SMART ENERGY REGIONS

COST AND VALUE

Editors: Phil Jones, Vincent Buhagiar, P. Amparo López-Jiménez and Aleksandra Djukic.

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IN SCIENCE AND TECHNOLOGY

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Executive summary

Ever since the landmark Earth Summit in Rio in 1992, global awareness of sustainability has come a long way in terms of reduction of carbon emissions and increasing energy efficiency in the context of environmental issues. Moreover, in view of our limited land resource and the realisation of finite earth resources, there is currently an ever-growing thrust in favour of retrofitting and reusing existing buildings for re-use. Underpinning all this, perhaps stemmed from the aftermath of the financial crisis in 2008, there has been an equally important financial sensitivity to the cost of a project.

An investment in retrofitting a building may take various forms, including its façade restoration, indoor refurbishment for a designated re-use. These inherently bring with them an added value to the building in its new state, for the given capital cost. Equally in today's energy-conscious, carbon-reduction era, such a retrofit would typically include upgrading the building fabric to improve the building's energy efficiency, through passive design, complemented with RES, without compromising the general comfort and well-being of its occupants. Today the latter is considered to be higher on the owner's agenda, given evidence that it increases productivity. This is perhaps one way of 'doing more with less' – a smarter way towards building design.

This COST Action, purports to do just that. It promotes smarter use of energy at both building and regional levels. Workgroup 3 focuses explicitly on demonstrating the link between cost and value of such retrofitting, applicable to both new and old buildings, as well as infrastructure and energy systems, at regional and national levels. Chapters collate papers from different member states covering aspects related to cost and value, covered under four principal chapter headings, namely Environmental Design, Sustainable Retrofitting, Energy Systems and Technologies as well as Smart energy Regions, touching on strategies for a top-down versus a bottom-up approach. The book starts with an introduction to the subject area by the Action Chairman and ends with a concise set of Conclusions by the workgroup chair. This publication covers the deliverable of Working Group 3 for COST Action TU1104, better known by the acronym, Smart-ER.

Vincent Buhagiar

Introduction to cost and value

There are increasing impacts from burning fossil fuel at global, local and building scale, in relation to climate change, air pollution and security of energy supply. The need for an eventual transition to a zero carbon built environment is now generally accepted. The problem is how, and over what period, this transition takes place, and how government and industry will rise to the challenge.

Smart-ER's 28 member countries have looked at the drivers and barriers that may impact on the long-term creation of low carbon regions in Europe, through a catalogue of case studies, based around low carbon policy and low carbon technologies, illustrating good and best practice for different scales. The Action have identified identify what can be done to assist the large-scale implementation of low carbon technologies and processes, focussing on process, performance, cost and value, and skills and supply chains. The main focus is on both new and retrofit of existing buildings, their efficient design and operation, and the potential for using low and zero energy supply. The term 'smart' applies to energy supply and energy demand, from smart grids to smart living. Energy takes a 'systems' approach, linking reduced energy demand, renewable supply and storage. All this is considered at a regional scale, relating government policy and aspirations, to industry capacity and needs.

In March 2014, the European Commissioner for Energy, Günther Oettinger, stated that '*People's well being, industrial competitiveness and the overall functioning of society are dependent on safe, secure, sustainable and affordable energy'.* He followed on by saying that: *'The energy infrastructure which will power citizens' homes, industry and services in 2050, as well as the buildings which people will use, are being designed and built now. The pattern of energy production and use in 2050 is already being decided. Despite the importance of energy policy aims, there are serious gaps in delivery*', and new technologies are being developed but they are not finding their way easily into the market.

There is a need to share information on innovation and emerging technologies, in relation to how to get from policy to practice, and increasing the understanding of the low carbon agenda by decision makers. Smart-ER has identified a range of low carbon technology ready solutions for application in the built environment that, with the appropriate training and skills development, can produce affordable solutions, with added value through multiple benefits, such as improved quality of life, reducing fuel poverty, and reduced energy demand. They will be regionally driven, providing stakeholder action, jobs, investment and profits, all at a local scale and other positive 'multiple benefit' impacts, such as affordable warmth, and improving health and quality of life. For example, reducing a building's energy demand, can lead to affordable warmth, alleviate fuel poverty, improve health, and reduce air pollution. A 'bottom-up' approach to green development can also result in socio-economic benefits, including a more supportive community, creating jobs, and generating local industries. This follows the up-cycling concept of 'more good', whereas 'top-down' approaches generally follow the 'less bad' concept. Sustainability is not just about avoiding problems, it is about promoting a better quality of living. This is potentially more engaged and comprehensive in relation to the needs of the inhabitants of the built environment. Sustainability is directed towards contributing positive outcomes, and is systems-based and place-based, considering the interconnections within and between ecological, social and economic systems at various scales, but with an emphasis on local thinking, experience and delivery. 'Systems thinking' includes integrating technologies, architecture from a people perspective, both designers and users of the built environment, but also linking to government regulations and industry needs, spinning out bottom-up activities through the so-called knowledge triangle of research, industry and government.

It is the practical implementation of low carbon technologies as part of a 'smart' system that determines the added value to which they are successful, and to what extent predicted targets and cost/value benefits can be achieved in practice. In particular, it is at the interfaces of supply and demand technologies that often determine performance. Many technologies, when applied, do not deliver their optimum performance and cost, as they are often 'bolt on' solutions. A more systematic and holistic approach is necessary, combined with financial models, which follow a systems and life cycle approach, and which fully address issues of value and yield on investment in relation to low carbon developments. Building regulations are also needed to drive innovation and encourage new innovative high value products from industry, while controlling unsustainable increases in construction and development costs. A systems approach does not draw a boundary around the technical solutions, but cost and value, and regulations also contribute to the 'whole system'.

There has been little attention to how the various issues across policy and practice can be 'joined-up'. An overall low carbon strategy should link government policy to business opportunities, technology advances, training and awareness raising, and, issues relating to cost and value. This may be best addressed at a regional scale, where there is autonomy, understanding and decision-making that take account of specific regional attributes. It may also prove advantageous to tackle the transition to a low carbon economy at a regional scale.

At a regional scale, there is often devolved government decision making, with the subsequent development of policy through, for example, Building Regulations and Planning Guidance. Issues resulting from government's policy aspirations can be followed up through regional research and development activities.

The economic benefits of a low carbon economy are huge, with opportunities for both wealth and job creation. There are other 'softer' 'multiple' societal benefits through improved quality of life, more efficient resource management and less pollution. However, the transition to a low carbon economy is not obvious, and we must find a route through the instabilities that might arise from climate change, versus the instabilities from economic change. The largest potential early win is to reduce energy demand, and this can provide the bridge to the low carbon future. Most of the technologies required already exist and are readily available. A smart systems approach will optimise their use for specific project applications. Whether the current austere times are an advantage or disadvantage remains to be seen, together with, to what extent the low carbon agenda can drive the economy.

We must accept that delivering reductions in energy and carbon dioxide emissions, should also achieve cost and socio-economic 'products' in the development of regional built environment programmes, linking the low carbon agenda with economic growth. All this seems to be best driven forward through a 'smart-up' systems approach at a regional level, linking policy to industry and societal needs for maximum benefit. Rather than the 'less bad' global agenda of climate change, it focuses more on the 'more good' local agendas related to cleaner environments, economic and social benefits, together with healthy, comfortable, productive energy efficient buildings.
The development, and joint ownership, of the understanding of low carbon regions is fundamental to future government and industry thinking. It is particularly important that decision makers and their advisers have the appropriate information for short and long term decision making, and that there is public engagement and awareness. The EU COST Action TU1104, Smart-ER has explored the understanding and relationships between government, industry and academia in relation to the low carbon agenda, centred on the built environment, up to regional scale, and how this can help inform decision-making.

Phil Jones

Introduction to environmental design

This chapter contributes to the discussion about the cost and value of green buildings which have a key role in retracting climate change, and supports the arguments in favour of a strategy towards a high quality built environment. According to previous research, green buildings are more energy efficient, with lower demand for water and allied services. On a regional level, green design also presents lower costs for infrastructure as well as curtailing demands for its extensions.

This chapter consists of four papers. The first paper presents different scenarios about the cost of green buildings, together with their quantifiable and qualitative added value. It looks at current practices in identifying the value of green buildings, and highlights the multiple benefits from green building design, in addition to the usual focus on energy savings. The second paper evaluates occupants' subjective response to controlled architectural interventions in historic buildings, as part of a comprehensive plan to restore, rehabilitate and re-use the edifice. The research was done on four case studies with the questionnaire survey, followed-up with structured interviews. It is also more oriented towards the qualitative added value of retrofitting. The third paper is focused on improving of functionality, cost and enhancing the aesthetic aspects of a building through sustainable design, both for new and retrofitted construction. The fourth paper is dedicated to the qualitative added value such as human health and productivity. It provides concentrated reviews on cumulative environmental effects and concludes that some of the scientifically proven relations between environmental factors and human response can be integrated into a cost-benefit analysis while planning building refurbishment actions or designing new one.

The four papers give what may perhaps be termed as a 'wide brush' overview of the potential of different aspects of environmental design, and how sustainability can realistically improve the quality of life for all people. Today it is an established fact that green buildings have lower operating and maintenance costs, provide better comfort and well-being for occupants, have lower risk potential, with lower environmental impact, emissions and running costs. They induce savings from increased productivity through improved health and well being of their occupants. These are but the main attributes towards a better quality of life.

Cost and value multiple benefits in relation to the design of green buildings

This paper reviews the cost of green buildings, together with their quantifiable and qualitative added value. It reviews energy costs in relation to other benefits of green building design and retrofit, at building, community and national scales. Where data is available it presents cost benefits and also discusses benefits of a more qualitative nature

Author

Phil Jones
jonesp@cardiff.ac.uk

Welsh School of Architecture, Cardiff University, Wales UK

Introduction

It is widely accepted that a green and more sustainable building will provide added value to its owners and occupiers, justifying any cost increase incurred in its design and construction. However, it has been difficult to attach an actual financial value to the benefits of green buildings, to assess whether they are more attractive to tenants and occupiers, and, the extent to which they attract a financial premium in terms of any increased rental and sales value. Generally, the main recognised quantifiable return on an investment in green design has been the energy savings, and even this is often uncertain in relation to the finished building, and how its users operate it. However, there is the potential for multiple benefits arising from green buildings, in addition to the actual energy savings. The IEA report, 'Spreading the net: the multiple benefits of energy efficiency improvements', published in 2012 (Ryan and Campbell 2012), recognises the wider benefits of 'clean energy' projects, which in addition to being of direct benefit to the individual or organisation implementing the project, also has benefits for both national and global economies. However, such 'non-market' and socio-economic benefits are often difficult to quantify. Projects are often assessed by energy professionals, with little experience of how energy efficiency might impact on other non-energy sectors. The report also recognised the "rebound effect", by which non-energy sector benefits may result in the predicted energy savings being less than expected. A report by the US IEA, 'Assessing the Multiple Benefits of Clean Energy' (Environmental Protection Agency 2011) identified environmental and health benefits, and a broad range of economic benefits, as well as reducing stress on the energy system.

Green buildings using clean energy systems can also enjoy the wider economic and environmental benefits. Although currently not well understood, the potential added value of the total package of benefits can be considerable, and much greater than just the energy savings alone, though there also may be rebound effects as introduced above for clean energy systems in general. For example, a rebound effect through the take up of affordable warmth in houses that are designed or retrofitted to be more efficient to heat, which is a positive benefit.

On a life cycle cost basis, even allowing for any rebound effects, the energy savings alone should typically exceed any additional design and construction cost premiums, within a reasonable payback period. There may be increased costs associated with green buildings, especially retrofitting existing buildings to a greener standard. However, by adopting an integrative holistic design approach, these additional costs can be reduced, to an affordable level, and potentially to a level comparable with standard building costs for new build, and within acceptable budgets for retrofit. In addition to energy savings, operations and maintenance costs have the potential to be reduced, for example, through the use of less complex environmental systems for heating, cooling and ventilation.

Energy costs are generally small in comparison to overall business operating costs, which are usually dominated by staff costs. For commercial buildings, green design can lead to a better quality indoor environment, which can improve worker productivity, and occupant health and well-being. This can result in improved productivity 'bottom line' benefits for businesses. However, in spite of these potential benefits, the improved indoor environmental quality associated with green buildings has not generally been a priority in building design and construction.

Buildings that are not designed with sustainability credentials may in future be considered high risk, which might affect their rental income and future asset value, in turn affecting their return on investment. So, buildings with better sustainability credentials could enjoy increased marketability, and their asset value should increase over time. They should be able to more easily attract tenants and to command higher rents and resale prices, and as a result offer a greater overall yield on investment.

Future trends in building regulations to reduce carbon dioxide emissions have also become a concern to building owners, as regulations place greater emphasis on the existing building stock. Changing tenant requirements and investor risk screening may also affect the value of buildings that do not have green credentials. The indication is that in markets where green is becoming more main-stream, there are emerging 'brown discounts', where buildings that are not green, may rent or sell for less. There is therefore an increasing interest in retrofitting existing buildings. Therefore developing retrofit solutions for different building types, and new investment models to address financing retrofits, are crucial to maintaining a building's future asset value.

In summary, green and more sustainable buildings need not necessarily incur significant additional design and construction costs. Their impact scales up to national and global levels, for example, energy cost savings at building scale will result in reduced carbon dioxide emissions at a global scale. The benefits are both quantitative and qualitative, and in future, developers who do not provide green buildings, will potentially incur an investment risk, and reduced marketability. However, these factors and benefits, although having been identified over the last decade or more, have yet to make a marked penetration into the building construction and operation industry.
When assessing the benefits of a green building, the main analysis is still generally based on cost of energy saving measures versus cost of energy savings.

This paper reviews the above cost and value benefits associated with green building design. It is based on a review of some of the emerging findings from research and practice, with the main focus on office buildings and housing. I t contributes to the activities of the EU COST T1104 Action, Smart Energy Regions, which is exploring a regional approach to implementing low carbon policy into practice in the built environment.

Cost and value

The additional cost of a green building relates to how much money is spent on the building compared to a non-green building. If a 'bolt-on' approach is used, the costs are easily identified in relation to the additional 'bolt-on' items of construction or equipment. Such a 'bolt-on' approach tends to incur relatively higher additional costs compared to a holistic and more integrative design approach, where costs may be reduced. Where a more holistic approach is used, it can be difficult to assess costs precisely, as the additional 'green' technologies used in the building may be offset by reducing costs in other areas. For example, the increased cost of a high performance façade may be offset by reduced costs for heating and cooling equipment. Also, a green feature may also be simultaneously used as a more traditional building element, for example, when a Photo Voltaic (PV) panel over a window can 'double up' as a shading device.

The value of a green building can be related to the overall return on the investment, which may be in quantitative terms, for example, energy saved, or, of a more qualitative nature, such as, improved quality of life, although such qualitative improvements can also result in cost benefits. Assessing payback on investment using a single cost parameter, such as the cost associated with energy savings, does not recognise the total value of a green building in use. Added value aspects might include multiple benefits, such as, for a commercial building: more satisfied occupants; longer tenancies and higher lease rates, reduced absenteeism and an overall higher asset value; future proofed and reduced risk of obsolescence; less need for refurbishment in the future; higher demand from institutional investors and satisfying corporate social responsibilities; and, lower operating and maintenance costs.

There is a growing body of evidence, which identifies increased costs and added value benefits for office buildings. It has been shown that, in general, the costs associated with green offices are often exaggerated, and their added value underplayed. The World Green Building Council's report in 2013 (World Green Building Council 2013), based on a variety of building types in United States, United Kingdom, Australia, Singapore and Israel, summarised a range of benefits from adopting a green building approach, and stated that, whereas the increased design and construction costs associated with a new green building are perceived to be as high as 29 %, the actual cost increases found in practice are less than 12.5 %, and sometimes equal to, or even slightly less than, the costs of a standard building. Some ten years earlier Kats et. al. published a report (Kats et al. 2003) indicating that the additional costs of a green building were on average (from a sample of 33 buildings) around 2 % and this could be repaid ten-fold over a twenty year lifetime through lower energy, water and waste costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased health and productivity. They reported increased productivity and health contributing 70 % of the benefits, reduced operations and maintenance 16 %, and energy savings 11 %.

The increased costs for a green building may therefore often be over-estimated, whilst the additional value-added benefits are not always appreciated, and are generally underestimated, or not considered at all. Johnson Controls (Johnson Controls 2012) reported a range of value-added benefits that green buildings exhibit, including: increased resale value (2 – 17 %); increased rental rates (5.8 – 35 %); higher occupancy rates (0.9 – 18 %); lower operating expenses (30 %); higher net operating income (5.9 %); lower capitalisation rates (50 – 55 basis points); and, productivity gains (4.8 %).

A study by Davis Langdon (2007) has also identified benefits for green building owners including: potential higher occupancy rates; higher future capital value; reduced risk of obsolescence; less need for refurbishment in the future; ability to command higher lease rates; higher demand from institutional investors; lower operating costs; mandatory for government tenants; lower tenant turnover; and, less cost to maintain and operate.

Further studies by RICS (2005) identified green building benefits to: be quicker to secure tenants; command higher rents or prices; enjoy lower tenant turn over; cost less to operate and maintain; attract grants, subsidies and other inducements to do with environmental stewardship, increase energy efficiency and lessen greenhouse gas emissions; improve business productivity for occupants, affecting churn, renewals, inducements and fitting out costs; and, benefit occupants to anextent that may even exceed the underlying asset's value.

In 2010 Eichholtz et al (2010) reported a study of some 10,000 buildings indicating that there was an effective rental premium of around 7 %, and selling premium of 16 % for green office buildings in the US. Pivo and Fisher (2009) found that green buildings had up to 5.9 % and 13.5 % higher market values, driven by 9.8 % lower utility bills, 4.8 % higher rents, and 0.9 % higher occupancy rates. A study by McGraw-Hill (2013) looked into the payback period for green investments and operating costs. It was found that over a one-year and a five-year period, new green buildings were expected to reduce operating costs by 8 % and 15 % respectively, and by 9 % and 13 % for retrofits. The payback times were expected to be eight years for new green buildings and seven years for green retrofits. Building values were expected to increase by 7 % and 5 %, and asset values by 5 % and 4 %, for new build and retrofit respectively.

A recent study (Kok and Devine 2015) showed that improved property performance is strongly correlated to green building certification. The research analysed ten years of financial performance data across a 58 million square feet office portfolio in the USA and Canada, indicating: net effective rents on 3.7 % higher in LEED certified properties, and 9.5 % higher with ENERGY STAR certification in the U.S. compared to similar non-certified buildings, and 18.7 % higher in Canadian buildings having both LEED and BOMA BEST certification; tenant renewal rates were 5.6 % higher in Canadian buildings with BOMA BEST Level 3 certification than in buildings with no BOMA BEST certification; tenant satisfaction scores were 7 % higher in Canadian buildings with BOMA BEST level 3 and 4 certification than in non-certified buildings; energy consumption per square foot was 14 % lower in U.S. LEED certified properties than in buildings without certification.

However, although there are positive signs that green buildings attract higher value in the US, a study by RICS on London offices was not so positive (Chegut et al. 2012.), and failed to identify improvements of significance.

The energy savings for new build may be related to three levels (table 1). The first is the level of energy reductions (also relating to carbon dioxide emission reductions) in relation to typical improvements in Building Regulations. In the UK typically there would be 25 % carbon dioxide reductions between subsequent upgrades of building regulations, which may be every 4 to 5 years. These are considered relatively easy to achieve in an incremental way. The next level might relate to the best level of energy reductions associated with building environmental assessment methods, such as LEED and BREEAM, which are typically 40 to 50 %. Finally savings relating to a PassiveHaus level of performance would be of the order of 75 %, the remaining 25 % potentially provided by renewables, creating a carbon neutral building. Actual energy use will vary with building type and location, but ballpark average levels (UK) might be 200kWh/m^2 per year for housing, and 360kWh/m^2 per year for offices, with average energy costs of £12/m^2 per year and £25/m^2 per year respectively.

Table 1 - Levels of energy savings

Level	% savings	Description
1	25	Building regulation improvements
2	40-50	High LEED BREEAM
3	75	PassiveHaus

Retrofitting existing offices can yield similar benefits as new build. A US study (Pacific Northwest National Laboratory 2011) has identified three levels of approach to office retrofit:

- commissioning, which can typically achieve up to 25 % energy savings. An example from a US study of commissioning projects found that office buildings typically realised 22 % energy savings through 'existing building commissioning, with an average simple payback period of 1.1 years (Mills 2009);
- standard retrofit, which can typically produce 25 – 45 % savings with payback period of less than 4 years. Such retrofits generally adopt a cost-effective low risk approach, typically using a package of component-level replacements of existing equipment;
- deep retrofits, which are based on an integrated whole-building approach to energy savings projects. Savings of 45 % and higher, with a typical payback period of up to 3 years, are achievable when upgrades to the building envelope are combined with retrofits of lighting and mechanical systems. In order to achieve a good performance for a building in use, it is essential to provide a high level of commissioning, and operations and maintenance. The report identified a range of benefits from improved operations and maintenance, including: energy savings; reduced comfort complaints; equipment that operates adequately until the end of its planned useful life, or beyond; improved indoor environmental quality; safe working conditions for building operating staff. It identified energy costs typically constituting 30 % of overall operating costs, leading to a substantially increased net operating income and asset value.

The above discussion has focussed on a green approach to commercial buildings, covering both new build and retrofit. For housing, the increased costs associated with new build together with value added benefits, cover a similar range as for offices. However, whereas a component approach to retrofit can be affordable, though perhaps limited in benefits, 'deep' retrofits are generally currently considered high cost, and difficult to finance. In the UK, homes account for more than 28 % of total UK energy use, with related carbon emissions (based on 2009 figures).
In the UK, the rate of new build for housing in a year is around 120,000, of a total housing stock of around 27 million, which is a renewal rate of around 0.5 % per year. It is expected that 80 % of existing dwellings will still be in use in 2050, so housing retrofit is a major area for saving energy and reducing carbon dioxide emissions. A large demonstration programme of housing retrofit was carried out in the UK between 2010 and 2012. Reported results from this programme (Baeli 2013) indicated that energy saving measures from deep retrofit schemes could produce on average around 63 % energy reduction with most cases in the range 50 % to 85 %, and for an average cost of around £77,000, from a range of about £45,000 to £118,000. In addition, for most cases between £42,000 and £100,000 was spent on non-energy saving improvements. Clearly these costs are high in relation to potential payback. However, there are indications that costs can be reduced, and if combined with value-added benefits, can sometimes make deep retrofits financially acceptable. This will be discussed later, with reference to recent case studies.

Environmental assessment methods

'Green' labels are often used to assess the green credentials of a building. A range of Environmental Assessment Methods are now available to apply to buildings in order to assess their performance during design. They include BREEAM (UK) and LEED (US), and they address a range of design aspects, such as indoor environment, material use, location, etc, as well as energy performance. There have been studies to assess the cost of achieving a high assessment rating and the return on the investment. The cost increase associated with majority of certified green buildings typically ranges from <0 % to 4 %. Higher levels of certification (such as BREEAM Very Good and LEED Silver/Gold) have been shown to have a cost increase in the range from 0 % to 10 %. Highest levels, such as BREEAM Excellent and LEED Platinum have increased costs of around 2 % to 12.5 %.

A review of ENERGY STAR and LEED projects (Jackson 2009) has identified rent and occupancy premiums that not only pay for the additional green development costs, but also provide an attractive internal rate of return (IRR) on green investments, for an incremental cost of between 1 and 5 %.

David Langdon (2007) has indicated from their research in Australia that the initial impact on construction costs (compared to non-Green projects) is likely to be in the order of 3 – 5 % for a 5 Star solution, with a further 5 % plus for a 6 Star non-iconic design solutions.

A review of recent studies has found that office buildings with green certifications command between around 2 to 27 % higher rents than otherwise comparable buildings (Appraisal Institute and the Institute for Market Transformation 2013). There are also significantly higher occupancy rates for buildings with green and efficient certifications. However, the cost of an environmental assessment can be considerable. For some companies, the value is in having the certificate, and not always in the improved performance, so there are sometimes pressures to deliver a high assessment rating level for minimum investment.

Organisation costs

Green building costs, and in particular related to energy performance, should be looked at in the context of the total organisation costs of a building, especially for commercial and public buildings. Studies have estimated that building construction costs and energy savings are a relative small proportion of total organisation costs. For commercial buildings, staff costs make up the bulk of operational expenses, with over 85 % of total workplace costs spent on salaries and benefits, compared to less than

10 % on rent, and less than 1 % on energy (World Green Building Council 2013).

Operational costs can greatly exceed design and construction costs over a buildings lifetime. Examples of two whole life-costing studies for offices have been described by Evans et al. (1998) and Hughes et al. (2004). Evans quotes a ratio of 1:5:200, for design/construction costs to operating costs to business costs, respectively. Hughes et al., however, question the validity of this ratio, and suggests a ratio of 1:0.4:12, as being more realistic for commercial buildings. However, this still indicates that business costs, a large proportion of which will be staff salaries, outweigh design, construction and operating costs, which include energy costs (typically 30 % of operational costs). Design costs can also be included in this ratio, simplistically as 10 % of construction costs. Other studies have suggested that an initial 2 % upfront investment for a green building will generate a return ten times higher than the initial investment over the life cycle of the building (Kats et al. 2003). They report that salary costs (USA) of around $65,000 are roughly ten times higher than operations and maintenance costs, which include energy and rent, energy being only 1 % of overall costs.

The above analysis implies that the largest return on investment should arise when green buildings also improve business productivity.

Productivity, health and quality of life

The previous section has argued that the benefits of increased productivity for a green building outweigh any energy savings, and by itself justifies increased design and construction costs. So life-cycle assessments based on energy savings alone, only provide a relatively small part of the potential overall value benefits to an organisation. David Langdon reported that the Building Commission of Victoria indicated that optimal levels of indoor environmental quality would increase Australian workforces' productivity by as much as 30 % (Langdon 2007).

Therefore a major aim of green building design is to achieve good standards of indoor environment, which can in turn improve worker productivity, and occupant health and well-being. In commercial buildings, sick building syndrome (SBS) has often been associated with spaces that have poor indoor environments, usually associated with air-conditioned offices. As long ago as 1984, the World Health Organisation (WHO 1984) reported that 30 % of buildings globally may have indoor environments that contribute to SBS. More recently, Heerwagen (2010) reported that up to 20 % of workers might be affected. Reducing SBS symptoms can potentially reduce absenteeism, as well as increasing productivity, and creating a more favourable working environment, which in turn can reduce staff churn.

As already discussed, an estimated average increase in productivity for a green building with a good environment is 4.8 % (Johnson Controls 2012), with increases up to 30 % suggested in some reports (Langdon 2007). If the cost of an office worker is estimated at around £30,000 per year (UK), a 4.8 % improvement in productivity would therefore be equivalent to a value of around £150/m^2 of office floorspace per year (roughly assuming 1 person per 10m^2). If the average sick leave is about 7.0 days per year, using the same estimated staff costs, and assuming 220 working days per year, the average cost of absenteeism is estimated at around £100/m^2 per year. A 10 % reduction in absenteeism would benefit the business by around £10/m^2 per year. These estimated potential cost benefits totalling some £160/m^2 are relatively large compared to typical energy cost savings of typically around £3 (to a maximum £30)/m^2 a year.

Loftness et al. (2003) presented results from eight case studies linking individual temperature control to productivity gains of up to a 3 %; fifteen studies linking improved ventilation with up to 11 % gains in productivity; twelve studies linking improved lighting design with up to a 23 % gains in productivity; and, thirteen studies linking the accessto the natural environment through daylight and operable windows to individual productivity gains of up to an 18 %. Lucuik et al. (2005) cited 35 % less absenteeism in spaces with higher office ventilation rates.

Fisk (2000) has identified for the USA, potential annual savings through productivity gains are $10 to $30 billion from reduced Sick Building Syndrome symptoms and $20 to $60 billion from direct improvements in worker performance that are unrelated to health.

However, although the benefits of a good environment on staff moral and productivity seem obvious, improved indoor environmental quality has not generally been a priority in building design and construction.

Future proofing

Both businesses and householders are becoming increasingly concerned of the future energy performance of their property. Energy costs, though often considered relatively small for the majority of businesses and households, are rising significantly. Also, security of energy supply may become an issue in future. Energy related building regulations are expanding to consider existing as well as new build. The value of a building in future may therefore be affected by its energy performance, carbon dioxide emissions, and its indoor environmental quality. These may affect the rental income, resale value, and the future overall value of real estate assets, in turn affecting their return on investment.

There may also be affects of extreme weather events and changes in weather patterns that might affect future insurance costs, in relation to a building's resilience. As building buyers, tenants and investors, begin to understand these risks, non-green buildings may become obsolescent. Green buildings may be considered a lower risk, which could result in a higher yield on investment. Interest rates on building related loans may be less for green buildings, reflecting their reduced risk. A green building, whether new or retrofit, can therefore future-proof against these potential cost liabilities.

A positive stance towards environmental issues may in future impact on supply chain acceptance. A company's 'green' real estate can demonstrate a visible signal of the adoption of an environmental policy. It may even contribute to a firm's success in attracting and retaining high-quality employees.

Corporate responsibility

Carroll's pyramid of Corporate Social Responsibility (Carroll1991) for a business includes ethical and philanthropic responsibilities, alongside economic and legal responsibilities. The economic and legal responsibilities relate mainly to its shareholders, owners, and employees. The ethical and philanthropic level responsibilities relate mainly to public interest, which includes the environment.

Green buildings can form a major part of a company's Corporate Social Responsibility Strategy. They have many tangible benefits to a company, as discussed in previous sections, together with the less tangible benefits that can contribute to a favourable corporate reputation. A company therefore may be inclined to choose a green building in comparison to a standard building, to enhance its environmental credentials. A green building can therefore meet both social responsibilities whilst achieving cost savings and other 'quality of life' and economic benefits.

Marketability

There are many reports that relate to the added value of green buildings. Generally they support the argument that buildings with better sustainability credentials enjoy increased marketability. Green buildings are able to more easily attract tenants and to command higher rents and prices. In markets where green has become more main-stream, there are indications of emerging 'brown discounts', where buildings that are not green may rent or sell for less.

The World Green Building Council's report (World Green Building Council 2013) focusing on commercial buildings, explained that green buildings have a higher asset value, as evidenced by higher sale prices, with higher rental/lease rates, lower operating expenses, higher occupancy rates and lower yields (leading to a higher transaction price). They can be quicker to secure tenants, command higher prices enjoy lower tenant turnover, cost less to operate.

However, as discussed above, there are some barriers relating to understanding the benefits of green buildings, including, the assumption that it costs more to build green, the fact that green strategies are not widely understood, construction companies lack experience, there is a lack of awareness of the market, a shortage of engineers with experience of operating green building systems, a lack of incentives for owner-investors as opposed to owner-occupants. There is also a perceived lack of evidence between lower energy costs for building occupiers, and the benefit to the landlord. Leases do not generally take account of green issues. However green leases can provide benefits to both tenants and landlords (Langley, Hopkinson, Stevenson, 2008).
The tenant will benefit from reduced energy bills and improved indoor environments, whilst the landlord can benefit from longer lease periods, a more stable tenant base, and a higher asset value on their estate.

Fuel poverty and health

The 'rebound' effect introduced above (Ryan and Campbell 2012) may occur when energy savings are not fully realised due to other benefits. One such benefit is affordable warmth in fuel poor housing. Fuel poverty is defined as when a household pays more than10 % of its annual income on energy, and extreme fuel poverty is when they pay more than 20 % of annual income on energy. In some countries this is becoming of epidemic proportions. For example, up to 25 % of UK households, and up to 33 % in Wales, live in fuel poverty (Association for the Conservation of Energy 2014).

Fuel poverty will often result in households not being able to achieve sufficient warmth. Substandard housing is already estimated to cost the UK National Health Service £2.5 billion a year (National Housing Federation / ECOTEC 2010). When energy saving measures are applied in fuel poor communities, often a large proportion of the benefit will be 'taken back' in improved comfort. This take-back, or rebound effect, has been estimated to be up to 50 % of the expected energy saving measures (Lomas 2010).

Referring to the above, some 25 % of the UK's 26.4 million housing may experience fuel poverty, which generally contributes to substandard environments, and or the need to improve energy efficiency. This would equate to around 6 million dwellings. Based roughly on the above £2.5 billion health impact from substandard housing, the potential health impact cost per dwelling would equate to an average of £400 per substandard dwelling per year. If say a retrofit dwelling has a health benefit lifetime of twenty years, this equates to a saving of £8,000 per retrofit, by the health industry. So, from this simplistic analysis, reducing fuel poverty can potentially save the health industry considerable amounts of money.

Community benefits

The above discussion has focussed on the building scale benefits from green buildings, in terms of reduced energy costs, improved well-being and productivity, and increased building asset value. There are also potential benefits to the community in which the building is located. Green housing can increase wealth through reduced operating costs. Green commercial buildings can improve the quality of the built environment, attracting higher value businesses, and creating higher value jobs. There are also jobs associated with green industries, which are often appropriate to the mix of available skills within the local community. For example, the construction sector could create 400,000 new jobs from making buildings more energy efficient to meet the requirements of the Energy Efficiency Directive (European Commission 2014).

It is difficult to quantify the cost benefit of a green building to the community, but it could be of a level equivalent to the benefit to the building operator, as benefits of increased productivity, asset value may all be reflected in downstream community economic and quality of life benefits, and the increased value feeds through to the community, through higher wages, green jobs, and less pollution.

Environmental damage

Burning fossil fuel contributes to considerable environmental damage at a global and national level, which results in huge cost penalties. The DARA group have reported (DARA 2012) that climate change is already contributing to the deaths of nearly 400,000 people a year and costing the world more than $1.2 trillion a year, with developing countries bearing the brunt, through deaths from malnutrition, poverty and their associated diseases. Air pollution caused by the use of fossil fuels is also separately contributing to the deaths of at least 4.5m people a year. By 2030, it is estimated that the cost of climate change and air pollution combined will rise to 3.2 % of global GDP, with the world's least developed countries forecast to bear the greater cost, of up to 11 % of their GDP.

The Stern Review (Stern 2006) estimated that the overall costs and risks of climate change will be equivalent to losing at least 5 % of global GDP each year and the estimates of damage could rise to 20 % of GDP or more. In contrast, it suggests that the costs of reducing greenhouse gas emissions to avoid the worst impacts of climate change can be limited to around 1 % of global GDP each year.

The most environmentally damaging business sectors are oil and gas producers, followed by industrial metals and mining. These together accounted for almost a trillion dollars' worth of environmental harm in 2008 (PRI 2010). In 2003, research results on socio-environmental damages due to electricity production and transport (European Communities 2003) showed that, if the external cost of producing electricity from coal were to be factored into electricity bills, 2-7 cents of euro per kWh would have to be added to the then current price of electricity in the majority of EU Member States.

The European Environment Agency reported that air pollution in Europe cost more than 100 billion euro in 2009 alone due to health and environmental damage (European Environment Agency 2011). Emissions from power plants in Europe made up the largest share of the environmental damage costs, at £56.8bn-£96.4bn. The construction and operation of the built environment is closely linked to these industries. If we assume 40 % of electricity is used in buildings the environmental damage equates to around £120 per household per year across Europe. That includes damage associated with global warming, acid rain, resource depletion, habitat destruction by fuel extraction, environmental damage from processing and transportation, and photochemical smog.

Future increases in environmental damage and resource depletion, could potentially lead to governments to apply a "polluter pays" principle. This in turn will affect the built environment, with reduced asset values for non-green buildings, higher insurance premiums on companies, carbon taxes, and the costs associated with retrofits that could be the subject of future changing building regulations.

Case studies

Many of the studies discussed above have been associated with large-scale surveys. However, there are an increasing number of green building projects, both new build and retrofit,which are yielding invaluable information on green building design and the resulting benefits. The following case studies, carried out by the author, are used to further evidence some of the above discussion points.

Office design (Figure 1): A green approach to modern office design should adopt an integrative systems approach, to maximise performance, reduce costs and improve reliability. The EMPA zero energy office in Zurich is a good example of this approach, using a combination of 'smart' façade design, thermal mass cooling and renewable energy supply (Jones and Kopitsis 2005). It uses a central atrium for night cooling in summer, using a ''passive' approach by exposing the concrete ceiling to absorb daily heat gains from the space. At night the building is naturally ventilated through the atrium, cooling the building down. This is combined with a ground ventilation cooling system, which operates during the daytime, typically cooling outside air by up to 8oC for delivery to the occupied space. The building is highly insulated and does not need a conventional heating or cooling system. The increased cost of the façade is offset by the reduced costs of the environmental systems, so the total costs are comparable to a standard office building. The mechanical ventilation ground cooling system that operates during the day, provides enough fresh air for occupants, and not the larger quantities that would be associated with more traditional air-conditioning systems. Therefore, fan power and space for ducts and systems are reduced. The EMPA building uses passive thermal mass ceiling cooling. This, to some extent, decouples the cooling from the ventilation system. Whereas a standard air cooling (heating) system would be based on the ventilation being provided by the heating and cooling system. This holistic approach to design leads to multiple cost and value attributes, including: lower fan power; less space for plant; less space for air distribution; greater use of space for occupants; good thermal comfort; better air quality; more stable easier to control conditions; good use of daylight. Such an integrative systems approach to new commercial buildings can therefore provide an overall more sustainable design solution at affordable costs.

Figure 1 - EMPA zero energy office

Energy positive house (Figure 2): An energy positive house (Welsh School of Architecture, SOLCER project) has been designed within an affordable budget, equivalent to the standard costs of good quality one-off social housing. It incorporates near PassiveHaus standards, PV and solar thermal renewable energy systems, and has thermal and electrical storage, within the cost budget. The design adopted a systems approach integrating reduced energy demand, renewable energy supply and energy storage. It has electricity grid back-up, for periods when the energy storage system is not sufficient.

Its energy positive design means that it can export more energy to the grid than it imports from the grid.

Figure 2 - Zero carbon house (SOLCER project)

This is an example of how such a holistic approach can result in a budget cost building. The house was constructed over a sixteen-week period ending in March 2015, and will be subject to detailed monitoring. There is the potential for further cost reductions and performance improvements with fine-tuning of the design and economies of scale.

Individual house retrofits (Figure 3): The SOLCER project has also carried out retrofits of existing social housing. The first one completed in September 2014 (Figure 3a) used a whole house 'deep' retrofit systems approach including, solar PV (the whole of the south facing roof is replaced with a PV roof system), MVHR, external wall insulation, battery storage, and increased airtightness. The total package of measures cost around £27,000, with an estimated carbon dioxide emission reduction of 70 %. An additional £25,000 was spent by the housing association to bring the house up to current standards. This compares with a previous case study (Figure 3b) for a similar size end-terrace house, which cost around £54,000 to achieve 80 % carbon dioxide emission reductions with an additional £70,000 spent on non-energy saving improvements. This previous case study as one of the TSB cases discussed above (Baeli, 2013), and generally adopted a less integrative more 'bolt-on' approach.

Figure 3 - Examples of social housing retrofit. Figure 3a shows a recent retrofit where the whole south facing roof has been replaced by a PV panel. Figure 3b shows a 'bolt on' approach to PV

For the SOLCER house, prior to retrofit, the house was unoccupied, thus losing the housing association around £450/month in basic rent. Post retrofit, a tenant was easily found, and the house rented at an increased rate of around £540/month (plus 20 %), therefore achieving considerable multiple cost benefits for the housing association. There are currently around 20,000 such empty houses in Wales, in many cases where this approach could be implemented, bringing current unoccupied housing back into the market place, so they become an asset rather than a liability to their owners. Bringing empty houses into use also benefits the community and reduces the need for new build.

Large-scale retrofit: Housing retrofit programmes are often carried out on large samples (Jones et al. 2013). An example is that of the whole housing stock in the Neath Port Talbot local authority in Wales. This targeted lower cost 'elemental' energy saving measures, rather than the deep whole house approach discussed above. It was carried out from 2004 to 2007, and some 49,831 households were assessed, and 28,799 energy efficiency measures carried out to 18,832 properties. Around 28,799 tonnes of carbon dioxide emissions were saved. The project took advantage to provide multiple benefits in addition to energy savings, including: improved comfort; creating 54 new jobs, 127 workers receiving training; 2,305 households removed from fuel poverty; a total £10.3 million invested in the Borough. This project demonstrates the added value that can be applied to large-scale retrofit projects.

The earlier single house and the large-scale retrofit projects have illustrated the range of cost versus energy savings and carbon dioxide emission reductions in relation to shallow elemental measures and deep whole house measures (Figure 4). The recent single house retrofit (Figure 3a) illustrates the speed at which costs are being reduced through a more systems based approach. Both scales illustrate the range of value added benefits in addition to energy savings.

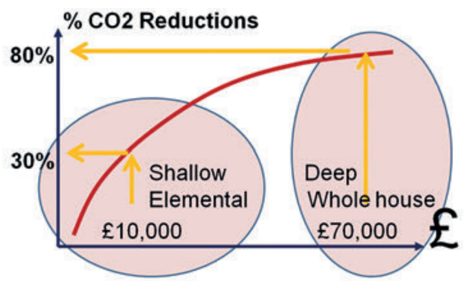

Figure 4 - Range of retrofit costs versus carbon dioxide emission reductions (Jones et al. 2013)

These above case studies indicate that, for new build, it is now possible to achieve near zero carbon performance at an affordable cost. The cost of deep retrofits for housing is also being reduced significantly. Both of these developments have involved a systems approach, carefully selecting the most appropriate combination of reduced energy demand, renewable energy supply and energy storage, to meet the requirements of the specific buildings in question.

The value of green buildings

The above sections have introduced a number of issues associated with cost and value of green buildings. Some of the areas covered have associated the estimated costs of the value added aspects of green buildings. In some sections, an estimation has been provided, based on rough values from the literature, with some 'back of envelope' estimates. The intention has been to provide an initial estimation for an overall cost and value estimate. In the estimations, neither increased energy costs nor interest rates have been considered, so they should be considered 'ball park' figures. In the past, a cost analysis has mainly related increased cost of a green building against the reduced operating costs, which have been mainly energy savings. What the above discussion has identified is a range of added value factors, some of which are potentially considerably higher than the potential energy savings. It has also identified a scale of value added which benefits not just the building owner, but also considers benefits at community and national (and global) levels. At the national/global level, benefits include, reduced environmental damage (eg. from climate change and air pollution), reduced national health costs (eg. arising from affordable warmth and improved well-being), and security of energy supply and reduced energy imports. At a community level, there is the potential for green jobs, a better quality built environment, and higher value local economic activities. At a building level, which is where the majority of this discussion has been based, the benefits are associated with energy savings, increased value of the building, future proofing, and improved health, well-being and productivity. Table 2 summarises these three areas of green building multiple benefits.

Office buildings have the potential for considerable added value, in relation to the increased asset value of the building, productivity gains, as well as energy savings, which are relatively small compared to the total benefits. The above discussion has identified a range of sources of information in this area. These have been interpreted into an overall cost value performance. Figure 5 indicates the range of cost benefits for a new 'green' office taken from the above review. Retrofit offices will have a similar range of benefits, although not to the extent of new offices.

New houses designed to green standards will also incur a range of benefits. The national/global, and to some extent the community benefits, will be as for offices. The building benefits include energy savings, increased value of the building, future proofing, affordable warmth, and improved health and well-being.

Table 2 - Summary of potential Green Building cost and value benefits

National / Global	Community	Building
• Carbon emissions reduction • Reduced use of resources • Security of energy supply • Improved public health and well-being, and reduced health related costs • Reduced environmental damage	• Jobs • Skills and training • Local economy • Less pollution	• Increased resale value • Increased rental rates • Higher occupancy rates • Lower operating expenses • Higher net operating income • Lower capitalisation rates • Increased energy efficiency and lessening greenhouse gas emissions • Reduced risk of obsolescence • Less need for refurbishment in the future • Lower tenant turnover affecting renewals, inducements and fitting out costs amongst others • Quicker to secure tenants • Better indoor environment: health, well-being and productivity gains • Attract grants, subsidies and other inducements to do with environmental stewardship • Higher demand from institutional investors mandatory for government tenants • Contribute to company CSR policy

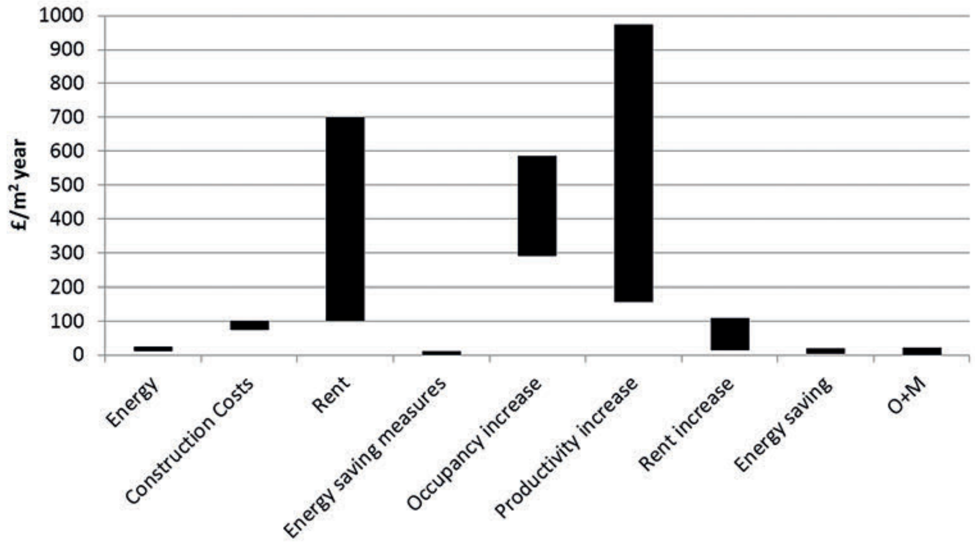

Figure 5 - Range of potential cost savings for a 'green' office

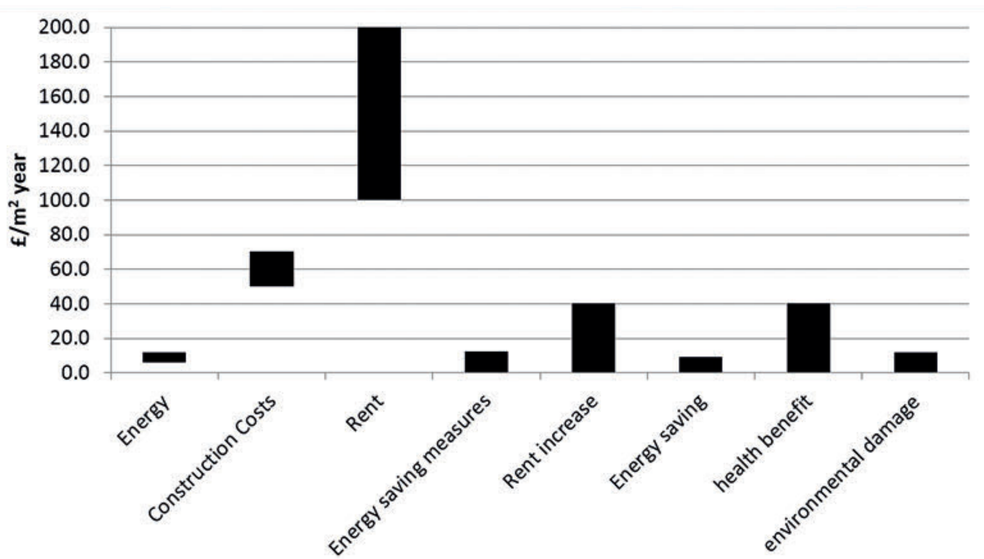

Figure 6 - Range of potential cost savings for a new 'green' house

The range of cost benefits are summarised in Figure 5. For new build offices and housing, the increased costs associated with low to zero energy performance are being driven down by new technologies, integrated into the building design through a systems approach. This was demonstrated in the case studies presented above. The cost of retrofit is also being significantly reduced, through the lowering of costs for renewables, improved understanding of the process, and, as for new build, a more systems based approach. This was also demonstrated in the above case studies, for deep housing retrofits. The above discussion has also indicated that retrofit of office costs are highly beneficial with relatively short payback times, in just terms of energy savings.

Conclusions

This paper has highlighted the multiple benefits from green building design, in addition to the usual focus on energy savings. There are of course significant energy savings and carbon dioxide emission reductions to be achieved for both new build and retrofit. However, it is the additional 'value added' multiple benefits that are becoming increasingly attractive, and to some extent they are zero or low cost, as the energy savings alone justify the initial green design costs. In summary, green buildings do not necessarily incur significant additional initial cost. For new build, and retrofit, costs are being reduced. The benefits are multiple and both quantitative and qualitative, and are realised at a building, community and national / global scale. Energy savings alone can potentially exceed any design and construction cost premiums, within an acceptable payback period. The total benefits can far outweigh any additional cost outlay. Developers who do not provide green buildings incur investment risk, and reduce marketability. Non-green buildings may now be considered short term, and can potentially spiral down the economy. Green buildings can provide better places to live and work, a higher value asset, and generally spiral up the economy at building, community and national levels, and promote tangible benefits to people.

Addressing the low carbon agenda at a building development level may be termed 'bottom-up', compared to say 'top-down' approaches, such as large-scale renewables, carbon trading, smart meters, and green-deals. A bottom-up approach, which is based within an overall systems approach, can be termed 'smart-up', with reference to the added value of a green building as it impacts at higher levels of community and national/global scale, providing the potential for cost and other benefits at these higher levels. It also localises the low carbon agenda, as it promotes economic activity at a regional scale, with potential social benefits, through jobs, local investment and ownership. Top-down approaches may also be termed 'smart' but they are often associated with high risks, and any added benefits are generally more 'big industry' commercial and national based. Smart-up has the potential to reduce the pressure on top down scenarios, making them easier to implement, as demand is reduced, being displaced by building based distributed generation. These factors all contribute to the overall value-added outcomes.

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Occupant satisfaction in post-refurbishment of historic buildings: baroque case studies in Valletta, Malta

This paper evaluates occupants' subjective response to controlled architectural interventions in listed historic buildings, as part of a comprehensive plan to restore, rehabilitate and re-use the edifice. The overall strategy was to monitor a series of historic buildings, which typically represent the same period, namely 16th century architecture, depicting the Baroque period in Malta's World Heritage Capital, Valletta. Such buildings often had discrete traditional physical features, such as ventilation stacks through their thick massive walls and an open courtyard, generating the typical introvert planning. These assisted the acclimatisation of their indoor spaces. Interventions were limited to exposing their thermal mass and re-activating the original features. The buildings were partially assessed for their thermal performance through a post-occupancy survey (POS), based on subjective evidence. Questionnaires and structured interviews were conducted with office staff, two years after entering the commissioned refurbished buildings. Results indicated that the revival of modest passive design solutions was effective in attaining comfort levels today, thus reducing the dependence on energy guzzling modern environmental control systems. This suggests that such feature-revealing interventions can be easily adapted to other similar historic buildings offered for refurbishment – albeit at a cost, but achieving energy efficiency all round. Certainly, such refurbishment cost is deemed to add value to the edifice, not only in its historic appraisal as a property, but moreover the investment results in an overall lower carbon footprint.

