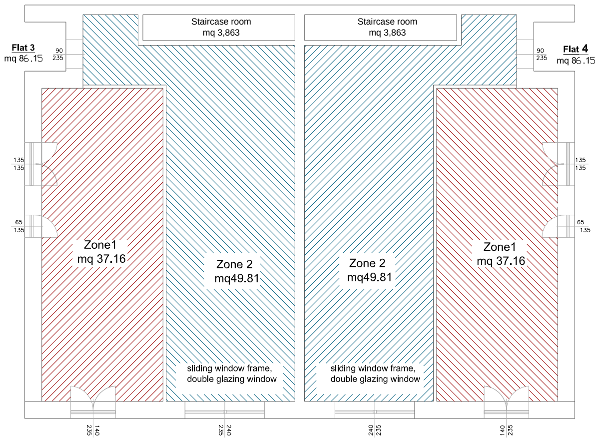


Figure 51 The thermal zones of the ground floor

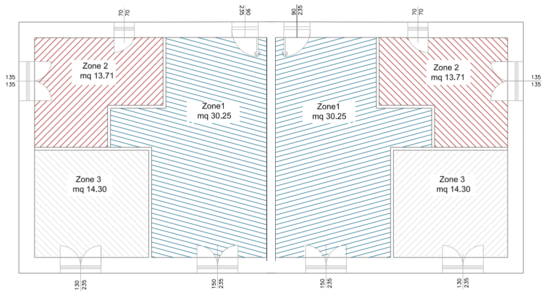


Figure 52 The thermal zones of the first floor

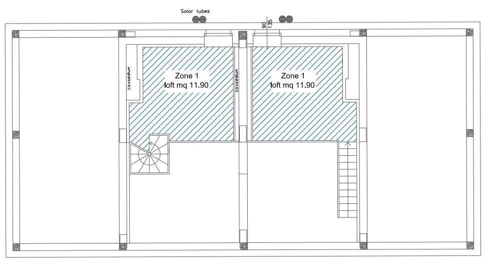


Figure 53 The thermal zones of the second floor

Each zone is simulated taking into account the real orientation of the building to better assess the solar gains, more detailed information will be shown in the following pages.

Now it is described the Building Model creation by TRNBUILD. In the project initialization window, the user enters some general information about the project, defines the orientations of walls required by the described building, defines some basic material properties, views the list of required INPUTS to TYPE 56, and selects the desired outputs of Type 56 (Figure 54).

The building description begins following the BUILDING keyword. Each zone description is initiated with the keyword ZONE followed by the name associated with the zone to be described. The names of all zones to be described must have been defined with a ZONES TYPE. After zone name the AIRNODE has to be specified. Up to know every zone has only one AIRNODE. Thus the AIRNODE name is the same name as the zone name. Within each ZONE description, there are three primary descriptions: WALLS, WINDOWS, and REGIME.

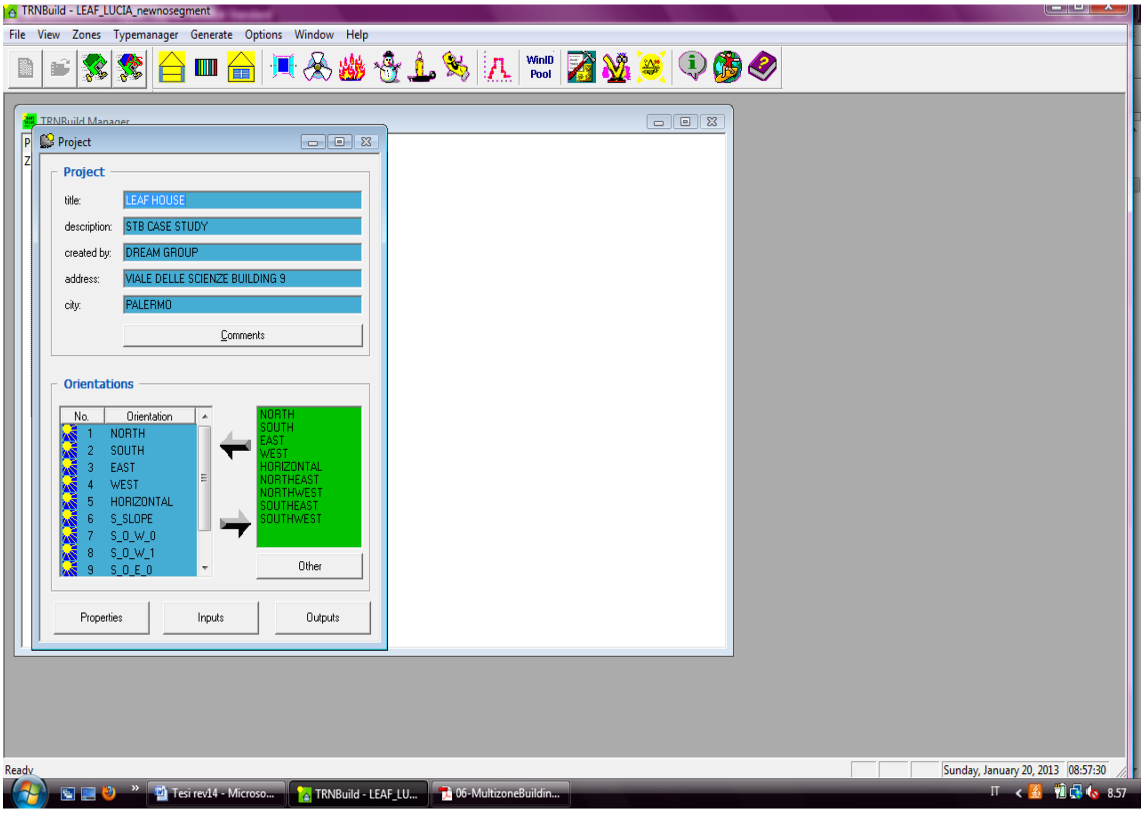


Figure 54 TRNSYS initialization window

The data describing a zone can be divided into four main parts:

a) the required REGIME DATA,

b) the WALLs of the zone

c) the WINDOWs of the zone and

d) optional equipment data and operating specifications including INFILTRATION, VENTILATION, COOLING, HEATING, GAINS and COMFORT.

The following data is entered in the REGIME DATA portion of the ZONE window:

• zone volume of the air within the zone

• capacitance total thermal capacitance of zone air plus that of any mass not considered as walls (e.g. furniture,...)

• initial temp. initial temperature of the zone air

• initial rel. humidity initial relative humidity of the zone air

• humidity model a simple (capacitance) or detailed (buffer storage) model.

In order to simplify the input, default values for all parameters except the ZONE VOLUME are provided. The CAPACITANCE will be automatically set to a default value of 1.2*VOLUME.

In order to model the buffer effect of humidity within a zone, two humidity models are available. The simple humidity model represents an effective capacitance model in which only the humidity capacitance ratio must be specified. The humidity capacitance ratio entered accounts for humidity capacitance of the air plus any other mass within the zone.

WALL descriptions refer to previously defined WALL TYPEs. There are four applications of walls that may be specified: external walls (EXTERNAL), walls separating zones (ADJACENT), internal walls (INTERNAL), and walls having a known external boundary condition (BOUNDARY). Type 56 also offers the possibility to define a certain energy flux to a certain wall surface. Also, thermally activated walls for cooling/heating are integrated in Type 56. If the wall type includes an active layer, optional Keywords are used for specification. A special external wall type to model thermal bridges is added to the wall description. In the following descriptions, the FRONT of a WALL is associated with the first layer given in the WALL TYPE definition. External walls are subjected to ambient conditions. The wall front is assumed to be at the inside of the zone.

The zone window contains all information describing a thermal zone of the building as shown in Figure 55.

All possible orientations of external building walls must be defined by unique names. The table on the left side contains all orientations defined for this project. The table on the right side provides a list of standard orientations. For adding select the desired standard orientation and click on the upper arrow. The selected orientation will then appear in the left window. For each orientation name specified, an input of incident radiation to the Type 56 TRNSYS component will be required. This is generally provided by the Type 16 Radiation Processor.

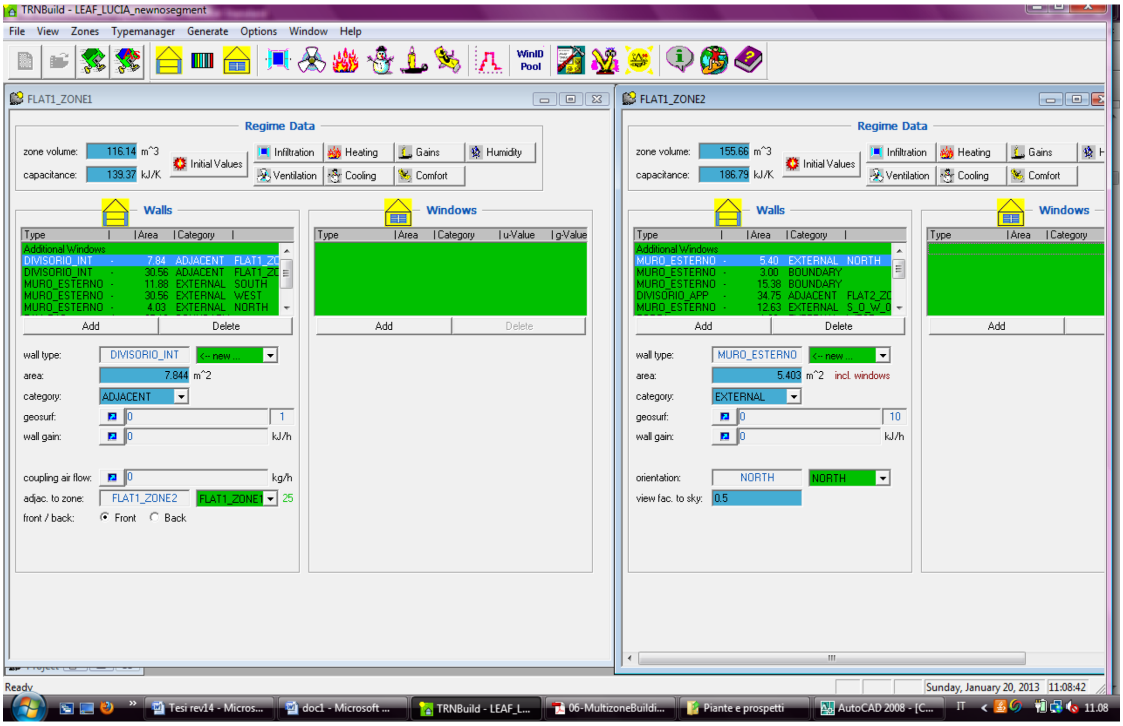


Figure 55 The Zone Window of the Leaf House project

The type 56 model has been built taking into account the real configuration of the flats of the leaf house. The six flats are well monitored with many air temperatures reader, assigned to different thermal zones. Almost every room in the house has more than one temperature and air condition reader.

The information about WALLs within a zone is displayed in the left lower part of the ZONE window. Here, the user can add, delete or edit the walls of a zone. A box in the upper part provides an overview of all defined walls. By clicking on a wall within this overview box, the definition of the selected wall is displayed below and can be edited (Figure 56).

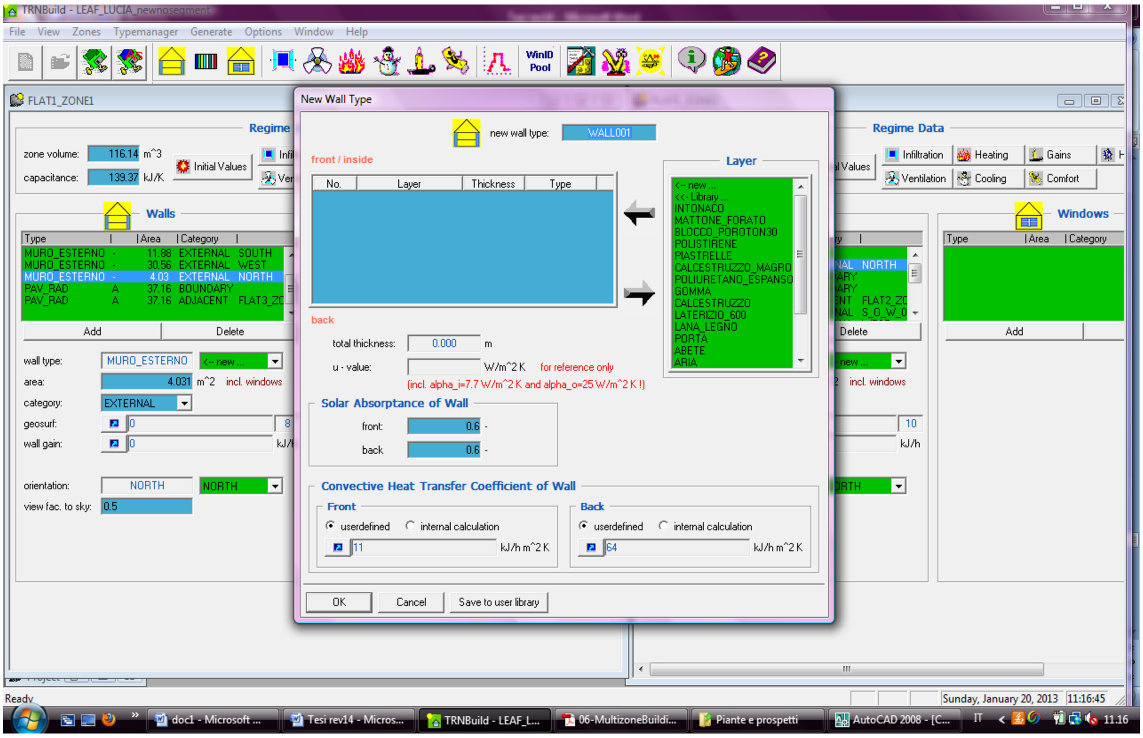


Figure 56 Wall type manager

To define a new wall the following information are needed (Figure 56):

• WALL TYPE

The wall type can be specified by using the pull-down menu on the right side. This menu offers the option of defining a new wall type, selecting a wall type out of a library, defining a wall with coldbridge effect, or selecting a previously defined wall type.

• AREA

The entered area of the wall should include the area of all windows within the wall. For internal walls, the area should be doubled, because the front as well as the back surface of the wall is exposed to the zone.

• CATEGORY

The wall category is set to EXTERNAL by default. The following wall categories are available:

EXTERNAL an exterior wall;

INTERNAL a wall within a zone, an internal wall is a wall with both surfaces within the same zone. Internal walls are assumed to affect building response only as the result of their mass;

ADJACENT a wall that borders another zone, for a wall separating zones, it is necessary to specify the name associated with the adjacent zone and the side of the wall that is within the zone. If the wall is symmetrical about its center, then the specification of FRONT or BACK for the wall is arbitrary. It is also possible to specify a mass flow rate of air (COUPLING) from the adjacent zone to the current zone across this wall;

BOUNDARY a wall with boundary conditions, a wall having a known boundary condition might be a concrete floor resting on ground of a known temperature or a wall adjacent to a zone whose temperature is known. The front of the wall is considered to be at the inside of the zone. Normally, the boundary condition is the temperature of a node connected to the back surface of the wall through a pure resistance;

• GEOSURF

Explicit distribution factors can be defined by the user for the distribution of direct solar radiation entering a zone. The value of GEOSURF represents the fraction of the total entering direct solar radiation that strikes the surface. The sum of all values of GEOSURF is not allowed to exceed 1 within a zone. The movement of the sun patches within a zone can be modeled by defining a SCHEDULE or an INPUT. The default value of GEOSURF is 0. If the sum of values within a zone is zero, the direct radiation is distributed the same way as the diffuse radiation (by absorptance weighted area ratios).

• SURFACE NUMBER

The surface number is a unique number used for surface identification. The number is generated by TRNBUILD automatically and displayed behind the edit box of GEOSURF in blue.

• WALL GAIN

With wall gain an energy flux to the inside wall surface can be defined. The display of the other required input data adjusts automatically based on the window category.

For the “view factor to the sky” (fraction of the sky to the total hemisphere seen by the wall) a value ≤ 1 must be entered (i.e. 1 for a horizontal surface, 0.5 for a vertical surface with unobstructed view). The value is used as a weighting factor between ambient and sky temperature.

Before creating a new wall type, it is recommended that the user first check the wall library by selecting LIBRARY from the WALL TYPE pull-down menu within the ZONE window. The wall library window opens as shown in Figure 57.

In the TRNBUILD Model of the Leaf House, the walls, roof, radiant floors have been created.

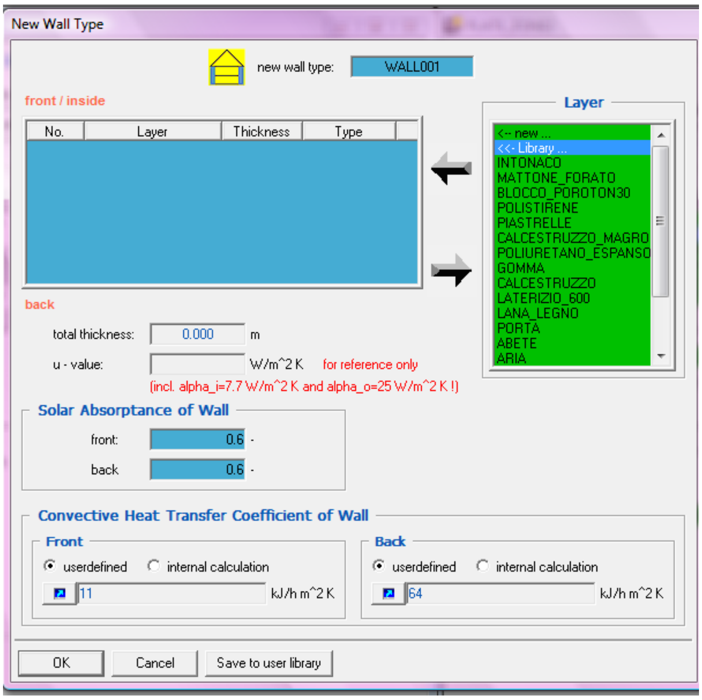


Figure 57 The Wall type window

To define a new wall type, selecting NEW from the pull-down menu of WALL TYPE within the ZONE window, a window as shown in Figure 58 will pop up. Besides entering a unique name for the wall type, the solar absorptance, and the convective heat transfer coefficient, the user must specify the construction of the wall type. The construction is specified by a series of layers starting from the "inside" surface (front) of the wall to the "outside" (back). It has been created a new layer for each construction material, selecting a layer from a library or selecting a previously defined layer by using the right box and the arrow buttons. After entering the thickness the selected layer appears in the left box. TRNBUILD calculates the total wall thickness as well as a standard U-value. This standard U-value is determined with combined heat transfer coefficients of 7.7 W/ (m² K) inside and 25 W/ (m² K) outside.

Before defining a new layer, the user should first check the provided layer libraries by clicking on LIBRARY in the layer box. The layer library window opens as shown in Figure 58. Here, the user can select layers from two different libraries: a program library and a user library. A default layer name is given by the program, but it is recommended that the user change it into a more meaningful one. Finally, the user must specify the thickness of the layer. The user can now enter the corresponding material properties for the layer. Henceforth, the saved layer will be available for other projects and will appear in the previously described layer library window.

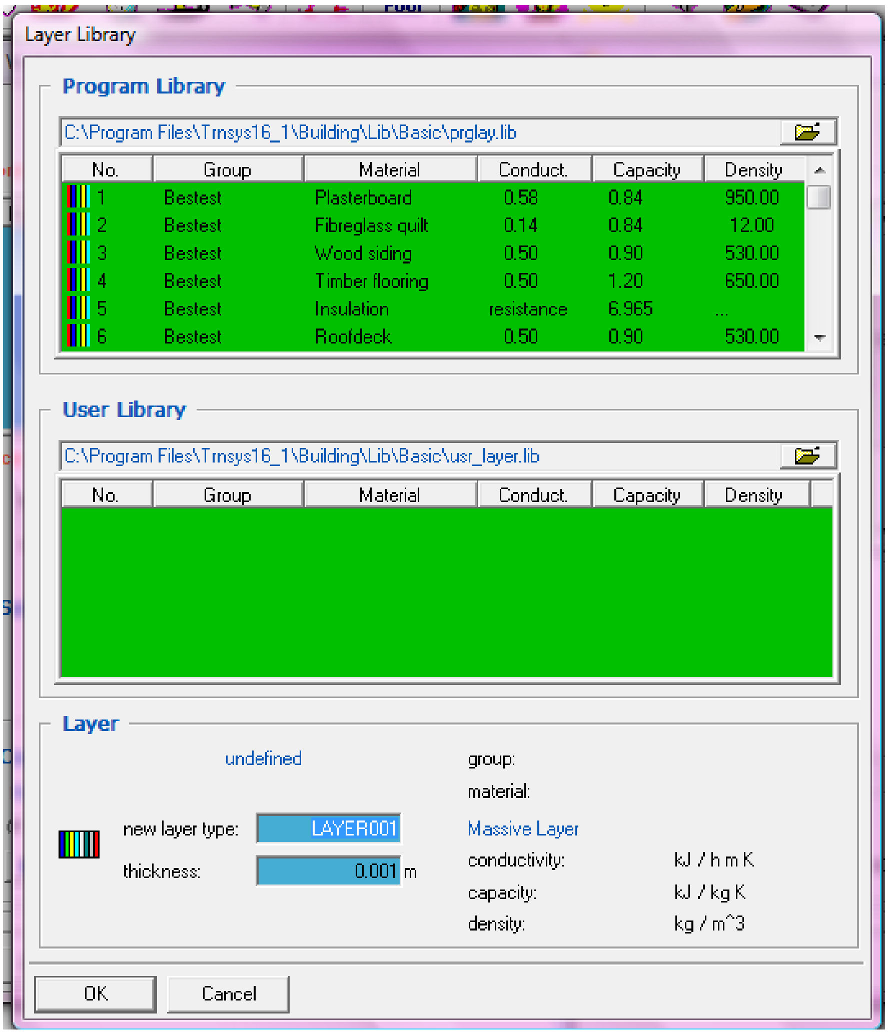


Figure 58 Layer Library

Again, path and file name for program lib or user lib might be changed for each selected layer by use of file dialog boxes. For the definition of a new layer there are 4 options:

•Massive: this is the most common one usually used in all constructions;

•Massless: only used when TRNBUILD is not able to create the transfer functions of a wall with only massive layers. In that case this layer type is used for very thin layers where the thermal mass can be neglected;

•Active: used for concrete core cooling and heating, capillary tube system and for floor heating and cooling systems. In the Leaf House model massive, massless and active layers have been created (Figure 59).

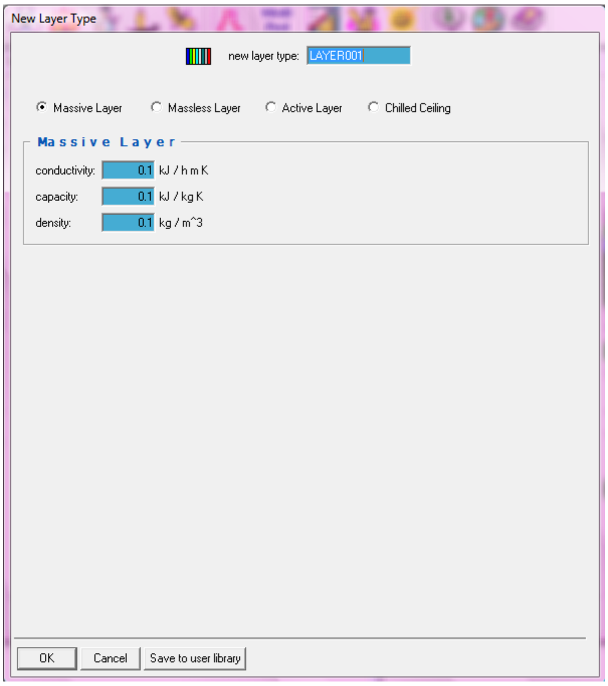


Figure 59 The new layer window

In addition to the wall construction coefficients of the solar absorptance is required. The solar absorptance coefficient depends on the properties of the wall finish.

Finally, the convective heat transfer coefficient (without a radiative part) must be defined.

Common values are:

• inside: 11 kJ / h m² K

• outside: 64 kJ / h m² K

Definition of a wall with an active layer

For modeling a radiant heating and cooling, an "active layer" is added to the wall, floor or ceiling definition. The layer is called "active" because it contains fluid filled pipes that either add or remove heat from the surface. In general, the definition process begins similarly to that of a normal wall. The active layer is described by 5 parameters (see Figure 60).

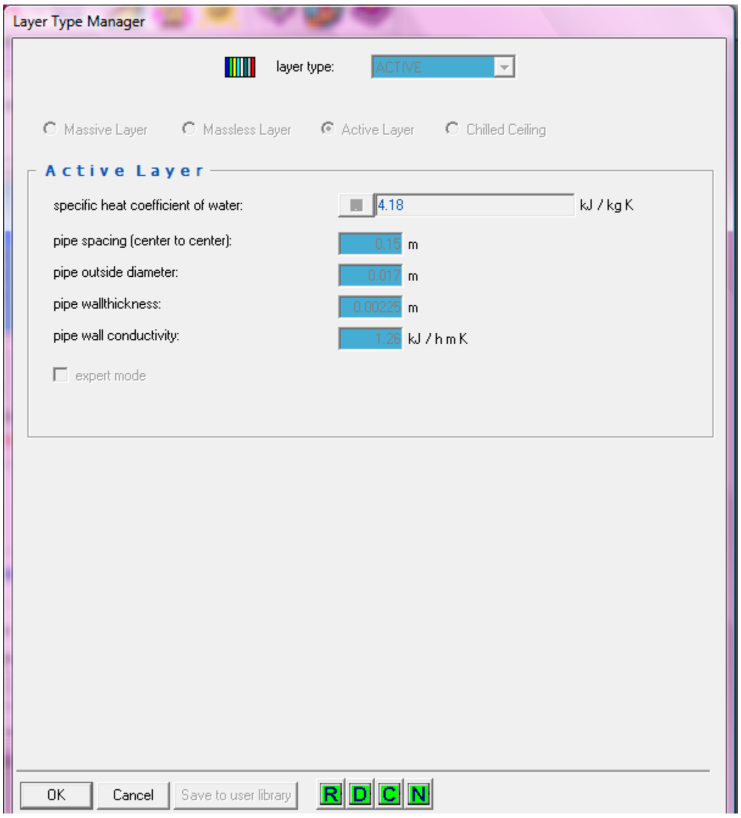


Figure 60 New active layer window

For surfaces containing an active layer, the convective heat transfer coefficient between surface and zone air depends on the temperature of the active layer. Consequently, it is recommended to use the internal calculation of heat transfer coefficient. After finishing the wall definition, the wall is marked with an "A" in the overview box of walls. In addition, a button for the active layer specification is displayed in the zone window. By clicking on this button entities like the inlet mass flow rate, inlet temperature, number of loops and additional energy gain at the fluid level (see Figure 61) can be modified. The number of loops is used for calculating the pipe length:

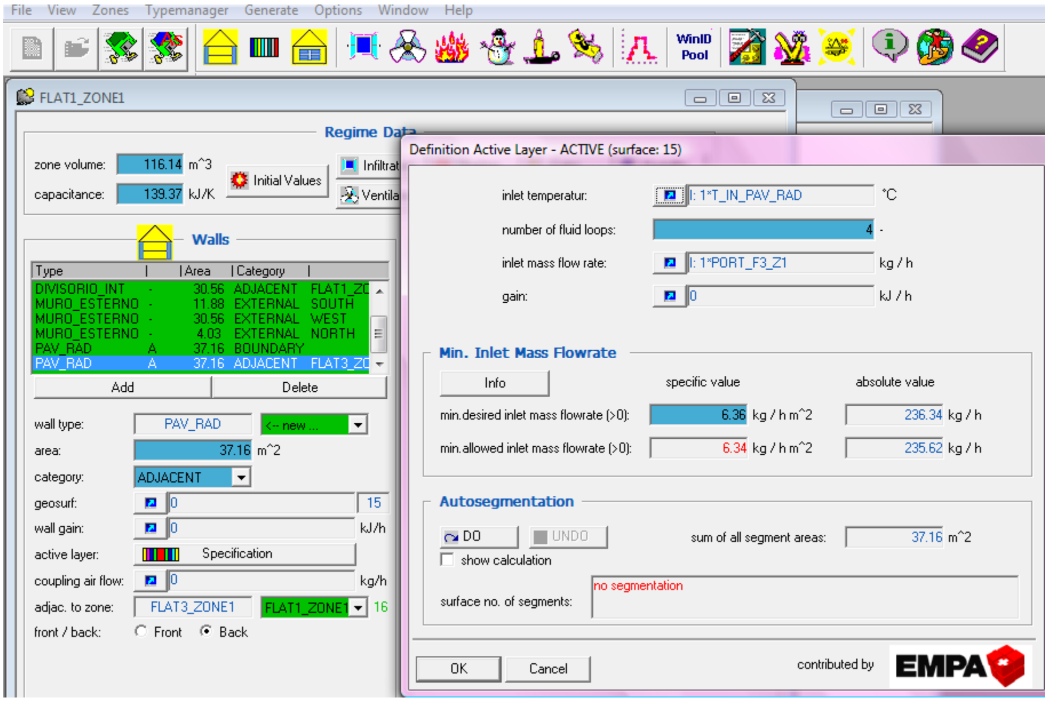


Figure 61 Active layer window

In this thesis the active layer is used to model the radiating floor of the Leaf House flats. When an active layer is defined, automatically, a new layer with the same properties of the layer above the active layer is added below.

Input of Windows

Windows can be defined for external and adjacent walls or as additional window without a related wall. If an external or adjacent wall (without coldbridge effect) is highlighted in the overview box of walls, the right part of the ZONE window allows the user to edit, delete or add windows for that particular wall. By clicking on a window within the overview box, the definition of the selected window is displayed below and can be edited (Figure 62).

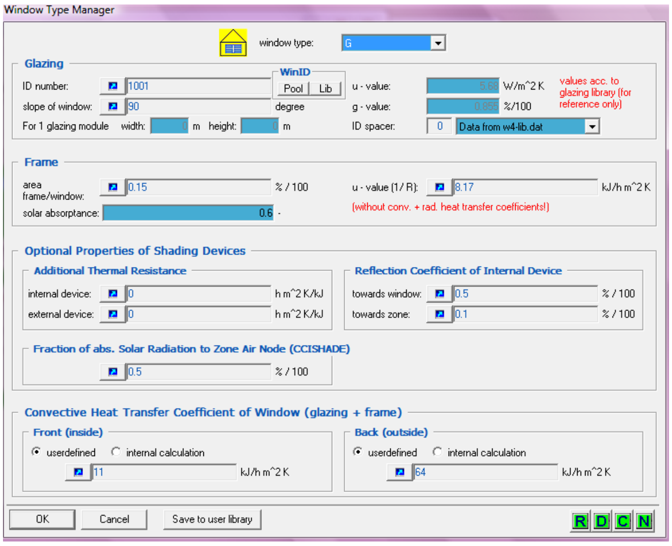


Figure 62 Window type manager

To define a new window the following parameters have to be known:

• WINDOW TYPE

The window type can be specified by using the pull-down menu on the right side. This menu offers the options of defining a new window type, selecting a window type out of a library or selecting a previously defined window type. The name of the selected window type appears in the display box. Also, TRNBUILD displays the Uvalue (describing window losses) and the g-value (solar heat gain coefficient or SHGC) of the selected window for user information (if available).

