european
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Steering through the maze #4

Capturing the collective knowledge base on building retrofit

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An eceee guide into issues relating to implementation of the EPBD, including an extensive review of related Summer Study papers.

6 May 2011

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About the European Council for an Energy Efficient Economy (eceee)

eceee is a non-profit, membership-based European NGO. The goal of eceee is to stimulate energy efficiency through information exchange and co-operation. To facilitate this, eceee provides an information service through its website and e-mail newsletter, arranges workshops and conferences, and takes active part in the European Policy making process.

One of eceee's principal events is the Summer Study, held for five days every odd year in the early summer. The Summer Study attracts about 400 participants from a wide range of backgrounds. eceee and its summer study offer governments, industry, research institutes and citizen organisations a unique resource of evidence-based knowledge and access to reliable information.

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This paper is based on a review of papers submitted to eceee and ACEEE summer studies and conferences over the last few years, including a preview of the 2011 eceee summer study papers on building retrofit. In all, over 70 abstracts were reviewed to compile this paper, the aim of which is to bring together the combined knowledge base of experts operating in the field of building retrofit across Europe, North America and beyond into a single reference point. It is intended that this will provide a platform from which readers can explore their areas of interest by following the links and references to specific papers which describe a particular topic in more detail.

If there is one overall conclusion that could be drawn out from the mass of literature written on the subject of building retrofit, it is this:

> Despite some excellent initiatives and approaches to improving the energy performance of existing buildings, the immense potential for cost effective energy saving and carbon reduction is unlikely to be achieved without a combination of: strong policy drivers; effective financing schemes; and increased propensity among building owners/occupiers to take action.

Context

At both Member State and EU level there are numerous directives, policies and action plans that stress the importance of improving the energy performance of the EU building stock, with the potential for significant benefits in terms of CO_2 emissions reductions, improved energy security, increased employment, development of the green economy, and increased affordability of energy running costs. These are supported by a wide array of programmes and initiatives, ranging from information campaigns and grants through to best practice case studies and innovative financing mechanisms. Yet despite these drivers, levels of retrofit currently being undertaken, both in terms of its depth (i.e. % reduction in energy use) and number of buildings being addressed (annual percentage of building stock) is significantly below the trajectory required to achieve the full potential.

The main EU policy tool, the recast Energy Performance of Buildings Directive[1] (EPBD), requires (with certain exemptions) minimum energy performance requirements (based on cost optimality[2]) whenever existing buildings are subject to major renovation, or when technical components such as heating, ventilation or cooling plant are replaced. However, the EPBD places no requirements on the vast majority of buildings that are not subject to major renovation. As a result, the rate of improvement in the energy performance of the existing building stock is far below that required to achieve the economic potential for cost effective carbon saving from Europe's building stock.

[1] Directive 2010/31/EU

[2] The Commission will publish its methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements by 30th June 2011.

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Preview of 2011 eceee Summer Study

This year's eceee Summer Study, June 6-11, 2011, includes a session entitled "**Saving energy in buildings: The time to act is now**"[3]. This section briefly reviews all 30 papers that address improving the energy performance of the existing building stock through reviews, analyses and scenarios of the market for building retrofit.

The ***scale of the challenge*** is considered by **Shorrock** (paper ref. 5-019), as he examines historic uptake rates of energy saving measures[4] in the UK, which may or may not have received financial support, while others have been mandated through building regulations. He concludes that the 2050 ambitions for carbon reduction in the buildings sector are unlikely to be achieved, even with a tightening of policies to require, rather than simply encourage, householders and other property owners to act.

Milin (5-050) also argues that the challenge of a 75% reduction of greenhouse gas emissions cannot be met without a deep reorganisation of regulations and governance which currently hinders investments in energy efficiency. He cites the example of social housing in many EU countries where landlords are not able to recoup investments through raising tenants' rents. To address this barrier, an Intelligent Energy Europe project "FRESH" brings together social housing operators and ESCOs from 4 Member States to work out the legal, financial and technical framework for Energy Performance Contracts (EPCs) in social housing. **Murphy** (5-131) argues that EPCs have the potential to make an impact on the retrofit market in The Netherlands, though **Staropoli** (5-302) notes that the reliance on performance measures, particularly ex post energy savings, may limit the ability for EPCs to deliver their full potential.