Author

Vincent Buhagiar
vincent.buhagiar@um.edu.mt

Department for the Built Environment, University of Malta, Malta

Introduction

As part of a programme of revitalisation of cultural heritage all over Europe, historic city centres are being resuscitated through the architectural refurbishment and re-use of listed buildings. Given their heritage sensitive character, such buildings cannot accommodate and hide the standard air conditioning or ventilation systems with complex ducting layouts and respective services, since out of their own historic nature the fabric typically needs to be exposed throughout.

This presents a stronger design challenge to expose and exploit the natural bioclimatic features of the original buildings, as these were often blatantly or unwittingly ignored through earlier refurbishments in the 1960's and 1970's. Moreover, at the time the emerging energy-conscious design trends and thermal comfort standards had not yet been evaluated for their cost-benefit and added value to the historic edifice. Other added values include:

- lower carbon from transportation, as such historic office buildings are located in Valletta, a central transport hub, for the island, easily accessible from all over the Island, thus deterring the use of the private car. Hence the double added value at building level as well as regional (city) level;
- moreover, the end result renders the finished building closely authentic to the design intent of the original architect, since such environmental features are revealed, adding value to the overall heritage of the Island's built environment.

Background

At the onset it was necessary to understand the need to elaborate on the ultimate objectives of a questionnaire survey. These need to be carried out on the basis of proper design and planning based on a good degree of clarity of goals. What is often considered a simple questionnaire or an informal interview could easily turn out to be a hollow fruitless complex 'chore', with no new revealing results. Oppenheim underlines the case that setting up a questionnaire and interview survey is no simple task (Oppenheim, 1992).

"*Fact-gathering can be quite an exciting and tempting activity to which a questionnaire opens a quick and seemingly easy avenue; the weaknesses in the design are frequently not recognised until the results have to be interpreted – if at all then!*"

Although questionnaires and interviews may not seem challenging enough, if not properly designed, output results, probably inadvertently collected in a misguided manner, could lead to pompous conclusions.

Through a pilot study of a similar single case study building (Buhagiar and Jones1997), here referred to as building one, and earlier studies with subjects in school buildings by the author the lessons learnt were that questionnaires and interviews need to ultimately address the primary goal of the study, in this case thermal comfort and its constituents (Buhagiar 1995). It was realised that certain questions may have been internally conflicting, others generating self-implied answers. Such refinements were addressed in this broader four case study, post-occupancy survey.

Literature review

Earlier established work by Leaman et al. in their BUS (Building Use Studies) in 1985, sets forth a standard comprehensive twelve-page questionnaire prepared for a generous sample of over fifty office buildings with a population sample of 125 per building (Leaman et al.1985). Considering the limited size of offices in Malta, particularly in the wake of upcoming trends in refurbishment and re-use of historic buildings in Valletta, Malta, in this context, Leaman's BUS questionnaire was considered too complex for a staff contingent of eighteen, occupying an equally small building footprint of around 150 m^2, spread on three floors, a third of which is occupied by a central courtyard. (Such offices are classified as 'small scale' by EU standards).

It is also worth noting that the footprint area of a listed historic building limits the size of the office and its potential expansion. Business directors often claim that the low potential for expansion does not limit business growth; to the contrary this may be a positive asset for proper management of both limited human as well as physical resources (Marsh 1983). Therefore the history of the building and its size can actually curtail unwarranted multi-faceted energy wastage. Endorsed maintenance and good house-keeping also enhances cultural appraisal of the country's heritage.

Further work by Bordass et al (1999), as part of their PROBE project (The PROBE Team 1999), a building survey undertaken in 1999, forty nine variables were categorised in twelve groups of independent parameters for a 'sample' of sixteen representative buildings. Post Occupancy survey experts, Leaman and Bordas (1999), state that:

"*many surveys end up with too much data and not enough time to consolidate and analyse the results. A smaller core data set avoids this 'data bloat' problem, and also releases time for managing the wider data set*".

This is what made benchmarking achievable as surveyed under BUS with a large buildings sample of over 50. However in the context of the survey behind this paper this was not achievable due to a sample of four case studies with less than 20 users each. Although the sample choice was a rigorous double short-listing process from an exhausted list of 32 refurbished historic buildings, none presented any sample of over a 50 staff contingent. Other parameters such as the building's history and its architectural integrity were considered more important.

The same work (The PROBE Team, 1999), highlights the case that a smaller core data representative sample can give a very good general overview (without benchmarking) while, on the other hand, a broader survey over scores of buildings with a more intricate questionnaire survey will result in benchmarking. Very often an overview in a relatively new field of study (as in Malta) becomes more important than the detailed deductions. Therefore the work reported in this paper modestly purports to do just that. It contends to give general trends rather than specific findings.

Aim of the study

The aim of this paper was to assess human response to refurbished built form. It sets out to explore occupants' assessment of thermal comfort and their knowledge of the potential of traditional built form to control the indoor environment. Subjective feedback was collected through a questionnaire survey and a structured interview.

It is therefore of paramount importance to generate a user-sensitive approach not only in new build design but particularly in the acclaimed '3R', – to restore, refurbish and re-use – three-in-one architectural commission of a historic listed building (U.S. Department of the Interior National Park Services1993). Referring to dated listed buildings Parsons (1993), goes on to state that in the design of a refurbishment and other changes for devising a re-use to a building…

"…*it is useful to exploit the built environment as an asset, to determine which are the prevailing environmental conditions, but if a subjective assessment can give a percentage of dissatisfaction, then that is a bonus not to be missed.*"

Existing built form presents the opportunity to monitor and predict new scenarios that are unavailable on a virgin green site or a total rebuild job. This field study is primarily concerned with the human dimension of thermal performance of buildings. The subjective survey was designed as a binding instrument to other tools used as part of a greater study forming the basis of a four-year research project (Buhagiar 1999). It was projected to assess subjects' views about the design intent of the architects behind the original versus their present day use of the historic edifice.

Methodology

Choice of case studies:
The case study buildings were selected not so much on their occupants, but predominantly chosen on the basis of their historic nature, their inherent physical features and their architectural integrity, being as authentic as possible to their original design. The type of uses and consequently the respective occupants these bring with them were only given secondary importance. However underlying trends were never disregarded: If not fully refurbished, all case studies were upgraded to modern comfort, health and safety standards – even if to a marginal degree.

Such an upgrading included only new sanitary facilities, services, finishes and furnishings, whereas, being listed buildings, full refurbishments were only limited to re-opening blocked partition walls, doorways and removal of any timber panelling and false ceilings.

The four case studies identified were all in Valletta, the capital city, located on a natural promontory, practically exposed to all wind directions. Figures 1 and 2 illustrate the natural peninsula.

Given their historic context, these 16th century buildings, had typical thick load-bearing walls and high ceilings, typical construction for such 17th century buildings. Therefore their thermal mass exposure and natural ventilation influenced directly the building's overall thermal performance. This was further enhanced given their location in the Capital City, Valletta, a natural promontory exposed on all sides (Figures 1 and 2).

Figure 1 - Map of Malta

Figure 2 - Valletta promontory

The case studies

All four case study buildings were built in the same era, typically 17th century houses, originally designed as 'palazzi' or modest city dwellings for noble families in Valletta, built circa 1600 – 1670. The architectural style was predominantly Baroque, with touches of neo-classical proportions. The typical planning format consists essentially of an imposing hallway, followed by an open staircase, leading onto a central courtyard, of approximately one fifth to one fourth the footprint area. The planning is introvert, with no back yards or front terraces, spread out on three floors with an overall height of circa seventeen meters. The ground floor, and even the first floor (called the 'piano nobile') typically has a higher floor to ceiling height. The front room was originally the lounge area, regularly entertaining guests, as part of the pomposity of the day in the Baroque period.

Such buildings are built in local stone, known as Globigerina limestone, which manifested the mason's craftsmanship through ornate external and interior architraves, cornices and angels in prominent places. The Baroque style exploited the massive deep soft stone walls (globigerina limestone) for such sculptural embellishment. The heavyweight structure also contributed to resilient environmental characteristics, resisting temperature extremes through thermal mass and ventilation across high spaces. Today most of these buildings have been converted into small scale offices of around 20 staff contingent, some even family run, or used as a family business and habitat en-suite, rendering them to be truly a 'casa-bottega' (house-workshop), as the order of the day. These buildings only had localised seasonal heating or cooling (heaters or fans), manually controlled by occupants independently in each office space. Figures 3, 4, 5 and 6 illustrate the respective floor layouts for such buildings, considered as the four case studies.

Figure 3 - Building 1: 112, West Street, Valletta

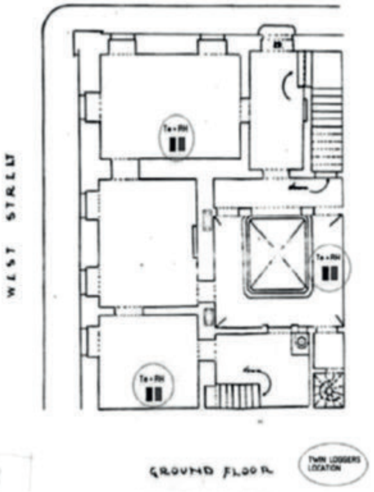

Figure 4 - Building 2: 89, Old Theatre Street, Valletta

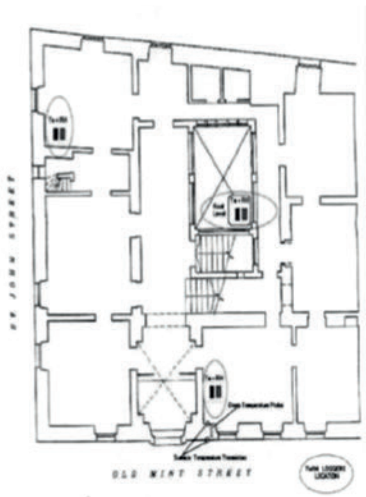

Figure 5 - Building 3: 36, Old Mint Street, Valletta

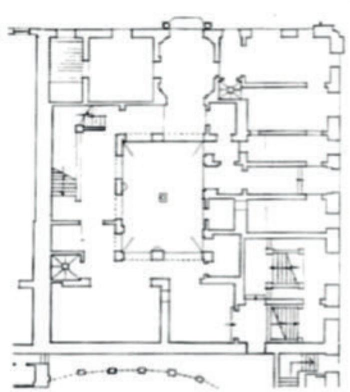

Figure 6 - Building 4: 115, Street, Valletta

Results and discussion

Before reporting on the findings proper, an overview is first given with information concerning the four case studies surveyed. This is reported under questionnaire and interviews respectively.

The questionnaire survey:
Sample size: due to the small population sample, after the questionnaire survey, follow-up structured interviews were carried out based on a standard set of questions. Since the number of users in each building numbered less than twenty, no sample representation was done. Instead, the subjective survey was aimed at accessing the full staff contingent and regular users of the buildings. Table 1 gives an overview of the sample size and respondents for each case study building.

Table 1 - The four case studies - samples and response received

Building	Use	Occupants	Responses
1	Offices	18	16
2	Residence	5	5
3	Offices	16	16
4	Café	8	6
Total		**47**	**43**

After subsequent collection and analysis, interviews were carried out over three consecutive days on Tuesday, Wednesday, and Thursday, in April intentionally selected as mid-week days, away from any potential weekend comparative influences. April is also considered as a representative 'average' month being in mid-spring, also having weather conditions reasonably identical to autumn. These shoulder months were considered practically free from the influence of peak summer/winter conditions when subjects answered questionnaires.

On the three days of the interviews for the full survey the weather was fair, with outdoor air temperatures varying between 18 – 21^{O}C and relative humidity between 63 – 85 %. Wind speed stood at an average 3.5m/s. This was extracted from collected official Meteorological data for the respective months of the full survey.

Questionnaire response:
The questionnaire was personally delivered to each subject at the respective building by the author. Out of a total (full) population of 47 persons a good representative sample of 43 responded. The other four lost the enthusiasm they showed when receiving the questionnaire, a fortnight earlier. This sample response, equivalent to 91 %, is considered as 'very good'. Babbie classifies response rates of 50 % as adequate, 60 % as good and a response rate in excess of 70 % as very good in such questionnaires (Babbie 1989). Although such a high response rate was achieved, some secondary and more personal questions related to behavioural patterns after working hours were either left unanswered or invalidated by comments. However the questions related to the thermal environment of the building were all correct and fully answered. These are the ones reported herewith. For reasons of a small sample survey and some partially incomplete questionnaires a more specific in-depth subjective assessment of the building was felt necessary through a one-to-one interview.

The structured interview:
Interviews have distinctly different purposes – from press interviews, therapeutic interviews, to employment interviews. There are essentially two different types of interviews concerned with subjective surveys (Oppenheim 1992).
These include exploratory interviews, better known as in-depth, free-style interviews, or standardised interviews, normally used for large samples such as opinion polls, market research, population census and government surveys. In this context the exploratory or in-depth, free-style structured interview was conducted. A set of questions was posed in accordance with the aims set out following the introduction to this paper.

Interview feedback:
The users were generally unaware of the in-built passive physical features of the buildings.
At the time of the survey no mention was made of these originally designed features such that the occupants will not be influenced in their responses. There was also a fear by architects and owners that staff could raise an eyebrow over potential health problems (typically Legionnaire's disease, Sick Building Syndrome) and associated sickness benefits (Wilson et al. 1987).

Given the limited length of this paper, only an overview of general findings is given. Output results were detailed at length in a comprehensive research project conducted by the same (Buhagiar, 1999)"

General findings

The fieldwork revealed that with a refurbishment and re-use of historic buildings, inherent traditional physical features were abandoned for new technological solutions, such as air conditioning. Users were largely unaware of the potential of such features to modify the indoor environment, to deter seasonal discomfort. On the other hand, building owners, if aware of them, blatantly ignored them, for lack of knowledge about their quantifiable effects. A subtle lack of faith was expressed in the potential effectiveness of such features to achieve 'natural comfort' and a significant energy saving.

The use of natural ventilation was greatly under-estimated in terms of its potential to cool the buildings, particularly through night purging. One reason for its disregard was due to noise pollution from traffic and regular street vendors, since most (converted) office buildings lay in a mixed residential and commercial area. Another concern was air pollution, though to a lesser degree. Night ventilation was claimed 'unthinkable' for security reasons.

The heavyweight construction was never perceived as a positive asset – as a thermal sink. To the contrary, the monolithic construction was negatively viewed as a source of dampness, increasing the % RH of the space, apart from promoting flaking stonework and decoration, with the occasional foul smell.

Simple suggestions made by some respondents include the use of mechanical ventilation to lower high RH levels and expel foul smells from rising damp. Night purging, if seriously considered, was suggested to come with security grills and insect screens. Finally it emerged that a greater awareness among users was necessary to operate shading devices and open windows for the right ventilation regime.

Moreover most occupants, although middle-aged, accepted a marginal thermal discomfort given the age of the building (unlike if it was a modern out of town office block). Therefore comfort was only considered as 'acceptable' since it is deemed a 'comfort trade-off' to work in a 'prestigious address' from a national heritage building, as opposed to working in a 'pigeon-hole' office in today's modern office building.

Self critique

Admittedly the author's original ambition was to use findings from this survey to compare results with other buildings at EU level or worldwide, thus increase the scope of the study, but this was not possible due to the small sample size as detailed earlier; experience in earlier work also shows that occupants tend to fear loss of confidentiality, thus questionnaire response may not be so frank and spontaneous, given the small office staff contingent. The importance of a broad representative sample for pertinent benchmarking was also highlighted by O'Sullivan et al. in 1992 (O'Sullivan et al. 1992), and also in their LINK project in 1994 (LINK initiative1994). In this instance one must also realise that given the small scale of such offices residing in refurbished historic buildings, the broadest possible sample of subjects interviewed was realised with 91 % response. This was really and truly representative of the whole office contingent. Hence the POS remains just as valid.

Conclusions

Contrary to omitting questions about spring and autumn as suggested by Bordass and Leaman (The PROBE Team, 1999), for the PROBE 2 study, independent studies by O'Sullivan et al. (1992) and the (Buhagiar, 1995) had revealed that these months were actually more critical for energy savings. Based on trends in seasonal use of environmental control systems during shoulder months, spring and autumn, between relatively mild winters and hot summers (typical Mediterranean climate), it is evident that HVAC systems were being switched on as early as April to May and September to October, as a reaction to the onset of nominal thermal discomfort in spring and autumn respectively. This attracted a greater demand for electrical energy per annum.

Through this subjective survey it was established that occupants now prefer to rely on the in-built physical features of the buildings, rather than switch on air conditioning during spring and autumn when temperatures are less mean. This naturally attracts not only an energy-cost saving but also an environmental benefit in reducing the carbon footprint of the building. Moreover, such inherent features are also exposed as part of the cultural heritage of the country. Hence such refurbished building stock may be deemed as being sustainable all round.

Cost and value aspects

Results from this study have indicated that the re-discovery and re-use of inherent passive design features could provide an effective solution for achieving comfort levels within today's standards. These in turn reduce the dependence on energy demanding modern environmental control systems, hence reducing carbon emissions. This suggests that such feature-revealing interventions can be easily adapted to other similar historic buildings offered for refurbishment – albeit at a cost, but achieving energy efficiency all round. Certainly, such a refurbishment cost is deemed to add value to the edifice, not only in its historic appraisal as a property, but moreover the investment results in an overall lower carbon footprint.

Overview

Today business managers argue that instead of moving into an 'out-of-town' large modern open plan expandable office with leading edge facilities, it is worth considering the trade-off to having a small compact office with adequate facilities in a more manageable historic edifice with a prestigious address. This has been found to curtail human resource complaints, building maintenance and utility bills. This results in an overall reduction in the carbon footprint.

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Increasing the value of buildings through environmental design

The environmental design of the built environment can be defined as a design strategy focused on reducing the depletion of resources such as energy, water, and raw materials. Sustainability in new constructions and refurbishment has achieved paramount importance in the last decades for all the agents involved in building management such as urban planners, policymakers, developers and designers as well as citizens, due to social, economic and environmental implications.

The application of environmental design to new and existing buildings becomes a tool to increase the value in two ways: on one hand, the use of materials and techniques with smaller environmental impact can make the building more attractive for particularly conscious consumers. On the other hand, the use of adequate strategies for heating, cooling and ventilation can make the building less energy consuming. The purpose of this paper is to analyse how environmental design can positively affect the cost and final value of a building.

Authors

P. Amparo López-Jiménez[1]
palopez@upv.es

Miguel Mora Pérez[1]
miguelmora@gmail.com

Giuseppe La Ferla[2]
g.laferla.licitra@gmail.com

Jaume Roset Calzada[3]
jaime.roset@upc.edu

1) Universitat Politècnica de València, Spain
2) Chapman Taylor / Universidad Politécnica de Madrid, Spain
3) Universitat Politècnica de Catalunya, Spain

Introduction

Comfort achievement in building is the final objective for many designers. Maintaining comfort conditions uses resources and energy, thus efforts must be done during the design phase to decrease the operational costs for maintaining the performance of the building. Environmental design is focused on reducing the use of resources while providing final products of high quality. This is achieved by optimising the potential for 'passive' strategies which make use of the environmental conditions (Desideri et al. 2010).

The environmental conditions in which human beings are in a state of comfort are limited within a small range of temperature, humidity and air speed. These conditions are mostly imposed by our physical constitution, but are also affected by cultural standards.
As comfort conditions do not always exist in nature, men have developed clever strategies to generate barriers that protect them from adverse weather and make them feel comfortable. These strategies include the development of buildings appropriate for the local climatic conditions (Ralegaonkar and Gupta 2010). Some years ago in the work of Garg (1991) it was concluded that two thirds of the cases of discomfort could be solved by using simple passive techniques based on thermo-physical and geometric properties of buildings.

Responding to local climatic conditions, environmental designers will try to achieve indoor comfort conditions with the least possible expenditure of energy (Aksoy and Inalli 2006). These principles have guided the design of traditional buildings, which take advantage of local conditions through the layout and shape of the building, and in recent times have inspired the concept of 'passive' architecture (Parasonis et al. 2012).

Nowadays, comfort conditions in buildings are generally achieved with large amounts of energy, as little attention is paid to the resources needed. As buildings are responsible for 33 % of the total energy consumption in the world (Urge-Vorsatz et al. 2013), buildings are major contributors to problem of climate change and, more generally, environmental pollution. This situation clearly needs to change.

As indicated by Alaa El Dean El-Alfy (2010), sustainable development meets the needs of the present generation without compromising the ability of future generations meet their own. 'Green' buildings refers to buildings which are environmentally responsible and resource-efficient throughout their life-cycle, from siting to design, construction, operation, maintenance, renovation, and demolition (Ji and Plainiotis, 2006). Thus these buildings attempt to meet the needs of society whilst reducing their impact in social, economical and environmental terms.

From an economical perspective, there are benefits in the improvement of energy efficiency buildings and resource use in buildings.
The implementation of sustainability can be a powerful tool to save on energy bills, to reduce energy dependence and to increase competitiveness.

Environmental design has many benefits; among others, it can reduce annual utility expenses and maintenance costs (Zhou et al. 2003). In order for this design approach to be effective, significant decisions regarding technology are taken during the design phase and have an effect on the final performance of the building.
Nowadays, several assessment methodologies exist to evaluate the sustainability of buildings. These can be categorised into three groups (Macías and García 2010):

- those based on the evaluation of actions and associated impacts, such as LEED V3 (USGBC, 2014) and BREEAM (BREEAM, 2014);
- those based on the concept of efficiency such as the Japanese CASBEE (CASBEE, 2014).
- those based on a tree structure with different categories and criteria, in order to be adapted to each country particularities. In this case we can find the SB tool (IISEB, 2015).

Increasing building value through environmental design

'Value engineering' should be considered as a philosophy to optimise the value of an item fulfilling the objectives of its purpose. In our case, this involves many aspects of the design of buildings without compromising their final quality. During the design phase, engineers and architects must select and finalise materials, and components of the building. Environmental design includes the sustainability assessment of construction products, which is becoming easier to conduct through Environmental Product Declarations (EPD).

When considering the sustainability of the built environment, the focus quickly moves to energy retrofit projects, since existing buildings have high environmental impact. Economical considerations are also involved, as existing buildings often present high operational energy costs as well as a large potential for energy savings.

Economic benefits of environmental design

The economic benefits of environmental design include lower energy and water consumption, smaller construction waste, lower operations and maintenance costs, lower environmental impact, and increased comfort, health and productivity. Unfortunately environmental design can require higher investments during design and construction phases. However, this situation is changing, and operational savings do not have to come at the expense of higher initial costs.

Some environmental design features have higher initial costs, but payback periods are often short and the life-cycle cost typically lower than the cost of conventional buildings. Apart from those direct savings related to energy consumption, there are other potential economic benefits that can increase in the value of the building if the correct indicators are shown:

- increase in health and comfort of the building occupants. This can reduce levels of absenteeism and increase the productivity of workers. For instance, it has been estimated

that improving occupants' productivity in commercial buildings, considering Indoor Environmental Quality (IEQ) aspects, in the US could bring economic gains between $20 – $160 billion in 1996 (Jin et al. 2012);
- longer building lifetime and less investment in retrofitting and maintenance;
- higher community acceptance and support;
- reduced costs from air pollution at the regional scale.

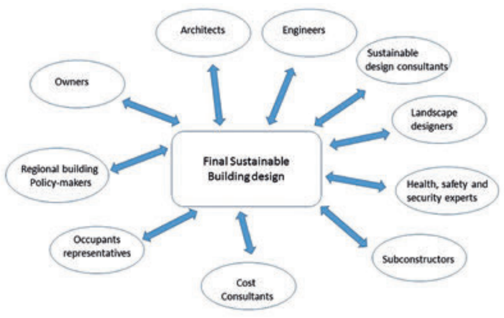

Figure 1 - Agents involved in sustainable design

Initial cost of environmental design

A project should include environmental design in its conceptual phase in order to realise the full benefits. The design team should be composed by all the agents involved in the final product, in order to increase the synergy of the solution. Environmental design requires close cooperation of all these agents (Figure 1) who form an integrated design group. The team should assess the sustainability of products and components used in the building in order to meet the specific sustainable requirements of the project.

Furthermore, the goal of the design team is to develop innovative solutions without increasing the budget of the building. Most of the times, environment-friendly products are more expensive than conventional ones. Nevertheless these additional costs imply higher energy savings during the life of the building, and therefore if the economical savings overtake the initial expenses, the investment is profitable.
Significant decisions must be taken in order of not to increase the initial and final cost of the building:

- eliminate unnecessary elements in the building. Designers have to consider whether some elements can be avoided, like internal doors, ornamental features, etc. This will decrease the use of materials, make the building lighter and decrease the initial cost;
- use recycled materials and modular solutions;
- choose a correct location for the building in order to decrease the initial need for site infrastructure. Some particular locations increase very much the initial cost because the waste disposal or de conditioning of the site costs are very high. This must be avoided by choosing a better location;
- have a bioclimatic approach to study how to achieve high comfort levels for the occupants, adaptating geometry, orientation and construction techniques to the climate of the site (Barajas et al., 2015).

Environmental design aims to create buildings which are more comfortable and healthier than conventional buildings without implying an increase in costs by supporting comfort conditions with minimum energy demand.

Cost savings across the life of green buildings

The benefits of green buildings should be considered throughout their life-cycle and not just in comparison to the upfront costs, because savings resulting from investment in environmental design usually exceed the additional upfront costs.

As well as there are design decisions that can reduce the initial cost of a building, there are design solutions that can reduce the operational cost of a building. The aim of these efforts is to decrease the energy cost across all the life-cycle of the building. For example:
- optimise site and orientation. An appropriate choice of site will decrease the energy cost across the life-cycle. Solar radiation, natural ventilation and shading can decrease the use of energy used to achieve the comfort of the occupants;
- choose the best room distribution considering the future use the building;
- install adequate thermal insulation. A well-insulated envelope limits heat losses and therefore less energy will be needed to reach the thermal comfort conditions.

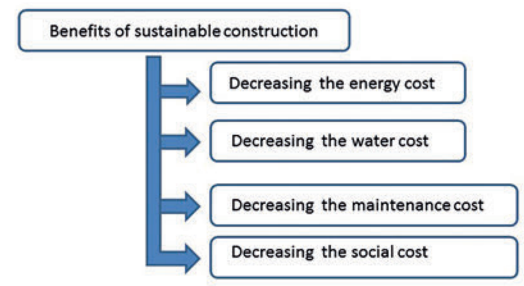

Figure 2 - Benefits associated with environmental design

The benefits of environmental design include some elements that are relatively easy to quantify (Figure 2), such as energy and water savings, as well as those that are less easily quantified, such as the decreases in maintenance and material costs, as well as other indirect social and environmental benefits.

Mid-term energy savings: decreasing the energy cost

Nowadays, many commercially available technologies can help designers to effectively minimise a building's energy costs. However, these technologies should be integrated in the first stages of the design process.

A complete strategy should be adopted in order to decrease the medium term energy costs. The aspects to be considered are referred in Table 1. First, a high percentage of the total building energy demand is due to heat losses through the building envelope. Appropriate envelope insulation will limit heat losses. Nowadays many different materials are being developed to meet the need for energy efficiency, environmental design and cheaper costs. Additionally, adequate envelope design can maximise the use of natural ventilation techniques which help reducing the heat gains,

Table 1 - Energy implications of sustainable building in the mid-term perspective

Item	Measure	Action
Building envelope	Window distribution	Optimise solar radiation and natural ventilation
	Wall insulation	Sustainable materials. Ventilated façades
	Efficient windows	Automatic performance avoiding thermal bridges
	Thermal bridge	Improve continuity between insulation layers to avoid heat losses
Mechanical Systems	Main system controller	Energy management. Choose the best way to produce/consume energy. Smart-consume or energy-saving
	Heating, Ventilation and Air Condition systems (HVAC)	High efficient systems: forced ventilation, underfloor heating, heat pumps, etc.
	Domestic Hot Water	Produce it through renewable energies such solar thermal collectors and heat pumps. Recapture energy from waste hot water.
	Low pressure ducts	Enlarging the duct sizes for saving energy
Lighting	Increase day lighting.	Add skylights
	Reduce lighting intensity	Appropriate lighting power
	Perimeter automatic daylighting controls	Daylight sensors

such as ventilated façades, atria and effective distribution of windows.

A ventilated façade generally consists in a continuous layer placed over the building wall leaving a naturally ventilated cavity. Depending on outdoor conditions, a cooling effect can be produced by the ascending flow of air, which is induced by the chimney effect, reducing the heat gains (Giancola et al. 2012).

An atrium is a building central space mainly designed to expose indoor spaces to daylight and to maximise direct solar gains. An appropriate atrium design can also help reducing the heat gains of by increasing the natural ventilation (Moosavi et al. 2014).

HVAC systems are used to create comfortable indoor conditions in buildings. An efficient HVAC system can also reduce the amount of energy needed to meet the demand for heating and cooling the building.

Currently, air- and ground-source heat pumps are one of the most advanced technologies available for heating/cooling and domestic hot water (DHW). Ground-source heat pumps collect energy stored in the earth and use it to heat water. The energy stored in the ground is an extremely reliable and constant energy source. The heat pump uses some amount of electrical energy to accomplish the work of transferring heat from the original source to a medium (usually water) with very high efficiency, as for each kW of electric energy used by the system, a higher quantity of heat is extracted form the source. Heat pumps emit no harmful substances and use very small amount of electricity. This technology can be used in combination with solar thermal heating and condensing gas boilers, though it needs to be managed by an intelligent control to guarantee the lowest use of energy and the highest level of comfort. The system must be able to choose the best energy source to decrease the operational cost in each moment: smart energy supply.

Regarding lighting, building openings can be designed to increase the penetration of natural light and therefore reduce the artificial lighting demand where possible. Energy-saving light bulbs can be installed and steps have to be taken to ensure that lights are turned off in unused areas.
To provide a general quantification of energy costs is difficult, but literature indicates than energy saving induced from eco-feedback system can range from 5 % to 55 %, (Pisello and Asdrubali 2014; Azar and Menassa 2012; Fabi et al. 2013; Chen et al. 2013; Selig-man et al. 1978; Yang et al, 2014).

Water heating represents also an important amount of the energy demand across the building life-cycle. The use of roof condensers and a rational layout of the hot water distribution system (minimising the distance between heater and consumption points) can decrease significantly the energy lost in the system.

Mid-term water savings: decreasing the water cost

Nowadays, several techniques can be used to reduce the water consumed in buildings. These technical devices decrease the midterm use of fresh water and not necessary increase the cost of the design project: ultra low-flow showerheads, faucet aerators, or dual-flush toilets. In certain application, the re-use of non potable or regenerated water can be proposed. Environmental design will also be focused on the necessity to improve the efficiency of water uses. This can be done implementing new water reuse systems and better controls on water losses (Matos et al. 2013). Green building water conservation strategies can be considered into four categories (Kats et al. 2003):

- efficiency of potable water use through better design/technology;
- capture of grey water – non-faecal waste water from bathroom sinks, bathtubs, showers, washing machines, etc. – and use for irrigation;
- on-site storm water capture for use or groundwater recharge;
- recycled/reclaimed water use.

Facilities repair: decreasing the maintenance costs

Environmental design is intended to increase durability and easier maintenance. The accessibility to services areas or the use of durable materials will decrease maintenance and repair costs. Seasonal maintenance strategies will promote proper use of facilities getting an efficient use of resources.

Furthermore, environmental design potentially improves efficiency and convenient collection of recyclable materials, such as glass, paper, plastic or others. This affects the environmental value of the building by reducing annual disposal costs for the occupants.

Indirect benefits of environmental design: social cost savings

Environmental design has additional benefits related to social and life quality aspects. It is difficult to quantify their economical effects in a single indicator, but there is no doubt that these aspects increase the value of the final building (Frontczak, et al. 2012). For instance, a lower absenteeism and improved productivity is related to these types of buildings.

The social response to some of the features of green buildings can be an increase in people's satisfaction, reduction in mistakes, reduced absenteeism and increased productivity, thus reducing labour costs (Haynes 2008).

However, economical benefits are not the main motivating factor everyone. The cost-effectiveness of green buildings makes environmental design a pragmatic way to ensure the protection of the planet's resources. Furthermore, buildings that are constructed or retrofitted according to environmental design usually provide high-quality indoor environment, thereby decreasing the risk of illnesses in the occupants due to indoor pollution.

The retrofit of buildings occupied by households in conditions of fuel poverty can result in substantial energy savings. A retrofit based on environmental design can tackle fuel poverty problem with high cost-effectiveness and generate additional benefits (Urge and Tirado 2012). For example in Spain domestic building retrofits generate near 17 full-time workplaces per million Euro invested, or of 47 full-time workplaces per 1,000 square meters retrofitted domestic area (Tirado et al. 2012). Other social, economical and environmental benefits are linked with the refurbishments of existing buildings, such as the reuse of materials (decreasing the overall environmental impact), possible reductions in transport costs, reduced landfill disposal, local economic development, retention of community infrastructure and neighbourhood renewal and management (Power, 2008).

There are several certification programmes such as Green Globes and the U.S. Green Building Council's LEED: Leadership in Energy and Environmental Design Green Building Rating System. These certifications aim to certify the 'performance' of green buildings, or how much 'sustainably designed' is the building, in order for society to take it into account.

Conclusions

This paper provided an overview of the value added to green buildings through environmental design. The main points arising from this reflection can be summarised as follows:

- There is a common perception that green buildings are more expensive than conventional buildings. This might have been the case in the past but the present situation is much more favourable;
- Green buildings increase the energy savings across their life-cycle. The over investment due to environmental design, if quickly recovered, can generate earnings;
- Environmental design encourage scientist to investigate and create new materials, building solutions and HVAC systems more environment-friendly;
- There are several social benefits associated with improved health and enhanced building occupants performance.

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Air quality and thermal comfort in smart energy regions: a cost-benefit approach

Buildings use 40 % of total EU energy consumption and generate 36 % of greenhouse gases in Europe. One of the major goals of the EU for the next decades is improving energy performance of buildings as well as reducing emissions of greenhouse gases. It is however tightly associated with health and quality of life of EU citizens. Tools for reliable evaluation of building energy performance and life-cycle analysis are being improved. Yet, effects of the built environment on humans are in most cases not considered as it is harder to quantify. Overview of known effects of indoor and outdoor air quality and thermal comfort on people will be discussed in this paper from the perspective of return on investment. Air quality relates mostly to health effects, including toxic reactions, allergies, sick building syndrome (SBS) symptoms, building related illnesses (BRI), cross-infection of airborne diseases as well as sick leave. Thermal comfort relates to occupant satisfaction levels and work performance. Some of the scientifically proved relations can be integrated into cost-benefit analysis while planning building refurbishment actions or designing new buildings.

Authors

Andrius Jurelionis
andrius.jurelionis@ktu.lt

Rokas Valančius
rokas.valancius@ktu.lt

Kaunas University of Technology, Lithuania

Introduction

Buildings use 40 % of total EU energy consumption and generate 36 % of greenhouse gases in Europe. The construction sector is on its critical path to de-carbonise the European economy by 2050, reducing its CO_2 emissions by at least 80 % and its energy consumption by as much as 50 %. Energy policy scenarios by 2050 show that a 40 % to 50 % reduction of the building 'sector' energy consumption is mandatory by 2050, where fossil fuel heating represents a major share (60 %) (EC 2014).

Replacement rate of the existing building stock in Europe is very small at the moment reaching up to 2 % per year while construction is a lucrative sector for the European economy in general. The 2011 statistics from the European Construction Industry Federation (FIEC) report that construction is the largest European single activity accounting for 9.6 % of the EU-27 GDP worth just above EUR 1.2 trillion, when considering the extended value chain (e.g. the manufacture of construction products, architecture and engineering) (EC 2014; FIEC 2013).

One of the major goals of EU for the next decades is improving energy performance of buildings as well as reducing emissions of greenhouse gases. It is however tightly associated with health and quality of life of EU citizens. Tools for reliable evaluation of building energy performance and life-cycle analysis are being improved to be provided for the building construction industry. Yet, effects of built environment on people are in most cases not considered as it is harder to quantify.

Strategies for creating better environmental conditions for people are outlined by European Commission in Multi-annual roadmap for the contractual PPP under Horizon 2020 (EC 2014).

One of the general objectives for Horizon 2020 is to develop innovative and smart systemic approaches for green buildings and districts, helping to improve the competitiveness of EU building industry by providing cost-effective, user-friendly, healthy and safe products for smart cities (EC 2014). Healthy and comfortable indoor environment is identified as one of the target research areas by European Commission and includes such topics as:

- empirical and reliable epidemiological data on correlation between buildings and human health;
- improvement of building material properties in order to maximise human comfort;
- Reducing the volatile organic compound (VOC) content of building materials.

The aim of this paper is to provide concentrated review on environmental effects on human health and productivity. References of methods which can be used to perform cost-benefit analysis for evaluation of interrelations between building refurbishment actions, energy consumption, HVAC (heating, ventilation and air conditioning) systems in buildings and occupant productivity are provided as well.

Health effects of outdoor air pollution

Relative impact of outdoor air pollution on human health is reduced within past decades due to the fact that people spend most of their time indoors and levels of outdoor pollutants such as particulates, sulphur oxides and carbon monoxide have been declining in many countries in European Union and United States. However, when discussing human response to air quality in smart energy regions and cities, outdoor pollution cannot be neglected as it may cause chronic diseases, increase mortality and decrease quality of life. Impact of outdoor air pollutants can be estimated from macro-economic or regional perspective.

This paper provides some known effects of outdoor air pollution on human health. Yet, quantification of these health effects in a monetary value for specific urban-scale projects can be complicated and may require detailed statistical analysis. A study presented by Pope et al. (2009) can be listed as an example. This study showed that reduction in exposure to ambient fine-particulate air pollution contributed to significant and measurable improvements in life expectancy in the United States. An increase of 10 µg per cubic meter in the PM2.5 concentration was associated with a reduction in life expectancy of 0.46±0.22 year (P=0.039) from 1978 to 1982 and 0.37±0.20 year (P=0.091) from 1997 to 2001 (Pope et al. 2009).
In most cases data on the human health effects of outdoor air pollutants are grouped into eight sections based on the organ system they affect:

- Respiratory effects;
- Cardiovascular effects;
- Cancer;
- Reproductive and developmental effects;
- Neurological effects;
- Mortality;
- Infection;
- Other effects.

Health effects of gaseous air pollutants

Gaseous outdoor air pollutants have a documented impact on such chronic diseases as chronic obstructive pulmonary diseases (COPD), cardiovascular diseases (CVD), asthma and cancer. By-products of oxidative stress found in air pollutants are common initiators or promoters of the damage produced in such chronic diseases. Such air pollutants include: ozone, sulphur oxides, carbon monoxide and nitrogen oxides. A great deal of information exists concerning the effects of gaseous air pollutants but the current under-standing of such effects, including the effects of mixed components on human mortality and morbidity, are limited (Yang et al. 2009).

Certain groups of people such as asthmatics, atopic patients, patients with emphysema and bronchitis, heart and stroke patients, diabetes, pregnant women, the elderly and children are especially sensitive to the health effects of outdoor air toxicants. It is estimated that about 20 % of the United States population suffers from asthma, emphysema, bronchitis, diabetes or cardiovascular disease and is thus especially susceptible to outdoor air pollution. More than 147.6 million people 47 % of the nation live where pollution levels are too often dangerous to breathe (Curtis et al. 2006).

Chronic obstructive pulmonary disease (COPD) is the non-specific terminology commonly used to describe the spectrum of various diseases causing limitation of respiratory airflow, e.g., asthma, chronic bronchitis, and emphysema. Sunyer et al. studied emergency room visits in Spain. High levels of SO_2 were significantly associated with daily emergency room visits for COPD on the same day and the next day (Sunyer et al. 1991).

The association of each pollutant (SO_2, CO, NO_2, and O_3) with COPD admissions remained significant after controlling for other pollutants. The findings support the conclusion that air pollution does affect the respiratory health of susceptible persons (Sunyer et al. 1991).

Evidence from population-based studies shows that workers exposed to CO in combination with other combustion by-products from automobile exhaust (Stern et al. 1988), as well as other industrial workers (Kristensen 1989), have increased risk of developing atherosclerotic heart disease. Results showed consistently positive relationships between the ambient CO level and different groups of cardiovascular admissions, although the male gender and age older than 60 groups were the most affected. Data suggest a positive correlation between ambient CO levels and hospital admissions for CV diseases (Kristensen 1989).

The poisonous effect of CO is due to its ability to unite directly with the hemoglobin of red blood cells forming carbon monoxide–hemoglobin (carboxyhemoglobin), which is more stable than the oxyhemoglobin and prevents the red cell from absorbing oxygen (Yang et al. 2009).

Epidemiologic studies over the last 40 years suggest rather consistently that general ambient air pollution, chiefly due to the incomplete combustion of fossil fuels, may be responsible for increased rates of lung cancer. This evidence is derived from studies of lung cancer trends, studies of occupational groups, comparisons of urban and rural populations, and case–control and cohort studies using diverse exposure metrics (Pope 1995).

The most important form of NOx causing adverse health effects is NO_2. NO_2 is chemically reactive and exist in the atmosphere. Nitric acid vapour is produced largely as a part of the photo oxidation cycle of polluted air derived primarily from automobile emissions.

Once NO2 is deposited in the lung it may dissolve in lung fluids, producing nitric and nitrous acids (Yang and Omaye 2009; Goldstein et al. 1997).

Sulphur dioxide (SO_2) is a heavy, penetrating gas, which is a colourless, suffocating gas with an odour and unites with water to form an acid. Catalysed by transition metals, SO_2 readily oxidizes to sulphate (Yang and Omaye 2009).

During the smelting of metals and the combustion of fossil fuels, sulphuric acid can adsorb to metal oxide particles, i.e., in some coals, 9 % of the resident sulphur may be sulphuric acid. Among the weak acids, SO_2 and its hydrolysis products have been associated with both acute bronchon-constrictionand elevated morbidity and mortality rates.
The current U.S. ambient air levels of SO_2 are generally within the current primary NAAQS of 80 g/m³ for an annual average (365 g/m³ for a 24-h maximum). SO_2 is predominantly an upper airway irritant, producing bronchon-constriction and mucus, reflected as a measurable increase in airflow resistance. Humans subjected to 1 – 13 ppm SO_2 for 10 min exhibited rapid bronchon-constriction response (Yang and Omaye 2009; Lewis et al. 1969).
Clearly, asthmatics and others affected with hyper-reactive airways are most sensitive to acute exposures to SO_2 of an order of magnitude lower than those affecting healthy persons.

Clinical studies showing large decrements in respiratory function that were proportional to the ambient O_3 concentrations (Spektor et al. 1988; Horstman et al. 1990) are consistent with the results obtained in a series of field studies. In addition, non-specific airway reactivity has been found related to O_3 exposure.

The increased airway sensitivity may lead to increased responsiveness to other pollutants such as sulphuric acid, which causes bronchon-constriction (Yang and Omaye, 2009).

Health effects of aerosol particles in ambient air

Air pollution, mainly from vehicles, industry, and power plants, increases the risk of lung cancer (Rossner et al. 2008; Sorensen et al. 2003). DNA adducts, as well as being markers of early damage, including mutagenicity, are directly linked to exposure to air pollutants, particularly particulate matter PM10 or PM2.5.

Carcinogenic effects of PM may relate both to the content of polycyclic aromatic hydrocarbons (PAH) and oxidative damage to DNA generated by transition metals, benzene, metabolism and/or inflammation (Yang and Omaye 2009).

Dutch researchers studied 5000 people in the Netherlands from 1986 to 1994 who were participants in a prospective cohort study on diet and cancer. They found that people living near major roads with higher concentrations of black smoke were at increased risk of premature death from cardiopulmonary causes. These linkages have been found in different studies using different methodologies and in different cities (Yang and Omaye 2009; Hoek et al. 2002).

There is good evidence that air pollution episodes aggravate respiratory disease, especially asthma. A study of the relationship between fine particulate matter and emergency room (ER) visits for asthma in the metropolitan Seattle area was designed to help confirm whether air pollution was a risk factor for asthma (Yang and Omaye 2009; Mortimer et al. 2002; Schwartz et al. 1991; Schwartz et al. 1993). Using Poisson regressions controlling for weather, season, time trends, age, hospital, and day of the week, a significant association was found between fine particles measured at the residential monitoring station used in the study and visits to emergency departments in eight participating hospitals.

Both organic and inorganic materials are found in what is referred to as particulate matter. Compositional distribution can vary significantly. The health effects of particulate matter are significant for short-term and long-term exposures, particularly those containing several metals and silicate-derived constituents that can be cytotoxic to lung cells. Fine particles of less than 2.5 µm diameter (PM2.5) predominate in the particle mixes around most U.S. cities. These and the smaller amounts of coarse dust, between 2.5 and 10 µm in diameter (PM10) are generated by combustion sources. Particles smaller than 2.5 µm in diameter can penetrate the deepest (alveolar) portions of the lung. If these particles are soluble in water, they pass directly into the blood in the alveolar capillaries and if they are not soluble in water, they are retained in the deep lung for long periods (Yang and Omaye 2009).

All of the above mentioned effects can be relevant in the case when outdoor air pollutants are present in the indoor environment as well.

Indoor environment and occupant productivity

There is a confident number of studies performed to evaluate occupant productivity effects of indoor environmental parameters such as air temperature, air change rates and dissatisfaction levels.

Seppänen et al. outlined a relation between human performance and air temperature based on various productivity studies (Seppänen et al. 2006). It showed that performance increases when the air temperature rises up to 21 – 22 °C and decreases by approximately 2 % per 1 °C increase of air temperature in the range of 25 – 35 °C.

The relationship was statistically significant within air temperature ranges below 20 °C or above 24 °C. The maximum performance is achieved at air temperature of ca. 22 °C (Figure 1).

Lan et al. outlined the correlation between indoor temperature, human performance and different clothing insulation (0.86, 1.0 and 1.19 clo) levels during the winter season (Lan et al. 2012). It revealed that the maximum performance was achieved at 21.9 °C with the clothing insulation equal to 0.86 clo and at 19.7 °C with the clothing insulation equal to 1.19 clo.

Indoor air quality (IAQ) has impact on office work performance as well. Wyon reported that poor IAQ could reduce office work performance by 6 % – 9 % (Wyon et al. 2002). Seppänen et al. presented a study that incorporated the results of nine surveys and identified that increasing air change rate in the building from 6.5 to 65 litres per second per person results in an increase of productivity of the occupants (Figure 2). However, statistically significant results were obtained when the airflow was increased to 15 L/s per person (95 %) and to 17 L/s per person (90 %) (Seppänen et al. 2006).

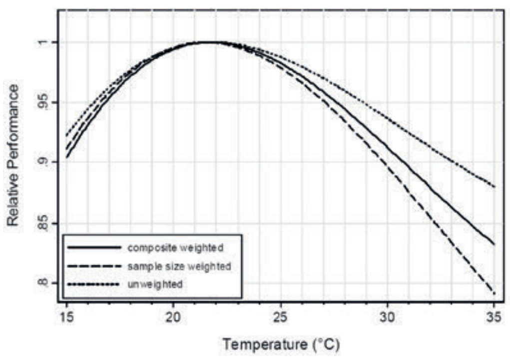

Figure 1 - Normalised relation between occupant performance and air temperature in rooms (Lan et al. 2012)

According to the study presented by Seppänen and Fisk, decreased occupant dissatisfaction with IAQ by 10 % results in a 1.1 % reduction of their productivity by while performing tasks such as text typing, calculating or editing (Figure 3). The results were statistically significant when the dissatisfaction with IAQ was in the range of 25 % – 70 % (Seppänen and Fisk 2006).

Other indoor environmental factors such as humidity, frequency of occurrence of sick building syndrome symptoms have an impact on office work productivity as well. However, the thermal sensation of the occupants has a major influence on overall satisfaction with indoor environmental quality compared with the impact of other indoor environmental conditions (Frontczak and Wargocki 2011).

Impact of thermal sensation can be expressed either using productivity as a function of predicted mean vote (PMV) or productivity as a function of air temperature. Using the latter, may require modifications of effects on productivity based on physical activity and clothing level of the occupants.

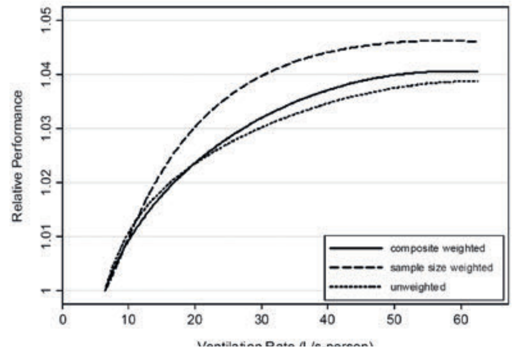

Figure 2 - Normalised relation between occupant performance and ventilation rate (Seppänen et al. 2006)

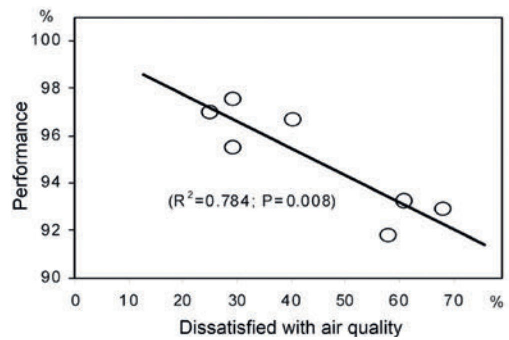

Figure 3 - Performance of simulated office work as function of proportion of dissatisfied with air quality (Seppänen and Fisk 2006)

Methods of cost-benefit analysis for occupant productivity evaluation

Various authors have presented numerous studies dealing with energy efficiency and potential savings of renovation. However, more often than not, these ignores the effects of refurbishment actions on the productivity of the building occupants (Kaklauskas et al. 2005; Smid and Nieboer 2008; Tuominen et al. 2013). Nevertheless, there are studies showing that measures for improving indoor climate are cost-effective when health and productivity benefits resulting from improved conditions are calculated. In most cases financial losses related to decreased office work performance are several times higher compared to the energy saved due to reduced indoor environmental conditions (Djukanovic et al. 2002; Fisk 2000; Fisk et al. 2003; Fisk et al. 2011; Hanssen 2000; Kempinski 2003; Seppänen and Vuolle 2000).