• AREA

When the *.BUI file is written, the entered area of the window will be subtracted automatically from the wall area.

• CATEGORY

The category is created automatically by TRNBUILD depending on the wall category (external or adjacent)

• GAIN

With gain an energy flux to the inside window surface can be defined

• ORIENTATION

The orientation needs to be defined for adjacent windows and so called “additional windows” (windows that do not relate to a wall). For the adjacent windows either the orientation of the front side or the back side can be used.

• SHADING DEVICE

For an EXTERNAL window the user can select an internal and/or external shading device and must specify its shading factor. As the DEF button indicates, the shading factor can be a constant, an input or a schedule. For an adjacent window an internal shading device can be defined at the FRONT side only. The display of further required input data adjusts automatically based on the window category. For the “view factor to the sky” (fraction of the sky to the total hemisphere seen by the window) a value ≤ 1 must be entered. For an unobstructed surface with the slope β, FSKY is calculated by the following equation: $FSKY= (1+\cos\beta)/2$ (i.e. 1 for a horizontal surface, 0.5 for a vertical surface with unobstructed view). The value is used as a weighting factor between ambient and sky temperature and thereby especially important for windows.

In the Leaf House model the shading devices have been introduced in order to simulate the real conditions of the rooms in which the shading elements were installed.

Infiltration

An air flow into the zone from outside the zone can be specified by INFILTRATION. The specification of infiltration is optional and the default setting of the infiltration is off. After clicking on the INFILTRATION button in the ZONE window, a dialog box opens as shown in Figure 63. The user can switch the infiltration on and define an infiltration type for the zone by selecting a previously defined type or a new type from the pull-down menu. In the leaf house infiltration is set to off (Figure 64).

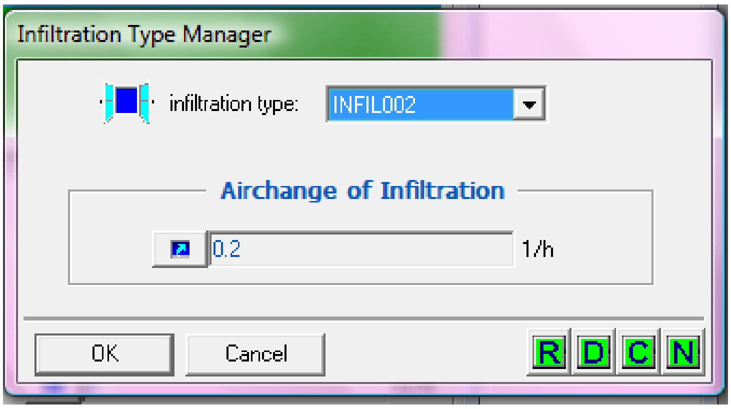


Figure 63 Infiltration Type manager

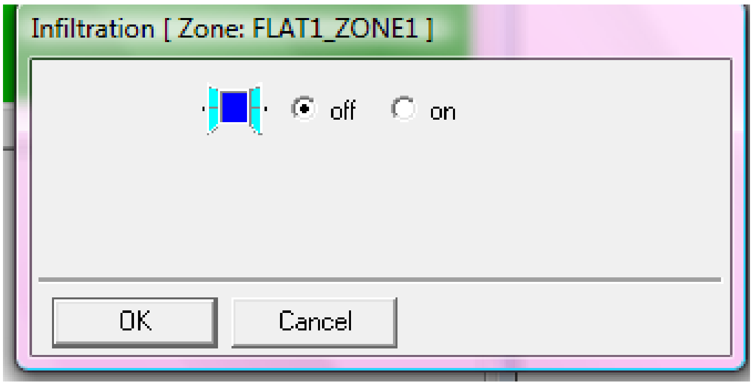


Figure 64 Leaf House infiltration setting

Ventilation

An air flow e.g. from heating or cooling equipment into the zone can be specified by VENTILATION. The specification of ventilation is optional and the default setting of the ventilation is off. After clicking on the VENTILATION button in the ZONE window, a dialog box opens as shown in Figure 65. The user can add/delete ventilation types by selecting a previously defined type or a new type from the pull-down menu.

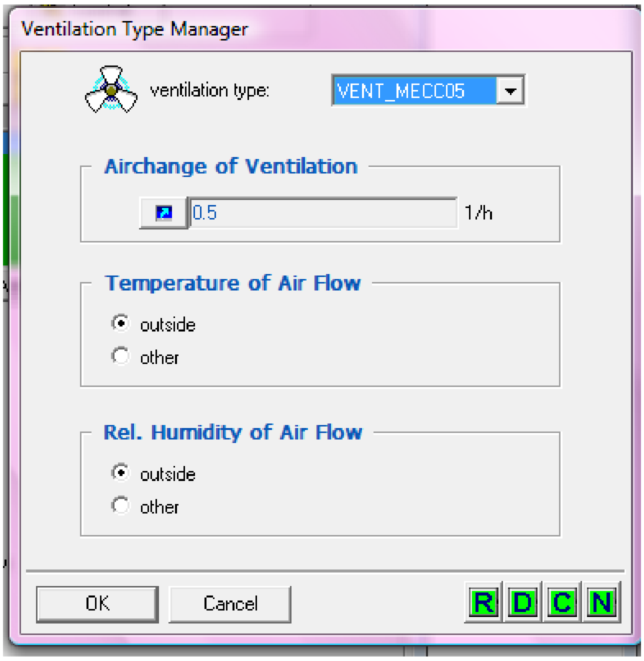


Figure 65 Ventilation type manager

The thermal exchanges due to mechanical ventilation in the Leaf House are evaluated setting up 0.1 or 0.2 volumes/hour of ventilation, depending on day time schedule (Figure 66). The $C0_2$ sensors activate the mechanical ventilation only when the CO_2 concentration is higher than the set point value while other sensors automatically stop the mechanical ventilation when windows are open.

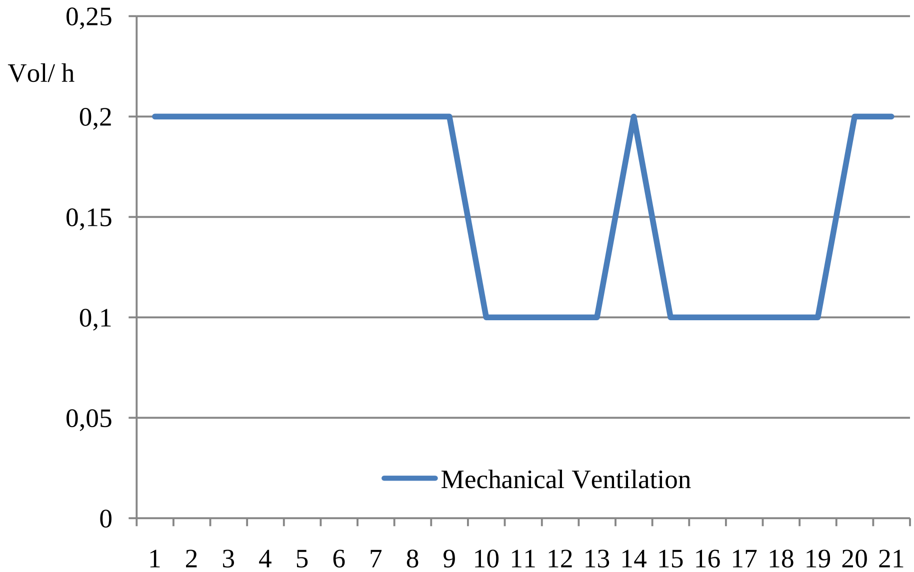


Figure 66 Mechanical ventilation schedule

Gains

Internal gains (including persons, electrical devices, etc. Figure 67) can be defined by GAINS. The specification of gains is optional. By default there are no gains defined.

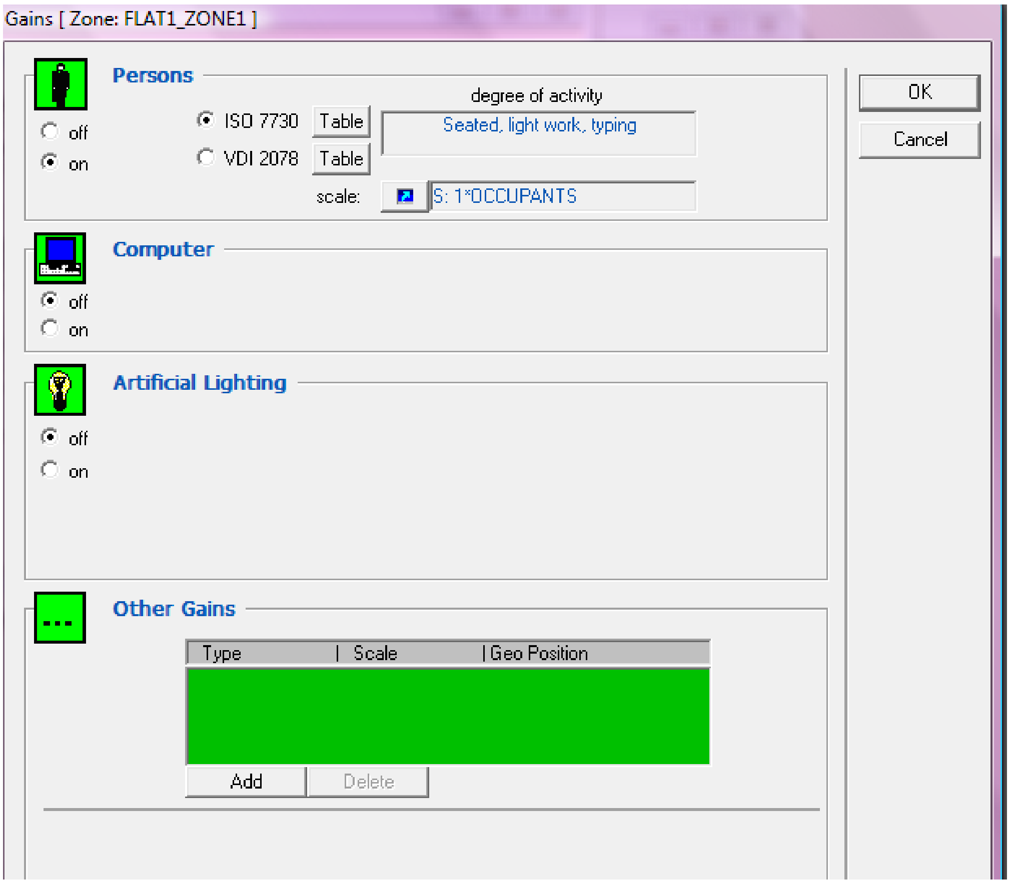


Figure 67 The standard GAINS window

In order to simplify the definition of common internal gains like persons, computers and artificial lighting, there are predefined options. The user can select the desired item from a pull-down menu (computer, artificial lighting) or tables (person) and then specify the scale by clicking the DEF button. The scale indicates the number of people or computers, because the predefined values correspond to a single person or computer only. For artificial lighting, the related floor area as well as the convective part must be defined in addition to the type of lamp. Also, the user can define a control strategy as an input or schedule (brightness control for optimal use of daylight, for example).

The thermal gains of the zones of the Leaf House are calculated through the TRNSYS "Gains" function: a detailed function that considers the number of people inside the house at all hours of the day, every day. Furthermore, different activity levels for the people in the house were set up as shown in Figure 68. In TRNSYS the Gains function is set considering the real presence of peole (one or two people) in the flat during the day.

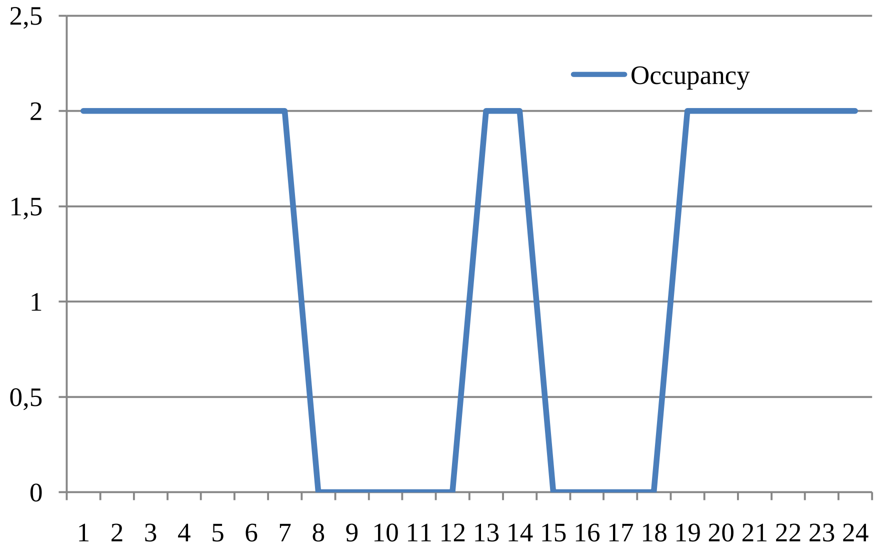


Figure 68 Example of the occupancy level daily schedule for flats 1-4

The zone division

In this paragraph a detailed description of the thermal zone division will be explained.

The thermal zones in which the LH was modeled are: two symmetrical zones for the ground and first floor apartments (Figure 69): Zone 1 (red area), Zone 2 (blue area); three symmetrical zones for the second floor flat (Figure 70):Zone 1(blue area), Zone 2 (red area) and Zone 3 (grey area). This inner division has been chosen to consider the temperature sensors position, this to allow the comparison between monitored temperatures and simulated ones.

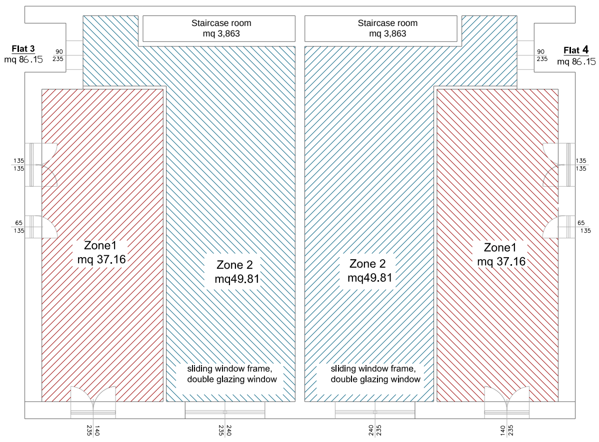


Figure 69 Three thermal zones in which the ground and first floor of the Leaf House are divided to

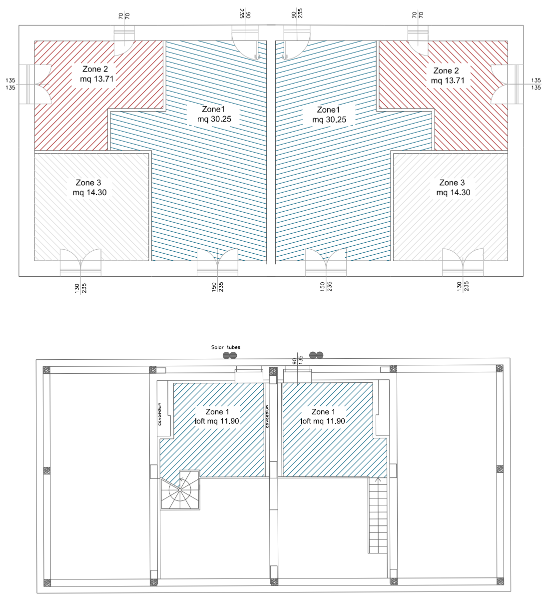


Figure 70 Three thermal zones in which the second floor flats are divided in

In the TRNBUILD simulation every flat has been simulated as divided in two or three thermal zones, as described in figure 70 and 71.

For each Zone the following REGIME data has been provided:

Table 26 Flat 1-Zone1 REGIME data (the same for Flat 2 Zone 1)

Zone volume	116.14	m^3
Capacitance	139.37	kJ/K
Initial Zone Temperature	20	°C
Initial Zone Relative Humidity	50	%

Table 27 Flat 1-Zone2 REGIME data (The same for flat 2 Zone 2)

Zone volume	155.66	m^3
Capacitance	186.79	kJ/K
Initial Zone Temperature	20	°C
Initial Zone Relative Humidity	50	%

Thanks to the symmetry these information are the same of the first floor flats.

For the second floor flat three thermal zones have been defined, the following tables describes the main characteristics:

Table 28 Flat 5-Zone 1 REGIME data (the same for Flat 6 Zone 1)

Zone volume	117.964	m^3
Capacitance	141.56	kJ/K
Initial Zone Temperature	20	°C
Initial Zone Relative Humidity	50	%

Table 29 Flat 5-Zone 2REGIME data (the same for Flat 6 Zone 2)

Zone volume	37.25	m^3
Capacitance	44.7	kJ/K
Initial Zone Temperature	20	°C
Initial Zone Relative Humidity	50	%

Table 30 Flat 5-Zone 3 REGIME data (the same for Flat 6 Zone 3)

Zone volume	38.85	m^3
Capacitance	46.62	kJ/K
Initial Zone Temperature	20	°C
Initial Zone Relative Humidity	50	%

Thanks to the symmetry these information are the same of the other second floor flat.

The following tables shows the composition of the external (Table 31) and of the roof (table 32).

Table 31 Wall layer composition

Layer Description	**s**	**l**	**R**
(From inner to outer surface)	[cm]	[W/mK]	[m²K/W]
Plaster	2,0	0,29	0,070
Poroton block 30	30,0	-	1,430
Cement plastering	1,5	1	0,010
Polistyrene Rofix EPS100	18,0	0,036	5,000
Plaster	2,0	0,3	0,070

Table 32 Roof layer distribution

Layer Description	s	λ	R
(from inner to outer surface)	[cm]	[W/m°C]	[m^2°C/W]
Plasterboard Pregyplac BA10	0.95	0.210	0.05
Plasterboard Pregyplac BA10	0.95	0.210	0.05
Plasterboard Pregyplac BA10	0.95	0.210	0.05
Klober Wallint T3	0.10	0.130	0.01
Wood fibre (170kg/m^3)	10.00	0.120	0.83
Rock wool	10.00	0.040	2.50
PermoEasy H	0.10	0.350	2,85*10^{-3}
Air space	4.00	0.280	0.14
Pinewood	2.00	0.120	0.17

Every zone is connected to the real orientation and is described in detail as in the following image. All the layers of the wall are here described in detail, as well as the connections with the other thermal zones, the zone volume, the ventilation, the layers composing wall. The "Ventilation type manager" adds a 0,2 volumes/hour ventilation, with an inlet temperature of 20°C.

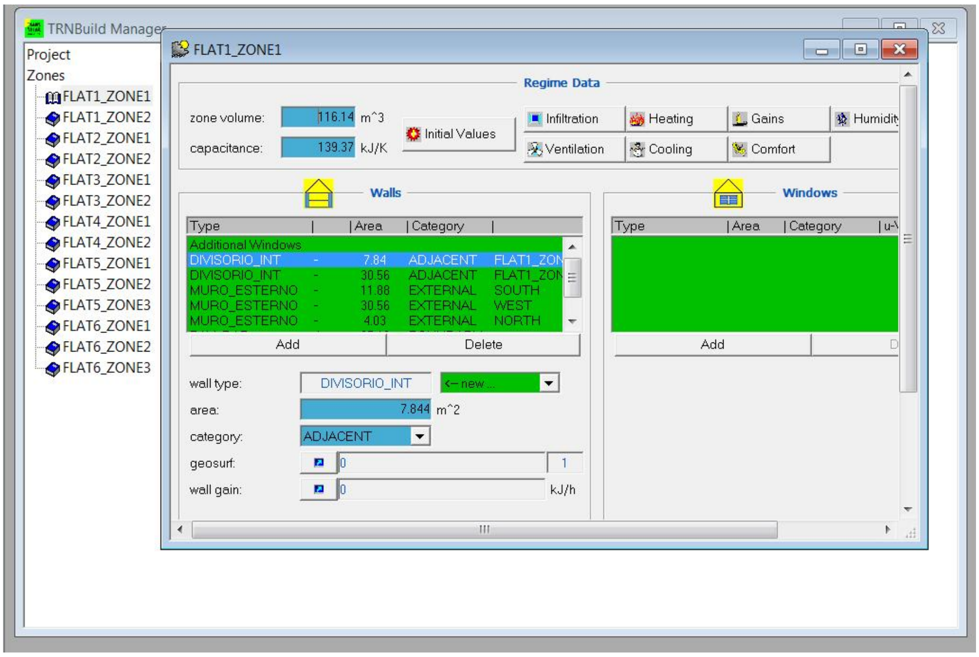


Figure 71 TRNBUILD interface : thermal zones

The following images show the layers used to define the different WALLS introduced in the model.

1.DIVISORIO_APP: it is made by three massive layers and two massless layers.

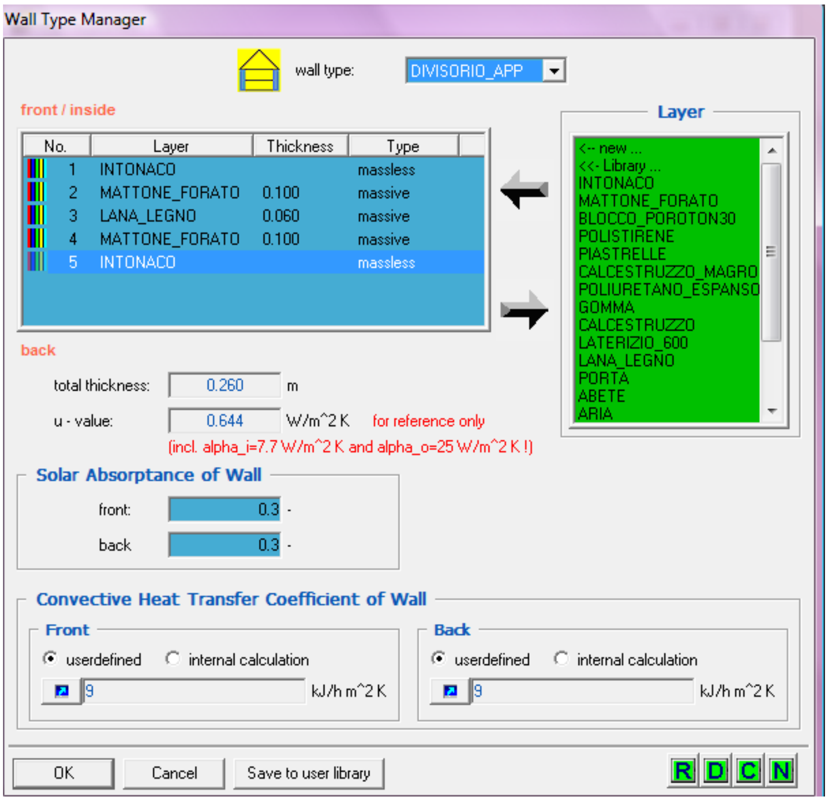


Figure 72 DIVISORIO_APP layer division

2.DIVISORIO_INT: it is made by one massive layer and two massless ones.

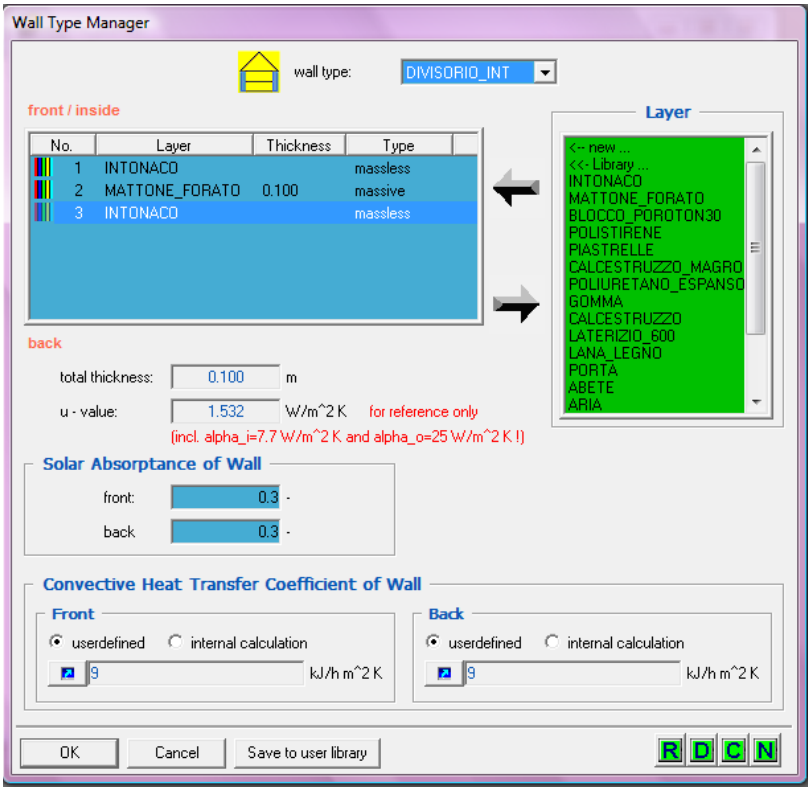


Figure 73 DIVISORIO_INT layer division

3.MURO_ESTERNO: it is made by two massive layers and two massless ones.

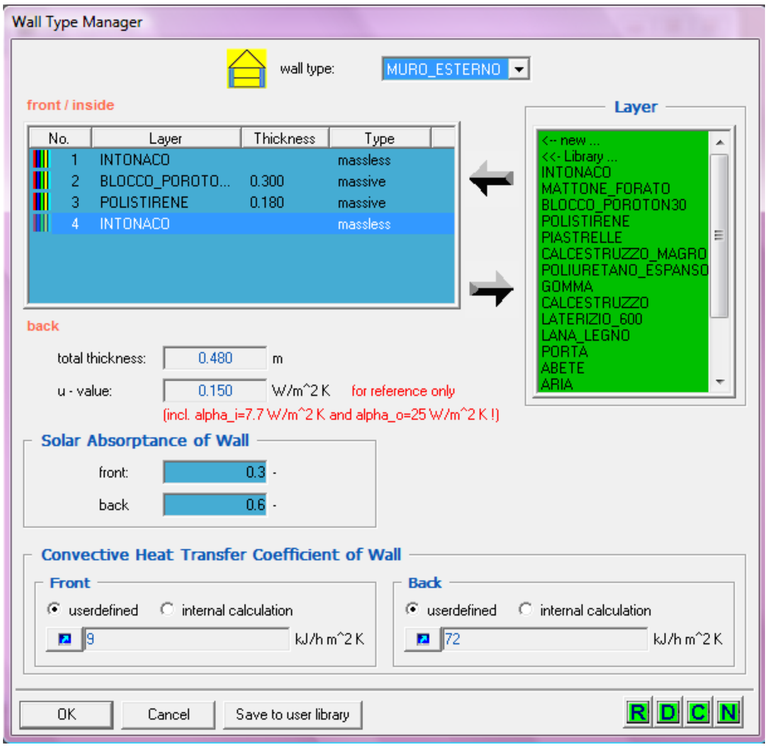


Figure 74 MURO_ESTERNO layer division

4.TETTO: it is made by five massive layers.

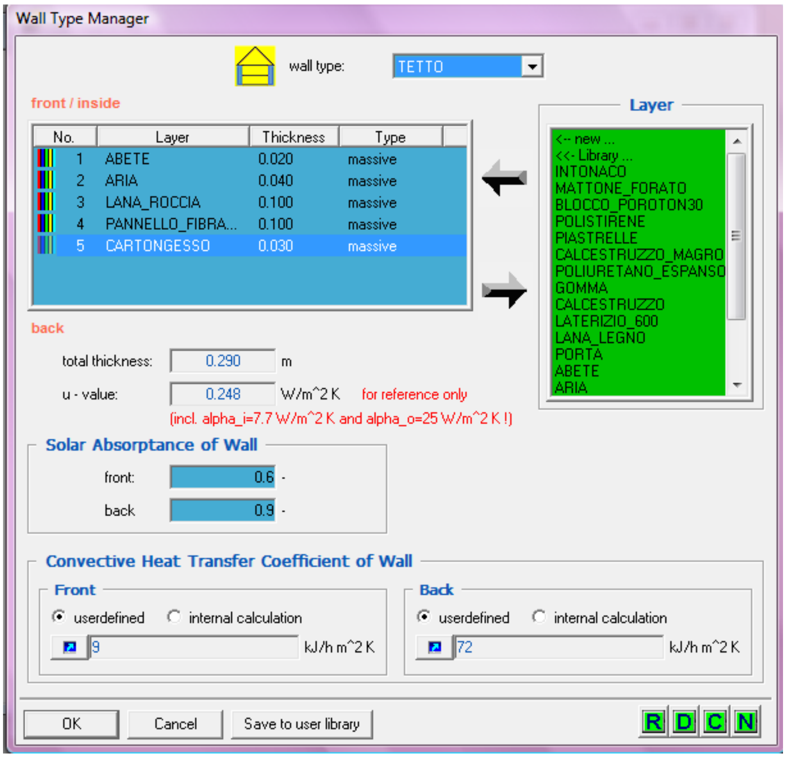


Figure 75 TETTO layer division

5.PAV_RAD: it is made by ten massive layers one massless one and an active layer.

