

## Beyond energy efficiency in evaluating sustainable development in planning and the built environment

### ABSTRACT

The EU has set the policy target of reducing energy use by 20% by the year 2020. Therefore, a substantial consumption decrease is needed in built environment sector. Despite the great energy efficiency improvements in households, recent energy consumption data analyses show that these targets will unlikely be reached. The general aim of this study is to point out the need to define new indicators and evaluation approaches in urban planning and the built environment which are based on the concept of “energy subsidiarity”, focusing on local renewable resources rather than on current approaches based on energy efficiency. This concept correlates energy consumption with the energy supply from local renewable resources and is here proposed as new urban planning evaluation approach toward sustainable built environment.

In the paper, the “Jevons Paradox” concept and the “energy rebound effect” phenomenon are used to demonstrate how current approaches based on energy efficiency, alone, cannot lead to a remarkable reduction of energy consumption. This is also supported by data on European energy consumption and European energy efficiency in the built environment. Finally, a number of well-known European ecological districts (“eco-districts”) are analyzed in term of sustainable energy strategy as well as energy efficiency and energy balance.

This study shows that there is a contradiction between the purpose of some of the eco-districts to be low consumption (or low impacts), and the district renewable energy balance. Only few of the analyzed eco-districts are able to cover energy needs by using renewable energy obtained in the surrounding area. In most of the cases, the focus of the districts’ activities is on energy efficiency. According to the “Jevons Paradox” and “energy rebound effect” paradigm, energy efficiency alone will unlikely lead to an effective reduction in resources’ consumption. These results point out the need to a radical shift toward the development of new approaches in the assessment and management of the built environment for sustainability.

**Keywords:** built environment, EU target policies, eco-district, energy consumption, energy efficiency, environmental sustainability, urban metabolism.

## 1. Introduction

Sustainability is certainly one of the greatest and most challenging paradigms faced by humans. The concept dates back more than 40 years and was explicitly coined to suggest that it was possible to achieve economic growth and industrialization without environmental damage.

Over these four decades, the definition of sustainable development has evolved, and currently at the core of conventional sustainability thinking are the three 'pillars' of environmental, social and economic sustainability. During this period, governments, communities and businesses have tried to respond to the challenge of sustainability, and innumerable conferences and summits have produced declarations, agendas and strategies.

Despite all these efforts, a recent four-year global study into the state of global ecosystem services and the possible consequences of anticipated ecosystem change on human wellbeing has found that 'the results of human activity are [still] putting such a strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted' (Millennium Ecosystem Assessment, 2005, p.2).

This warning is also shared by many other international environmental agencies and official reports, including the Intergovernmental Panel on Climate Change (IPCC, 2007) and the United Nations Environment Programme (UNEP, 2008). The latter found that nearly two-thirds of the essential services provided by nature to humankind are in decline worldwide, and in many cases we are literally living on borrowed time.

According to the latest estimates developed by the International Energy Agency (IEA), in 2010, the energy-related carbon-dioxide (CO<sub>2</sub>) emissions were the highest in the history of mankind, about 30.6 Gigatonnes (Gt). It is clear that new and more effective actions have to be undertaken to save the planet.

In order to tackle the climate issue, the European Union (EU) has recently set a number of important targets that match with the world's commitment to lowering greenhouse gas emissions. The goal known as "20 – 20 – 20" implies that three fundamental targets have to be reached by 2020: a reduction in EU greenhouse gas emissions of at least 20% below the 1990 levels, the achievement of 20% of EU energy consumption from renewable resources and a 20% reduction in primary energy use.

The 20% energy saving target was set in 2007 against a fixed baseline. This reference was the projection of energy use for 2020 presented by the European Commission, which was close to 2,000 Mtoe. More specifically, 20% energy savings means that, in the year 2020, the consume of primary energy in the EU shall not exceed 1,600 Mtoe . This figure is 14% less than the amount of energy that was consumed in 2005. In other words, the EU needs to implement technologies and policies to avoid the use of around 400Mtoe. This "Climate and energy package" was agreed upon by the European Parliament and Council in December 2008 and became law in June 2009.