Wargocki et al. have presented generalisation of the studies in the field of indoor environment and productivity and outlined key aspects on how occupant productivity assessment could be integrated into cost-benefit calculations (Wargocki et al., 2006).
The method presented by Wargocki et al. is based on the equation:

1) $B \cdot a + E + M + C + S = P - G$

where:
B – investment capital costs related to building, furnishings, equipment and installations;
a – annuity factor (amortisation factor);
E – annual energy costs;
M – annual operating and maintenance costs;
C – annual cleaning costs;
S – annual salaries including all related costs;
P – annual production revenue (products/fees, etc.);
G – annual profit. (Wargocki et al. 2006)

Equation (1) can be rewritten to assess the relationship between costs and benefits by introducing the alteration quantity (Δ) in relation to the reference situation and assuming no increase in salaries (ΔS=0) and profits (ΔG=0) (Wargocki et al. 2006). The modified equation (2) can be used for specific cases to evaluate particular building intervention actions and benefits gained:

2) $\Delta x / x + (E / a \cdot x)(\Delta E / E) + (\mathbf{M} / a \cdot x)(\Delta M / M) + (C / a \cdot x)(\Delta C / C) \leq (P / a \cdot x \cdot y)(\Delta P / P)$

where:
x – total building costs per m²
y – building area used by one employee, m²/employee.

Equation (4) can be used in sensitivity analysis to demonstrate the relative importance of each parameter (Wargocki et al. 2006). All values should be used per square meter of the building area per year. Jensen et al. have introduced a performance index (Π) which can be used to compare directly the different building designs and to assess the economic consequences of the indoor climate with a specific building design by using the Bayesian Network (Jensen and Toftum 2007).

Valančius et al. have presented the Energy Performance and Occupant Productivity assessment method (EP-OP) for complex assessment of office building refurbishment in consideration of existing indoor environmental conditions, predicting increased office work performance, energy consumption and technical state of the building envelope as well as HVAC equipment was developed (Valančius et al. 2013).

The core of the EP-OP method is the algorithm of procedures which should be followed for cost-benefit calculations while retaining flexibility for adapting various probabilistic models as well as statistical analysis. The evaluation procedure in the form of an algorithm is presented in Figure 4. The main steps of the procedure are grouped into:

- initial data collection;
- data analysis;
- data processing.

The outcome of the solver calculations is a combination of measures for energy use reduction as well as productivity improvement.

The main concept of sensitivity analysis present in the EP-OP method is the definition of pessimistic and optimistic scenarios. Methods suggested by Wargocki et al. are used to combine evaluation of different indoor environmental parameters on productivity (Wargocki et al. 2006). Refurbishment actions would have different impacts on productivity changes in different cases. For example, additional insulation of the building envelope may have no effect on productivity in a pessimistic scenario, however, it may lead to increased air temperature in rooms, and therefore predicted productivity gains may be included in the optimistic scenario. On the other hand, some actions may increase energy costs while having a positive effect on occupant productivity.

Data collected within previous steps of EP-OP method would be processed using TOPSIS (Hwang and Yoon 1981) as a tool for determination of optimal solution. Matrix for application TOPSIS technique for pessimistic and optimistic scenario are produced. The result is obtained outlining technical measures,

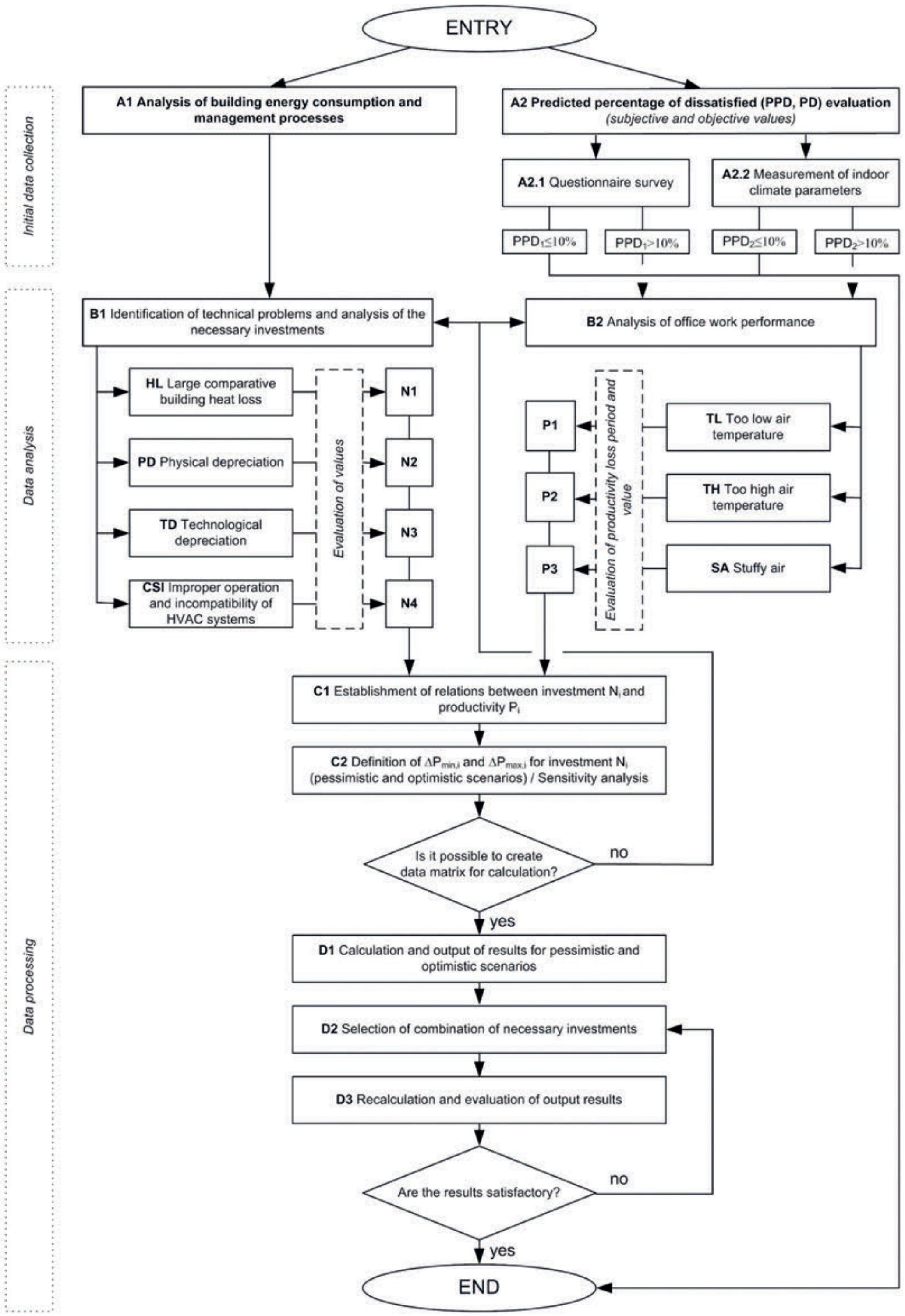

Figure 4 - Algorithm of EP-OP method procedures (Valančius et al., 2013)

which should be taken into account in order to optimise energy use in the building and work performance of the employees.

Implementation of the procedures using the EP-OP method algorithm is related to a high level of uncertainties when dealing with relations between indoor environment and productivity. Therefore, selection of pessimistic and optimistic scenario for sensitivity analysis is an important step within the data analysis and data processing procedures.

Case study analysis (Valančius and Jurelionis 2014) revealed that using the TOPSIS technique both for pessimistic and optimistic scenario did not alter the final results considerably, as regards calculation of the relatively most cost effective solution amongst the selected alternatives.

It is however important to note, that the alternatives should not be dependent on each other, e.g., heat recovery ventilation may be less effective without reducing air leakage of the building. Therefore, values for energy saving with or without renovation of building envelope might be different for such alternative as heat recovery ventilation.

Uncertainty of results when applying the EP-OP method may be provoked by inaccuracy of the initial input data such as selection of alternatives, identification of potential energy saving and productivity gain.

It would be useful to apply a probabilistic approach for expected energy savings as well. This would lead to creating more matrices for the analysis where pessimistic and optimistic values of potential energy saving would be included.

The TOPSIS technique could also be improved by adding coefficients of significance for each analysed criterion. In this case, decision makers should outline which criteria are most important for the case in the data input step. Higher values of significance for reducing energy consumption or increasing productivity might alter the final results of the analysis.
Results of the analysis of case study buildings showed that the EP-OP method can be used efficiently in order to combine energy performance and human productivity evaluation in office buildings while handling uncertainties of initial data collection by use of TOPSIS technique (Valančius and Jurelionis 2014).
In most analysed cases the highest benefit regarding energy consumption and office work performance could be obtained by installation of fan-driven ventilation system with heat recovery and cooling. Improvement of HVAC systems control would be highly beneficial as well. It was identified that the pay-off term from the above mentioned interventions would be relatively shorter compared to such refurbishment actions or replacement of heat generators (Valančius and Jurelionis 2014).

Discussion and conclusions

As it was outlined above, some of the scientifically proved relations between environmental factors and human response can be integrated into cost-benefit analysis while planning building refurbishment actions or designing new buildings.

Most of the studies are fixed on effects of indoor environment on health and productivity of the occupants. However, there's no sufficient data on impact of Sick Building Syndrome (SBS) symptoms on productivity. There's also lack of studies showing how outdoor air pollution levels can be evaluated from the perspective of sick leave.

Methods which can be used for life cycle analysis can be classified into two major groups:
- retrofitting of building and HVAC systems can be assessed from the perspective of occupant productivity, cross-infection of airborne diseases and sick leave;
- impact on health and sick leave can be assessed by predicting the change of outdoor air quality evoked by large scale urban projects and regulations.

More statistical data is needed to fully interpret effects of outdoor air pollution on costs related to increase of illnesses and value lost due to decreased health. Lower life expectancy of people living in a city or region however can be expressed in monetary value lost. On the other hand, known links between indoor environment and productivity can be used for reliable integration into cost-benefit analysis on a single building scale.

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Introduction to sustainable retrofitting

The second chapter of the book, Sustainable Retrofitting, contributes to the discussion about cost and value of retrofitted buildings, built mostly in the second part of the twentieth century.
The existing buildings in Europe comprise the largest segment of the built environment. Since this building stock presents a significant amount of energy consumed for heating, lighting and cooling, it is important to initiate retrofitting to reduce such energy consumption and the cost of maintenance and frequent replacement. Retrofitting of existing buildings, whether historical or not, can reduce operation costs and environmental impacts. Furthermore, energy-efficiency initiatives can significantly increase building adaptability, durability, and resilience.

This chapter of the book consists of the three papers. The first one presents the retrofitting of low-income social housing, with attempts to address the problem of refurbishing a naturally-ventilated, multi-family apartment in a holistic manner, to improve indoor comfort sustainably, with minimal use of electrical energy, combined with occupants’ methods of adaptive comfort. It provides a concentrated literature review on recent developments in thermal comfort theory for the Maltese climate.

The subject of the second paper considers the retrofitting of multi-family housing, using LCC analysis that deals with the feasibility of measures taken to improve thermal performance of the building envelope in order to reduce energy demands for space heating. LCC analysis is carried out on one exemplary apartment in multi-family buildings with recently refurbished façades in a settlement in Belgrade.

The third papers is dedicated to methods of cost and value assessment and its standardisation. It is focused on CEN’s contribution and its versatile application in the building sector.

This chapter gives an overview with case studies of how sustainable retrofitting can be carried out to the building fabric applying a range of passive and active heating and cooling techniques, in the context of local energy policy and established standards.

Cost and value of refurbishment: retrofitting social housing for low energy affordable comfort

Today, in low-income Maltese homes thermal comfort is considered a social commodity. Affordable energy bills have become first priority relative to retrofitting for energy efficiency and comfort in the home. In consideration that domestic electricity tariffs have been reduced by as much as 25 %, as part of a social benefit scheme, few families have taken up the opportunity to retrofit for curtailing their energy bills. There are also plans by the Government of Malta to retrofit social housing, typically the external fabric, with a view to render them more affordable to heat and cool as well as to improve the social status of the families and enhance the aesthetic appeal of such housing. This paper investigates options for retrofitting through both objective and subjective audits, as well as running simulations to test out such retrofit options.

Authors

Vincent Buhagiar
vincent.buhagiar@um.edu.mt

Justin Zarb
zarb.uno@gmail.com

Faculty for the Built Environment,
University of Malta, Malta

Introduction

This paper attempts to address the problem of refurbishing a naturally-ventilated, multi-family dwelling in a holistic manner, to improve indoor comfort sustainably.

The research is based on a broad literature review, covering recent developments in thermal comfort theory, the Maltese climate, energy policy, building fabric and a range of passive and active heating and cooling techniques.

A 1970's social housing building in Ta' Giorni, Malta was used as a case study. Fieldwork included questionnaires and an objective survey among the occupants, temperature and humidity monitoring as well as thermal imaging. A set of standard interventions was also modelled on the building using IES.

Background

EU legislation for energy efficient buildings has been growing rapidly since the late 1980s, the latest development being the EPBD recast (EPBD Recast- 2010/31/EU). Among other things, this requires energy performance certificates to be issued to new buildings and refurbishments and requires governments to refurbish a number of buildings to nearly-zero-energy by 2020.

Energy use in buildings

Statistics recently published by the NSO (Said 2012) show a gradual increase in domestic energy consumption from 27.8 % to 28.46 % between 2000 and 2007. However, at an average of 0.5toe/dwelling, Malta still has the lowest energy consumption per dwelling in Europe (ADEME 2012). Heating and cooling accounts for around 24 % of this figure (Said 2012) and varies according to two criteria: the system's efficiency and occupants' willingness to use it, assuming that occupants can exercise control over such systems.

Willingness to use active heating or cooling depends on thermal preference, tolerance, available alternatives and economical awareness. For a given temperature, these four factors vary depending on the individual, on culture, energy costs and the standard of living. It may be difficult to predict accurately the scenario that will play out over the entire lifespan of a building, which is why predictions for final energy use might not always measure up to reality.

The Maltese climate

Monthly mean temperatures lie in the range of 12.4°C and 26.3°C. Mean monthly maximum temperatures in excess of 30°C occur between June and September and mean minimum temperatures fall below 5°C in January and February. Ground temperature at a depth of 1m varies between 14°C in March and 23°C in September (Galdies 2011). The average daily diurnal variation between 2006 and 2011 varied between 4°C and 8.5°C; the mean monthly diurnal variation has decreased by around 2°C over the past 25 years (www.maltaweather.com).

Natural nocturnal ventilation of high-mass buildings cannot cool the internal mass enough to provide daytime comfort; however, radiant, desiccant and evaporative cooling techniques can cool inflowing air to a few degrees below the ambient temperature with no energy input.

Adaptive thermal comfort and alliesthesia

The Adaptive Hypothesis states that one's satisfaction with an indoor climate is achieved by matching the actual thermal environmental conditions prevailing at that point in time and space with one's thermal expectations of what the indoor climate should be like (Yao, et al.2009). Annex A2 of EN 15251 includes an adaptive comfort temperature model, which applies to all free running buildings. This model relates neutral temperatures indoors to outdoor temperatures, based on the Smart Controls and Thermal Comfort project (SCATs) (Nicol and Wilson 2010).

Alliesthesia provides an explanation as to how an increase in air velocity can be perceived as pleasant or unpleasant depending on the relative state of the body's core temperature. In the warm adaptive comfort zone, any peripheral stimulation of the skin's cold receptors will be perceived as a pleasant sensation. This can explain why the increases and fluctuations in air movement typical of buildings with operable windows are valued by occupants of such buildings (Candido and de Dear 2012). Although the adaptive model has been shown to predict comfort temperatures better than the popular chamber model in free-running buildings, it does not account for the contribution of radiant temperature and air velocity. Concepts such as alliesthesia and the effects of physiological cooling (Szokolai 2008). are important principles to be considered when designing naturally-ventilated spaces.

Case study: Housing block C "Ta' Giorn'

The building used as a case study is built on a West-facing slope at an altitude of 62.5m above sea level and a roof height of 14.85m. It is symmetrical along its shorter North-South axis which is aligned 3.19° due West and splits the building levels into two mezzanines.
Each mezzanine has a three bedroom and four-bedroom apartment, with a total of 16 apartments. Access is provided by a central stairwell with shafts on either side.

The building's external walls are 150mm single leaf limestone blocks for kitchens and bathrooms and double-leaf limestone walls with an open unventilated or filled gap (230mm/25mm/230mm) elsewhere.

The external finish is bare and joints were pointed during construction. The roof construction, identical to that used for the intermediate floors, uses 150mm Precast T-beams and hollow-bricks; with finishes varying between light grey concrete tiles laid to falls, black bituminous membrane and a dark grey rubber compound. Windows are operable single pane, side hung in a galvanised steel frame.

Key features that constitute thermal comfort

Thermal mass: given the right properties, thermal mass should be able to store daytime heat and dissipate it after sunset. An inadequate cooling rate will result in generally higher indoor temperatures than the simultaneous outdoor temperature. Exposed thermal mass transfers heat by conduction and radiation. Insulation on one or both sides may be used to block these paths, thus altering the attenuating and time-lag properties of thermal mass.

Insulation reduces heat transfer through the building envelope making it very useful at reducing heat loss in winter. German Passivhaus standards specify maximum U-values of 0.15 throughout the building envelope. Despite the drive for insulation in national policy, studies suggest that wall and roof insulation with U-values below 0.57W/m²K give a negligible reduction in cooling energy under warm climatic conditions (Kim and Moon 2009).

Windows account for a high percentage of heat losses through radiation and convection in winter; however, as long as they are adequately shaded in summer, the effect of windows on the cooling needs of a building is insignificant (Givoni 1994).

Colour and reflectivity of the external walls and roof have a large impact on the surface and indoor temperatures of the building. Experiments on white and grey- coloured walls and roofs have demonstrated that darker surfaces can increase internal ceiling temperatures by at least 12°C. By contrast, white roofs could reduce ceiling temperatures by around 2°C below outdoor temperatures (Givoni 1994).

Methodology

This study was carried out using both objective and subjective modes of assessment for thermal comfort as typical for such studies.

Objectively, data loggers were deployed in various flats at various levels to monitor the temperature and relative humidity changes over time, at hourly intervals. This is deemed to be an impartial scientific audit of the temperature and humidity profiles, independent of building users' intervention or lifestyle preferences – albeit these were measuring the end result of the actual situation. Such objective monitoring was carried out by calibrated instruments, namely through the use of HOBO® data loggers for air temperature and RH, monitoring both internally and externally. Thermal imaging was carried out using a FLIR® infra-red hand-held camera.

Subjective auditing was carried out to collect and collate of people's opinions on indoor comfort by means of a carefully designed questionnaire and a series of dedicated one-to-one interviews with flat owners (namely the bread winners, who typically forked out the money for their family's energy bill). Hence these were considered to be perhaps more sensitive to energy costs rather than to the environmental benefit of any energy efficient measure adopted (or improvised). It must be spelt out from the onset that no debates on environmental benefits or cost savings were entertained, as these would have possibly biased their opinions, distorting the actual genuine response. Such questionnaires and interviews flagged any direct impulsive interventions made in favour of adaptive comfort.

Internal temperature and relative humidity:
Six temperature and humidity loggers were placed in different apartments between the 3rd August 2012 and 3rd May 2013; an additional 9 data loggers were added on the 1st April 2013. The first configuration monitored two rooms each in flats 8, 10 and 13 at a height between 1.5 and 2.5m. In December, one logger was removed from each apartment and relocated to flats 1, 2 and 16 in an attempt to observe any variations in temperature due to the floor level of each representative flat.

External temperature, relative humidity
Weather data for the period of testing was obtained from a private weather station in Iklin, approximately 4km inland from Ta' Giorni.

Thermal imaging
A thermal camera was used to obtain images of the West façade; these were later compared to ordinary photographs of the façade.

Questionnaires
Two questionnaires for this study were conducted among the residents of Block C, one regarding comfort and adaptation to heat in summer and a similar one for winter.

The summer questionnaire included questions designed to obtain information about: the age and sex of the occupants, their living patterns, current cooling methods, adaptations to the building, behavioural adaptations, sensible humidity and the perceived hottest rooms in the house.
The winter questionnaire focused only on qualitative questions concerning adaptation. Comfort was subsequently assessed using a quantitative survey where instantaneous values were gathered for comfort on the ASHRAE

7 point scale thermal preference according to McIntyre's 3 point scale and thermal acceptability. These results were plotted against simultaneous indoor temperatures, which were obtained from the data loggers.

Modelling
The modelling phase was split into two approaches: ventilation design with a constant building envelope and envelope design with a constant ventilation profile. As each approach opens many possibilities, a thorough investigation would require several dedicated studies.

Due to the broad range of topics being covered, experimentation of each approach was restricted due to time limitations. Many ideas that emerged from the literature review were not modelled as they required greater expertise in IES or other software packages for testing through simulation. In most cases, experimentation would be the preferred option, particularly if this could be carried out on a habitable building at a full scale.

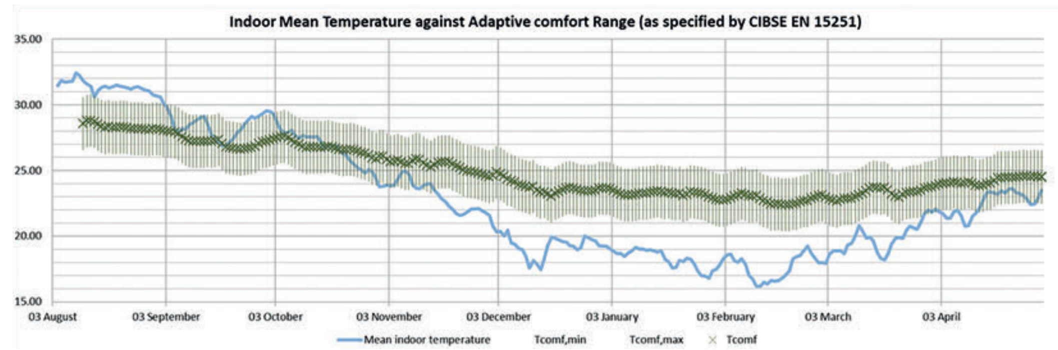


Figure 1 - 90 % adaptive comfort temperature range according to EN15251 (green) vs mean indoor temperatures

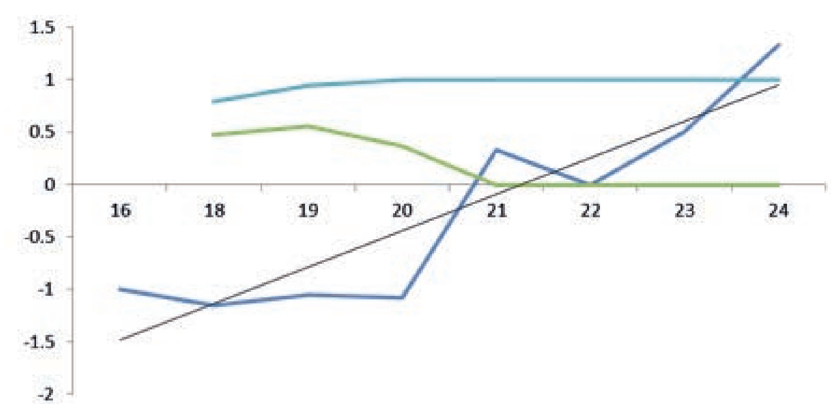
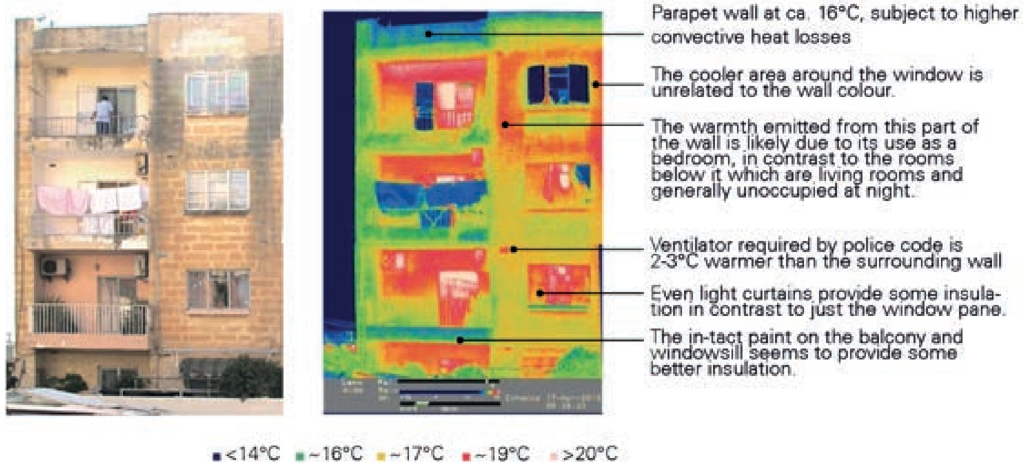


Figure 2 - Results of quantitative comfort survey

Summary of key results	
Air Temperature Monitoring	Indoor temperatures are generally higher than outdoor temperatures except at peak hours, probably due to the stabilising effect of thermal mass. The following are likely contributors to this phenomenon:
	• Internal heat generation and solar gain through windows
	• Heat retention by the thermal mass of the building envelope
	• A lack of nocturnal ventilation
	• Inadequate daytime ventilation rates
	According to the subjective survey, the warmest rooms are either those with the largest apertures (resulting in solar gain) or those with the largest sources of internal gain
	Internal temperatures during the months of September to mid-November were largely within the adaptive comfort range
	There is both a heating and a cooling problem; however, transgressions of the adaptive comfort boundary were greater in winter, with indoor temperatures as low as 16°C during the coldest weeks of February
Qualitative Questionnaires	A variety of behavioural adaptations was observed. These included sleeping in the balcony, wetting the roof, nocturnal evaporative cooling and attempts to improve cross-ventilation by putting extractor fans in front of windows
	The range of winter adaptations was narrower. Some individuals showed a strong preference for fresh air at the expense of lower temperatures, even at the beginning of December (when outdoor temperatures varied between 11 and 16°C)
Quantitative Survey	Results suggest a slightly lower minimum for the adaptive comfort temperature than recommended in EN 15251. Temperatures of 20oC and higher were unanimously considered acceptable whereas the lower limit of the adaptive comfort band during the entire recording period was 20.39°C
Dynamic Simulation	• Double Glazing caused a global temperature increase of +1°C
	• Addition of roof insulation only affected the top flat by +1°C
	• Two different attempts to model roof shading and increase its reflectivity were made but no cooling was achieved
	• External wall insulation made the biggest difference in the larger living rooms, with temperature increasing between +2°C and +4°C



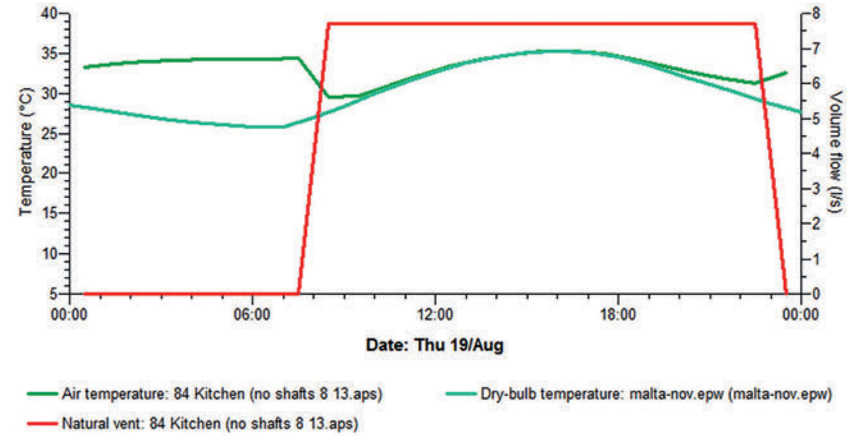


Figure 3 - Thermal image of west façade

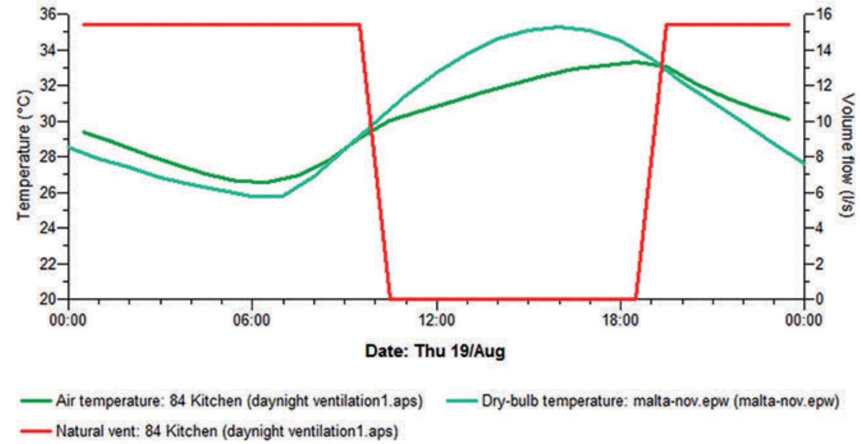
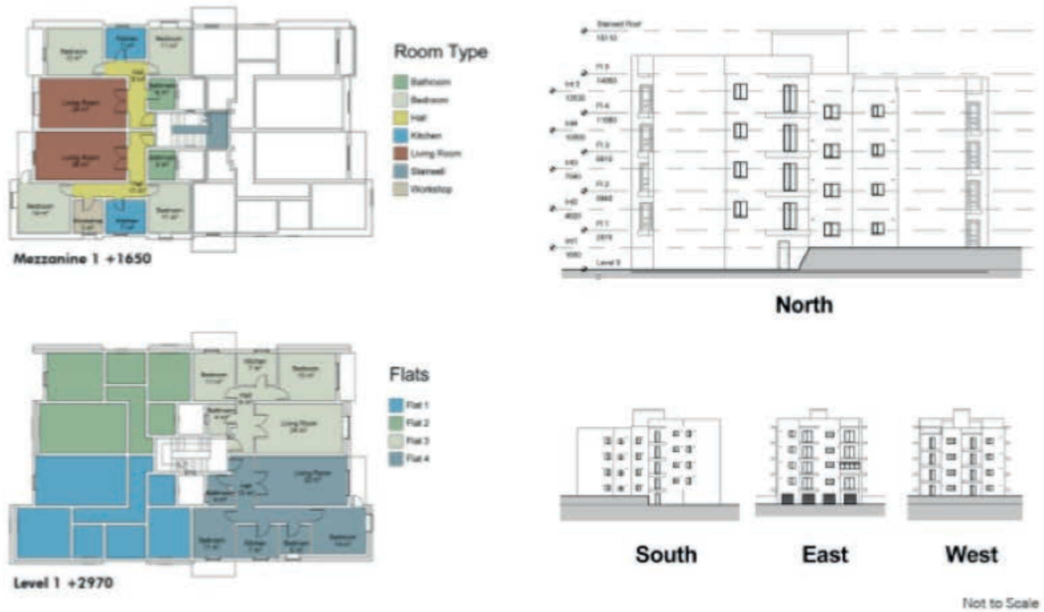


Figure 4 - Cooling effects of micro-blinds and optimized window opening for nocturnal ventilation



From top (1) Plans and elevations of Block C; (2) Contextual map, sie plan of Ta' Giorni housing estate

Figure 5 - Position, context and layout of the case study

Summary of passive heating and cooling principles		
	Winter	**Summer**
Solar	**Maximum absorption of solar energy:** • *Trombewalls:* Internal thermal mass behind a glazed wall absorbs short wave solar radiation and radiates it back to the interior after sunset • Large, well-insulated windows • Use internal walls and floors for heat storage	**Maximum rejection of solar energy:** • Shade and insulate thermal mass by day • Intercept radiation before it penetrates windows • Increase wall and roof reflectivity (albedo)
Heat gain	**Warm air and surface temperatures:** • U-values for the envelope determined by minimum winter temperatures Special attention should be given to windows • Vapour barriers in wall cavities; reduce air leaks and thermal bridging • Use exhaust air to heat incoming air • Insulate internally if thermal bridging is inevitable. This provides higher radiant temperatures but may cause condensation • Reduce surface area available for heat loss: ideal building shape is compact and cube-like	**Dissipate heat gain from envelope:** • Long wave radiation from walls and roofs • Indirect evaporative cooling (e.g. roof ponds) • Natural and enhanced convection • Cool thermal mass by convection using high air velocities or by conduction using pipes with cool air or water flowing through • Increase surface area of exposed thermal mass by protrusions on the façade, porches, courtyards and elongated plans

Summary of passive heating and cooling principles		
	Winter	**Summer**
Airflow	**Replace stale air with pre-heated fresh air at low-velocity for minimum levels of CO_2 and other pollutants** **Avoid drafts**	**Increase airflow to 2m/s (light breeze), personalise cooling, cool the air before entry into the building:** • Long, narrow windows are better for natural ventilation • Fans assist internal circulation where air movement is slower • Wing walls redirect wind into windows using positive and negative pressure • Air buoyancy (stack effect) will provide air movement even at low wind speeds. Making this system preferable in naturally ventilated buildings • Combine stack with cooling tower or roof cooling system for a cyclic pattern • Wind scoops direct air downwards or suck upwards through a duct using the Venturi effect • Use ducts to deliver fresh, passively cooled air directly over occupants
	Pre-heat air • Underground pipes • Heat exchangers • Glazed solar space	**Passive pre-cooling of air** • Cool using a thin roof radiator (which also shades the roof) • Cool and dehumidify using thin roof radiator and desiccant layer • Humidify and cool using a – cooling tower – ground or roof pond (possibly – combined with a radiator) – single or double- stage direct – evaporative cooler – window-mounted cooling pads • For mechanically-controlled ventilation in a well-insulated, airtight building, a heat wheel may be used to cool incoming air (preferably pre-cooled from underground pipes) further by transferring its heat to exhaust air

Problems encountered

The data used to compile the weather file that was used came from an unknown source; a comparison with Met office records from 1999 (which the weather file claims to contain) exposed certain discrepancies. The implications on the research might not have been serious, but more reliable data should be available for building designers. The lack of reliable, up-to-date weather data is currently the largest obstacle to local research involving dynamic modelling. Weather files with predictions for future climates should also be available if buildings are to be designed sustainably.

No previous research using IES-VE deemed suitable for comparison could be found for Maltese buildings. The two known cases of previous similar research were carried out using ESP-r (ESP-r software package) and DesignBuilderEnergyPlus (website www.designbuilderusa.com) (Yousifet al. 2012).

The application of micro-louvers and solar shading had a cooling effect. When the daily opening profile was replaced by a weekly profile of combined day-time and night-time ventilation, the same intervention resulted in increased heat gains. This problem could not be resolved due to time restrictions.

Attempts were made to carry out a multi-zone CFD simulation on an entire apartment and shaft using MicroFlo (a component of the IES-VE interface) to test different methods of improving natural ventilation within the existing layout. The results achieved were unsatisfactory due to the complexity of the openings and spaces, as well as limitations on the part of the software and the user. A study focusing on improving natural ventilation in such a scenario would be best carried out in a dedicated CFD package.

An oversight of the analysis methodology was the omission of information regarding door and window profiles. Assumptions had to be made for these values in the model.

The thermal images could only be carried out during working hours due to the logistics involved, despite the fact that ideally this is done at night. The resulting images thus contain colours and reflections which are not necessarily thermal signals from the building itself.

The researcher had no indication of the indoor temperature, the independent variable, prior to conducting a comfort survey among occupants. As a result, fewer readings were obtained for certain temperatures than others. It is recommended that data from at least one sensor should be transmitted live to the researcher. This would remedy the hit-and-miss nature of the readings taken in this study.

Conclusions

The introduction of the adaptive comfort model into American and European standards was an essential move in promoting natural ventilation strategies for buildings in warmer climates. The investigation conducted in this study identifies a number of physiological, behavioural and psychological adaptations used by occupants to adjust to the ambient temperature.

Results also suggest that occupants' thermal preference in winter is slightly lower than the adaptive equation in EN15251; this is based on a number of field studies carried out in offices around Europe. It is thus recommended that further field studies be conducted on domestic and commercial buildings to validate, and if necessary calibrate an adaptive model for local use.

The accuracy of the simulation model depends on the user's understanding of the program and a good of its limitations. Calibration of a model against a real building requires an accurate understanding of the building fabric and the ability to judge which parameters must be changed to improve correlation.

Considerable progress could be made with small investments such as rebates on insect screens, neighbourhood security, tax incentives and increased awareness of the benefits of nocturnal ventilation. These tackle issues which often prevent people from opening their windows at night, missing out on free cool air throughout summer.

Scope for further research

The following list assesses possible future research into adaptive thermal comfort and retrofitting:

- the compilation of reliable weather files for present and future conditions;
- verification of the adaptive comfort model for the local population and climate by conducting Class II (at least) field studies on several building typologies. This could eventually result in incorporation of adaptive comfort in local design guides;
- a catalogue of the in-situ thermal properties of locally used masonry elements;
- the development of a durable and reliable mechanism which provides operable wall and roof insulation;
- research into enhancing the rate of natural ventilation through typical shafts in terraced houses;
- examining the effects of desiccant-based cooling systems, possibly in combination with heat wheel exchangers, downdraught towers, ground cooling and radiant cooling systems.
- an experimental study of the potential cooling effect of thin metal radiators used in different applications, including combination with low-flow air inlets.

This list is however not exhaustive.
Each subject area could be the springboard for new ideas to follow up further research in the respective thematic area.

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Retrofitting of multifamily housing: life-cycle costing aspects

This Life-Cycle Costing (LCC) analysis deals with the feasibility of measures taken to improve thermal performance of building envelope in order to reduce energy demands for space heating. LCC analysis is carried out on one exemplary apartment in multifamily buildings with recently refurbished façades in Karaburma, a settlement in Belgrade. Results of the analysis show that by improving properties of envelope with poor thermal U value, the reduction of electricity consumed for heating in Belgrade climate is 28 %. Considering Serbian system for electricity charging, reduction of monthly costs for electricity can be doubled.

Authors

Aleksandra Djukic
adjukic@afrodita.rcub.bg.ac.rs

Aleksandra Krstic-Furundzic
akrstic@arh.bg.ac.rs

Marija Grujic
grujicm@grf.bg.ac.rs

Faculty of Architecture,
University of Belgrade, Serbia

Introduction

Recent research has shown that Serbia has experienced a temperature increase in the last century and that in the last two decades there were 14 years with temperatures above the normal recorded in the period from 1960 to 1985 (Krstic-Furundzic, and Djukic 2009). Three years were designated as distinctly warmer, while the years 2000 and 2007 were the warmest in the previous century. The region of Belgrade has gotten the most pronounced growth with an increase over 1.4C°/100 years (Karadžić and Mijović (eds.) 2007). At the same time, it is important to emphasise that Serbia, as well as Belgrade's region, belong to the sub-region of South-Eastern Europe where a higher temperature increase than that of the global level is forecast. This increase will be from 2.2°C to 5.1°C by the end of the 21st century (Karadžić and Mijović (eds.) 2007), especially during the summer months. Furthermore, humidity will decrease on the annual level, which will lead to increased risk of summer droughts. Increase in air temperature contributes to the facts that the energy consumption in buildings is rising over the summer months because of the cooling systems and that the energy efficiency of the buildings is important not only for decrease of energy consumption during the winter time but during the whole year.

The existing residential buildings have an important role in contributing to the carbon emissions and energy consumption in Serbia and Belgrade`s region. More than one third of energy consumption, primary as well as finally, (Sumarac 2010) in Belgrade`s region are from housing sector, one half being in Serbia. Average energy consumption in residential housing sectors are between 150kWh/m^2 and 200kWh/m^2 (Sumarac 2010) which is three times more than the average consumption in the EU. According to the draft version of the report prepared under the auspices of UNFCCC and presented in October 2010, a total of GHG emissions are approximately 8.9t per capita (Djukic and Stupar 2011). The largest emitter is the energy sector, with a share of 76.19 %, followed by agriculture with 14.32 % and CO_2 is the gas with the highest share in total emissions (over 90 %).

Most of the CO_2 emissions originate from the burning of fossil fuels for energy. However, 48 % of the CO_2 emissions from energy sector are caused by construction sector and almost 65 % from that part are from residential buildings. According to the data collected by the Serbian Statistical Office, about 50 % of existing buildings in Serbia and Belgrade`s region were built before 1975, without consideration to energy demands and consumption (Krstic-Furundzic and Bogdanov 2003). Those buildings are without thermal insulation and with box-type timber windows, single glazed, with 4mm float glass and badly maintained during the past half century. Belgrade`s settlement Karaburma was built during the fifties and sixties in the 20th century as housing for workers in nearby factories. The settlement is placed on a north slope and organised as detached apartment buildings, surrounded by free open space. Until energy crises in the seventies, there were no regulations in Serbia that treated minimum thermal properties of buildings envelope or energy consumption in a residential sector. As a result, these buildings were built with poor material quality and with poor thermal properties of the envelope. Over the years, poor quality and lack of maintenance led to deterioration of buildings in this settlement. As Belgrade city expanded its area, the settlement is no longer on the far periphery of the city. However, considering real-estate sector, Karaburma settlement still has one of the lowest residential prices per square metre.

In 2009 the refurbishment of Karaburma settlement began (Krstic-Furundzic and Djukic 2014). Most of the renovated buildings expanded by one floor at the top of the building, terraces were added or they widened the existing ones, exterior walls were lined with thermal insulation and old wooden windows were replaced. Part of the settlement along the street Dr. Nike Miljanica is analysed in this paper (Figures 1 and 2).

Figure 1 - Position of retrofitted buildings in Karaburma, Belgrade

Figure 2 - Position of the retrofitted building on the street, Dr. Nike Miljanica,Karaburma, Belgrade

Figure 3 - Building appearance before refurbishment, street Dr. Nike Miljanica, Karaburma, Belgrade

Figure 4 - Building appearance after refurbishment, street Dr. Nike Miljanica, Karaburma, Belgrade

In addition to above mentioned interventions, some tenants have expanded living space by closing the balcony (Figures 3 and 4). Façades were painted in different colours which improved the identity of the neighbourhood.

Subject of this LCC analysis is one of the apartments from the renovated building in Karaburma settlement (Figures 5, 6 and 7). The goal of this LCC analysis is to evaluate economic efficiency and feasibility of façade improvement on prefabricated, multifamily housing in Karaburma, Belgrade. LCC analysis evaluates feasibility of measures taken to improve thermal performance of building envelope in order to reduce energy demands for space heating.

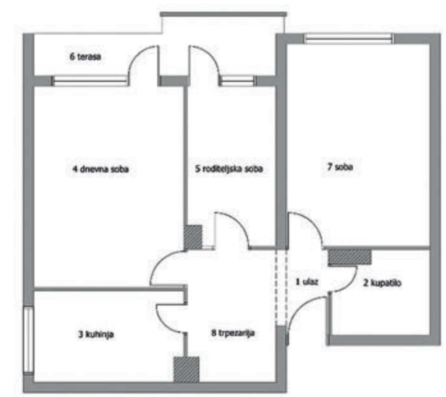

Figure 5 - Plan of the apartment before the refurbishment (source: B. Begenisic, S. Markovic)

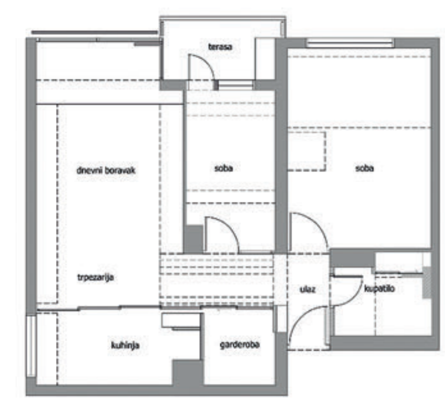

Figure 6 - Plan of the apartment after the refurbishment (source: B. Begenisic, S. Markovic)

Figure 7 - Interior of the apartment after the refurbishment (authors: B. Begenisic, S. Markovic

LCC analysis - envelope improvements

The refurbishment of the façade, on one of the Karaburma multifamily buildings, was carried out in spring 2011. The refurbishment focused on replacement of envelope components such as, windows and laying of thermal insulation on façade walls in order to match the properties usability to, increasing demands of energy efficiency. For the purpose of this analysis one apartment of 64m^2 was selected as representative example of reduction of energy consumption due to improved façade properties.

LCC analysis is carried out by Net Present Value Methodology, which implies present value of investment, plus discounting of all future costs to present value.

In this study the selected tool for LCC analysis is BLCC (Building Life Cycle Cost) software, version 5.3-13 (BLCC5 Program 2013). BLCC software was developed by the United State Department of Energy and it is used for the calculation of buildings life-cycle energy savings. The LCC calculations are based on the FEMP (Federal Energy Management Program) discount rates and energy price escalation rates which are updated and published every year on April 1. With certain modifications, this software was used in several investment analyses in Serbia which required feasibility study for different models of optimisation of façade, building structure, lighting and heating system (Plavšića and Grujić 2005).

Evaluation criteria of the analyses results are divided into criteria that concern financial efficiency of investment and criteria that concern external effects (Plavšić2004).

Evaluation criteria that concern financial efficiency of investment include:
• net Present Value (NPV);
• adjusted Internal Rate of Return (AIRR) and;
• simple Payback Period (in years).

Evaluation criteria that concern external effects include:
• protection and conservation of the environment (CO_2 emissions);
• market value of the apartment.

Criteria for efficiency evaluation

Economic efficiency criteria
As stated above, the criteria for the evaluation of financial efficiency of investment include: Adjusted Internal Rate of Return (AIRR), Net Present Value (NPV) and Simple Payback Period (SPP).

Net Present Value (NPV) is the sum of costs/income during building life cycle which is reduced to its first year value (present value). Net Present Value presents an absolute indicator of profitability of the design, taking into account the time preferences and using the discounting technique, which reduces all future design effects to their present value.
NPV is calculated as a specific design profit. For practical reasons, the initial investment period of building economic life cycle (beginning of investment study) is taken as base time for calculation of NPV. Discounting is performed according to a previously established discounted rate which is usually, the individual discount rate that makes the weighted arithmetic mean of real interest rates on funding sources. The discount rates of 10 – 12 % are traditionally used by The World Bank for all funded projects. However, as the entire calculation in this study was done in Euro currency, the average interest rate in the EU was taken into account. In the EU, recommended real discount rates for infrastructure investments was recently lowered to 5 %.

Adjusted Internal Rate of Return (AIRR) represents the discount rate which is the investment value reduced to zero. This data indicates optimal ratio of income (savings) and expenses (costs) during economic life cycle of building.

Simple Payback Period (SPP) refers to necessary time (in years) for return of initial investment. Invested funds are returned in the year when the cumulative net effects of economic life cycle become positive. The aim is to reduce a simple payback period (value SPP), in order to be as short as possible.
The acceptable payback time of the initial investment is considered to be before the end of last year of the economic life cycle.
Data such as initial investment, annual costs and balance savings during life cycle of the design are used to calculate SPP. Building Life Cycle Cost (BLCC) software operates with simple payback period, which is a simple ratio of initial investment increases for all annual costs and savings (as the equivalent of income in one year).

External effects
External effects are represented by different social and economic effects which do not need to be quantified. For improvement of energy efficiency these effects are of great social benefit such as, conservation of the environment and non-renewable resources, influence on technical progress, quality of life of the population, increase of consumer surplus, etc.

LCC input parameters

LCC analysis for thermal performance improvements of the building envelope takes into account initial investments and costs of electricity for heating through certain periods of building use. The overall results of façade improvement are measured according to: (a) initial capital costs and (b) energy costs only. Operating, maintenance and repair (OM&R) costs are not included in the analysis since these costs are the same for façade before and after refurbishment, so these costs would not influence results of the analysis. Capital replacement costs are also not included in the analysis since the observed period of the analysis is based on life expectancy of the whole façade, which represents life cycle period of 30 years.

Investment
A capital investment is considered as a one time cost in the first year of the economic life cycle of the project.

Façade refurbishment of the existing building included placing of thermal insulation on external wall surface and replacement of old wooden windows. Placing of 5 cm expanded polystyrene provided external wall U value of 0.46 W/m²K. Windows were replaced with double glazed components within five-chamber PVC frame (U=2.3W/m²K). Façade area of selected apartment is about 40m² (approximately 33 m² of wall and 7m² windows). Capital investment share for selected apartment in whole façade refurbishment was € 1,540.

Energy costs
The price of electricity was adopted according to the current price list approved by “EPS - ElektroprivredaSrbije” (February 22, 2013; EPS–ElektroprivredaSrbije. 2013). It should be noted that price per kWh in Euro currency has not been changed in Serbia for more than a decade. EPS pricing system is divided into green, blue and red zones of residential sector energy consumption, each with different value per kWh, which depends on monthly amount of consumed energy (10). Consumption of electricity within the blue zone (351-1,600 kWh per month) represents the zone average of household electricity consumption per month and is charged 0.06 €/kWh. Electricity consumption within the red zone (above 1,600 kWh per month) represents households with high electricity consumption per month and is charged double than the blue zone - 0.12 €/kWh.

Depending on energy consumption of a particular month the price of 0.06€/kWh or 0.12€/kWh was established as an input for electricity costs calculation.

Energy consumption for selected apartment
Detailed energy consumption for heating of a selected apartment was not available. Electricity consumption for heating was derived from monthly bills for overall electricity consumption (for whole apartment) before and after façade refurbishment.

Measuring electricity consumption for specific use within a building is an expensive, time consuming procedure and requires a lot of equipment. Methodology which uses monthly electricity bills, to verify savings from energy conservation measures, is much cheaper and by now well established. Most studies that use this methodology are based on statistical regression models where utility bills and outdoor dry-bulb temperature have been applied to baseline monthly and annual energy use. In this case, since there were no long-term observations of electricity consumption before and after refurbishment, only monthly electricity bills during two heating seasons were used (heating seasons before and after refurbishment). Presented energy consumptions for heating, during selected seasons, are not precise but represent an approximation of energy used for heating, which was derived by subtracting average energy consumption for the apartment in periods where no heating or cooling is required in Belgrade`s climate. This energy consumption for heating was corrected according to climate mean temperatures, in order to make energy consumption before and after refurbishment comparable.

Overall monthly electricity consumption for a whole apartment was selected in consideration of the heating period in Belgrade climate, which lasts about six months, from mid-October to mid-April. Energy consumption before the façade refurbishment (heating season 2010/11) was compared with energy consumption after façade refurbishment (heating season 2011/12) (refer to Table 1). From Table 1 it can be concluded that after the refurbishment, overall electricity consumption for the selected apartment, during heating period, was reduced from 8,518 kWh to 6,382 kWh (around 25 %).