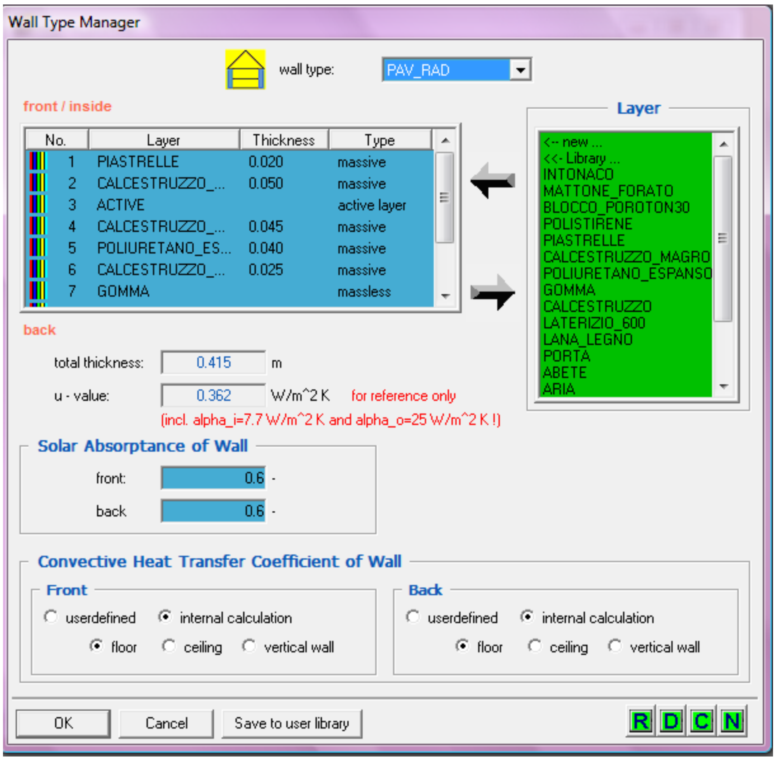


Figure 76 PAV_RAD layer division

6.PORTA: The door has been simulated by a massive layer

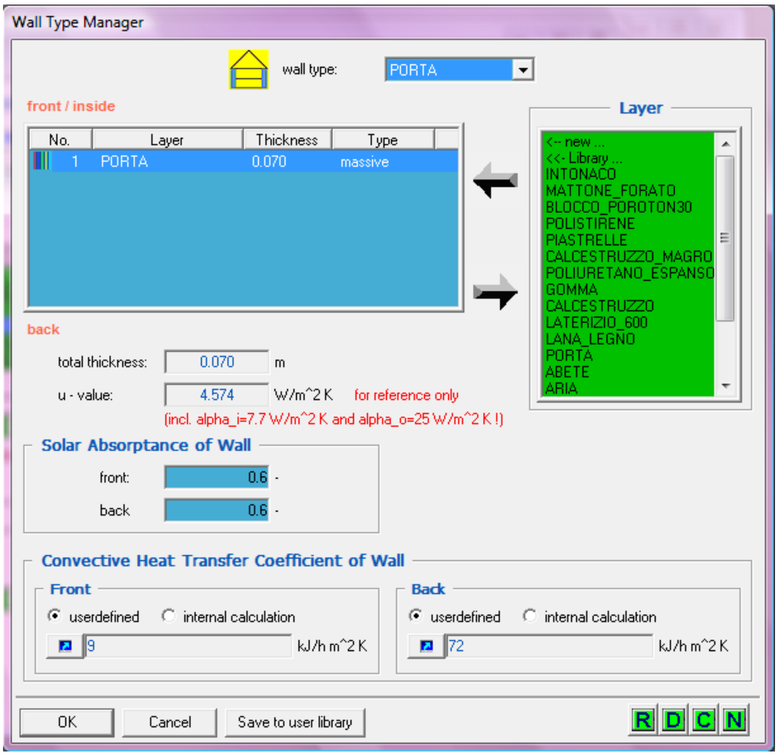


Figure 77 Porta layer division

7.SOFFITTO: the roof of a zone was simulated by seven massive layers and two massless ones.

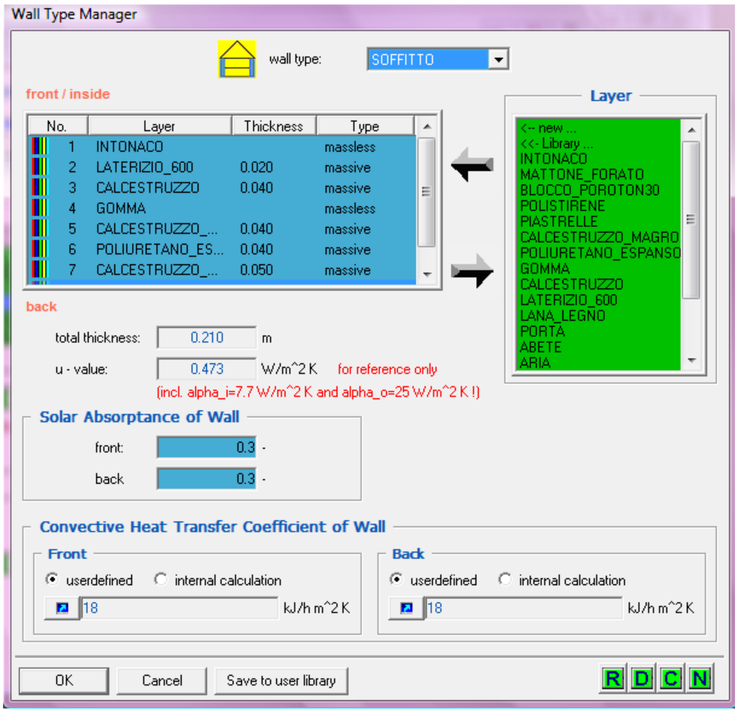


Figure 78 SOFFITTO layer division

8.SOFFITTO_TERRAZZA: the roof of the ZONE1 of the first floor flat has an external part so this particular roof has been defined, it is divided into six massive layers and a massless one.

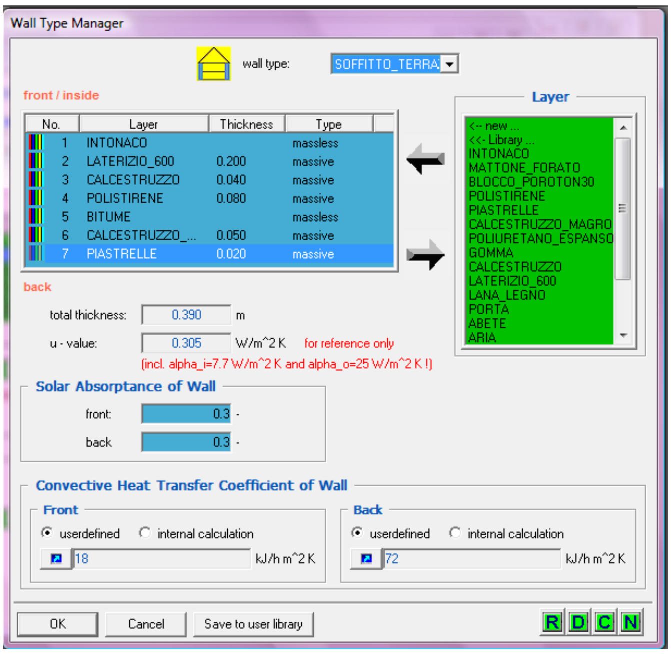


Figure 79 SOFFITTO_TERRAZZA layer division

More information about walls composition is represented in Annex II-BUI.inf file.

Gains

Thermal gains for the zone are calculated through TRNSYS "Gains" function: a detailed function describes the number of people inside the house at every hour of the day, every day. While choosing a degree of activity for the people in the house, TRNSYS calculates the hourly heating load.

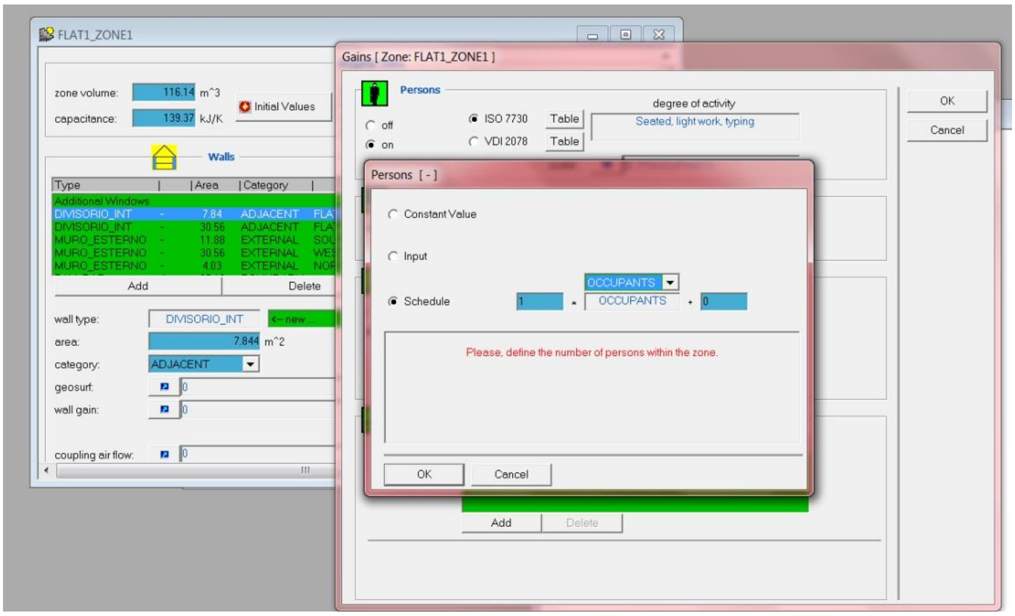


Figure 80 TRNBUILD interface : Gains

Active layer

The radiating floors are described in this page as an active layer in the walls. The incoming water temperature is calculated by TRNSYS while the inlet mass flow rate is divided in each zone on the thermal zone volume ratio, starting from the base flux.

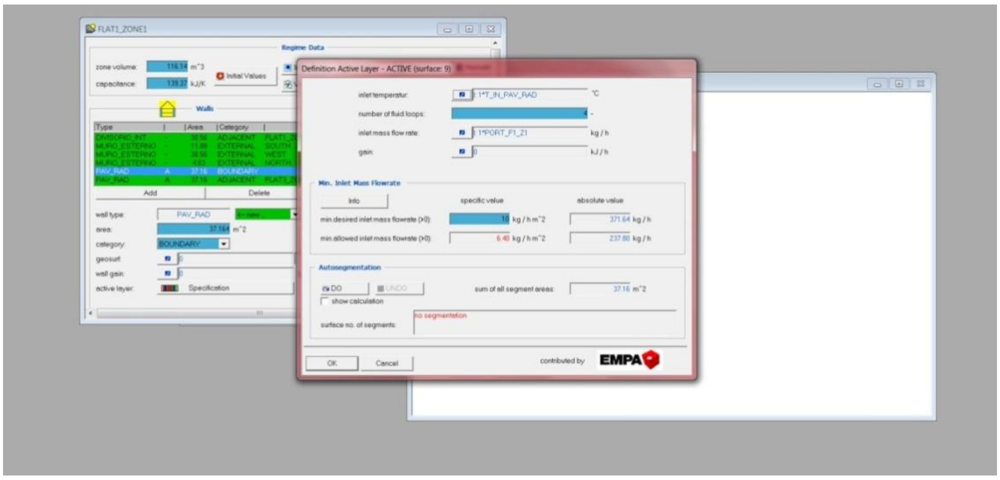


Figure 81 Active Layer

A screenshot of the simulation process running has been taken, thus completing the simulation description section. As in the legend, the colored lines represent the air temperature of the different thermal zones: two or three according to the flat considered.

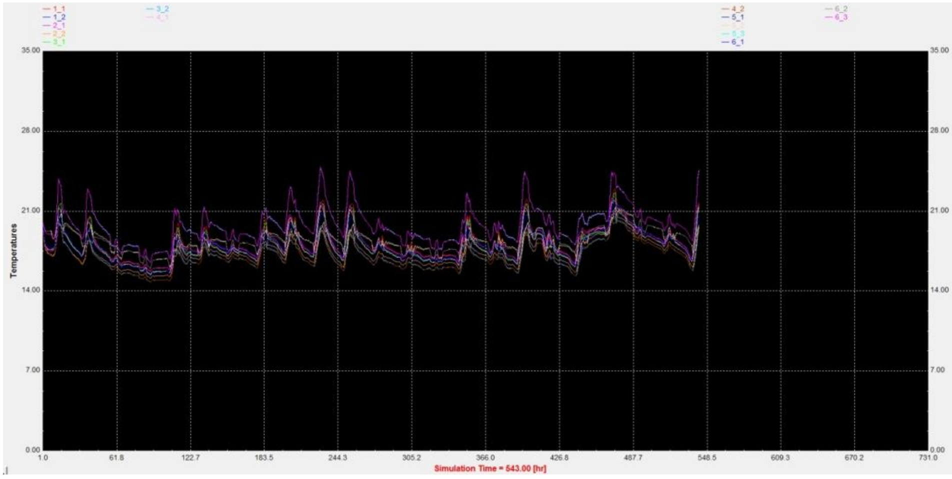


Figure 82 Simulation outputs – Inner air temperature

The thermal behavior of a building in TRNSYS is described by transfer functions rather than heat loss coefficients (U-values). For the calculation of these functions the building data must be entered in a special format. The program TRNBUILD provides an easy way to enter the necessary input data which creates the building description file. The Annex II show the file for the Leaf House (LEAF HOUSE.BUI) created by TRNBUILD.

6.4. Calibration of the model

The weather data for the 2009 have been directly implemented into TRNSYS in order to compare simulated to monitored data, as TRNSYS data files are made of average data collected for decades.

At first, the trends of the average air temperature of each thermal zone and the trends of temperature in some particular days were compared. The results of some comparisons are showed in the following figures where it is possible to see the good correspondence between monitored and simulated data.

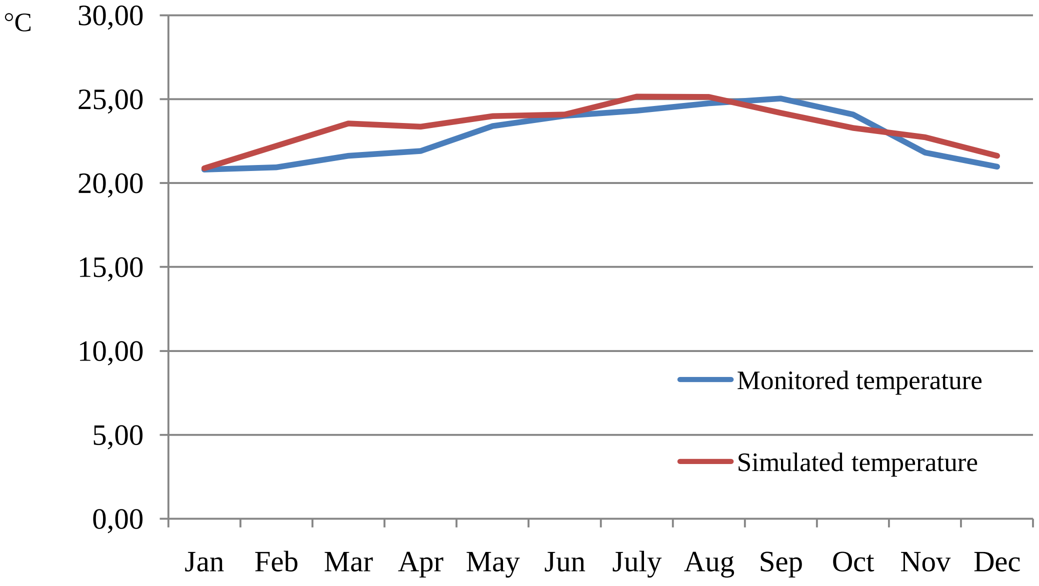


Figure 83 Comparison of the average air temperature of flat 3

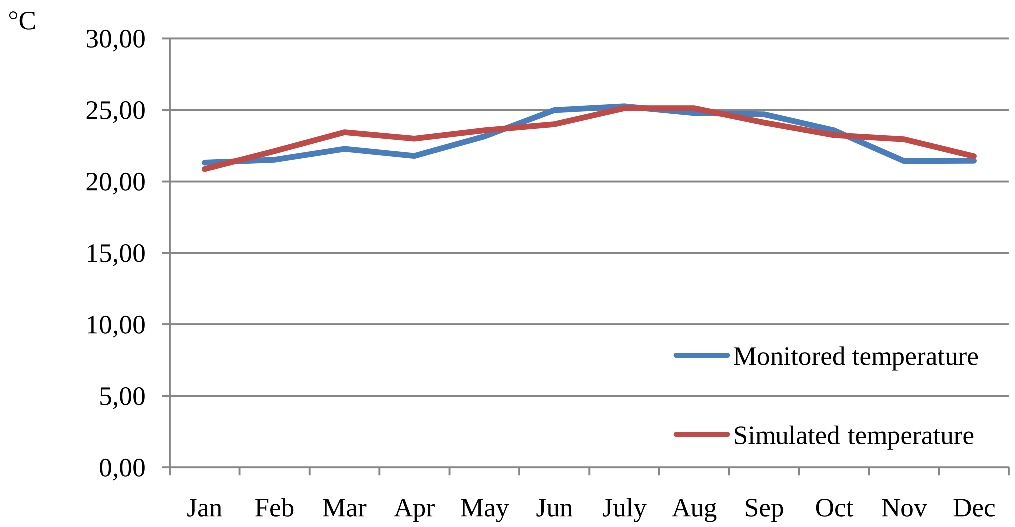


Figure 84 Comparison of the average air temperature of flat 4

The average difference between monitored and simulated data is 0.8 °C for figure 83 and 0.6 °C for figure 84. The highest difference is 1.5 °C for the Figure 83and around 1 °C for the graph represented in Figure 84.

To study the answer of the dynamic model, the temperature trends in particular days were analyzed.

Four days have been chosen:

- 24th January (Cloudy cold),
- 6th March (Sunny cold),
- 24th July (Sunny hot),
- 4th August (Cloudy hot).

The average temperature of the air in all thermal zones of the LH has been calculated, as well as the PV production. Figure 86 describes the air temperature calculated in two different thermal zones during 24th July. Also the Load Match Index has been considered when evaluating the results.

24th July Sunny hot

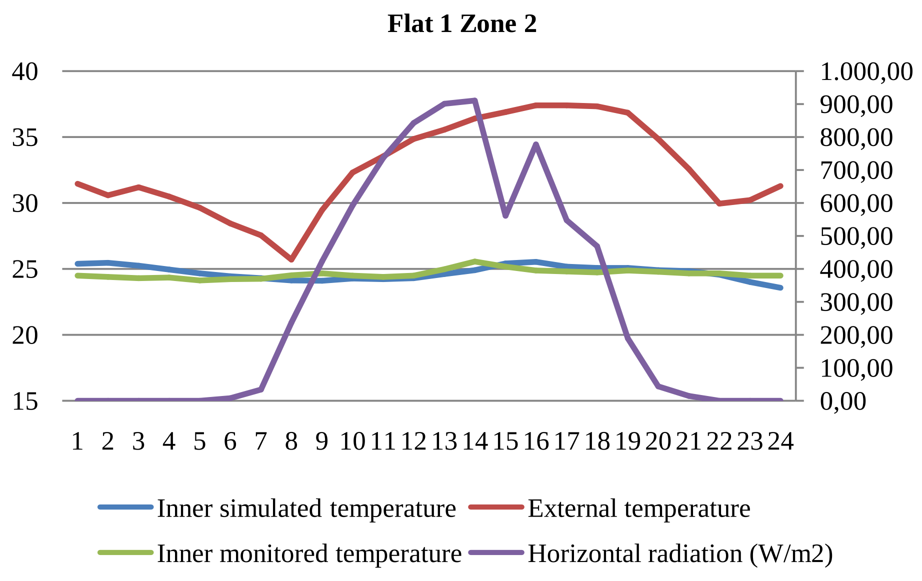


Figure 85 Comparison between monitored and simulated air temperature data for July 24th

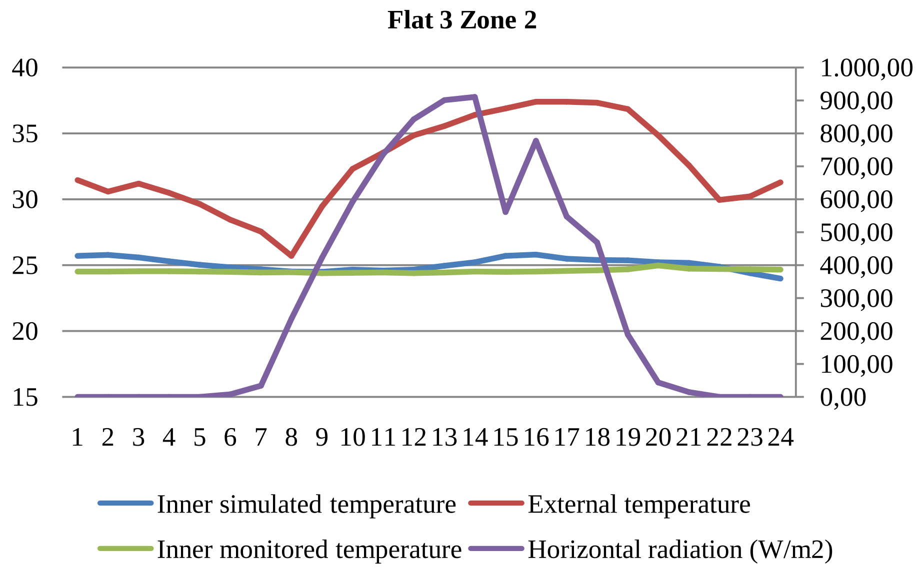


Figure 86 Comparison between monitored and simulated air temperature data for July 24th

The average difference between simulated and monitored data is 0.4°C for the first and 0.5°C for the second graph, while the maximum difference is respectively around 1°C and 1.4°C.

In Figure 87 some energy data are compared.

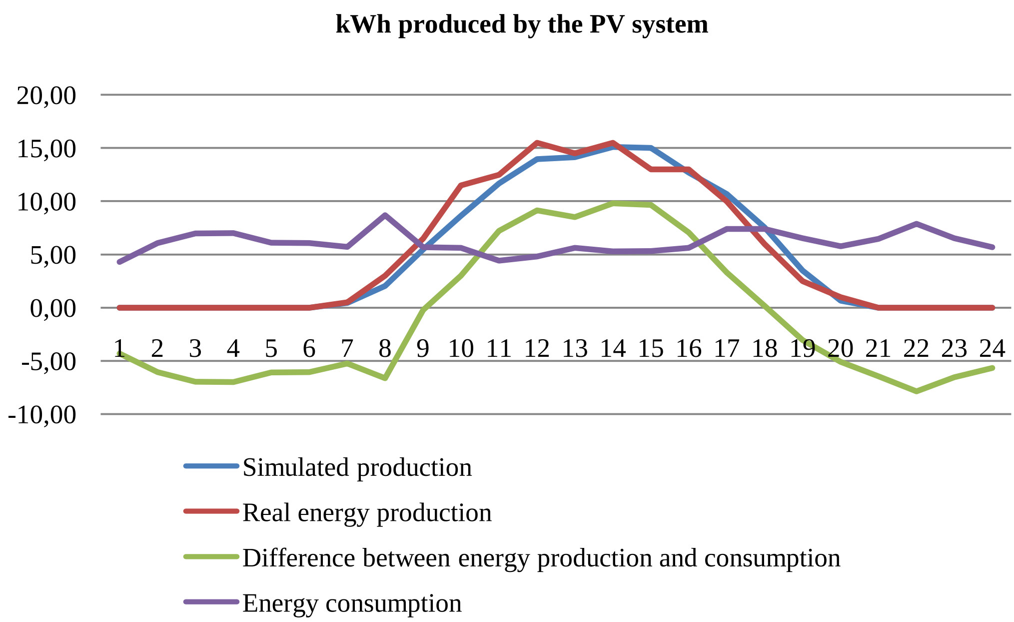


Figure 87 Comparison between monitored and simulated energy production data for July 24th

In order to calibrate the model, the Load Match Index (LMI) that is defined as the minimum value between 1 and the ratio of the electrical production and the load, has been calculated. It can be used to better understand how much and when the energy production of the LH is mismatching or not the energy needs.

$$\text{Load Match Index} = \min\left[1, \frac{on-site\ generation}{Load}\right]$$

When LMI index is 1, it means that the system produces more energy than the real needs of the system. Figure 88 shows the Load Match index trend for the hot sunny day.

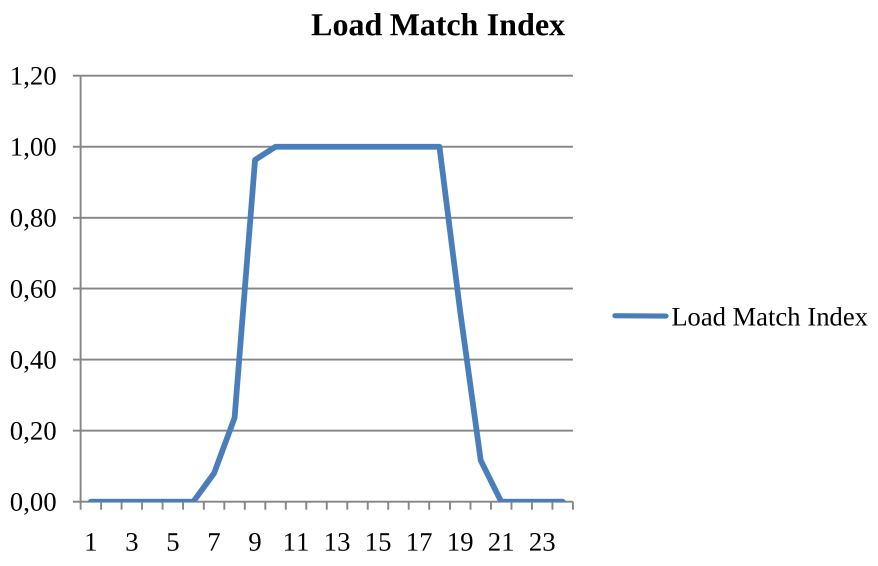


Figure 88 Load Match Index for the hot sunny day

The monitored data in 2009 show an energy production of 25,651 kWh from the PV panels. In the TRNSYS model, the calculated production was 25,143 kWh per year.

The simulation gives a value smaller than the monitored one, with an error of 2 %.

A further validation of the model was made by comparing the monitored and simulated data of the electrical needs of the GHP .The simulated data for the heating season is about 4.7 MWh while the simulated cooling consumption is 2.7 MWh. Comparing with monitored value of 7.9 MWh/year, there is an error of about 6%. These data are close enough to claim that the simulation results are acceptable.

6.5. Results

Photovoltaic model

The monitored data for 2009 show an energy production of 25651 kWh from the photovoltaic panels. The simulated production from TRNSYS is 25143 kWh for the year, while the PVSYST simulation gives as result 24160 kWh / year. The precision of the two results is high enough to consider significant and solid the two models.

Both approaches give a lower value than the monitored one : the TRNSYS model has a degree of error of the 2 %, while the PVSYST reaches the 6 %.

The results are summarized in the following graph.

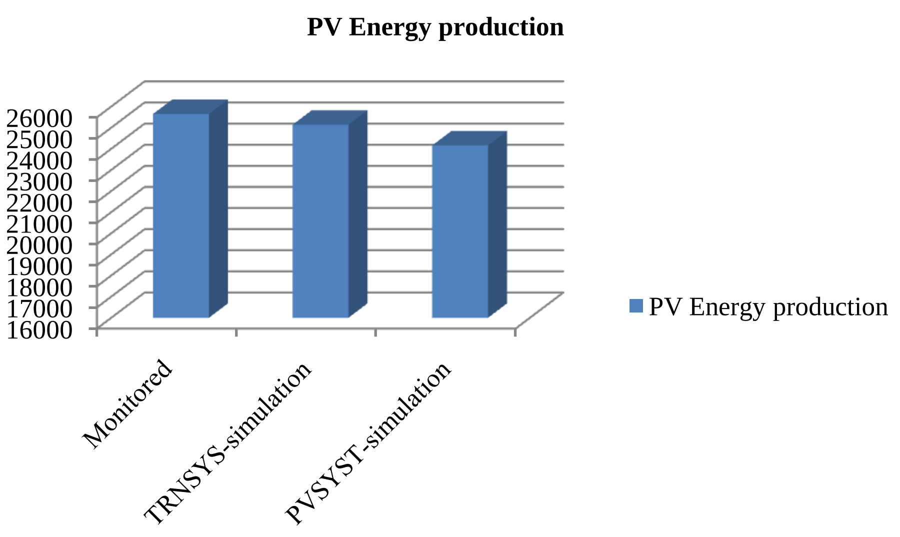


Figure 89 Monitored and simulated photovoltaic energy production

HVAC model

In evaluating the results of the heating model, far more complex from the PV one, it must be taken in consideration that both the simulated system is more simple than the operating one and many assumptions have been made in order to obtain an instrument that could study the real plant system. The calibration of the model has been made on both the temperature results compared to the average values in the year and on the heat pump electricity demands, calculated by TRNSYS.

Before moving to the description of the temperature results, the heat pump electricity absorption results will be briefly described.

The real HP uses nearly 5.3 MWh for the heating season and 2.6 MWh for the cooling one. The simulated data for the heating season is close to 4,7 MWh while the simulated cooling consumption is 2.7 MWh. Those data are close enough to claim the simulation results as acceptable: the difference between simulated and monitored data is around 6 %.

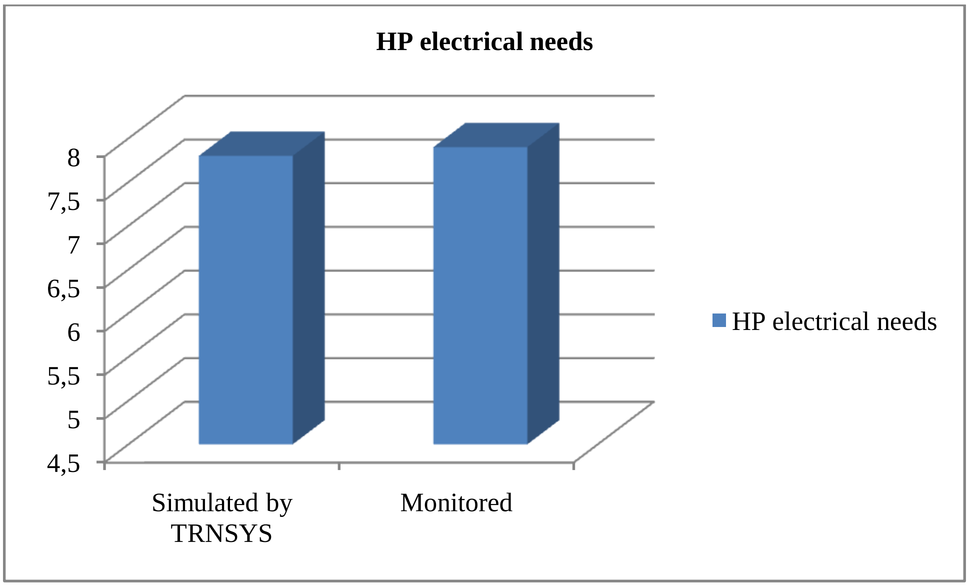


Figure 90 Simulated and monitored heat pump electrical needs

Average values have been calculated from the results of the simulation for the air temperature in every thermal zone and are aggregated on monthly and later seasonal base, in order to have some temperature information for every flat, during the year.
There are differences as it is not possible to avoid in a similar context, but they are not macroscopic and anyway do not ruin the model's similarity to the real plant.
The collection of data is also arranged in graphs for a better understanding.