Over the last few years, great efforts have been made to reduce greenhouse gas emissions and to increase the percentage of renewable energy. Many policies have been put forward related to these items and the first two targets of the "20 – 20 – 20" strategy are likely to be reached (Energy Efficiency Plan - COM(2011) 109).

On the basis of these good results, more ambitious targets have been planned: the "Roadmap 2050", a comprehensive global and EU modeling scenario analysis on how the EU could shift towards a low-carbon economy, proposes a reduction of 80 - 95% of CO<sub>2</sub> within by 2050 (COM(2011) 112 final).

Despite these results, the third "20 – 20 – 20" target concerning energy saving will unlikely be reached (Impact Assessment of the Energy Efficiency Plan 2011- SEC(2011) 277 final). The "Climate and Energy Package", endorsed by the European Parliament and the European Council in December 2008, formally adopted in April 2009, claims that 20% energy savings by 2020 is crucial for green house gasses reduction. A failure in reaching this target would lead to more

comprehensive and costly measures in order to meet the green house gas and renewable energy targets by 2020.

The need to drastically reduce energy consumption is a global matter. In 2010 energy consumption in the world raised by 5,5% and reached a new record. Despite a slight decrease in 2009, caused by the economical crises, the trend is firmly oriented towards continuing growth (Enterdata 2011). From a global viewpoint, since the 1990, the share of renewable energy in relation to the total final energy consumption is about 13% (Enterdata 2011). This means that the rate of conversion to sustainable technologies is very low compared to the rate of the global growth. As a consequence, the need to control environmental impacts will become more and more demanding.

In front of such a context, the authors of this paper believe that the scientific research goals on environmental sustainability assessment indicators and metrics should not be limited to environmental impacts mitigation approaches as current practices are showing (Binswanger 2001, Buluş 2011, Herring 2006, Hong 2006). Rather it should focus on the development of new approaches and metrics based on a mechanism able to balance between energy consumption/production and population density required for supporting human activities within a urban district.

This paper introduces a new index, named “energy subsidiary” index and adopts a methodology based on a detailed literature review and a case studies analysis, encompassing ten of the most famous eco-districts in Europe. Furthermore, the paper illustrates an application of the new index in the context of a strategic urban district regeneration process, in Turin, highlighting benefits and opportunities, as well as limitations or threats.

This paper is structured as follows: in the next Section 2, the relationship between consumption and household energy efficiency is analyzed and the concept known as “Jevons Paradox” (Polimeni et al., 2009) is introduced in order to show that energy efficiency on its own is not sufficient to reduce the total primary energy consumption. Section 3 develops a new approach for measuring urban sustainability in urban planning at district level. This is based on the analyses of the most famous European “ecological districts”. A new concept, named “energy subsidiarity” is introduced which is able to support development of meaningful indicators and strategies, focusing on the exploitation of renewable local resources rather than on energy efficiency. In section 4, the new “energy subsidiary index” is developed and illustrated through an example of urban redevelopment in Turin (Italy). Finally, Section 5 discusses main findings and way forward.

## **2. Household energy efficiency and consumption**

This section focuses on energy consumption in the households sector in Europe, since households sector is the most energy demanding sector according to the last survey by Eurostat in 2010 (“Final energy consumption, by sector” made by Eurostat database 2010).

The household sector uses 11.8% of the total energy yielded in Europe, while, for instance, the services sector uses just 3.6% (Eurostat 2008). Between 1990 and 2009 energy efficiency in the household sector increased by 24%, at an average rate of 1.4% per year.

At the same time, the final household energy consumption increased by 13% in EU-27, at an annual average growth rate of 0.7%. (Eurostat 2012).

