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EDITORIAL

Building a greener construction sector for Europe

Environmental improvements to the construction sector would increase its competitiveness and make significant contributions to a more resource efficient society. The EU's Roadmap to a Resource Efficient Europe[1] indicates that better construction and use of buildings in the EU could influence 42% of our final energy consumption, about 35% of our greenhouse gas emissions and more than 50% of all extracted materials, for example. It could also help us save up to 30% of water.

The Roadmap, produced in the context of the Europe 2020 strategy[2], calls for a Communication on Sustainable Buildings. Due to be published this year, the Communication will address inefficiencies in construction by proposing new measures which aim to reduce the environmental impacts of building throughout the life cycle. These are intended to complement existing policies for buildings in Europe, such as the Energy Performance of Buildings Directive[3].

This Thematic Issue from Science for Environment Policy presents key pieces of research that help us understand how the construction sector can be improved to reduce its overall environmental impact, which could help policymakers and the construction sector meet goals proposed by the Roadmap, as well as the Energy Performance of Buildings Directive.

The issue begins with a critical question: how do we define a sustainable building? Indicators are often used to answer this question; however, there is a danger that the vast number and variety of sustainability and green building indicators in existence could reduce trust in assessments of buildings and lead to misunderstandings about their purpose. Strong justification for indicator systems is therefore needed.

One such indicator system is presented in the article **'Sustainability 'score' for buildings accounts for range of environmental impacts'**, which addresses the complexity of this issue. The concept involves different dimensions that are not always measured in the same units and which have different priorities according to the context.

We need a better understanding of multi-criteria approaches to assessing building sustainability as well as which core indicators to use. This article calls for a more holistic approach to sustainability assessments, and considers impacts, such as air pollution, in addition to CO_2 emissions.

Improved quality and validity of sustainability indicators for buildings was one of the main targets of the European research project SuPerBuildings[4]; some of the project's findings are presented in **'Top-down approach recommended for assessing sustainability of buildings'**. Under a top-down approach, objectives for sustainability are first identified, before indicators are developed and selected to measure their achievement.

The article **'Absolute approach to assessing building sustainability'** further emphasises that there is a growing demand for evidence-based indicators to evaluate the sustainability of buildings. It focuses on stored carbon in a building project, presenting a methodology for its calculation. The improved understanding of indicators provided by academic studies, such as these, has the potential to support regulatory instruments in widening their scope beyond buildings' energy performance.

Integrated solutions for an energy-efficient built environment are an important focus of current research into sustainable buildings. Danish experiences of an integrated solution are discussed in **'Potential of zero energy buildings for district heating systems assessed'**, where excess heat production from net zero energy buildings was found to benefit district heating systems and reduce reliance on combustible fuels.

Several articles in this issue explore green retrofits of homes, in this case, focussing on energy efficiency benefits of refurbishment. **'Building refurbishments could bring energy savings of 20% for heating'** and **'Energy-efficient refurbishments in homes: more incentives needed'** show that significant savings can be achieved in housing stock with the help of existing energy efficiency measures, such as double-glazed windows or insulation.

Financial concerns can form a major barrier to retrofitting, which may be solved with the help of appropriate incentives or fiscal instruments. **'Can loans scheme encourage green refurbishment of homes?'** presents the potential and problems of a new government programme in the UK designed to help homeowners fund energy-saving measures for the home. It recommends providing better information for homeowners to encourage uptake of the initiative.

The ability of planning and building permit authorities to provide more guidance and consultation for designers and builders in building projects can therefore support better refurbishment and retrofitting solutions. Experiences from the Netherlands, outlined in '**Barriers to installing innovative energy systems in existing housing stock identified'**, recognise several enabling factors that could be used to ensure the success of greener energy solutions in existing social housing stock. These include a motivated project leader, a skilled project team and external subsidies.

One important consideration in construction is the significance of 'embodied energy', that is the energy consumed during the production, use and demolition phases of a project, which can be seen as being 'hidden' or 'embodied' in the building. Research outlined in **'The significance of embodied carbon and energy in house construction'** highlights the large amounts of energy used and carbon emitted when a house is built, for example, onsite waste production was found to account for 14% of total embodied carbon in this UK case study.

The increased importance ascribed to a range of environmental impacts of building products also highlights the significance of product and material selection, as well as product development. For example, **'From grey to green: environmental impact of concretes must be fully assessed'** shows that the environmental impact of concrete is reduced if it incorporates industrial by-products (such as blast furnace slag and fly ash), compared with ordinary Portland cement. Impacts covered here include ecosystem damage and water depletion. It also emphasises the importance of robust and consistent environmental data and standard methodologies. **'Standardising building life cycle assessments can improve energy efficiency'** points out that, without good product level environmental data, it is impossible to select products and develop the best construction solutions which consider both the operational energy and the embodied energy of a building project, as well as other environmental impacts.

However, we still lack methods which effectively track the sustainability requirements of a building throughout an entire project and which are easy to use in the first phases of design process, in particular. Research has investigated the potential of integrating sustainable building assessment and benchmarking methods with Building Information Models (BIM). The BIM can be seen as a common repository that stores all the knowledge needed for a given construction project. A US survey, reported in **'Could Building Information Modelling support sustainable building practices?'**, suggests that contractors and designers see BIM as an effective tool to improve sustainable building, but there are also many who point out problems.

Research, included that highlighted in this issue, clearly points to the need to take a holistic view of construction and the built environment, and to identify robust methods for assessing and developing sustainable solutions. Currently, the European Commission is preparing an impact assessment of different options for achieving these goals, and plans to launch a public consultation to gather further feedback in 2013.