SIMULATED	1	2	3	4	5	6
Jan	17,68	17,66	17,38	17,35	18,59	18,58
Feb	18,88	18,80	18,56	18,48	20,05	19,96
Mar	20,79	20,71	20,54	20,46	22,15	22,06
Apr	23,36	23,08	23,16	22,88	24,76	24,42
May	22,10	21,79	22,15	21,84	23,84	23,44
Jun	21,14	21,08	21,25	21,19	22,68	22,59
July	23,01	22,98	23,20	23,17	24,71	24,64
Aug	23,09	23,08	23,26	23,25	24,84	24,81
Sep	20,94	20,88	21,01	20,95	22,58	22,48
Oct	21,47	21,44	21,33	21,29	22,83	22,79
Nov	20,82	20,98	20,57	20,73	21,82	22,01
Dec	18,55	18,65	18,23	18,34	19,39	19,53

MONITORED	1	2	3	4	5	6
Jan	17,33	17,86	20,80	21,31	18,00	17,13
Feb	21,67	21,37	20,93	21,52	18,93	18,96
Mar	21,73	21,91	21,62	22,27	19,98	21,15
Apr	21,50	21,13	21,91	21,77	20,08	20,39
May	22,75	22,18	23,40	23,15	23,01	23,01
Jun	23,06	23,59	24,01	24,99	23,95	25,18
July	24,20	24,62	24,32	25,26	26,01	26,06
Aug	24,31	24,46	24,75	24,78	25,91	25,58
Sep	25,10	24,52	25,04	24,69	24,37	24,19
Oct	24,19	24,06	24,09	23,58	21,93	22,31
Nov	22,57	21,72	21,81	21,43	19,08	20,66
Dec	22,62	21,10	20,97	21,43	20,11	20,86

Table 33 Average monthly simulated and monitored temperatures

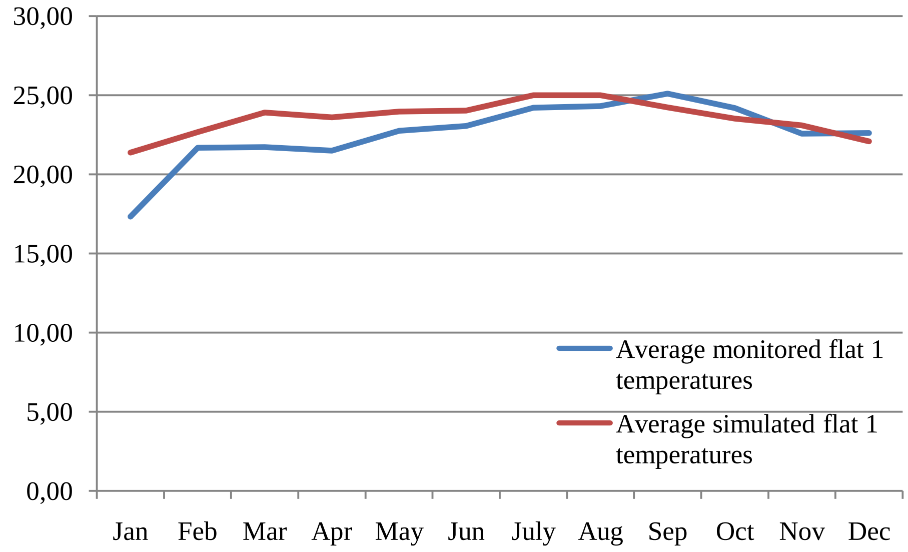


Figure 91 Average flat 1 temperatures

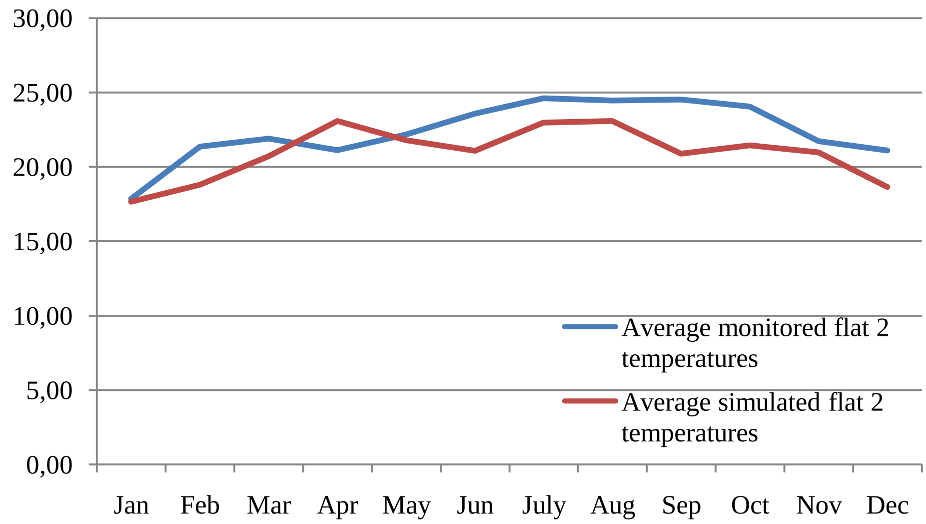


Figure 92Average flat 2 temperatures

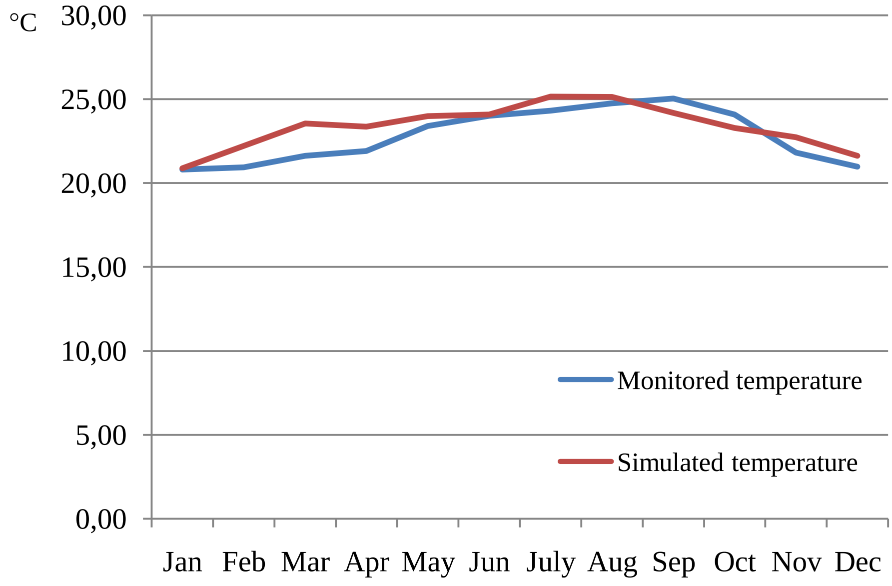


Figure 93Average flat 3 temperatures

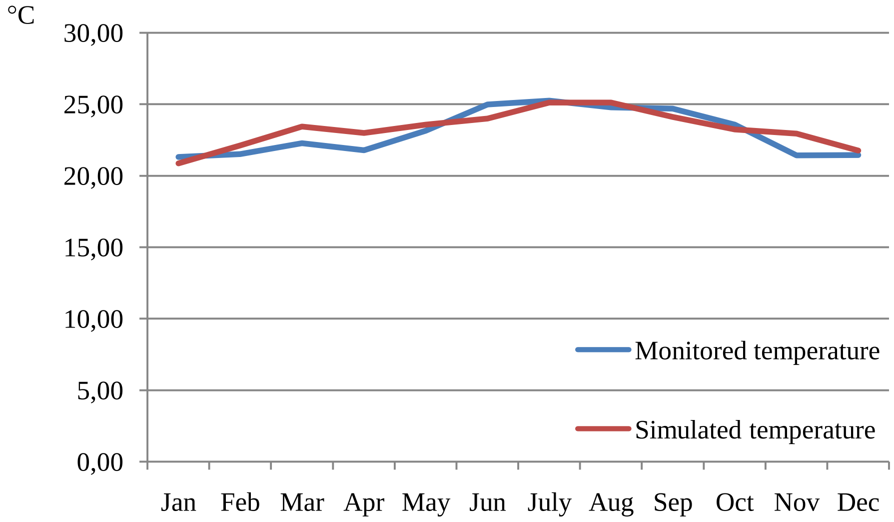


Figure 94Average flat 4 temperatures

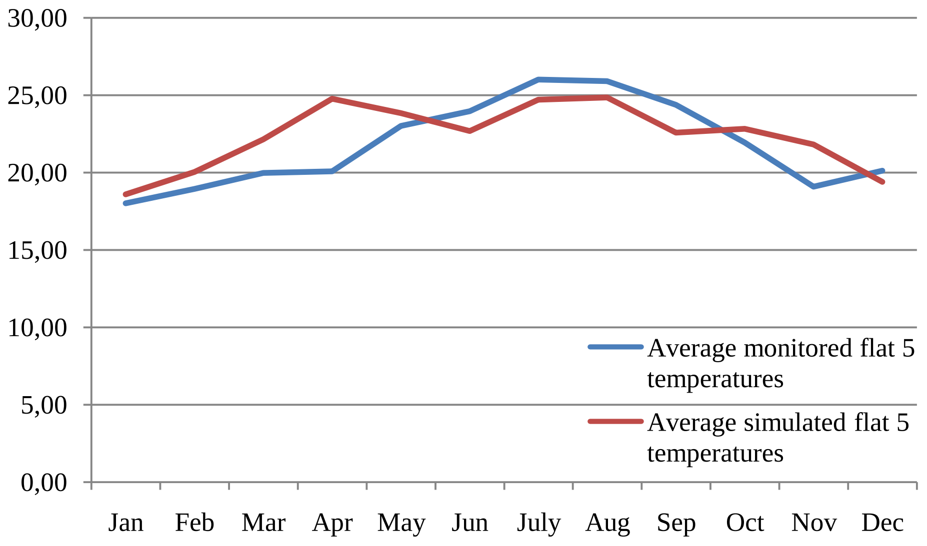


Figure 95 Average flat 5 temperatures

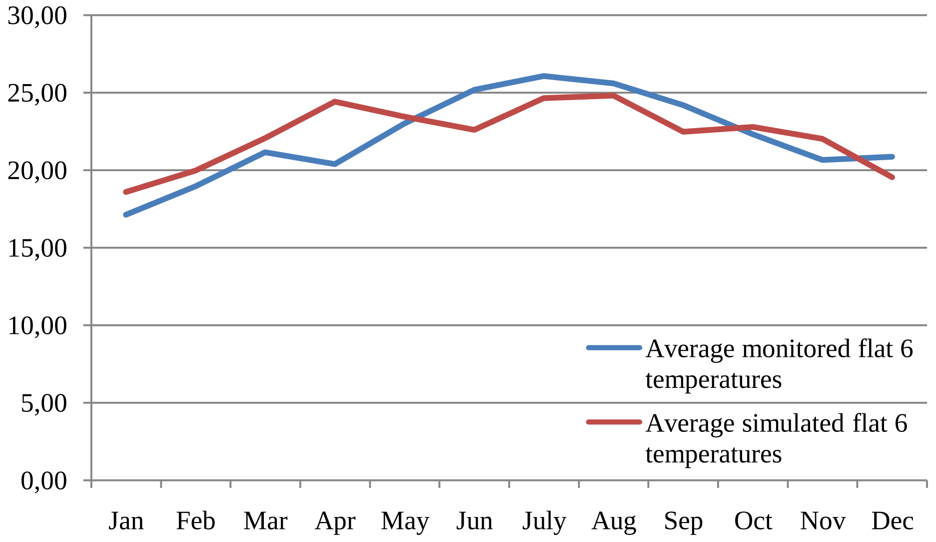


Figure 96 Average flat 6 temperatures

On a seasonal base, the aggregated results are described below.

Table 34 Seasonal simulated and monitored data

		Flat 1	Flat 2	Flat 3	Flat 4	Flat 5	Flat 6
Simulated	Oct-April	20,21	20,19	19,96	19,94	21,35	21,33
	May-Sept	23,00	22,91	23,09	23,00	24,70	24,57
Monitored	Oct-April	21,83	21,37	21,77	21,93	19,79	20,35
	May-Sept	23,88	21,77	24,31	24,57	24,86	24,63

The sensitive and latent heat needs have been evaluated through TRNSYS.

The aggregated data for the year show 8.8 MWh heating needs and 12.7 MWh of cooling needs. Yearly latent needs are nearly 10 MWh. The Sentitive / Total heat ratio is around 0,69.

Data in the following graphs is expressed in kWh and represent the trend over the year of both sensitive and latent heat needs for the LH.

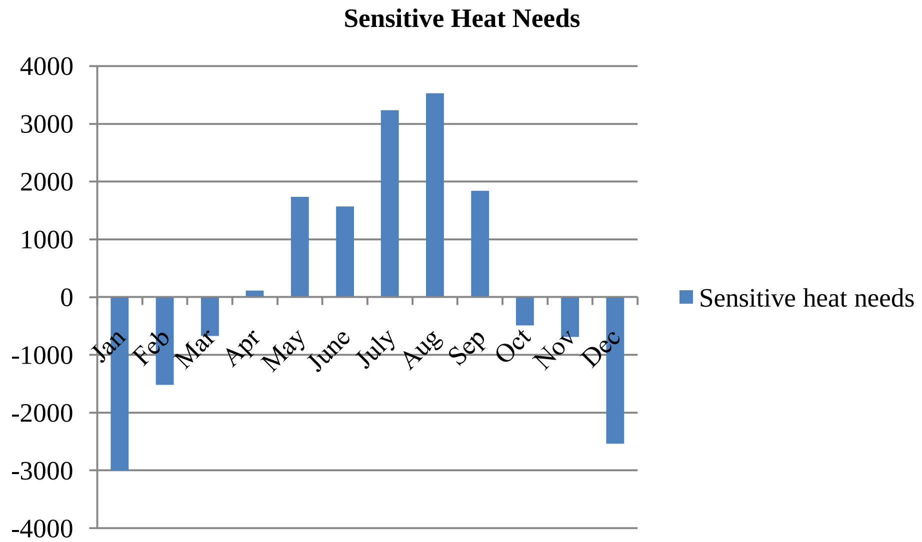


Figure 97 Sensitive heat needs

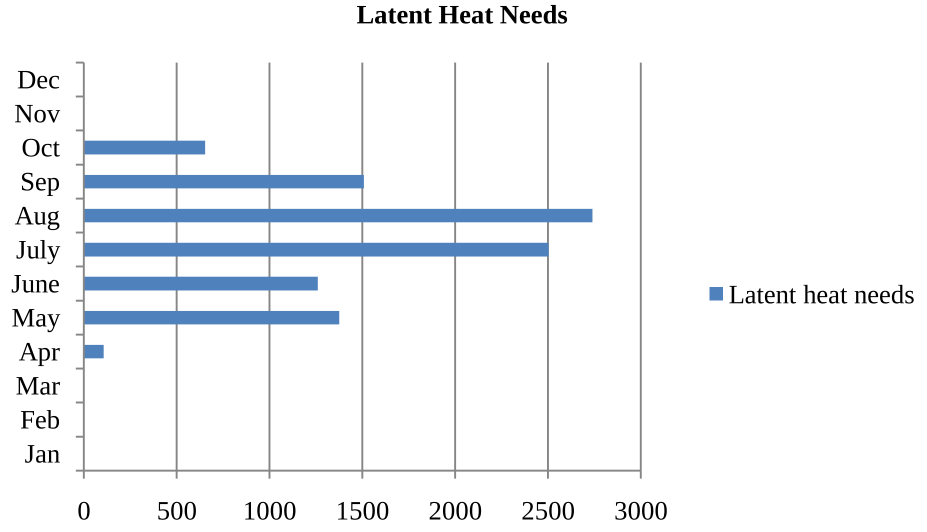


Figure 98 Latent heat needs

The in-depth heat exchange of the heat pump and the solar system in the heating season has also been evaluated.

The inlet and outlet temperature of the fluid from both the subsystem have been simulated for a year and the heat exchanged has been evaluated. The solar system produces nearly 4 MWh (4 227 kWh monitored) while the HP around 18.5 MWh during the year.

The ratio Solar heat / Total heat is 0.18.

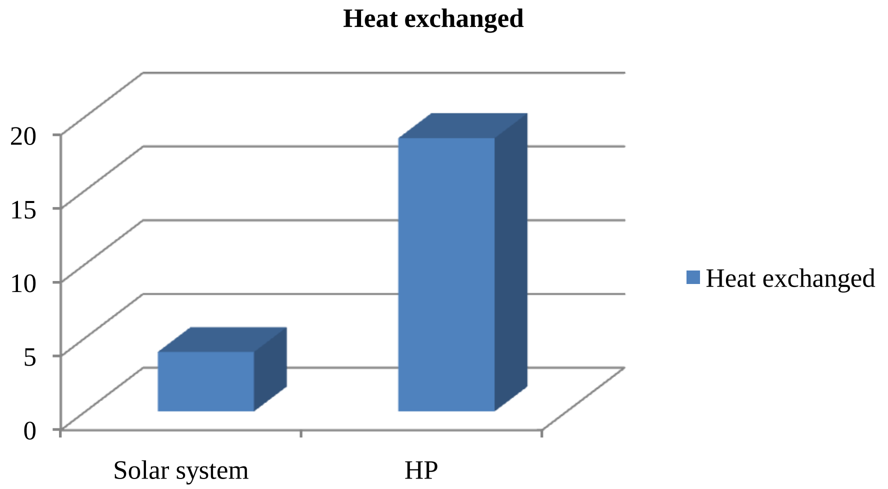


Figure 99 Heat exchanged

6.6. Single day analysis

Temperatures

The analysis has been pushed on to a higher level of accuracy. The simulated data have been collected, studied and compared to the monitored data of the single day.

Some critical days, in terms of temperature and insulation, have been analyzed. Four days have been chosen with particular characteristics of insulation and temperature : as the literature describes them, they are the hot sunny day, hot cloudy day, cold sunny and cold cloudy day.

The definition of the hot\cold parameter has been made according to the temperature data available for the whole 2009. Average values for the month considered and the single day have been evaluated, in order to compare the temperature trend for the single day to the context in which it found itself.

On the same way the sunny\cloudy specification, has been analyzed in term of solar insulation. Average values for the insulation have been calculated from the hourly data, in order to compare the average monthly value on hourly base, with the daily average value on hourly base.

The four days chosen are : 24^{th} January (Cold Cloudy), 6^{th} March (Cold sunny),24^{th} July (Sunny hot), 4^{th} August(Sunny cloudy).

The results are summarized in the following tabs.

Table 35 Average temperature and solar radiation on horizontal

Month	**Temperature (°C)**	**Solar radiation on horizontal (W/m^2)**	**Day**	**Temperature (°C)**	**Solar radiation on horizontal (W/m^2)**
Jan	7,75	107,84	**24th Jan Cold Cloudy**	6,16	55,93
Mar	10,32	271,25	**6th Mar Cold Sunny**	8,98	311,13
July	25,16	433,19	**25th July Hot Sunny**	28,20	454,92
Aug	25,23	409,57	**4th Aug Hot Cloudy**	20,75	223,29

As it is possible to see the chosen days are significant for the differences or similarities to the average values.

The cold cloudy day (24th Jan) shows an average temperature lower of nearly 2 degrees than the average monthly value while the solar radiation on horizontal value is almost a half of the monthly one.

The cold sunny day (6th March) shows a temperature way lower than the monthly value, while the solar radiation on horizontal value is only a little higher if compared to the monthly value, as expected.

The hot sunny day shows a temperature more than 3 degrees higher than the monthly average and an solar radiation on horizontal value comparable to the monthly value.

The hot cloudy day shows a lower temperature than the average values in august, but that is clearly explainable with the value of solar radiation on horizontal, that is nearly a half of the average one.

It is now possible to summarize the results of the evaluation and simulation process.

The following graphs represent the monitored and the simulated temperature in the thermal zone of interest, the external temperature and the value of horizontal radiation.