Table 1 - Real monthly overall electricity consumption for selected apartment for Winter period before refurbishment (Winter 2010/11) and after refurbishment (Winter 2011/12)

Real monthly overall electricity consumption for selected apartment (kWh)		
Month	Winter 2010/11	Winter 2011/12
October	1,013	815
November	1,112	1,088
December	2,326	1,176
January	1,468	1,351
February	1,605	1,116
March	994	834
Σ=	8,518	6,382

Detailed analysis of monthly electricity consumption for the whole year, for the selected apartment, led to the conclusion that average energy consumption, in months when no cooling or heating is required, is around 350 kWh. As a result, overall electricity consumption for the selected apartment was reduced by 350 kWh (Table 2).

Table 2 - Monthly electricity consumption for selected apartment - heating only - Winter period before refurbishment (Winter 2010/11) and after refurbishment (Winter 2011/12)

Monthly electricity consumption for selected apartment – heating only (kWh)		
Month	Winter 2010/11	Winter 2011/12
October	663	465
November	762	738
December	1,976	826
January	1,118	1,001
February	1,255	766
March	644	484
Σ=	6,418	4,282

A part of this reduction, about 33 % in energy use, might be due to a little warmer winter 2011/12. Monthly mean temperatures for selected heating months before and after refurbishment, are shown in Table 3. In order to make energy consumption before and after refurbishment more accurately comparable, energy consumption in selected months for both heating periods needed to be adjusted according to climate mean temperatures for selected months. Typical climate mean monthly temperatures calculated for period 1981-2010 (Republic Hydrometeorological Service of Serbia 2010) are also shown in Table 3.

Table 3 - Monthly mean temperatures for selected heating moths: climate averages, before (winter 2010/11) and after refurbishment (winter 2011/12)

Temperature T (C°)			
Month	Climate	Winter 2010/11	Winter 2011/12
October	12,9	10,6	12,1
November	7,1	12,2	4,4
December	2,7	2,5	5,5
January	1,4	1,6	2,1
February	3,1	-1	7
March	7,6	8	10,1

Selected real energy consumption for heating (from Table 2) was corrected according to climate mean temperatures in selected heating months. Correction factor (presented in Table 5) represents ratio of ΔT (difference between outside and desired inside temperature - 20°C) for climate mean temperature and ΔT for measured mean temperature (heating period before refurbishment 2010/11 and heating period after refurbishment 2011/12) (refer to Table 4).

Table 4 - Monthly temperature difference between outside and inside desired temperature (20°C): climate ΔT, ΔT before (Winter 2010/11) and ΔT after refurbishment (Winter 2011/12)

Temperature difference - ΔT *			
Month	Climate	Winter 2010/11	Winter 2011/12
October	7.1	9.4	7.9
November	12.9	7.8	15.6
December	17.3	17.5	14.5
January	18.6	18.4	17.9
February	16.9	21	13
March	12.4	12	9.9

* temperature difference between outside and inside designed temperature (20°C according to Regulations on energy efficiency of buildings, Serbia)

Table 5 - Correction factor for ΔT (difference between outside and designed inside temperature - 20°C) for adjustment of energy consumption in selected seasons

Correction factor for ΔT		
Month	Winter 2010/11	Winter 2011/12
October	0,76	0,90
November	1,65	0,83
December	0,99	1,19
January	1,01	1,04
February	0,80	1,30
March	1,03	1,25

Adjusted energy consumption presented in Table 6 is an approximation of heating energy consumption for the selected apartment before and after façade refurbishment which is corrected according to Belgrade climate mean monthly temperatures for heating period.

According to Table 6 average reduction of electricity consumption for heating per year is 1.863 kWh (around 28 %) which is a substantial reduction. Also, considering the current electricity pricing system in Serbia, with improved thermal properties of façade, this apartment is not reaching overall energy consumption within the red zone. Table 6 shows only electricity consumption for heating, but overall energy consumption would be around 350 kWh higher. Marked fields in red in Table 6 show that, before refurbishment of façade during November and December, overall electricity consumption for the selected apartment was within red zone (above 1,600 kWh consumption per month) and all whom consumed electricity was double charged during these two months (0.12 €/kWh).

Table 6 - Adjusted monthly electricity consumption for heating only - Winter period before refurbishment (Winter 2010/11) and after refurbishment (Winter 2011/12)

Adjusted monthly electricity consumption for heating only (kWh)		
Month	Winter 2010/11	Winter 2011/12
October	501	418
November	1,260	610
December	1,953	986
January	1,130	1,041
February	1,010	996
March	665	607
Σ=	6,520	4,657

Results of life cycle cost analysis

Financial efficiency

Life cycle cost analysis is performed for improved thermal properties of façade on a selected multifamily building. Using BLCC software, financial efficiency of investment in façade refurbishment is determined. All future costs are discounted to present value using a discount rate of 5 %. Basic assumption is that inflation has a neutral effect on building life cycle.

The results of LCC analysis and savings in 30 year period life cycle of thermally improved façade in a Karaburma building apartment are shown in Table 7 and Table 8. Results of LCC analysis for façade thermal performance improvements compared to LCC analysis before refurbishment are shown in Table 7. Results of Life cycle savings analysis are shown in Table 8.

Table 7 - Results of LCC analyses for façade thermal performance improvements compared to LCC analysis before refurbishment

Scenario	Before refurbishment	After refurbishment	
Annual electricity consumption for heating (kWh)	Blue zone 0.06 €/kWh	3,306	4,657
	Red zone 0.12 €/kWh	3,214	
	Σ	6,520	4,657
Total Initial capital costs (€)	-	1,540	
Annual electricity costs (base-year) (€)		584	279
Discounted total energy costs (€)		8,908	4,296
LCC(€)		8,908	5,836

There is quite a big difference in reduction of energy consumption and discounted energy costs before and after refurbishment of building façade. The reduction of discounted energy costs, from € 8,908 before refurbishment to € 4,296 after refurbishment, is around 52 %.

On the other hand, the reduction of energy consumption is around 28 %. Such high difference is due to energy consumption in November and December before refurbishment, when energy consumption was above 1,600 kWh and was charged twice as much then the consumed energy below 1,600 kWh.

Table 8 - Results of Life cycle savings analysis for thermal performance improvements of the building envelope

	Scenario	After refurbishment
Energy savings (+) or cost (–) (kWh)	Blue zone 0.06 €/kWh	-1,351
	Red zone 0.12 €/kWh	3,214
	Σ	1,863
First year savings (€)		305
Simple Payback Period (SPP)* (year)		5.06
Adjusted Internal Rate of Return (AIRR) ** (%)		8.97
Total discounted operational savings (€)		4,683
Savings to Investment Ratio (SIR) ***		3.04

* total investment/first-year savings
** (1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period
*** total discounted operational savings/total investment

Almost 50 % of energy consumption was charged 0.12 €/kWh. That is why Annual electricity costs before refurbishment were doubled comparing to annual energy costs after refurbishment.

Total Life Cycle Costs are lowered after refurbishment around 35 % (from € 8,908 to € 5,836). The difference between LCC's is 35 % and Discounted Total Energy Costs of 52 % is due to Initial Capital Costs (investment in façade refurbishment). Such a small Initial capital cost of € 1,540 can produce such high energy savings (1,863 kWh or 28 %) and cut energy costs by double (€ 4,683 or 52 %) (Table 6). The initial investment in upgrade of façade thermal properties is returned within 5/6 years. All this makes Savings to Investment Ratio very favourable (3.04).

External effects

Greenhouse gas emissions

Analysis of greenhouse gas emissions for façade thermal performance improvements compared to greenhouse gas emissions before refurbishment are shown in Table 9. Greenhouse gas emissions are also lower by 28 % after façade refurbishment. Electricity consumption for heating is also reduced by 28 % (Table 8).

Table 9 - Analysis of greenhouse gases emissions for façade thermal performance improvements compared to greenhouse gases emissions before refurbishment

	Before refurbishment		After refurbishment	
	Annual emissions	Life-Cycle emissions	Annual emissions	Life-Cycle emissions
	(kg)	(kg)	(kg)	(kg)
CO_2	2,284.73	68,532.37	1,631.90	48,950.19
SO_2	6.08	182.38	4.34	130.27
NO_x	3.12	93.65	2.23	66.89

Effects of façade improvement on property value

Since the building's envelope refurbishment, in spring 2011, Serbian real-estate market has suffered the consequences of world economic crises and value of apartments has dropped by 30 %. Unpredictability of prices per square meter in present and future real-estate markets is the reason why this analysis is focused on economic effects on property value immediately after building's envelope refurbishment.

Similar apartments to the selected one in the analysis, with improved envelope thermal properties, at the same location in spring 2011, had a market value around 1,150 €/m², while apartments with poor envelope thermal properties had up to 25 % lower value per square meter (900-1,000 €/m²) (Figure 8). These prices per square meter are valid for apartments with good living conditions.

Figure 8 - Seven year back period: example value of one bedroom apartment at the end of year 2010 in Pere Cetkovicastreet in Karaburma, Belgrade

It can be concluded that average price per square meter of this 64 square meter apartment, before envelope refurbishment, was around 950 €/m². The price of 950 €/m² generates property value of €, 60,800 and the price of 1,150 €/m² generates property value of € 73,600, which is about 21 % higher value.

Conclusion

LCC analysis was carried out on the basis of real monthly electricity consumption during heating seasons before and after façade refurbishment. Real consumption was adjusted to match long term Belgrade climate temperature conditions during the heating season. So, the results of this analysis may be considered as an approximation of heating energy reduction for an average apartment in Belgrade settlement Karaburma.

Results of this analysis show that a relatively small investment in improvement of façade thermal properties can produce heating energy reduction by about 28 % and considering the Serbian system for electricity charging, reduction of monthly costs for electricity can be doubled. Although monthly costs for electricity are reduced to half, Net Present Value for selected apartment is lower after façade refurbishment by 35 %, due to initial capital investment. This investment is returned within 5 years.

In the real estate market, apartments in buildings with improved thermal properties of façade reach up to 25 % to 30 % higher price per square meter, which depends on location and state of living conditions of the apartment. Façade refurbishment is also making these buildings more appealing for potential buyers.

Benefits of energy use reduction, for every apartment in this settlement, can be noticeable in local environment preservation (mitigating city's heat island effect). Huge benefits of energy use reduction, for settlements like Karaburma in Belgrade, are at 28 % and thus, also 28 % of green gas emissions, which is a very high reduction of energy consumption in residential sector. For comparative purposes, the EU 2010 Directive on the energy performance of buildings (recast) is demanding 20 % reduction of energy consumption by 2020, so every energy reduction above 20 % is contributing to this goal.

However, the quality indicators of value of the entire neighbourhood have also increased. This is due to the improvement of the visual identity of the buildings and whole settlements, improving of the living comforts of outdoor / indoor space and better maintaining of the whole area. The environmental benefits of retrofitting the buildings in Karaburma settlements and Belgrade`s region are in decreasing the emission of GHG and CO_2 due to the fact that retrofitted buildings are more energy efficient.

Existing residential buildings that were built before 1975 in Belgrade`s region form the main bulk of the building stock and they are significant consumers of energy. Upgrading the existing residential buildings by retrofitting can increase the value of property but also the value of neighbourhood and settlement. The LCC analyses shows that investment in retrofitting of those buildings could be returned within 5 years.

Aside from energy efficiency, many other significant sustainability improvements can be made in existing residential buildings. In terms of resource use, significant reductions can be achieved in potable water use and waste reduction via recycling programs, as well as use of renewable's (solar and geo-thermal energy). Also, sustainable purchasing policies, procurement, ongoing operations and maintenance procedures can improve a property's performance.

The only obstacle in retrofitting the existing residential buildings in Serbia is in a fact that 90 % of apartments are owned by tenants in Serbia and Belgrade`s region and that retrofitting should be privately invested. Furthermore, all tenants would have to agree to retrofitting their building which could be problematic and a challenging task. In this case study, this problem was overcome by choosing an investor who succeeded to find his interest in gaining the right to annex the attic or a new floor, which resulted in new housing units which become his property.

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Cost and value assessment standardisation: CEN's contribution in the building sector

Since early 2004, CEN has prepared and delivered a series of standards under a mandate given by the European Commission and the European Free Trade Association (Mandate M/343) in order to support essential requirements of the EU Directive 2002/91/EC on the energy performance of buildings (EPBD). All these standards aimed at European harmonisation of the methodology for calculation of the energy performance of buildings. An overview of the whole set of standards is given in prCEN/TR 15615.

This case study aims to present the activities of the CEN with regard to cost and value related standards for the building sector. Issues related to the economic performance of buildings with regard to the evaluation procedures will be discussed. Particularly the definitions and the structure of the types of costs, which are taken into account for the calculation of the economical efficiency of saving options in buildings will be introduced. The data required for the definition of costs related to systems under consideration, calculation methods and the expression of the result of the economic calculation will also be discussed. The application of the CEN procedures will be implemented for selected case studies in Cyprus.

Authors

Angeliki Kylili
res.ka@frederick.ac.cy

Paris A. Fokaides
eng.fp@frederick.ac.cy

Frederick University, Cyprus

Introduction

The key objective of the EU Directive 2002/91/EC on the energy performance of buildings (EPBD) is to promote the improvement of the energy performance of buildings within the European Community, taking into consideration outdoor climatic and local conditions, indoor climate requirements and cost-effectiveness. Under this context, the directive laid down specific requirements in view of the attainment of its key objective. These included the development and adoption of a methodology for the calculation of the energy performance of the building including heating, ventilation, cooling and lighting systems, which would also form the basis for the energy certification of all buildings. Additionally the EPBD required the application of minimum requirements on the energy performance of new buildings and existing building undergoing major renovation and the regular inspection of the heating, ventilation, and air-conditioning (HVAC) systems.

However, the realisation of the objective would require the development of additional measures and instruments. Accordingly, since early 2004 CEN has prepared and delivered a series of standards under a mandate given by the European Commission and the European Free Trade Association (Mandate M/343) in order to support the essential requirements of the EPBD. The standards aimed towards the European harmonisation of the methodology for calculation of the energy performance of buildings by providing the Member States the opportunity to select one or more of a limited range of options for expressing the energy performance of buildings. An overview of the whole set of standards is given in the Umbrella document CEN/TR 15615 (CEN 2008).

Currently, only a limited number of Member States have fully implemented the EPBD and the cost and value of buildings is considered to be a fundamental aspect for its large-scale implementation. Amongst others, standardised methodologies for the cost and value of the building sector have also been developed by CEN. These standards contribute to the calculation of the economic performance of buildings so as to provide evidence that additional expenditure for energy systems and components on new and existing buildings can offer increased value to the built environment and reduction in long term operational and maintenance costs.

This work presents the activities of the CEN with regard to cost and value related standards for the building sector. Section 2 explains in detail these cost and value related standards, discussing the significant issues that express the economic performance of buildings into the evaluation procedures. The definitions and the structure of the types of costs, which are taken into account for the calculation of the economical efficiency of saving options in buildings, are also introduced. Additionally, the data required for the definition of costs as well as the process of the calculation methods are discussed. In section 3, the application of the CEN procedures is implemented for selected case studies in Cyprus. The results of the analysis as well as some significant discussion points are also presented in Section 3. Concluding remarks regarding the effectiveness of these standards based on the case studies are given in Section 4.

CEN contribution with regard to cost and value related standards for the building sector

Umbrella Document and EN 15459 CEN/TR 15615

The Umbrella Document CEN/TR 15615 portrays the European standards that are anticipated to support the EPBD by providing the calculation methods and associated material to obtain the overall energy performance of a building. The scope of the standards is to assist the implementation of the Directive in the Member States. Through these standards, the governing bodies of the Member States are given the opportunity to select one or more of the options given for expressing the energy performance of buildings, depending on the purpose of the calculation and the type and complexity of the buildings and their services. The development of the CEN/TR 15615 was coordinated by CEN/BT TF 371, the Energy performance of buildings project group, while the Technical Committees (TC) of CEN that were involved in the preparation of the standards also included:

- CEN/TC 89 Thermal performance of buildings and building components;
- CEN/TC 156 Ventilation for buildings;
- CEN/TC 169 Light and lighting;
- CEN/TC 228 Heating systems in buildings;
- CEN/TC 247 Building automation, controls and building management.

Additional published standards of the coordinating committee are given in Table 1 (CEN, 2014).

Table 1 - List of additional published standards of CEN/BT TF 371 (CEN 2014)

Reference	Title
EN 15603:2008	Energy performance of buildings - Overall energy use and definition of energy ratings
CEN/TS 16628:2014	Energy Performance of Buildings - Basic Principles for the set of EPB standards
CEN/TS 16629:2014	Energy Performance of Buildings - Detailed Technical Rules for the set of EPB-standards

The calculation methodology of the energy performance of buildings is based on the building characteristics, as well as the installed systems of the building. CEN/TR 15615 outlines the calculation sequence according to the following three levels of the methodology:

- calculation of the building energy needs for heating and cooling;
- calculation of the building delivered energy for heating and cooling, ventilation, domestic hot water and lighting;
- calculation of the overall energy performance indicators (primary energy, CO_2 emissions, etc.).

The Umbrella document finally summarises the standards and their role when applying the calculation for the energy performance of buildings. The standards are distinguished according to the three levels of calculation:

- standards that relate the delivered energy

and the energy performance indicators for buildings;
- standards that relate the energy needs of buildings with the delivered energy for space heating and cooling, ventilation, domestic hot water and lighting;
- standards that provide methods for the calculation of energy needs for heating and cooling purposes.

EN 15459 cost and value related standard

Scope
According to the Umbrella document, EN 15459 is among the standards that link the delivered energy and the energy performance indicators. In particular, it provides the calculation methodology for the economic aspects of heating systems and other systems, which are involved in the energy demand and energy consumption of the building. The main goal of EN 15459 is to standardise the required inputs, the calculation methods, and the required outputs for the economic calculations of the installed equipment and systems that are play a role in the energy performance of buildings. The calculation methodology provided in this standard enables the economic performance assessment and comparison between different energy saving options in buildings such as insulation, better performing generators and distribution systems, efficient lighting, renewable sources, and Combined Heat and Power (CHP) systems (CEN 2007).

Structure
The definitions and structure of the types of costs, which are included in the calculation of the economic performance of saving options in buildings, are primarily presented in EN 15459. Also, the required data for the definition of costs related to systems examination are also provided. The following section of the standard presents the calculation methodologies for the calculation of the economic efficiencies of different systems. In addition, the EN 15459 provides details for the expression of the result of the economic calculation and informative annexes that make available default values necessary for the calculations.

Calculation methodology
The process for the calculation method for the economical issues of heating systems and other systems related to the energy performance of buildings is linear and is explained thoroughly in the standard in six steps:

Step 1: Financial data
According to the standard, the acquiring of specific financial data is the first step for the implementation of the economic assessment. These data include the duration of the calculation, the financial rate, the human operation costs and the energy prices.
The duration of the calculation can be represented by a default value of the expected lifetime of the building, or be a fixed value according to the project objectives. The financial rate is obtainable from past economic data, while the rate of development of human operation costs is typically dependant on the costs for operational staff. Regarding the rate of development of the energy prices, as a basis this is considered to be equal to the inflation rate.

Step 2: General information about the project
This step is involved with the identification of the systems to be considered in the calculations, and also with the identification of environmental data that might constrain or influence in any other way the energy consumption of the building and the selection between alternative choices. Energy requirements on the building fabric and systems are also identified in this step in order to spot any opportunities or constraints for HVAC systems. Examples include the orientation of the building and possibilities for the installation of renewable energy systems, and the existence or non- existence of district heating.

Step 3: Systems characteristics
The systems characteristics step is primarily concerned with the data collection regarding the lifespan, maintenance and operation of components and systems. Also, the investment costs, the replacement costs, and the running costs of any building fabric or system that relates to the energy consumption and the energy conservation of the building are recorded.

Step 4: Energy costs
The fourth step is concerned with the calculation of the overall energy consumption of the building, which is performed according to standardised methods. Thereafter, the overall energy costs can be calculated taking into consideration the energy pricing.

Step 5: Global cost calculation
The global costs can be calculated by determining on the replacement timing and costs of each of the building systems and components considered in the calculation, and by summing the final value of all systems.
Step 6: Annuity cost calculation
This last step for the calculation method for the economical issues of the building systems and components is concerned with the calculation of the annuity cost of each system and component.

EN 15643 Sustainability assessment of buildings framework

EN 15643-1 General framework
The EN 15643 provides the general principles and requirements for the assessment of buildings in terms of environmental, social and economic performances, and by also taking into consideration the technical characteristics and functionality of the buildings (CEN 2010). The standard is provided through a series of standards written by CEN/TC 350. The methodology provided in the series basically quantifies the contribution of the constructions under consideration to sustainable construction and sustainable development. This is achieved by employing the Life Cycle Assessment (LCA) approach and quantifying the impacts and the environmental, social and economic performance of buildings using quantitative and qualitative indicators. The primary scope of this series of European Standards is to enable the comparability of the results of the assessments.

The EN 15643 was developed CEN/TC 350 “Sustainability of construction works”. The specific TC is responsible for the development of voluntary horizontal standardised methods for the assessment of the sustainability aspects of new and existing construction works and for standards for the environmental product declaration of construction products. A list of the published standards of the CEN/TC 350 is indicated in Table 2 (CEN, 2014). The WG that were involved in the preparation of the standards included:
- CEN/TC 350/WG 1 Environmental performance of buildings;
- CEN/TC 350/WG 3 Products Level;
- CEN/TC 350/WG 4 Economic performance assessment of buildings;
- CEN/TC 350/WG 5 Social performance assessment of building;
- CEN/TC 350/WG 6 Civil Engineering works.

EN 15643-4 Cost and value related standard

Scope
The fourth part of the standard is related to the assessment of the economic performance of new buildings over their life cycle, and of existing buildings over their remaining service life and end of life stage (CEN 2012). The assessment of a building enables the calculation of the life cycle costs, by basically expressing then into economic quantitative indicators. In fact, the assessment takes into account only the economic aspects of a building within the area of the building site and eliminates the economic risk assessment and return on investment calculations.

Structure
Firstly, EN 15643-4 introduces the terms and definitions used in the calculation of the economic performance of buildings and also the general principles under which the standard was developed. The methodology of the LCA, as well as the requirements for the application of the assessment methods is the main focus of this standard. Finally, informative annexes are also made available, providing economic indicators that can be employed for the calculations.

Calculation methodology
The standards developed under this framework provide a European system for the assessment of economic performance of buildings based on life cycle approach. The two indicators of economic performance directed by the framework is cost and financial value. These indicators are represented in two approaches to the economic assessment.

Table 2 - List of additional published standards of CEN/TC 350

Reference	Title
CEN/TR 15941:2010	Sustainability of construction works - Environmental product declarations - Methodology for selection and use of generic data
EN 15643-3:2012	Sustainability of construction works - Assessment of buildings - Part 3: Framework for the assessment of social performance
EN 15643-4:2012	Sustainability of construction works - Assessment of buildings - Part 4: Framework for the assessment of economic performance
EN 15643-2:2011	Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance
EN 15942:2011	Sustainability of construction works - Environmental product declarations - Communication format business-to-business
EN 15978:2011	Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method
EN 15804:2012+A1:2013	Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
EN 16309:2014+A1:2014	Sustainability of construction works - Assessment of social performance of buildings - Calculation methodology

1. Economic performance expressed in cost terms over the life cycle. In this concept, the' lowest life cycle cost' building over its life cycle is the most economic one. This implies that the building variants do not differ with respect to their functionality nor with respect to any income streams produces by the building. This concept of economic performance does not include developments on real estate market, only the cost related to the building over the life cycle. Therefore, only cost data needs to be gathered for this approach.
2. Economic performance expressed in terms of financial value over the life- cycle. In this concept, the best financial value building is the most economic one, i.e. the building with the highest (discounted) revenue minus the cost over the life cycle. This concept is close to the income approach in property valuation and includes market- related revenue streams. Therefore, for this kind of economic assessment revenue data also needs to be gathered.

EN 15643-4 presents and thoroughly explains the process and the mandatory requirements for the implementation of the assessment of the economic performance of buildings:

1. Object of assessment and system boundary. The object of assessment is by definition the building, its foundations and external works within the area of the building's site and temporary works associated with the building's construction. On the other hand, the system boundaries are according to the scope of the assessment and include aspects that are directly building- related.
2. Functional equivalent. The functional requirements are described together with intended use and the relevant specific technical requirement, so that the functional equivalence of different options and types of buildings is enabled. This leads to the reliability and the transparency of the results.
3. Type of data and their assignment to the building life cycle. This point is concerned with the allocation of aspects and impacts to the appropriate building life cycle that they occur. Also, the assessment of the economic performance of the building should incorporate information regarding the economic aspects and impacts from every stage of the building's life cycle, including the Before Use Stage, the Use Stage, the building operational use, and the End of Life. Ultimately, this step involves the development of specific scenarios, on which the economic assessment will be based.
4. Data quality. The quality of the data used, in terms of accuracy, precision, completeness and representativeness, is required to be in accordance with the requirement of the assessment standard for economic performance.
5. Verification. The cost information and the results of the assessment are also required to be verifiable and in accordance with the requirement of the assessment standard for economic performance.
6. Transparency of the assessment methodology. The standard also requires the transparency of the data, methodologies, results and communication of the economic assessment.
7. Reporting and communication. For the transparency of the understanding and interpretation of the results, the results of the economic assessment are expected to be reported and communicated according to information groups defined in the standard.

Application of CEN procedures for cost and value to a case study in Cyprus

This section presents the application of the CEN procedures as defined in the EN 15459 cost and value related standard, to a selected case study building of 200m^2 in Cyprus. In this work, four different scenarios have been considered for the assessment of the cost and value performance of the case study building:

- installation of building insulation, where the U-value of the case study building is reduced from 1.5 to 0.75 W/m^{2}K;
- replacement of the heating system (efficiency 0.65) with a more energy- efficient (efficiency 0.9);
- replacement of the cooling system (COP: 1.5) with a more energy- efficient system (COP 3);
- replacement of the lighting equipment (20 Lumen/ Watt) with more energy- efficient equipment (60 Lumen/ Watt).

Results

The results of the calculation process are presented according to the six steps indicated in the standard.

Step 1: Financial data

Table 3 indicates specific financial data and assumptions for the implementation of the economic assessment of the case study. The duration of the calculation was taken to be equal to expected lifetime of the building – 50 year, while the financial rate and the energy prices data have been defined according to past economic data. The rate of development of human operation costs that is generally defined according to the cost expenditure for operational staff was set at 2 %. According to the standard, the rate of development of the energy prices is considered to be equal to the inflation rate- therefore set at 2 %.

Table 3 - Financial data regarding the case study building

Identification of systems	
Building construction	walls
	floor
	roof
Energy systems	Heating system
	Cooling systems
	Lighting
Environment of the project	
Type of building	single-house, ground floor
Surface	200 m^2
Meteorological and environmental data	
Heating demand	600 degree days
Cooling demand	1200 degree days
Energy chosen for space cooling and lighting	electricity

Step 2: General information about the project

The second step is concerned with the definition of the building under examination, as well as the identification of the systems to be considered in the calculations.

The description of the case study building, its installed energy systems and some additional general information are given in Table 4.

Table 4 - General information regarding the case study building

Investment costs for systems related to energy		
System	Investment costs	Lifespan
Building fabric	19000 €	Building
Heating	4000 €	20 years
Cooling	6000 €	15 years
Lighting	1500 €	15 years

Periodic costs for replacement							
Scenarios	Investment costs	15 years	20 years	30 years	40 years	45 years	Total
1	19000 €						19000 €
2	4000 €		4000 €		4000 €		12000 €
3	6000 €	6000 €		6000 €		6000 €	24000 €
4	1500 €	1500 €		1500 €		1500 €	6000 €

Running costs except energy costs		
System	Investment costs	2.75 % of the investment costs
Building fabric	19000 €	-
Heating	4000 €	110 €
Cooling	6000 €	165 €
Lighting	1500 €	-
Total		**275 €**

Here, it is also worth mentioning that the insularity of the Cyprus energy system presents some constraints as regard as the energy consumption of the case study building and the selection between energy- related alternatives. An insular energy system is defined by the country's incapability, due to smallness and/ or remoteness, to interconnect with other electricity generators and consumers through a wider transmission grid outside its national borders (Fokaides and Kylili, 2014). Also, insular systems are characteristically greatly dependent on imported energy sources for electricity generation, whose high transportation costs are reflected in the electricity prices as it is indicated later (Kakazu, 1994; Hoyle, 1999; Mayer, 2000). Another characteristic of insular energy systems, also evident in the case of Cyprus, is the dominance of a sole enterprise, which is fully responsible for generating, transmitting and distributing electricity Domah, 2002) The Electricity Authority of Cyprus (EAC) is currently the sole producer of electricity from conventional fuel on the island, while the share of Renewable Energy Sources (RES) in electricity generation amounts to only the 1.2 % of the total electricity production (Fokaides and Kylili, 2014).

Step 3: Systems characteristics
The information regarding the lifespan, the investment costs, the replacement costs, and the running costs of the building fabric or the energy system considered in each of the scenarios for the case study building have been recorded and are presented in Table 5.

Step 4: Energy costs
The overall energy consumption of the case study building for the current condition and the four scenarios under examination has been calculated and are presented in Table 6.

Table 5 - Systems characteristics of the case study building

Investment costs for systems related to energy		
System	Investment costs	Lifespan
Building fabric	19000 €	Building
Heating	4000 €	20 years
Cooling	6000 €	15 years
Lighting	1500 €	15 years

Periodic costs for replacement							
Scenarios	Investment costs	15 years	20 years	30 years	40 years	45 years	Total
1	19000 €						19000 €
2	4000 €		4000 €		4000 €		12000 €
3	6000 €	6000 €		6000 €		6000 €	24000 €
4	1500 €	1500 €		1500 €		1500 €	6000 €

Running costs except energy costs		
System	Investment costs	2.75 % of the investment costs
Building fabric	19000 €	-
Heating	4000 €	110 €
Cooling	6000 €	165 €
Lighting	1500 €	-
Total		**275 €**

Subsequently, by taking into consideration the energy pricing in Cyprus, the overall energy costs can be calculated (Table 6).

Step 5: Global cost calculation
The global costs for the case study building have been calculated by taking into consideration in the calculation the investment costs, the replacement timing and costs, the running costs, and the energy costs of the building systems and components in each considered scenario. Also taken into account where appropriate is the inflation rate, the discount rate coefficient and the net present value that have been calculated according to the duration of the calculation of the economic performance of the building. The results of the calculation of the global costs are given in Table 7.

Step 6: Annuity cost calculation
This calculation of the annuity cost for each of the considered scenarios is the last step for the assessment of the economic performance of the case study building. Also where appropriate the inflation rate and the annuity factor have been taken into consideration in the calculation. The results of the analysis are presented in Table 8.

Discussion

EN 15459 provides the calculation methodology for the economic aspects of heating systems and other systems, which are involved in the energy demand and energy consumption of the building. The calculation methodology provided in this standard enabled the economic performance assessment and comparison of the four different energy saving scenarios for the case study building. The results have

Table 6 - Calculation of the energy costs for the case study building

Calculation of energy consumption (primary energy)				
Energy consumption (kWh/a)				
Scenarios	Heating	Cooling	Lighting	Total
Current	16000	24000	10000	50000
1	12000	14000	10000	36000
2	12000	24000	10000	46000
3	16000	14000	10000	40000
4	16000	24000	6000	46000

Energy costs	
Type of energy	Energy pricing
Electricity	0.25 €/kWh
Heating	0.15 €/kWh

Energy consumption (kWh/a) Energy costs (€/kWh)							
Scenarios	Heating	Cooling	Lighting	Heating	Cooling	Lighting	Total
Current	16000	24000	10000	2400	6000	2500	10900
1	12000	14000	10000	1800	3500	2500	7800
2	12000	24000	10000	1800	6000	2500	10300
3	16000	14000	10000	2400	3500	2500	8400
4	16000	24000	6000	2400	6000	1500	9900

indicated that the most cost-efficient solution is the installation of insulating material in the building envelope. At the same time the specific scenario also achieves the greater energy savings, based on the calculations in section 3.4. The second most cost- and energy-efficient scenario is the third, where the current cooling system is replaced with a more energy-efficient one.

Scenarios 2 and 4 achieve the same amount of energy savings, whereas the global and annualised cost of scenario 4, where the light bulbs are replaced by a more energy efficient lighting equipment, are slightly lower. Additionally, it is worth mentioning that the calculation methodology reveals that the energy costs, rather any other type of costs (investment, replacing, running), are the main source of expenditure for any energy- related system or component of the case study building.

Conclusions

Currently, only a limited number of Member States have fully implemented the EPBD, and the development of different measures and instruments, such as the standardisation of methodologies are expected to facilitate its large scale uptake. CEN has already delivered a series of standards, summarised in the Umbrella Document CEN/TR 15615, in order to contribute to this aim. However, this work focuses solely on the presentation of the activities of the CEN with regard to cost and value related standards for the building sector. The EN 15459 presents a methodology for the economic calculation of the heating systems and other systems that may influence the energy consumption of buildings. It main goal is to standardise the required inputs, the calculation methods, and the required outputs for the economic calculations of the

Table 7 - Calculation of the global costs for the case study building

Investment costs				
Scenarios	Total year 0	Inflation rate	Present value factor	Total
1	19000 €	N/A	1	19000 €
2	4000 €	N/A	1	4000 €
3	6000 €	N/A	1	6000 €
4	1500 €	N/A	1	1500 €
Replacement costs				
Scenarios	Total year 0	Inflation rate	Discount rate coefficient	Total
1	N/A	N/A	N/A	N/A
2	8000 €	2 %	0.4836	3868.8 €
3	24000 €	2 %	0.4836	11606.4 €
4	6000 €	2 %	0.4836	2901.6 €
Running costs				
Scenarios	Total year 0	Inflation rate	Present value factor	Total
1	-	2 %	25	-
2	110 €	2 %	25	2750 €
3	165 €	2 %	25	4125 €
4	-	2 %	25	-
Energy costs				
Scenarios	Total year 0	Inflation rate	Present value factor	Total
1	7800 €	2 %	25	195000 €
2	10300 €	2 %	25	257500 €
3	8400 €	2 %	25	210000 €
4	9900 €	2 %	25	247500 €

Global costs calculation	
Scenarios	Total
1	214000 €
2	268118.8 €
3	231731.4 €
4	251901.6 €

Table 8 - Calculation of the annuity costs for the case study building

Investment costs				
Scenarios	Value yr 0	Inflation rate	Annuity factor	Annualised cost
1	19000 €	2 %	0.04	760 €
2	4000 €	2 %	0.04	160 €
3	6000 €	2 %	0.04	240 €
4	1500 €	2 %	0.04	60 €
Replacement costs				
Scenarios	Value yr 0	Inflation rate	Annuity factor	Annualised cost
1	N/A	N/A	N/A	N/A
2	8000 €	2 %	0.04	320 €
3	24000 €	2 %	0.04	960 €
4	6000 €	2 %	0.04	240 €
Running costs				
Scenarios	Value yr 0	Inflation rate	Annuity factor	Annualised cost
1	-	2 %	0.04	-
2	110 €	2 %	0.04	4.4 €
3	165 €	2 %	0.04	6.6 €
4	-	2 %	0.04	-
Energy costs				
Scenarios	Value yr 0	Inflation rate	Annuity factor	Annualised cost
1	7800 €	N/A	1	7800 €
2	10300 €	N/A	1	10300 €
3	8400 €	N/A	1	8400 €
4	9900 €	N/A	1	9900 €

Annualised costs	
Scenarios	Total
1	8560 €
2	10784.40 €
3	9606.60 €
4	10200 €

installed equipment and systems that are play a fundamental role in the energy and cost performance of buildings.

In this work, four different scenarios have been considered for the assessment of the economic performance of a case study building according to the methodology provided in EN 15459. The first scenario considered for the installation of insulating material in the building envelope, while the second and third scenarios considered for replacement of the heating and cooling systems, respectively, with more energy- efficient ones. Lastly, the fourth scenario considered for the replacement of the light bulbs with more a more energy-efficient lighting equipment. The calculation methodology has been proven a very valuable and effective tool in assessing the economic performance of energy systems in buildings and in comparing different energy-and cost-saving options. Additionally, through the implementation of the case studies, the clarity of the standard and the easiness of application of its methodology are portrayed. The results of the analysis have indicated that the most cost- and energy- efficient solution for the case study building is the installation of insulation in the building envelope.

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Introduction to energy systems and technologies

The European Union is committed to reducing greenhouse gas emissions to 80 % below 1990 levels by 2050. All Member States consider this to be a very ambitious plan, that will require an almost complete de-carbonisation of the European power sector. Although the road to 2050 will not be easy, it is possible to improve reliability and security of supply of energy and to produce “green energy“, through new technology applications, services, and operations. Furthermore, in future energy systems should be sustainable, efficient, cost effective, integrated as well as ‘intelligent’.The fourth chapter of this book deals with energy systems and technologies. The papers are generally related to the discussion about cost and value of installation and use of new technologies and improved energy systems, on a city or regional level.

The section equally consists of four papers. The first presents cost and value rationale based on large-scale renewable energy technology projects that have been licensed and commissioned. Two case studies in Cyprus of installed RET projects are presented. The findings of this study revealed the importance of cost and value analysis for renewable energy technology projects, thus affecting their payback period, associated with the ‘return on investment’ in economic terms.

The subject of the second paper is an analysis of micro-grids and local power generation through a feasibility study for local authorities in Southern Italy. It highlights the importance of integrating such small local grids through smart ICT (information and communication technology), particular in today’ latest technology where cables are now handling energy flow in dual directions, both grid and RES.

The third paper evaluates the environmental and economic potential of using earth as construction material. It presents an option of using local materials and technologies aimed at recovering and reinterpreting vernacular construction in new buildings. Used in parallel with the refurbishment and rehabilitation of existing buildings, thee can provide cleaner forms of energy and more efficient buildings. This paper presents a comparison on the use of traditional adobe solutions as an alternative to the conventional hollow brick in exterior walls, showing a significant environmental impact reduction.

The fourth paper presents comparative analysis of combined heat and power production vs. heat pumps, for the heating for new residential developments. It presents a thorough analysis of GHG at both local and regional levels, particularly appealing for town planners.

This chapter therefore highlights the need for a thorough assessment of BAT (best available technologies) for grid-connected energy systems, currently expected to work smarter in consideration of today’s day and age of technology.

A holistic cost and value assessment of large-scale renewable energy technologies installations: lessons learnt from Cyprus

Cyprus, being an EU member state since 2004, adopted a range of measures to promote renewable energy sources in its energy system. From 2010 onwards, four wind farms with a cumulative power of 140 MW, that cover 2 % of the island’s needs, were licensed and are operated. The biomass sector followed with the licensing and operation of 8 MW power plants, using biogas derived from livestock waste. Photovoltaics contribute significantly to the energy system of Cyprus; so far 50 MW photovoltaic systems are installed and operated, whereas the outlook for 2020 includes the licensing of at least another 120 MW of photovoltaic installations. The example of Cyprus is particularly remarkable, regarding the potential integration speed of renewable energy technologies in the energy system of a country. Contractual obligations towards the Community Acquis forced Cyprus to move rapidly and to adopt very ambitious targets.

However post-construction cost and value assessment of large renewable energy technologies installations reveal several issues that were not sufficiently considered, as technical, environmental and societal challenges arose. This case study aims to present the cost and value rationale based on which large renewable energy technologies projects are licensed and commissioned. Cyprus will be used as the case study and details with regard to the alternative energy installation processes on the island will be presented. Two case studies of installed RET projects are presented. Funding schemes in terms of incentives are also presented. A case study regarding the licensing procedure of 50 MW PV projects by means of an auction process is also described. Drawbacks revealed after the operation of the first projects will be discussed, aiming to identify the gaps in the cost and value assessment practices followed.

Authors

Elias A. Christoforou
res.ce@frederick.ac.cy

Paris A. Fokaides
eng.fp@frederick.ac.cy

Frederick University, Cyprus

Introduction

In an effort to achieve the EU targets set with regard to the reduction of energy consumption as well as the mitigation of greenhouse gases, renewable energy technologies (RET) have been promoted by the majority of developed countries. According to the European directive 2009/28/EC on the promotion of renewable energy, renewable energy sources shall share 20 % of the total EU’s energy consumption by 2020 and 10 % with regard to the transport energy of each member country. (European Commission 2012). Member states are obliged to design long-term renewable energy measures and policies and to develop detailed estimations of the contribution of renewable energy to their final energy consumption. To achieve this, the European Commission established a template for national renewable energy action plans. These plans define the member states’ targets for the use of renewable sources in transport, electricity, heating and cooling by 2020 and define a trajectory to accomplish these goals.

This work presents the cost and value rationale based on which large renewable energy technologies projects are licensed and commissioned. Section 2 describes whole life costs comprised within the analysis of RET projects and presents several techniques for their financial analysis. In Section 3, the energy system of Cyprus is briefly described and two case studies of projects in Cyprus in the field of renewable energy sources are presented.

The main characteristics of each project are also tabulated. A discussion on the profitability of those case studies as well as the parameters considered in the financial analysis of the projects is included in Section 4. Additionally, an open-auction procedure recently applied in Cyprus is presented in this section. Concluding remarks and drawbacks revealed after the operation of the first projects are presented in Section 5.

Theoretical background

Decisions regarding the implementation of large renewable energy sources projects are based on the profitability of the projects. The analysis usually considers the whole life costing as well potential variations on these costs, which will affect the financial performance.

RET projects whole life costing

Some of the main costs which are comprised in the Whole life cost analysis of a RET project are listed below (Booty 2009):

- capital expenditure;
- financing costs;
- occupancy costs, subdivided into the following categories;
  - Premises costs;
  - Business support costs;
  - Residual values and disposal costs classification for ease of reference.

Property expenditure is normally associated with payments for rent, rates, insurance which always must be considered.

- rent costs: an amount paid by a tenant in exchange for the use of a property, usually regulated under the terms of a lease. Rent tends to be fixed for long periods;
- rates: a mean of taxation based on the value of the property;
- service charges;
- insurance costs.

Principles of RET projects finance

Some background principles of the financial analysis are listed below (Booty 2009):

- taxation: Significant investments should be evaluated carefully through the identification of the correct tax burdens throughout their life cycle, using financial analysis techniques. The effect of input and output value added tax (VAT) payments and recovery on cash flow is particularly significant.
- capital and revenue expenditure: Two types of expenditure exist, namely capital and revenue expenditure. Their definitions are as follows:
  - Revenue expenditure is associated with purchasing goods and services in the short term, including any associated business input costs: materials, labour, rent, rates, insurance, utilities, and maintenance.
  - Capital expenditure is the cost associated with acquiring fixed assets which cost a significant amount and usually provide economic benefits in the long term.
- depreciation: Fixed assets are normally discounted in the accountancy process in order to show the true economic benefit of a capital investment over a period of years. There are two common methodologies for calculating depreciation;
  - The ‘straight line’ method: this divides the capital sum by the useful economic life of the asset.
  - The ’reducing instalment’ method: the asset is treated as if it loses its value more quickly in the early years compared with later years. A fixed percentage is applied to the reducing balance year on year.
- capital allowances: The law and regulations surrounding capital allowances are particularly complex, with the primary difficulty being how to determine ’qualifying expenditure’, that is, capital and revenue expenditure, described above in basic terms. Allowances may be available for certain categories and elements of land, plant, machinery, buildings, and fixtures and fittings.

Financial Analysis Techniques

In practice, the financial techniques used often centre around the analysis of future cash flows. The applied techniques are:

- net present value (NPV): NPV compares the sum of the discounted cash flows with the initial capital expenditure. When the sum total of the discounted cash flows exceeds the initial capital expenditure then the NPV becomes positive and the project can be viewed as economically feasible. When the initial capital expenditure is greater than the total discounted cash flows then the NPV is negative and the project is considered uneconomic;

- internal rate of return (IRR): The IRR determines the discount rate at which the present value of the cash flows equals the initial capital expenditure, that is, where the NPV equals to zero.

Cyprus energy system and RET case studies

The energy system of Cyprus. The power system of Cyprus operates in isolation and is mostly depended on imported fuels to cover the needs for electricity generation. Heavy fuel oil (HFO) is the primary imported fuel used in electricity generation followed by diesel, sharing 92 % and 8 % of the energy mix respectively (Poullikkas et al. 2010). The island has no indigenous hydrocarbon energy sources nor is interconnected with other energy networks. The isolation of the energy system of Cyprus increases the electricity generation costs and makes the energy supply more expensive and vulnerable compared to other interconnected systems.

Cyprus power generation system consists of three thermal power stations at Moni, Dhekelia, and Vasilikos. All thermal power stations use HFO for the steam turbine units and gasoil for the gas turbine units (Poullikkas et al. 2010; Central Bank of Cyprus 2013). The total installed capacity -prior to the accidental explosion at Mari naval base that destroyed 60 % of the island’s power generating capacity (Fokaides et al. 2013), was 1438 MWe, generating 98.7 % of the total electricity production (i.e. 5.204 GWh). In 2009, the average generating system efficiency, based on the total units generated by the EAC’s three power stations, was 34.3 %, and the heat rate per kWh generated was 10.5 MJ/kWh. In 2009, commercial and domestic sectors shared 41.2 % and 37 % of the total electricity use, respectively, followed by industrial (17 %), agriculture (3.1 %) and street lighting (1.7 %). In an effort to comply with the European Union (EU) 2020 obligations, under the Directive 2009/28/EC on renewable energy, the National Renewable Energy Action Plan for Cyprus was developed. The plan sets the roadmap and addresses the targets of raising at 13 % the share of energy from RES, at 10 % the share of RES in the transport sector, and reducing by 5 % the GHGs emissions from 2005, by 2020. This action plan intends to install 192 MW of solar PVs, 75 MW of concentrated solar power, 300 MW of wind turbines and 17 MW of biomass (Republic of Cyprus, 2010). Table 1 presents the aforementioned estimation of RET contribution in terms of installed capacity as well as an interim estimation of the use of renewable sources for electricity generation.

Table 1 - Estimation of the total contribution of renewable energy technology in Cyprus from 2005 – 2020

Installed capacity (MW)				
	2005	2010	2015	2020
Photovoltaic	0.16	6	115	192
Solar thermal	0	0	50	75
Wind energy	0	82	180	300
Biogas	0	6	10	17
Total	0.16	94	355	584

The promotion of renewable energy projects to meet the set targets also offers social and environmental benefits and enhances the security of the energy supply. The importance and benefits of the introduction of RET into the energy mix of an insular system were highlighted by previous studies (Liebenthal et al.1994; Headley 1997; Balaras et al. 1999; Kaldellis et al. 2001; Wright 2001).

Prior the operation of the largest wind farm on the island in 2010, only 2.9 % of primary energy was shared by renewable sources. From 2010 onwards, four wind farms with a cumulative power of 140 MW, that cover 2 % of the island’s needs, are licensed and operated generating an amount of 33,286 MWh. Furthermore, 8 MW power plants using biogas derived from livestock waste licensed and operated, producing 24,802 MWh. Finally, the photovoltaic (PV) sector significantly contributes to the energy system of Cyprus. The installation of PVs in 2014 reaches 50MW of installed capacity, in dwellings as well as in medium and large scale PV farms.

Case study 1: Orites wind farm

Orites wind farm is currently the largest wind project in Cyprus as well as the largest wind farm in the Mediterranean (Figure 1), (Fokaides et al., 2014). Although the project was initiated in 2002, the farm started its operation in September 2010 due to a series of regulatory difficulties. The wind farm has 41 wind turbines installed, each one rated at 2MW, giving a total capacity of 82 MW. The annual wind speed at 60 m above the ground is 5.85 m/s, and the prevailing wind direction is stable. The V90-2 MW turbines manufactured by Vestas Wind Systems A/S of Denmark were used in the project (Vestas Wind Systems, 2011). The main characteristics of the Orites wind farm are presented in Table 2.

Figure 1 - Orites wind farm location

Prior to the construction of the Orites Wind farm, wind measurements were recorded from 2005-2008. The wind potential analysis and the Weibull distribution were used in order to estimate the potential annual energy yield of the project. The wind potential of the Orites wind farm was evaluated with the graphical method for the estimation of the Weibull parameters (Figure 2). The measured and calculated wind velocity probability is presented in Figure 3.

Table 2 - Orites wind farm – Main characteristics

Feature	
Location	34°43'N,32°38'E
Total area (m^2)	22 km^2
Average area height above sea level (m)	450
Date commissioned	Sep.2010
Number of wind turbines	41 (currently)
Type of wind turbines	Vestas V90-2.0 MW
Total capacity (MW)	82
Hub height (m)	80 m
Average wind potential (Weibull parameters) (–; m/s)	k=2.4; C=6.8
Estimated annual energy yield (GWh)	170
Investment cost (M€)	174
On-shore wind power feed in tariff (€/kWh)	0.166

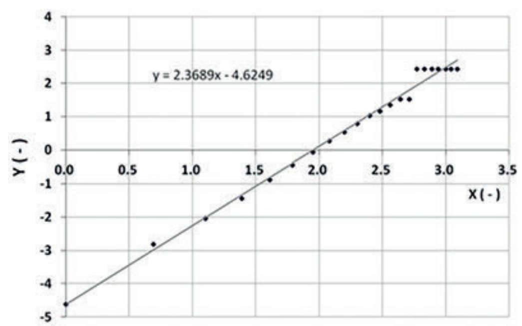

Figure 2 - Orites wind farm - Weibull probability plot

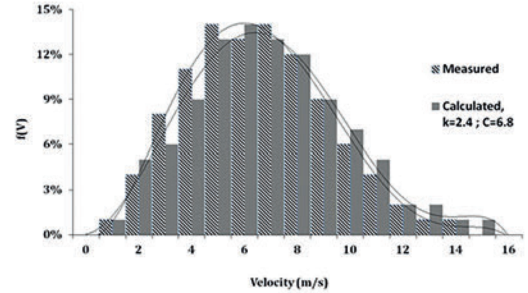

Figure 3 - Orites wind farm - Wind velocity probability density function. Measured and calculated data plot

Case study 2: 1 MW PV Farm

The second case study examined within this study regards a 1 MW PV farm. The PV farm has 60 cells - polycrystalline PV panels installed. The efficiency of the PV panels stays at a level of 15 % and the used mounting system of the panels is static. Transformerless string inverters were also used in the PV farm. The performance ratio of the installed PV system was calculated by PVSyst (PVSyst, 2010) to 80 %. According to the results, the examined PV system gives an average annual energy yield of 1583 kWh/ kWp. (Figure 4). (Fokaides, and Kylili 2014).