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1 *http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf*
2 *http://ec.europa.eu/europe2020/index_en.htm*
3 *http://europa.eu/legislation_summaries/other/l27042_en.htm*
4 *http://cic.vtt.fi/superbuildings/*

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Theme(s): Sustainable consumption and production

Sustainability 'score' for buildings accounts for range of environmental impacts

Researchers in Lithuania have assessed and ranked the sustainability of buildings on a wide range of criteria, from pollution caused by the building materials to the running costs of the building. An overall sustainability index based on these criteria allows the comparison of different buildings and, using this index, the study estimated that a wood-based building is 7.5% more sustainable than a house made of bricks..

"...sustainability is a complex concept involving different dimensions that are not always measured in the same units and which have different priorities according to the context."

Sustainable urban development needs sound assessment procedures that evaluate different aspects of sustainability. However, sustainability is a complex concept involving different dimensions that are not always measured in the same units and which have different priorities according to the context.

The study takes a multi-criteria approach that evaluates a number of options according to a range of sustainability criteria. It analyses data on the economic, social and environmental impacts of construction materials and amalgamates it into one 'sustainability index' or score. On the environmental dimension it considers emissions of CO_2, sulphur dioxide, phosphate and ethane. On the economic and social dimensions, it considers the overall building price, the maintenance cost, the time taken for construction, the durability of the building and the energy use.

Overall, it considers nine different sustainability criteria to be measured, for example, building price is measured in euros per 100 m^2 of the building, CO_2 emissions in kg per 100m^2 of the building and energy use in megajoules. Since the measurements of these criteria are in different units, they are amalgamated using the Simple Additive Weighting method with grey numbers (SAW-G), which calculates an overall index of sustainability. This is achieved using a weighting procedure called the Analytic Hierarchy Process (AHP), which gives each criterion a measure of importance. This requires a team to identify the goal of sustainability and break this down into a hierarchy of management options.

AHP then conducts pair by pair comparisons of the nine different criteria according to the management goals and uses these to obtain different weightings. Once the weighting procedure has been conducted the measurements of the different criteria can be amalgamated into one index.

The study applied the method to three of the most widely used alternatives for residential houses in Lithuania: a traditional brick house, a blockhouse made mostly of wood-based materials, and a house built from a wooden frame, using wood-based and mineral-based materials. The sustainability index for the block house was 0.303 which is 6.6% better than the house with the wood frame at 0.286. The worst results were obtained for the traditional brick house, with a sustainability score of 0.280, which is 7.5% worse than the block house.

The use of SAW-G and AHP is a suitable way to assess the sustainability of a building, suggest the researchers. It can be applied directly to making decisions between different alternatives when it is necessary to compare different sub-goals with criteria that are measured with different units.

Source: Medineckiene, M., Turskis, Z. & Zavadskas, E.K. (2010) Sustainable construction taking into account the building impact on the environment. *Journal of Environmental Engineering and Landscape Management*. 18(2):118-127. Doi: 10.3846/jeelm.2010.14.

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Top-down approach recommended for assessing sustainability of buildings

There is a wide range of systems for assessing and communicating the sustainability of buildings, but the variation can be confusing. Recent research has analysed the elements needed for effective assessment and examined the needs of stakeholders to inform the presentation and communication of assessment results.

"...a new generation of assessments should take a top-down approach that identifies objectives for sustainability before measuring their achievement, and encompasses the concept of sustainability in its fullest extent."

The variety of existing methods and systems to assess building sustainability means they are difficult to compare and there is a need for standardisation. The 'first generation' assessments used a bottom-up approach, with a focus on measuring resource conservation and environmental protection. However, a more complex approach is needed that extends beyond this to consider the interactions between environmental, social and economic issues. In addition, more attention is needed on the actual use of the building in terms of durability, resistance and adaptability.

The study suggests that a new generation of assessments should take a top-down approach that identifies objectives for sustainability before measuring their achievement, and encompasses the concept of sustainability in its fullest extent. These assessments would have the following elements:

- A clear definition of the object of assessment, whether that be the location, the site, the building (and its entire life-cycle) or the process of planning, constructing and operating the building, or a combination of these elements.
- A top-down approach that defines the dimensions of sustainability and assigns various goals to these. For example, on the environmental dimension, goals are protecting ecosystems and biodiversity; on the social dimension, goals are protecting cultural values and safeguarding health; and on the economic dimension, goals are optimising life-cycle costs and protecting capital
- Indicators that assess achievement of the goals and are based on quantitative values. For example,preservation of resources is measured by consumption of energy, water and land use

Using survey data from the EU SuPerBuildings[1] project, the study also provided insights on what stakeholders need from assessments. This indicated that different stakeholders require different types of information. Architects and designers would like a simple self-assessment tool, whilst third party certification is most appropriate for authorities, grant providers, planning authorities and professional associations. Community representatives and planning authorities prefer a short checklist. This further supports the use of a top-down approach, which allows goals to be defined by stakeholders and feedback to be integrated into the process to produce the most user-appropriate assessment.

In conclusion, the study provides several recommendations for future development of sustainability assessment systems. These include producing a more precise definition of sustainability and specifying its overarching goals. Alongside this, these principles should be adapted to the specific object under consideration, such as the building and its site. This can be achieved using weighting methods where criteria are prioritised according to the specific context. When weighting is used, it is crucial that it is transparent and understandable to the stakeholders to allow optimal use in decision-making processes. By applying these recommendations it is hoped that assessment systems can become more alike in content and easier to compare.

1. SuPerBuildings is supported by the European Commission through the Seventh Framework Programme. See: http://cic.vtt.fi/superbuildings/

Source: Lützkendorf, T., Hájek, P., Lupíšek, A., *et al.* (2012) New trends in sustainability assessment systems – based on top-down approach and stakeholders needs. *International Journal of Sustainable Building Technology and Urban Development.* 3(4): 256-269. Doi:10.1080/20937 61X.2012.747113.