January,24th, Cold cloudy

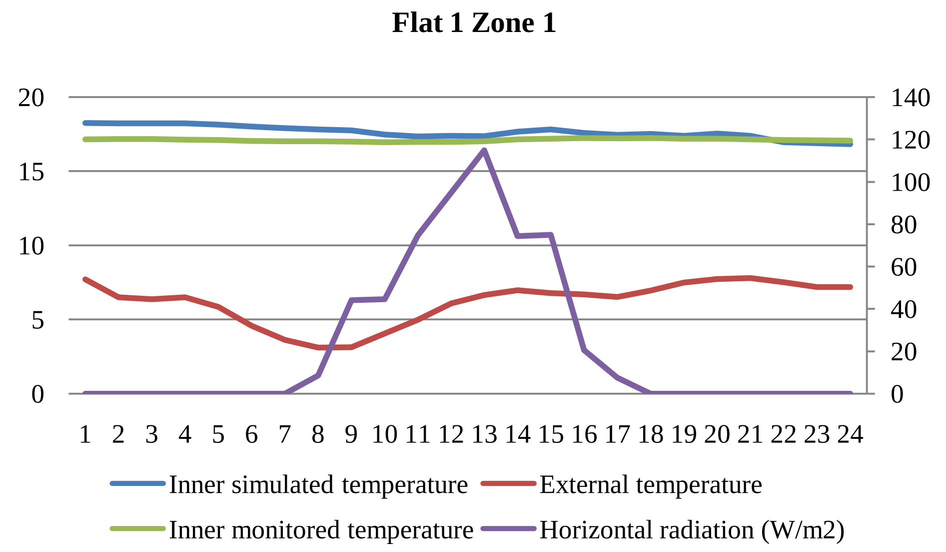


Figure 100 Flat 1 Zone 1, Temperatures

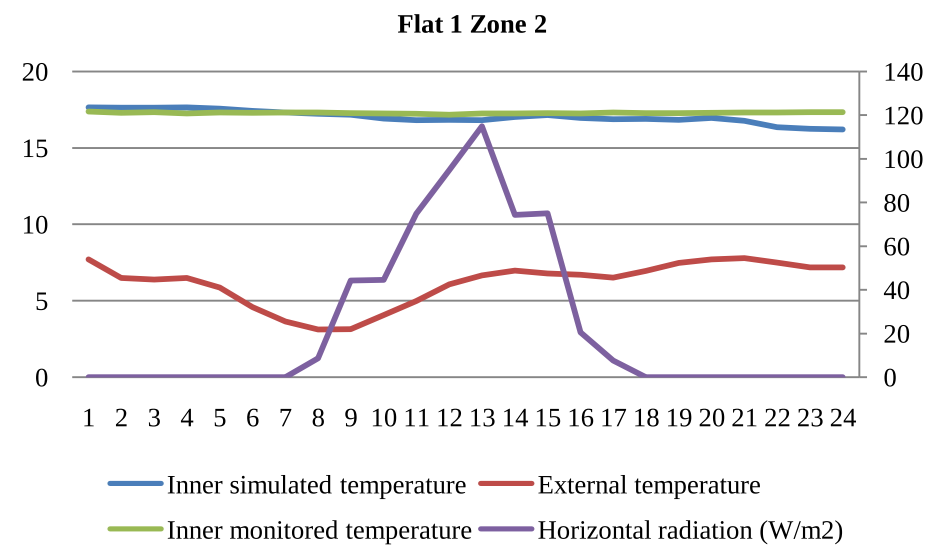


Figure 101 Flat 1 Zone 2, Temperatures

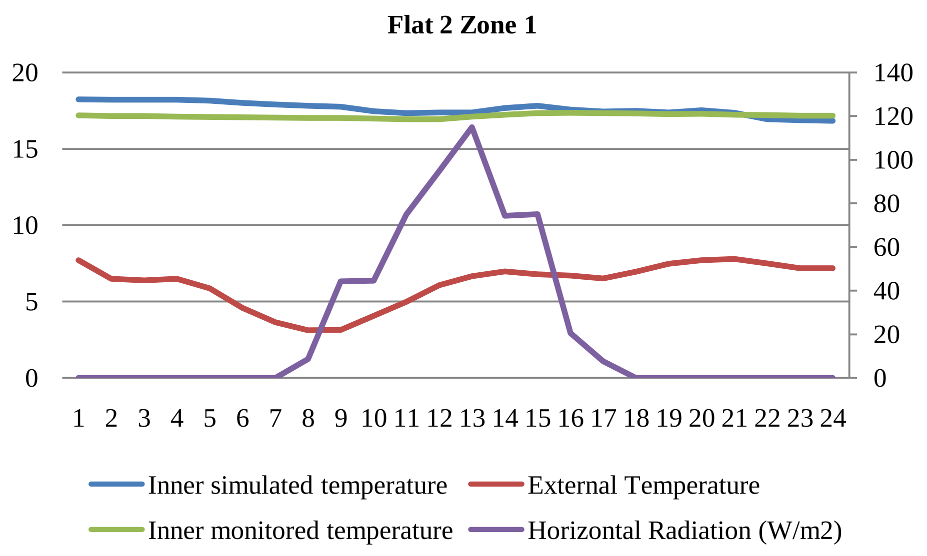


Figure 102 Flat 2 Zone 1, Temperatures

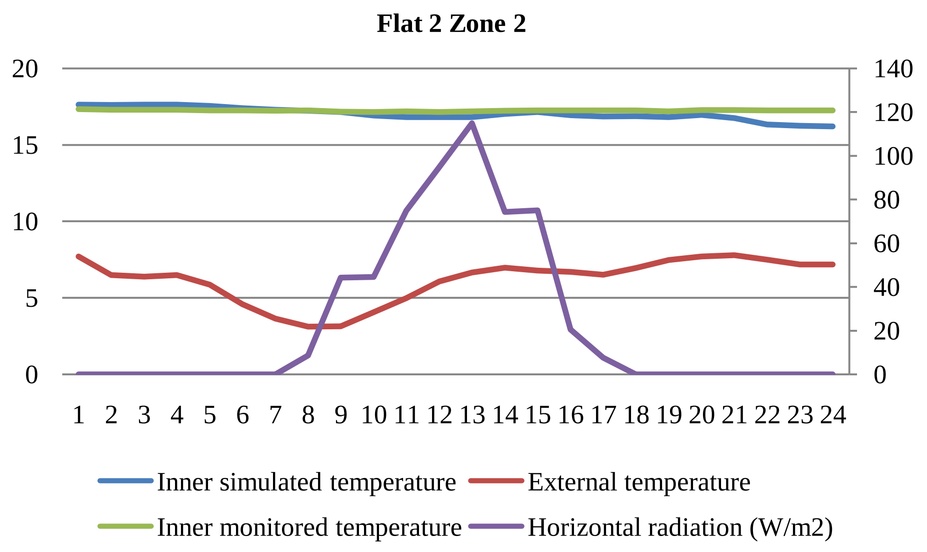


Figure 103 Flat 2 Zone 2 - Temperatures

March, 6th , Cold Sunny

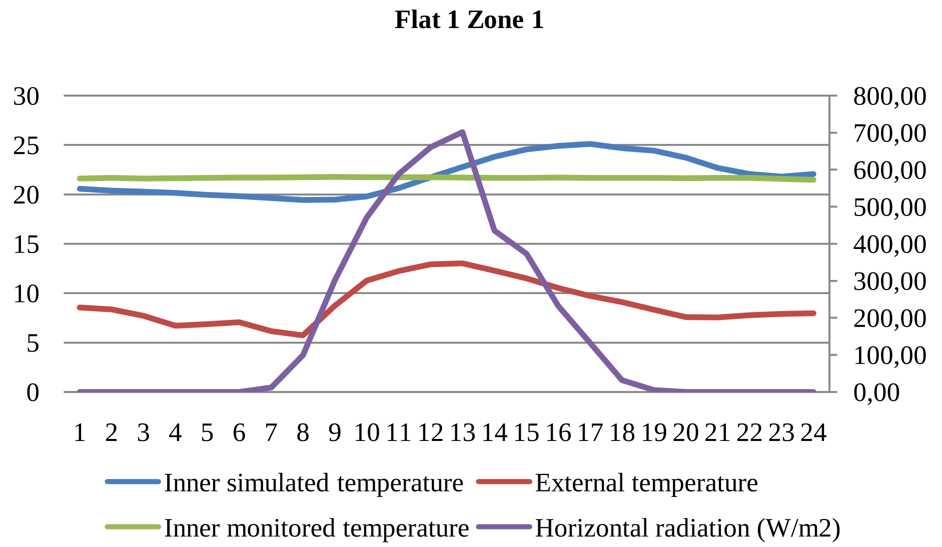


Figure 104 Flat 1 Zone 1 Temperatures

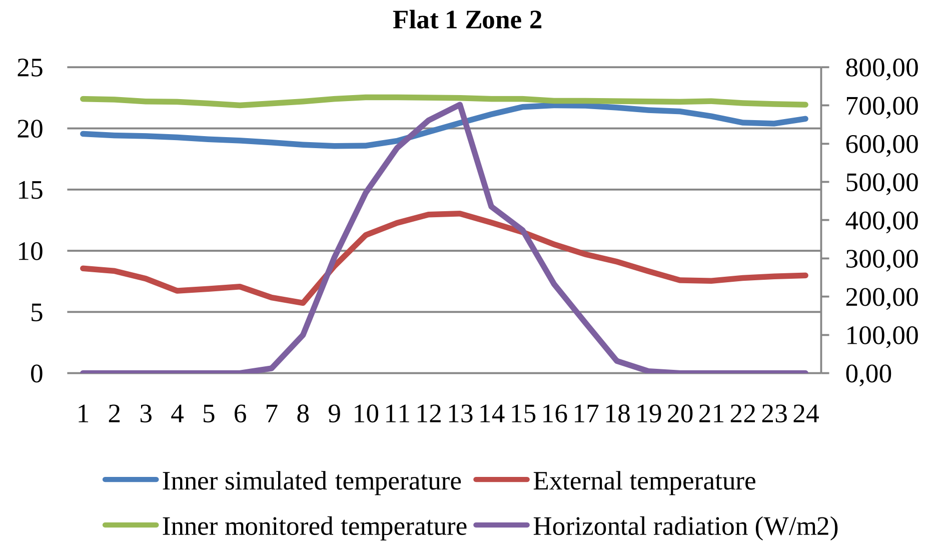


Figure 105 Flat 1 Zone 2 Temperatures

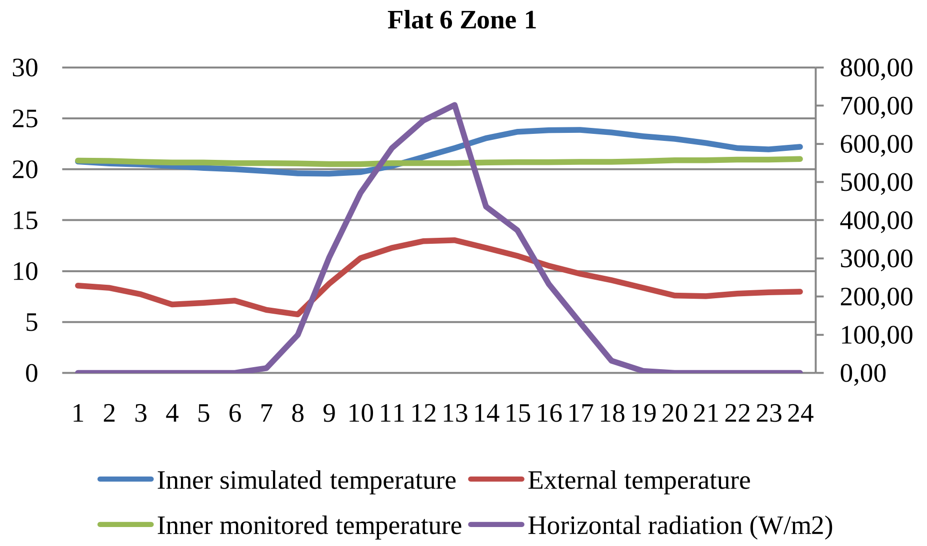


Figure 106 Flat 6 Zone 1 Temperatures

July, 24th, Sunny hot

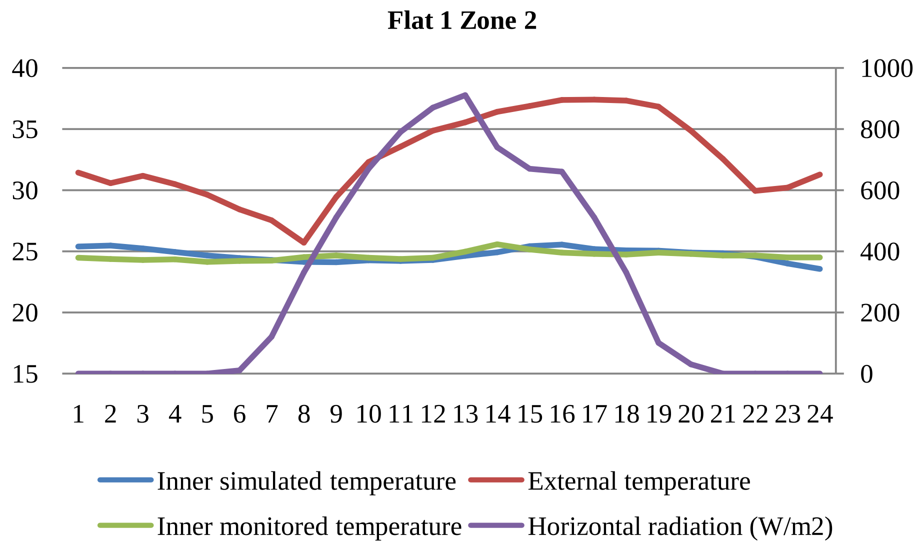


Figure 107 Flat 1 Zone 2 Temperatures

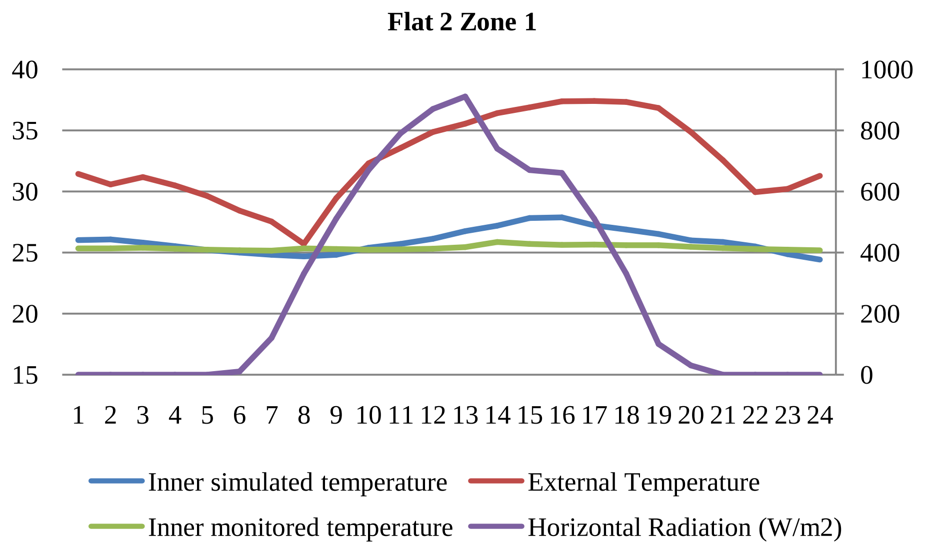


Figure 108 Flat 2 Zone 1 Temperatures

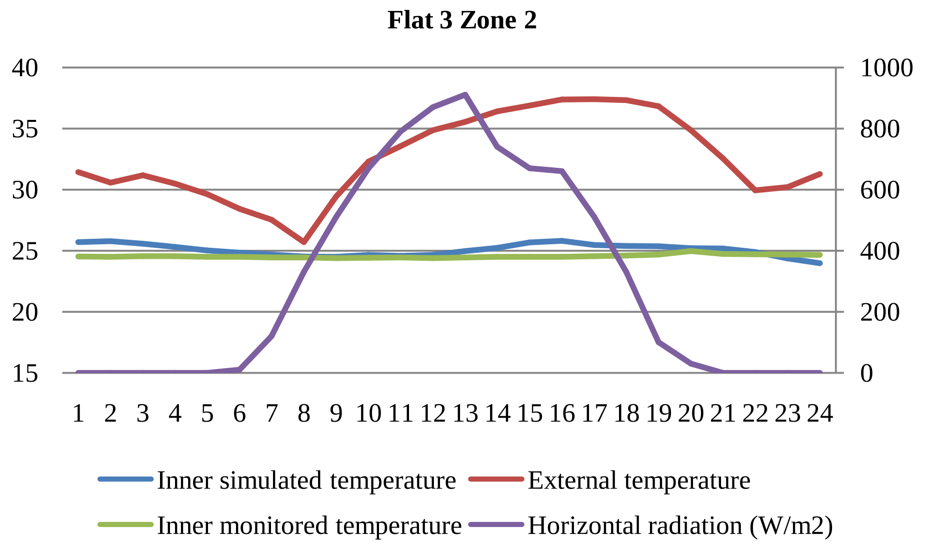


Figure 109 Flat 3 Zone 2 Temperatures

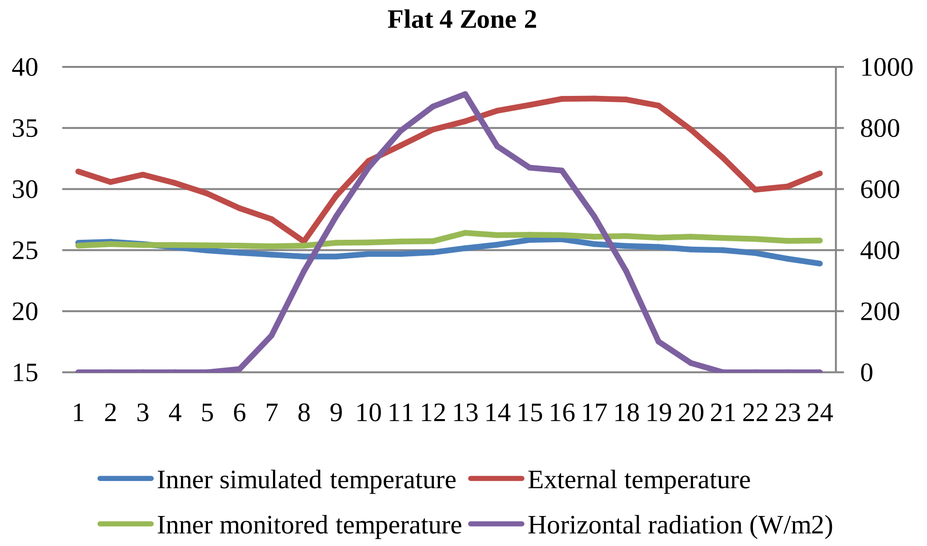


Figure 110 Flat 4 Zone 2 Temperatures

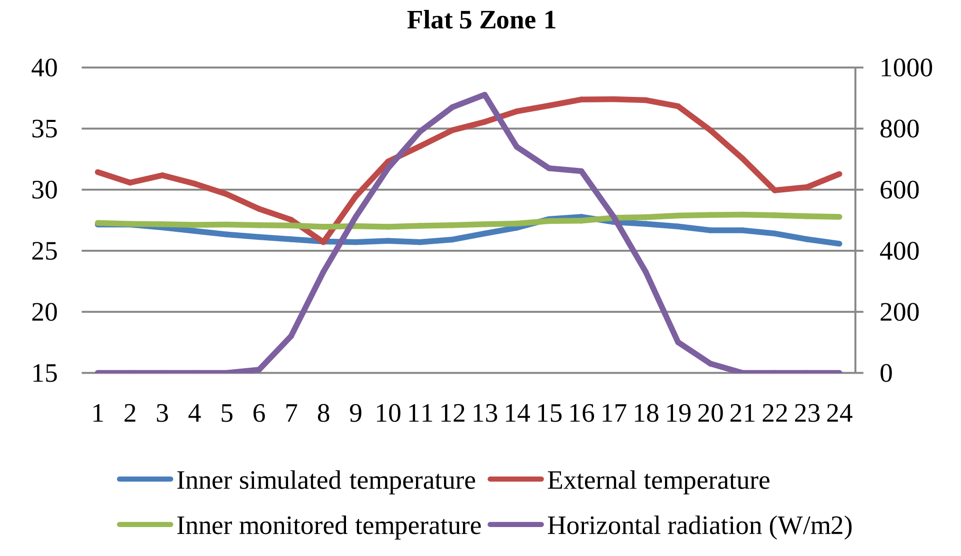


Figure 111 Flat 5 Zone 1 Temperatures

August, 4th , Cloudy hot

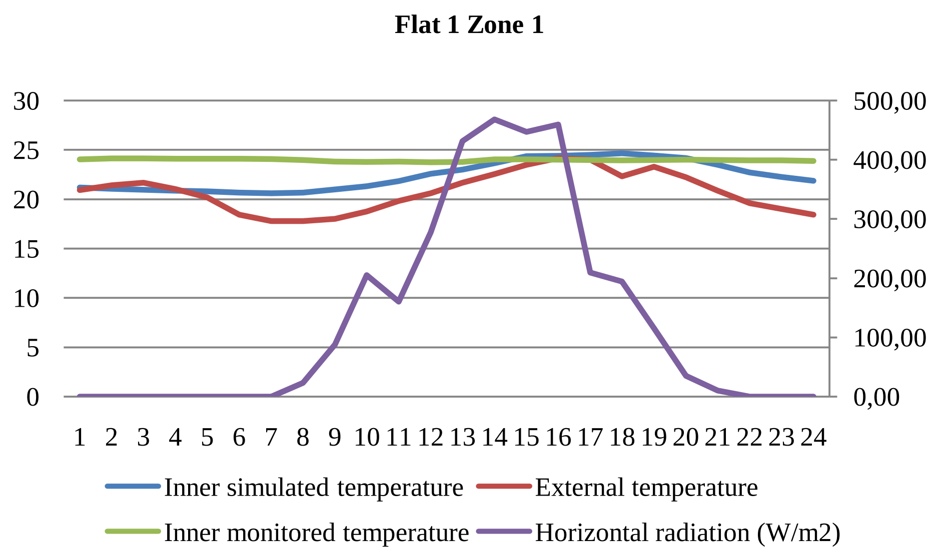


Figure 112 Flat 1 Zone 1 Temperatures

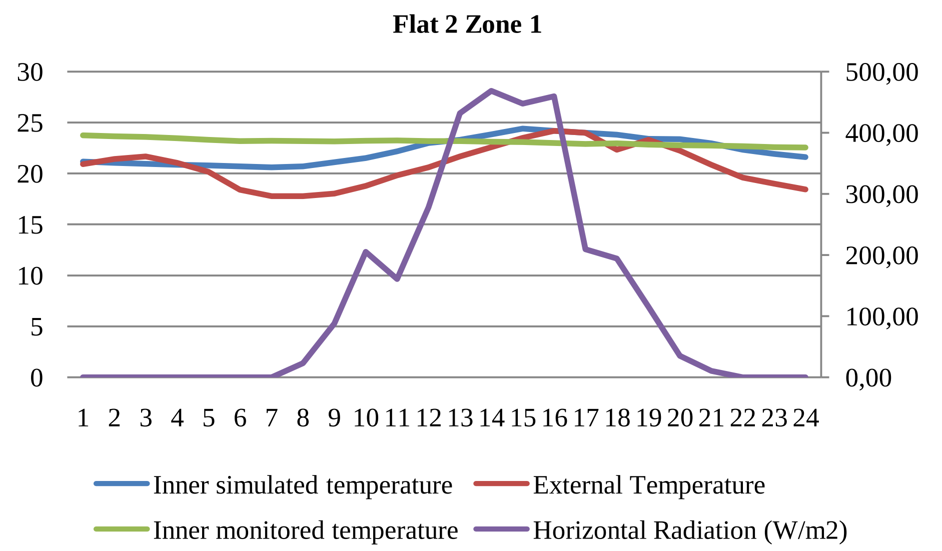


Figure 113 Flat 2 Zone 1 Temperatures

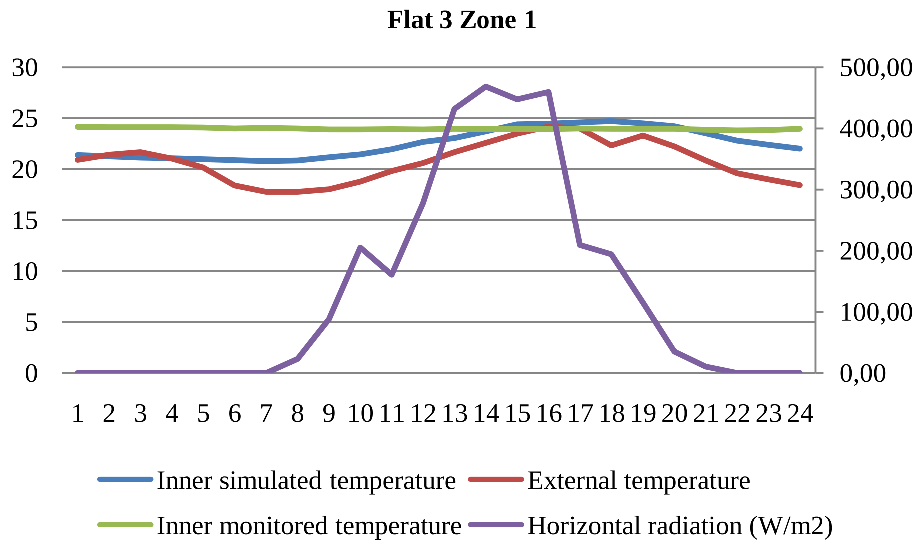


Figure 114 Flat 3 Zone 1 Temperatures

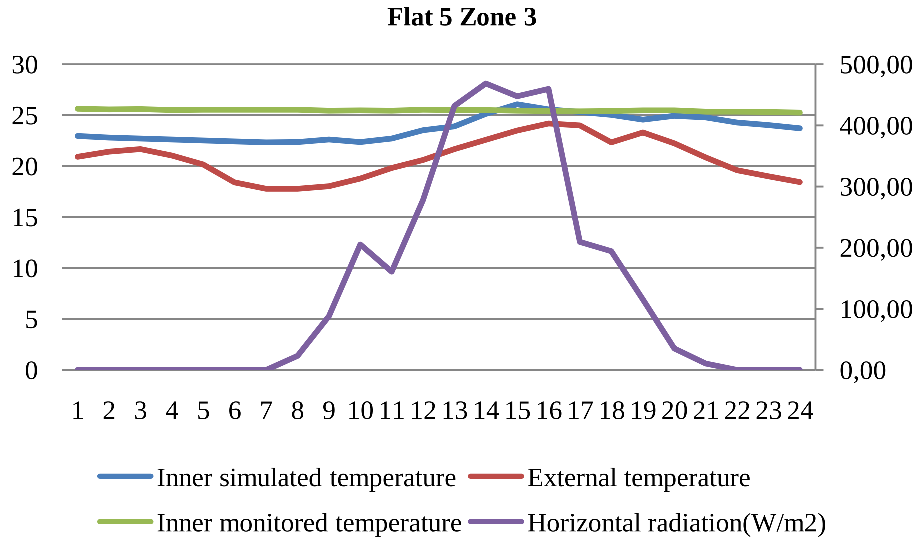


Figure 115 Flat 5 Zone 3 Temperatures

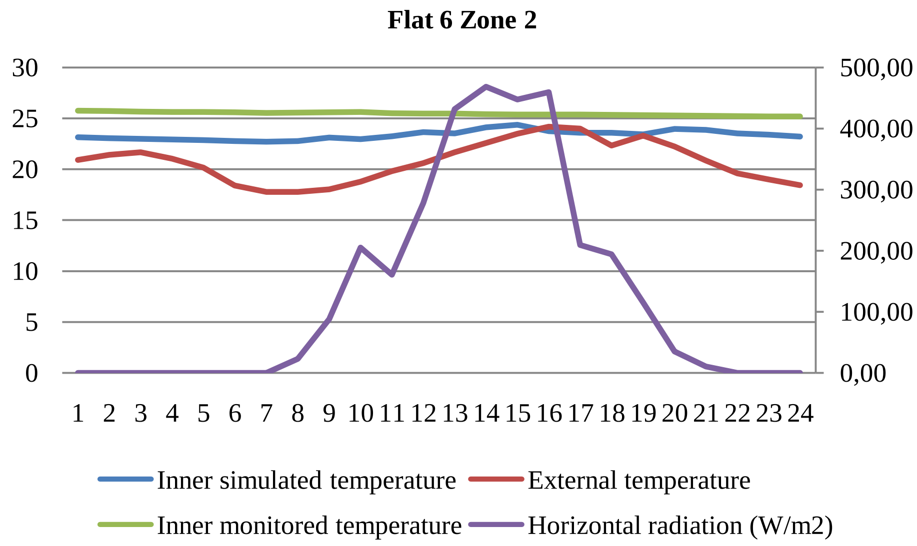


Figure 116 Flat 6 Zone 2 Temperatures

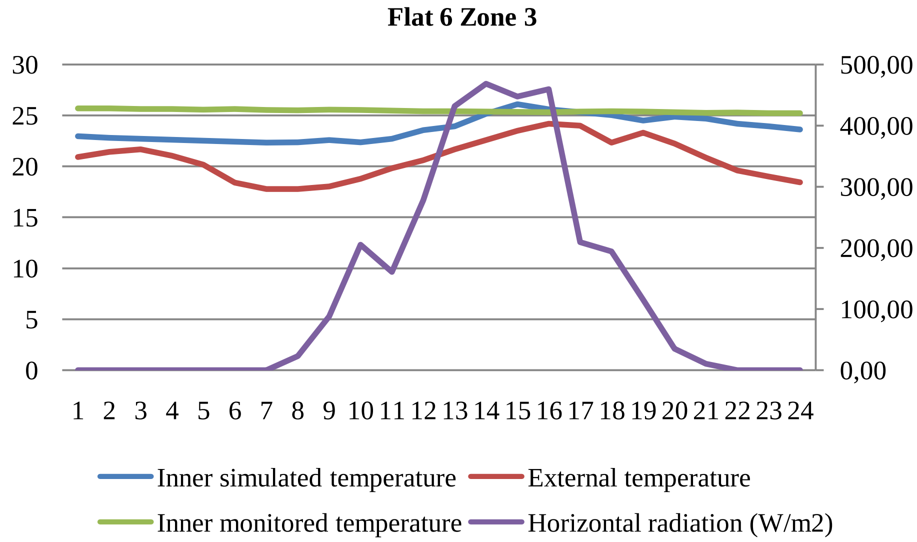


Figure 117 Flat 6 Zone 3 Temperatures

Photovoltaic analysis

The photovoltaic production /energy consumption has been studied on a daily base using as parameters the production monitored, the real monitored consumptions and the TRNSYS simulated hourly photovoltaic production.

In the following summarizing tabs and graphs both the simulated production in kWh and the real monitored production are compared, and the monitored data for the real consumption is also added in order to have a direct comparison between production and consumption. These data are also arranged into graphs for a better understanding.

A parameter used in the evaluation of the results is the Load Match Index, described as follows:

$$f_{load} = \min\left[1, \frac{onsitegeneration}{load}\right]$$

It is an index of the capability of the system to cover all the electrical needs of the site. A value higher than one could mean that the production may be higher than the needs: it could have a practical meaning if the panels are connected to a storage system or if the plant is grid-connected, thinking to the capability of this kind of systems to use energy produced before, in another moment. However, limiting the upper value of this parameter means that the attention is focused on the hourly rate and capability of energy production, using a point of view more interested in avoiding mismatching problems. In other words it is important and desirable to produce in every moment the exact quantity of energy that is needed.

This parameter has been evaluated for both the hourly base and daily base for every one of the four days chosen.

While calculated on a daily base, this parameter does not give many information on the mismatch, while it gives only an idea on the capability of the system to produce the needed energy.

January, 24th

Table 36 24Th January data

Simulated production (kWh)	Monitored production (kWh)	Energy consumption (kWh)	Difference between production and consumption	Load Match Index
0,00	0,00	4,35	-4,35	0,00
0,00	0,00	4,35	-4,35	0,00
0,00	0,00	4,44	-4,44	0,00
0,00	0,00	3,09	-3,09	0,00
0,00	0,00	5,31	-5,31	0,00
0,00	0,00	3,13	-3,13	0,00
1,84	0,276	4,83	-4,55	0,06
5,50	4,852	4,00	0,85	1,00
9,23	4,192	3,96	0,23	1,00
8,25	8,916	3,52	5,39	1,00
5,51	11,444	4,39	7,05	1,00
10,82	11,8	2,70	9,10	1,00
3,70	6,988	3,52	3,46	1,00
1,06	9,072	4,00	5,07	1,00
0,66	0,936	2,22	-1,28	0,42
0,00	0,00	5,74	-5,74	0,00
0,00	0,00	4,00	-4,00	0,00
0,00	0,00	6,09	-6,09	0,00
0,00	0,00	4,48	-4,48	0,00
0,00	0,00	7,00	-7,00	0,00
0,00	0,00	7,44	-7,44	0,00
0,00	0,00	4,83	-4,83	0,00
0,00	0,00	6,22	-6,22	0,00
0,00	0,00	4,79	-4,79	0,00
46,57	**58,48**	**108,42**	**-49,94**	

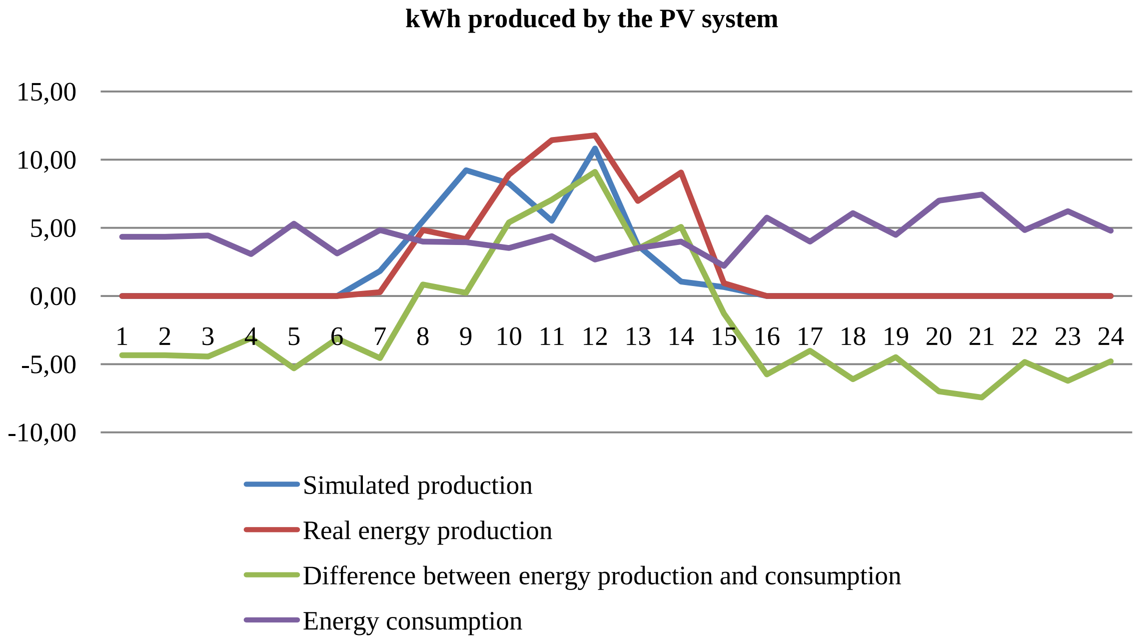


Figure 118 24th January data

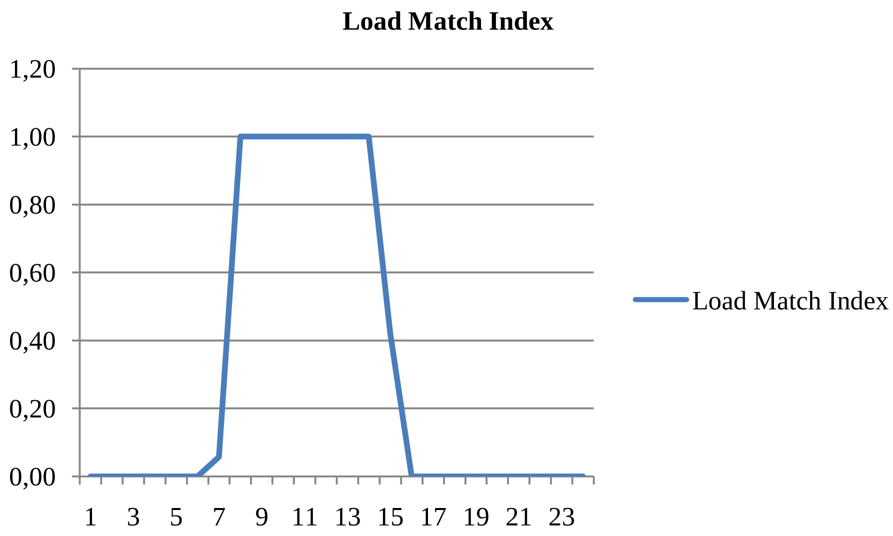


Figure 119 Load match index

The LM Index for the 24th of January shows a not very wide peak, showing a lack of production in comparison with the electrical needs of the day.

This evidence is best shown if the attention is driven towards the LM index on daily base, that gives **0,34** as result.

March, 6th

Table 37 6th March data

Simulated production (kWh)	Monitored production (kWh)	Energy consumption (kWh)	Difference between production and consumption	Load Match Index
0,00	0,00	3,02	-3,02	0,00
0,00	0,00	3,59	-3,59	0,00
0,00	0,00	2,01	-2,01	0,00
0,00	0,00	3,04	-3,04	0,00
0,00	0,00	2,54	-2,54	0,00
0,48	0,00	2,31	-2,31	0,00
0,56	0,276	3,54	-3,27	0,08
4,74	4,852	2,29	2,56	1,00
11,42	11,5	3,04	8,46	1,00
15,38	14	2,29	11,71	1,00
14,65	15,5	1,81	13,69	1,00
8,72	12	1,51	10,49	1,00
4,79	8,5	2,04	6,46	1,00
5,87	6,5	1,81	4,69	1,00
4,58	5	1,28	3,72	1,00
1,27	2	1,78	0,22	1,00
0,00	0,5	3,32	-2,82	0,15
0,00	0,00	3,04	-3,04	0,00
0,00	0,00	3,80	-3,80	0,00
0,00	0,00	2,84	-2,84	0,00
0,00	0,00	4,30	-4,30	0,00
0,00	0,00	2,79	-2,79	0,00
0,00	0,00	3,59	-3,59	0,00
0,00	0,00	3,77	-3,77	0,00
72,46	**80,63**	**65,35**	**15,28**	

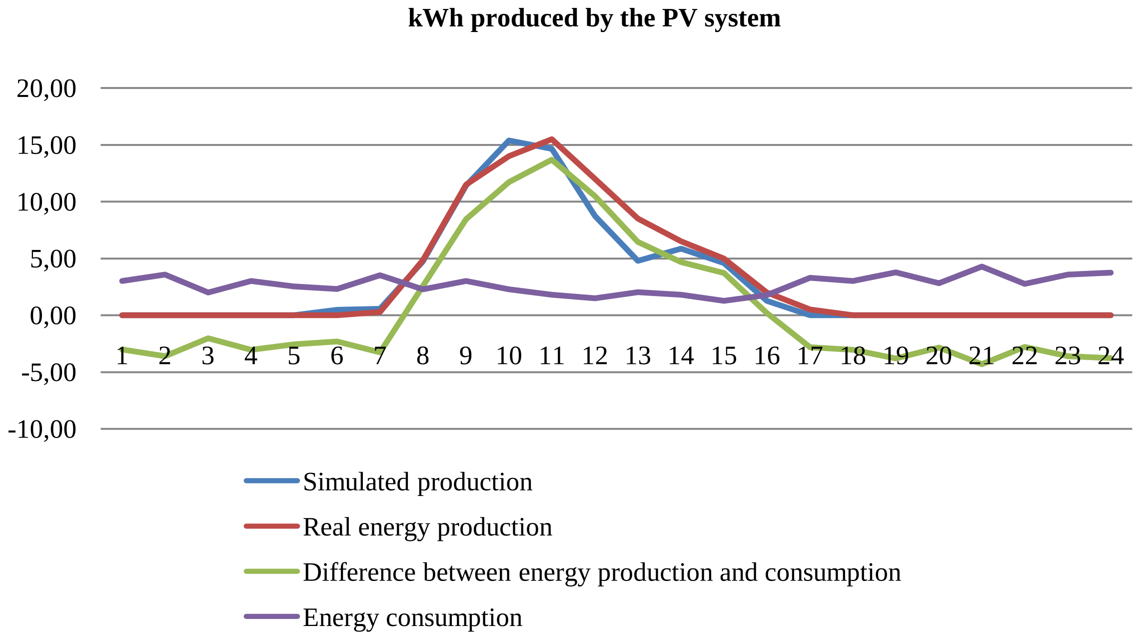


Figure 120 6Th March Data

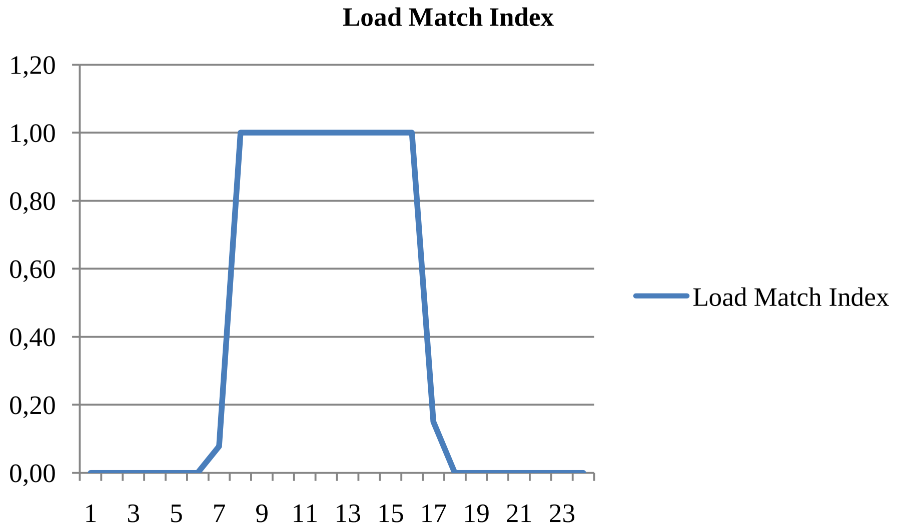


Figure 121 Load Match Index

The LM Index calculated on daily base is 1. In other words, the production of energy is equal or higher than the consumptions. This does not mean that in every hour of the day the consumptions are covered by the pv system, as the previous graph clearly states.