Further more in Europe in recent years there has been a strong growth in space heating energy efficiency (20%) that has not led to any space heating consumption decrease [figure 1].

Figure 1 - Trends in housing heating energy consumption and energy efficiency - EU-27  
(European Environment Agency 2013)

Efficiency has increased especially in lighting, with the introduction of the energy bulbs and in space heating, because of a larger penetration of high efficiency boilers (e.g. condensing boilers) and better thermal insulation. A new building currently consumes about 40% energy less than a similar buildings built in 1990, above all because of new building codes (Eurostat 2008).

However, these remarkable technological improvements have not led to any improvement in the consumption. The heating consumption has grown, where the use of electricity is still overwhelmed by fossil fuels, and the total consumption of primary energy has also increased. The current growth in both consumption and efficiency is not related to a specific technology or a particular policy, but it concerns all the aspects of the built environment.

This European building progress situation appears quite contradicting since it shows that the total consumption has not decreased. This is even more surprising considering the effort put in the field as a consequence of the European Directive 2002/91/UE, which firstly fixed a minimum target requirement in the building energy efficiency. It is quite disappointing that in spite of such huge effort, there has not been any decreasing in the total energy use.

The phenomenon illustrated above, i.e. the lack of correspondence between an increasing of the efficiency of the elements of a system and a decrease in the resources used by the system, is not new in economic theory. William Jevons, a British economist of the middle of the 19th century, observed that an increase in the efficiency of using coal to produce energy tended to increase consumption, rather than reduce it. He published his studies in “The coal question” in 1865, in which he called attention to the gradual exhaustion of the UK's coal supplies together with the improvement of steam engines. He noticed that innovations on the steam engines made coal a more cost-effective power source, and led to increasing use of it in a wide range of industries. He was the first to argue, and was supported by scientific data, that, contrary to common intuition, technological improvements could not be relied upon to reduce fuel consumption. His theory is known as “Jevons Paradox” and should be taken into account in every policy that is addressed to reducing energy consumption through an improvement in efficiency (Alcott 2009). Instead, it has almost been completely neglected in energy planning policies, although its effects are very evident in many fields, such as in oil consumption.

The Jevons Paradox has been used in more recent years to define “energy rebound” effect (Kazzoom 1980), that i.e. the extent to which improvements in energy efficiency fail to translate fully into reductions in energy use. This happens because we are able to buy more energy inputs if the costs per unit of output fall because of a better efficiency. One can buy more of the same product, or other products, which also require energy inputs for his/her production and consumption. “Energy rebound” is measured as a percentage of engineering savings; it can be even greater than 100%, and in this case is called “backfire”, which means that the increase in efficiency has caused an increase in energy consumption that is greater than the energy saved because of the better efficiency obtained.

In the next section, ten European innovative and ecological settlements, commonly known as “eco districts”, are analyzed as possible way forward in urban sustainable development. These eco districts are nowadays considered the most advanced and organic attempts that have been made in order to decrease the negative impacts of human activities in the build environment (Rogers 1997, Butera 2004, Droege 2006, Girardet 2008, Kildsgaard 2008, Cecchini 2010). They constitute a symbol and a reference for the new eco designers as well as a starting point for any further achievement in the field of sustainable built environment. The analysis will show that they are strongly based on an “efficient” paradigm, without considering the energy rebound effect illustrated above.

### 3. Analysis of “Eco districts” in Europe

The analysis of eco-district presented in this section is set to survey the relations between energy efficiency of the buildings and exploitation of local renewable resources in order to understand how much the “ecology” of these new districts relies on simple efficiency and how much on renewable resources. Finally the analysis is addressed to find out which of them are suitable models to achieve a global lowering of energy impacts.