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Theme(s): Climate change and energy

Absolute approach to assessing building sustainability

There is growing demand for sound evidence-based indicators to evaluate the sustainability of buildings. In a recent study, researchers have presented a new sustainability assessment that considers carbon emissions from site development, construction and operation of a building and compares this to the original or 'native' level of carbon storage before the building project commenced.

"The model can be used to target carbon neutrality, report life cycle carbon emissions, estimate carbon debt and help assess building sustainability."

Since the early 1990s, there has been a growing interest in the assessment of building sustainability to inform market values of buildings, documentation for corporate sustainability and target-setting by policymakers. However, there has been a call for more subjective 'absolute' indicators of sustainability, rather than comparisons to 'typical' buildings.

The study adopts an ecological carrying-capacity-based method to assessing sustainability, which estimates the amount of carbon stored on the building project site before work began (the 'native-site carbon storage' or carrying capacity) and after completion of the building project. If the net amount of carbon stored on the building site after completion is equal or greater than the native site carbon storage, the project is considered sustainable. Although other elements of sustainability, such as water and waste, are also important, there was not enough scope in this study to consider these in addition to carbon emissions.

The model is an important example of good practice as it provides an absolute measurement of the building's sustainability performance with regard to carbon emissions, rather than a relative comparison to a typical building. It also takes a top-down approach, as it identifies the subject of concern of sustainable development, i.e. carbon emissions, and seeks to measure this objectively.

The researchers suggest it has advantages over previous approaches, which do not necessarily offer direction as to the stages in the building project where sustainability can be improved, as is the case for the ecological footprint, or have insufficient scientific grounding, as is the case of the net zero energy approach. It also works at the correct scale of the site; targets do not need to be scaled down from Intergovernmental Panel on Climate Change reports.

The method accounts for carbon emissions from three aspects: site development, construction and operation. Site development emissions are those produced or stored by the removal or addition of vegetation and other carbon storing elements. These are estimated using data on carbon storage of vegetation and/or trees. Emissions from construction are those produced from raw material extraction or from the manufacture and transport of building materials. They are often estimated using life cycle analysis (LCA) methods. Lastly, operation emissions result from the consumption of electricity and other fossil fuels on site.

The study applied the approach on a case study of an institutional building in Florida, USA and estimated that, over 100 years, the project must reduce and offset carbon emissions at a rate of 16 tonnes of carbon per year. The model can be used to target carbon neutrality, report life cycle carbon emissions, estimate carbon debt and help assess building sustainability.

The researchers highlight the need to quantify the uncertainty in the model's estimations but also stress that, no matter the exact amount of uncertainty, there is a need for building designers to reduce emissions.

Source: Bendewald, M. Zhai, Z. (2013). Using carrying capacity as a baseline for building sustainability assessment. *Habitat International*. 37:22-32. DOI: 10.1016/j.habitatint.2011.12.021

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Themes: Climate Change and energy, Resource efficiency

Potential of zero energy buildings for district heating systems assessed

Denmark aims to develop an energy system based only on renewable energy sources by 2050. Energy saving buildings are an essential part of this plan, according to new research, which investigates how excess heat production from net zero energy buildings (NZEBs) can benefit district heating systems and reduce reliance on combustible fuels.

"Net zero energy buildings' excess production can usefully replace biomass consumption. Biomass use is increasing, and its costs are variable, so replacement with NZEB energy is a positive development."

NZEBs are buildings connected to the existing energy infrastructure that have very low energy demand and are supplemented by renewable energy sources. NZEBs produce as much energy as they consume annually and they can be connected to district heating systems, which distribute heat to a number of buildings through a network of pipes carrying hot water or steam. This enables them to send and receive energy from these systems, for example, excess heat from NZEBs, generated with solar panels, can benefit district heating by reducing the systems' need for energy from other sources, such as combustible fuels.

Most buildings in Denmark are connected to electricity grids and around half are connected to district heating systems. The researchers analysed and created technology development scenarios for different types of district heating system for use in Denmark which can incorporate NZEBs. They aimed to identify where NZEBs should be built, what heat demand would be from these and existing buildings, and how excess heat production from these buildings can be used to increase energy efficiency.

To conduct the analysis, they used a heat atlas, which generates a database with heat demand and supply for each building, and estimated economic returns for different energy projects. They use data from the Danish buildings register to estimate future development in building construction.

The findings indicate that NZEBs' excess production can usefully replace biomass consumption. Biomass use is increasing, and its costs are variable, so replacement with NZEB energy is a positive development. Even in areas where districts use non-biomass resources, solar thermal production from NZEBs would optimise limited resource use.

In some district heating areas, summer heat demand is already covered by renewable energy. To benefit from the excess heat that NZEBs generate, districts need additional seasonal heat storage. This additional storage could also be used to draw on excess heat from areas with industry, waste incineration or geothermal sources.

More work is needed to ensure the best use of excess heat production from buildings, including analyses of actual heating systems, the study suggests. This research focused on optimum use of energy to meet targets, however, the economic costs related to the implementation of solar thermal energy and storage also need to be factored in, along with economies of scale and land use issues.

Source: Nielsen, S., & Möller, B. (2012). Excess heat production of future net zero energy buildings within district heating areas in Denmark. *Energy*. 48: 23-31.

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Theme(s): Climate change and energy, Environmental information services, Resource efficiency

Building refurbishments could bring energy savings of 20% for heating

Implementing energy efficiency measures in existing housing stock could save 10% of current heating consumption by 2020 and 20% by 2030, according to a recent study of nine European countries. Planning authorities can play a major role by providing support and unbiased information to all stakeholders involved in the renovation.