Bullier (5-052) and **Hüttler** (5-301) both raise the issue of valuing sustainable refurbishments, which Bullier calls "green value" - the somewhat intangible additional net value generated by the environmental performance of a property. He argues that it is possible to quantify the intrinsic quality of such buildings, the performance of their management and operation, and the quality of their use, thereby taking the green value fully into account in the valuation of properties and in investment decisions. Likewise, Hüttler illustrates how to value sustainability aspects in property valuation, based on results from a collaborative EU project.

Concerning co-benefits, **Ürge-Vorsatz** (5-250) presents a study in which the employment, energy security and fuel poverty alleviation impacts from a large-scale, deep retrofitting of the Hungarian building stock are quantified. In the study, a novel combination of Input-Output analysis with detailed bottom-up estimates was applied.

Barriers and drivers to energy efficient renovation in the residential sector is the topic for the paper by **Beillan** (5-072). Based on empirical findings from five European countries, initial findings are that:

- people getting involved in projects of energy-efficient refurbishment aren't mainly and exclusively motivated by energy savings;
- there's a lack of skilled work force able to meet the requirements of energy efficient retrofitting;
- public support schemes for retrofitting measures play a crucial role; and
- the local embedding of projects is important.

Another case study by **Gosselain** (5-423) looks at the situation in 2 former communist countries by reference to owner occupier surveys in Latvia and Bulgaria. While

[3] – see panel 5: http://www.eceee.org/summer_study/Theme_panels/#accepted_abstracts

[4] The term "energy saving" throughout this paper is taken to include energy efficiency and buildings integrated renewable, together with passive and behavioural measures

homeowners are motivated to improve comfort levels, in both countries, lack of money is the main barrierto undertaking energy-related renovation.

Penrith (5-424) discusses ongoing results of a large energy labelling pilot of 5,000 homes in Seattle, USA, designed to increase residential retrofit rates. The programme seeks to create an expandable infrastructure for municipalities to engage homeowners, using a web-based information delivery system and energy labelling as the focal point. In this way homeowners take advantage of "one-stop shopping" that shows them specific information on their home audit, comparisons of energy upgrade bids, and proposed financing information.

Two papers examine city-wide approaches. In **Bierwirth's "**Low Carbon City Wuppertal 2050" (5-160), emissions need to be reduced by 95% by focusing on municipal level action in the transportation and residential sectors, as well as considering land use and material flows, but only a third of the target could be met with current trends of renewable energy development and energy efficiency measures such as retrofitting the building stock - the remaining two thirds pose a serious challenge, requiring innovative measures to be developed. In a similar vein, **Yamaguchi** (5-274) concludes that every available technology must be fully implemented if the aspiration of reaching a low carbon status for the central business &cultural area in Osaka, Japan, is to be achieved. Meanwhile, **Koch** (5-545) considers the infrastructure requirements as neighbourhoods generate more of their own energy (electrical as well as thermal) and the impact this has on the balance between supply and demand.

Villot (5-152) bases his paper on surveys undertaken in France with various actors, including social housing occupants. He uses a decision tree type called a success tree to better understand the dynamics of refurbishment projects, examining in particular four types of barriers and levers - financial, behavioural, technical and political and normative.

A wide range of papers look at ***scenarios and strategies to deliver carbon saving from building retrofit.***

Kletzan-Slamanig (5-141) applies the concept of technology wedges to the sector. Reducing energy demand per m^2 can be accomplished by combinations of: improving thermal quality of the building stock (refurbishments); a faster diffusion of passive houses in new construction; more efficient heating systems and appliances; and increasing use of renewables and decentralised production of electricity. In addition to the energy and carbon impacts of implementing the wedges, their economic impacts are assessed.

Wittchen (5-507) examines data extracted from the Danish building Energy Performance Certification scheme data-base (one that predates the EPBD requirements in that building energy labelling became mandatory in Denmark in 1997) to consider pathways and investment profiles required in the building sector for Denmark to achieve its ambition of carbon neutrality by 2050.