Examples of eco-districts are spread all over Europe. In particular, this analysis encompasses all the following: Bo1 and Hammarby in Sweden, Viikki in Finland, Vauban, Am Schlierberg and Kronsberg in Germany, The Millenium Greenwich Village and Bedzed in the United Kingdom, Valderspartera in Spain and Solar City in Austria. These eco-districts are mainly residential but with a comprehensive multiplicity of activities: green public spaces, retail facilities, schools, offices. These new “eco districts” include only new buildings, are quite intensive density; are built on areas that were originally industrial, military or green lands (see figure 2). In particular, Viikki (FL) and Kronsberg (D) have been built on former farming areas and thus their objective to become sustainable district is even more challenging.

Every “eco district” is first of all committed, by the designing statement, to drastically reduce the CO<sub>2</sub> emissions but they pursue this goal with different sustainability strategies, which range from smart water management to maintenance of the biodiversity to a sustainable mobility. However, there is only a common factor among all the districts: this is the attention to the energy efficiency. In each urban district design statement, the energy efficiency is considered the key issue for tackling the energy problem. In each district, the efficiency of the heating system is at least three times higher of any traditional heating system in the household sector at national level, as shown in figure 2.

Figure 2 - EU urban sustainable districts comparison

In the following, an energy balance analysis of the above mentioned “eco districts” has been conducted by using data available in literature (Lazarus 2009, Rossaro 2003, Twinn 2003, web sites listed in the references). For each eco district, the amount of renewable energy yielded in the district has been calculated and then put in relation with the total primary energy consumption of the district itself. In the energy balance of each district, the percentage of local renewable energy has been highlighted.

The Household Energy Balance is given by the local renewable energy share of heating, lighting, electric appliances and water heating consumptions. The source of the energy has been analyzed in terms of both: percentage of renewable energy in the energy balance and percentages of renewable energies used in the different sectors of household consumption. Unfortunately the data on energy consumption of the different districts are very draft and rough, since there is a lack of monitoring on most of these districts. In the calculation, according to the International Energy Agency guidelines (IEA 2006), the average consumption has been generically considered as follows: 55% for heating and cooling, 11% for lighting, 15% for electric appliances and 19% for water heating.

Only three of the analyzed districts, i.e. Bedzed (UK), Bo01 (SE) and Am Schlierberg (D), are planned not only to be energy efficient but also to create synergies, such as district cogeneration by biomass or biogas by sewage, that can lowering the energy supplies from outside the district. These eco districts are self sufficient by relying on the deployment of all the local available renewable resources, both natural stocks (such as sun or wind) and entropic renewable resources (such as

organic waste or sludge that can be transformed into biogas, as it happens in Hammarby or in Bo01 in Sweden).

In general, the most fulfilling strategy of these eco-districts is to rely on a wide range of different technologies to produce renewable energy (see figure 2). In other words, according to this strategy, the adoption of more technologies lead to an increasing opportunities of synergies. However, it has to be remarked that two of the most energy self sufficient districts among those analyzed, i.e. Bo01 and Hammarby, rely mainly on wind energy supplied from turbines set in the surrounding out of the districts. Furthermore, Bedzed (UK), a self energy district, relies on a biomass district plant, which is nowadays closed for economical reasons. This should collect the wood from the trees surrounding the districts.

In all the compared eco-districts, the main and common factor used toward sustainable development in the built environment is the adoption of energy efficiency, especially in space heating. On the contrary, the issue of renewable local resources is not considered fundamental. In particular, in the Millennium Greenwich Village (UK), in Valderspartera (E) and in Solar City (A) the efficiency is mainly the only strategy adopted to cope with the energy issue. The percentage of renewable energy produced in these three districts is so low to be quite neglected in any energy balance analysis calculation.

The above synthetic energy analysis shows that designers have paid great attention to the deployment of energy efficiency strategies, avoiding the inclusion of any sort of renewable sources strategies, and more in general, the “Jevons Paradox” and the “rebound effect” discussed in previous section 2. None of the analyzed district schemes set a limit for the total energy primary consumption (kWh); only the consumption of the heating plants has been forecasted but the ex-post assessment has pointed out an increased level of consumption (from 10% to 30%). Only in Bedzed (UK), the total energy consumption has been continuously monitored and ex-post assessed in order to check whether the target had been reached. However, also in this case the total primary energy consumption has been greater than the forecasted one.