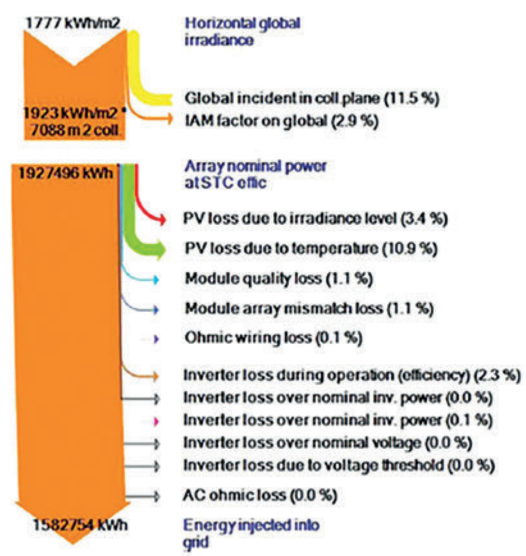

Figure 4 - Sankey loss diagram of a 1 MW PV farm in Cyprus

Case study 3: auctioning of 50MW photovoltaic projects in Cyprus

In 2013, an auction-based procurement was established for the licensing procedure for 50MW PV plants in Cyprus. The PV projects were classified into 4 categories based on their capacity and the maximum number of plants per category was defined. Separate auctions would be drawn for each category. The project categories and the number of projects were as follow:

- Category A: 12 projects up to 1.5 MW;
- Category B: 4 projects from 1.5MW to 3MW;
- Category C: 2 projects of 5 MW;
- Category D: 1 project of 10 MW;

A limit FiT was set, called safety net value, for each project category, below which bids would be excluded:

- 0.155 €/kWh for projects of 1.5MW;
- 0.15 €/kWh for projects of 3MW;
- 0.145 €/kWh for projects of 5MW;
- 0.14 €/kWh for the project of 10 MW.

Whole life cost of RET case studies in Cyprus: results and discussion

Case study 1: Orites wind farm

The costs estimations for generating electricity at the Orites wind farm are shown in Table 3. The operational and maintenance costs, as well as the funding conditions were provided by the owner of the wind farm. The total investment cost for the Orites farm was € 174 M, which accounts for 2.1 €/W. The cost of the project is quite higher compared to the average wind farm cost, which does not exceed 1.2 €/W (Zhang et al. 2012).

Based on the data presented in Table 3 and considering a service life of the wind turbines of 20 years, the power generation costs of the project are 0.10 €/kWh. According to (Hau, 2006) this generation cost can determine the economic viability of a project. Since the feed-in-tariff level is currently 0.166 €/kWh, which is considerably higher than the power generation cost, the project can be considered as economically feasible.

Table 3 - Orites wind farm – Power generation costs

Feature	
Investment costs	
Ex-works price (€)	111,000,000
Planning, installation and commissioning (€)	63,000,000
Total investment cost (€)	174,000,000
Annual cost	
Maintenance and repairs, insurance and operation (€)	6,480,000
Service of capital (repayment period 15 years, 6.8 % interest p.a.) (€)	13,000,000
Annual energy yield	
At 98 % technical availability (GWh)	185
Eq. CO_2,e (Department of Energy and Climate Change UK 2010) (Mtonnes)	143.4
Specific investment cost with respect to annual energy yield (€/kWh)	0.94
Power generation cost	
With repayment in 15 years (€/kWh)	0.10

Case study 2: 1 MW PV farm
The financial analysis of the project was performed for a 20 year time period which was the duration of the contract currently offered in Cyprus by the Energy Regulator for feeding energy produced by renewable energy sources to the grid. For the purposes of the analysis, the NPV to the shareholders was set to 4 %. A total leverage of 70 % was also assumed, considering a 6.5 % constant interest and 10 years maturity. Also, the rate of the electricity retail cost was assumed to be 0.20 €/kWh. Table 4 presents the cost of equipment and the construction and commissioning costs for the project while Table 5 presents the operation and maintenance (O&M) costs in year one. The assumed values regarding equipment costs were defined using the PV Magazine index (PV Magazine 2013). Construction costs of the project were defined after an extensive market research (Energy Works Ltd 2013). Furthermore, the running costs of the project were assumed to be equal to 1 % of the total equipment cost, an assumption which is consistent with previous works found in literature. (Koner et al., 2000; Talavera et al., 2010; Swift, 2013)

Table 4 - Breakdown cost of PV farm

Item	Cost (€/W)	Total (€)
Equipment (PV panels, string inverters, static mounting system)	0.90	900,000
Electrical installation (including cabling) and construction works	0.20	200,000
Grid connection	0.10	100,000
Engineering (design and commissioning)	0.02	20,000
Other	0.03	30,000
Total cost (€)		1250,000
Total cost (€/W)		1.25

Table 5 - Additional costs of the PV farm

Type of cost	% of equipment cost (%)	Cost (€)
Operation and maintenance cost	1.0	9,000
Insurance fee	0.2	1,800
Safety	LOT	10,000
NfE	0.5	4,500
Total cost (year one) (€)		25,300

The analysis of the profitability of the 1 MW solar farm was initially examined a basic scenario which was taking into consideration the aforementioned data regarding the construction costs, the operation and maintenance costs, the energy yield of the PV system and the deterioration rate of the PV panels. The results of the analysis indicated a 17.58 % of all equity IRR and a 38.96 % leverage IRR of the investment. A parametric analysis was also performed considering variations in three basic parameters, in order to assess their impact on the IRR of the investment:
• cost of the PV modules;
• performance ratio (PR), and
• the retail price of electricity.

The conditions under which grid parity is achieved were examined and all equity IRR and leverage IRR were calculated under these conditions. Those parameters were selected since there a potential change may occur in the future which can affect the profitability of such projects. Specifically, the PV module cost has revealed a significant drop the last years which may continue the following years. The performance ratio may also drop due to a number of reasons including bad manufacture quality of the panels or the inverters, rise in the temperature of the panel, poor electrical installation etc. Increase in the efficiency is also possible to be achieved in the future, as a result of research and development (R&D) initiatives. Finally, the very high retail price of electricity is expected to become lower in the forthcoming yeas due to the introduction of natural gas in the energy mix of Cyprus, as a result of the recent discovery of natural gas reserves. Figure 5 gives the impact of possible change on the construction costs of the PV farm and the retail price of electricity on the feasibility of the projects in terms of IRR calculation. The impact of the construction costs of the PV farm and the performance ratio of the PV modules on the IRR of the project is presented in Figure 6. Finally, the impact of the selling price of the energy produced and the performance ration of the PV installed modules on the profitability of the project is given in Figure 7.

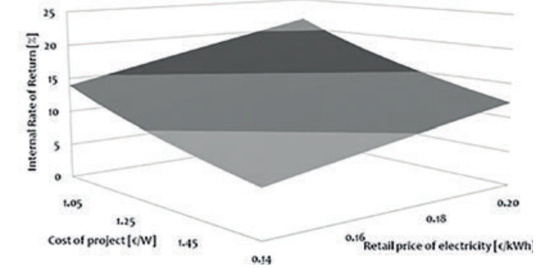

Figure 5 - Impact of a 1 MW PV farm construction cost and of the retail price of electricity in Cyprus on the IRR of the investment

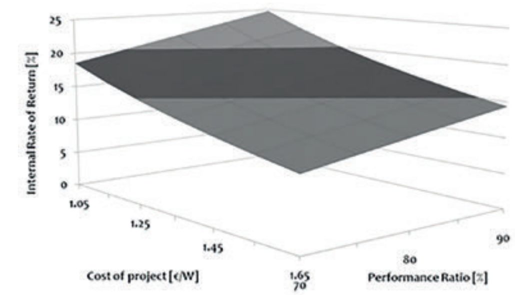

Figure 6 - Impact of the retail price of electricity and of the performance ratio in Cyprus on the IRR of the investment

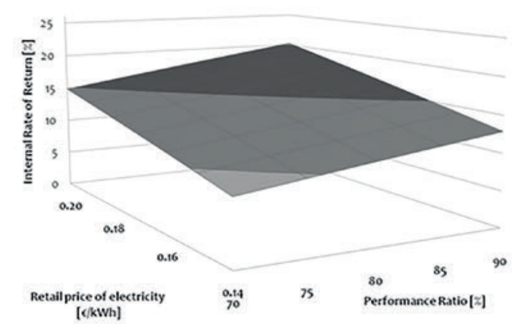

Figure 7 - Impact of a 1 MW PV farm construction cost and of the performance ratio in Cyprus on the IRR of the investment

Funding mechanisms – a paradigm from Cyprus

The penetration of RET into the energy mix of a country is promoted through different funding support mechanisms established by the regulatory bodies of the state and the governments. The most common support mechanisms used in several cases in the EU were reviewed in the study conducted by Kylili and Fokaides (Kylili and Fokaides 2015):

- renewable energy auctions: According to this mechanism, the desired capacity to be installed for a specific RET is set by the government or the regulatory body. Bids are placed by the interested investors in the form of cost per electricity unit (€/kWh). The bidder with the lowest bid allocates the project for a certain period of time for the proposed tariff rate;
- feed-in Tariff scheme (FiT): The FiT scheme considers the minimum guaranteed price per electricity unity (€/kWh) that an electricity utility has to pay to a private, independent producer of renewable power fed into the grid;
- tradable Green Certificates (TGC): According to the TGC mechanism, electricity generated by RET is sold in the electricity market at market prices, while these are also corresponding to certificate trading in a separate market for green certificates. The buyers, who are either electricity suppliers or consumers are obligates to buy certificates corresponding to a certain quota of their total electricity sales or consumption.

Case study 3: Auctioning of 50MW PV projects in Cyprus

In 2013, an auction-based procurement was established for the licensing procedure for 50MW PV plants in Cyprus. General information about the Cyprus PV projects action procurement, the number and capacity of the proposed projects as well as the licenses awarder are given in Table 6.

The feasibility of the awarded projects was determined by defining the IRR of the investment. The feasibility analysis was based on the following assumptions:

- 70 % loan leverage;
- 6.5 % constant interest;
- 10-year maturity;
- 20-year period;
- Polycrystalline, static mounted, PV panels of 60 cells, with an efficiency of approximately 15 %;
- Transformer-less string inverters.

The equipment, construction and commissioning costs are presented in Table 7 while the operation and maintenance (O&M) costs are listed in Table 8.

Table 6 - Cyprus PV projects auction procurement

General Information Category	A	B	C	D
Capacity of projects (MW)	90.32	80.89	33.77	47.94
Number of candidate projects	76	32	8	5
Number of licenses awarded	15	5	2	1
Total capacity (MW)	17.95	14	7.45	10.00
Price range of awarded projects (€cent/kWh)	9.43-9.9	7.81-8.98	8.15-8.51	7.41
Category's average bidding price	12.5	9.64	11.26	12.06
Category bidding prices' standard deviation	1.82	1.12	2.10	2.75

The feasibility analysis of the project, considering a cost of 1.00 €/W indicated the economic viability of the awarded projects for all four categories. However, when the safety net values were considered, all equity IRR per project were significantly different, giving much more profitable results (Table 9).

Table 7 - Cyprus PV projects auction procurement - Breakdown cost of PV farmItem Cost (€/W)

Equipment (PV panels, string inverters, static mounting system)	0.45
Electrical installation (including cabling) and construction works	0.15
Grid connection	0.10
Engineering (design and commissioning)	0.20
Other	0.10
Total cost (€/W)	1.00

Table 8 - Cyprus PV projects auction procurement - Additional costs of the PV farm

Type of cost	% of equipment cost (%)	Cost (€)
Operation and maintenance cost	1.0	9,000
Insurance fee	0.2	1,800
Safety	LOT	10,000
NfE	0.5	4,500
Total cost (year one) (€)		25,300

Table 9 - Comparison of all equity IRR based on the lowest bid and the safety net value for the awarded PV projects

All equity IRR (%)		
Project Category	Lowest bid	Safety net value
A	8.3	17.09
B	6.1	16.77
C	6.9	16.24
D	5.8	15.67

The contracts of the awarded projects were found to be sealed at extremely low prices that can barely ensure project economically feasibility or viability. Furthermore, the EU Commission has already put in force Regulation EU No 513/2013 since June 2013 that imposes an anti-dumping duty on all crystalline silicon PV panels, cells, modules and wafer imported from China. The duty has been set at 11.8 % until August 2013 and at 47.6 %. As a result, the costs of the projects will rise to one and a half times the previously calculated costs at the time of the tenders. This increase in costs brings the IRR of the awarded project for the 10 MW PV park to 1.36 %, considering the lowest current costs (1.5 €/W). Also the safety net was set by the organising authority (Energy Service of Cyprus) in an attempt to maintain the offered prices within reasonable limits, while any bids below this value would be excluded. Clearly, the safety net was not used appropriately. Part of the failure can be attributed to the organising authority, as the price of the safety net was set too high, so that the bids fell below it as soon as the tenders started. According to the feasibility analysis, an appropriate safety net would range from 0.12 €/kWh to 0.125 €/kWh, i.e., prices that produce a satisfactory and profitable all-equity IRR in the range of 12 to 13 %. Another defect of the auction process was found in the participation terms and conditions. 30 MW out of the total of 50 MW of the auction procurement were awarded to two dominating companies. Both companies are also both importers and installers of PV systems. The participation of all importers, installers and producers in the auctions under the same conditions with the rest of the interested parties led to market distortion and thus to the failure of the process.

Conclusions

The feasibility and economic viability of RET is dependent on a number of parameters that affect the whole life cost of the projects. In this study, two case studies of projects in the field of RES, namely a wind farm and a 1 MW PV farm in Cyprus were presented. The results of the financial analysis of the projects were also examined. Additionally, an example of a recent auction procurement procedure for the licensing of PV projects with a total capacity of

50 MW was investigated. The feasibility of the awarded projects was also examined.
The findings of this study revealed the importance of cost and value analysis for renewable energy technology projects. The financial aspect is the main decision parameter towards promoting green energy. Also it was also revealed that if the appropriate analysis is not conducted, the supporting schemes may lead to unfeasible projects, such as in the case of the auctioning in Cyprus for the 50MW PV projects.

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Microgrids and local power generation: a feasibility study for local authorities in Southern Italy

In order to create in Europe a greener and low-carbon economy, based on a more effective use of resources, coordinated actions between local and regional governances must be carried out according to a bottom-up, cross-level approach. In this framework energy efficiency and the promotion of renewable energy sources are two key aspects for reducing emissions, improving the security of energy supply and competitiveness as well as making energy more accessible for consumers.

In recent years, feed-in tariffs and other incentives have boosted in some European countries, including Italy, the distributed generation of electricity from renewable sources requiring a reorganisation of current electric power systems from passive to active networks where "prosumers" can play a key role in balancing the electricity system (smart grids). Microgrids can be considered as the "building blocks of smart grids" which utilise local load and local microsource generation, providing a large variety of economic, technical, environmental and social benefits to different stakeholders in terms of flexibility of ownership constitution, global optimisation of power system efficiency and motivation of end-consumers (Schwaegerland Tao 2014).

This paper presents the results of an ongoing research concerning a comprehensive assessment of benefits and costs that microgrids development can provide at local/regional scale. First, the role of smart grids and microgrids is discussed with reference to the latest normative regulations and scientific findings. Second, we introduce a local case study (City of Potenza, Basilicata region, Southern Italy) which has been recently under the focus of a feasibility study focusing on microgrids. Finally, the main costs and benefits (economic and environmental) associated with the proposed intervention are evaluated, discussing about their replicability in other territorial contexts and providing some lessons learnt and final conclusions.

Authors

Senatro Di Leo [1]
senatro.dileo@imaa.cnr.it

Monica Salvia [1]
monica.salvia@imaa.cnr.it

Antonio Mauro [2]
anmauro@hotmail.it

Michelangelo Morrone [2]
michelangelomorrone@gmail.com

1) National Research Council of Italy, Italy
2) Geco SRL Unipersonale, Italy

Introduction

Sustainability, security of supply and competitiveness are the main objectives of the European Union energy policy and represent also important challenges for National Governments and Local Authorities in order to achieve their economic, social and environmental objectives.

The 20-20-20 targets for 2020 on which there was based the EU climate and energy package are now under assessment in order to update the EU energy strategy with new targets for 2030 (European Commission 2010).

The European Commission proposals for 2030 foresee an emissions reduction of 40 % and a 27 % share of renewables (European Commission 2014a) and there is also "some momentum for a binding energy efficiency target that could be set at 30 %" (Zachmann 2014). The differentiated increase in the three targets indicates a change in priorities among the key challenges for the energy and climate policy of Europe and Member States.

On the longer term, with the Energy Roadmap 2050, the European Union commits itself to reducing GHG emissions to 80-95 % below 1990 levels by 2050 through increased innovation and investment in clean technologies and low- or zero-carbon energy (European Commission, 2011). Moving towards a low-carbon economy will require a much greater exploitation of renewable sources of energy, energy-efficient building materials, hybrid and electric cars, 'smart grid' equipment, low-carbon power generation and carbon capture and storage technologies.

In order to address the energy technology innovation challenge, the European Strategic Energy Technology Plan (SET Plan) was launched in 2007 as the technology pillar of the EU energy and climate policy (European Commission 2014b). The SET Plan has established a strategic frame for the development and advancement of low carbon energy solutions, encouraging joint planning and programming for a smarter employment of available resources. In particular, among the European Industrial Initiatives (EIIs) introduced by the SET-Plan, the Smart Cities and Communities Initiative, launched in 2011, has the objective to create the conditions to trigger the mass market take-up of energy efficiency technologies in order to secure CO_2 reductions. The focus is on cities that have committed themselves to create a more sustainable future, for instance adhering to the Covenant of Mayors (Covenant of Mayors, 2014). These are cities that are willing to transform their buildings, energy networks and transport systems into those of the future, demonstrating transition concepts and strategies to a low carbon economy as well as the feasibility of going beyond the current EU energy and climate objectives – i.e. towards a 40 % reduction of greenhouse gas emissions through sustainable production, distribution and use of energy by 2020.

In the latest years, more and more Smart City initiatives have arisen Europe-wide to help cities to start planning their future in a new way: adopting a comprehensive multi-sector approach and accelerating innovation to become more sustainable and resilient.
As concerns Italy, up till now many independent smart cities initiatives have been carried out by local governments without a common national strategy. In a recent study on smart cities in Italy (ABB Smart Cities in Italy, 2012), it was pointed out that a "high fragmentation and dispersion of initiatives, tendency to organise initiatives in isolation and extremely disparate nature of solutions under the generic heading of "smart". The same study auspicates "a country-wide project (in other words, a national perspective and related national strategy) that is centrally coordinated".

As remarked by the Digital Agenda for Europe, the smart city concept "goes beyond the use of ICT for better resource use and less emissions. It means smarter urban transport networks, upgraded water supply and waste disposal facilities, and more efficient ways to light and heat buildings. And it also encompasses a more interactive and responsive city administration, safer public spaces and meeting the needs of an ageing population" (European Commission, Digital Agenda for Europe. Smart cities, 2014c).

In holistic vision of smart cities, smart grids play a strategic role in order "to ensure resilient delivery of energy to supply their many functions, present opportunities for conservation, improve efficiencies and, most importantly, enable coordination between urban officialdom, infrastructure operators, those responsible for public safety and the public" (Geisler, 2013).

The following sections discuss on the possible role that smart grids and microgrids can have at local/regional scale. To this end, the main results of a feasibility study focusing on the realisation of a microgrid in an urban case study are presented, pointing out costs, benefits and lessons learned.

The role of smart grids

Italy's import dependence is among the highest in the EU (European Commission (2013)). In 2010, Italy imported 84 % of the overall national energy needs, among which 93 % of oil (the first source of energy used) and 90 % of gas (the second energy source). The third source of energy used comes from renewables which have been steadily increasing over recent years representing around 10 % of the Italian energy mix, which seems in line with the expectations of the National Renewable Energy Action Plan (NREAP) towards the 17 % 2020 targets for renewables (Republic of Italy (2011)).

In particular, renewables play a central role in electricity generation where they account for 27 % of total generation. In the latest years there has been a remarkable growth in solar power, whose contribution to electricity production increased from almost zero in 2007 to 10.7 TWh in 2011, as well as in wind power increased from 2.9 TWh to 10.1 TWh (European Commission, 2013).

This steady increase in electricity generation from renewables is the result of consistent incentives at the national level, which included "a mix of a feed-in premium mechanism ("ContoEnergia") for solar power, tradable feed-in tariffs for small installations and green certificates with technology banding, resulting in an estimated financial support to solar power projects of around € 5 billion in 2011" (European Commission, 2013).

Reducing the environmental impact of current energy systems and increasing the electricity production from renewable energy sources, in compliance with the EU 20-20-20 targets, requires a reorganisation of current electric power systems which are based on a substantially unidirectional flows of energy from the generation plants to the multiple points of consumption.

This deals both with a reduction of energy demand and an improvement of the efficiency of generation, transmission and distribution of electricity. Typically, transmission and distribution losses of electricity grids can be reduced through the adoption of innovative materials and components (e.g. transformers, cables, circuit breakers), increasing the capacity of the transmission system but also making transmission and distribution more flexible in order to balance the fluctuation of loads.
The sharp increase in the distributed generation of electricity from renewable sources, especially wind and solar photovoltaic, which has been observed in Italy and other European countries in the latest years is causing a discontinuous production of electric power which has to be managed and balanced through fossil production and storages (Autorità per l'energiaelettrica e il gas, 2011).

We are moving towards a new scenario where the electricity flows through generation, transmission, distribution and use can be handled bi-directionally assuring an effective and efficient electricity system. In this new configuration it is necessary to optimise the performance of different sources of generation, both concentrated and distributed in relation to the network conditions (quality of service interruption, etc.) and consumptions. Moreover it has to be ensured the reliability, quality and security of the transmission and distribution grid, assuring an active role of consumers in adjusting their consumption profile under the conditions of the energy market.

All these characteristics are embedded in the concept of "smart grid" which is "an electricity network that can efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety" (European Smart Grids Technology Platform, 2010).

In summary, distribution grids are being transformed from passive to active networks where decision-making and control are distributed, and power flows bidirectional (Schwaegerland Tao, 2014).

According to the EU Commission Task Force for Smart Grids (EU Commission, 2010), "smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:
- better facilitate the connection and operation of generators of all sizes and technologies;
- allow consumers to play a part in optimising the operation of the system;
- provide consumers with greater information and options for how they use their supply;
- significantly reduce the environmental impact of the whole electricity supply system;
- maintain or even improve the existing high levels of system reliability, quality and security of supply;
- maintain and improve the existing services efficiently;
- foster market integration towards European integrated market."

Therefore in a Smart Grid a "prosumer", that is a consumer (e.g. household, plant, office) that also produces energy, can play a key role in balancing the electricity system. Shandurkova et al. (2012), believe that "new business models and roles will be required in order to facilitate the integration of prosumers in the electricity market" and that introducing "advanced metering infrastructure and innovative technologies for control will allow for high degree of flexibility for the end users".

In this perspective, the smart grid can revolutionise the energy market in the medium to long term: even small users, and not just the big retailers will be able to buy energy at varying prices throughout the day.
This is confirmed also by Directive 2009/72/EC, which recognises the importance of innovative pricing formulas, intelligent metering systems and smart grids as important measures to promote energy efficiency.

Microgrids can be considered as the "building blocks of smart grids" and, according to Schwaegerl and Tao (2014) are the most promising, novel network structure. A microgrid can be defined as "an electrical system that includes multiple loads and distributed energy resources that can be operated in parallel with the broader utility grid or as an electrical island" (Jeevan and Imran, 2013).

The main advantages deal with an enhanced local reliability, reduced feeder losses, emissions reduction, an increased efficiency through CHP and the provision of uninterruptible power supply (UPS) functions. Furthermore, micrograms make effective the participation of both supply-side and demand-side resources in distribution grids (Schwaegerland Tao, 2014).

As a matter of fact, consumers can play an active role choosing a profile of consumption and quality of service depending on his real needs. At the same time they can benefit from the possibility to purchase electricity at the best conditions of the electricity market and the real possibilities of active demand. This means that consumers can determine the amount of energy which is produced locally and supplied to the market but are also the biggest beneficiaries of the benefits related to microgrids.

The regional framework

Basilicata is a small region in Southern Italy with an area of 9,992 square kilometres and 576,194 inhabitants at 31 December 2012 (ISTAT National Institute of Statistics, 2014a). It is characterised by a very low population density (57.6 inhabitants per square kilometres) and a trend of population in decline (it was observed a reduction of about twenty thousand inhabitants from 2001 to 2011). Basilicata is one of the twenty regions of the Italian Republic and is split into two provinces: the Province of Potenza, including 100 municipalities among which Potenza - the capital city, and the Province of Matera, with 31 municipalities.

Basilicata is still one of the poorest regions of Italy, disadvantaged by its morphological constitution (a prevailingly mountainous territory - 46.9 % -, with only 8 % of plain areas) and for a long time marginalised by national investments. Although the region still lacks of major infrastructures (highways, railways, etc.), the regional economy has grown significantly in the last 20 years, due to the exploitation of oil reserves.

This is confirmed by the observed trend of GDP per capita (Figure 1) which reached the maximum value in 2008 (19,080 Euro) before the economic crisis.

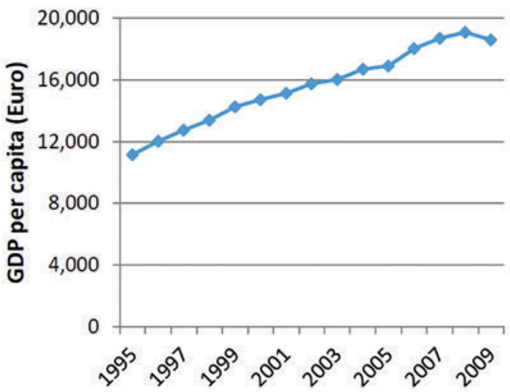

Figure 1 - Trend of GDP per capita.
(source: National Institute of Statistics (2014b)

In the latest ten years (2004-2013) the employment rate in Basilicata reached the maximum value in 2006 (50.3 %) and then decreased until 46.1 % in 2013 (Figure 2). It is worth noting that although the regional employment rate is always lower than the national average, it is still higher than the average value of Southern Italy. In 2012, the labour market in Basilicata was affected by the contraction in economic activity with a decline of employees and hours worked. This has resulted in an increase in the unemployment rate (15.3 % in 2013 compared to the national value of 12.4 %).

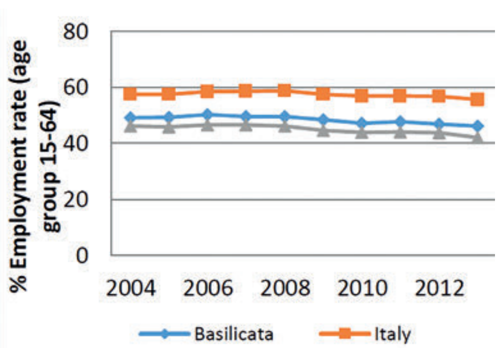

Figure 2 - Employment rate (%)
Source: National Institute of Statistics (2014c)

The built heritage of the Basilicata region was heavily influenced by numerous natural disasters and in particular by an earthquake which struck Southern Italy in 1980.

The most common house typology is represented by masonry buildings with 1 – 2 floors built before 1919 (Figure 3).

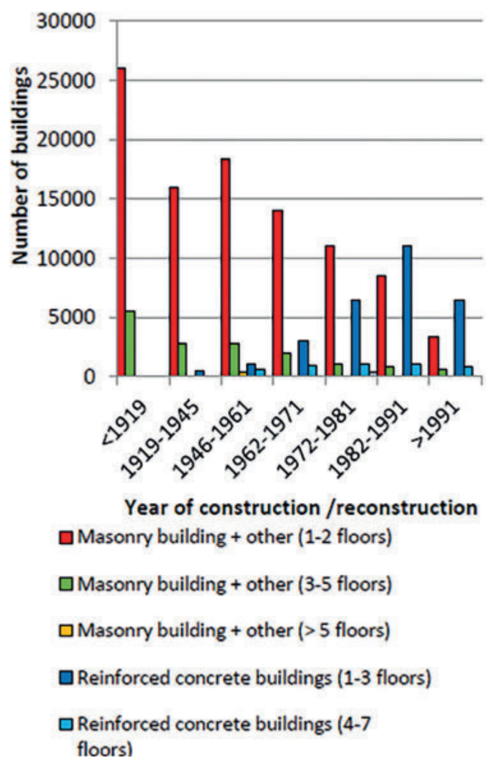

Figure 3 - Distribution of house typologies in the Basilicata region based on year of construction/ reconstruction (Samela et al., 2009)

Into this category fall more than 25,000 buildings (17 % of the total number, which is 147,972). The construction or reconstruction of masonry buildings is considerable also for the other time periods. For reinforced concrete buildings the main category is with 1-3 floors, reaching the peak in the 1982-1991 period, with approximately 12,000 buildings (8 % of the total).

As concerns the status of retrofitting in the region, it can be roughly estimated on the basis of the requests for tax deductions sent to ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), 2012).

Figure 4 shows the number of interventions on buildings with respect to the cumulative number of apartments over the period 2007-2012. In particular, most of the interventions realised in 2012 dealt with the replacement of fixtures (72 %), followed by the installation of solar thermal (17 %), interventions on vertical opaque structures (6 %) as well as the installation of heat pumps (4 %).

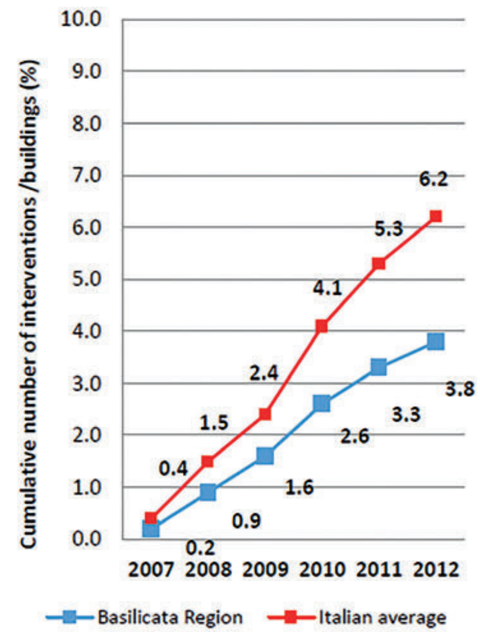

Figure 4 - Cumulative number of interventions in the period 2007-2012 compared to the number of apartments (National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), 2012)

Basilicata holds the largest oil reservoir of continental Europe. In 2013 in the Agri valley two oil companies (Eni and Shell) extracted about 3,940 kton of crude oil, corresponding to 80,000 barrels per day, and 1,271 Mm^3 of natural gas, corresponding to 3 million of m^3 per day. These figures are expected to increase in the near future given that such oil companies were authorised to reach a production of 104,000 barrels per day. Furthermore, new oil extractions the Total company have been recently authorised in the Sauro valley: the new oil plant, once fully operational, will have a daily production capacity of approximately 50,000 barrels per day of oil, 230,000 m^3 per day of natural gas, 240 tons per day of LPG and 80 tons per day of sulphur.

The region is also very rich in water and has a highly developed system of water infrastructure through which it provides water for drinking, irrigation and industrial uses not only within the region but also to neighboring regions (Apulia and Calabria).

The climate of Basilicata can be defined as continental with a Mediterranean character only in coastal areas. In fact penetrating a few kilometres inland, especially in winter, meekness is immediately replaced by a cold and humid climate. The region is characterised also by favourable climate conditions also for electricity production by photovoltaic and wind sources.

An estimation made by GSE (the Italian Energy Services Operator) on the basis of the ENEA database, afferent to the Italian Atlas of solar radiation, shows an estimate of solar radiation for each municipality of Basilicata. Figure 5 shows that the greatest potential, above 4 kWh/(m^2*day), can be found in the South-West Coast (Maratea) as well as in the Matera Province (South-East).

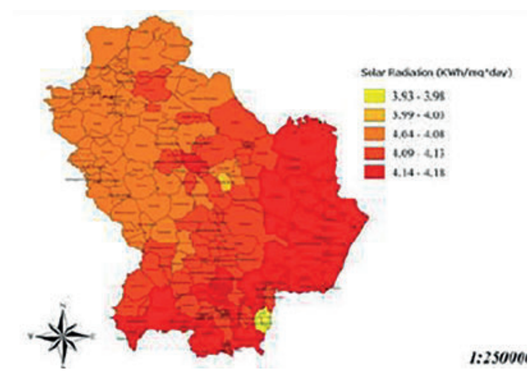

Figure 5 - Map of solar radiation

Information on the regional wind potential can be derived from the maps of the "Wind Italian Atlas", which refer to an altitude of 75 m above the sea level. Figure 6 shows that there is a good wind potential, in particular in the Potenza Province, although it is distributed unevenly within the provincial territory. The average wind speed is around 6 – 7 m/s but many areas are characterised by a speed higher than 7 m/s, with peaks between 8 and 9 m/s.

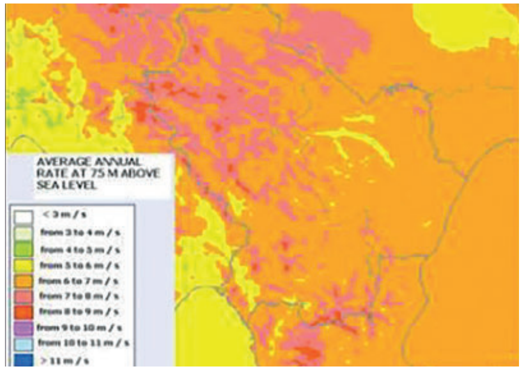

Figure 6 - Map of the average a annual rate of wind at 75 meters above sea level

The Regional Environmental Energy Plan (PIEAR) (Basilicata Regional Authority, 2010) approved by Basilicata Regional Authority in 2010, contains the regional energy strategy to be implemented to 2020, based on a careful analysis of the baseline energy system. In 2007, the total energy consumption was 59.23 PJ, mainly due to the Industrial sector (47 %), followed by Transport (29 %), Residential (13 %), Commercial (8 %) and Agriculture (4 %) (Figure 7).

Natural gas and diesel are the most used fuels (23 %): natural gas is mainly consumed by Industry (6.3 PJ) and Residential (5 PJ), whereas Transport is the largest consumer of diesel (10.5 PJ). Also electricity contributes substantially to the final energy consumption (18 %), with 10.5 PJ, of which 6.3 PJ in Industry, 2.02 PJ in Commercial and 1.84 PJ in Residential (Figure 8).

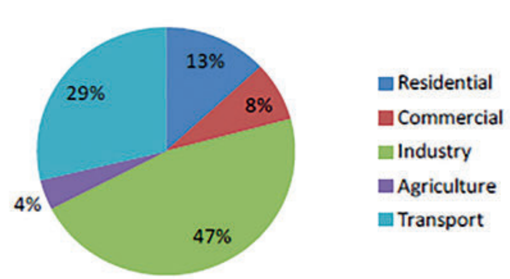

Figure 7 - Share of energy consumption by sector, 2007

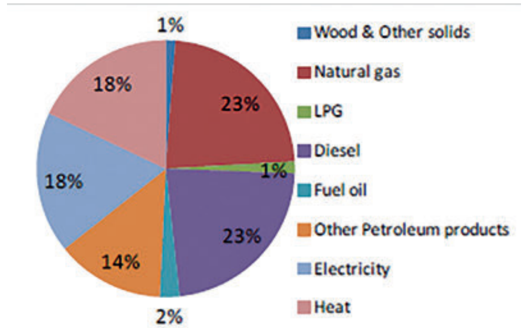

Figure 8 - Share of energy consumption by fuel, 2007

In Table 1 a summary of energy consumption in 2007, by fuel and sector, is reported.
Table 1 - Energy consumption (PJ) by fuel and sector, 2007 (Source: CNR-IMAA elaborations on PIEAR data and ENEA statistics). Residential RES, Commercial COM, Industry IND, Agriculture AGR and Transport TRA.

The last available regional energy balance (ENEA Regional Energy Statistics - Basilicata 1988 – 2008) is relative to 2008, and it reports that 86 % of electricity production is due to natural gas, 9 % to hydro source, 5 % to renewable sources (photovoltaic and wind) and 1 % to petroleum products. Thermoelectric powers are characterised by an efficiency level below the national average, as they are quite old installations. The installed capacity of cogeneration plants is about 70 % of the overall thermoelectric power plants.

Data related to 2012 show a strong increase of electricity production from photovoltaic and wind compared to 2008 ones. The main contribution is provided by wind power plants with a net production of 586 GWh and 369 MW of installed capacity. Furthermore with the introduction of the "energy bill" there has been an increase in permits for the installation of photovoltaic (PV) systems, which has led to 330 MW of installed capacity and 586 GWh of electricity production from PV. Hydroelectricity production is 304 GWh with an installed capacity of 129 MW. However, the Region is still heavily dependent on imported electricity from neighbouring regions, importing about 881.1 GWh in 2012, corresponding to 29 % of the consumed electricity (TERNA spa, 2014). As concern CO_2 emission factors for gross

Table 1 - Energy consumption (PJ) by fuel and sector, 2007 (Source: CNR-IMAA elaborations on PIEAR data and ENEA statistics). Residential RES, Commercial COM, Industry IND, Agriculture AGR and Transport TRA

Energy source	RES	COM	IND	AGR	TRA	Total
Wood & other solids	0.29	-	0.44	-	-	0.77
Natural						
Gas	5.02	2.14	6.3	0.04	0.06	13.56
LPG	0.24	0.14	0.24	-	0.25	0.87
Diesel	0.38	0.24	0.27	2.01	10.54	13.44
Fuel						
Oil	0.002	0.04	1.43	-	-	1.47
Other petroleum						
Products	-	-	1.98	-	6.07	8.05
Electricity	1.84	2.02	6.28	0.26	0.1	10.5
Heat	-	0.0003	10.6	-	-	10.6
Total	7.77	4.57	27.6	2.3	17.02	59.23

electricity production by fuel, it is necessary to refer to the national average data provided by the Italian National Institute for Environmental Protection and Research (ISPRA, 2012). In 2010, they were estimated in 0.87 $kgCO_2$/KWh for solid fuels, 0.38 $KgCO_2$/KWh for natural gas, 1.66 $KgCO_2$/KWh for derived gases, 0.67 $KgCO_2$/Kwh and 0.51 $kgCO_2$/KWh for other fuels (biowaste, biogas and vegetable biomass). The National Law n. 208/2008 introduced the concept of "burden sharing", which involves the decision to split among regions the duties to achieve the EU target set for Italy for a 17 % share of renewable energy by 2020. On 15 March 2012 this Law was acknowledged by a Ministerial Decree which set, in the particular case of Basilicata Region, an increase of the total share of thermal and electric energy produced by renewable energy sources in order to reach 33.1 % of the gross final consumption within 2020.

The regional energy strategy was set by the Regional Energy Plan, which identifies the 20 % reduction of energy consumption among the objectives to be achieved. It proposes actions mainly focused on the efficiency of public and private buildings by means of provision of grants for the implementation of appropriate measures. Also for public transport measures to improve energy efficiency are planned, encouraging the rationalisation of urban and extra-urban mobility. On the other hand, in private transport the use of more efficient engines is promoted. The plan encourages the distributed generation of electricity and, in particular, the installation of auto-production power plants from renewable sources, connected to electricity distribution grids in low and medium voltage and localised in proximity of end-users. Similarly, it promotes coupled production of electricity and heat (CHP).
In 2006 the total production of CO_2 emissions was about 3,418 kton with the highest

contribution (42 %) due to the Civil sector (Commercial and Residential), followed by Transport (28 %), Energy Production (16 %), Industry (10 %) and Agriculture (4 %) (Mankuso, 2011).

Therefore, if the 13 % national target of CO_2 emission reduction to be achieved by 2020 compared to 2005 levels (as required by the energy package) will be evenly distributed among all regions, then Basilicata will be allowed to have a maximum production of CO_2 emissions equal to 2,767 kton (respect to the 3,180 kton in 2005).

The case study

The case study focuses on the realisation of a microgrid in the capital town of Basilicata region (Southern Italy). The municipality of Potenza has a population of 66,403 inhabitants (2013), corresponding to 387.4 inhabitants per square kilometres. According to the Sustainable Energy Action Plan (SEAP) of Potenza (Sustainable energy action plan of the City of Potenza (2012)), which refers to calendar year 2009, the final energy consumption is about 1165 GWh and the most consumed energy carriers are natural gas (33 %), diesel (25 %), gasoline (21 %) and electricity (15 %) (Figure 9).

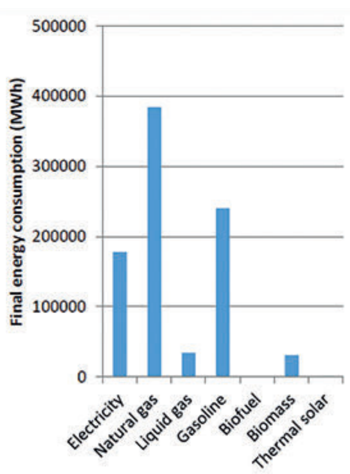

Figure 9 - Final energy consumption per energy carrier (MWh)

The transport sector has the highest energy consumption (about 563 GWh), followed by Residential (358 GWh) and Commercial (206 GWh).

In 2009, electricity production from renewable sources amounted for 2.78 % of the total energy consumption, in particular due to biomass and thermal solar contribution. Nevertheless, in the last years an increase of electricity production from photovoltaic plants has been observed as a result of national incentives. Tables 2 and 3 provide a detailed overview on the number of photovoltaic plants and their total capacity realised for the city of Potenza and some comparisons with the regional and national figures.

The energy system of Potenza represents an interesting case study in order to assess the economic feasibility and environmental benefits related to the implementation of a microgrid in a small-medium sized town.

This pre-feasibility study (Mauro and Morrone, 2014) was committed by the municipality of Potenza to the engineering company "Geco SRL Unipersonale" in the framework of the South East Europe project "RE-SEEties: Towards resource efficient urban communities" (RE-SEEties project, 2014).

Table 2 - Photovoltaic plants at local, regional and national level (August 2014). (Atlasole, 2014)

	City of Potenza	Basilicata Region	Italy
No of plants	403	6,578	550,792
Total capacity	7439	35,119	17,773,000

Table 3 - Photovoltaic plants in the municipality of Potenza per capacity (August 2014). (Atlasole, 2014)

	No of plants	Total capacity
< 3 kW	134	381
From 3 kW to 20 kW	250	2085
From 20 kW to 200 kW	11	772
From 200 kW to 100 kW	8	4202

The proposed application is aimed to manage electric flows for a residential complex which has been recently realised in Bucaletto, a residential settlement built in 1981 in the eastern area of the city as a housing neighbourhood for homeless people after the 1980 earthquake. This new residential complex is constituted by two buildings with a total number of 34 apartments in which are expected to live 128 tenants.

The energy requirement for private households, reported in Table 4, was evaluated on the basis of the average consumption for private users in the municipality of Potenza which is around 1,932.80 kWh/year.

Table 4 - Energy requirements for private user

Buildings	A	B	Total
Apartments (No.)	16	18	34
Surface (m^2)	1092.58	1295.35	2387.93
Foreseen tenants (No.)	56	72	128
Energy consumption (kWh)	30,925	34,790	65,715

In order to compute the overall energy requirement it should be included also the contribution of the common zones of the two buildings. The unitary energy requirement per each of the seven identified common zones is 7,592 kWh/year, as shown in Table 5. Thus, the overall amount of common zones accounts for 53,144 kWh/year.

Table 5 - Energy requirement for common zone

Electricity end-user	Hours /day	Power (kW)	Annual consumption (kWh)
Elevator	2.0	3.3	2409
Stairway lighting	2.5	0.6	547.5
Box/cellar lighting	1.0	0.7	255.5
Emergency lighting	24.0	0.1	876.0
Intercoms	24.0	0.2	1,752
Antennas	24.0	0.2	1,752
Total			7,592

Based on the above calculations, the overall energy requirements of the new two buildings is about 120,000 kWh/year, which takes into account both the private users and common zones (elevator, stairway lighting, intercoms, etc).

Components of the microgrid are a photovoltaic plant, a system of electric storage (lead-acid battery), efficient lighting, building automation and smart appliances.

The electricity production was estimated utilising the PVGis software (Photovoltaic Geographical Information System (PVGIS, 2014), considering an annual productivity of 1,300 kWh/kWp.

In order to satisfy the total energy requirement of the residential complex, it was considered the installation of a photovoltaic plant characterised by a capacity of 98 kWp, a surface of 800 square meters, and an annual average production of 121,030 kWh. It is assumed a 20-year time horizon of electricity generation, with a maximum yearly production of 127,400 kWh in the first year, which decrease annually by 0.5 % over the following years.

Table 6 - Investment costs of the microgrid

Technology	Size	Investment costs (€)
Photovoltaic plant	98 kWp	147,000
Storage system	160 kWh	70,000
Timed electrical outlets	2 for each dwelling unit	680
Remotely controllable outlets	2 for each dwelling unit	2,040
Management System and Smart Meter	1 Central system and 34 Smart meters (1 per unit)	12,000
Control unit and Alarm ZigBee	2 Central systems and 34 Smart meters (1 per unit)	3,000
Total		234,720

Generally, the consumption of energy produced by a photovoltaic system, even in case of daytime attendance in apartments, not exceeds 35 % of the electricity production. For this reason the share of self-produced electricity in excess (at least 65 %) is compulsorily sold to the national grid.

The overall efficiency of the photovoltaic system can be improved through the installation of an electric storage system which can increase the percentage of self-consumed electricity from 30-35 % to 80-85 % thanks to the accumulation of the electricity produced from photovoltaic plant (which can provide a further 45-50 % of the estimated average daily consumption).

As the average daily consumption is about 330 kWh/day, then the electric storage system can assure a capacity of about 160 kWh.
Another key issue is to assure the matching between electricity consumption with the periods of peak production. To this end the main appliances (dishwashers, washing machines, etc.) of the connected users will be provided with suited control systems (e.g. radio-controlled outlets, remotely controllable outlets, etc.) in order to adapt their load profile with the production's one, turning on and off automatically.

The management, control and monitoring of energy flows is ensured by a hardware and software control system that can interface the electronic systems and can assure communications with the public grid. Smart meters allow the constant monitoring of electricity consumption and the real-timetransmission of information.

The estimated total investment cost for the realisation of this microgrid is about 234,720 Euro (Table 6), 63 % of which is due to the purchase of the PV system.

In Table 7 the operation & maintenance costs are reported on the 20-year time horizon, assuming a 3 % average annual increase.
For the evaluation of financial savings it is necessary to make an assessment of the procurement costs both before and after the installation of the plant, using the costs provided by the Italian Authority for Electricity Gas and Water (Italian Authority for Electricity, Gas and Water, 2014) Table 8 shows the economic savings obtainable by the realisation of the proposed microgrid, which account for 21,449 Euro in the first year with an annual increase of 2.5 % due to the expected increase of energy prices.

Table 7 - Operation & maintenance costs of the microgrid

Years	Photovoltaic plant	Storage system	Management system and Smart Meter	Control unit and Alarm ZigBee	Other costs	Total
1	0	0	0	0	0	0
2	5,880	1,500	1,000	150	100	8,630
3	6,056	1,545	1,030	155	103	8,889
4	6,238	1,591	1,061	159	106	9,156
5	6,425	1,639	1,093	164	109	9,430
6	6,618	1,688	1,126	169	113	9,713
7	6,817	1,739	1,159	174	116	10,005
8	7,021	1,791	1,194	179	119	10,305
9	7,232	1,845	1,230	184	123	10,614
10	7,449	1,900	1,267	190	127	10,932
11	7,672	1,957	1,305	196	130	11,260
12	7,902	2,016	1,344	202	134	11,598
13	8,139	2,076	1,384	208	138	11,946
14	8,383	2,139	1,426	214	143	12,304
15	8,635	2,203	1,469	220	147	12,673
16	8,894	2,269	1,513	227	151	13,054
17	9,161	2,337	1,558	234	156	13,445
18	9,436	2,407	1,605	241	160	13,849
19	9,719	2,479	1,653	248	165	14,264
20	10,010	2,554	1,702	255	170	14,692

Table 8 - Comparison among costs of electricity purchase with and without the microgrid, in the first year

	Scenario	Purchased energy (kWh/year)	Cost (€/year)
Private users	Pre-intervention	65,715	11,228
	Post-intervention	9,857	2,941
	Saving	55,858	8,288
Common zone	Pre-intervention	53,144	16,323
	Post-intervention	10,629	3,161
	Saving	42,515	13,162
Total	Pre-intervention	118,859	27,551
	Post-intervention	20,486	6,102
	Saving	98,373	21,449

Moreover it should be considered the incomes which can be obtained from the sale of the electricity produced and not self-consumed to the GSE (Italian Manager of Electricity Services (2014). Erring on the side of caution it was assumed a sale price lower than the current one but with an annual increase of 2.5 %. Table 9 reports, per each year, the electricity production of the PV plant and the related revenues which can be obtained from the sale of electricity to the national grid. Such revenues account for 33,878 Euro on the overall 20-year time period.

Assuming that the proposed intervention will be paid by the owners of the new buildings, then according to the current national laws, it will be possible to deduct taxes, in the extent of 50 % of the total investment. This tax deduction is split into 10 constant annual instalments which account for 5 % of the total annual investment, allowing an annual saving of 11,736 Euro.

Economic feasibility analysis

The methodology used to perform the analysis of economic feasibility is consistent with the criteria established by the evaluation techniques of public utility investments, according to the guidelines provided by the Evaluation Unit of the European Commission - DG Regional Policy (Guide to cost-benefit analysis of investment projects, 2003).
The assumptions adopted to perform the analysis of economic feasibility relate to a period of 20 years and a 3.5 % discount rate. Moreover, assuming a 25-year useful life for the photovoltaic system, the residual value of the proposed works amounts to 29,400 Euro, which represents 20 % of the investment cost of the PV system.

Preliminarily it is necessary to convert the benefits and financial costs associated with the investment to the shadow prices in order to approximate the prices to those of a perfectly competitive market. To this end, it was used a 0.8850 conversion factor for investment costs of plant works, producing the results reported in Table 10.

Table 9 - Assessment of the yearly electricity production and revenues from the sale to the national grid

Years	Electricity produced (kWh/year)	Self-consumed electricity (kWh/year)	Electricity sold to the national grid (kWh/year)	Sale average price (Euro/kWh)	Total revenue (Euro/year)
1	0	0	0	0.06	0
2	127,400	98,373	29,027	0.0615	1,785
3	126,763	98,373	28,390	0.063	1,790
4	126,169	98,373	27,796	0.0646	1,796
5	125,499	98,373	27,126	0.0662	1,797
6	124,871	98,373	26,498	0.0679	1,799
7	124,247	98,373	25,874	0.0696	1,800
8	123,625	98,373	25,252	0.0713	1,801
9	123,007	98,373	24,634	0.0731	1,801
10	122,392	98,373	24,019	0.0749	1,800
11	121,780	98,373	23,407	0.0768	1,798
12	121,171	98,373	22,798	0.0787	1,795
13	120,566	98,373	22,193	0.0807	1,791
14	119,963	98,373	21,590	0.0827	1,786
15	119,363	98,373	20,990	0.0848	1,779
16	118,766	98,373	20,393	0.0869	1,772
17	118,172	98,373	19,799	0.0891	1,764
18	117,581	98,373	19,208	0.0913	1,754
19	116,994	98,373	18,621	0.0936	1,743
20	116,409	98,373	18,036	0.0959	1,730

Analogously, a 1.0182 conversion factor was used to derive operating and maintenance costs of plant works, as showed in Table 11 (second column).