Using data from Sweden, **Broin** (5-281) sets out both a top-down and a bottom-up methodology to estimate energy demand for residential space and water heating to 2030. Using two future price scenarios, he concludes that the price mechanism alone will not be sufficient to achieve the full techno-economic potential for energy efficiency.

Bettgenhäuser (5-169) used the Ecofys Built Environment Analysis Model (BEAM) to consider the parameters necessary for the German building sector to achieve a 40% carbon reduction by 2020 compared to 1990 levels. He concludes that the current retrofit rate of 1.4% would fall slightly short of this target.

Scaling up the perspective, **Ürge-Vorsatz** (5-429) presents a novel approach to building energy forecasting, utilising a model of world building energy consumption in a multi-

year effort within the framework of the Global Energy Assessment's (GEA) scenario work. The novelty of the method is that it follows recent developments in state-of-the-art construction and retrofit, considering buildings as complex systems rather than as sums of individual components.

Croft (5-214) considers the case for amending the current UK property purchase tax to reflect the energy rating of a home. This would act as a lever to encourage sellers to improve energy performance before putting a home on the market.

To address the argument over demolition vs. refurbishment, **Osso** (5-226) undertook a regional cost-benefit analysis using French national data, supplemented by surveys from over 2000 households. She considers in particular the scenario where old houses are replaced with small multi-storey residential buildings. In addition to much improved thermal efficiency, such developments contribute to reductions in urban sprawl and car use.

Killip (5-240) applies the principles of market transformation (commonly used in sectors such as appliances) to the buildings sector. However, the complexity of buildings means that factors such as acquisition of new skills and knowledge; technical risks associated with doing low-carbon refurbishment work; and the role of policy in simultaneously stimulating supply and demand need to be taken into account. He argues the need for much closer alignment between training, standard-setting and compliance checks to bring design and observed performance closer together.

Using evidence drawn from developments in the residential sector in UK and France, **Nösperger** (5-516) describes a "system of professions" approach, which incorporates the role of intermediaries (e.g., architects, engineers, builders, etc.) and their work. From this perspective, a profession is linked to a set of socially-accepted tasks considered to be its jurisdiction. Professional groups compete and develop interdependently, based in part upon their ability to perform the tasks within their jurisdiction. Growth in knowledge can create opportunities for new professional groups.

Pehnt (5-247) outlines a proposal currently being considered in Germany to introduce a long-term renovation plan, the core of which is a series of 5-yearly obligations where every building must meet certain parameters in terms of final energy demand and CO2 emissions. Building owners can choose to undertake renovations in 5-yearly steps to meet each round of targets or undertake major refurbishments to meet future targets. Where it is technically or economically not possible to meet a particular target, the owner pays a compensation fee, which is used to subsidise improvements for low income occupants or social housing.

Agents of change is the subject of paper 5-249, in which **Janda** looks at three case studies on the role of building professionals and other so-called middle agents as enablers, aggregators and mediators which can facilitate the transition to low carbon building.

Deutsch (5-251) also explores the issue of market transformation, in particular how building energy performance information is reported on websites across Europe. The aim is to see whether current consumer habits, in terms of online searching and shopping, can be used to influence choice in favour of a more energy efficient property.

In a major data gathering exercise, **Economidou** (5-286) presents preliminary findings from a country-by-country review on the energy performance of buildings across Europe. By monitoring and evaluating the current policy and legal frameworks in place and by providing a picture of the performance status of the building stock of each Member State, a roadmap for improving the energy efficiency of the European building stock is being developed.

Two practical examples of how to help Danish householders to take the first steps towards home renovation are presented in papers 5-343 and 5-351. **Lüders** describes how the Home Energy Check, a web-based tool to identify potential energy improvements, can motivate home owners/renters to analyse the energy-related conditions in their homes and hence start the journey towards greater energy efficiency. **Reuss** then describes the 'Find a Tradesman' interactive web platform that offers consumers the opportunity to find energy efficient solutions provided by competent approved tradesmen.