Few districts have been designed with the aim to exploit the local resources (wind, sun and biomass), such as Bedzed, and to create synergies among the inputs and outputs of the urban metabolism, such as Bo01 or Hammarby where biogas is produced by sewage, have a lower energy environmental impacts. This because they have both a good efficiency in the use of energy and a very low share of energy supplied from outside the district.

According to the theories of the Jevons Paradox and of the “energy rebound”, the paradigm of energy efficiency is not suitable for reaching the goal of global energy saving (Boqiang 2012, Bulus, Freire-González 2011, Topalli 2011, OuYang 2010, Dimitropoulos 2007, Herring 2006, Hong 2006, Brannlund 2005, Binswanger 2001, Brookes 2000). In order to evaluate urban sustainability a better paradigm is the urban metabolism model, which is able to take into account the contribution provided by the local renewable resources (such as in Bedzed, in Bo01 and in Hammarby), rather than on models based on the increasing of an efficiency rate (such as in Millenium Greenwich and in Valderspartera). This paradigm is better explained in the next section, in connection with the development of a new index for evaluating sustainable development in urban planning and the built environment.

#### **4. “Energy subsidiary” metrics**

Recent scientific studies (Suzuki and Dastur, 2010; Brandon and Lombardi, 2011; Lombardi and Trossero, 2011) have pointed out the need to move from a partial and sector viewpoint toward a more holistic and comprehensive sustainability concept which includes the notion of urban metabolism (Wolman, 1965). Other studies, such as the Swiss’s “2000 Watt Society” project, suggest ambitious strategies which focus on the power (W) rather than on the energy (kWh). If we

aim to decrease energy impacts, we should focus more on kWh (energy) rather than on W (power). In the field of urban planning, new approaches have been put forward which focus on closed loop recycles and renewable energy rather than on efficiency rate (Tillie 2009, Van den Dobbelsteen 2008, 2009, 2011). These approaches usually take into account the “exergy”, i.e. the energy that is available to be used, in order to achieve a more systemic and effective strategy of sustainability in urban districts. Finally, there are approaches focusing on the exploitation of local renewable resources rather than on efficiency or exergy rate. For instance, the districts of Bedzed, Bo01 and Hammarby set their sustainability on closed recycling loop and on the exploitation of their local resources.

Several recent studies have demonstrated that the density in urban areas as opposite to the concept of urban sprawl, is a requirement for achieving sustainability in the built environment (Jenks 2006). In particular, the research of Peter Newman and Jeffrey Kenworthy (1999) have remarked that the consumption of fossil fuels is strictly connected to the urban density of a settlement and therefore a great part of the energy consumption in cities is determined by the shape of the city itself.

There are a number of examples available at urban district level, showing there is a correlation between population density and urban synergies required to fully exploit renewable energy sources on site, such as food and goods chain supplies, energy grids, waste recycle loops. These examples include: the critical mass of organic waste required to produce biogas, the critical mass of solar heated water required to gain seasonal heating storage, or the number of households required to have an efficient heating central plant; all these factors are strictly related with the urban density.

According to the metabolism theory, the development of sustainable urban areas can be based on an appropriate balance between population density and available local resources. The latter is a requirement for the urban district in order to self-sustain the internal energy production and consumption. This carrying capacity of the district is named “load capacity” (Catton 1986, ).

In urban regeneration and planning, the above concept requires an evaluation of the most appropriate population density in relation with the available resources and technologies for the production of the energy required by human activities. This evaluation approach is based on the idea that the energy provision of an urban district should be forecasted and should rely on internal local resources, mostly renewable resources, rather than by fossil fuels and electric production which are external to the city’s boundary. At the same time, the number of population and human activities forecasted in the urban district development should be based on the renewal energy capacity of the urban districts.