An assessment of the socio-economic convenience of the proposed investments is provided in Table 12, which reports the revenues obtainable by electricity sale and tax deduction.

In order to monetise the economic benefit due to the lack of production of CO_2 emissions, it is considered that every kWh of electricity produced by a PV system on average allows to avoid 0.531 $KgCO_2$. This means, for the first year, a total emission saving of 67.65 $tonCO_2$ on the basis of an electricity production of 127,400 kWh/year. As concerns the following years, the environmental benefits slightly decrease, due to the reduction in electricity generation, reaching the minimum value of 61.81 $tonCO_2$ in correspondence of the twentieth year.

Table 10 - Assessment of socio-economic convenience of the investment - Investment costs

Years	PV plant	Storage system	Other equipment	Total investment
1	130,095	61,950	15,682	207,727
2 to 19	0	0	0	0
20	-26,019	0	0	-26,019

Table 11 - Assessment of socio-economic convenience of the investment – Operating costs

Years	Change in O & M costs	Change in costs of energy purchase	Total operating costs
1	0	0	0
2	8,787	-21,449	-12,662
3	9,051	-21,985	-12,934
4	9,323	-22,535	-13,212
5	9,602	-23,098	-13,497
6	9,890	-23,676	-13,786
7	10,187	-24,268	-14,080
8	10,493	-24,874	-14,382
9	10,807	-25,496	-14,689
10	11,131	-26,134	-15,003
11	11,465	-26,787	-15,322
12	11,809	-27,457	-15,647
13	12,163	-28,143	-15,980
14	12,528	-28,847	-16,319
15	12,904	-29,568	-16,664
16	13,292	-30,307	-17,015
17	13,690	-31,065	-17,375
18	14,101	-31,841	-17,740
19	14,524	-32,637	-18,114
20	14,959	-33,453	-18,494

Considering a constant price of CO_2 of 6.2 Euro/ton, which is the value observed by the $SENDECO_2$ Stock Exchange in August 2014, (Shively and Galopin, 2014), the monetary evaluation of the avoided CO_2 emissions ranges from 420 Euro/year (in the first year) to 383 Euro/year (in the twentieth year) with an overall saving of 7,621 Euro on the 20-year time horizon.

The cash flow values are obtained for each year (Table 14), subtracting the total investment costs (Table 10) and the total operating costs (Table 11) to the values of revenues (Table 12) and externalities (Table 13).

Table 12 - Assessment of socio-economic convenience of the investment – Revenues

Years	Sale electricity	Tax deduction	Total economic benefit
1	0	0	0
2	1,785	10,386	12,171
3	1,790	10,386	12,176
4	1,796	10,386	12,182
5	1,797	10,386	12,183
6	1,799	10,386	12,185
7	1,800	10,386	12,186
8	1,801	10,386	12,187
9	1,801	10,386	12,187
10	1,800	10,386	12,186
11	1,798	10,386	12,184
12	1,795	0	1,795
13	1,791	0	1,791
14	1,786	0	1,786
15	1,779	0	1,779
16	1,772	0	1,772
17	1,764	0	1,764
18	1,754	0	1,754
19	1,743	0	1,743
20	1,730	0	1,730

Table 13 - Assessment of socio-economic convenience of the investment – Externalities

Years	Electricity produced (kWh)	Avoided CO_2 emissions (ton)	Externalities (Euro)
1	0	0	0
2	127,400	67.65	420
3	126,763	67.31	417
4	126,169	67	415
5	125,499	66.64	413
6	124,871	66.31	411
7	124,247	65.98	409
8	123,625	65.64	407
9	123,007	65.32	405
10	122,392	64.99	403
11	121,780	64.67	401
12	121,171	64.34	399
13	120,566	64.02	397
14	119,963	63.7	395
15	119,363	63.38	393
16	118,766	63.06	391
17	118,172	62.75	389
18	117,581	62.44	387
19	116,994	62.12	385
20	116,409	61.81	383

Table 14 - Assessment of socio-economic convenience of the investment – Cash flows

Years	Cash flows
1	-207,727
2	25,254
3	25,531
4	25,813
5	26,099
6	26.391
7	26,688
8	26,990
9	27,297
10	27,609
11	27,926
12	17,862
13	18,191
14	18,524
15	18,863
16	19,208
17	29,558
18	19,914
19	20,276
20	46,663

Main results and conclusions

The analysis carried shows that the microgrid realisation in the City of Potenza can allow significant economic and environmental benefits to the local community. In particular, evidence of the economic feasibility of the project can be provided through the following indicators, commonly utilised in benefit – cost analysis (see, for instance, Shively and Galopin 2014):

- net Present Value (NPV), which expresses the profitability of the project on the basis of the financial and economic flows required, as well as their collocation along the time horizon;
- internal Rate of Return (IRR) which identifies the discount rate at which the discounted value of revenues equals the present value of the costs, individuating a limit to the effective rate of interest over which the project is no longer affordable;
- ratio between actualised benefits and actualised costs (BCR).

In the Potenza's case study these indicators of economic convenience amount to:

- NPV=129,030 Euro
- IRR =10.03 %
- *BCR=1.66*

Analysing the significance of such values makes evident the economic convenience of realising a microgrid system in the City of Potenza. As a matter of fact, being the NPV value well greater than zero then the project appears to be a very good candidate for implementation from an economic point of view. This is confirmed by an IRR greater than the discount rate (3.5 %) and a BCR which exceeds one, both the values outlining that the proposed project might be a good candidate for acceptance.

It should be pointed out that the success of the economic feasibility of the proposed intervention is mainly due to the use of tax deductions which makes particularly favourable investments in renewable energy technologies and, in particular, photovoltaic plants. From an environmental point of view, energy savings in the generation of electricity from fossil fuelled power plants produces interesting benefits in terms of greenhouse gas emissions avoided, allowing a yearly saving ranging from 67.65 and 61.81 tonCO_2, respectively, for the first and the twentieth year. This brings to an overall benefit of about 1,230 tons of CO_2 on the overall time horizon (20 years).

This paper shows how profitable could be the realisation of microgrids in a territory like Basilicata, which has a very high potential in terms of exploitation of renewable energy sources, particularly sun and wind. This is particularly true in those regions which benefits from tax deductions related to investments in green technologies and energy-efficiency measures.

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Environmental and economic potential of using earth as building material in the north of Portugal

Recently, the growing environmental awareness and greater legal requirements on energy efficiency led to rethink the construction industry in Portugal. The concerns of this industry, in the recent past, have been essentially focused on the reduction of economic costs through the optimisation of production processes, essentially based on its energy efficiency. They were also more related to the construction of new buildings that, although more efficient in several parameters, present some environmental problems, in many cases due to an extensive use of mechanised construction methods and prefabricated industrial materials.

Apart from the use of more efficient envelope walls, roofs, windows and HVAC equipment, there is still the opportunity for improvements that can rely on less energy demanding strategies. In this turning era, seeking for cleaner forms of energy and more efficient buildings, it is worth returning to study the vernacular buildings in order to develop and adapt their strategies to the current context of construction, contributing to its sustainability. This option of using local materials and technologies aimed at recovering and reinterpreting vernacular construction in new buildings, in pair with the refurbishment and rehabilitation of existing buildings, is nowaday a considerable growing phenomena.

This paper aims to evaluate the environmental and economic potential of using earth as construction material. These solutions were common on traditional buildings, especially in the centre-south region of Portugal, particularly in the vertical exterior envelope, where it can present interesting properties when compared with conventional solutions based on hollow brick. A case study is presented to illustrate this potential.

Authors

Fernando B. Alves [1]
alves@fe.up.pt

Paulo Mendonça [2]
mendonca@arquitectura.uminho.pt

Cecilia Rocha [1]
carocha@fe.up.pt

1) University of Porto / CITTA, Portugal
2) University of Minho, Portugal

Introduction

The construction industry is a large consumer of raw materials and energy, which are associated with pollutant emissions, not only related with the extraction, production and transport of building materials, but also with the use and eventual demolition of the building at its end of life. These negative consequences manifest both in the flora and fauna of the ecosystems and in the humans who inhabit and exploit them for subsistence. Technologies that minimise the resource consumption and the environmental impact of the built environment need to be developed (Kibert, 2008). Sometimes, the appropriate responses already exist and can even be found in the past, exploring vernacular solutions that can easily be reintroduced with minor improvements to fulfil contemporary needs.

Vernacular buildings use local materials, only slightly transformed, handled and transported for short distances, so it can be said that their environmental impact in terms of energy and material resources is almost null. The knowledge inherent to this type of construction will contribute to reducing waste and energy consumption. Construction remains a matter of international interest, currently associated with awareness regarding sustainable construction. Portugal is no exception, and despite its small dimension, there is a large number of examples of such type of constructions (Fernandes, et al., 2012).

The most common building system used in Portugal is currently steel-reinforced concrete frame, using hollow brick as filling material in the walls and ceramic blocks on slabs (both weighting approximately 350 kg/m² if one consider a 0,22 m thick slab and a double wall of 0,40 m thick).

A vernacular building in Portugal generally presents massive masonry exterior walls (almost 1000 kg/m² of stone or earth) and lightweight pavements and roofs in natural timber (around 150 kg/m²). These buildings, built according to the principles of bioclimatic Mediterranean vernacular architecture, are characterised by the presence of seasonal constant temperatures and have natural ventilation that guarantees comfort, especially during summer.

Presently, it can be concluded that, on average, the global weight of buildings is similar to the weight of traditional vernacular houses but, despite some increases on mechanical and functional performances, the environmental impacts are significantly higher, due to use of industrialised materials, processes and systems, together with the decrease of recycling and reuse possibilities, since the components are cemented and not only juxtaposed or mechanically fixed as in the past.

Figure 1 - Left - Aerial view of a vernacular settlement in the central region of Portugal. All houses present massive masonry exterior walls of shale stone and the structure of the roofs in natural timber. Courtesy of FotoEngenho – Francisco Piqueiro. Right - Detail of a masonry exterior wall of shale stone (Portugal – littoral Douro region)

Courtesy of Nuno Abrantes

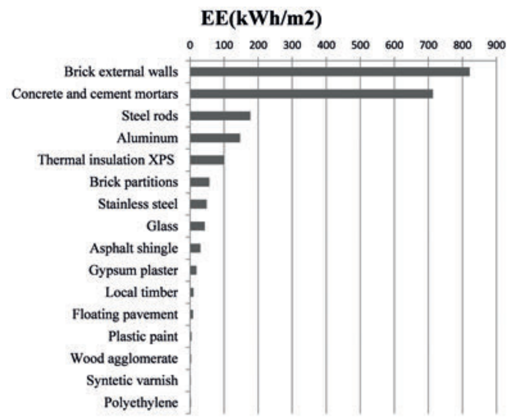

Figure 2 - Material's Embodied energy in a conventional building in Portugal (Fernandes et al., 2012)

The energy needed to produce a building material - Embodied Energy (EE) - corresponds on average to 80 % of the total energy of a building product. From a research study performed by Mendonça (2005), the most significant impact, in terms of EE, in Portuguese conventional buildings as it can be seen in Figure 2, is related with the use of bricks, on external walls as well as on partitions and as blocks in concrete slabs.

Focusing on the central topic of 'Cost & value analysis', this paper examines the environmental and economic potential of using earth as a building material, starting from the knowledge of a regional and vernacular building practice to the implementation of new constructive solutions, more sustainable, as they induce less environmental impacts, once they are produced locally, with local raw materials that suffer less transformations.

It proposes a new model of reinterpreting old construction practices and techniques, involving natural materials, leading to innovative construction techniques capable of improving the quality of life and housing conditions that can be replicated at regional and national levels, and even internationally, in countries with similar climate characteristics.

Cost and value in vernacular construction

In recent years a large number of research studies, from Europe, North America and Asia, have been published, highlighting the potential of vernacular construction in energy efficiency strategies. Those studies analysed the response of ancient construction practices in terms of energy consumption, hygrothermal indoor comfort, natural ventilation and potential use in retrofitting.

In a moment when the concerns about climate change are strongly discussed, regarding adaptation and mitigation measures, and with the increasing price of all forms of energy the challenge is to develop or to recover practices and techniques of construction that enable a more efficient use of those resources. Vernacular architecture emerges as an adequate response (Nguyen, et al., 2011) to these concerns. The good thermal behaviour during the warmer seasons and the conditions for storing energy in the cooler periods (due to building elements with high thermal mass), implies smaller variations in indoor temperatures (per season), reducing the cooling needs and assuring that traditional heating systems will be enough,regarding indoor thermal comfort in periods of lower temperatures (Cardinale, et al., 2013).

In particular, compared to contemporary building materials with high embodied energy "(…) the energy required to produce mud brick and straw bale buildings is minimal. In addition to their energy efficient behaviour during use, these two materials are completely bio-degradable." (Elias-Ozkan et al., 2006). Although this kind of vernacular techniques requires higher maintenance, they still are more appropriate and affordable.

Nowadays, a few scientific studies have been driven to test the efficiency of vernacular materials when compared to the use contemporary materials. In those studies, rather than test single elements, experiments on the full wall assembly were conducted, in order to represent the entire envelope.

Masonry solutions for external walls

In Portugal, hollow brick has been the most common construction material of exterior walls since the middle of the past century (Mendonça, 2005).

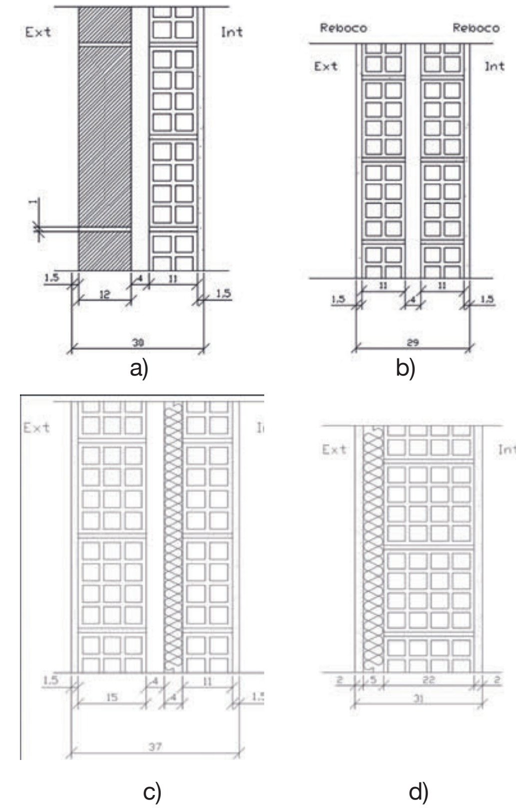

Figure 3 - Hollow brick external walls:
a) Double with stone masonry on the exterior leaf, without thermal insulation;
b) Double without thermal insulation;
c) Double with thermal insulation;
d) Simple with external insulation (ETIC system)

In the 50's double walls were introduced, sometimes with stone masonry (Figure 3a) or massive brick on the outside leaf. During the 60's the double walls traditionally, consisted of hollow bricks, most times with a thicker layer in the exterior leaf. In 70's the construction quality has decreased with both leafs of small thickness (Figure 3b), or even simple walls, especially in the South of Europe, where the climate is warmer. Only in the 80's the use double walls demonstrated improved qualities, including the construction of exterior thicker leafs with thermal insulating materials in the air gap (Figure 3c) that emerged as rule with the introduction of the first Portuguese Thermal Regulation in 1990 (Portugal, 1990).

New regulatory requirements associated with the revision of the Building thermal regulation in 2006 (Portugal, 2006) and 2013 (Portugal, 2013) forced the introduction of new solutions, including the correction of thermal bridges and increased U-values, achieved mostly with the ETIC system (Figure 3 d), used in most of the European countries.

The use of adobe and rammed earth, especially when reinforced with timber grid structures, is not a novelty in the north of Portugal. Taipa - a type of rammed earth - is a vernacular building technique (a very common solution until the XIXth century) based in clay and gravel, used to build walls. Until the 50's, taipa was the most widely used construction technique, both in the southern regions of Alentejo and Ribatejo, as in the Algarve (south of Monchique and Caldeirão mountains).

Although the inner north and centre of the country (highlands) are dominated by stone masonry, sometimes it is possible to find "Taipa de Fasquio" (wattle and daub) and "Taipa de Rodízio" (daub and half-timbered) both in some houses with two or more floors, and also in the poorest housing of one floor. Regarding the use of this technique, it is frequently found in lighter walls (Correia & Merten, 2010). Figure 4 shows a wall that is made with both of these solutions, exposed due to the absence of the covering layer.

Figure 4 - "Taipa de fasquio" and "Taipa de rodízio" – Wattle and daub/Daub and half-timbered techniques in the same wall, on a traditional house in Guimarães, Portugal

The research around this vernacular building system has been divided between monographic studies, relating to the conservation of built heritage sites and research studies alluding to contemporary architecture and, with respect to constructive standards or rules and aspects related to the behaviour of construction material and construction technology (Francese et al., 2013; Fernandes, 2013).

It is known that the use of this material is not limited exclusively to a construction technique, it also reflects social, cultural and economic perspectives of an era. One of the most relevant characteristics of these vernacular houses, particularly in the south of the country, is the possibility of adjusting the interior structure of dwellings according to the family growth. Therefore, this type of construction is not rigid, and presents some flexibility, enabling changes according to the needs and preferences.

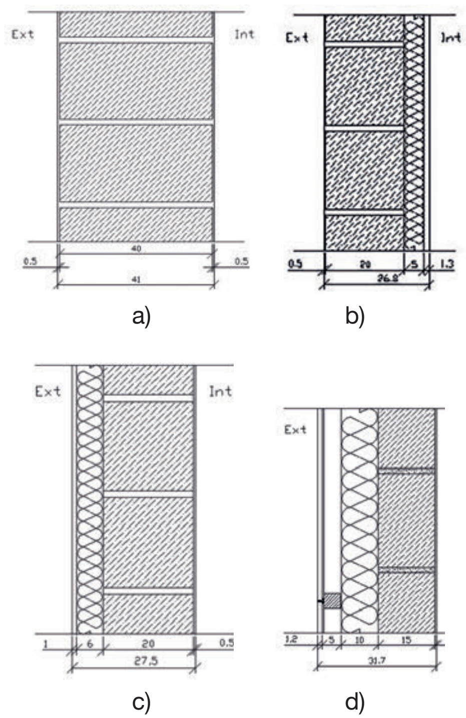

Figure 5 - Adobe / Rammed earth walls: a) traditional structural; b) non-structural with interior insulation; c) non-structural with exterior insulation; d) non-structural with exterior insulation and ventilated façade

Although the use of this non-reinforced rammed earth or adobe massive walls (Figure 5a) prevailed in the south of Portuguese territory, this construction technique fitted well with the European southern climate, warmer and with less pluviosity. The timber reinforced solutions, more suitable for the urban settlements, present less thickness, around 20 to 30 cm.

The solutions evaluated and proposed within this paper are presented on Figure 5b), c) and d). All of them fulfil the U-value presently required on REH for I1 areas of the Portuguese territory (less demanding in winter) (Portugal, 2013) and include a protective layer against rainfall in the exterior leaf.

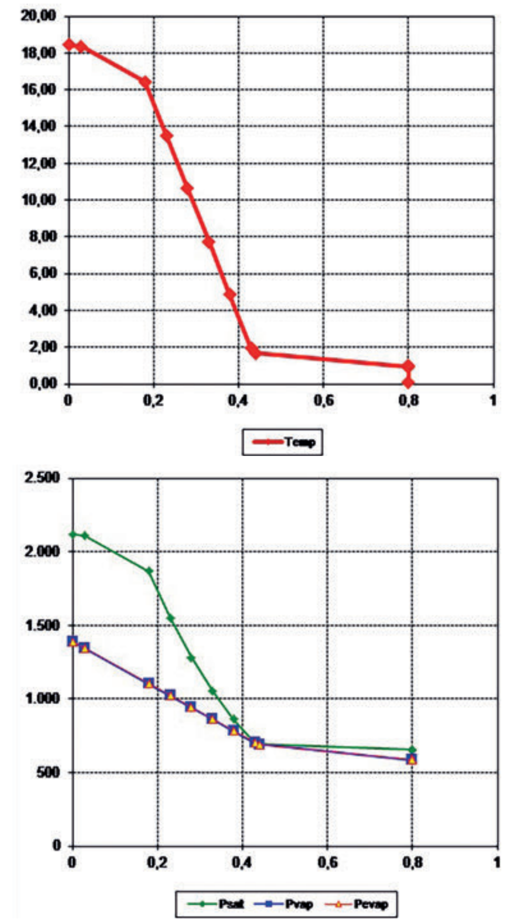

Figure 6 - Study of the condensation occurrence probability on the A15 adobe wall with ventilated facade, insulation in cork 10cm and ventilated air gap 5cm based on EN 13788, for an exterior critical temperature of 0ºC

Condensation occurrence probability for the exterior wall solutions studied

The study of condensation occurrence probability of the studied walls was analysed according to EN ISO 13788 (ISO, 2012). The evaluation was performed for a critical situation of winter: outdoor temperature of 0°C, 90 % of relative humidity (RH), indoor temperature of 20°C, 75 % of RH. From the results obtained following the procedures stated in EN ISO 13788 it was observed that, even in situations of critical temperature and humidity, there is no condensation inside the walls studied, as it can be seen on the examples of Figure 6 and Figure 7.

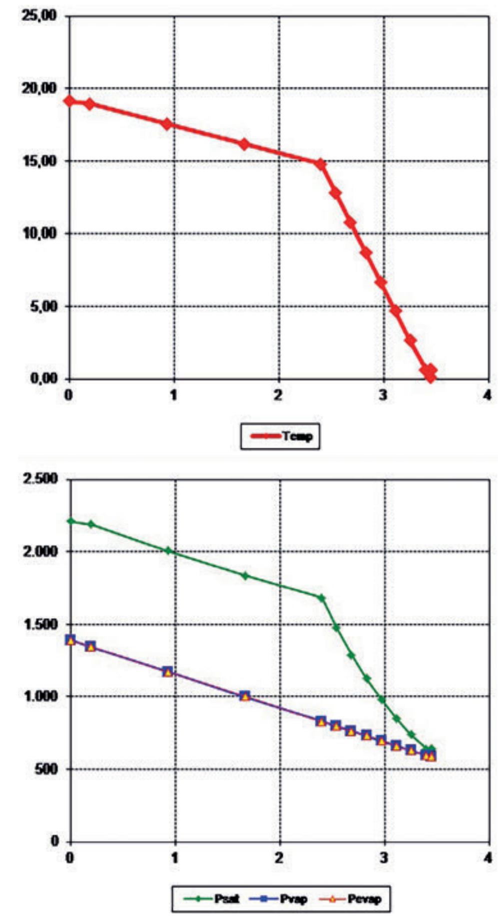

Figure 7 - Study of the condensation occurrence probability on the B22 hollow brick 22cm and exterior insulation EPS 5cm (ETIC) based on EN ISO 13788, for an exterior critical temperature of 0ºC

Acoustic insulation estimation for the exterior wall solutions studied

The airborne sound insulation (Rw) of the exterior wall solutions should also be a factor taken into account in the selection. The curve was estimated according to EN 12354-3 (CEN, 2000), and in order to present a unique value, this was weighted with a reference curve as described in EN ISO 717-1 (ISO, 2013). Examples of the simulations are shown in Figure 8 and in Figure 9.

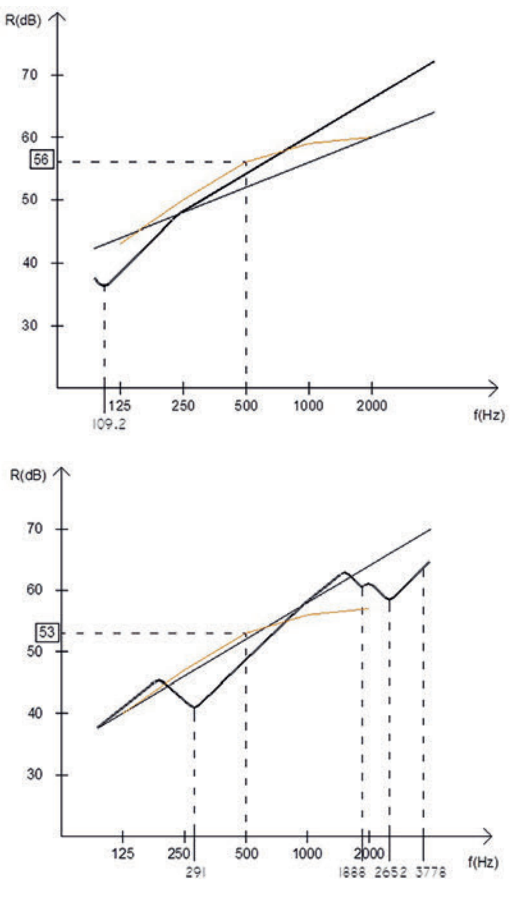

Figure 8 - Airborne sound insulation (Rw) of A40 and A15 adobe wall solutions estimated according to EN 12354-3 (CEN, 2000) and EN ISO 717-1 (ISO, 2013)

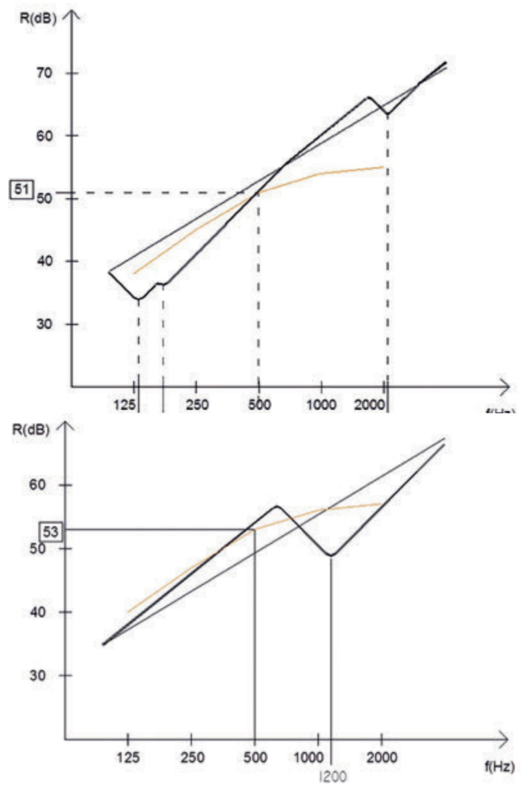

Figure 9 - Airborne sound insulation (Rw) of B11+15 and T22 hollow brick wall solutions estimated according to EN 12354-3 (CEN, 2000) and EN ISO 717-1 (ISO, 2013)

Synthesis of the properties of the analysed walls

Table 1 shows some characteristics of the walls analysed, with a summary of the properties more related with human comfort and environmental impact. In the constitution of each wall the numbers correspond to the thickness in cm and the letters to the material, from inside to outside, for example L0,5+A40+L0,5 refers to 0,5 cm of lime on the inside, 40 cm of adobe masonry, 0,5 cm of lime on the exterior leaf.
The materials used are indicated as follows:
A) Adobe masonry
B) Hollow brick
C) Expanded Cork
G) Air gap
L) Lime
P) Plaster
V) Cement wood particle boards
X) XPS / EPS thermal insulation

Table 1 - Properties of the adobe walls in comparison with the conventional hollow brick walls (adapted from (Mendonça, 2005)

Wall type designation	A40 – Figure 5 (a)	A20 – Figure 5 (c)	A15 – Figure 5(d)	B11+15- Figure 3 (c)	B22 – Figure 3(d)
Composition	L0,5+ A40+ L0,5	L0,5+ A20+ X6+P1	L0,5+ A15+ C10+G 5+V1,2	P2+B1 1+X4+ G4+ B15+P2	P2+ B22+ X5+P1
Acoustic Insulation – Dn,w (dB(A))	56	52	53	51	53
U value	2.66	0.44	0.43	0.45	0.44
(W/m²ºC) Embodied Energy (kWh/m²)	80	229	179	910	812
Weight (kg/m²)	620	350	257	313	277
Thermal mass – Msi (kg/m²)	150	150	150	150	150
Economic cost (€/m²)	27.1	45.2	54.3	63.4	56.7

Hygrothermal performance comparison between traditional adobe walls and conventional hollow brick housing construction

Test cell facility
Based on the traditional daub and half-timbered system referred previously, using a non-structural adobe exterior wall solution, a proposed test cell (TC1) was built in the University of Minho, Guimarães. A reference test cell (TC2), located close to the previously referred one, using hollow brick on the external envelope, was used to evaluate the performance of the conventional solution. The test cells facility is represented in Figure 10.

The housing type and methodology considered for this study are described in detail by Mendonça in previous studies (Mendonça, 2005; Mendonça & Bragança, 2007).
Both TCs have a rectangular shape (approximately 6,5x 3,1 m), are south/north oriented and have a telescopically moveable window on the south façade in order to allow this space to work as an attached sunspace or a dynamic/trombe wall. The preference was for a good thermal performance in winter rather than in summer, that is why the solution of attached sunspace was the adopted (Mendonça, 2005). Beyond the favourable values foreseen for the heating needs, the sunspace allows a useful area advantage that can be used as circulation in the proposed architectonic solution, and it does not represent a significant increase of cost in relation to a trombe wall system for indirect gains.

TC1 was divided in two parts separated by a timber moving partition: 1 – an heavyweight south oriented zone (sleeping area) with adobe walls and a concrete structure, pavement and ceiling slabs, 2 – a lightweight north oriented zone with timber structure and sandwich pavement, ceiling and walls.

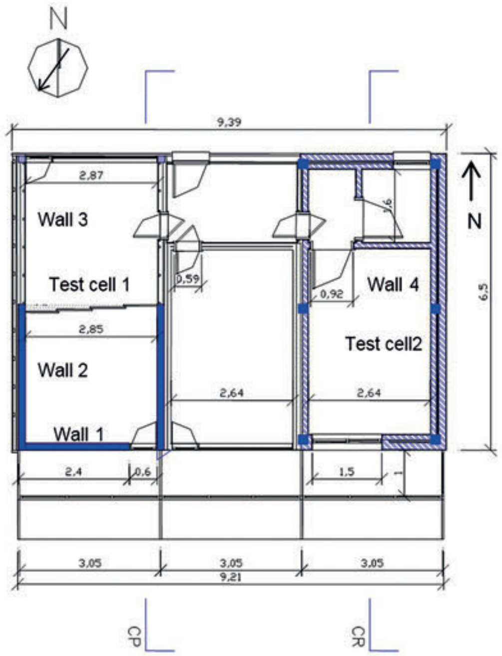

Figure 10 - Test cells plan (Mendonça, 2005)

In the heavyweight area there are two types of walls whose positions are indicated in Figure 10: wall 1 (A40) is an adobe wall without insulation and a black exterior finishing, suitable for thermal gains; wall 2 (A15) (Figure 5d) is a double leaf wall with a 15 cm adobe leaf on the interior, a fibre-wood cement board exterior leaf and a ventilated 15 cm air gap with 10 cm expanded cork insulation. The north oriented zone (working area) has lightweight triple leaf wall (wall 3) with an exterior ventilated 15 cm air gap and an interior layer with 8 cm of expanded cork and 2 cm of coconut fibres (Mendonça & Bragança, 2007).

TC2 has the same dimensional characteristics of TC1, but is made with a conventional construction solution. This test cell corresponds to the most traditional construction system in the contemporary Portuguese buildings – based on a steel reinforced concrete structure, with pavement and ceiling formed by pre-stressed concrete “T” beams and pot slabs. The exterior walls (wall 4 – B11+15) are double leaf (11+15 cm) hollow brick with 4 cm of extruded polystyrene insulation (XPS) placed in the air gap and finished with plaster on both sides. Figure 3c show the vertical scheme of this type of wall.

Hygrothermal performance measurements
The moveable partition, separating in two halves the TC1, allowed the evaluation of distinct compartment layouts – (A) open space and (B) divided in two compartments - both by hygrothermal measurements made in-situ (Mendonça, 2005). A significant thermal lag difference due to compartment layouts can be verified by the analysis of the resultant temperature charts. With the partition opened during summer, only TC1 presented values partially inside the comfort zone of the ASHRAE comfort chart, in particular the south compartment of TC1 almost always inside the comfort zone, as it can be seen in Figure 11a. Closing partition and with high exterior ambient temperature, only TC1 presented values totally inside the comfort zone for the south compartment and partially inside the north compartment, even if the thermal lag was significant – approximately 7OC. TC2 was always outside the comfort zone even if it was by a small difference, essentially due to relative humidity, as can be seen in Figure 11b.

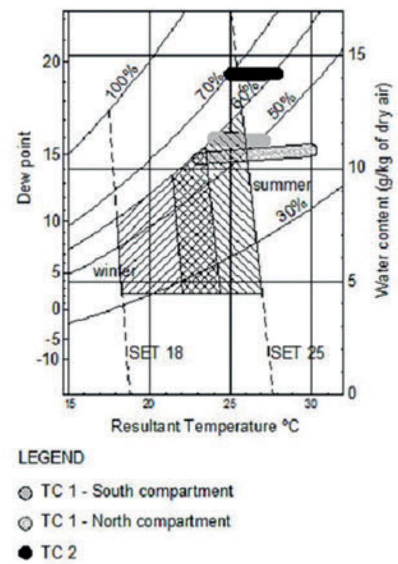

Figure 11a - Comfort evaluation on ASHRAE´s comfort chart in the end of summer (15 till 21 September – opened partition on TC 1

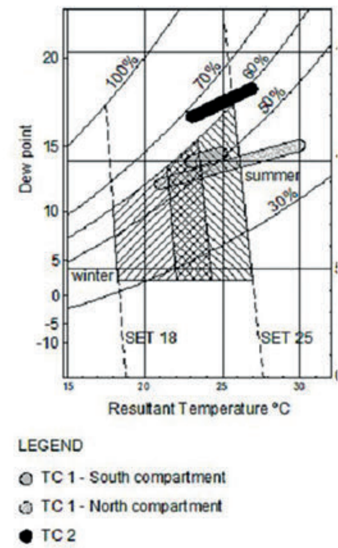

Figure 11b - Comfort evaluation on ASHRAE’s comfort chart in the end of spring with high temperatures (14 till 20 May – closed partition on TC 1;

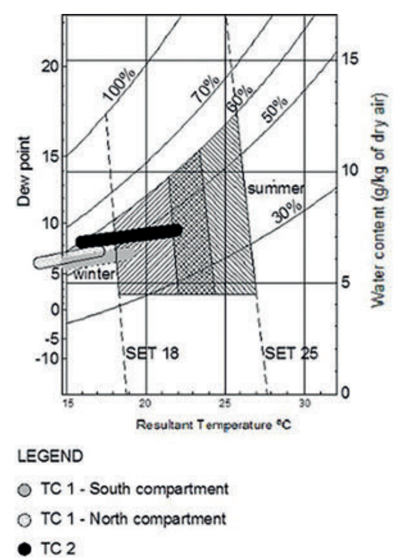

Figure 11c - Comfort evaluation on ASHRAE’s comfort chart in the autumn, with low temperatures (12 till 16 November – closed partition on TC 1) (Mendonça, 2005)

Considering the partition on TC1 closed during the measurements period with low temperatures, only TC2 showed values partially inside the comfort zone. TC1 presented a minor difference for the comfort zone on the south compartment, yet with relative humidity values slightly lower than the rest of the studied compartments, as is shown in Figure 11c.
This example shows that the proposed test cell demonstrated a more favourable hygrothermal performance during the cooling season (summer) and slightly more unfavourable throughout the heating season (winter), due to a larger area of window on the north facade. In terms of relative humidity TC1 was always more favourable, with measured values under 60 % in most of the cases, while TC2 reached values over 70 %, especially during summer, what is going to limit the comfort as well as durability and indoor air quality. This was induced by the hygroscopic inertia of the adobe.

Analysis of environmental indicators

To synthetise the environmental impact that each material used in the construction has on the environment, three parameters were considered: embodied energy (EE), global warming potential (GWP), acid potential (AP) and chemical oxygen depletion/photochemical ozone creation potential (COD/POCP) (ISO, 2012). Table 2 presents the results for conventional hollow brick dwellings considered in TC2.

Replacing, in the same dwelling, only the hollow brick on the exterior leaf by adobe, the analysis of Table 3 allows concluding that the general reduction in the considered parameters is around 30 % and can reach even more than 80 % in the COD. Table 4 presents a synthesis of the economic and environmental costs of the building compartment considered in the TC presented previously in this paper, considering different types of wall.

For the energy needs calculation, only heating needs were considered. In the north littoral area of Portugal, the cooling needs are not significant, as it could be concluded from the analysis of Figure 11, so there is no tradition in using HVAC equipment for cooling.

Table 2 - Environmental assessment of the analysed conventional hollow brick dwelling (TC2)

	Weight (kg/m²)	EE (kWh/m²)	GWP (g/m²)	AP (g/m²)	COD / POCP (g/m²)
Brick external wall	651.9	821.39	123,861	1,303.8	11,082.3
Concrete and cement mortars	2,160.8	713.06	140,452	2,160.8	648.2
Steel rods	63.7	177.09	35,480.9	191.1	254.8
Aluminium	3.3	146.78	36,636.6	198.0	392.7
Thermal insulation EPS	3.6	100.30	5,940.0	39.6	0.7
Brick partitions	45.04	56.75	8,557.6	90.1	765.7
Stainless steel	5	48.65	11,150.0	50.0	0.0
Glass	8.5	43.44	4,836.5	374.0	17.0
Asphalt shingle	7.5	30.38	3,667.5	30.0	0.0
Gypsum plaster	18	18.90	4,770.0	54.0	36.0
Local timber	56.7	10.21	6,577.2	56.7	56.7
Floating pavement	6.3	8.76	4,825.8	18.9	50.4
Plastic paint	0.8	4.45	3,120.0	24.0	33.6
Wood agglomerate	2.7	2.92	2,068.2	8.1	21.6
Synthetic varnish	0.1	2.16	390.0	3.0	4.2
Polyethylene	0.1	2.42	75.1	0.9	0.0
Total	3,034	2,188	392,408	4,603	13,364

Table 3 - Environmental assessment of the analysed dwelling (TC2) using adobe exterior wall instead of hollow brick

	Weight (kg/m²)	EE (kWh/m²)	GWP (g/m²)	AP (g/m²)	COD / POCP (g/m²)
Total	3,332.14	1,391.89	276,147.4	3,299.18	2,281.65
	(+10 %)	(-36 %)	(-30 %)	(-28 %)	(-83 %)

From Table 4 one can conclude that adobe walls present less economic and environmental costs. The later ones are associated to embodied energy, transport and heating. Nevertheless, the thickness of the adobe wall is inversely related to the total cost: the thinner wall (A15) has the best performance in terms of construction cost and energy due to the existence of an insulation layer, an air gap and also a non-structural exterior leaf.

Table 4 - Estimated economic and environmental costs of a building compartment with the analysed wall solutions (adapted from (Mendonça, 2005)

Wall type designation	A40	A20	A15	B11+15	B22
Economic indicator					
Costs associated with building construction (€/TC)	1,092	1,018	1,056	1,112	1,057
Environmental indicators Costs associated with EE and transport of materials – converted in economic costs at present cost of electricity – 0,16 €/kWh (€/m2)	206	218	213	286	280
Costs associated with Heating Energy in 1 year (kWh/m2.year)	144	67	66	73	67
Costs associated with Heating Energy in 1 year converted in economic costs at present cost of electricity – 0,16 €/kWh (€/m2.year)	23.3	10.9	10.7	11.8	10.9
Total	229.3	228.9	223.7	297.8	290.9

Conclusions

In life cycle analysis, the issue of the economic cost is essential in choosing more environmentally friendly solutions. This study presents a simple comparison on the use of traditional adobe solutions as an alternative to the conventional hollow brick in exterior walls, showing a significant environmental impact reduction.

However, some aspects have to be upheld. For example the vernacular simple adobe wall (A40), although it is the best solution in terms of embodied energy, does not present an appropriate thermal performance for contemporary legal requirements and has an excessive thickness.

By adding insulation to an adobe solution and a protective and finishing layer, the costs with the thermal comfort decrease to almost half, and a better preservation of the wall can be achieved (A20).

A ventilated façade can also guarantee a better durability in a rainy climate, such as the north of Portugal (A15). This is also the most lightweight solution, assuring that not just the facade walls, but all the remaining building elements, including structural elements, can be optimised in terms of weight, environmental and economic costs. This explains the choice of a mixed solution with natural materials, where the heavy parts are only intended to assure the minimum thermal storage capacity.

With this study it was possible to demonstrate that vernacular architecture practice and knowledge, with its bioclimatic principles and the use of traditional construction materials, can contribute to the promotion of passive and low energy architecture towards a sustainable future. Therefore, not only the intrinsic cost related to the materials, transformation processes and transport is reduced but there is also an added value to the environment and its future sustainability.

Under a cost & value context, Portugal as other European countries with a strong tradition of native construction should explore the mentioned mixed solutions as an efficient way of making contemporaneous architecture.

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A greenhouse gas comparison of combined heat and power and heat pump as the heat solution of a new residential development

Power plants burning fossil fuels generate the majority of the global anthropogenic greenhouse gas (GHG) emissions. Combined heat and power (CHP) production is seen to carry an important GHG mitigation potential. In Finland, CHP production is the dominant energy generation mode in cities and it is considered highly desirable due to the shared environmental burden and overall high efficiency. However, the production fuels are currently predominantly fossil and thus a substantial amount of GHG emissions results from CHP production. At the same time, the average GHG intensity of the Nordic electricity grid, which Finland belongs to, is relatively low due to high shares of hydropower and nuclear power, but the current marginal production intensity is relatively high.

These conditions lead to a situation where defining the actual consequential GHG impact of a change in the built environment is but simple or even unequivocal. Firstly, there is no unanimously right way to allocate the emissions from CHP between electricity and heat, but several established allocation methods exist. Secondly, the selection between average and marginal production is but unambiguous, and has a huge impact on the assessment outcome often leading also to a very different policy implication. In this paper we present an analysis and discussion of the problems related to the assessment of GHG emissions from CHP production from the perspective of urban planning. We present a theoretical comparison of CHP heat utilisation vs. ground-source heat pumps (HP) in a new residential development to demonstrate how strongly the arising policy guidelines depend on the assessment method and assumptions. We look through different assessment method options and discuss the policy guidelines arising from GHG mitigation perspective depending on the method decision. The results of this analysis depict how complex the emissions assessments become and how difficult it is to give valid policy guidelines in the context of local CHP production and low-carbon grid electricity.

Authors

Jukka Heinonen [1, 2]
heinonen@hi.is

Jani Laine [2]
jani.laine@aalto.fi

KaroliinaPluuman [2,3]
karoliina.pluuman@lut.fi

Seppo Junnila [2]
seppo.junnila@aalto.fi

1) University of Iceland, Iceland
2) Aalto University, Finland
3) Lappeenranta University of Technology, Finland

Introduction

Power plants burning fossil fuels generate the majority of the global anthropogenic greenhouse gas (GHG) emissions. Of these, over two thirds are driven by the energy demand of cities (World Energy Outlook 2008, 180; C40 Cities 2011; UN 2007). Cities are an important entity also in the sense of mitigation policies. E.g. Hoornweg et al. (2011) have suggested cities to have an even more significant role than their share of the emissions indicates due to cities being able to respond to the GHG mitigation aspirations better than higher governmental levels.

The compactness of cities also allows for combined heat and power (CHP) production, which increases the efficiency in required fuels up to a third in comparison to separate production with the same fuels (Berta et al. 2006; Rajala et al. 2010, 21; Lund & Andersen 2005). In Finland, CHP production is already currently the dominant energy generation mode in cities (IEA, 2013) and it is considered highly desirable due to the shared environmental burden and an overall high efficiency (e.g.

Rinne & Syri, 2013). However, the production fuels are predominantly fossil (IEA, 2013) and thus a substantial amount of GHG emissions results from CHP production despite it being more efficient than separate production with the same fuel-mix. On the other hand, the average GHG intensity of the Nordic electricity grid, which Finland belongs to, is relatively low due to high shares of hydropower and nuclear power, but the current marginal production intensity is rather high.

The selection between average and marginal production in an emissions assessment is but unambiguous. In general marginal production refers to the final energy output following a small change in demand. Only certain production technologies allow them to be used to adjust supply with demand (due to storing of electricity being technologically very limited currently) and thus act as marginal production technologies (Soimakallio 2011). In Finland the marginal production technology is thus often considered to be conventional coal condensing (Pöyry 2010), which has one of the highest GHG intensities in the Finnish context. The decision whether to use average or marginal data in an assessment is thus extremely important.

Taking a certain single technology as the marginal technology has been criticised, however, by e.g. Mathiesen et al. (2009) and Lund et al. (2010) who suggest rather using a combination of multiple technologies to represent the marginal production. Furthermore, when the assessment boundary is relaxed further and further, it actually becomes impossible to define the actual marginal, since when energy imports come along to balance supply and demand, the definition of marginal production technologies based on the technological qualities loses its basis. For example, extensive construction of wind power capacity may cause excess energy production (Lund 2007), and one way to balance the supply and demand are exports. In addition, a temporal perspective to an assessment adds complexity to identifying and naming the exact marginal fuels and production technologies. Moreover, marginal fuels within a single plant should be assessed as well.

It is actually very complex task to even define when a “marginal increase” in demand occurs requiring “marginal production”. Regarding energy use in the built environment, the majority of changes, e.g. new residential developments, are actually just re-locating the demand, not increasing it in overall. Furthermore, since the CHP networks are local or regional, and electricity grid in Finland international, a certain change may increase heat demand locally, but be just a re-location of demand of electricity. On the other hand, any change in the electricity production system, or grid, has an impact on the marginal production at some level, but the scope of an analysis defines the technologies and resources under the term marginal production.

Furthermore, a major problem with CHP production is that there is no unanimously right way to allocate the emissions between electricity and heat (e.g. GHG Protocol 2014). Each one can be claimed as the side product of the other and claimed to carry no or little emissions. As the result, several allocation principles have been presented, the variation being huge between them. In such a context as the Finnish case, where the average grid emissions are relatively low, the situation leaves a lot of room for the one conducting the assessment or suggesting a policy guideline to present the emissions in the best light for the occasion. How to define the grid boundary is an additional aspect that amplifies the space to manoeuvre with the assessment methods. A certain utility in Finland can for example choose to allocate the CHP emissions mostly to electricity, which is sold to the grid with little impact on the grid average, and then claim to sell very low-carbon energy as the sold heat is considered to have low emissions and the electricity sold to the end-user is purchased from the grid with low average emissions. At the same time the fuel-mix of this utility can include only fossil fuels.

In a more general context this situation leads to the selected assessment method and technology assumptions to have a far too great impact on the arising policy guidelines, especially from the perspective of urban planning, which relies on the utility information given by earlier assessments or planning tools

(Säynäjoki et al. 2014). A certain city-level or regional GHG mitigation strategy can rely on the information from an assessment that, if a different allocation method was adopted, had led to very different, even fully opposite, policy recommendation. Furthermore, the impact of the assessment method may often not be transparent at all.

We present in this paper an analysis and discussion of the problems related to the assessment of GHG emissions from CHP production from the perspective of urban planning. We present a theoretical comparison of CHP heat utilisation vs. ground-source heat pumps (HP) in a hypothetical new residential development to demonstrate how strongly the arising policy guidelines depend on the assessment method and assumptions. We look through different assessment method options and discuss the policy guidelines arising from GHG mitigation perspective depending on the method decision. The results of this analysis depict how complex the emissions assessments become and how difficult it is to give valid policy guidelines in the context of local CHP production and low-carbon grid electricity. An extended version of the study with an actual case area has been published as Heinonen et al. (2015).

The paper proceeds through a presentation of different allocation methods for CHP, case description, assessment results and discussion to conclusions in the final section.

CHP GHG allocation methods

Several different allocation methods exist for the emissions from CHP production. These include benefit method, energy method, exergy method, all to heat/electricity methods, product price method, EN 15316-4-5: 2007 standard method, ratio method, and work method. In this paper we use (1) benefit method, (2) energy method and (3) all-for-electricity /heat methods to depict how the allocation choice affects the results. The selected methods are commonly used in GHG assessments. Next these methods are briefly described.

Benefit method

The benefit method gives significant weight for both outputs, but veers towards electricity in terms of allocated emissions. The method divides the emissions of CHP production according to the ratio of fuels required for alternative production of the same output (Liikanen 1999), which leads to higher share being allocated to electricity due to the different efficiencies of separate production of heat and electricity. The typically utilised alternative production modes are condensing production with 39 % efficiency for electricity and thermal water boiler with 90 % efficiency for heat. Bearing upon the efficiencies of separate production, the benefit method is considered to allocate the emissions of combined production relatively fairly, if the assumption is that otherwise the production would take place separately. Mathematically the benefit method can be expressed as follows:

$$F`_e = \frac{E_e}{\eta_e} \tag{1}$$

$$F`_h = \frac{E_h}{\eta_h} \tag{2}$$

$$F_e = \frac{F`_e}{F`_e + F`_h} F \tag{3}$$

$$F_h = \frac{F`_h}{F`_e + F`_h} F \tag{4}$$

where,

F’e = fuel consumption of alternative acquisition form for electricity
F’h = fuel consumption of alternative acquisition form for heat
Ee = produced electricity in cogeneration
Eh = produced heat in cogeneration
ηe = efficiency of separate production of electricity
ηh = efficiency of separate production of heat
Fe = calculated fuel consumption of electricity production in cogeneration
Fh = calculated fuel consumption of heat production in cogeneration
F = consumption of fuel in cogeneration

Energy method

In energy method the emissions are divided according to the ratio of the energy outputs of electricity and heat. The method penalises heat in comparison to the benefit method, because efficiency of separate heat production is higher than the efficiency in cogeneration. Mathematically the method can be expressed (the definitions being the same as for the benefit method below equation 4):

$$F_e = \frac{E_e}{E_e + E_h} \cdot F \quad (5)$$

$$F_h = \frac{E_h}{E_e + E_h} \cdot F \quad (6)$$

All-for-heat/electricity methods

In the all-for-electricity/heat methods either one of the energy outputs is considered as the primary product and the other as the side product. The emissions are divided by calculating first the emissions from separate production of the primary output and allocating these emissions to it and the remaining share to the side product. The technologies used for the calculation of the emissions from separate production are thermal water boiler for heat and condensing power plant for electricity. Consequently, the method penalises the primary product more whereas the side product carries a lighter load. For electricity the mathematical expression goes according to (7) and (8), and for heat similarly but heat and electricity in an opposite order.

$$F_e = \frac{E_e}{\eta_e} \quad (7)$$

$$F_h = F - F_e \quad (8)$$

Energy in Finland

Heat demand and sources in Finland

District heat (DH) is the most important heating mode in Finland with a share of nearly 50 %, but individual oil boilers, electricity, HPs and wood have significant shares as well. DH is in a dominant role especially in cities, and of apartment buildings nearly 90 % are connected to DH networks (Statistics Finland 2013). Table 1 shows the distribution of heating modes in Finland.