Höfele (5-358) describes a new four-year project "bigEE" – Bridging the information gap on Energy Efficiency in buildings, whereby theoretical evidence on what policy support markets need is combined with empirical evidence on which combinations or packages of policies have worked. By providing evidence-based information, the project aims at developing an international internet-based knowledge platform for energy efficiency in buildings.

Review of previous eceee & ACEEE papers:– 2005-2009

Many of this year's crop of papers build on topics covered in previous eceee and ACEEE events. A selection of these papers is reviewed in the Annex, grouped under 5 broad headings:

- Programmes addressing building retrofit
- Case studies, pilots and surveys
- Scenario Analysis, Models and Tools
- Non energy benefits
- Energy Performance Contracting

Conclusion

Policy makers, researchers and others concerned with improving the energy performance of the existing EU building stock of homes, offices, public buildings and other properties would do well to examine the wealth of knowledge already built up through eceee and ACEEE networks. It is hoped readers will find this paper a useful source of reference.

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Annex – A selection of papers on building retrofit from eceee Summer Studies and ACEEE Conferences, 2005-2009[5]

Programmes addressing building retrofit

1. GreenBuilding – Europe wide renovations of non-residential buildings[6]

In 2004, the European Commission initiated the GreenBuilding Programme. Thirteen organisations from ten European countries agreed to reduce primary energy demand of their building by 25% (if economically viable) and to report the results of the renovation measures. The paper describes the GreenBuilding Programme before presenting a summary of the refurbishment projects, including the various technologies applied. The paper also discusses possible improvements to the present programme.

2. Home Performance with ENERGY STAR: Accelerating Energy Efficiency Improvements[7]

Home Performance with ENERGY STAR® (HPwES) is a programme to significantly increase energy efficiency in existing US homes. HPwES promotes whole-house improvements via home performance contracting, including comprehensive assessments and building-science based improvements where homeowners and the ENERGY STAR brand are protected by a robust quality assurance program. As of May 2008, HPwES programmes in twenty-three states are increasing both the **demand** for home performance contracting and the **supply** of qualified home performance contractors.

3. An Integrated Whole Building Diagnostic Approach to Improving California's Existing Multifamily Buildings[8]

Since 2002, the Designed for Comfort (DfC) programme in California has provided multifamily building owners guidelines and incentives for an integrated design approach to identifying the most cost effective energy efficiency measures. The paper describes how the programme provides a mechanism for whole building analysis, and highlights the successes, challenges, and lessons learned over 3 funding cycles. It also proposes strategies to expand to all multifamily buildings and tailor building simulation software to existing multifamily buildings.

4. Minnesota B3 Benchmarking Results: Prioritizing the Energy Savings Opportunity in Minnesota Public Buildings[9]

Minnesota initiated the "B3" building energy benchmarking programme to guide effective allocation of energy conservation investments in existing buildings. The data collection process relies on a web-based tool through which building representatives of public buildings enter data, including building characteristics and utility bills. The users can see how their buildings compare to individualized benchmarks. B3 advances a unique approach to determine the benchmarks: a parametric model based on space-type simulations and prescriptive requirements in the current Minnesota energy code. The advantage of this modelling approach is precise knowledge of the underlying building

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[5] ACEEE also had a Summer Study on the Energy Efficiency in Buildings in August 2010. Details of the papers from that event are available at http://www.aceee.org/conferences/2010/ssb.

[6] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.278/
[7] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2008/Panel_2/2_52/
[8] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2008/Panel_2/2_368/
[9] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2008/Panel_3/3_157/

characteristics associated with the current energy code. Buildings with actual energy use significantly above their benchmark are most likely to have a better return on investment for conservation improvements.

5. EnerGuide for Houses Retrofit Incentive Program: A Winning Strategy to Improve Energy Efficiency of Canadian Housing[10]

The EnerGuide for Houses (EGH) programme promotes energy efficiency retrofits in existing low-rise houses through a home energy rating system. To the end of April 2006, over 252,000 houses (about 3.1% of the eligible housing stock across Canada) had received the initial rating. Typically, homeowners implement about two thirds of recommended measures. On average, the homeowner retrofit incentive is C$735 – which represents approximately 10% of the total retrofit costs. The success of the EGH and its incentive programme has also influenced various utility and provincial government agencies to work together. These groups offer a matching incentive to the homeowner creating a winning strategy for promoting energy efficiency in existing houses.