According to this approach, in a planning process, firstly it should be calculated the amount of energy that can be yielded by local renewable resources. The quantity of local renewable energy available will become one of the main parameters for planning an urban area, together with the other traditional social (population) and economic (financial resources) parameters.

These resources can be both natural and atrophic ones: such as sun, biomass, wind, waterfall or sewage, waste and heat. The expected quantity of energy will become the main element for defining the urban district dimension, including: number of household, services, transports and so on.

The above approach requires the calculation of both:

- amount of energy that can be produced within the district boundaries from renewal resources;
- number of people and facilities that the district can support (carrying capacity) without exceeding the load capacity of the district, considering an average (al city level) of citizen consumption.

Clearly, in high density cities, there is not enough land to guarantee the energy self sufficiency of the district (Rees, Wackernagel 1996). However, according to this approach, the less energy is supplied by the grid, the more sustainable is the energy management of the district. Therefore, a new sustainability index can be defined, named the “energy subsidiarity” index. The following methodological steps are required in order to calculate the above index:

- a) a survey of the local available renewable resources suitable for energy production ;

- b) a calculation of the quantity of energy that can be produced with current cost effective technologies;
- c) a calculation of the carrying capacity of the new district in relation to the quantity of energy produced and consumed.

The expected amount of energy constitutes one of the fundamental parameters for developing alternative planning scenarios.

The urban district “energy subsidiarity” index can be expressed as a difference between the average primary energy consumption of an average urban district (in square meter) and the consumption that is supplied by local renewable resources (Lombardi and Trossero, 2011).

$$\text{Energy Balance} = \text{CkWh}/(\text{m}^2 \text{ anno}) - [[(\text{CkWh}/(\text{m}^2 \text{ anno})) * \% \text{ R}]]$$

Where C kWh/(m<sup>2</sup> anno) is the average consumption of a virtual meter-squares of household surface floor and R is the percentage of renewable energy yielded in the district in relation to the total consumption of primary Energy.

A real case study can better illustrates this new index. This is related to a strategic regeneration project called “Variante 200”, a large former industrial area in Turin, one of the largest metropolitan city of North Italy.

In the 2009 city of Turin, in partnership with public and private sectors, has started the development of the “Vanchiglia depot railway”. This is currently a 850.000 square meters area, completely surrounded by residential and facilities blocks. According to the “city planning policy” document, all the existing buildings currently included in the area will be demolished. The new area will include a minimum of 300,000 square meters (up to a maximum of 400,000 square meters) of new built-up area for a total of about 8.700 inhabitants. About 20,000 square meters will be commercial areas (shopping centre). In addition, along the built area, a large urban linear park is designed that will occupy a rectangle of about 900 meters long and 60 wide, a total green area of 54.000 square meters that will be the main “green lung” of the new district.

In the following, the three methodological steps for calculating the energy subsidiarity index are developed as follows:

- a) a survey of the local renewable resources suitable for energy production.

In this area there is not a strong enough wind to yield wind power, neither channels or pipes with enough water flow from which produce hydropower, nor exploitable geothermal resources. Therefore, only solar energy and bio-mass energy derived from biomass-waste and trees pruning of the park can be considered.

- b) a calculation of the of the quantity of energy that can be produced with current cost effective technologies.

In Turin, an average solar irradiation of 1370 kWh/ m<sup>2</sup> year (ENEA) can be assumed. Assuming an average of eight floors height for new buildings, 43.750 square meters of roof area are considered in the area.

In addition, considering that the PV panels have an average efficiency of 12%, with an average covering of 50% of the available roof area, every year 164 kW/m<sup>2</sup> of electricity can be produced. In other words, the whole roof area of the district could produce 3.587.500kWh of electricity every year.