Table 1 - The split in heating modes in Finland in 2012 (Statistics Finland 2013)

Fuel	Share
District heat	46 %
Electricity	20 %
Heat pumps	8 %
Oil	11 %
Wood	13 %
Other	2 %

CHP market in Finland

The overall heat production in Finland was approximately 90 TWh in 2012, of which 53 TWh was industrial heat and 37 TWh district heat (Statistics Finland 2013). Of the latter, the vast majority of 27 TWh was produced in CHP plants. The fuel-mix of the CHP plants relies heavily fossil fuels in Finland, their share being over 50 % as depicted by Table 2. In addition, the share of peat, which also carries a high GHG intensity, is nearly 20 %. Nearly one fourth is biomass, and the share has been increasing.

Table 2 - The CHP plants fuel-mix in Finland in 2012 (Finnish Energy Industries 2013)

Fuel	Share
Natural gas	26 %
Coal	30 %
Oil	1 %
Other fossil	2 %
Peat	16 %
Biomass	23 %
Other	3 %

Electricity market in Finland

The Finnish electricity production fuel-mix consisted of 41 % renewables, 20 % fossil fuels (of which roughly 50 % coal and 50 % natural gas), 33 % nuclear power and 6 % peat in 2012 (Statistics Finland 2013). The share of CHP electricity is around one fourth of the Finnish electricity production. Due to fluctuation in the availability of renewables, currently especially in the water conditions, the shares are in constant fluctuation, and, when needed, the replacement comes from imports and fossil fuels depending on the market conditions.

Finland belongs to the Nordic Pool Spot electricity market along with the other Nordic Countries, Estonia and Lithuania. Nord Pool grid is also connected to the Russian, Polish and German grids (Nord Pool Spot 2013). The production profile in overall in the Nordic Countries connected to the Nord Pool Spot market is significantly more renewables based than the Finnish electricity production. In 2012, hydropower accounted for 59 %, wind for 7 %, geothermal power for 1 %, nuclear for 13 % and heat power for 20 % (Finnish Energy Industries 2013). This creates a situation where it is not obvious which grid intensity to utilise for an assessment taking place in Finland.

The Nord Pool Spot market is an open market where prices guide the supply, the most expensive production modes thus forming the marginal production. From the Finnish perspective, the connection to the Nord Pool Spot market allows for the utilities to sell lower GHG content electricity than they would if the market was restricted to Finland only. Furthermore, the Nordic countries are net importers of electricity, and Finland within the Nord Pool grid (IEA 2013), which makes it even more complex to define the actual electricity markets in Finland.

Ground-source heat pumps (HP)

Several technologies exist for distributed production of energy, but here we present only HPs due to the setting of the study (see Introduction). HPs are used widely and their market share is increasing especially in regions outside of DH networks. They provide an alternative to DH also in the locations on the edges of DH networks, and in certain studies have suggested them as a better option even if DH was available (e.g. Ristimäki et al. 2013). In the future HPs might more and more be utilised in DH networks.

The efficiency measure of HPs, COP, i.e. the ratio of produced heat to required electricity to run the pump, is typically 2.6-3.6 (Vartiainen et al. 2002) but can reach levels of 4-5.

Even though HPs are typically not fitted to provide 100 % of the needed heat due to that decreasing the overall pump efficiency, the COP figure takes this into account. During the peak demand HPs are typically supported with electric heaters (Nystedt et al. 2012), but the typical fitting of HPs to provide 60-80 % of the peak power requirement is enough to cover 95-99 % of the actual annual heat demand.

GHGs from energy production

Assigning the emissions to the production or burning different fuels is a complex task as well. The GHG intensity depends on the utilised fuels, production technologies (within a certain production mode), on the assessment boundary definition (e.g. how far the production and delivery chains are traced) and on several other assessment assumptions as well. Especially with regard to biofuels and waste the assumptions are in a critical role. Consequently, in the published studies the variation is huge. Table 3 presents the spreads given by Cherubini et al. (2009) for GWP100 which are employed in this study.

Table 3 - Output GHG intensities for certain electricity and cogeneration technologies and fuels from Cherubini et al. (2009)

Technology/fuel	Emission factor (gCO_2e/MJ)
Hydro	0.5…10
Wind	1…10
Biomass	15…30
Nuclear	5…30
Oil	200…300
Natural gas	100…200
Coal	300…500

The spreads are huge as Table 3 depicts (taken also that the numbers in Table 3 are not minimums and maximums presented in the literature, just those presented by Cherubini et al. (2009)). There is also an ongoing debate about how GHGs should be assigned to wood fuels (see e.g. Soimakallio et al. 2011). Suggestions for even higher GHG factors than the upper figure in Table 3 have been presented.

Nevertheless, if the figures in Table 3 are utilised and the lower boundary is taken, the average Nordic grid electricity GHGs are approximately 112 gCO_2e/kWh, whereas if the upper boundary is adopted the average is 290 gCO_2e/kWh. Any assessment is thus likely to lead to very different outcome depending on the emissions factors assigned to the production technologies/fuels. In our demonstration in the next section we employ the average of these, 201 gCO_2e/kWh since the technology and LCA problematics are not in the nexus of this paper.

Given that we use coal condensing as the marginal separate electricity production technology in this paper (see introduction), the marginal production output emissions factor is 1,080...1,800 gCO_2e/kWh according to Table 3. These together with the efficiency conversion range of 2.5...4.2 from the same study of Cherubini et al. (2009) give an average intensity of 1,103 gCO_2e/kWh for coal condensing. This figure will be used in the analysis later in the paper.

Regarding CHP GHG intensity we utilise the same approach. Following the averages of Cherubini et al. (2009) for both fuels and their conversion efficiencies, and the fuel-mix from Table 2, the average GHG intensity of CHP production in Finland is 253 gCO_2e/kWh.

Case setting

The power of urban planning to promote sustainability relies strongly on housing development and enabling more sustainable transportation (Säynäjoki et al. 2014). Regarding housing, urban planning has the power to enable certain energy options. In Finland, CHP is promoted strongly, and, consequently, the utilisation of DH. However, opinions favouring HPs rather than DH have been presented, and there is a debate on the pros and cons of the two energy systems in Finland currently. Furthermore, even if from purely energy production perspective a preference order could be given, in a certain planning context the situation is likely very complex, and still the planning decisions strongly affect the market penetration.

The case setting is as follows:

- 1,000 m^2 of living space;
- 90 kWh/m^2 overall energy demand complying with the definition in Finland for a modern low-energy building:
  - 60 kWh/m^2 for heating and hot water;
  - 30 kWh/m^2 for building and household electricity;
- Two heating options:
  - CHP heat, 85 % production efficiency;
  - HP heat, COP 3.0 ;
- Two electricity options:
  - Nordic grid average;
  - Marginal ;
- coal condensing in HP option;
- CHP electricity in CHP option;
- Four emissions allocation methods:
  - benefit method;
  - energy method;
  - all-for-heat method;
  - all-for-electricity method.

For simplicity, we assume that all the required heat is provided by the chosen heating mode. The difference is very small to the situation where HP would be fitted slightly below the peak power requirement, and supported by electric heaters. Peak demand shows also as separate heat production in DH networks, but here we omit that as well. Regarding electricity, the demand of the case area complies almost perfectly with the consequential CHP electricity output as the result of meeting the 60 $kWh/m^2/a$ heat demand with the assumption that electricity output increase will follow the current average, which is approximately 0.5 kWh of electricity per 1 kWh of heat output.

Regarding the marginal electricity options, we suggest that for CHP the marginal electricity option should be the electricity from CHP production. The case has strong justifications, since the emissions allocated to electricity are actually the consequential emissions from an increase in CHP production from the perspective of electricity. And as we will demonstrate in the next section, assessing the electricity-related emissions with the CHP electricity reduces significantly the potential free rider problem arising from the different CHP emissions allocation methods. In our demonstration case, the assumed electricity requirement of the new settlement is also fairly close to the electricity output resulting from an increase in CHP heat demand (taken that the average heat/electricity distribution is maintained).

Results and discussion

The GHG outcome possibilities provide an interesting array of policy guideline options. The variation for the hypothetical new residential development of 1,000 m^2 of living space goes from 10,000 $kgCO_2e/a$ to 55,000 $kgCO_2e/a$ depending on the adopted method and assumptions regarding the assessment. The variation is thus huge. Furthermore, both extremes are provided by HP depending on the average or marginal assumption (and strongly on the assumption that marginal technology for HPs is 100 % coal condensation). Thus, giving a planning guideline needs an assumption between average and marginal electricity: if grid electricity is allowed for HP it is the preferable option, but if HP usage is assumed to force

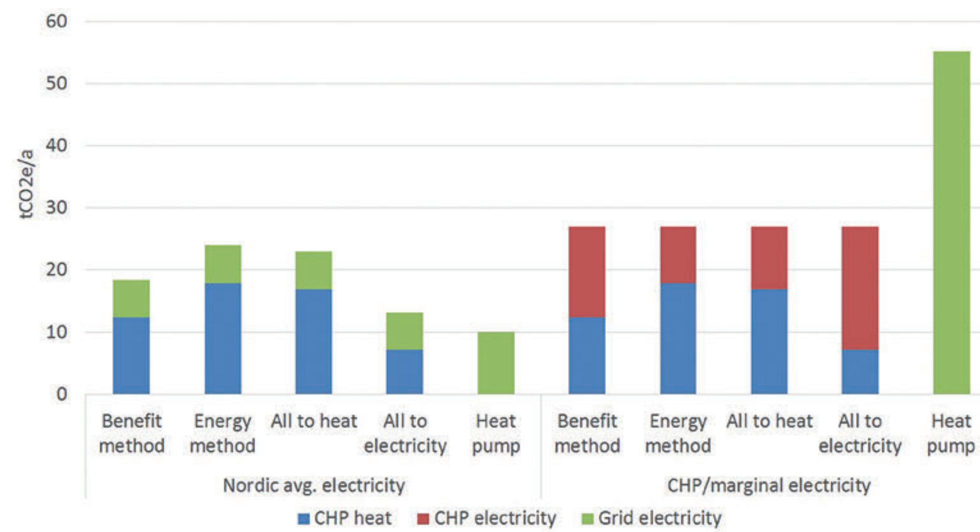

Figure 1 - The GHGs forced by the new settlement with different heat options, CHP allocation methods and electricity assumptions

marginal (coal condensing) production, CHP becomes the most viable option. However, there is much more to take into account when the question is analysed further. Figure 1 presents the results, which are opened and discussed further in the following sub-sections.

GHGs from CHP

In our assessment the increase in CHP production generates approximately 27,000 kg of CO_2e/a, and depending on the allocation method smaller or larger share of these is considered as the share of electricity. Thus selecting a method allocating the majority to electricity and assuming average grid electricity to be used gives an opportunity for de facto omitting a significant share of the actual consequential emissions resulting from an increase in CHP output. In all CHP options the 27,000 kg is actually the amount of GHGs forced by the heat requirement of the settlement. From policy perspective, such schemes might thus be preferable to avoid which allocate very little emissions to heat.

Especially as the average grid electricity has relatively low GHG content, the high fossil fuels share of CHP can go unnoticed if assessment schemes like all-for-electricity are used. Figure 2 demonstrates the shares being allocated to heat and electricity with the selected four allocation methods.

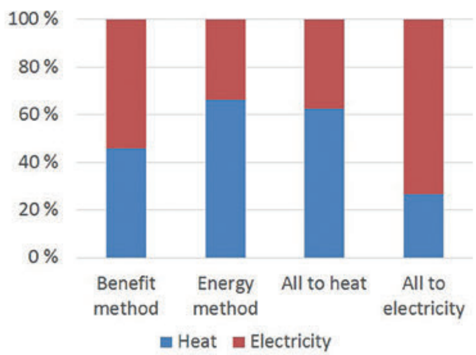

Figure 2 - The allocation of the emissions from CHP to heat and electricity with the selected four allocation methods

In urban planning, a more robust way to assess the emissions might thus be to consider the same CHP clients to primarily utilise the CHP electricity output and thus take the responsibility for the actual consequential emissions forced by their settlement, not just of those allocated to heat. The electricity as the by product of the required 60 MWh heat to the case development would actually lead an increase of 31 MWh of electricity production from CHP according to the Finnish average ratio. This complies nicely with the assumed electricity demand of 30 MWh of the case settlement. The problem with this allocation system is that the output from CHP and the electricity demand of the settlement doesn't necessarily meet from a temporal perspective at least as well as over a longer time-span. This allocation suggestion will be discussed in more detail in the next sections.

An additional aspect to assessing and allocating the emissions from CHP is that there is sort of a marginal production in CHP as well, referring in this context to the change in the fuels when the demand increases. Here we made the calculations based on the Finnish average fuel-mix, but the plant where actual production takes place might operate with very different fuel-mix, and the change in demand might cause an increase in certain fuel use instead of the average of even that particular plant. Would that marginal fuel be oil or coal, the overall emissions assignable to this residential development could even double from those presented in Figure 1. Of course, be the marginal fuel biomass, the impact would be significantly lower.

Average vs. marginal electricity

The most important assessment decision affecting the outcome is the choice between average and marginal electricity. In our paper the marginal options depict how the results are an order of magnitude higher in the case of marginal electricity. The fully marginal production based options are hypothetical in the sense that quite obviously not all the electricity demand should be allocated to the marginal production. As mentioned in the introduction, even regarding a new residential development, a significant share of the electricity demand is actually re-location of demand, not an increase in the overall demand. The direction of the overall demand cannot actually be determined ex ante, since the residents might be moving from less energy efficient buildings, buildings with direct electricity heating, away from a district heating network etc., which affects the allocation of their energy demand in the new residence.

An important additional problem with the average-marginal choice is that the marginal production hardly should be defined as one single technology. E.g. Mathiesen et al. (2009) and Lund et al. (2010) have suggested a combination of multiple technologies to be used to represent the marginal production rather than one single technology. This would already affect the assessment results significantly in the marginal production options of our assessment, since we have now used as the marginal technology the technology with the by far highest GHG intensity, namely coal condensing.

A step further from the marginal technology aspect is the impact of the assessment boundary on the applicability of the marginal thinking. Even if there was a clear marginal technology in Finland, the case is different already on the level of the Nord Pool Spot market. The technologies are different, and especially in Sweden and Norway fossil fuels don't play similar role as in Finland (IEA 2013). The weather conditions define the market situation, and in overall both countries are net exporters of electricity. In Denmark the situation is somewhat similar in the sense that the fluctuation in wind conditions may cause excess production periods which can be deployed by exports. Finland is also a significant importer for Russian electricity (IEA 2013). Thus, extending the assessment boundary to the Nordic grid level and further to taking into account the trade between the Nordic countries and their neighbours dims entirely the one technology marginal production argument.

CHP replacing marginal production?

The choice between different systems carries also consequential aspect on the grid level which again increases the complexity of assessment. Electricity production from CHP can be seen to replace marginal production in the grid. This could lead to negative consequential GHG emissions for CHP. It can be argued, however, that only the surplus exceeding the electricity requirement of the new settlement could be considered to have this effect. Since in our case the electricity output from CHP production is virtually equal to the demand of the new settlement (31 MWh/a vs. 30 MWh/a), the replacement is not an important factor. Previously, with significantly lower energy efficiency, this was an important advantage for CHP, but along with the emergence of low-energy and passive buildings, the situation is changing rapidly.

However the outcome is different if produced electricity as a total from a CHP plant is considered to replace marginal production. In other words, if the energy demand of the area would otherwise be supplied through marginal electricity production. With this assumption CHP can end up having negative emissions. Yet it is crucial to notice that the marginal technology won't necessarily be stable under a life-cycle of a site under analysis. When considering the consequences of any action, a move towards better situation has always positive impacts. In this case and if assuming the CHP electricity to replace marginal electricity production, the impact to electricity production system as a whole is positive as long as the electricity production technology replacing the marginal technology comes to marginal as itself. Still it is important to notice that the replacement is hypothetic as markets tend to react on the increased demand and there are also other options to increase the production of electricity as well as heat. The replacement is hypothetical also from the perspective that the results are strongly dependent on the adopted CHP allocation method. Furthermore, another way round, if the HP option would not force marginal production but operated with lower impact electricity, HP could be claimed to replace more GHG intensive CHP (as is a potential option especially in the future due to the improvements in the electricity production technologies).

Uncertainties in the GHG factors

The GHG factors related to different fuels and production modes are subject to high uncertainty. Here we have utilised for the Nordic grid electricity the averages of the lower and higher boundaries of Cherubini et al. (2009). According to the lower boundaries, the GHG intensity of the grid electricity is 112 gCO_2e/kWh and according to the higher boundaries 290 gCO_2e/kWh, the variation thus being substantial. And the scales given by Cherubini et al. are by no means the extreme values presented in different LCA studies. The variation in the LCA literature arises from several regular problematic issues related to conducting an LCA, e.g. the efficiency factors, the truncation error arising from the boundary selection (e.g. Matthews et al. 2008), spatial variation, data gaps and data quality (Reap et al. 2008a-b).

We utilised the average figures since LCA problematics are not in the nexus of this paper. However, it is obvious that such a high variation in the suggested emissions intensities is very problematic from urban planning perspective in a more general situation. Typically in urban planning certain intensities, allocation method and average/marginal assumption are taken and the results are believed to be objective (e.g. Säynäjoki et al. 2014), but actually these choices can turn around the policy guideline arising from an assessment. Furthermore, with such a high variation in just the emissions intensities, running life cycle comparisons between different activities becomes extremely difficult (e.g. the GHGs from producing the case area vs. the use phase emissions (see e.g. Säynäjoki et al. (2012) for an example of such a comparison).

With regard to the marginal technology the intensity question is also of high importance. If the marginal technology assumption is relaxed towards a "basket" of marginal technologies (as suggested e.g. by Mathiesen et al. (2009) and Lund et al. (2010)), the average GHG factor decreases rapidly since the chosen coal condensation is the most GHG intensive technology. For example natural gas as the marginal technology might already lead to HP arising as the better option in comparison to CHP even when marginal electricity is assumed depending on the adopted GHG intensity for natural gas and the actual CHP fuels.

Conclusions

In this paper we have presented an analysis and discussion on the complexity of assessing the emissions from energy production with regard to an urban development project and using these types of assessments to give policy guidelines for urban planners. We utilised in our analysis a hypothetical new residential development with 1000 m^2 of low-energy living space, and compared CHP and HP as heating modes with the assumption that electricity comes from the Nordic grid. The building was set to simulate a modern low-energy building in Finland giving us thus a good basis for our analysis and discussion.

According to the results of our assessment, the arising policy implication is strongly tied to the electricity assumption. If in both options, CHP and HP, grid average electricity is assumed, HP arises as the preferable option. If HP is assumed to force marginal production, it leads to the highest emissions. However, we suggest that in the marginal production option, HP should be compared to CHP assuming that the CHP clients also primarily utilise CHP electricity due to the overall CHP emissions being the consequential impact of the new settlement, and CHP electricity thus comparable to the actual marginal production in the HP option. In addition, a dynamics and change prospects of a marginal production portfolio within a life cycle under analysis should be acknowledged as well. Furthermore, this allocation method allows to avoid utilisation of different CHP allocation methods to manipulate the GHGs from CHP in favour of the one conducting an assessment or utilising the results.

We also presented an extensive discussion on the problems related to making the choice between the average and the marginal production. The issue is of high importance, especially as the urban authors and planners look for reliable information to guide their decisions. In our case the difference between the two in the GHG outcome is huge and significantly affects the arising policy guideline. A further problem arises from the definition of marginal production technology. It might not be entirely justifiable to use the technology with the highest GHG intensity as the only marginal technology as we did in our analysis (and as is often done). Adding other energy production technologies to the "marginal basket" would quickly decrease the emissions related to marginal production and blur the policy guidelines further. Relaxing the assessment boundary in the sense of adding energy imports further increase the complexity of an assessment, but highlights the point that a single marginal technology is not a well justified premise in an assessment.

Finally, there can actually be a kind of an equivalent to marginal production in CHP as well in the form of marginal fuel. Thus, to assess correctly the emissions forced by an increase in the CHP demand, one would need to know the marginal CHP fuel for the particular plant producing the energy. This being coal or biomass could either duplicate the emissions from CHP or make CHP a much more competitive option in comparison to the case we presented, where we utilised the Finnish average fuel-mix for CHP.

This paper concentrated on the existing problems, not so much on finding solutions. The final conclusion of ours is thus that the number of problems is high and their significance immense, but more research is needed in the future in order to overcome them.

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Top-down or bottom-up approach?

It is often claimed that in general the built environment consumes between 40 – 45 % of the national bill, with respect to the construction and running of the present building stock. EU member states are paying hefty energy bills in this respect. It is therefore not surprising that improving energy-efficiency in buildings is high on both the national and international political agenda.

It was with this in mind, together with an over-arching sensitivity towards the protection of the environment, depletion of finite resources, as well as reducing carbon emissions for a better air quality, that current energy-related legislation is being drawn up and persistently enforced from Brussels, later transposed to individual member states as national law. But this is only a top-down approach. In today’s technology realm, where the public has greater access to information through the media via hi-tech devices, we cannot complain that we are not informed of the consequences of using fossil energy, due to lack of conformity with such legislation. Therefore a bottom-up approach is perhaps much more desirable.

The first paper tackles energy-efficiency initiatives in the context of a small economy in an independent island-state, such as Malta, which is dependent on imported fossil fuels for its energy supply. Energy incentives are highlighted and their costs are weighted against the added value to buildings and society at large, within the domestic, commercial and industrial sectors.
Given its fossil energy dependency the paper shows how Malta is making the shift towards Renewable Energy Sources (RES), through grants and other fiscal incentives. This should augur well for an equivalent shift of inherent values and a culture change.

Mechanisms for financing such initiatives are highlighted in the second paper, where indicators for improvements are highlighted. It also argues in favour of a thorough assessment of a cost-benefit analysis before embarking on retrofit projects, purporting to not only promote green jobs but may moreover result in a profitable execution of such a project, for both contractors and end users alike.

The third paper in this section relates to energy savings through smart technology. It presents simulations carried out for a passive house example, applied in Hungary. Different climatic zones are also considered, for both heating and cooling demands for energy. Separately it assesses the geothermal potential to feed an energy system in a small town.

The fourth and final paper makes a point for a greater community need for energy efficiency as people move form single unit, two-storey house to a multi-storey high rise housing estates, thus moving from a single dwelling to a city scale. The paper also takes a close look at renovation examples from Latvia including two kindergartens and one multi-story apartment building.
The renovation package for both kindergartens as well as for the residential building included similar improvements to building façades, as well as heating and ventilation systems.

Smart cities and regions are here seen as the test bed to demonstrate the general concepts of energy efficiency, balancing cost and value. Improvements of performance at an urban scale can go along way today, especially through the implementation of large-scale Information and Communication Technologies (ICT) and by engagement of stakeholders. Hence a truly bottom-up approach will be implemented.

Energy-efficiency and renewable energy financial incentives: public perception in Malta – top-down, or bottom-up approach?

Considering the high energy bill paid by developed countries when it comes to energy, especially that related with the built environment, it is not surprising that improving energy-efficiency in buildings is high on both the national and international political agenda. Unfortunately improving the energy-efficiency of buildings through applications such as installing double glazing or roof insulation or renewable energy devices such as solar water heaters or photovoltaic panels comes at a premium.

This partially hinders their competitiveness and eventual market penetration. To address this issue most countries have developed a number of incentives, typically fiscal ones, specifically targeted at helping such applications or devices to become competitive and increase their presence on the respective national market. Malta like other EU member states has adopted its own measures to incentivize such a market. In this context, this paper focuses on what type of incentives has the local market (both government and privately driven) used to improve the situation and increase the market presence of such applications and device. Indications are that although the start-up has been slow, these financial incentives have created a thriving market which is however essentially dependent on such incentives. Similarly it shows that in the case of Malta, a bottom-up approach has stimulated an educated shift towards smarter energy use.

Authors

Vincent Buhagiar
vincent.buhagiar@um.edu.mt

Simon Paul Borg
simon.p.borg@um.edu.mt

University of Malta, Malta

Introduction

Energy consumption in the built environment in the EU accounts for around 40 % (Enerdata, 2012) of the total energy consumption. Buoyed by the ever-increasing search for thermal comfort in indoor spaces, this figure is bound to increase or at best remain stable for the foreseeable future. This of course is putting a lot of pressure for countries to develop their own strategies so as to address this demand, possibly decreasing within a sustainable threshold. Energy-efficiency applications such as installing double glazing or roof insulation in buildings or renewable energy devices such as solar water heaters or photovoltaic panels come at a premium in the form of a possibly hefty capital expenditure or a long payback period which are far from being attractive.

Some countries opt to have the use of some of these applications and systems mandated by law, as indeed few individuals or companies will enter such an expense voluntarily. Such a method typically relies on obligatory requirements for permitting new buildings or refurbishing existing ones. The requirement of having a solar water heater installed on every new building in Cyprus (Korniotis et al., 1999) or the enforcement of regulations for the minimum energy performance of new and refurbished buildings in EU countries as established in Directive 2010/31/EU (European Parliament, 2010) are examples of such mandatory regulations.

Most countries however, prefer a softer approach where incentives, predominantly of the financial form, are given to promote energy-efficient technologies. The effectiveness of a bottom-up or a top-down implementation has therefore been tested. It is clear that public perception and attitudes are all about a ‘carrot or stick’ approach.

Background and scope behind financial incentives

Financial incentives are special purpose made mechanisms, which countries through their central or regional authorities, may decide to use in order to assist and promote selected technologies, typically environmentally friendly or energy-efficient ones. In most cases such financial incentives are required in order to overcome the initial capital investment cost, which is often higher than that of conventional systems.

Financial incentives typically take the form of either upfront capital grants, offsetting part of the higher capital cost incurred through the purchase of such systems, or else Feed-in Tariffs payable on any exported energy. The former is particularly common where the system does not involve the production of energy and is typically reserved for energy-savings measures such as improving the building envelope through measures such as installing double glazing or roof insulation, etc. The latter is more common where energy is produced and exported to the grid such as in the case of electricity produced from photovoltaic panels, combined heat and power systems and wind energy.

Malta’s experience at using financial incentives – an overview

Up to ten years ago, the market for renewable energy or energy-efficient measures in Malta was a practically insignificant part of the local energy scene. The prices of these applications and systems were considered to be exorbitant and their payback period (considering the cost of alternative conventional systems – electricity and fossil fuel) deemed unreasonable, even when considering the lower operational costs involved.

Come Malta’s accession into the European Union and the ratification of international agreements and obligations, not only related directly to the European Union such as the Renewable Energy Directive (European Parliament, 2001) and the Energy Performance of Buildings Directive (European Parliament, 2002), but also to international agreements such as the Kyoto Protocol, etc., governments started to develop the first incentives aimed at increasing the uptake of such systems and applications.

What follows is a summary of what has been done in Malta at public level through government driven incentives and privately, mainly through specialised bank loans.

Government driven financial incentives aimed at the residential sector

The first schemes aimed specifically at increasing the uptake of solar water heaters took the shape of soft grants covering part (generally up to 15 – 20 %) of the capital cost of such systems. Concurrently the local electricity supplier, Enemalta, offered to waive off the electricity connection fee to any household which had installed a solar water heater prior to applying for its energy meter. Pick up for the scheme was slow and the number of systems installed totalled only in the few 100s (MRRA, 2011).

Given the non-encouraging results obtained from this first scheme a more aggressive campaign was initiated. This time round the scheme was specifically intended at increasing the energy-efficiency at end-use. In this context, and as part of its plan to promote a higher appreciation of energy-efficiency in residential buildings, in 2007 the Maltese Government launched a once-only grant payment for the purchase of energy-efficient appliances (MEH, 2014a). The scheme involved the payment of a grant on the purchase price (up to 20 % of the total cost with a maximum capping) of energy-efficient washing machines, fridge freezers, tumble dryers, air conditioners and dishwashers as shown in Table 1 (MEH, 2014b).

This scheme was followed in 2009 by a scheme for the replacement of incandescent light bulbs with Compact Fluorescent Lamps (CFLs). The scheme did not revolve any specific fiscal incentive but rather the Maltese Government announced that through the local Energy Authority, the Malta Resources Authority, it would make available a number of energy saving lamps free of charge to every household.

Table 1 - Energy efficient appliances scheme

Appliance	Category	Grant of 20 % on selling price with maximum cap of
Fridge Freezer	A	€ 58.23
Washing Machine	A	€ 116.47
Dishwasher	A	€ 58.23
Tumble Dryers	A	€ 58.23
Air conditioner	A	€ 58.23

These two schemes proved to be successful not only in improving end-use energy-efficiency as shown through the calculated energy savings shown in Table 2 (MRRA, 2011) for the energy-efficient appliance grant scheme, but also as a learning tool towards the public's appreciation of the benefits of energy-efficiency in buildings.

Table 2 - Calculated energy savings obtained through the energy-efficient appliances grant scheme

Annual Calculated Savings (kWh)			
Appliance	2007	2008	2009
Fridge Freezer	374,532	391,989	18,699
Washing Machine	138,463	124,800	1,677
Dishwasher	35,596	41,272	2,684
Tumble Dryers	1,950	2,400	150
Air conditioner	562,086	690,228	11,151

In this context, statistics (MEH, 2014b) have shown that there has been a drastic change in user preference, resulting in a larger share of appliances with a better energy classification present on the national market.

Proof of this is the fact that the average sales of each category of appliances increased in the A/A+/A++ class sector as shown in Table 3.

Table 3 - Transformation in the appliance market

Level of Sales			
Appliance Category	2007	2008	2005(EU15)
Refrigeration	36	77	59
Air conditioner	16	44	N/A
Washing Machine	75	86	85
Dish Washers	85	96	80

In parallel to these schemes and aimed directly at improving the building envelope, a scheme has been in place since 2006, to promote the purchase and installation of roof insulation and double glazing in residential buildings (9). The scheme has been generally less effective with an annual uptake of around 100 units as shown in Table 4 (MRA, 2011) totalling to a total uptake 750 grants to date (NZEB2021, 2014).

Table 4 - Number of Installations aided by the building envelope grant scheme

	2008	2009	2010
Number of Installations	145	194	28

Though no official statistics exist confirming so, the reasons for such a poor uptake can be attributed to three factors:

1. Given the low heating and cooling demands associated with the Maltese Mediterranean climate, improvements in the building envelope are generally associated with a high payback period;
2. A general poor public knowledge of energy-measures associated with improving the building envelope; and
3. The perceived bothersome (and labour intensive) aspect of installing such applications.

In 2009, concurrently with the agreement of its 10 % Renewable Energy Target by 2020, the Maltese Government also devised two schemes for the greater uptake of photovoltaic panels and solar water heaters in residential buildings. Compared to the previous grant scheme aimed at solar water heaters, these new grants were based on a more financially robust and rewarding upfront grant covering part of the capital cost, up to a maximum set capping, and in the case of photovoltaic panels, on a very lucrative Feed-in Tariff.

In the case of the photovoltaic panels the grant on the capital cost which covered up to 50 %, was augment with a guaranteed Feed-In Tariff based on the electrical throughput (units of electricity) exported to the grid. The effective Feed-In Tariff on photovoltaic produced electricity ranges from € 16c to € 25c on the basis on when the system was purchased and the type of agreement in offer at the time. These were intended to be more financially attractive than the previous schemes and proved to be successful with high subscription rates. Similar schemes were re-launched in 2013 and extended into 2014. Table 5 shows the steady increase in electricity generation from photovoltaic since 2009 (MEH, 2014b).

Table 5 - Electricity generated from photovoltaic devices

	2009	2010	2011	2012
PV Generated Electricity (MWh)	530	1,730	12,392	13,620

In the case of solar water heaters sector, as discussed previously uptake has never been exceptional with various schemes having different levels of success. Nonetheless as shown in Table 6 below (MEH, 2014b), it can be observed that the highest number of units installed annually was in reaction to the improved grant being given as a financial aid.

The solar water heaters grant incentive offered an interesting backdrop for a study which was done in 2010 by Yousif et al. In this study the social aspect was investigated as to determine the mindset of Maltese with respect to the installation of solar water heaters in dwellings.

Table 6 - Incentive schemes for the purchase of SWH

Launch Year	Rebate (% of Capital Cost)	Capping	Uptake
2005	20 %	116.48	Low
2006	40 %	232.94	1,700/yr
2009	66 %	460.00	3,500/yr
2010	40 %	560.00	N/A
2011	40 %	400.00	Ongoing

The study which was based on survey carried out amongst the villagers in Victoria and Marsalforn, two villages in Malta's sister island of Gozo, looked not only at the general perception on solar water heaters but also, and most interestingly as to what people considered as being the predominant driver in installing one such system. Among the results highlighted by the authors, the survey indicated that:

1. 88 % of the survey respondents who had a SWH were satisfied with their system's performance;
2. 71 % of those who owned a SWH had benefited from the financial government grant on capital cost;
3. 90 % of those who had no SWH, knew about the government's financial support scheme; and
4. Although 50 % of those interviewed in the survey had said that the capital incentive was a primary motivation towards buying a SWH, 58 % of those interviewed and who did not own a SWH said that they considered such a system either to be too expensive (27 %) or that they would consider buying a SWH only when necessary (31 %), such as for example, when their installed electric water heater would fail.

Apart from Government driven schemes, the private sector, mainly through a number of local banking operators in Malta also started offering lending facilities towards improving energy-efficiency. In fact a number of Malta based banks offer loan facilities and banking products to facilitate the purchase and installation of energy-efficiency products. Table 7 lists a number of these bank products, their respective provider and a short description for each, identifying what type of energy-efficiency measure can be financed.

Although no official statistics exist in terms of the uptake of the scheme, it was established that most of these schemes have been very successful in promoting energy-efficiency in buildings.

Private sector (Bank products) financial incentives aimed at the residential sector

In terms of commercial buildings, a number of EU funded grant schemes, administered by Malta Enterprise have been targeted specifically at improving the energy-efficiency in industrial and commercial buildings. Such schemes mainly included Energy Grant Schemes offered either as financial help to set *Energy Saving Measures or Renewable Energy Sources* (Malta Enterprise, 2015).

Table 7 - Selected bank products aimed at driving energy-efficiency

Provider	Name of Product	Description of product
BOV	ECO Personal Loan	Product finances the purchase of environmentally friendly equipment such as solar water heaters, solar lamps, solar collectors, photovoltaic systems and products/systems/ services which save on electricity consumption including Class 'A' white goods, double glazing, energy audits, residential energy management systems and thermal insulation products (BOV, 2015).
APS Bank	Green Loans	Finances home owners and businesses in financing their investment in solar water heaters and PV panels (APS Bank, 2015).
Banif Bank	Banif Green	Financial product aimed at clients who wish to buy environment friendly products such as solar water heaters, roof thermal insulation, double glazing, external shading devices, photovoltaic systems, and energy efficient appliances (Banif Bank, 2015).
HSBC	HSBC Green	Finances a range of environmentally friendly initiatives and energy saving products: solar water heaters, photovoltaic installations, double glazing, solar film/room darkening, PIR (Passive Infra Red) sensors, solar lights – photo sensors, thermal insulation, external shading, and energy efficient appliances with a minimum rating of A++ (HSBC, 2015).

Grants and schemes aimed at the commercial sector

Energy Grant Schemes offered for Energy Saving Measures include all those grant scheme investments aimed at the implementation of energy saving solutions such as intelligent lighting systems, thermal insulation, building management systems, ground source cooling and energy-saving lighting. Examples include the geothermal energy system at Baxter Ltd. where the system provides 84,184kWh worth of annual electricity savings, through a system of 22 ground dug boreholes which guarantees high annual Coefficient of Performance (COP) ratings irrespective of outdoor conditions (R.E.S.I, 2012). The project was co-financed through an ERDF grant covering 50 % of the capital cost. Energy Grant Schemes offered for Renewable Energy Sources include all those grant scheme investments targeted towards the installation of energy generating solutions based on the use of renewable energy sources, mainly solar energy. Examples include:

The "Distributed CHP Generation from Small Size Concentrated Solar Power" (DIGESPO) at Arrow Pharm Ltd. an EU FP7 funded project which includes a modular micro Combined Heat and Power system comprising a small-scale concentrated solar power panels and a Stirling engine, Figure 1 (R.E.S.I, 2012). Though not fully operational, the system is already capable of producing 7MWh/year in energy savings.

Figure 1 - Part of DIGESPO plant installed at Arrow Pharma, through an EU FP7 funded project

The Solar Water Heating project at the Fortina Hotel & Spa, Figure 2 (R.E.S.I, 2012), which relies on a series of solar collectors for the production of it hot water demand. The available EU funding, made available through an ERDF fund was of 50 % the total capital cost.

Figure 2 - Solar Water Heating project at the Fortina Hotel & Spa, Sliema, Malta

Financing the energy-effciency refurbishmnet of public buildings – EU funding

Incentives aimed at public building have again been mainly through EU funded ERDF projects, specifically targeted at improving the energy-efficiency of buildings. Table 8 are excerpts taken from the Official Website of the Malta/ EU Funded projects (MEAIEM, 2015) showing a selected list of such projects.

CO_2 Reduction at Gozo General Hospital (ERDF 262 – Funding € 3,383,537)
This project involved the installation of a Combined Heat and Power system for space and water heating, a centralised heating and cooling system for space conditioning as well as a photovoltaic installation aimed at improving the energy-efficiency at the Gozo General Hospital. The objectives of this project were to reduce the hefty hospital's fossil fuel driven energy consumption levels. Besides the services provided by the hospital most of which are energy intensive, the thin fuel oil fired boiler for hot water and space heating, as well as the split units for space heating and cooling contributed significantly to the hospital's conventional energy demand. In this context, the primary objectives of this project were to:

A. Generate green energy to offset part of the electricity demand of the hospital;
B. Improve energy-efficiency for hot water and space conditioning to reduce the hospital's demand for energy generated from fossil fuels;
C. Reduce CO_2 and other pollutant emissions from hospital related activities; and
D. Contribute to the national target of 10 % share of renewable energy by 2020.

The amount of electricity generated by the project and fed to the national grid averages almost 2.1MWh annually.

CO_2 Reduction at ZAK House (ERDF 276) (Funding: € 17,495)
This project involved the installation of a new electricity and plumbing system at the Head Quarters of voluntary organisation. In detail the project included the installation of:

- A Photovoltaic system;
- Motion detectors/ time-lag switches that trigger lighting;
- Low consumption water mixers, flushing cisterns and shower heads; and
- Low consumption lighting equipment such as Compact fluorescent lamps, LED's and T-5 CFLs.

The project intended to:

- contribute to the generation of electricity through renewable clean energy sources. It is foreseen that the project will generate an average of 12,300KWh per annum over 20 years;
- make use of low consumption lighting, motion sensors/time-lag switches and low consumption water fittings, thus reducing the foreseen consumption of electricity by 3,360kWh/ year;
- reduce water consumption by 150m^3/year and saving the equivalent of 472kWh/year in desalination driven energy at the Water Services Corporation; and
- reduce the overall annual demand for electricity by 16,960kWh.

Energy-efficiency project at the Tal-Qroqq National Pool Complex (ERDF 339) (Funding: € 488,090)
The project involved the introduction of energy efficient measures at the Tal-Qroqq National Pool complex, thus promoting resource efficiency and the reduction of the carbon-footprint. It included the installation of new heat-pump technology in conjunction with solar collector panels and an efficient VRF air-conditioning system.

Conclusion

There is a broad consensus that concrete efforts need to be done to improve the energy-efficiency of buildings, thus reducing the energy demand of the sector. Unfortunately, such efforts needs to take in consideration the hefty capital layout often required to implement such measures. In this context, many EU countries have developed specialised and dedicated financial incentives to drive the market.

Malta has followed such a market oriented model and through the use of a number of financial incentives it has tried to shape and promote such a market. Looking at what has been done, it can be concluded that after a slow start, these financial incentives have been well received by the public and commercial establishments alike, and indeed have positively shaped the market and public perception on energy efficiency.

These financial incentives have been particularly successful at for example, increasing the uptake up of photovoltaic panels on residential and commercial roofs and increasing public awareness towards energy efficient appliances and lighting. Unfortunately, possibly given the little information available, other measures such as the promotion of the installation of double-glazing and roof insulation have been less successful.

This is an area where a lot of work needs to be done, not only to make such measures more financially attractive but also at educating the public on the benefits of such measures in the context of achieving smarter buildings and regions.

In conclusion it can be said that a bottom-up approach (incentives-based approach) can be seen not only as a direct measure towards decreasing energy consumption, but also as an indirect teaching mechanism. Beyond this such a shift towards a 'state-of-the-art' energy efficient technology not only makes buildings smarter, adding value for a given cost, but also contributes to green jobs, for a more circular economy at regional level.

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Energy saving with smart building technology. Implications on cost and value

In order to achieve sustainability, it is essential to know and apply widely the latest eco-innovations including energy consumption of buildings, transport, water supply management and waste management, renewable energy production and storage, household energy consumption.

Our aim is to increase the demand for energy saving, the consciousness about climate changes while using renewable energy sources, the role of small communities. It is also important to change the way of thinking of the population by propagating alternative solutions ensuring sustainability. This may bring with it an additional cost, at building or refurbishment stage, but also an added value environmentally, in the long-term.

Authors

Ildiko Molnar [1]
molnar.ildiko@bgk.uni-obuda.hu

Ákos Nemcsics [1]
nemcsics.akos@kvk.uni-obuda.hu

Attila Trembulyak [2]

1) Óbuda University, Budapest, Hungary
2) Miskolc University, Miskolc, Hungary

Introduction

The operation of heating and cooling systems largely makes up the energy consumption of buildings. Substantial energy saving can be achieved by modernising the ventilation and lighting systems. This article presents the following:
innovative technological solutions;

- as a real example: the results of the simulation tests carried out for a passive house (not yet certified) built in Hungary;
- the implementation of the project "The expansion of the geothermic utility network in Veresegyház by drilling two new thermal wells" step by step.

In the future, some buildings will be like living systems. These buildings will be characterised in accordance with which eco-system or environment they belong to. More efficient local councils will help to solve problems related to the sustainability and healthcare of regions.

Creating green surfaces will enable us to reduce the gap between cities and the agricultural areas surrounding them.
The intelligence of buildings can be compared to smart phones. They will dispose of the same functions as smart phones. The strengths of these buildings will include: heating and cooling systems, windows, blinds, internal and external lighting, alarm and security camera systems, irrigation systems which can be controlled by a remote control from the building or from a distance. I would like to present two innovative solutions.

Air mixing technology

Operating air filter and air rotor extraction has two aims. One of them is to filter bacteria, viruses, harmful gases in the air with great efficiency. As a result, it will improve the health of people residing in the room considerably. The other aim is to reduce energy consumption and the emission of carbon dioxide indirectly. It means that we can achieve 20 – 50 % energy saving in terms of heating and 20 – 40 % regarding cooling. Indirect emission of CO_2 can be reduced by 20 – 50 % with it. This equipment optimises the heating and the cooling systems, which means that it blows the lifting warm air down to the floor. It makes the air move around and therefore no temperature layers will form. As a result, less energy is needed to control the temperature of the air. Hence an added investment cost renders an added value to the finished building.

Ceramic thermal insulation

The material of this ceramic thermal insulation coating contains microscopic air-filled silicone balls suspended in a liquid medium. This feature ensures that the material is superior in terms of energy-saving efficiency, while special additives provide protection against extreme weather conditions. It is water-based, thus environmentally friendly. The physical properties of the ceramic coating are significantly different from those of traditional insulation materials. The air in the microscopic hollow ceramic balls practically does not conduct heat. The convective heat transfer coefficient of the ceramic is much lower (1.29 to 2.2 W/m²C) than that of other construction and insulating materials (9 to 29 W/m²C).

The ceramic coating has good thermal insulating, waterproofing, anti-corrosive (rust inhibitor) and sound insulating properties. (www.carbonsolutionsglobal.com)

Case study – Simulation analysis of an existing passive house

In this article we will show the results of a passive house not yet certified in Hungary. The wall system, the size of windows can be easily changed with the help of a simulation software. The obtained results can be compared with the measurement results. We can clearly see how the heating energy demand and the indoor temperature of the building change.

Theoretically we placed the house in different climatic areas in order to find out whether it still meets the strict requirements. Frontal windows of different sizes and different wall systems were examined to determine whether energy consumption improves. In addition, sunshades should be used because this would help to improve energy efficiency but the house does not have one.

The analysed building is a two-storey detached house of 104,7 m² facing south. Ten identical thermic zones were defined. During the monitoring analysis, the external temperature was also measured as well as the temperature of internal zones. There is an air filtration system in the house which recovers 93 % of the heat and it consists of a ground air heat exchanger too. The walls of the house were built in a ICF structure with external and internal insulation layers and air fast ACTUAL windows.

Figure 1 shows the comparison of temperatures.

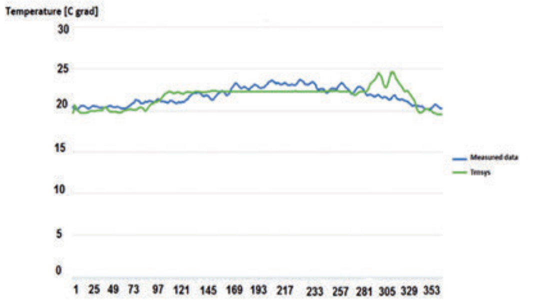


Figure 1 - The results of the measurements and analyses

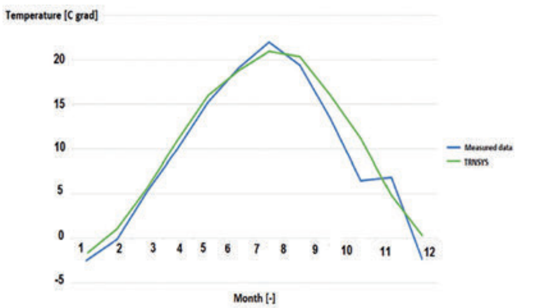


Figure 2 - The curves of simulated and measured external temperature

In Figure 3 we can see the results of the simulation test including the minimum and the maximum temperatures and the additional heating energy demand with different window sizes.

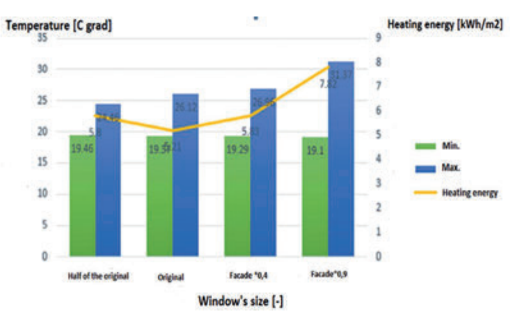


Figure 3 - The minimum and the maximum temperature and the additional heating energy demand with different window sizes

Figure 4 shows the difference in temperature of wall materials. The results confirm that the simulation software can give detailed and correct data about a building. Controlling strategies can be made by using this software. In addition, time and energy can be saved as well (András 2014).

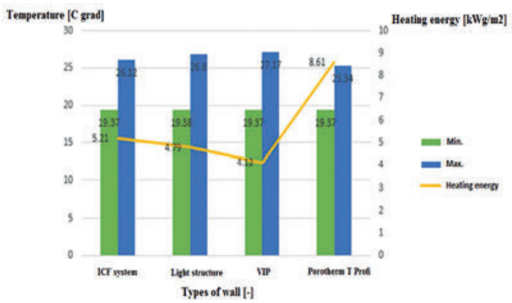


Figure 4 - The difference in temperature of wall materials

The heating demand of the house in different climate zones

A standard passive house was designed to fit in Central or Northern Europe climate. But we know from the experience we have about the existing passive house that it is possible to adapt the standard in different climate zones through planning and implementation and by taking into consideration all the special local attributes. The essential technical content does not change but we need to protect ourselves from the cold at one place and from the heat at other places.

How do climate zones affect the heating and cooling demand of the house if it is placed in another environment? We have chosen two European locations, one Australian and one Russian city. During the simulation, only weather conditions were changed as well as the operations of the heat inductor, everything else remained unchanged.

Stockholm, Sweden

Stockholm is situated in a wet continental climate zone where the average annual temperature is 6.6 ˚C. The heating period lasts from 31 October to 31 March. Figure 5 illustrates the supplementary heating demand of the house and the temperature of different zones inside the house during the year.

The heating demand is 13.57 kWh/m², which means that this house does not meet the strict requirements of a passive house because we would need to add the consumption of the heat exchanger too.

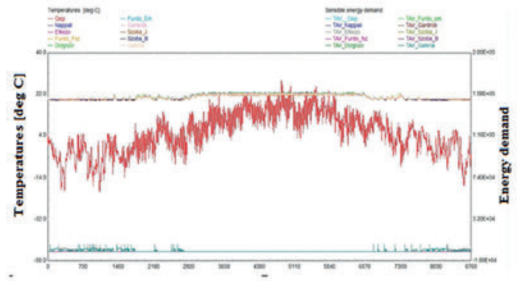


Figure 5 - Heating demand, indoor and outdoor temperatures in Stockholm

Rome, Italy

Rome is situated in a Mediterranean climate zone and the average annual temperature is g 15.2 ˚C. During the simulation, the indoor temperature was even all along: 22 – 23 ˚C. The floor heat exchanger was set to a cooling function and the windows were open a lot. As a result the temperature was convenient. There was no need to use supplementary heating. We can say that it is cheaper to live in this house in Rome than in Hungary. The building can be cooled down in a more optimal way without opening the windows but we can achieve to have fresh air.

Sydney, Australia

Sydney is located far from the equator in the South in a moderate Oceanic climate zone. This area is characterised by hot summers and mild winters (maximum 2 ˚C). As it is on the other side of the Earth, the hottest season is completely different (from December to February) and the coldest season is in July. The buildings need to be oriented differently. They should be oriented toward the North because of the Sun's position. Therefore this area is tested in two ways: once oriented toward the South and a second time oriented to the North by rotating it by 180 degrees.

Figure 6 illustrates the results of the simulations. The result of our first simulation was really interesting when the orientation

of the building remained the same. In this case the supplementary heating demand was zero although the heat loss was clearly more because the windows were mostly facing the South. During the second simulation the building was rotated by 180 degrees and the large windows were facing the North. In this case we saw a surplus energy demand of 1.45 kWh/m².