"Across Europe there are a large number of older buildings where refurbishment and retrofitting measures, such as replacing single-glazed windows with double glazing, have the potential to achieve significant energy savings."

Across Europe there are a large number of older buildings where refurbishment and retrofitting measures, such as replacing single-glazed windows with double glazing, have the potential to achieve significant energy savings. Such energy efficiency is a priority of the EU's energy policy[1].

As part of the EU-funded IDEAL EPBD project[2], this study investigated energy savings that could be made in the existing building stock of nine EU Member States: Bulgaria, the Czech Republic, Denmark, Finland, Germany, Latvia, the Netherlands, Portugal and the UK. In addition, barriers to energy conservation and policies to overcome these barriers were examined in these countries, plus Belgium.

The researchers analysed the inventory of housing stock, previous and potential rates of renovations to improve energy savings and the range and costs of energy efficiency measures in each country. From this, they calculated that a total of 146 TWh/a (terawatt hours per year) of energy (or 10% of the current heating energy consumption) could be saved over the nine countries by 2020. This includes 88 TWh/a of energy savings from single homes and 58 TWh/a from apartment buildings. By 2030, 279 TWh/a of energy (or 20% of current heating energy consumption) could potentially be saved in the nine Member States: 169 TWh/a from houses and 110 TWh/a from apartments.

Four main barriers to the uptake of energy efficiency measures were identified from interviews with stakeholders, including directors of ministries, housing agencies, construction bodies and building renovators in the ten countries considered. Financial concerns formed a major barrier and the most common obstacle was the belief that energy efficiency would not increase the value or rent of a property. Other financial barriers were a lack of affordable schemes to help homeowners switch to energy-saving measures and the non-inclusion of the environmental cost of energy, such as pollution, in energy prices, which reduces the incentive for people to cut their energy consumption.

The other three barriers were: regulatory barriers, including insufficient or lax regulation that do not, for example, set building regulations high enough; barriers related to decision-making, including the inability to make decisions in housing organisations; barriers to information, promotion and education, including low awareness of energy efficiency by consumers, and a lack of skilled individuals to carry out energy efficiency measures. One suggested solution for overcoming some of these barriers is for planning authorities to provide a web-based database containing unbiased information on all products and solutions available.

Among the reported policy measures, nine of the ten countries provide subsidies for energy saving retrofits, and most countries widely provide information on energy efficiency measures. In addition, most countries have an ecological tax, typically an energy tax.

Source: Tuominen, P., Klobut, K., Tolman, A. *et al.* (2012). Energy savings potential in buildings and overcoming market barriers in member states of the European Union. *Energy and Buildings*. 51: 48–55. Doi.org/10.1016/j.enbuild.2012.04.015

1. See: http://ec.europa.eu/energy/efficiency/index_en.htm
2. The IDEAL-EPBD project was co-funded by the European Union under the Intelligent Energy Europe Programme. See: www.ideal-epbd.eu

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Theme(s): Climate change & energy, Environmental information services, Resource efficiency

Energy-efficient refurbishments in homes: more incentives needed

Motivating homeowners to carry out energy-efficient refurbishments remains a significant challenge for policymakers. New research from Germany has called for more government incentives and better communication strategies to ensure homeowners are aware of the advantages of making energy saving changes to their homes.

"...researchers identified three measures responsible for the largest reductions in energy use: the insulation of façade walls, roof insulation and the use of renewable heating systems...these measures, as well as the targeting of older houses, should be given priority in any new policy instruments."

It is estimated that buildings are responsible for more than 40% of energy consumption and greenhouse gas emissions in Europe. Residential buildings have particularly high energy requirements for heating and hot water and, as a result, efforts have been made across the EU to encourage homeowners to implement energy efficiency measures. The EU Energy Performance of Buildings Directive[1], for example, was introduced in 2002 to help EU governments frame their national policies for energy efficient buildings.

Since the 1970s, Germany has played a pioneering role in encouraging citizens to make energy saving changes to their homes. For instance, programmes to fund energy-efficient space heating have a long tradition here, and the available range of energy-efficient products for buildings is considered greater than in some other European countries. Analysis of the impact of national policy on home improvements in this country therefore provides a valuable insight into any barriers limiting uptake.

As with other EU Member States, current energy-saving refurbishment rates remain low in Germany, despite efforts to encourage changes. The annual refurbishment rate for building façade insulation was just 0.8% between 2005 and 2008, and the annual rate for roof insulation is 1.3%. The study focused on energy efficiency refurbishment of single-family and semi-detached houses, which make up the majority of housing in Germany and have the greatest energy requirements.

Using data from 2000 homes, the researchers identified three measures responsible for the largest reductions in energy use: the insulation of façade walls, roof insulation and the use of renewable heating systems. The researchers suggest that these measures, as well as the targeting of older houses, should be given priority in any new policy instruments.

A survey of 1008 homeowners who had refurbished in recent years revealed that the barriers to making energy saving refurbishments were: a lack of involvement or interest in energy efficiency from the homeowner; a lack of financial means, particularly as high initial costs are often involved; an aversion to borrowing money; a lack of long-term perspective; worries about disturbance, plus building restrictions and structural barriers.

More than half of those surveyed were unsure whether refurbishment measures were really profitable. Contrary to previous studies, socioeconomic factors such as age, education, and income, showed no significant influence on the decisions taken by homeowners to add energy improvements to their homes.

Financial incentives were shown to lead to better results than regulatory standards alone. Although large incentives can result in homeowners taking advantage of the system, the researchers suggest that targeting socially disadvantaged groups may avoid this problem.

Two approaches to increase the energy efficient refurbishment of homes seem promising: ensuring compliance with regulations using random audits, and making more use of refurbishment occasions, i.e. when houses are sold. The findings also suggest that more government incentives are needed to convince homeowners of the profitability and benefits of making energy saving changes.