July, 24th

Table 38 24th July data

Simulated production (kWh)	Monitored production (kWh)	Energy consumption (kWh)	Difference between production and consumption	Load Match Index
0,00	0,00	4,30	-4,30	0,00
0,00	0,00	6,06	-6,06	0,00
0,00	0,00	6,96	-6,96	0,00
0,00	0,00	7,00	-7,00	0,00
0,00	0,00	6,10	-6,10	0,00
0,00	0,00	6,06	-6,06	0,00
0,46	0,50	5,71	-5,25	0,09
2,05	3,00	8,68	-6,63	0,35
5,46	6,50	5,67	-0,21	1,00
8,64	11,50	5,63	3,01	1,00
11,65	12,50	4,42	7,23	1,00
13,96	15,50	4,81	9,15	1,00
14,14	14,50	5,63	8,51	1,00
15,09	15,50	5,28	9,81	1,00
14,99	13,00	5,33	9,66	1,00
12,68	13,00	5,63	7,05	1,00
10,68	10,00	7,39	3,29	1,00
7,55	6,00	7,39	0,16	0,81
3,49	2,50	6,53	-3,04	0,38
0,67	1,00	5,76	-5,09	0,17
0,00	0,00	6,44	-6,44	0,00
0,00	0,00	7,86	-7,86	0,00
0,00	0,00	6,53	-6,53	0,00
0,00	0,00	5,67	-5,67	0,00
121,51	**125,00**	**146,82**	**-21,82**	

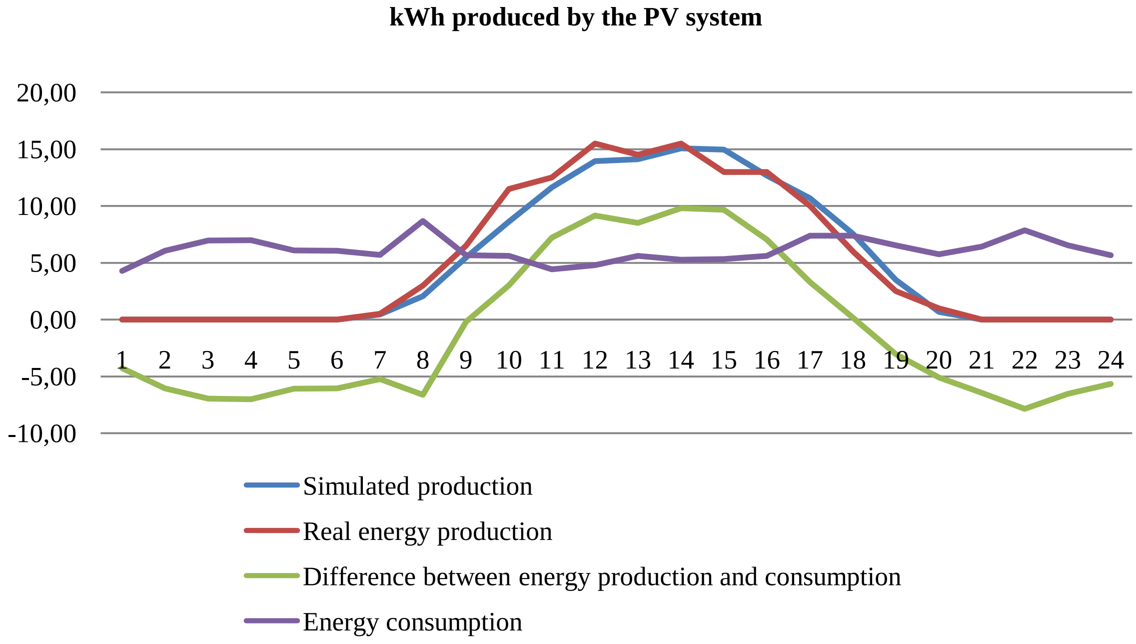


Figure 122 24Th July Data

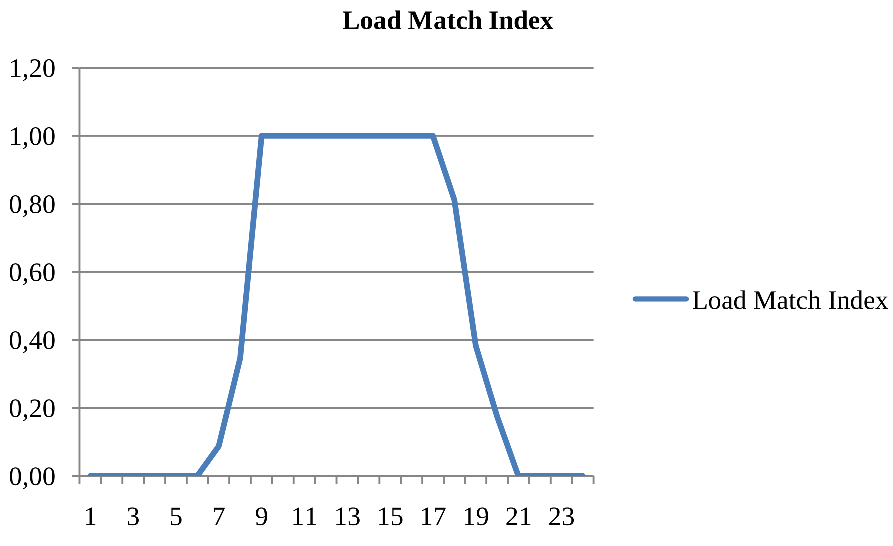


Figure 123 24Th July data

The LM index on a daily base, gives 0,83 as a result. As it is possible to see from the previous graph, from 9: 00 AM to 6:00 PM all electrical needs are completely covered by the PV system. The plateau level, however means that in that hours the weight of mismatching problems is particularly significant.

August, 4th

As expected from the nature of “cloudy” day, even if in August, the photovoltaic production is much lower than reasonably expected from a day in this period of the year.

Table 39 4th August data

Simulated production (kWh)	Monitored production (kWh)	Energy consumption (kWh)	Difference between production and consumption	Load Match Index
0,00	0,00	5,52	-5,52	0,00
0,00	0,00	7,96	-7,96	0,00
0,00	0,00	7,40	-7,40	0,00
0,00	0,00	5,15	-5,15	0,00
0,00	0,00	6,16	-6,16	0,00
0	0,00	6,90	-6,90	0,00
0,6	0	4,74	-4,74	0,00
2,1	1,5	6,02	-4,52	0,25
2,7	4	6,62	-2,62	0,60
3,2	4	5,52	-1,52	0,72
5,8	4,5	7,04	-2,54	0,64
8,5	7,5	4,64	2,86	1,00
8,2	8,5	5,66	2,84	1,00
8,1	8,5	7,04	1,46	1,00
5,7	3	5,56	-2,56	0,54
3	3	5,15	-2,15	0,58
1,4	1,2	5,61	-4,41	0,21
0,4	0,00	5,66	-5,66	0,00
0	0,00	5,56	-5,56	0,00
0,00	0,00	5,66	-5,66	0,00
0,00	0,00	5,61	-5,61	0,00
0,00	0,00	6,48	-6,48	0,00
0,00	0,00	5,15	-5,15	0,00
0,00	0,00	7,04	-7,04	0,00
49,70	**45,70**	**143,85**	**-98,15**	

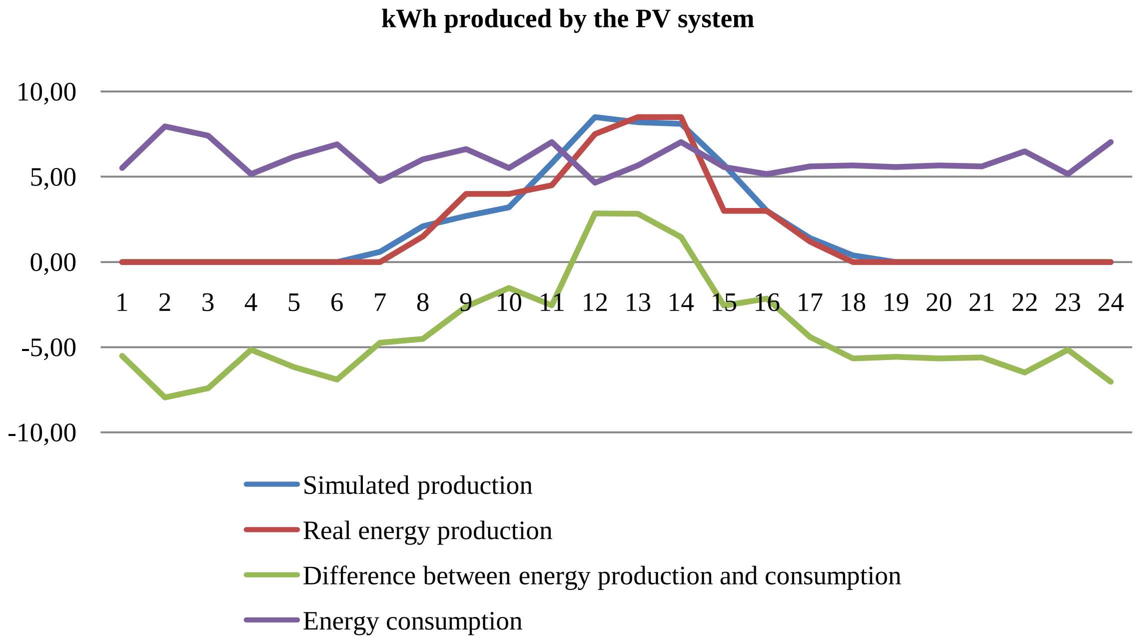


Figure 124 4Th August data

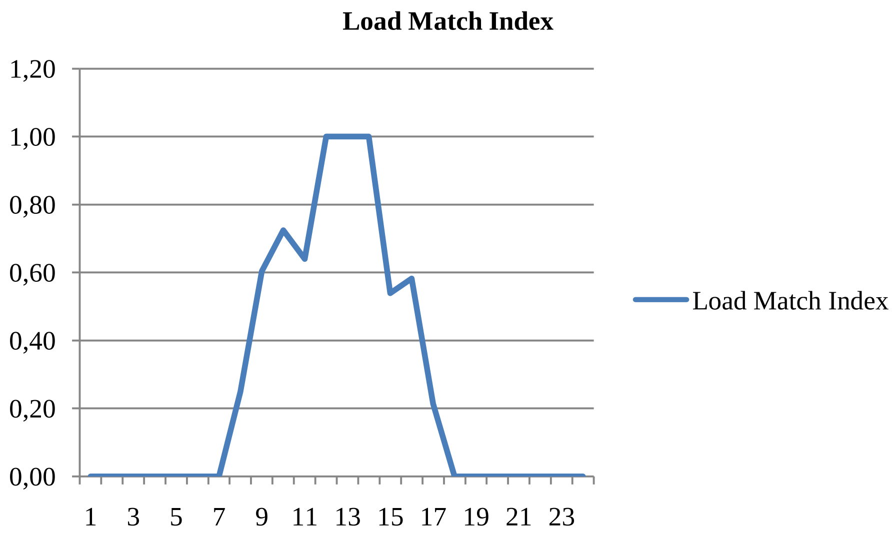


Figure 125 Load Match Index

The LM Index for the day examined shows a low level of production, notably the mismatching problems are not so relevant since the LM index is nearly always lower than one. On a daily base the value of the LM index is in fact low : 0,35.

Chapter 7 Different Scenarios to achieve the Net Zero Energy target

The redesign hypothesis were made under the following conditions:

1. replacement of the PV panels with different ones (19 % module efficiency, electrical features are listed in tab 40);
2. replacement of the GHP with a more efficient model;
3. elimination of the GHP heat exchanger and consequent direct connection of the fluid heated\cooled with the main pipeline;
4. modification of the roof layer composition to reach a lower U value (0.15) W/m^2°C;
5. combination of hypothesis 1,2 and 3.

The redesign options have been selected trying to reduce consumptions and to increase the energy production. The Heat pump, as presented by the designers, had a 4.6 COP but monitored data showed a much lower value. This is a source of inefficiency and we tried to estimate the magnitude of these energy losses. The elimination of the heat pump heat exchanger tries to estimate the weight of one element of complexity of the thermal plant. The aim is to evaluate how much could be saved by a simpler plant in terms of electric energy. While the building insulation and the quality of the envelope are above the standards, a simulation has also been performed adding 10 cm more of rock wool in the roof composition (Global U value for the roof = 0.15 W/m^2°C).

The simulations gave back these results:

- in the hypothesis of substitution of the PV panels with a 19 % efficiency model, the energy yield forecasted (TRNSYS simulation) would be about 38,296 kWh: this solution –would allow a complete covering of the total electrical needs of the building;
- the replacement of the GHP with a model characterized by a higher COP (4,6) would require 5.4MWh per year, comporting a reduction of 26 % (2MWh);
- the simplification of the plant would grant around 400 kWh$_e$ of savings (less than 2% of the consumptions);

- the lower U value of the roof would lead to 200kWh of electric energy savings for the winter season. However consumptions would be higher in the summer and would lead to an overall 300 kWh rise in the consumptions;
- the combination of hypothesis 1-2-3 would grant a 2.6 MWh_e reduction of consumptions and a production increasing of 12.65 MWh_e from the PV system.

Table 40 PV modules electric features

	On-site	**Redesign**
Pmax [W]	175.00	240.00
Vmp [V]	36.40	43.70
Imp [A]	4.67	5.51
Open circuit V [V]	43.50	52.40
Short-circuit I [A]	5.20	5.85

Although the first redesign hypothesis allows the reaching of the NZEB target, options 2,3 identify significant consumption reduction: the fifth hypothesis reaches the highest value of the Production/Consumptions ratio, as it is shown in Table 41.

Table 41 Results of the redesign hypothesis5

ENERGY	MWh	%
Production	38.30	137.87
Consumption	27.78	100.00
Production - Consumption	+10.52	+37.87

The energy performances of the building shows that the envelope is already very effective while a partial redesign of the thermal plant could permit reaching a nearly Net Zero Energy performance.

Furthermore, the adoption of a better building automation system could significantly improve the energy behavior of the building.

Redesigned studies should identify better alternative solutions for plants, building envelope or impact on the environment that significantly modify the building.

A brief summary of the 2009 data for the LH plant and electrical needs follows: both simulated and real values are arranged in a table for a quick comparison of the Scenario 0 with the redesign options.

Table 42 Scenario 0, Energy production and needs

PV (kWh)		
Energy production		**Energy Needs**
Simulated	Monitored	Monitored
25143	25651	37080

The forecasted energy needs were way lower than the monitored ones. That lead to a Energy produced\Energy needs ration equal to 0,69 : in order to reach the NZEB status this ratio must be equal to one, in the chosen time interval.

A deeper analysis should be conducted, in order to examine in a higher detail the electrical needs of the Leaf House. It has been conducted an in-depth simulation on the weight of the heat pump electrical needs on the overall needs.

Table 43 Scenario 0, HP electrical needs

HP electrical needs (MWh)	
Simulated	Monitored
7,4	7,9

The heat pump electrical needs\ total needs ratio is around 0,21: it has an overall high enough impact to justify redesign options in this direction.

In order to obtain a NZEB performance two different level of intervention can be pursued: obtain better performances with higher energy efficiencies and thus reducing the energy needs (moving from right to left on the x axis in the graph see Figure 126) or higher energy supplies\production (moving on the y axis).

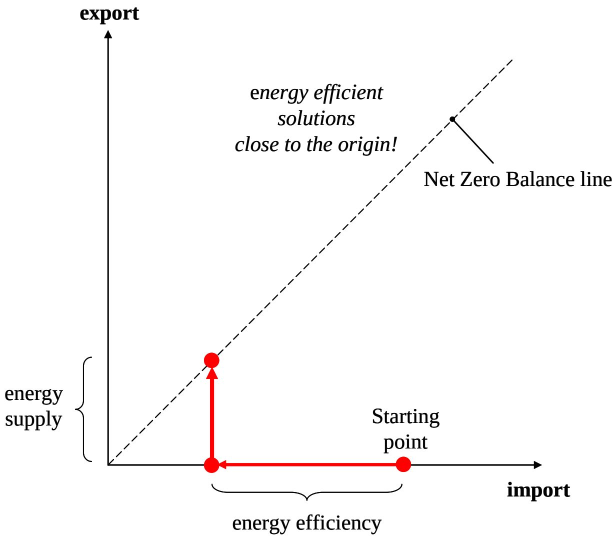


Figure 126 Example of the redesign process

To achieve the goal of NZEB different scenarios have been proposed to improve the real plant-building system.

In detail, to increase the energy performance of the building it has been decided to simulate four scenarios:

- Scenario 1: Increase PV energy production;
- Scenario 2: A more efficient GHP (COP 4.6);
- Scenario 3 : Elimination of the heat pump heat exchanger and the use of glycol-water in the main system line,
- Scenario 4 : Combination of scenario2 and 3.

7.1. Scenario 1: More efficient photovoltaic modules

The first scenario touches the PV energy production.

The monitored data for 2009 show an energy production of 25651 kWh from the photovoltaic panels. The simulated production from TRNSYS is 25143 kWh for the year.

With the substitution of the PV panels with a 19 % efficiency model the energy yield forecasted (TRNSYS simulation) would be 38296 kWh: this solution should allow a complete covering of the total electrical needs of the LH.

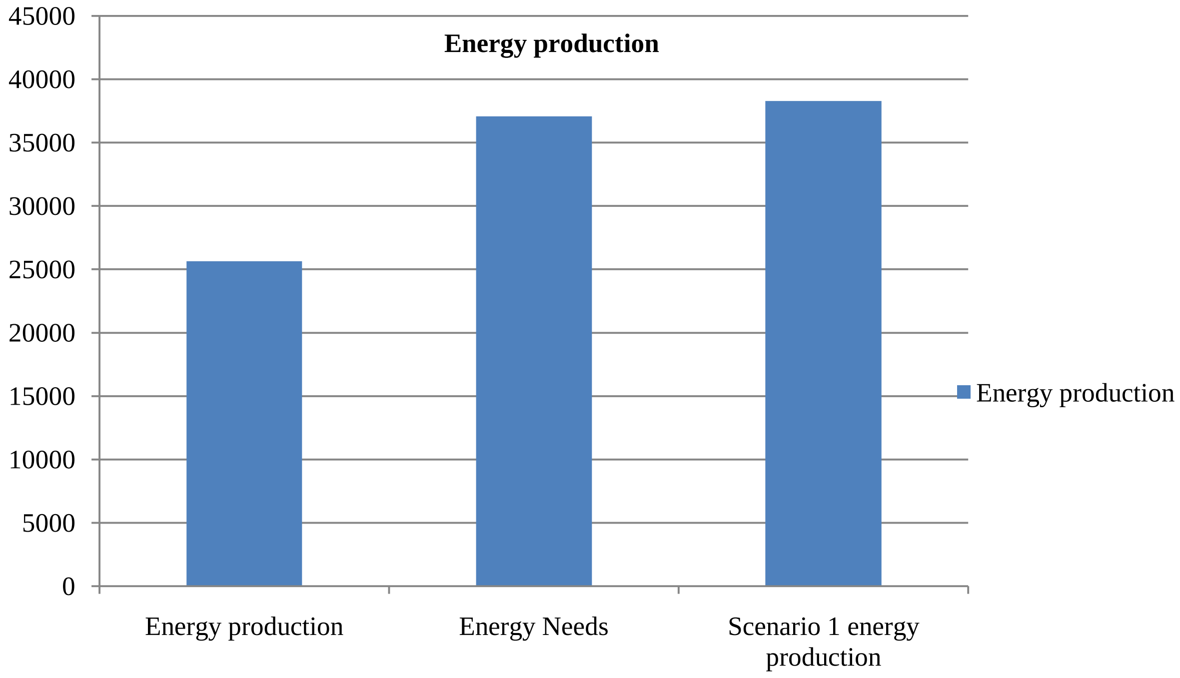


Figure 127 Energy production

7.2. Scenario 2: A more efficient GHP

The second scenario takes in consideration a COP higher than the one resulting from monitored data. A 4.6 COP heat pump simulated with the same model and assumptions gives an overall yearly data of around 5.4 MWh.

This value is 2 MWh (26 % lower) lower than the scenario 0 simulated one.

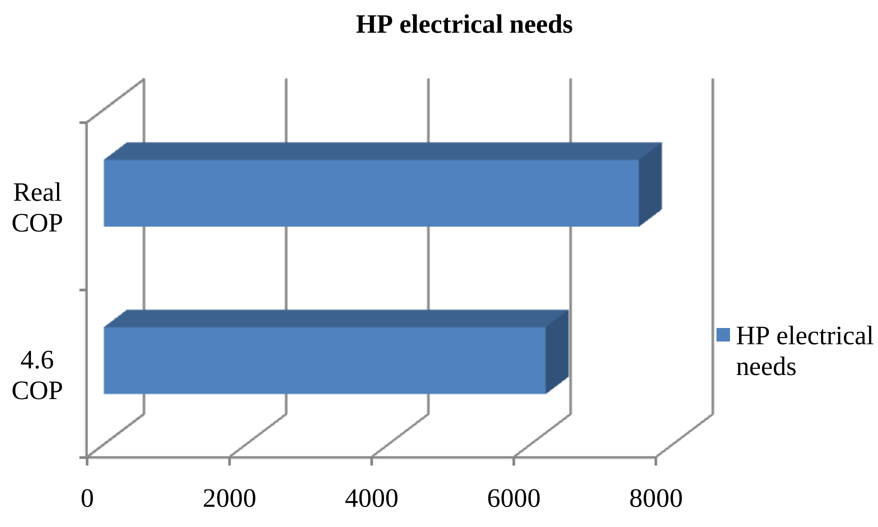


Figure 128 Scenario 2

7.3. Scenario 3: A different Thermal plant layout

The third hypothesis was the elimination of the heat pump heat exchanger and the use of glycol-water in the main system line.

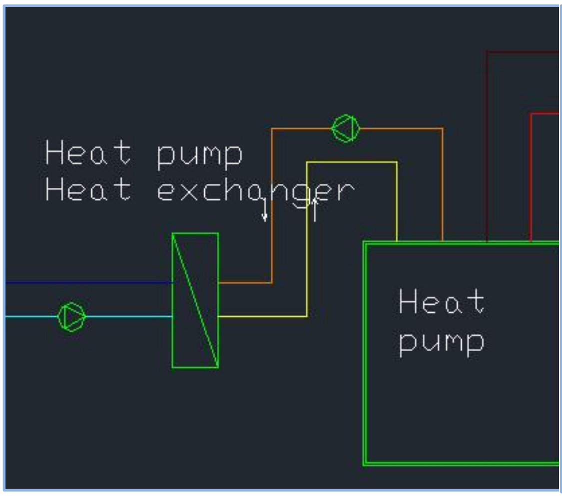


Figure 129 Real plant scheme

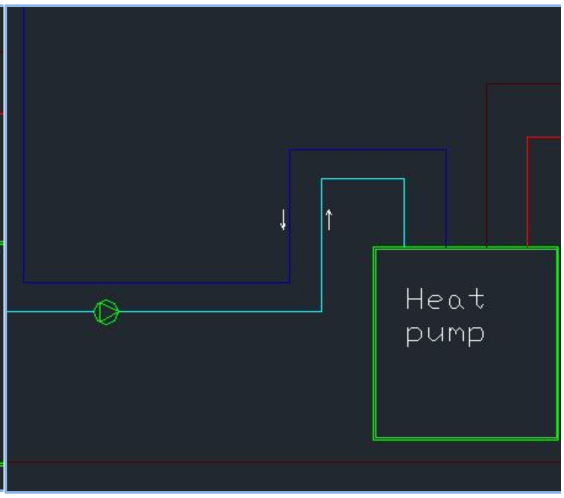


Figure 130 Scenario 3

The impact on the overall electrical needs was significant: it lead to a 500 kWh saving during the year. While simulated needs were 7524 kWh, the simulated results of this redesign option are around 7020 kWh.

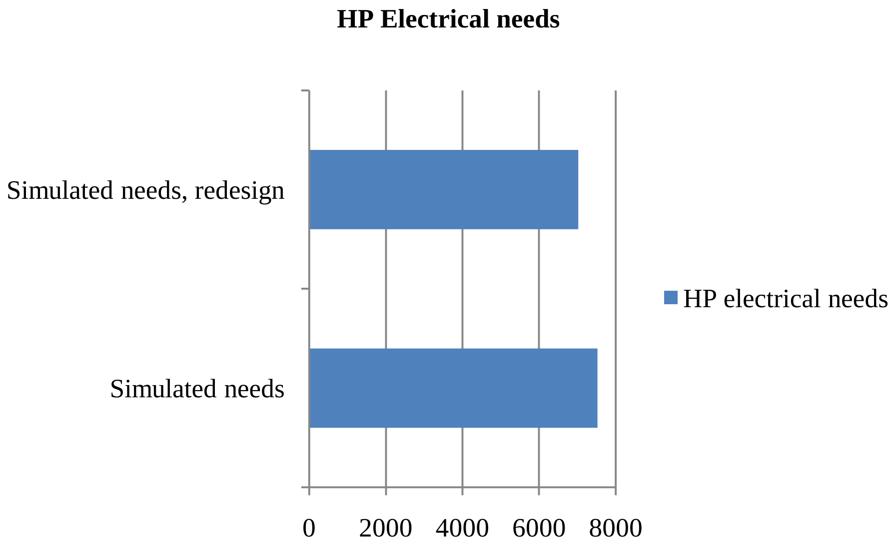


Figure 131 Hp electrical needs, Scenario 3

7.4. Scenario 4: Combining different retrofit hypothesis

The combination of the adoption of a more efficient GHP proposed in the Scenario 2 and the new system configuration described in the scenario 3 leads to an energy saving of around 400 kWh on the energy needs forecasted in the second scenario.

The energy needs forecasted are around 5 MWh for the year taken in consideration.

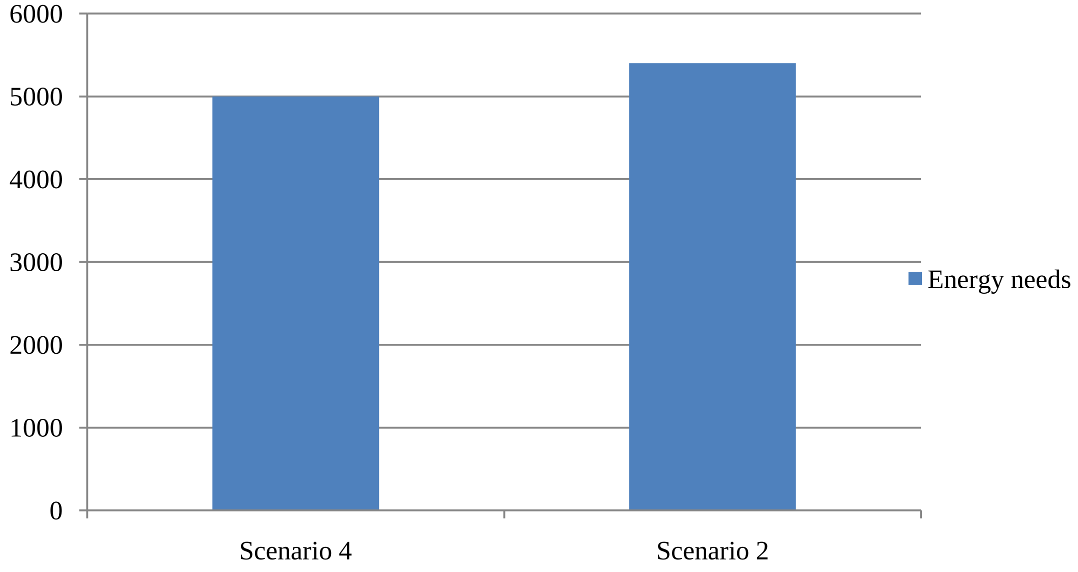


Figure 132 HP energy needs (kWh)

The substitution of the PV panels allows the possibility to reach the NZEB standards with no other interventions. However further investigations on the GHP shows that achieving 2 MWh savings or more is possible by choosing another heat pump with better performances.

The results are summarized in the following tabs.

Table 44 PV re-design options (kWh)

Scenario	Simulated PV production	Monitored PV production	Energy needs
0	25143	25651	37080
1	38296		37080

Table 45 HP-related re-design options (MWh)

Scenario	Monitored	Simulated
0	7,9	7,5
2		5,4
3		7
4		5

Chapter 8 Conclusions

The work presented in this thesis has been largely developed in the context of the International Energy Agency (IEA) joint Programme Solar Heating and Cooling (SHC) Task40 and Energy Conservation in Buildings and Community Systems (ECBCS) Annex52: Towards Net Zero Energy Solar Buildings. The ***objectives*** of this Task/Annex are to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding, a harmonized international definitions framework, tools, innovative solutions and industry guidelines. As discussed in Chapter 1, a study on the European Union Energy Policies, and of the National ones, was carried out in order to evaluate the standard requirements which a Net Zero Energy Building has to enforce. As known, the energy consumption in European Union residential and commercial buildings member states represents approximately 40% of total final energy consumption of the building sector. For this reason the implementing of energy efficiency measures in buildings is recognized as a priority by EU due to its potential to invert the actual trend of energy consumption. A strategy will have to be fully implemented beginning 2019 in Europe to offset the growing energy demand of buildings with renewable energy harvested on site.
After clarifying which is the energy target imposed by the law, a detailed excursus on the Net Zero Energy building concept was done in this thesis. As described in Chapter 2, when energy efficiency measures are successfully combined with on-site renewable energy sources, and the energy consumption is equal (or nearly) to the energy production, then the output achieved can be referred to as “near net zero energy” or “net zero-energy building”. Although these terms have different meanings and are often still poorly stated or understood, the net-zero energy building (NZEB) concept may be defined as a building that over a year is neutral, meaning that it delivers as much energy to the supply grids as it uses from the grids. Chapter 2 also describes the main typologies of NZEB, the most important ones are the following: site-ZEB and source-ZEB depending on where the energy balance is calculated.

The successful application of this strategy, which in practice may lead to zero energy, depends on choosing the adequate technical strategies that respond better in the local context to the defined objective. This goal is pursued through detailed modelling and analysis of specific NZEB case studies. In this thesis, it was decided to examine in detail the specific case study of the IEA Task 40 (Sub Task B) Programme: the Leaf House (LH) located in Ancona, Italy.