6. Integrating Demand Side Bidding with an Existing New Construction Efficiency Program: Differentiating Early Retirement Retrofit and New Installation[11]

In 2003, Long Island Power Authority launched a programme to achieve 75 MW of demand savings from existing buildings. This paper explores the challenges integrating a demand-side bidding initiative delivered by a contractor with an existing new construction programme delivered by the Authority, using actual cost and savings data from both programmes to compare project level economics using cash flow analysis and internal rate of return.

7. An evaluation based on Service Economy theory: the case of an EDF-supported refurbishment programme in rural area[12]

Selling services rather than products is a key feature of the Service Economy theory, which focuses on the performance of a response to functional needs. Such a theory can be used for assessing regional energy efficiency programmes beyond the single energy savings inasmuch as it seems more relevant to consider them in a wider local development scheme.
This paper describes a 5-year multi-million Euro programme whose goals are: to make this territory an example in the field of energy efficiency; to propose efficient home refurbishment solutions; to boost local craftsmen's work in the construction field; and to promote training in renewable energy.

Case studies and demonstration projects

8. Demonstration, inspiration … replication? Assessing the impact and limits of social learning from Eco-Homes Open Days in the UK[13]

In 2007-2008, communities and organisations across the UK organised ten area-wide open day events focussing on home eco-renovation and eco-new build, plus a host of single event open days at eco-renovated homes. These have proved extremely popular, with an average of 500 visitors per event, and have provided unrivalled opportunities for social learning about greenhouse gas reductions from eco-renovated and environmental

[10] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2006/Panel_2/p2_11/
[11] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2006/Panel_4/p4_23/
[12] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_3/3.217/
[13] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.074/

new build houses. This paper evaluates the open days and their achievements against the crucial need for step change to the UK's approach to eco-renovation.

9. Retrofitting technology to real homes: assessing the multiple impacts of solar-powered ventilation[14]

This paper presents the monitoring results and lessons learned from a project installing ventilation and energy efficiency measures into homes in Northern Ireland and the Republic of Ireland. The intention of the project was to enhance indoor air quality, reduce domestic energy consumption and bills and improve the health and wellbeing of the householders. The focus was on the fuel poor, who made up 78% of the 120 households. Monitoring showed improvements in the indoor environment and reported self identified health benefits. In addition to the monitoring findings, this paper draws lessons from the project management and evaluation design on critical issues and considerations around the treatment of existing homes. The paper reveals the importance of demonstration or technology test projects, the difficulties in assessing cost-effectiveness of measures with multiple priorities and the importance of partnerships for holistically addressing these priorities.

10. Making the home consume less – putting energy efficiency on the refurbishment agenda[15]

Despite high awareness for energy efficiency and rising energy prices, home owners only slowly take action to cut down their personal energy use. In many cases, maintenance and repair activities only result in incremental improvements of energy efficiency. Thus, the dynamics of refurbishment seems to have a conservative bias. The paper presents results from an empirical survey, focussing on home owners' maintenance and refurbishment decisions. Drawing on approaches from social-psychology, lifestyle analysis and evolutionary economics, it explores the impact of attitudes, lifestyle orientations, cognitive frameworks and social resources on refurbishment decision especially on energy efficient ones and presents a model integrating the most important driving factors.

11. Better than new buildings – best practices turn into national standard[16]

The “Efficient Homes” project in Germany examined more than 143 existing buildings refurbished since 2003, partly using highly innovative passive-house-technology. On average, these renovated buildings require less than 50% of the minimum energy requirements for new buildings.

12. SOLANOVA – "Factor 10"-retrofit of large residential buildings[17]

Ongoing renovations of the huge stock of large residential buildings in the new Eastern European member states only result in minimal non-sustainable energy improvements. SOLANOVA (supported by the Fifth Framework Programme) proposes to make this process more sustainable by transferring the existing know-how about new passive houses to the renovation of large buildings. A 7-storey 1970s panel building in Hungary is to be transformed into a “Factor 10” building by reducing the space heat demand of the flats to almost 10%. Being the first project of this type in Eastern Europe dealing with a major renovation of a large existing building, SOLANOVA serves as a best practice example.