Source: Weiss, J., Dunkleberg, E., Vogelpohl, T. (2012). Improving policy instruments to better tap into homeowner refurbishment potential: lessons learned from a case study in Germany. *Energy Policy*. 406-415. DOI: 10.1016/j.enpol.2012.02.006.

1. See: http://europa.eu/legislation_summaries/other/l27042_en.htm

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Theme(s): Climate change and energy, Environmental economics, Resource efficiency

Can loans scheme encourage green refurbishment of homes?

A UK Government scheme, designed to help finance energy efficiency improvements in the home, has been assessed in a recent study. The researchers advise that better information for homeowners is needed to encourage uptake of the 'Green Deal' initiative, and point to Germany's Passivhaus standard as an aspirational model for green retrofitting.

"While retrofits, such as external wall insulation and double glazing, can help meet national CO2 targets, they may be uneconomical for homeowners who may not live in the property long enough to recoup the investment through savings on their energy bill."

Policy support is needed to encourage sustainable renovation of existing buildings in order to increase their energy efficiency and meet CO_2 reduction targets. To help meet this challenge, the UK Government introduced its key mechanism for improving the energy efficiency of homes, the Green Deal initiative[1], which was publically launched in January 2013. While retrofits, such as external wall insulation and double glazing, can help meet national CO_2 targets, they may be uneconomical for homeowners who may not live in the property long enough to recoup the investment through savings on their energy bill. The payback period on double glazing, for example, can take far longer than the windows' 20 year lifespan.

The Green Deal is designed to overcome these issues. Financed by private investors who are seeking a return on their investment, it loans money to homeowners to pay for refurbishments that improve their property's energy efficiency. The homeowner repays the loan in instalments on their energy bills, and the loan is attached to the property rather than the individual, i.e. subsequent residents take on the loan.

The researchers assessed the financial attractiveness of investing in the Green Deal. Investors are likely to seek a return rate of up to 11-15%, but the study warns that there are too many unknown risks associated with the initiative and it is presently a difficult way for investors to make money. Furthermore, investors are only likely to target a section of properties, i.e. those with easy-to-insulate cavity walls and lofts, rather than hard-to-treat solid walled properties, high rise flats and homes off the gas network, leaving a significant proportion of housing without renovations.

Among other concerns, the researchers also note that the effect of a Green Deal refurbishment on a property's value and ease of resell is as yet unknown, which may deter uptake up the scheme for some homeowners.

To encourage uptake of the Green Deal, the study recommends giving more accurate and understandable information to homeowners about long-term savings on fuel bills, payback periods, disruptions that may be caused during retrofit work, plus the effect on property value and re-sale.

The study also advises that energy reduction strategies take account of research indicating that actual energy savings in homes do not match their predicted levels. A phenomenon known as 'take-back' can mean that an average of 30% of predicted energy savings are lost as occupants often turn up the thermostat after insulating their homes or installing a new boiler to reach their preferred temperature.

The successful German Passivhaus standard, which combines super insulation, triple glazing and highly airtight fabric with mechanical ventilation with heat recovery, demonstrates that it is possible to cut energy savings in existing homes by over 80%. However, for this scheme to be viable in the UK, major investment in skills, materials and cost-effective components is needed. Above all, however, the refurbishment works must minimise disruption and the capital costs involved must be repayable through the annual energy savings for it to be compliant with the Green Deal.

Source: Dowson, M., Poole, A, Harrison, D., Susman, G. (2012) Domestic UK retrofit challenge: Barriers, incentives and current performance leading into the Green Deal. *Energy Policy*. 50: 294-305. DOI: 10.1016/j.enpol.2012.07.019

1. See: www.decc.gov.uk/en/content/cms/tackling/green_deal/green_deal.aspx

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Theme(s): Climate change and energy, Environmental information services, Resource efficiency

Barriers to installing innovative energy systems in existing housing stock identified

Several barriers to upgrading existing social housing with innovative energy systems (IES) have been identified by a study of eight large-scale renovation projects in the Netherlands. These include a lack of trust between stakeholders, opposition from tenants on grounds of increased costs or delays, or poor experience with previous energy projects.

"Using modern Innovation Energy Systems, such as renewable energy and energy efficiency measures, to heat homes can help to reduce the greenhouse gas emissions from a nation's housing stock."

Using modern IES, such as renewable energy and energy efficiency measures, to heat homes can help to reduce greenhouse gas emissions from a nation's housing stock. However, as well as requiring such systems in new homes, governments must also ensure existing homes are upgraded. One of the easiest ways in which policymakers can influence this uptake is through housing association-owned social housing.

To investigate the factors that affect the adoption of IES in social housing, the study focussed on the installation of IES during eight large social housing renovation projects in the Netherlands. Each renovation project included at least 100 homes and took place between 2000 and 2008. The researchers identified problems, enabling factors and the perceptions of housing associations, tenants and local authorities of the renovations.

Of the eight projects, only three managed to successfully install IES. The other five projects failed for several reasons, including the unexpected cancellation of a nearby biomass plant building project, tenant objections to collective heating systems or higher rents, not taking account of advice from energy audits, or poor experiences in a previous project.

The study also found that perceptions held by housing associations, tenants and local authorities influenced the decision to adopt IES. For example, housing associations felt that: they needed to find additional finance to support the projects, costs and benefits were unfairly distributed between stakeholders, energy goals become less important during reorganisations within housing associations, and they mistrusted IES due to previous cost overruns.

Tenants objected to IES if they thought it would result in rent rises. Project delays also sometimes meant IES measures were dropped, and tenants were worried about problems with new technologies. Finally, local authorities sometimes set overly ambitious targets, causing tension between stakeholders. Their influence also tended to decrease as projects progressed, and they became distanced from projects in which they did not own property rights, allowing energy targets to fall in importance.