The studied building is fully monitored in terms of thermal environment, energy production and consumption, water use and occupancy. As shown in Chapter 5, after a description of the main design choices and systems that led to the construction of the Leaf House, an illustration of the monitoring and control systems and the energy output of the building has been analyzed. A careful analysis of monitored data leds to search some improving strategies to reach the zero energy target. After the simulation of the real building systems (through the software TRNSYS-Chapter 6), several scenarios have been investigated to improve energy performances of the LH. Finally the implemented model has been properly calibrated.

The monitored situation shows an energy consumption of 37 MWh for the year 2009; although around 6 MWh are wasted in the monitoring equipment the energy production is lower than this value.

A simple solution, to reach the NZEB status is moving towards a higher production: e.g. the substitution of the PV panels with higher efficient others. In this way the energy balance reaches “zero” during the year.

Nevertheless the problem can be solved otherwise, reducing the energy needs. In this direction, the GHP and its energy needs have been analyzed in detail, after having checked the monitored data and verified that the ratio GHP needs/total needs is higher than 0,20. It has been verified that the COP of the machine is way lower than the declared 4.6 and that an effective 4.6 COP could lead to significant energy savings.

The idea of reaching higher efficiencies led to the proposal of a different plant scheme with the exclusion of a heat exchanger to reduce as much as possible energy losses. While it is possible to obtain the NZEB status simply making a substitution of the PV panels, the investigation on further energy savings has been continued.

In the context of the Task 40, the results of the disassembled analysis in the heat production are very significant. As the solar system produces only a low fraction of the total heat needed, new studies will point towards this direction, re-designing new plant schemes to be simulated on TRNSYS and compared with already extrapolated data.

Finally the Italian case study allow to identify the strategies to improve the energy performances of the a Near Net Zero Energy building to reach the NZEB target. It represents also an Italian reference for others who wish to build NZEBs in the Italian context.

Annex I The IEA/ECBS/Task 40 Programme

Objectives and scope

Energy use in buildings accounts for over 40% of the world's primary energy use and 24% of greenhouse gas emissions. Given the global challenges related to climate change and resource shortages, much more is required than incremental increases in energy efficiency. The "net zero" approach (NZEBs) incorporates on-site renewable energy but achieves an annual balance of energy supply and demand through interactions with electricity grids and other utilities such as community energy systems. To minimize impacts to grids by reducing the mismatch of supply and demand, the NZEB approach requires a very high level of energy-efficiency, smart controls, load management and on-site solar energy utilization. This approach applies to the existing building stock as well as to new buildings, clusters of buildings and small settlements. To achieve market adoption, what is needed is a clear definition and agreement on the measures of building performance that could inform "zero energy" building policies, programs and industry building practices and design tools, case studies and demonstrations that would support industry adoption. The ***scope*** includes major building types (residential and non-residential), new and existing, for the climatic zones represented by the participating countries. The work will be linked to national activities and will focus on individual buildings, clusters of buildings and small settlements. The work will be based on analysis of existing examples that leads to the development innovative solutions to be incorporated into national demonstration buildings. The Task will also study the interactions and integration of large numbers of NZEBs with electric and natural gas utilities. The work will be connected to other international collaborations on net zero energy solutions at the community level.

The main ***goal*** of Task 40/Annex 52 is to help advance the NZEB concept in the marketplace. The Task source book and the datasets will provide realistic case studies of how NZEBs can be achieved. Demonstrating and documenting real projects will also lower industry resistance to adoption of these concepts.

The ***objectives*** of this Task/Annex are to study current net-zero, near net-zero and very low energy buildings and to develop a common understanding, a harmonized international definitions framework, tools, innovative solutions and industry guidelines. A primary means of achieving this objective is to document and propose practical NZEB demonstration projects, with convincing architectural quality. These exemplars and the supporting source book, guidelines and tools are viewed as keys to industry adoption. This Task/Annex will pursue optimal integrated design solutions that provide good indoor environment for both heating and cooling situations. The process recognizes the importance of optimizing the design for the functional requirement, reducing loads and designing energy systems that pave the way for seamless incorporation of renewable energy innovations as they become cost effective.

Status of country participation and effectiveness:

Task 40/Annex 52 is well sourced (and continues to attract new enquiries for participation as observers. The table below summarizes the current (June 2012) status of participation and the effectiveness of this participation sourced by the SHC and ECBCS IAs.

Country		**NPP**	**IEA IA Support**	
			SHC	**ECBCS**
Australia	AUS	In process	✓	
Austria	AUT	**Yes**	✓	
Belgium	BEL	**Yes**	✓	
Canada	CAN	**Yes**	✓	
Denmark	DNK	**Yes**	✓	
Finland	FIN	**Yes**		✓
France	FRA	**Yes**		✓
Germany	DEU	**Yes**	✓	
Italy	ITA	**Yes**		✓
Rep. Korea	KOR	**Yes**		✓
New Zealand	NZL	**Yes**	✓	
Norway	NOR	**Yes**		✓
Portugal	PRT	**Yes**	✓	
Singapore	SGP	**Yes**	✓	
Spain	ESP	**Yes**	✓	
Sweden	SWE	**Yes**	✓	
Switzerland	CHE	**Yes**		✓
UK	GBR	**Yes**		✓
United States	USA	**Yes**	✓	

The majority of the National Experts (about 55 individuals) come from universities and bring along with them their graduate students to attend and participate in the meetings. There are also several participants that come from national and regional technology and buildings research centres including NREL (USA) , Canmet ENERGY (Canada), EURAC (EU) and AEE (Austria). Samsung Corporation (S. Korea) and Grocon (Australia) represent industry participation.

*Information dissemination***:**

During this reporting period various National Experts in Subtasks A, B and C participated in many regional and international events (workshops, seminar, industry sessions, national policy-related meetings, other) where they represented the Task/Annex through oral and/or poster presentations. Of notable events, there were presentations made (or will be made to)to:

- ASHRAE 2012 Winter Conference, Chicago, Illinois, USA, January 21 – 25, 2012;
- IEA SHCP Workshop on Solar Energy in Urban Planning, Lisbon, Portugal, March 26, 2012;
- Smart City world Congress, Barcelona, Spain, December 1, 2012;
- eSim 2012: Building Simulation Conference, Halifax, Nova Scotia, Canada, May 02-04, 2012.

The Task/Annex website continues to be a nexus of information dissemination of technical papers and Task/Annex related documentations. Publically released papers can be downloaded from: http://www.iea-shc.org/publications/task.aspx?Task=40

Subtask developments

Subtask A: Definitions and Implications:(Leads: Germany and Italy)

The objective of this Subtask is to establish an internationally agreed understanding on NZEBs based on a common methodology. The progress achieved during the reporting period include many activities described in the following paraghaph.

During this reporting period, further refinements of the NetZEB Definitions Evaluation Tool that performs energy demand and generation calculations linked NetZEB balancing procedures were undertaken and the testing of the tool was initiated. Elements of the work has been reported in technical papers submitted to Buildings and Energy Journal and to Buildings and Energy Journal in Fall 2012.

- A Technical report on literature review of NetZEBs (id DA-TR1) was completed incorporating feedback from both the SHC and ECBCS ExCo review committees, and a PDF version will be available for downloading by end of June 2012.
- The activity on LCA and embodies energy (activity A1-9) headed by National Experts from Switzerland and Sweden completed its work plan. Highlights of the results show that no country has national requirements on embodies energy, and there are numerous databases and tools on the market that people use for LCA; and, energy payback time for PV, solar thermal collectors and heat pumps, irrespective of the region is always below 5 years.
- Activity A2 (1-3) on developing monitoring, verification and compliance protocols for Net ZEB for checking annual balance in practice has completed its work plan (this is Activity is co-shared with Subtask C) and a draft report output (Italy and France lead) is being readied for ExCo approval.

Subtask B: Design Processes & tools:

This Subtask aims to identify and refine design approaches and tools to support industry adoption of innovative demand/supply technologies for NZEBS. The major activities of this STB are interconnected and they include (1) document processes and tools currently being used (Activity B1); (2) assess gaps and needs for integrating simulation and design optimization tools in Net ZEB (Activity B2); and (3) develop model-based tools guide, and in-depth worked examples of projects (redesign/optimize the worked examples) to support industry adoption (Activity B3).

This is a well-resourced Subtask that has made strong strides in the reporting period. STB is responsible for developing the information that will coalesce in Vol. 2 of the

Source Book, which will focus on design process and tools for designing Net ZEBS. During this reporting period, the table of contents of the source book was finalised, in which it delineated the remaining R&D work to be done in this Subtask.

A report including the results of the qualitative benchmark (Activity 2) was submitted at the end of March 2012 to STB for internal review.

There has been good progress made on optimisation (Activity 3) during this reporting: data analysis has been completed and a draft technical paper is being developed (for review in Q4 2012). .

Subtask C: Solution Sets (Advanced Design, Engineering, Technologies): (Lead by France and New Zealand)

The objectives of this Subtask are to develop a common understanding and methodology, guidelines, tools and innovative solution sets that would be the basis of demonstrations that would support broader industry adoption. The research plan of this Subtask is centred on Vol. 3 of the source book, which seeks to address this objective. There have been several developments achieved during this reporting period.

The work to (Activity 1) to develop a series of fact sheets to document the information on potentially 43 case studies made significant progress: 30 fact sheets (Excel-based data collection on energy performance and technology metrics has been completed. These potentially 43 case studies form the STC database will form the backbone of the Volume3 of the source book on solution sets. These case studies will be linked to the

STA database of over 300 buildings identified on Google-based mapping module. With the diminished involvement of the USA to lead the development of the Task/Annex database by incorporating the case studies into the DOE/NREL High Performance Building Database, an alternative strategy to display these case studies on a Google-based map with Germany leadership from German National Experts was adopted by the members. The database is hosted by the German, Research for Energy Optimised Buildings website located at http://www.enob.info/en/net-zero-energy-buildings/map/

- Activities C2, developing themes for the Analysis matrix has been completed during this reporting period following discussions on further refining the climate classification to reflect the kind of Net ZEB building energy requirements (e.g. in the same city, a residential building could be classified as heating dominated, whereas a commercial and high rise, could be both cooling and heating dominated). This work is reported in output #DC-TP8 that was presented at the IBPSA conference in Sydney in November 2011.
- There were discussions to initiate Post Occupancy Energy (POE) studies on 15 selected case studies by an independent consultant (Activity C3).
- Activity C4, developing the Vol.3 source book (deliverable id# DC-TB1 entitled *"Net Zero Energy Buildings Solution Sets: Lessons learned from international projects"*) has advanced on several fronts: developed a Wiki structure to share document development and chapter leads have been identified.

Subtask D: Dissemination & Outreach: (lead by the OA and ST leaders)

The objective of the dissemination activity is to support knowledge transfer and market adoption of NZEBs on a national and international level. STD integrates the activities of Subtasks A, B, and C. Each Subtask is responsible for the production of designated parts of the overall information dissemination activity. Subtask leaders are responsible for the coordination of the individual contributions of Subtask participants and for coordination with the other Subtasks where a combined output is planned. All Task/Annex participants are responsible to disseminate this work as widely as they possibly can.

The Task/Annex internal website (http://www.iea-shc.org/task40/index.html) continues to be an excellent tool to post management-related documents, technical Task/Annex reports and to disseminate them amongst all participants. There has also been a posting of all conference papers at the public website and this is in a way providing information to those visiting the website. The National Experts, and Participants and Regular Contributors to the Task/Annex are ambassadors for disseminating the outputs and knowledge generated by this collaborative effort, and has been active during the reporting period in presenting the results at various national and international seminar, conferences and industry-focused workshops. Major developments in the last 6 months include:

1-day "Meet the Experts" sessions in Naples, Italy May 10-11, 2012, sponsored by Enterprise Europe Network (EEN), ENEA, and the Chamber of Commerce of Naples. Task/Annex National Experts in one-to-one meeting with industry in discussions on NetZEBs.

Many oral presentations at seminars, conferences, university - course class sessions and workshops; technical articles in referred journals; and industry consultations.

Highlights of industry involvement

The Task/Annex continues to seek to engage the buildings industry, architects and energy consulting companies in its activities. Samsung C&T is one of the two major private industries participating in the Task /Annex - the other being Grocon from Australia. Samsung sent three top company researchers to the PhD summer workshop in Montreal. The EEN event in Naples was hugely successful and iver 25 industry representatives had private meeting with the experts in the Task/Annex.

STC member from the UK has begun organizing an international conference on Zero Energy Mass Custom Homes (ZEMCH) that will take place from September 12-14, 2012, in Glasgow, Scotland. The Task/Annex is expected to co-organize and chair several session on NetZEBS. The conference is targeting custom homebuilders and the building industry.

Annex II The BUI file created by TRNBUILD

```
*-----------------------------------------------------------------------------------------------------------------------------------------------------------
* L a y e r s
*-----------------------------------------------------------------------------------------------------------------------------------------------------------
LAYER INTONACO
 RESISTANCE=    0.019
LAYER MATTONE_FORATO
 CONDUCTIVITY=   1.04 : CAPACITY=    0.8 : DENSITY=    666
LAYER BLOCCO_POROTON30
 CONDUCTIVITY=   0.78 : CAPACITY=    0.7 : DENSITY=    950
LAYER POLISTIRENE
 CONDUCTIVITY=   0.13 : CAPACITY=   1.45 : DENSITY=     20
LAYER PIASTRELLE
 CONDUCTIVITY=   3.62 : CAPACITY=      1 : DENSITY=   2300
LAYER CALCESTRUZZO_MAGRO
 CONDUCTIVITY=   3.37 : CAPACITY=      1 : DENSITY=   2200
LAYER POLIURETANO_ESPANSO
 CONDUCTIVITY=   0.09 : CAPACITY=    1.5 : DENSITY=     40
LAYER GOMMA
 RESISTANCE=    0.017
LAYER CALCESTRUZZO
 CONDUCTIVITY=   4.92 : CAPACITY=      1 : DENSITY=   2200
LAYER LATERIZIO_600
 CONDUCTIVITY=   1.04 : CAPACITY=    0.8 : DENSITY=    600
LAYER LANA_LEGNO
 CONDUCTIVITY=   0.39 : CAPACITY=   1.45 : DENSITY=     60
LAYER PORTA
 CONDUCTIVITY=   5.18 : CAPACITY=    2.1 : DENSITY=    600
LAYER ABETE
 CONDUCTIVITY=   0.43 : CAPACITY=    2.1 : DENSITY=    450
LAYER ARIA
 CONDUCTIVITY=      1 : CAPACITY=      1 : DENSITY=      1
LAYER LANA_ROCCIA
 CONDUCTIVITY=   0.14 : CAPACITY=   0.83 : DENSITY=     40
LAYER PANNELLO_FIBRA_LEGNO
```

CONDUCTIVITY= 0.43 : CAPACITY= 2.1 : DENSITY= 170
LAYER CARTONGESSO
CONDUCTIVITY= 0.756 : CAPACITY= 0.95 : DENSITY= 750
LAYER BITUME
RESISTANCE= 0.008
LAYER ACTIVE
PSPACING= 0.15 : PDIAMETER= 0.017 : PWALLTHICKNESS=0.00225 : PCONDUCTIVITY= 1.26 : CPFLUID= 4.18
*---
* I n p u t s
*---
INPUTS T_IN_PAV_RAD PORTATA_IN_PAV_RAD FINESTRA_SUD FINESTRA_SUD45 FLAT1_ZONE1 PORTATA_FLAT1_ZONE2 PORT_F1_Z1 PORT_F3_Z1 PORT_F1_Z2 PORT_F3_Z2 PORT_F2_Z1 PORT_F4_Z1 PORT_F2_Z2 PORT_F4_Z2 PORT_F5_Z3 ;
PORT_F5_Z2 PORT_F5_Z1 PORT_F6_Z2 PORT_F6_Z1 PORT_F6_Z3 WIND_SUD_P_0 WIND2_SUD_P0_EST WIND_SUD1_P0_EST WIND_SUD2_P0_WEST WIND_SUD_P1_WEST WIND_SUD_P1_EST T_FAL_F1_Z1
*---
* S c h e d u l e s
*---
SCHEDULE OCCUPANTS
HOURS =0.000 8.000 12.000 14.000 18.000 24.0
VALUES=2. 0 2. 0 2. 2.
*---
* W a l l s
*---
WALL DIVISORIO_INT
LAYERS = INTONACO MATTONE_FORATO INTONACO
THICKNESS= 0 0.1 0
ABS-FRONT= 0.3 : ABS-BACK= 0.3
HFRONT = 9 : HBACK= 9
WALL MURO_ESTERNO
LAYERS = INTONACO BLOCCO_POROTON30 POLISTIRENE INTONACO
THICKNESS= 0 0.3 0.18 0

ABS-FRONT= 0.3 : ABS-BACK= 0.6
HFRONT = 9 : HBACK= 72
WALL PAVIMENTO
LAYERS = PIASTRELLE CALCESTRUZZO_MAGRO POLIURETANO_ESPANSO CALCESTRUZZO_MAGRO GOMMA CALCESTRUZZO LATERIZIO_600 INTONACO
THICKNESS= 0.02 0.05 0.04 0.04 0 0.04 0.2 0
ABS-FRONT= 0.6 : ABS-BACK= 0.3
HFRONT = 18 : HBACK= 18
WALL SOFFITTO
LAYERS = INTONACO LATERIZIO_600 CALCESTRUZZO GOMMA CALCESTRUZZO_MAGRO POLIURETANO_ESPANSO CALCESTRUZZO_MAGRO PIASTRELLE
THICKNESS= 0 0.02 0.04 0 0.04 0.04 0.05 0.02
ABS-FRONT= 0.3 : ABS-BACK= 0.3
HFRONT = 18 : HBACK= 18
WALL DIVISORIO_APP
LAYERS = INTONACO MATTONE_FORATO LANA_LEGNO MATTONE_FORATO INTONACO
THICKNESS= 0 0.1 0.06 0.1 0
ABS-FRONT= 0.3 : ABS-BACK= 0.3
HFRONT = 9 : HBACK= 9
WALL PORTA
LAYERS = PORTA
THICKNESS= 0.07
ABS-FRONT= 0.6 : ABS-BACK= 0.6
HFRONT = 9 : HBACK= 72
WALL TETTO
LAYERS = ABETE ARIA LANA_ROCCIA PANNELLO_FIBRA_LEGNO CARTONGESSO
THICKNESS= 0.02 0.04 0.1 0.1 0.03
ABS-FRONT= 0.6 : ABS-BACK= 0.9
HFRONT = 9 : HBACK= 72
WALL SOFFITTO_TERRAZZA
LAYERS = INTONACO LATERIZIO_600 CALCESTRUZZO POLISTIRENE BITUME CALCESTRUZZO_MAGRO PIASTRELLE
THICKNESS= 0 0.2 0.04 0.08 0 0.05 0.02
ABS-FRONT= 0.3 : ABS-BACK= 0.3
HFRONT = 18 : HBACK= 72

WALL PAV_RAD

LAYERS = PIASTRELLE CALCESTRUZZO_MAGRO ACTIVE CALCESTRUZZO_MAGRO POLIURETANO_ESPANSO CALCESTRUZZO_MAGRO GOMMA CALCESTRUZZO LATERIZIO_600 INTONACO

THICKNESS= 0.02 0.05 0 0.045 0.04 0.025 0 0.035 0.2 0

ABS-FRONT= 0.6 : ABS-BACK= 0.6

HFRONT = FLOOR : HBACK= FLOOR

*---

* W i n d o w s

*---

WINDOW G

WINID=1001 : HINSIDE=11 : HOUTSIDE=64 : SLOPE=90 : SPACID=0 : WWID=0 : WHEIG=0 : FFRAME=0.15 : UFRAME=8.17 : ABSFRAME=0.6 : RISHADE=0 : RESHADE=0 : REFLISHADE=0.5 : REFLOSHADE=0.1 : CCISHADE=0.5

WINDOW B

WINID=13002 : HINSIDE=9 : HOUTSIDE=72 : SLOPE=90 : SPACID=4 : WWID=1.35 : WHEIG=1.35 : FFRAME=0.2 : UFRAME=0.24 : ABSFRAME=0.3 : RISHADE=0 : RESHADE=0 : REFLISHADE=0 : REFLOSHADE=0 : CCISHADE=0.5

WINDOW L

WINID=13002 : HINSIDE=9 : HOUTSIDE=72 : SLOPE=90 : SPACID=4 : WWID=0.65 : WHEIG=1.35 : FFRAME=0.3 : UFRAME=0.24 : ABSFRAME=0.3 : RISHADE=0 : RESHADE=0 : REFLISHADE=0 : REFLOSHADE=0 : CCISHADE=0.5

WINDOW H

WINID=13002 : HINSIDE=9 : HOUTSIDE=72 : SLOPE=90 : SPACID=4 : WWID=1.5 : WHEIG=2.25 : FFRAME=0.24 : UFRAME=0.24 : ABSFRAME=0.3 : RISHADE=0 : RESHADE=0 : REFLISHADE=0 : REFLOSHADE=0 : CCISHADE=0.5

WINDOW C

WINID=13002 : HINSIDE=9 : HOUTSIDE=72 : SLOPE=90 : SPACID=4 : WWID=0.7 : WHEIG=0.7 : FFRAME=0.37 : UFRAME=0.24 : ABSFRAME=0.3 : RISHADE=0 : RESHADE=0 : REFLISHADE=0 : REFLOSHADE=0 : CCISHADE=0.5

WINDOW E

WINID=13002 : HINSIDE=9 : HOUTSIDE=72 : SLOPE=90 : SPACID=4 : WWID=1.3 : WHEIG=2.25 : FFRAME=0.26 : UFRAME=0.24 : ABSFRAME=0.3 : RISHADE=0 : RESHADE=0 : REFLISHADE=0 : REFLOSHADE=0 : CCISHADE=0.5

```
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* D e f a u l t  G a i n s
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
GAIN PERS_ISO04
 CONVECTIVE=180 : RADIATIVE=90 : HUMIDITY=0.11
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* O t h e r  G a i n s
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* C o m f o r t
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* I n f i l t r a t i o n
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* V e n t i l a t i o n
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
VENTILATION VENT1.1
 TEMPERATURE=OUTSIDE
 AIRCHANGE=1.1
 HUMIDITY=OUTSIDE
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* C o o l i n g
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
* H e a t i n g
*-----------------------------------------------------------------------------------------------------------
---------------------------------------------------------------------------------------------------
*
```

*---

* Z o n e s

*---

ZONES FLAT1_ZONE1 FLAT1_ZONE2 FLAT2_ZONE1 FLAT2_ZONE2 FLAT3_ZONE1 FLAT3_ZONE2 FLAT4_ZONE1 FLAT4_ZONE2 FLAT5_ZONE1 FLAT5_ZONE2 FLAT5_ZONE3 FLAT6_ZONE1 FLAT6_ZONE2 FLAT6_ZONE3

*---

* O r i e n t a t i o n s

*---

ORIENTATIONS NORTH SOUTH EAST WEST HORIZONTAL S_SLOPE S_O_W_0 S_O_W_1 S_O_E_0 S_O_E_1

*

*+++

BUILDING

*+++

*

*---

* Z o n e FLAT1_ZONE1 / A i r n o d e FLAT1_ZONE1

*---

ZONE FLAT1_ZONE1

AIRNODE FLAT1_ZONE1

WALL =DIVISORIO_INT : SURF= 1 : AREA= 7.844 : ADJACENT=FLAT1_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF= 2 : AREA= 30.563 : ADJACENT=FLAT1_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF= 3 : AREA= 8.585 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=G : SURF= 4 : AREA= 3.29 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 5 : AREA= 27.863 : EXTERNAL : ORI=WEST : FSKY=0.5

WINDOW=L : SURF= 6 : AREA= 0.8775 : EXTERNAL : ORI=WEST : FSKY=0.5

WINDOW=B : SURF= 7 : AREA= 1.8225 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 8 : AREA= 4.031 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =PAV_RAD : SURF= 9 : AREA= 37.164 : BOUNDARY=IDENTICAL : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F1_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 15 : AREA= 37.16 : ADJACENT=FLAT3_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F3_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 139.37 : VOLUME= 116.14 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT1_ZONE2 / A i r n o d e FLAT1_ZONE2

*---

ZONE FLAT1_ZONE2

AIRNODE FLAT1_ZONE2

WALL =MURO_ESTERNO : SURF= 10 : AREA= 5.403 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 11 : AREA= 3 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF= 12 : AREA= 15.375 : BOUNDARY=IDENTICAL

WALL =DIVISORIO_APP : SURF= 13 : AREA= 34.75 : ADJACENT=FLAT2_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF= 17 : AREA= 6.985 : EXTERNAL : ORI=S_O_W_0 : FSKY=0.5

WINDOW=G : SURF= 18 : AREA= 5.64 : EXTERNAL : ORI=S_O_W_0 : FSKY=0.5 : ESHADE=INPUT 1*WIND_SUD2_P0_WEST

WALL =PORTA : SURF= 23 : AREA= 1.88 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 24 : AREA= 4.995 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =DIVISORIO_INT : SURF= 25 : AREA= 7.844 : ADJACENT=FLAT1_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF= 26 : AREA= 30.563 : ADJACENT=FLAT1_ZONE1 : BACK

WALL =PAV_RAD : SURF= 41 : AREA= 49.81 : BOUNDARY=IDENTICAL : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F1_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 42 : AREA= 49.81 : ADJACENT=FLAT3_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F3_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 186.79 : VOLUME= 155.66 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT2_ZONE1 / A i r n o d e FLAT2_ZONE1

*---

ZONE FLAT2_ZONE1

AIRNODE FLAT2_ZONE1

WALL =DIVISORIO_INT : SURF= 19 : AREA= 7.844 : ADJACENT=FLAT2_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF= 21 : AREA= 30.563 : ADJACENT=FLAT2_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF= 27 : AREA= 8.585 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=G : SURF= 28 : AREA= 3.29 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 29 : AREA= 27.863 : EXTERNAL : ORI=EAST : FSKY=0.5

WINDOW=L : SURF= 30 : AREA= 0.88 : EXTERNAL : ORI=EAST : FSKY=0.5

WINDOW=B : SURF= 31 : AREA= 1.82 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 32 : AREA= 4.031 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =PAV_RAD : SURF= 61 : AREA= 37.164 : BOUNDARY=IDENTICAL : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F2_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 62 : AREA= 37.164 : ADJACENT=FLAT4_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F4_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 139.37 : VOLUME= 116.14 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*--

* Z o n e FLAT2_ZONE2 / A i r n o d e FLAT2_ZONE2

*--

ZONE FLAT2_ZONE2

AIRNODE FLAT2_ZONE2

WALL =DIVISORIO_APP : SURF= 14 : AREA= 34.75 : ADJACENT=FLAT1_ZONE2 : BACK

WALL =DIVISORIO_INT : SURF= 20 : AREA= 7.844 : ADJACENT=FLAT2_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF= 22 : AREA= 30.563 : ADJACENT=FLAT2_ZONE1 : BACK

WALL =MURO_ESTERNO : SURF= 33 : AREA= 5.403 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 34 : AREA= 3 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF= 35 : AREA= 15.375 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF= 36 : AREA= 6.985 : EXTERNAL : ORI=S_O_E_0 : FSKY=0.5

WINDOW=G : SURF= 37 : AREA= 5.64 : EXTERNAL : ORI=S_O_E_0 : FSKY=0.5 : ESHADE=INPUT 1*WIND2_SUD_P0_EST

WALL =MURO_ESTERNO : SURF= 38 : AREA= 4.995 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =PORTA : SURF= 39 : AREA= 1.88 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =PAV_RAD : SURF= 40 : AREA= 49.81 : BOUNDARY=IDENTICAL : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F2_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 44 : AREA= 49.81 : ADJACENT=FLAT4_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F4_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 186.79 : VOLUME= 155.66 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT3_ZONE1 / A i r n o d e FLAT3_ZONE1

*---

ZONE FLAT3_ZONE1

AIRNODE FLAT3_ZONE1

WALL =PAV_RAD : SURF= 16 : AREA= 37.16 : ADJACENT=FLAT1_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F3_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF= 46 : AREA= 7.844 : ADJACENT=FLAT3_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF= 48 : AREA= 30.563 : ADJACENT=FLAT3_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF= 50 : AREA= 8.585 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=G : SURF= 51 : AREA= 3.29 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 52 : AREA= 27.863 : EXTERNAL : ORI=WEST : FSKY=0.5

WINDOW=L : SURF= 53 : AREA= 0.88 : EXTERNAL : ORI=WEST : FSKY=0.5

WINDOW=B : SURF= 54 : AREA= 1.82 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 55 : AREA= 4.031 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =SOFFITTO_TERRAZZA : SURF= 56 : AREA= 16.24 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

WALL =PAV_RAD : SURF= 57 : AREA= 14.71 : ADJACENT=FLAT5_ZONE3 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z3 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 59 : AREA= 3.89 : ADJACENT=FLAT5_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z2 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=121 : AREA= 2.32 : ADJACENT=FLAT5_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 137.94 : VOLUME= 114.95 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT3_ZONE2 / A i r n o d e FLAT3_ZONE2

*---

ZONE FLAT3_ZONE2

AIRNODE FLAT3_ZONE2

WALL =PAV_RAD : SURF= 43 : AREA= 49.81 : ADJACENT=FLAT1_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F3_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF= 47 : AREA= 7.844 : ADJACENT=FLAT3_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF= 49 : AREA= 30.563 : ADJACENT=FLAT3_ZONE1 : BACK

WALL =DIVISORIO_APP : SURF=100 : AREA= 34.75 : ADJACENT=FLAT4_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF=102 : AREA= 6.985 : EXTERNAL : ORI=S_O_W_1 : FSKY=0.5

WINDOW=G : SURF=103 : AREA= 5.64 : EXTERNAL : ORI=S_O_W_1 : FSKY=0.5 : ESHADE=INPUT 1*WIND_SUD_P1_WEST

WALL =PORTA : SURF=104 : AREA= 1.88 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF=105 : AREA= 4.995 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF=106 : AREA= 5.403 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF=107 : AREA= 3 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF=108 : AREA= 15.38 : BOUNDARY=IDENTICAL

WALL =PAV_RAD : SURF=116 : AREA= 6.52 : ADJACENT=FLAT5_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=118 : AREA= 27.19 : ADJACENT=FLAT5_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =SOFFITTO : SURF=120 : AREA= 16.1 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 186.79 : VOLUME= 155.66 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT4_ZONE1 / A i r n o d e FLAT4_ZONE1

*---

ZONE FLAT4_ZONE1

AIRNODE FLAT4_ZONE1

WALL =PAV_RAD : SURF= 63 : AREA= 37.164 : ADJACENT=FLAT2_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F4_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF= 64 : AREA= 7.84 : ADJACENT=FLAT4_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF= 66 : AREA= 30.56 : ADJACENT=FLAT4_ZONE2 : FRONT

WALL =MURO_ESTERNO : SURF= 68 : AREA= 8.59 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=G : SURF= 69 : AREA= 3.29 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 70 : AREA= 27.863 : EXTERNAL : ORI=EAST : FSKY=0.5