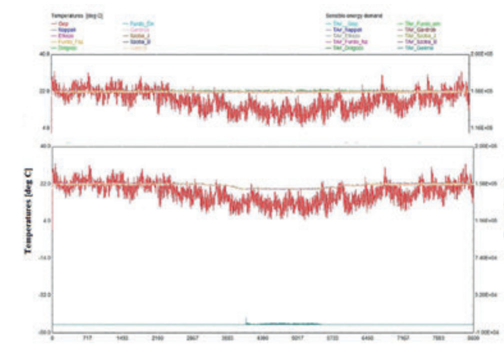


Figure 6 - Heating demand of the house and indoor and outdoor temperatures in Sydney

The graph above shows the house facing the South while the graph below shows the house rotated by 180 degrees facing the North.

Oymyakon, Russia

This Russian town can be found in the coldest part of the Earth in a subarctic climate zone. The average annual temperature is -16.4 ˚C with an amplitude of 30 degrees. The 6 February in 1933 was the coldest day when temperature was -67.7 ˚C. So this is the cold pole of the Earth. This location was chosen because of its extreme weather condition.

The results of the simulation show us that the heat exchanger must have frozen because its efficiency was only 0 per cent. This is not surprising as the soil in this area is frozen 365 days of the year even if the temperature is sometimes above 20 degrees. The conclusion is that the floor exchanger is not necessary. We can also clearly see (on figure 7) that the temperature indoors reached 28 degrees for a little time as the air pre-cooling system could not work.

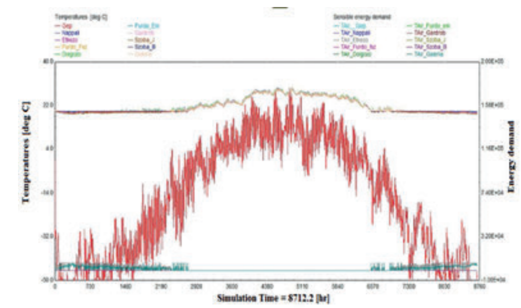


Figure 7 - The energy demand of the house, indoor and outdoor temperature in Oymayakon

The overall heating demand of the building reached 60.04 kWh/m², which means that not only does it not belong to the standard passive houses but it does not even qualify for a low energy building. Such cold weather requires different mechanical structures.

To sum up the simulations in towns of different climate zones, we can say that we can meet the requirements of the standard passive house to be found in Hungary in other countries of warmer climate as well provided the house has open windows.

How to use geothermal energy

Geothermal energy can be used in many ways: for heating, hot water, in thermal baths, in industries and in agriculture. With the increase in the energy prices, the use of the thermal water for heating and hot water is increasingly spreading. Not only can public buildings, offices, hospitals, warehouses, factories etc. be heated with thermal water but whole blocks of flats as well.

In terms of thermal water, Hungary is in a good position due to the rate of the geothermal gradient.

The amount of energy gained depends on the quantity of water. Thermal water has been used for heating buildings in places like Kistelken, Bólyon, Mórahalmon and Gárdonyban in Hungary to date. A production well and a pump are needed each time and the heat of the thermal water is conducted through a heat exchanger to the heating system of radiators (thermal water heated up by the soil temperature is brought up to the surface and it is circulated in the heating centres). The temperature of the thermal water depends on the depth of its location. The deeper it is brought up from, the warmer it is therefore the depth of the well should depend on the planned energy demand. When the cement or casing well (where the heat stems from) is designed, a sinking pump needs to be put in the upper part of the well.

The next example is a geothermal energy project in Veresegyház. Veresegyház is located in central Hungary. It hosts geothermal, geological facilities and it has good infrastructure. The aim of the local council was to support the use of renewable energy sources by establishing thermal water utilities to satisfy the local heating demand. This investment was implemented in several stages and it involved great sacrifices and large costs for this village.

The aim of the investment was to build an anchor-ring utility with geothermal energy. This facility enabled the reduction of (GHG) gases and it provided the region with economic and infrastructural benefits. Its consumers are social or educational institutions and small plants and industries. But there was a possibility for family homes located in the area to join the system as well.

Figure 8 - Institution to join the system. (Source: Veresegyház-KMOP pályázat, SzitaGáborprezentációja)

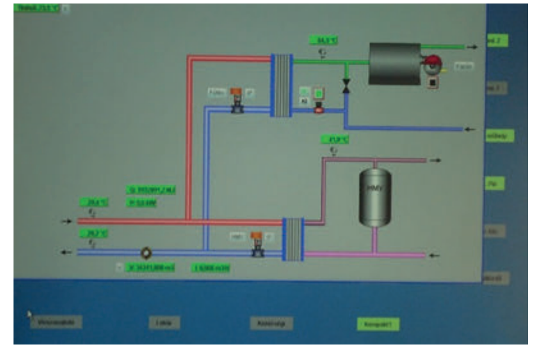
This utility network consists of: a producer and a gulper well, volume rate regular pumps and water pipes. The depth of the wells is 1400 – 1500 m, their water output is 2000 l/s and the water bed is made of limestone. The temperature of the water in a supply pipe is 60 – 64 °C and it contains solute gases.

The water is produced by diving pumps and it is forwarded to the consumers after removing the gases across pump houses. The used water of the system is conducted to rivers and it is returned to the gulper well with the help of gravitation. Methane to be found in water is removed from the water with the help of a puffer tank and it is released into the air. (Figure 9.)

Figure 9 - Puffer tank

To circulate water, variable frequency pumps are used (Figure 10). All the heating centres are controlled by computers which carry out control and regulatory processes (planned life expectancy 5 years) and they collect and store data. In the heating centres PLC-s are linked to the central server. (Figure 11) Signals are sent to the PLC-s by the computers and the PLC-s give order to the pumps.

Figure 10 - Monitoring operating systems



The experiments showed that the implementation of the system does not cause any damages in the environment. During its operation, neither the surface water reserves nor the underground water reserves are polluted. The returned water amount does not affect the underground energy distribution.

Table 1 - Reduction of toxic gas emission in the air right after the system is put into service

	After the system is put into service	During the 25 year life cycle of the system
CO_2	2125 t/year	53119 t
SO_2	214 kg/year	5342 kg/year
NO_x	2838 kg/year	70 959 kg/year

The results of this project have been analysed in terms of cost efficiency comparing thermal heat, ground heat and natural gas in heating a building. We have conducted fictional experiments comparing several building technologies supported by calculations. The heating demand can be calculated from the average annual days that heating is required which is about 180 days a year (in the examined school it is 203 days). In addition it is also calculated from the average indoor temperature which is t=20,7 °C as well as from the dimensioning temperature tm=-13° C.

The volume of the natural gas necessary to obtain the required temperature has been calculated. In addition to the heating energy demand, natural gas is needed to produce hot water as well. The addition of the two figures is necessary to find out the required natural gas demand.

Table 2 - Energy consumption

For heating buildings		For production of hot water		Total	
GJ/year	m³/ year	GJ/year	m³/ year	GJ/ year	m³/ year
307	8796	65	1855	372	10651

The volume of natural gas required per year is 10.651 m³. With the gas prices of 2010 this means as HUF 970.000. Geothermal energy currently costs 1.566 Ft/GJ. The same amount of energy produced by geothermal public utilities only costs HUF 580.000.

After putting the system into operation, the CO_2 emission decreases by 2 125 tons per year while the SO2 by 214 kilograms. The volume of the produced thermal water is 256 319 m³ which can replace 40,8 TJ/year natural gas energy.

Further consumers can join this system. In addition the system can be extended and it can also be linked with other technologies including heat pumps. (Trembulyák et al., 2011).

Conclusion

As an overview of investment cost and respective added value, the analyses conducted related to (the not officially certified) passive house demonstrate that a clear detailed evaluation can be obtained with a dynamic simulation software, which reconstructed exactly the real situation. The house can be prepared for changes in the weather if serious mathematical and programming skills are at hand and equations are given.

The results of the simulations let us conclude that more energy could be saved with different wall systems. In the future different types of shading systems should be analysed. The study of the geographical location of the building shows that this German innovation is suitable around the world if the climate varieties are taken into consideration.

The earth layer is thinner in the Carpathes especially in Hungary therefore our geothermal attributes are favourable. Hungary is the only country in Central Europe where the underground heat flow exceeds by far the world average value. Its importance should not be forgotten. This is a resource with zero cost yet an inherent added value.

The increase in depth per unit involves significant rise in the temperature. The average geothermal gradient usually makes up 0.020 – 0.033 °C/m in Hungary this figure reaches 0.042 – 0.066 °C/m. Due to the above mentioned thermal attributes, the temperature reaches or exceeds 60 °C 1000 – 2000 m deep under ground in Hungary (Great Plain). Izoterms in the temperature represent fields with temperatures over 100 °C at 3000 m deep. High ground temperature, thermal water and confined water are favourable for heat pump technology.

In Hungary there are favourable conditions for heating, cooling and supplying hot water with geothermal energy. Mostly ground heat can be used as energy source. It can be gained from ground water, running water and lake water through sensors placed 50 – 100 m deep under ground. The temperature of the ground water and rock strata in comparison to solar energy does not decrease in winter either, therefore geothermal energy can be used without a supplementary heating system. Hence an added investment cost renders an added value, rendering it to be an all round green building.

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A value based approach of the energy efficiency improvement in civil buildings: cost, financing sources, and efficiency indicators in retrofitting

High energy consumption and its implication emphasise the need for improving energy efficiency in buildings. One of the greatest barriers for such an increase in energy efficiency in buildings is the high capital cost of projects. The research is focused on different aspects of the measures for improving energy efficiency in civil buildings as: cost, ways of financing, benefits and categories of beneficiaries, and effects and modalities of evaluation.

Author

Liliana Mihaela Moga
liliana.moga@gmail.com

Dunarea de Jos University of Galati, Romania

Introduction

Energy efficiency is at the centre of the European energy policy and one of the main goals for the Europe 2020 Strategy for smart, sustainable and inclusive growth adopted by the European Council. Buildings have become a hard-core element of the measures concerning the energy efficiency improvement and lowering of carbon emissions. The private sector is quickly discovering what public agencies have known for years: that retrofitting buildings for energy efficiency brings substantial rewards (White, 2010). The energy performance of buildings is key to achieving the European Union Climate & Energy objectives and is a cost-effective way of fighting climate change and improving energy security while creating job opportunities European Economic and Social Committee, 2011).

Therefore, a major importance was accorded to the factors that influence of retrofitting buildings, and to the evaluation of the results that follow it.

Amstalden, Kost, Nathani, and Imboden (2007) researches show that the present Swiss policy instruments push investments for energy-efficient retrofitting to profitability. The European Commission studied the results of the financial support designed for energy efficiency in the building sector (European Commission, 2013). A complex system based on indicators as energy price expectations, policy instruments such as subsidies, income tax deduction and a carbon tax, as well as potential future cost degression of energy efficiency measures were taken into account. However, the most relevant factor for the investment analysis is the expected energy price. Roulet et al. (2002) evaluate the efficiency of retrofit.

Within the framework of the European project, a multicriteria-rating methodology was developed for this purpose, based on a rating method. The aim of this methodology is to rate or to rank office buildings and retrofit scenarios of the same building according to an extended list of parameters, which include the energy use for heating, the cooling and other appliances, the impact on external environment, the indoor environment quality, and cost.

The international and national framework for financing refurbishments in the residential area

In the European Union, industry uses the least energy (28 %), and transport uses a bit more (32 %). However, by far the largest users are buildings, mainly the civil ones (40 %). Thus, the greatest contribution will come from the increased energy efficiency of buildings (International Energy Agency, 2015). Substantial steps towards energy consumption reduction have to be made in the building markets, both in civil and institutional buildings, for new and old buildings. Nonetheless, Commission estimates showed that the European Union will achieve only half of the 20 % objective. Policies of refurbishing in the building sector

take into consideration its high energy consumption. One of the greatest barriers for the improving of the energy efficiency in buildings is the high capital cost of projects. Clean energy projects require large up-front investments, followed by a long period of payback through savings in energy bills of the building's owners (White, 2010).
A 2013 report from the European Commission studied financial support for energy efficiency in the building sector (European Commission, 2013) found that:

- the financial support for energy efficiency in the building sector has to be improved in order to meet its 2020 energy efficiency target;
- the analysis of the national environment shows that the financial support mechanisms vary significantly across European countries;
- barriers such as high initial costs, long payback periods and perceived credit risk hamper energy efficiency improvements in buildings;
- the information on the effectiveness of currently available financial support mechanisms are fair.

In this context, discussions related to measures for improving energy efficiency in apartment blocks focuses on the following directions: ways of financing, benefits and categories of beneficiaries, and effects of retrofitting by insulating with polystyrene. The retrofitting of buildings is one of the measures laid down in Directive 27 of the European Parliament and of the Council (2012) concerning the energy efficiency. Despite many positive experiences, there is still significant scope to improve the uptake and effectiveness of European Union financial support. On the other hand, the European Union has established the need that the European Union Member States to identify effective solutions as regards the costs, as well as policies and measures necessary to foster building refurbishment.

Moreover, the Member States have an obligation that, based on the data available to them, to carry out estimates related to energy savings. In order to set a pace that would enable the European Union to reach its target of diminishing the energy consumption by 20 % until 2020, it is proposed that energy suppliers to encourage end-users to reduce their consumption through improvements intended for increasing the efficiency.

Therefore, the European Union has introduced the compulsoriness of building refurbishment, leaving the technical solutions adopted and financing method up to the Member States. The Member States may opt for a number of mechanisms used in order to improve energy efficiency. They have developed complex solutions, some of them complementary, coordinated at national level. In Romania, funding the programs of retrofitting of apartment blocks was achieved through (Mereuta, 2013): the state budget: the national multi-annual program for enhancing energy efficiency in the apartment blocks.

In order to help member countries in achieving the goals of energy consumption decrease assumed through Directive 27, the European Union has provided financial support for the retrofitting achievement. The European Union has already some experience with financial instruments (1.3 % of the budget was allocated for instruments during the current programming period) and intends to rationalise and develop them further in the next period (2014 – 2020). Funds have been allocated through the Regional Operational Programme (REGIORop), Major Area of Intervention 1.2, Support for investments in energy efficiency of the apartment blocks. The objective of the ROP intervention is to support investments in energy efficiency of the civil buildings, creation and maintenance of jobs and furthering social cohesion through supporting the improvement of energy efficiency for the civil buildings, in accordance with the objectives of Europe Strategy 2020. This will lead to increase of the employment rate of labour force, low energy consumption and limiting the greenhouse gas emissions. The eligible applicants are administrative-territorial units (local public administration authority), at the level of municipality, residence of region, county, according to the law in force in each country.

The European Union, in cooperation with the EBRD, through the program RoSEFF – Small and Medium Sized (SME) Sustainable Energy Finance Facility, is supporting the SMEs and lodgers associations to invest in energy efficiency and renewable energy, by giving: loans through the Participating Financial Institutions (banking institutions), free technical consulting from Tractebel Engineering and European Union grants. Through the Window of Energy Efficiency Programme – Green Initiative, the European Investment Bank (EIB) manages funds for energy efficiency, mainly intended for the companies of energy services and owners associations that have an economic activity (Mereuta, 2013).

The European Union proposals for the next Multi Annual Financial Framework was to increase the cohesion policy funding for low carbon economy measures, mainly through the ring-fencing of 20 % of the ERDF for energy efficiency and renewable energy in more developed and transition regions and 6 % in less developed regions. In addition, it was proposed to expand the use of financial instruments and to remove the 4 % limit on support for sustainable energy investments in housing (European Commission, 2013).

Programmmes promoted at the national level

In European countries, the provision of financing or a grant in order to support the refurbishments in the residential area is a common practice. These complement other programs that run based on the preferential credit mechanism (Poland, France), funds (Croatia) or the energy services financing (Spain). In the UK was implemented the (Green Deal) program (Romanian Green Building Council, 2009) by which it was implemented a mechanism by means of which the value of energy rehabilitation works is paid through applying a tax that is included in the energy bills and which should not exceed the amount saved. Virtually, the investment recovery is made in instalments, the household paying during a fixed period the same amount for the energy bills as before the rehabilitation (Mereuta, 2013). In Germany, the main policy adopted was that of low-interest loans, a system that is beginning to be also implemented in Romania (Schröder et al, 2011). In Romania, under pressure of the European Union initiatives to obtain the agreement to finance retrofitting projects from European funds, there have been legislative changes such as adopting regulations that allow that rehabilitation to be carried out with European financial contribution, complemented by a share coming to the town halls, as well as a minimum contribution of the owners. Thus, it has been implemented the National Program for retrofitting, which is intended for the owners associations who want to increase the energy performance of the apartment blocks. It regulates the method of costs division, as it follows:

- the owners association pays 20 % of the total cost of rehabilitation works, the percentage is divided among all owners, each having a share based on the undivided share coming to each owner;
- the remaining 80 % is provided from the state and local budget, as it follows: 50 % from the state budget, through the Ministry of Regional Development and Public Administration, and 30 % from the local budget, within the limit of annually approved funds for the Local program concerning the energy efficiency increase in apartment blocks.

A number of initiatives playing a part in increasing the efficiency of implementing the programs for energy saving are taken by the bank or business environment. Thus, the representatives of the banks for housing in Romania have proposed the authorities amendment of legislation regarding retrofitting, to be accepted in the program loans with fixed interest rates offered by them.

Value and usage value in the decision to purchase a product or service

The function of civil buildings is to create a comfortable climate indoors regardless of the season. In this respect, the building elements that make up the cover of such buildings should be designed to ensure indoors adequate conditions for hygrothermal, acoustic, visual-light, olfactory-respiratory comfort. The hygrothermal comfort translates into easy to bear levels of temperature and humidity. The notion of comfort should suggest creating an environment corresponding to living a normal life. From any product of "building" type is finally an appropriate response to all users' requirements / exigencies formulated by those involved in its use. Formulating the users' requirements cannot be done but in qualitative terms with reference to the building as a whole (Local Energy Agency Bucharest, Romania, 2015).

In this regard, the Local Energy Agency Bucharest, Romania (2015) developed a brief dictionary of consecrated terms, as it follows:
- user exigency is the stating of a need for the civil building that has to be used;
- quality requirements are the qualitative expression of the building (in whole or for each part) characteristics that it must fulfil in order to meet users' requirements, taking into account the various agents acting on the civil building;
- technical condition is the expression in technical terms the performance of quality requirement;
- performance criterion is a feature that should be considered when detailing and quantifying the technical conditions in amounts termed 'levels of performance";
- level of performance is the imposed value for a particular performance criterion depending on the technical conditions, influence of agents acting on the building;
- performance is the behaviour of a product in relation to its use; the product can be understood as the building as a whole or any part of it;
- assembly is a combination of several components ensuring the achievement of a function.

Technical solutions for the buildings retrofitting

Any improving activity maintains the building in a better shape, extending its lifetime and increasing its value. Investments contribute also on a larger scale to saving primary energy resources, as well as to diminishing the environmental pollution by the gas emissions inherent in energy production. Understanding the manner in which a building works, both as concerns the construction and in terms of equipment and facilities serving it is essential in order to identify strategies that should be adopted for its energy rehabilitation. Strategies for energy rehabilitation of buildings should take into account ensuring indoor conditions of comfort, health and safety for all building users (Local Energy Agency Bucharest, Romania, 2015). Insulation with expanded polystyrene is the main technical solution adopted for retrofitting. The effects of interventions on indoor installations are relatively low in comparison with the effects of cover retrofitting (Cerna Mladin, 2012). Given that climatic zone greatly impacts the energy performance of a building, for an important increase in the building energy efficiency there are necessary additional measures, that target thermal losses recovery, use of heat pumps and renewable energy sources (Cerna Mladin, 2012). Although there are no recommendations at European or national level concerning the materials used for retrofitting, polystyrene is recognised as sustainable, recyclable and accessible from the costs point of view. On the other hand, organisations such as the Order of Architects from Romania argued against its large-scale use for the rehabilitation of apartment buildings constructed of prefabricated panels, taking into account its negative effects of "sealing" the buildings. Adopting the technical solution of insulation with polystyrene should be accompanied, at least, by complementary solutions for natural ventilation and air circulation between the wall and thermal insulation (Romanian Green Building Council, 2009). Countries such as Italy and Hungary have opted for solutions of interior thermal insulation, as well as for other complementary and/or alternative measures. In the UK, the optimal solution for each apartment/building is established following an evaluation by a Green Deal consultant.

Indicators

There was developed multiple modalities of approaching of the evaluation of energy efficiency for buildings, but no one of the proposed solution cover all the aspects. The main indicators systems used are focused on implementing energy efficiency investments aimed at reducing the energy consumption in physical terms.

The indicators for the retrofitting of buildings are mentioned both in the objectives of retrofitting programs and in the feasibility

studies for achieving these works. Other indicators, that are addressed to the value produced by the companies supplying materials and services (for companies) are issued observing the European environmental standards by the towns (authorities, inhabitants). A great part of the proposed approaches is oriented to the technical aspects or to the quality control. The results used by the use of these methods were not satisfactory for the evaluation purposes. More than, the classic methods of energy efficiency for buildings analysis and evaluation do not take into account the aspects introduced by the use of value based methods, which take in consideration the end users point of view. Therefore, the currently used system of indicators is completed with new indicators. The indicators' system proposed for the analysis of energy efficiency for buildings developed by means of value based methods, measure:
- the efficiency belonging to the energy efficiency for buildings developers;
- the degree of satisfying the needs of energy efficiency for buildings beneficiaries;
- unquantifiable effects.

The efficiency belonging to the energy efficiency for buildings developers is measured by evaluating the quantifiable effects, by indicators derived from value indicators of the production activity like:
- cost of retrofitting / apartment;
- total value of the intervention works;
- specific investment;
- execution time of the intervention works;
- warranty period for the intervention works;
- duration for the investments recovery in terms of economic efficiency;
- number of apartments rehabilitated for the increase in energy efficiency.

The degree of satisfying the needs of energy efficiency for buildings beneficiaries: represent, in fact, the measure of use value and is obtained by approximating and evaluating the use characteristics. The minimum limit of use value is defined as the minimum levels' sum of the characteristics and it presupposes a comparative evaluation with similar products:
- reduction of maintenance costs for heating and household hot water;
- annual energy saving;
- price of retrofitting;
- annual saving for the period of retrofitting fee payment:
- decreasing heat losses;
- reducing energy consumption;
- diminishing the maintenance costs for heating and consumption hot water;
- deadline for recovering the contributions;
- fire safety;
- human hygiene and health;
- protection against noise Accumulates less dust and pollen inside;
- improvement of indoor comfort.

Unquantifiable effects, which are connected with the added value for authorities and inhabitants is a distinct indicator by means of which the result of the retrofitting are evaluated is the socio-economic efficiency, which is defined as the aggregate of the useful socio-economic effects, registered after retrofitting, in relation to the efforts made for their acquirement. Given its particularly complex character, the situation asks for a deep approach of the socio-economic efficiency, back grounded by the implications on the management system. In this category are included:
- strength and stability;
- safety in operation;
- improvement of hygiene and thermal comfort conditions of the population;
- reducing pollutant emissions generated from production, transport and energy consumption;
- keeping the architectural, environmental and chromatic integration quality in urban areas;
- lowering the climate change effects by reducing greenhouse gas emissions;
- increasing the energy independence by reducing the fuel consumption used in the heating agent preparation;
- improving the urban appearance of localities;
- greening and protecting the environment;
- deterioration of the quality of construction;
- creating/ maintaining jobs and fostering social cohesion;
- increasing/ maintaining the workforce employment rate.

Conclusion

Funding sources are provided through European Union programmes to support Member States in implementing EU directives and for associated investments in order to comply with the energy efficiency objectives. Most of the European Union funding co-finances projects with grants that are combined with national financing sources. In order to meet its 2020 energy efficiency target the policy makers from European Union and national level have to coordinate their actions in order to find modalities that influence the increase of energy efficiency in the building sector, especially in what concerns the financial support and the effectiveness of currently available financial support mechanisms. In order to get new dimensions for the civil buildings renovation, a new approach of the benefits has to be done, based on value concepts.

The aim of this approach is to expose buildings and retrofit scenarios and their benefits for each stockholder category, directly or indirectly involved or affected. Towards this aim, a complex system based on indicators is proposed, that covers a large range of aspects of the retrofitting benefits.

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Low-energy and smart concept expansion: from single house to the city scale

Rapid urbanisation leads to the growing of cities both horizontal and vertical dimensions, what in turns leads to the increased energy consumption and poorer environment quality. That's why European Initiative on Smart Cities takes place. The aim is to improve quality of life and local economies through the investments in sustainable energy and reduction of carbon emissions. Residential buildings in Latvia are one of the essential heat consumers during the heating season. The majority of Latvian as well as European residential buildings were constructed within the period from 1965 to 1990. The average heat transfer coefficient of typical homogeneous single layer external wall of Latvian multi apartment building as well as all buildings constructed in USSR is 0.80 till 1.20W/(m^2K) (Borodinecs et al, 2013; Latvia State Agency, 2006). This paper presents study on multi apartment buildings renovation specifics in Latvia and its influence in total energy consumption and possibilities to spread different energy-efficient solutions from single house to the city scale.

The heat consumption for heating and hot water after applying of comprehensive renovation of buildings can be realistically reduced down to 70 – 100kWh/m^2 year in typical Latvian climate conditions. The optimal U-values of walls after thermal insulations is 0,18 – 0,25W/(m^2·K), while for roofs 0,12 – 0,15W/(m^2K). At the same time it is essential to provide possibilities of sharing the experience about smart city design and planning between cities and communities. Most successful and beneficial projects have to be repeated and recreated widely in Europe considering local differences in technical features of infrastructure.

Authors

Aleksandrs Zajacs [2]

Aleksandrs Korjakins [1]
aleks@latnet.lv

Jurgis Zemitis [2]

Anatolijs Borodinecs [2]

1) Institute of Materials and Structures, Riga technical University, Riga, Latvia
2) Institute of Heat, Gas and Water technology, Riga Technical University, Riga, Latvia

Introduction

Rapid urbanisation results in the growing of cities both horizontal and vertical dimensions, which in turn leads to an increased energy consumption and poorer living environment. That is why European Initiative on Smart Cities takes place from year 2010. Strategic objective of this Initiative is to demonstrate the feasibility of rapidly progressing towards our energy and climate objectives at a local level while proving to citizens that their quality of life and local economies can be improved through investments in energy efficiency and reduction of carbon emissions. This Initiative will foster the dissemination throughout Europe of the most efficient models and strategies to progress towards a low carbon future. The aim of this paper is to identify, review and evaluate the technical feasibility, applicability potential and the economic benefits of different activities in the housing in Latvia on the way to achieving smart status and low-energy house requirements. Smart City concept means efficiency, but efficiency based on the intelligent management, integrated ICT's and active citizen participation.

Housing sector can be divided to the existing and planned and while energy-efficiency of planned part can be regulated by legislation, existing part is more likely to be renovated and improved by introduction of more energy-efficient HVAC technologies combined with improvement of the thermal resistance of the building envelope. All energy efficient buildings are based on passive house concept. Passive house is a standard developed by Passive House Institute which at the same time provides energy efficiency of the building and comfort at affordable price. According to passive house concept the U-value is 0.1W/(m^2K) for walls, roofs and 0.8W/(m^2K) for windows. In modern energy efficient buildings sun energy, energy from internal heat sources, as well as heat regeneration is used effectively, in that way reducing required heating capacity to minimum even in coldest winter days, consequently it is not necessary obligatory to use traditional heating methods.

According to LBN 002-01 Latvian Building Code normative value of thermal transmittance for massive outer wall is 0.18 W/(m^2K), but in practice U-value of building envelope of existing buildings exceeds 1.0W/(m^2K). Studies have shown that thermal transmittance for typical building envelope built until year 1991 is in the range of 0.8 W/(m^2K) to 1.2 W/(m^2K), but there are cases where U-values of outer walls of the building reach up to 2.0 W/(m^2K). Only 3 % by number and 5 % by area of the building constructed after 2003 can be considered to be appropriate to the present thermal requirements. According to the current building energy efficiency policy until year 2016, the average heat consumption in buildings should be reduced from 220 – 250 kWh/m^2 to the 195 kWh/m^2 per year, but in 2020 it should not exceed the 150 kWh/m^2 per year.

Analysis of the current housing stock

Research project "Housing Energy audits 2005" data (audited 103 apartment houses in all Latvian regions), show that the building's envelopes does not meet thermal requirements of the LBN 002-01 and coefficient value of the thermal transmittance exceeds current regulatory requirements (Latvia State Agency, 2006).
In order To reduce the energy consumption of the building, it is necessary to understand what kind of heat losses should be compensated, why they occurred and what energy efficiency measures have to be taken. As each house is unique, then the energy efficiency measures will be different for each house. In order to determine the necessary investments that will pay off in the most efficient and fastest way, energy audit is carried out.
More generally, the energy efficiency measures in the buildings can be divided into several groups according to the unifying characteristics:

- building envelope – insulation of the building outer walls, windows, roof/attic, basement ceiling;
- management and control – energy-efficiency measures which allows controlling and keeping desired indoor environment parameters (balancing and thermostatic valves, mechanical ventilation etc.);
- engineering communications – insulating of the main and branching heating and hot water pipelines (attics and basement)
- lighting – changing by LED and smart control (dimming, move sensors, changing voltage);
- individual appliances – individual using of home appliances with higher energy efficiency rating A++.

For multi-apartment residential buildings to achieve the planned reduction in energy consumption is necessary to combine different groups of measures (Stankeviča, G and Lešinskis, 2012).

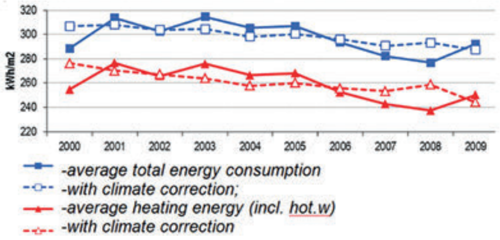

Figure 1 - Household energy consumption for residentials

During the last years since year 2000 the residential sector has experienced positive changes in the final energy consumption (Figure 1), according to the Central Statistical Bureau (CSB) year 2009. And in the year 2009 average total energy consumption (heating and electricity) in the households was 287 kWh/m^2 year. But still it is not enough to reach values set in the current building energy efficiency policy documents for the period up to 2016, the average heat consumption in buildings should be reduced to the 195 kWh/m^2 year, but in 2020 it may not exceed 150 kWh/m^2 year.

Increasing the scale of smartness

At the moment all countries of the European Union are obsessed with one common challenge – energetic self-sufficiency and reduction of the CO_2 emissions. And this is possible only by introducing the active measures in different sectors and different scales.

Modern cities can achieve EU20-20-20 goal only by improvements in all major sectors such as buildings, energy and transport. Each European City is free to choose their approach for achievement of EU20-20-20 target. The main document which defines actions and measures to be implemented in each City in order to reach CO_2 reduction by 20 % is Sustainable Energy Action Plan (SEAP). According to Covenant of Mayor (www.covenantofmayors.eu) data there are 3414 cities across the Europe and eastern partners which already have Sustainable Energy Action Plan. Typical Sustainable Energy Action Plan is focused on standalone actions such as insulation of buildings, use of efficient lighting, local renewable energy sources and etc. Nowadays the existing SEAP should be enhanced taking into account requirements for Smart Cities. Although there is no global definition of Smart City (Neirotti et al, 2014) the Smart Cities general concept can be characterised as improvement of urban performance by implementation of information and communication technologies (ICT) and by engagement of stakeholders. In addition more cross-sector energy actions should be introduced. Currently there are activities to start standardisation activities in field of sustainable development and smart cities (Marsal-Llacuna et al, 2014).

Efficiency and impact of each energy action should be evaluated on 3D scale taking into account sector, city dimension and implementation scale. The major city dimensions which characterise each energy action are “energy and technology”, “economics and finance” and “organisation and stakeholders”. Interaction between city dimensions and scale for each sector is shown in Figure 2. Each indicator impact is evaluated at implementation scale. This approach enables us to understand whether the implementation of actions is proportional to the city’s scale and dimension in each sector. For example, if city wants to realise existing building renovation at city scale the “economics and finance” and “organisation and stakeholders” should be addressed at proper level. The public/private finances should be used including ESCO (Energy Service Company) model and active work with wide range of stakeholder groups is necessary. Example of “energy and technology” indicator of building renovation process at different scale is shown in Figure 3.

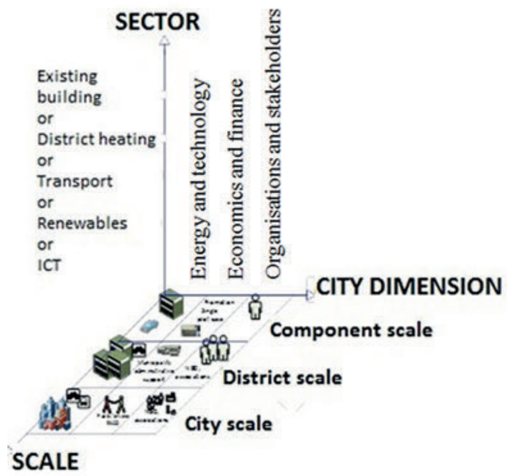

Figure 2 - Evaluation of dimension and scale of energy actions

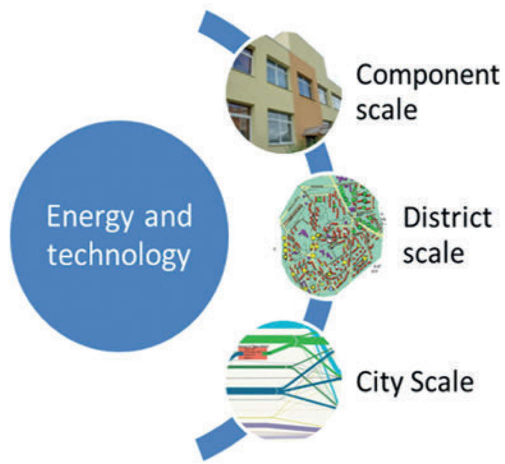

Figure 3 - Example of building renovation process on “energy and technology” dimension

In case of building renovation the component scale includes single building renovation. The district scale may include grouped building renovation. According to Borodinecs et al. 2013, the estimated savings can be about 10 % due to grouping development, compared to the component scale renovation. The city scale renovation can include analysis of different building renovation scenarios and future city energy flow planning.

As mentioned above, nowadays cross-sector energy action is one of main parts of Smart City. As a rule the cross sector action needs to affect at least three sectors at once – transport, energy and ICT.

It is essential to provide possibilities of sharing the experience about smart city design and planning between cities and communities. Most successful and beneficial projects have to be repeated and recreated widely in Europe considering local differences in technical features of infrastructure. In terms of Smart Cities the most powerful actions are those which directly affect at least these three sectors – energy, ICT and transport. Dissemination of such projects across the Europe will be possible due the fact that the projects have already been approved and implemented in other cities. Also energy saving potential can be assessed more accurately and possible shortcomings or limitations considered due to existing experience. It can be called Good Practice, which in the context of INTERREG IVC programme is defined as an initiative (e.g. methodologies, projects, processes, techniques) undertaken in one of the programme’s thematic priorities which has already proved successful and which has the potential to be transferred to a different geographic area. Proved successful is where the good practice has already provided tangible and measurable results in achieving a specific objective.

From “have to” to “done”

Building renovation examples from Latvia include two kindergartens and one multi-story apartment building. The renovation package for both kindergartens as well as for residential building included similar improvements to building façades, as well as heating and ventilation systems. In all cases façades were insulated with additional 100 mm of insulation, also the windows were changed to double glazed PVC windows, additional insulation on pipelines was placed, the radiators were replaced and system was rebalanced. The old one-pipe heating systems with old cast iron heating elements were completely replaced with two-pipe newly built heating system with panel type radiators equipped with thermostatic valves. Table 1 shows the completed renovation works in analysed buildings and the predicted energy savings from each measure (Borodinecs et al, 2013). To evaluate the effects of renovation measurements of consumed energy for heating have been performed and comparison to the predicted ones has been made. The Table 1 shows how these results stack up.

As seen from the table there are some differences between predicted and measured energy consumptions and mostly the actual measured heat consumption is higher than predicted one. This can be explained by reason that the indoor temperature had risen after renovation. In most cases this can be considered as a good thing because the indoor temperature before the renovation was too low and by increasing it the indoor climate quality is improved. However, if the temperature rise is unwanted the heating system needs to be rebalanced after the renovation or automation for heating boiler must be installed.

The research had shown unsatisfactory indoor air parameters in partly renovated and non-renovated buildings. The main reason for high level of CO_2 emission is lack of air exchange and absence of any ventilation systems (Latvia State Agency, 2006). Study (Borodiņecs et al. 2007). shows significant impact of ventilation on total energy consumption. In case of necessary air exchange rate 24/7 the share of heat consumption for ventilation needs is 40 % – 60 % of total energy consumption for space heating.

Comprehensive renovation
Under comprehensive renovation we understand a set of measures for increasing heat stability and energy efficiency of the building, including:

Table 1 - Comparison of heat consumption before renovation with theoretically predicted and measured heat consumption in Latvia

Objects	Heat consumption before renovation kWh/m² (kgCO_2)	Theoretical heat consumption after renovation kWh/m² (kgCO_2)	Measured heat consumption after renovation kWh/m² (kgCO_2)
Kindergarten	227 (30 464)	121 (17 326)	150 (21 765)
Kindergarten	245 (89 304)	117 (58 258)	145 (71 940)
Residential building	150 (89 304)	78 (54 450)	75 (44 652)

- insulation of the attic or the built up roof, the ground floor or the base of the building, the basement and the external walls;
- replacement of the windows in all the building,;
- renovation of the ventilation system without heat retrieval;
- renovation or replacement of the hot water system with mains pipeline insulation;
- renovation or replacement of the heating units (in Riga before 2008 all buildings connected to the district heating were equipped with autonomous modern heating units with secondary temperature control);
- renovation of the heating system, including replacement of radiators and in case of a single pipeline equipping them with a by-pass, installing temperature controls and allocators and other heat metering devices;
- improvement of the single pipe system with temperature controls installed on mains with reverse flow and an automatic balancing system for uniform temperature distribution to the radiators.

The maximum number of energy efficiency measures has been implemented in 7 of the total number of renovated buildings, which serve as an example of what can be achieved through massive renovation activities in a multi-apartment building. The Table 2 above shows the actual energy efficiency data (heating + hot water preparation) for these 7 multi-apartment houses.

Table 2 - Actual energy efficiency data (heating + hot water preparation) for renovated 7 multi-apartment houses (City of Riga, 2014)

Address	Total utilised area m²	ASHC in 2012 kWh/m²*
1. Anni**aris 60	2200.11	95.75
2. Be**et 4	1646.07	96.64
3. Kurz**ts 14	2342.91	95.09
4. Ce**et 5	2969.3	117.63
5. Rig**ve 7	1 916.00	107.62
6. Oz**eet 46 k.3	3955.9	107.48
7. Ga**reet 29 k. 1	2160.7	88.92
Average value		101.3

Wastewater heat recovery

The project "Wastewater heat recover from multi-apartment residential buildings" (Figure 4) which has been included in the e-catalogue "Best practice projects for a smart city" prepared by the municipal agency REA in 2013, has been developed and implemented in Riga, Kipsala, in the student hostel of the Riga Technical University at Azenes Street 22 and 22a for hot water preparation.

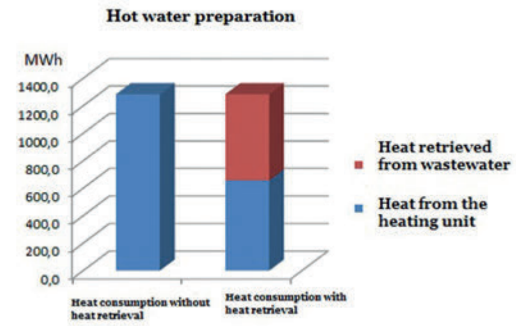

Figure 4 - Reduced heat used for hot water preparation (City of Riga, 2014)

Figure 5 - Wastewater heat recovery system (Gazette "REA vēstnesis" 2014)

The wastewater heat retrieval system implemented in 2013 has led to reducing the heat used for hot water preparation system by about 50 % (Figure 5).

Balancing and control

Almost all multi apartment buildings in Latvia built until year 1991 has one-pipe heating system. This complicates balancing of the system which in turn reduces indoor thermal comfort and does not contribute energy-efficiency at all. There are advanced technical solutions which help to adjust the single-pipe system to provide for the functionalities of a two-pipe system and, in fact, to have sufficient temperature control for ensuring comfortable temperature in all the apartments.

For this aim the system needs to be renovated at a minimum cost, including the following measures:

- radiators, where necessary, need to be replaced and equipped with a by-pass and a temperature control for tertiary heat regulation at each radiator. Notably, radiators are part of the collective property of the building and the owners collectively decide on their use;
- allocators (heat cost allocators) or other heat metering devices need to be mounted on radiators, preferably with a remote data reading system;
- the mains of the heating system need to be equipped with temperature controls which can adjust the temperature and control the reverse flow providing simultaneously for balancing of the system. This measure ensures a single heat carrier temperature at each radiator entry and provides for the desirable comfort.

The first building in Riga, where in 2011 all the above mentioned measures, including the allocators, were implemented as part of the comprehensive renovation was the residential building at Gaujas Street 29. Notably, management of heat consumption in the apartment reduces total heat consumption and heating costs, if reduction of temperature by 1ºC leads to a 5 – 6 % reduction of consumption. Software operated temperature controls on radiators provide even better options for adjusting heat consumption. Management of heat consumption (also from remote locations) allows to reduce the temperature during the day and during holidays, when the owners are outside their apartments, or to reduce the temperature by a few degrees during the night when there is less activity and to increase it again for comfort in the morning hours.

Conclusion

There are approximately 38,933 multi apartment buildings in Latvia. Until February of year 2013 the total number of already renovated multi storey buildings in Latvia had reached 156 or only 0,4 %. But there are 992 buildings where ERDF activities "Apartment House Improvement of Heat" took place and renovation process of apartment buildings is completed or are organised procurement procedures. The heat consumption after applying of comprehensive renovation of buildings can be realistically reduced down to 101 kWh/m^2 year in typical Latvian climate conditions. The optimal U-values of walls after thermal insulations is 0.20 – 0.25W/(m^{2}K), while for roofs 0.12 – 0.15W/(m^{2}K). Due to ventilation systems usually are not renovated, the IAQ measurements in renovated buildings have shown unsatisfactory situation with increased CO_2 concentration and high relative humidity.

Modern cities can achieve EU20-20-20 goal only by improvements in all major sectors such as buildings, energy and transport. Each European City is free to choose their approach for achievement of EU20-20-20 target. The main document which defines actions and measures to be implemented in each City in order to reach CO_2 reduction by 20 % is Sustainable Energy Action Plan (SEAP). The Smart Cities general concept can be characterised as improvement of urban performance by implementation of information and communication technologies (ICT) and by engagement of stakeholders. In addition more cross-sector energy actions should be introduced. The public/private finances for the district scale grouped building renovation should be used including ESCO (Energy Service Company) model and active work with wide range of stakeholder groups. The estimated savings can be about 10 % due to grouping development, compared to the component scale renovation (Borodinecs et al., 2013). It is essential to provide possibilities of sharing the experience about smart city design and planning between cities and communities. Most successful and beneficial projects have to be repeated and recreated widely in Europe considering local differences in technical features of infrastructure. In terms of Smart Cities the most powerful actions are those which directly affect at least these three sectors-energy, ICT and transport. Dissemination of such projects across the Europe will be possible due the fact that the projects have already been approved and implemented in other cities.

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Conclusions

It is a known fact that given today's energy-efficient building design and an ever-increasing cost consciousness, retrofitting has taken centre-stage au lieu to the take up of green tracts of land for new development. The latter also bring with them a greater demand for stretching the existing infrastructure to the new terrain. On the other hand, given the fact that over 80 % of Europe's building stock in city centres is mostly historic and listed, or if not, has inherent built-in passive design features, these are now being exploited for a passive design strategy. Hence a capital investment in refurbishing an old building for re-use, adds value not only to the building itself, but if done incessantly, appraises the whole town centre, uplifting its historic character and authenticity.

This book exposed many facets to different aspects of cost and value. Following an introduction to the scope of this workgroup, the first chapter takes off by tackling four aspects through four chapters related to the design of green buildings, occupant satisfaction in refurbished historic buildings, value increment through sustainable design, as well as air quality and thermal comfort norms for a smart energy retrofit.

Chapter two had two papers dealing with different aspects related to social housing. One considers options for adaptive comfort when retrofitting social housing, while another dwelt on aspects related to LCC of materials. Separately, another paper dealt with CEN's contribution in the building industry, considering four assessment scenarios for the standardisation of an assessment of cost and value.

Energy systems and technologies were presented in chapter three. One paper highlighted the importance of economic feasibility studies related to large scale RES, before embarking on such projects. Conversely, another paper dwelt on micro-grids and their smart interaction through ICT for added value. The third paper dealt with adobe-earth as a construction material as well as its inherent potential for recycling. In contrast the fourth paper presented a cost – value analysis of a combined heat and power system for a residential development.

Chapter four rounds up the work by presenting aspects of a top-down versus a bottom-up approach, in the context of the classical 'carrot and stick' strategy, namely comparing EU legislation, transposed to national law and its enforcement, contrasting with guidelines. complemented with fiscal incentives for RES in dwellings, commercial entities and industrial buildings.

In conclusion, through the diversified range of chapters presented in this book, it was realised that today's citizen empowerment initiatives are key to understanding and adhering to legislation, possibly without enforcement. Laws should be viewed as guidelines for living, a form of self-discipline for respecting the environment. This is probably the best bottom-up approach.

Consider green NGO's position and their demonstrations during global summits on climate change, they are perhaps the best manifestation of a bottom-up approach, where the citizen's voice is seldom considered seriously, albeit, often put aside, in favour of soft political commitments. Such aspects are presented separately through a Manifesto, as the outcome of this COST action. The principal political commitments and main thrust should certainly strive towards a cleaner outdoor environment, an energy efficient built environment as well as greater prosperity and social cohesion for a better quality of life for all.

Contact details

Cyprus		
Paris Fokaides	eng.fp.@frederick.ac.cy	Frederick University, School of Engineering and Applied Sciences. 7, Y, Frederickou Str., Nicosia 103. Cyprus
Angeliki Kylili	res.ka@frederick.ac.ky	
Elias A. Christoforou	res.ce@frederick.ac.cy	

Finland		
Jani Laine	Jani.laine@aalto.fi	Department of Real Estate, Planning and Geoinformatics, Aalto University, Espoo,
Karoliina Pluuman		
Seppo Junnila		

Hungary		
Ildikó Molnar	molnar.ildiko@bgk.uni-obuda.hu	Óbuda University, Tavaszmező utca 17, H-1084 Budapest
Ákos Nemcsics	nemcsics.akos@kvk.uni-obuda.hu	
Attila Trembulyák		Miskolc University, Egyetem út, 3515

Iceland		
Jukka Heinonen	heinonen@hi.is	Faculty of Civil and Environmental Engineering, University of Iceland, Reykjavik, Iceland

Italy		
Senatro di Leo	senatro.dileo@imaa@cnr.it	National Research Council of Italy, Institute of Merhodologies dor Environmental Analysys (CNR-IMAA), C. da Santa Loja, 85050 Tito Scalo (PZ), Italy
Monica Salvia	monica.salvia@imaa.cnr.it	
Antonio Mauro	anmauro@hotmail.	Geco SRL Unipersonale, Potenza, Italy
Michelangelo Morrone	michelangelomorrone@gmail.com	

Lithuania		
Andrius Jurelionis	andrius.jurelionis@ktu.lt	University of Technology, Faculty of Civil Engineering and Architecture, Kaunas, Lithuania
Rokas Valančius		

Latvia		
Aleksandrs Korjakins	aleks@latnet.lv	Institute of Materials and Structures, Riga Technical University, Riga, Latvia
Aleksandrs Zajac		Institute of Heat, Gas and Water Technology, Riga Technical University, Riga, Latvia
Jurgis Zemitis		
Anatolijs Borodinecs		

Malta		
Vincent Buhagiar	vincent.buhagiar@um.edu.mt	Department of Environmental Design, Faculty of the Built Environment, University of Malta, Msda MSD 2080,Malta
Simon Paul Borg	simon.p.borg@um.edu.mt	
Justin Zarb		Projects Design Office, University of Malta, Msida, Malta

Portugal		
Fernando Alves	alves@fe.up.pt	Faculty of Engineering, University of Porto / CITTA, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
Cecilia Rocha	carocha@fe.up.pt	
Paulo Mendonça	mendonca@arquitectura.uminho.pt	University of Minho, School of Architecture, Azurém Campus, 4800-058 Guimarães, Portugal

Serbia		
Alexandra Djukic	adjukic@afrodita.rcub.bg.ac.rs	Faculty of Architecture, University of Belgrade, Bulevar Kralja Aleksandra 73/II, Belgrade. Serbia
Aleksandra Krstic-Furundzic	akrstic@arh.bg.ac.rs	
Marija Grujic	grujicm@grf.bg.ac.rs	Faculty of Civil Engineering, University of Belgrade University, Belgrade, Serbia

Spain		
P. Amparo López-Jiménez	palopez@upv.es	Hydraulic and Environmental Engineering Department, Universitat Politècnica de Valencia. Camino de Vera s/n. 46022. Valencia. Spain
Miguel Mora Pérez	miguelmora@gmail.com	
Jaume Roset Calzada	jaime.roset@upc.edu	Universitat Politècnica de Catalunya. Barcelona, Spain
Giuseppe LaFerla	g.laferla.licitra@gmail.com	Chapman Taylor/Universidad Politécnica de Madrid. Spain

United Kingdom		
Phil Jones	jonesp@cardiff.ac.uk	Welsh School of Architecture, Cardiff University, Bute Building, King Edward VII Avenue, Cardiff CF10 3NB, Wales, UK

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This book presents work undertaken as part of the COST Action Smart Energy Regions (SMARTER). The link between cost and value is demonstrated for both new buildings and for the retrofitting of old buildings, as well as infrastructure and energy systems, at both regional and national levels. Aspects investigated within this book related to cost and value include environmental design, sustainable retrofitting, energy systems and technologies as well as smart energy regions. The impact of both a top-down and bottom-up approach are considered in relation to progress the low carbon agenda relevant at a regional scale.

This work supports the broader aims and objectives of the Smart Energy Regions COST Action to investigate the drivers and barriers that may impact on the large scale implementation of low carbon technologies in the built environment essential to meet the targets for sustainable development set by the EU and national governments. This publication is part of suite of outputs from the Smart Energy Regions COST Action investigating different aspects associated with implementation of the low carbon agenda at a region scale.

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