The study also identified several enabling factors, which could be used by policymakers to ensure such projects are successful. These include a motivated project leader, a skilled project team, external subsidies, testing of IES options, and the use of written energy audits and feasibility studies.

Source: Hoppe, T. (2012). Adoption of innovative energy systems in social housing: Lessons from eight large-scale renovation projects in the Netherlands. *Energy Policy*. 51, 791 – 801. DOI: 10.1016/j.enpol.2012.09.026.

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Theme(s): Climate change and energy, Sustainable consumption and production

The significance of embodied carbon and energy in house construction

Although most energy in homes is used for heating and hot water, significant amounts of energy are also used when a house is built. A lifecycle assessment of a low-energy, affordable timber house indicates that large energy and carbon savings can be made when alternatives to traditional methods of construction are used.

"Addressing the alternative methods of construction outlined in this study could be a valuable contribution to national carbon reduction efforts."

As almost a quarter of all global CO_2 emissions are attributed to energy use in buildings, reducing the energy demand and carbon emissions linked to buildings is an important goal for government climate policy. However, the energy used, and associated carbon emissions, when a house is built is often overlooked and mainly comes from the extraction, processing, manufacture, transportation and use of materials for construction. This energy and carbon is thus considered to be hidden or 'embodied' in the house.

The researchers assessed the energy used and carbon emitted in the construction of a novel low-energy house in the UK using a life cycle method. The house was a three-bedroom semi-detached house made with a factory-built, foam insulated, timber frame and assembled in modules at the building site, where it was clad with larch planks. It was compared with two similar buildings constructed using more traditional methods: a timber-framed house with brick cladding and a house built with traditional masonry techniques (block internal walls, insulated cavity walls and brick cladding).

The assessment, based on data from an inventory of all the materials and fossil fuels used during construction, revealed that the low-energy house required a total of 519GJ (gigajoules) of primary energy to build (5.7 GJ/m^2), embodying 35 tonnes of CO_2 (405 kilograms of CO_2 per square metre). 82% of the energy was used in preparing the materials (over a third of this from concrete) and the rest was used to transport materials, remove waste and for onsite energy requirements.

The brick-clad house embodied over 30% more carbon and energy, owing to the increase in minerals associated with the cladding (sand, brick and cement) and increases in transport and construction costs. The masonry house embodied 51% more carbon and 35% more energy compared to the timber framed, larch-clad house.

Most energy and carbon savings in the low-energy house came from the use of wood as an alternative to cement, bricks and steel; larch cladding produces an energy saving of 24% compared to bricks. Less structural support is also needed, further reducing the need for energy rich materials, such as steel and concrete. The offsite, factory manufacturing of the timber fames also reduced energy costs.

Addressing the alternative methods of construction outlined in this study could be a valuable contribution to national carbon reduction efforts. Further energy savings from construction include reducing onsite waste production, which accounts for 14% of total embodied carbon, and reducing the amount of cement used, by replacing it with ground granulated blast furnace slag, fly ash or other lower carbon alternatives.

Source: Monahan, J., Powell, J.C. (2011) An embodied carbon and energy analysis of modern methods of construction in housing: A case study using a lifecycle assessment framework. *Energy and Buildings* 43: 179-188. DOI: 10.1016/j.enbuild.2010.09.005

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Theme(s): Climate change and energy, Sustainable consumption and production

From grey to green: environmental impact of concretes must be fully assessed

When assessing the environmental impacts of new 'green' concretes, care should be taken to ensure that a range of impacts are considered, such as ecosystem damage and water depletion, rather than a sole focus on CO2 emissions, a recent study concludes. It demonstrates that cement incorporating industrial by-products performs substantially better than Portland cement when rated across several classifications of environmental impact.

"The environmental impacts of concrete production go beyond CO2 emissions and climate change. Impacts can include acid rain as a result of emissions of sulphur dioxide, nitrogen dioxide and nitric oxide; health risks of locally high concentrations of cement kiln dust, and the depletion of drinking water supplies."

The environmental impacts of concrete production go beyond CO_2 emissions and climate change. Impacts can include acid rain as a result of emissions of sulphur dioxide, nitrogen dioxide and nitric oxide; health risks of locally high concentrations of cement kiln dust, and the depletion of drinking water supplies.

The development of 'green' concrete, with reduced impact across a range of environmental considerations, is an important step towards a sustainable construction industry. Industrial by-products, such as blast-furnace slag (from steel production) or fly ash (from coal combustion) can be used to replace a proportion of the cement needed for concrete. However, careful evaluation is needed to assess the ultimate impact of these new methods.

Life cycle assessments (LCAs) have been used by many studies to quantify the environmental impact of different types of concrete, however, this review demonstrates that conclusions drawn from LCAs can vary depending on how different aspects of analysis are carried out.

Firstly, LCAs are based on a 'functional unit'- the unit for which environmental impact is calculated (e.g. 1km of road of a set width) and the choice of this functional unit can substantially affect estimates of impact. The researchers recommend that this reference unit should be a structural unit, such as a whole building, with a set mechanical load and life span. This takes into account durability, an important factor that is omitted if the impact of a product is not studied over its entire life-cycle.

Secondly, the type of environmental impact method can affect results. Different methods used include, for instance, the Intergovernmental Panel on Climate Change approach, which classifies impact only by greenhouse gas (GHG) emissions; the damage-based Eco-indicator 99 approach, which classifies impact by actual damage to human health, ecosystems and resource depletion and, finally, the problem-based CML 2002 approach, which uses a series of measures including human toxicity, ecotoxicity, acidification and global warming potential.