In Turin every dweller has an average production of organic waste of 35 kg/year (ISTAT 2003). Considering that 8700 new residents are foreseen for the new district, it can be assumed that every year 304 tons of organic waste are collected in the area. With the fermentation of one ton of biomass, an amount of about 70 up to 150 m<sup>3</sup> of biogas can be obtained, depending on the starting material, by which a cogeneration plant can produce about 190 kWh of electricity and 285 kWh of thermal power. Therefore, in the area a district biogas cogeneration plant can be developed which produces 57.760 kWh of electricity plus 86.640 kWh of thermal power. The output of this process is fertilizer that can be used in agricultural activities.

The linear park will host linden trees and plane trees which are very common in Turin. These trees have to be pruned every 15 years and produce every time they're loped 240 kg of wood chips. Supposing one tree every 225 square meter in the park, the results of about 240 trees could supply, just only by their pruning, about 3,8 tons of wood chips every year.

Cogeneration plants that burn wood chips produce 3.5 kWh of electricity every kilogram of bio mass. Therefore, through a cogeneration district heating system, an electric energy production of about 13.440 kWh every year, in addition to the 20.160 kWh of recovered thermal energy, are available for the district heating and power requirements.

Finally we can estimate that an amount of 3.658.700kWh/year of electricity can be produced from renewable sources within the boundaries of the new district (3.587.500 kWh from the PV panels, 57.760 kWh from the organic waste biogas and 13,440 kWh from the cogeneration plant supplied by the wood chips from the park trees pruning) plus 106.800 kWh of thermal power recovered from the cogeneration plant and available for a district heating system.

c) a calculation of the carrying capacity of the new district in relation to the quantity of energy produced and consumed.

Considering that Turin average electricity household consumption is 1164 kWh/year for resident, the maximum load capacity of the new district (electricity consumption), is 3143 inhabitants. This figure is very lower compared with the number forecasted in the "city planning policy" document, i.e. 8700 inhabitants.

This means that 64% of the officially foreseen population exceed the power load capacity of the urban district and therefore will rely on external resources to generate electricity for their needs, increasing the environmental impacts of surroundings areas.

## **5. Conclusions**

This paper has critically discussed the EU 20% energy saving target, claimed in the Communication to the European Parliament of the 8 march 2011 (SEC.2011- 277 final, COM(2011) 109 final) in relation to the present energy consumption trajectory in the household sector. The data shown in sections 2 demonstrate that in Europe the growth of efficiency in the built environment is not corresponding to a parallel energy saving. Energy efficiency is necessary, but not sufficient, to decrease global energy consumption, and environmental impacts.

This study has shown that sustainability assessment of the built environment, especially related to new buildings, must focuses more on strategies and politics which employ local renewable resources rather than only on energy efficiency.

In a context of continuing expansion of the built environment, it is necessary to adopt a new strategy. This study suggests to base a strategy on both the followings: a) limiting the expansion of the square meters of the built environment through socio economic policies, and b) applying the “energy subsidiarity” principle in urban planning and regeneration processes, for evaluating the energy sustainability of both new and existing settlements. In particular, the inhabitants effectively sustained by the load capacity of an urban district should become a fundamental indicator in urban renewal processes, informing all the spatial planning level.

A case study application of this new indicator has been presented in the paper, focusing on the energy issue. The analysis developed in the paper using a real urban regeneration case study has focused on the electric energy production and consumption which is clearly one of the most significant sustainability issue. However, the “energy subsidiarity” principle can be applied to other possible closed loop systems of the city’s life, such as the supplies and consumption of heating and cooling, the release and treatment of waste, the emission and absorption of CO<sub>2</sub>, the water collection and recycling, the production and consumption of local food, and so on. Each of this systems could be optimized in relation to the synergies created with other urban eco systems.

A major expected result from this study is the development of a comprehensive set of new metrics able to consider the different scales of the regeneration/planning process, shifting from the building scale to the territorial scale and back. This is seen as a concrete way forward toward the achievement of the EU targets and beyond.

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