WINDOW=L : SURF= 71 : AREA= 0.88 : EXTERNAL : ORI=EAST : FSKY=0.5

WINDOW=B : SURF= 72 : AREA= 1.82 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 73 : AREA= 4.031 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =SOFFITTO_TERRAZZA : SURF= 74 : AREA= 16.24 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

WALL =PAV_RAD : SURF= 77 : AREA= 3.888 : ADJACENT=FLAT6_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=109 : AREA= 2.317 : ADJACENT=FLAT6_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z1 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF= 75 : AREA= 14.71 : ADJACENT=FLAT6_ZONE3 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z3 : NLOOP = 3 : MFLOWMIN = 6.36

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 137.94 : VOLUME= 114.95 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*--

* Z o n e FLAT4_ZONE2 / A i r n o d e FLAT4_ZONE2

*--

ZONE FLAT4_ZONE2

AIRNODE FLAT4_ZONE2

WALL =PAV_RAD : SURF= 45 : AREA= 49.81 : ADJACENT=FLAT2_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F4_Z2 : NLOOP = 6 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF= 65 : AREA= 7.84 : ADJACENT=FLAT4_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF= 67 : AREA= 30.56 : ADJACENT=FLAT4_ZONE1 : BACK

WALL =MURO_ESTERNO : SURF= 93 : AREA= 5.403 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF= 94 : AREA= 3 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF= 95 : AREA= 15.375 : BOUNDARY=IDENTICAL

WALL =MURO_ESTERNO : SURF= 96 : AREA= 6.985 : EXTERNAL : ORI=S_O_E_1 : FSKY=0.5

WINDOW=G : SURF= 97 : AREA= 5.64 : EXTERNAL : ORI=S_O_E_1 : FSKY=0.5 : ESHADE=INPUT 1*WIND_SUD_P1_EST

WALL =MURO_ESTERNO : SURF= 98 : AREA= 4.995 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =PORTA : SURF= 99 : AREA= 1.88 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =DIVISORIO_APP : SURF=101 : AREA= 34.75 : ADJACENT=FLAT3_ZONE2 : BACK

WALL =PAV_RAD : SURF=111 : AREA= 6.52 : ADJACENT=FLAT6_ZONE2 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=113 : AREA= 27.19 : ADJACENT=FLAT6_ZONE1 : BACK : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =SOFFITTO : SURF=115 : AREA= 16.1 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 186.79 : VOLUME= 155.66 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT5_ZONE1 / A i r n o d e FLAT5_ZONE1

*---

ZONE FLAT5_ZONE1

AIRNODE FLAT5_ZONE1

WALL =MURO_ESTERNO : SURF= 79 : AREA= 7.252 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =PORTA : SURF= 81 : AREA= 2.115 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =DIVISORIO_APP : SURF= 83 : AREA= 33.345 : ADJACENT=FLAT6_ZONE1 : FRONT

WALL =PAV_RAD : SURF=119 : AREA= 27.19 : ADJACENT=FLAT3_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=122 : AREA= 2.32 : ADJACENT=FLAT3_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =MURO_ESTERNO : SURF= 87 : AREA= 8.445 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=H : SURF= 89 : AREA= 3.525 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =DIVISORIO_INT : SURF= 85 : AREA= 10.203 : ADJACENT=FLAT5_ZONE3 : FRONT

WALL =DIVISORIO_INT : SURF= 90 : AREA= 3.83 : ADJACENT=FLAT5_ZONE3 : FRONT

WALL =DIVISORIO_INT : SURF= 92 : AREA= 4.04 : ADJACENT=FLAT5_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF=124 : AREA= 5.16 : ADJACENT=FLAT5_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF=126 : AREA= 5.61 : ADJACENT=FLAT5_ZONE2 : FRONT

WALL =PAVIMENTO : SURF=128 : AREA= 15.44 : INTERNAL

WALL =TETTO : SURF=129 : AREA= 20.87 : EXTERNAL : ORI=S_SLOPE : FSKY=0.5

WALL =TETTO : SURF=130 : AREA= 8.535 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 141.56 : VOLUME= 117.964 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---
----

* Z o n e FLAT5_ZONE2 / A i r n o d e FLAT5_ZONE2

*---

ZONE FLAT5_ZONE2

AIRNODE FLAT5_ZONE2

WALL =PAV_RAD : SURF= 60 : AREA= 3.89 : ADJACENT=FLAT3_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z2 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=117 : AREA= 6.52 : ADJACENT=FLAT3_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF=123 : AREA= 4.04 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=125 : AREA= 5.16 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=127 : AREA= 5.61 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =SOFFITTO : SURF=146 : AREA= 13.71 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

WALL =MURO_ESTERNO : SURF=147 : AREA= 11.46 : EXTERNAL : ORI=NORTH : FSKY=0.5

WINDOW=C : SURF=148 : AREA= 0.49 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF=149 : AREA= 8.312 : EXTERNAL : ORI=WEST : FSKY=0.5

WINDOW=B : SURF=150 : AREA= 1.82 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =DIVISORIO_INT : SURF=151 : AREA= 6.79 : ADJACENT=FLAT5_ZONE3 : FRONT

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 44.7 : VOLUME= 37.25 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---
----

* Z o n e FLAT5_ZONE3 / A i r n o d e FLAT5_ZONE3

*---

ZONE FLAT5_ZONE3

AIRNODE FLAT5_ZONE3

WALL =PAV_RAD : SURF= 58 : AREA= 14.71 : ADJACENT=FLAT3_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F5_Z3 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF= 86 : AREA= 10.203 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF= 91 : AREA= 3.83 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=152 : AREA= 6.79 : ADJACENT=FLAT5_ZONE2 : BACK

WALL =MURO_ESTERNO : SURF= 88 : AREA= 10.203 : EXTERNAL : ORI=WEST : FSKY=0.5

WALL =MURO_ESTERNO : SURF=160 : AREA= 7.555 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=E : SURF=161 : AREA= 3.055 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =TETTO : SURF=162 : AREA= 14.71 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 46.62 : VOLUME= 38.85 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*--

* Z o n e FLAT6_ZONE1 / A i r n o d e FLAT6_ZONE1

*--

ZONE FLAT6_ZONE1

AIRNODE FLAT6_ZONE1

WALL =MURO_ESTERNO : SURF= 80 : AREA= 7.252 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =PORTA : SURF= 82 : AREA= 2.115 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =DIVISORIO_APP : SURF= 84 : AREA= 33.345 : ADJACENT=FLAT5_ZONE1 : BACK

WALL =PAV_RAD : SURF=110 : AREA= 2.317 : ADJACENT=FLAT4_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z1 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=114 : AREA= 27.19 : ADJACENT=FLAT4_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z1 : NLOOP = 4 : MFLOWMIN = 6.36

WALL =MURO_ESTERNO : SURF=131 : AREA= 8.445 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=H : SURF=132 : AREA= 3.525 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =DIVISORIO_INT : SURF=133 : AREA= 10.203 : ADJACENT=FLAT6_ZONE3 : FRONT

WALL =DIVISORIO_INT : SURF=135 : AREA= 3.83 : ADJACENT=FLAT6_ZONE3 : FRONT

WALL =DIVISORIO_INT : SURF=137 : AREA= 4.04 : ADJACENT=FLAT6_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF=139 : AREA= 5.16 : ADJACENT=FLAT6_ZONE2 : FRONT

WALL =DIVISORIO_INT : SURF=141 : AREA= 5.61 : ADJACENT=FLAT6_ZONE2 : FRONT

WALL =PAVIMENTO : SURF=143 : AREA= 15.44 : INTERNAL

WALL =TETTO : SURF=144 : AREA= 20.87 : EXTERNAL : ORI=S_SLOPE : FSKY=0.5

WALL =TETTO : SURF=145 : AREA= 8.54 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 141.56 : VOLUME= 117.964 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*--

* Z o n e FLAT6_ZONE2 / A i r n o d e FLAT6_ZONE2

*--

ZONE FLAT6_ZONE2

AIRNODE FLAT6_ZONE2

WALL =PAV_RAD : SURF= 78 : AREA= 3.888 : ADJACENT=FLAT4_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =PAV_RAD : SURF=112 : AREA= 6.52 : ADJACENT=FLAT4_ZONE2 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z2 : NLOOP = 1 : MFLOWMIN = 6.36

WALL =DIVISORIO_INT : SURF=138 : AREA= 4.04 : ADJACENT=FLAT6_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=140 : AREA= 5.16 : ADJACENT=FLAT6_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=142 : AREA= 5.61 : ADJACENT=FLAT6_ZONE1 : BACK

WALL =SOFFITTO : SURF=153 : AREA= 13.71 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

WALL =MURO_ESTERNO : SURF=154 : AREA= 11.46 : EXTERNAL : ORI=NORTH : FSKY=0.5

WINDOW=C : SURF=155 : AREA= 0.49 : EXTERNAL : ORI=NORTH : FSKY=0.5

WALL =MURO_ESTERNO : SURF=156 : AREA= 8.31 : EXTERNAL : ORI=EAST : FSKY=0.5

WINDOW=B : SURF=157 : AREA= 1.82 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =DIVISORIO_INT : SURF=158 : AREA= 6.79 : ADJACENT=FLAT6_ZONE3 : FRONT

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 44.7 : VOLUME= 37.25 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1

*---

* Z o n e FLAT6_ZONE3 / A i r n o d e FLAT6_ZONE3

*---

ZONE FLAT6_ZONE3

AIRNODE FLAT6_ZONE3

WALL =DIVISORIO_INT : SURF=134 : AREA= 10.203 : ADJACENT=FLAT6_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=136 : AREA= 3.83 : ADJACENT=FLAT6_ZONE1 : BACK

WALL =DIVISORIO_INT : SURF=159 : AREA= 6.79 : ADJACENT=FLAT6_ZONE2 : BACK

WALL =PAV_RAD : SURF=163 : AREA= 14.71 : ADJACENT=FLAT4_ZONE1 : FRONT : INTEMP = INPUT 1*T_IN_PAV_RAD : MFLOW = INPUT 1*PORT_F6_Z3 : NLOOP = 3 : MFLOWMIN = 6.36

WALL =MURO_ESTERNO : SURF= 76 : AREA= 10.2 : EXTERNAL : ORI=EAST : FSKY=0.5

WALL =MURO_ESTERNO : SURF=164 : AREA= 7.555 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WINDOW=E : SURF=165 : AREA= 3.055 : EXTERNAL : ORI=SOUTH : FSKY=0.5

WALL =TETTO : SURF=166 : AREA= 14.71 : EXTERNAL : ORI=HORIZONTAL : FSKY=0.5

REGIME

GAIN = PERS_ISO04 : SCALE= SCHEDULE 1*OCCUPANTS

VENTILATION = VENT1.1

CAPACITANCE = 46.62 : VOLUME= 38.85 : TINITIAL= 20 : PHINITIAL= 50 : WCAPR= 1
*---
* O u t p u t s
*---
OUTPUTS
TRANSFER : TIMEBASE=1.000
DEFAULT
AIRNODES = FLAT1_ZONE1
NTYPES = 58 : SURF = 9, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT1_ZONE2
NTYPES = 58 : SURF = 41, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT2_ZONE1
NTYPES = 58 : SURF = 61, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT2_ZONE2
NTYPES = 58 : SURF = 40, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT3_ZONE1
NTYPES = 58 : SURF = 16, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT3_ZONE2
NTYPES = 58 : SURF = 43, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT4_ZONE1
NTYPES = 58 : SURF = 63, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT4_ZONE2
NTYPES = 58 : SURF = 45, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT5_ZONE1
NTYPES = 58 : SURF = 119, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT5_ZONE2
NTYPES = 58 : SURF = 117, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT5_ZONE3
NTYPES = 58 : SURF = 58, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT6_ZONE1
NTYPES = 58 : SURF = 110, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT6_ZONE2
NTYPES = 58 : SURF = 78, : TOFL - fluid outlet temperature of active layer
AIRNODES = FLAT6_ZONE3
NTYPES = 58 : SURF = 163, : TOFL - fluid outlet temperature of active layer
*---
* E n d

References

[1]EPBD recast (2010), Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), *Official Journal of the European Union*, 18/06/2010.

[2] US DOE (2008), Building Technologies Program, *Planned Program Activities for 2008-2012*, Department Of Energy, US, http://www1.eere.energy.gov/buildings/mypp.html (downloaded .01/07/2010)

Chapter 1

[1]EPBD recast (2010), Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), *Official Journal of the European Union*, 18/06/2010.

[2] US DOE (2008), Building Technologies Program, *Planned Program Activities for 2008-2012*, Department Of Energy, US, http://www1.eere.energy.gov/buildings/mypp.html (downloaded .01/07/2010)

[3] 2011 Survey of resource efficiency policies in EEA member and cooperating countries, Country Profile: Italy, European Environment Agency, May 2011.

[4] MiSE data processed by ENEA

[5] Eurostat data processed by ENEA

[6] MiSE and ISTAT data processed by ENEA.

[7] RAEE 2010 – Energy Efficiency Annual Report

Chapter 2

[1] Torcellini, P., Pless, S., Deru, M. and Crawley, D. (2006), Zero Energy Buildings: A Critical Look at the Definition, National Renewable Energy Laboratory and Department of Energy, (US).

[2] Marszal, A. and Heiselberg, P. (2009), A literature review on ZEB definitions, *Aalborg University (DK).*

[3] ECEEE (2009), Net zero energy buildings: definitions, issues and experience, *European Council for an Energy Efficient Economy (EU).*

[4]Laustsen, J. (2008). Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings. International Energy Agency (IEA).

[5] Heinze, M., Voss, K. (2009) Goal: Zero Energy Building -Exemplary Experience Based on the Solar Estate Solarsiedlung Freiburg am Schlierberg, Germany, Journal of Green Building, vol. 4, nr. 4.

[6] (Torcellini, et al. (2006)

[7] http://www.peabody.org.uk/media-centre/factsheets/bedzed.aspx

Abel, E. (1994). Low-energy buildings. Energy and Buildings 21 (1994) 169-174

Bağcı, B. (2008). Towards a Zero Energy Island. Renewable Energy Vol. 34, Issue 3, March 2009, Pages 784-789;

Charron, R. (2008). A review of design processes for low energy solar homes. Open House International Vol. 33, Issue 3, 2008, pp. 7-16

Clark II, W.W. & Eisenberg L. (2008). Agile sustainable communities: On-site renewable energy generation. Utilities Policy Vol. 16, Issue 4, December 2008, pp. 262-274

Esbensen, T.V. & Korsgaard, V. (1977). Dimensioning of the solar heating system in the zero energy house in Denmark. Solar Energy Vol. 19, Issue 2, 1977, pp. 195-199

Gilijamse, W. (1995). Zero-energy houses in the Netherlands. Proceedings of Building Simulation '95. Madison, Wisconsin, USA, August 14–16; 1995, pp. 276–283.

Web address: http://www.ibpsa.org/proceedings/BS1995/BS95_276_283.pdf Griffith, B., Torcellini, P. & Long, N. (2006). Assessment of the Technical Potential for Achieving Zero- Energy Commercial Buildings. National Renewable Energy Laboratory (NREL), USA Web address: http://www.nrel.gov/docs/fy06osti/39830.pdf

Iqbal, M.T. (2003). A feasibility study of a zero energy home in Newfoundland. Renewable Energy Vol. 29, Issue 2 February 2004, pp. 277-289

Kilkis, S. (2007). A new metric for net- zero carbon buildings. Proceedings of ES2007. Energy Sustainability 2007, Long Beach, California, pp. 219-224

Kramer, J., Krothapalli, A. & Greska, B. (2007). The off-grid zero emission building. Proceedings of the Energy Sustainability Conference 2007, 2007, pp. 573-580

Laustsen, J. (2008). Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings. International Energy Agency (IEA). Web address: http://www.iea.org/g8/2008/Building_Codes.pdf

Mertz, G.A., Raffio, G.S. & Kissock, K. (2007). Cost optimization of net-zero energy house. Proceedings of ES2007. Energy Sustainability 2007, Long Beach, California, pp. 477- 488

Morbitzer, C. (2008). Low energy and sustainable housing in the UK and Germany. Open House International. Vol. 33, Issue 3, 2008, pp. 17-25

Noguchi, M., Athienitis, A., Delisle, V., Ayoub, J. & Berneche, B. (2008). Net Zero Energy Homes of the Future: A Case Study of the ÉcoTerraTM House in Canada. Presented at the Renewable Energy Congress, Glasgow, Scotland, July 2008 Web address: http://canmetenergy.nrcan.gc.ca/eng/buildings_communities/housing/ public cations.html?2008-112

Parker, D.S., Thomas, M. & Merrigan, T. (2001). On the path to Zero Energy Homes. Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory, and DOE national laboratory Web address: http://www.builditsolar.com/Projects/SolarHomes/zeb_path_29915.pdf

Platell, P. & Dudzik, D.A. (2007). Zero energy houses geoexchange, solar CHP, and low energy building approach. Proceedings of the Energy Sustainability Conference 2007, 2007, pp. 471-476

Pogharian, S., Ayoub, J., Candanedo, J.A. & Athienitis, A.K. (2008). Getting to a Net Zero Energy Lifestyle in Canada. The Alstonvale Net Zero Energy House. Presented to the 23nd European PV Solar Energy Conference, Valencia, Spain, September 2008

Rosta, S., Hurt, R., Boehm, R. & Hale, M.J. (2008). Performance of a zero-energy house. Journal of Solar Energy Engineering, Transactions of the ASME Vol. 130, Issue 2, May 2008, pp. 0210061-0210064

Saitoh, T (1984). Natural energy autonomous house with underground water reservoir. Bulletin of the JSME Vol. 27, Issue 226, April 1984, pp. 773-778

Saitoh, T., Matsuhashi, H. & Ono, T. (1985). An energy-independent house combining solar thermal and sky radiation energies. Solar Energy Vol. 35, Issue 6, 1985, pp. 541-547

Stahl, W., Voss, K. & Goetzberger, A. (1995). The self-sufficient solar house Freiburg. Geliotekhnika Issue 1-3, January 1995, pp. 50-80

Torcellini, P., Pless, S. & Deru, M. (2006). Zero Energy Buildings: A Critical Look at the Definition. National Renewable Energy Laboratory (NREL), USA Web address: http://www.nrel.gov/docs/fy06osti/39833.pdf

Torcellini, P. & Crawley, D. *(2006). Understanding Zero-Energy Buildings. ASHRAE Journal September 2006, Vol. 48 Issue 9, pp. 62-69

Voss, K., Goetzberger, A., Bopp, G., Häberle, A., Heinzel, A. & Lehmberg, H. (1996). The self-sufficient solar house in Freiburg - Results of 3 years of operation. Solar Energy Vol. 58, Issue 1-3, July 1996, pp. 17-23

Voss, K. (2008). What is Really New about Zero-Energy Homes?. Proceedings of 12th International Conference on Passive Houses 2008, Nuremberg, Germany pp. 187-19

"Centerline. Getting to zero-energy buildings". Center for the Built Environment (CBE), USA Web address: http://www.cbe.berkeley.edu/centerline/summer2008.pdf

General Information Report 89 "BedZED – Beddington Zero Energy Development, Sutton" (2002) "Project Profile: Riverdale NetZero Project—Edmonton, Alberta" Web address: http://www.riverdalenetzero.ca/Riverdale_NetZero_house_--_project_ profile.pdf

"The Potential Impact of Zero Energy Homes" (2006). Developed by the NAHB Research Center, the U.S. Department of Energy, and the National Renewable Energy Laboratory (NREL) Web address: http://www.toolbase.org/PDF/CaseStudies/ZEHPotentialImpact.p

[8] EPBD recast, Directive 2010/31/EU of the European Parliament and of the Coun-cil of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union, (2010) 18/06/2010.

[9] US DOE, Building Technologies Program, Planned Program Activities for 2008–2012, Department Of Energy, US, http://www1.eere.energy. gov/buildings/mypp.html, 2008 (downloaded 01/07/2010).

[10] UK, Green Building Council, http://www.ukgbc.org/site/info-centre/display-category?id=22, 2011(accessed 27/10/2011).

[11] UK, Green Building Council, http://www.ukgbc.org/site/news/show-news-details?id=398 (accessed 27/10/2011, 2011).

[12] P. Torcellini, S. Pless, M. Deru, D. Crawley, Zero Energy Buildings: A Critical Look at the Definition, National Renewable Energy Laboratory and Department of Energy, US, 2006.

[13] S. Kilkis, A new metric for net-zero carbon buildings, in: Proceedings of Energy Sustainability 2007, Long Beach, California, 2008, pp. 219–224.

[14] J. Laustsen, Energy Efficiency Requirements in Building Codes, Energy Efficiency Policies for New Buildings, International Energy Agency (IEA), 2008.

[15] ECEEE, Net Zero Energy Buildings: Definitions, Issues and Experience, European Council for an Energy Efficient Economy, EU, 2009.

[16] A.J. Marszal, P. Heiselberg, A Literature Review on ZEB Definitions, Aalborg University, DK, 2009.

[17] A.J. Marszal, P. Heiselberg, J.S. Bourrelle, E. Musall, K. Voss, I. Sartori, A. Napolitano, Zero energy building – a review of definitions and calculation methodologies, Energy and Buildings 43 (4) (2011) 971–979.

[18] J. Kurnitzki, F. Allard, D. Braham, G. Goeders, P. Heiselberg, L. Jagemar, R. Koso-nen, J. Lebrun, L. Mazzarella, J. Railio, O. Seppänen, M. Schmidt, M. Virta, How to define nearly zero energy buildings, REHVA Journal (May) (2011) 6–12.

[19] K. Voss, E. Musall, M. Lichtmeß, From low energy to net zero energy buildings – status and perspectives, Journal of Green Building 6/1 (2011) 46–57.

[20] I. Sartori, T.H. Dokka, I. Andresen, Proposal of a Norwegian ZEB definition: assessing the implications for design, Journal of Green Buildings 6/3 (2010) 133–150.

[21] M. Heinze, K. Voss, Goal: zero energy building – exemplary experience based on the Solar Estate Solarsiedlung Freiburg am Schlierberg, Journal of Green Building 4/4 (2009).

[22] K. Voss, E. Musall, Net Zero Energy Buildings – International Projects on Carbon Neutrality in Buildings, DETAIL, ISBN-978-3-0346-0780-3, Munich, 2011.

[23] IEA. SHC Task 40/ECBCS Annex 52, Towards Net Zero Energy Solar Buildings, IEA SHC Task 40 and ECBCS Annex 52, http://www.iea-shc.org/task40/index.html, 2008 (accessed 10/12/2009).

[24] EN 15603, Energy Performance of Buildings – Overall Energy Use and Definition of Energy Ratings, European Standard, European Committee for Standardiza-tion, Brussels, BE, 2008.

[25] Zero Carbon Hub, Carbon compliance – setting an appropriate limit for zero carbon new homes, Zero Carbon Hub, February 2011, London, UK, 2011.

[26] Zero Carbon Hub, Allowable solutions for tomorrow's new homes, Zero Carbon Hub, July 2011, London, UK, 2011.

[27] I. Sartori, A.G. Hestnes, Energy use in the life cycle of conventional and low-energy buildings: a review article, Energy and Buildings 39 (3) (2007) 249–257.

[28] Erneuerbare Energien Gesetz, Deutsches Bundesumweltministerium, www.bmu.de/gesetze verordnungen/doc/2676.php (download date 6.7.2011).

[29] I. Graabak, N. Feilberg, CO2 emissions in different scenarios of electricity gen-eration in Europe, SINTEF Energy Research, report TR A7058, Trondheim, NO, 2011.

[30] OpenEI, Hourly energy emission factors for electricity generation in the United States, http://en.openei.org/datasets/node/488, 2011 (accessed 22/09/2011).

[31] Red eléctrica de Espa˜na, Power demand tracking in real time, http://www.ree.es/ingles/operacion/curvas demanda.asp, 2011 (accessed 22/09/2011).

[32] TDV, Time-dependent valuation, http://www.energy.ca.gov/title24/2005 standards/archive/rulemaking/documents/tdv/index.html, 2005 (accessed 22/09/2011).

[33] I. Sartori, J. Candanedo, S. Geier, R. Lollini, A. Athienitis, F. Garde, L. Pagliano, Comfort and energy performance recommendations for net zero energy build-ings, in: Proceedings of EuroSun 2010, Graz, AT, 2010.

[34] BPIE, Cost Optimality – Discussing methodology and challenges within the recast EPBD, Building Performance Institute Europe, Brussels, BE, 2011.

[35] ECEEE, Cost Optimal Building Performance Requirements – Calculation Methodology for Reporting on National Energy Performance Requirements on the Basis of Cost Optimality within the Framework of the EPBD, European Council for an Energy Efficient Economy, 2 May 2011, 2011.

[36] EPBD-CA, Cost optimal levels for energy performance requirements – execu-tive summary, Energy Performance of Buildings Concerted Action, July 2011, 2011.

[37] BPIE (2011) Principles for nearly zero-energy buildings, Report from the Building Performance Institute of Europe, http://www.bpie.eu/ pub principles for n zeb.html, 2012 (accessed 09/02/2012).

[38] K. Voss, I. Sartori, E. Musall, A. Napolitano, S. Geier, M. Hall, B. Karlsson, P. Heisel-berg, J. Widen, J.A. Candanedo, P. Torcellini, Load matching and grid interaction of net zero energy buildings, in: Proceedings of EuroSun 2010, Graz, AT, 2010.

[39] J. Salom, J. Widen, J.A. Candanedo, I. Sartori, K. Voss, A. Marszal, Under-standing Net Zero Energy Buildings: evaluation of load matching and grid interaction indicators, in: Proceedings of Building Simulation, Sydney, AU, 14–16 November, 2011.

[40] J. Widen, E. Wäckelgård, P. Lund, Options for improving the load matching capability of distributed photovoltaics: Methodology and application to high-latitude data, Solar Energy 83 (2009) 1953–1966.

[41] R. Baetens, R. De Coninck, L. Helsen, D. Saelens, The impact of domestic load pro-files on the grid-interaction of building integrated photovoltaic (BIPV) systems in extremely low-energy dwellings, in: Proceedings of the Renewable Energy Research Conference, Trondheim, Norway, 7–8 June, 2010.

[42] U.S. Department of Energy, Office of Energy Efficiency and Renew-able Energy, Measurement and Verification Guidelines for Federal Energy Management Projects, Abgerufen am, 2000 (January 2011 von http://www1.eere.energy.gov/femp/pdfs/mv guidelines.pdf).

[43] A. Napolitano, Measurement and verification protocol for net zero energy build-ings, technical report in subtask A of the IEA – SHC/ECBCS – Task40/Annex52 – Towards Net Zero Energy Solar Buildings, 2011.

[44] J.C. Haberl, The design of field experiments and demonstrations, in: Field Mon-itoring Workshop. IEA Proceedings, Gothernburg, 2008.

[45] EVO, Efficiency Valuation Organization, International Performance Measure-ment and Verification Protocol – Concepts and Options for Determining Energy and Water Savings, vol. 1, Abgerufen am 24, 2010 (January 2011 von www.evo-world.org).

[46] Australian Government, Energy Efficiency Opportunities Section, Energy and Environment Division, Energy Savings Measurement Guide: How to Estimate, Measure, Evaluate and Track Energy Efficiency Opportunities, Department of Resource, Energy, and Tourism/WorleyParsons Service Pty Ltd., 2008.

Chapter 3

IEA Task 40/Annex 52, a joint activity the Solar Heating and Cooling (SCH) and Energy Conservation in Buildings and Community Systems (ECBCS) Programmes.

Chapter 4

[1] Nowak, T. (2009), Heat Pump incentive schemes: Experiences from EU Member States. Poznan, Poland

[2] ArcGuide (2010), Corporate Headquarter der Solon SE, http://www.arcguide.de/arcguide/haus-und-hof/Corporate-Headquarter-der-Solon-SE.php, accessed 20/05/2010

[3] Voss, K., et al. (2010), Load Matching and Grid Interaction of Net Zero Energy Buildings. Graz, Austria

[4] (Torcellini et al. 2006, Marszal et al., 2011

[5] Voss, K., Sartori, I., Napolitano, A., Geier, S., Gonçalves, H., Hall, M., Heiselberg, P., Widén, J., Candanedo, J.A., Musall, E., Karlsson, B., Torcellini P. 2010. Load Matching and Grid Interaction of Net Zero Energy Buildings. EuroSun 2010, Graz, Austria. September 29th - October 1st.

[6] Newsham, G.R and Bowker, B.G. 2010. The effect of utility time-varying pricing and load control strategies on residential summer peak electricity use: a review, NRCC-52707, National Research Council Canada.

REE 2010, El sistema eléctrico español 2009, Red Eléctrica de España, Madrid.

[7] Fechner, H. 2011. Energietechniken zur Erreichung des Plus-Energie-Standards. Presentation at the workshop “Plus-Energier-Technologien und –Gebäude”, January 31st.

[8] Verbruggen, B., De Coninck, R., Baetens, R., Saelens, D., Helsen, L., Driesen, J. 2011. Grid Impact Indicators for Active Building Simulation, IEEE PES Conference on Innovative Smart Grid Technologies 2011, Anaheim, California, US, January 17-19.

[9] Colson C.M. and Nehrir M.H. (2009). A review of challenges to real-time power management of microgrids. In 2009 IEEE Power & Energy Society General Meeting, Calgary, Alberta. July 26-30.

[10] Lund, H., Marszal, A., Heiselberg, P. 2011. Zero Energy Buildings and Mismatch Compensation Factors. Energy and Buildings.

[11] Widén, J., Wäckelgård, E. 2010. Net zero energy solar buildings at high latitudes: The mismatch issue. Paper presented at the EASST 2010 Conference: Practicing Science and Technology, Performing the Social, Trento, Italy, Sept. 2-4

[12] Willis, H.L., Scott, W.G. 2000. Distributed Power Generation: Planning and Evaluation, Marcel Dekker, Inc.: New York.

[13] REE 2010, El sistema eléctrico español 2009, Red Eléctrica de España, Madrid.

[14] IEA Task 40/Annex 52, a joint activity the Solar Heating and Cooling (SCH) and Energy Conservation in Buildings and Community Systems (ECBCS) Programmes.

Chapter 7

[1]Torcellini P, 2006. Zero Energy Buildings:

A critical look at the definition, ACEEE Summer Study, Pacific Grove, California.

[2]V. Karsten and M.Riley, 2009.

“IEA Join Project: Towards Net Zero Energy Solar Buildings (NZEBs)”, IEA SHC Task 40 – ECBCS Annex 52

[3]Cellura, M. The evaluation of the energy performances of a Net Zero Energy Building : an Italian Case Study. Euro sun 2010 International Conference on Solar Heating Cooling and Buildings, Graz Austria.

[4]Cellura, M, Lo Brano V, Ciulla G., Orioli A., Campanella L., Guarino F., Nardi Cesarini D.

The redesign of an Italian building to reach Net Zero Energy performances: a case study of the SHC Task 40 – ECBCS Annex 52.