This review concludes that to fully quantify environmental impact, definitions should include other measures beyond GHGs, and that the high uncertainties surrounding damage-based approaches suggest that a problem-based approach may be more reliable.

Analyses using the CML 2002 approach show that the use of blast-furnace slag and fly ash in cement result in a much lower environmental impact than that of ordinary Portland cement, when impacts of the by-products are allocated by economic value. For example, the global warming potential of 1kg of Portland cement is the equivalent of 0.84 kg of carbon dioxide, but only 0.13 kg for blast-furnace slag and 0.20 kg for fly ash. Much lower environmental impacts for these two industrial by-products are also observed when looking at the other impact categories, such as human toxicity and ecotoxicity.

Source: Van den Heede, P., De Belie, N. (2012). Environmental impact and life cycle assessment (LCA) of traditional and 'green' concretes: Literature review and theoretical calculations. *Cement & Concrete Composites*. 34: 431-442. DOI: 10.1016/j.cemconcomp.2012.01.004.

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Standardising building life cycle assessments can improve energy efficiency

As buildings become increasingly energy-efficient in terms of heating and operation, researchers are highlighting the importance of reducing the energy needed to construct the buildings. However, there is a lack of accurate, consistent data, or a standard methodology to properly assess energy requirements at this stage, a new study has found.

"...improved data, standards and calculations offer opportunities to improve our understanding of the effects of building materials, linking their embodied energy directly to greenhouse gas emissions targets."

Buildings account for 40% of the EU's total energy consumption and are therefore an important target for increased efficiency, as shown by the Energy Performance of Buildings Directive[1]. The total life cycle energy of a building includes both 'embodied' and 'operational' energy. Embodied energy is consumed during the production, use and demolition phases, whereas operational energy is required to operate the building, e.g. heating and lighting.

In order to maximise embodied energy efficiency, decision makers need comparable and reliable data to decide which materials or components to select. However, the study found that this was currently lacking. Buildings can be large, complex, and incorporate many materials and products and these components' environmental impacts may be hard to track.

Buildings also have a long lifespan, during which they can be altered, and building processes, and methods of measuring what is used or deciding what to include, are not standardised. All of these factors make data collection and life cycle assessment (LCA) for buildings challenging.

Selecting a less energy-intensive building material may save embodied energy in the construction phase; however, it may be more energy-efficient to use a more energy-intensive material for building if it reduces a building's operational energy consumption during its lifetime. Without access to improved and standardised data and methodology, this type of decision will be difficult to make.

Data on embodied energy are one of the components of ecolabelling schemes, which inform users of a product's environmental impacts, both upstream (raw materials and processing) and downstream (recycling and disposal) of their use. Ecolabelling experts say that without correct and relevant information on ecolabels for building products, their usefulness for decision making and product choice is weak.

The researchers also found that current LCA standards need improvement to increase their usefulness for buildings. Life cycle experts have recommended developing a new set of standards to streamline the embodied energy calculation process, leading to globally-accepted embodied energy protocols; but they must survey and evaluate current standards first.

The recommendations for improved data, standards and calculations offer opportunities to improve our understanding of the effects of building materials, linking their embodied energy directly to greenhouse gas emissions targets.

Source: Dixit, M.K., Fernández-Solís, J.L., Lavy, S., Culp, C.H. (2012). Need for an embodied energy measurement protocol for buildings: A review paper. *Renewable and Sustainable Energy Reviews*. 16: 3730-3743. DOI: 10.1016/j.rser.2012.03.021.

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Could Building Information Modelling support sustainable building practices?

Building Information Modelling (BIM) can enhance the design of a building, reduce costs and save energy. However, little research has been carried out on its impact on sustainable practices. A US survey illustrates that many practitioners do not see sustainability as a primary application, suggesting that more effort is needed to encourage the integration of 'green' design and construction into BIM..

"...more effort is needed to encourage the integration of 'green' design and construction into Building Information Modelling."

In the construction industry, BIM is a useful tool that can create accurate scheduling timetables and calculate, and ultimately reduce, the costs of a building project. Using BIM, a 'virtual' building can be constructed to analyse the feasibility of a project, which helps to design structures that reduce waste and optimise energy use. Information from multiple disciplines, companies and project phases can be combined and features of BIM include highly detailed and realistic images of the building structure; a 3D model integrated with cost, energy and structural analysis; and 4D scheduling (linking 3D components with time-related information).

A US study used a web-based questionnaire to obtain the views of practitioners attending the 2009 Design Build Institute of America National Conference in Washington, DC. The survey addressed the use of BIM in current design and construction, the perceived importance of sustainability and how BIM can be used to support sustainable building projects.

The 123 completed surveys indicated that most of the respondents were contractors, architects, engineers or subcontractors working on commercial projects. Half were LEED (Leadership in Energy and Environmental Design) accredited. BIM was found to be widely used in the design and construction industry (89% of company practices), but the majority (65%) have only used BIM practices for between one and five years.

The majority of respondents agreed that their company considers sustainability important (63%) and encourage building owners to pursue sustainable methods, such as sustainable site development, water and energy efficiency, the use of sustainable materials, and effective project management.

Of those interviewed, 91% indicated that BIM is best used to support sustainable design and construction practices early on in a project's design stage. The surveys also indicate that design-build projects (in which the design and construction services are contracted by a single entity) and integrated project delivery methods provide the best environments to use BIM software for 'green' buildings.

Although contractors and those engaged in design-build projects saw BIM as an effective tool to help improve sustainability, this was not the case for architects and respondents from companies engaged in the traditional method for project delivery with separate entities for the design and construction phases.

25% of green building projects worked on by the respondents' companies within the preceding 5 years had been LEED certified. The majority (88%) of those certifications had been required by the owner.

Most respondents also still believed sustainability was not a primary application of BIM and flagged up the problem that diverse applications of BIM software did not always work together efficiently. Therefore, in order to improve the sustainability of building projects, the study suggests that design and construction professionals would benefit from more education about the potential benefits of BIM use and steps should be taken to improve information exchange.

Source: Bynum, P., Issa, R.R.A., Olbina, S. (2012) Building information modeling in support of sustainable design and construction *Journal of Construction Engineering and Management*. DOI: 10.1061/(ASCE)CO.1943-7862.0000560.

A selection of articles on Green Construction from Science for Environment Policy's News Alert.

Open to all: free online tool to assess buildings' sustainability in development (28 February 2013)
A free online system for assessing the sustainability of buildings is due to be launched across Europe in July this year. The tool captures scientific complexity whilst being accessible and easy-to-use, its developers say.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/319na5.pdf

Offsite construction waste management: lessons from Hong Kong (7 February 2013)
The last two decades have seen a series of new construction waste policies management in Hong Kong. One of the most significant is an offsite construction waste sorting (CWS) programme which, since its implementation in 2006, has separated 5.11 million tonnes of construction waste into different materials. The researchers suggest that the study provides an important reference for other countries working to minimise construction waste.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/316na4.pdf

Stronger concrete is more environmentally-friendly (7 November 2012)
Using high-strength concrete in construction could help to reduce its impact on the environment, according to a study by French researchers. The researchers compared the environmental impacts of bridges built from ordinary and high-strength concrete and found that the high-strength solution had a lower impact on the environment overall.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/304na3.pdf

Energy Performance Buildings Directive: comparing Member State performance (20 September 2012)
A method has been developed to compare how EU Member States have implemented the Energy Performance Buildings Directive. It suggests that implementation varies widely across Europe but that the Czech Republic, Finland, Portugal and Slovakia have kept to the Directive's aims and guidelines most closely, based on data available in 2009.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/298na4.pdf

'Cool' paving materials make summer in the city more comfortable (31 May 2012)
Using 'cool' materials to construct roads and walkways is an effective way of lowering urban temperatures to make cities more comfortable in hot weather. According to a recent study, surface temperatures were reduced by 12°C and ambient temperatures were reduced by 1.9°C after cool pavements were installed in a city park in Greece.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/286na2.pdf

Sustainable natural materials can be used for noise insulation (5 May 2011)
Researchers have found that natural materials, such as plant fibres or wool, can be used to construct sustainable sound absorbers that help prevent noise pollution, which are as effective as conventional absorbers made from combinations of minerals and plastics.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/238na5.pdf

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You may also be interested in reading the following reports and past Thematic Issues.

The Multifunctionality of Green Infrastructure (March 2012)
Green Infrastructure (GI) stands to improve quality of life in many ways, through its environmental, social and economic credentials, based on the multifunctional use of natural capital. This In-depth Report describes the different functions that GI seeks to execute and explores the scientific evidence behind its ability to perform these functions.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR3.pdf

Soil Sealing (March 2012)
Sealing soils with artificial, impenetrable surfaces interferes with the essential environmental, economic and social functions performed by soils. This In-depth Report explores the extent of Soil Sealing and its consequences for the water cycle and city temperatures.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR2.pdf

Resource Efficiency (May 2011)
Humanity is demanding ever greater economic productivity at a time when natural resources, the input that feeds this productivity, are dwindling. To reduce pressure on key assets, such as water, minerals, fuel and land, we must use less of them, and we need to increase the efficiency and productivity of resources that we do use, to achieve more output per input. Put simply, we must do more with less. This Thematic Issue reports on research which helps guide the way to a more resource efficient society.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/26si.pdf

Urban Environments (February 2009)
Half the world's population live in cities. By 2050, the total number of urban dwellers is expected to nearly double, rising from 3.3 billion to 6.4 billion. How do we accommodate urbanisation while ensuring good quality of life and health? How do we minimise environmental damage but still develop our cities? This Thematic Issue provides a window into the research evidence that can help us create healthier urban environments and more sustainable urban policies.
http://ec.europa.eu/environment/integration/research/newsalert/pdf/11si.pdf

To view any of these publications in full, please visit: *http://ec.europa.eu/science-environment-policy*

Related research projects

A number of interesting and promising policy-relevant research projects related to Green Construction are supported by the European Commission under the `Seventh Framework Programme. Here is a selection:

C2CA
Advanced Technologies for the Production of Cement and Clean Aggregates from Construction and Demolition Waste
http://www.c2ca.eu

IRCOW
Innovative Strategies for High-Grade Material Recovery from Construction and Demolition Waste
http://www.ircow.eu

LORE-LCA
Low Resource consumption buildings and constructions by use of LCA in design and decision making
http://www.sintef.no/Projectweb/LoRe-LCA

OPEN HOUSE
Benchmarking and mainstreaming building sustainability on the EU based on transparency and openness (open source and availability) from model to implementation
http://www.openhouse-fp7.eu

PANTURA
Flexible Processes and Improved Technologies for Urban Infrastructure Construction Sites
http://www.pantura-project.eu

SUPERBUILDINGS
Sustainability and performance assessment and benchmarking of buildings
http://cic.vtt.fi/superbuildings

SUSREF
Sustainable refurbishment of building facades and external walls
http://cic.vtt.fi/susref/

SYNER-G
Systemic Seismic Vulnerability and Risk Analysis for Buildings, Lifeline Networks and Infrastructures Safety Gain
http://www.vce.at/SYNER-G/

More information about EU-funded research projects under the Environment Theme of the Seventh Framework Programme for Research can be found here:
http://ec.europa.eu/research/environment/index_en.cfm?pg=environment

http://ec.europa.eu/science-environment-policy