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[14] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_7/7.230/
[15] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_8/8.256/
[16] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.277/
[17] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_2/2136hermelink/

13. Energy efficiency refurbishment - are end-users doing their bit?[18]

The carbon saved by residential energy efficiency programmes are assumed by policy-makers to achieve best practice results. But what is the reality? Do end-users who diverge from best practice necessarily use their installed systems inefficiently? And how does this dynamic affect the utility end-users derive from their systems? An in-depth survey of 150 households in social landlord tenure aimed to address these and related issues. All respondents' homes had been improved through energy efficiency refurbishment programmes. The analysis found that only about one quarter of respondents used their heating systems in an efficient or best practice manner, about half did so in a way that was reasonable given their lifestyles, and the remaining quarter used their systems inefficiently. Diagnostic tools were developed to assist installers and housing managers in determining the extent of energy advice required - based on tenants' current heating system knowledge, and the type of advice required - based on age, employment and other demographics. Consequently recommendations intended to maximise energy savings from refurbishment programmes were made to all major stakeholders.

14. Improving energy efficiency for low-income families[19]

This paper describes a German pilot project to improve the efficiency of electricity use in low-income households. All participating households received a free energy audit combined with a set of measures called the "instant help package" - compact fluorescent light bulbs, the elimination of stand-by losses through switched extension leads, as well as water-saving measures and timers to reduce losses in electric water heating. 18% of electricity consumption could be saved with costs less than 7 cents per kWh. The average benefit per household was €840.

15. Innovative retrofit to improve energy efficiency in public buildings[20]

In this paper two demonstration projects are reported. In Denmark, an old factory constructed in the 1930s and converted to a cultural centre, is described, including the installation of solar photovoltaic and solar thermal and a building management system. The Norwegian demonstration project concerns a Community Centre close to Oslo. Both proved that introduction of the right concepts for energy saving measures and renewable energy integration into a renovation project can bring the resulting building up to an energy standard that is considerably higher than that required by the current national building regulations at a reasonable cost and payback time.

16. Successful energy efficient building renovation at state schools[21]

The project's starting point was the thesis that a large economic potential to make schools more energy efficient exists. However the budgetary situation of the local authorities and the existing administrative structure prevented necessary action. The authors developed the "Solar&Save" concept for realising the saving potentials in German buildings and proved that the combination of solar energy with energy- and water savings can be economically profitable. Pupils and teachers have also been involved in the project and now benefit from its financial success. They are taught about the new efficiency technologies and sustainable energy resources in their schools.

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[18] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_5/5010smith/
[19] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_2/2.130/
[20] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.192/
[21] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_3/3.335/

17. Market Development Potential of Residential Refurbishment Packages[22]

The objectives of this study were to identify and cost technological pathways that could be adopted that would reduce the emissions attributable to specific residential dwellings by approximately 50% by 2030 and evaluate the response of householders to the costs of these intervention sets. For the two dwellings considered here the costs were found to be £21,300 and £31,800. Using whole life cycle costing methodology, no economic justification could be found for these investments using benefits based solely on potential savings in utility bills. A "willingness to pay" survey was conducted in the UK in 2008 - the findings point to a small but substantial "innovator" sector that may be willing to make the necessary investment. These findings are important in exploring future policy and (critically) marketing approaches that may be successful in accelerating the development of a mass market for residential refurbishment packages capable of delivering the scale of reductions necessary.

Scenario Analysis, Models and Tools

18. Transforming UK buildings: achieving a 60% cut in carbon emissions by 2050 in homes [23] [24] and non-residential buildings[25]

Market Transformation aimed at reduced carbon emissions uses a mixture of information, incentives, and regulation to transform the market for a given product. Here, the approach is extended to transforming the market for buildings. This series of papers describe the development of a model to explore the energy and carbon intensity of the UK stock of buildings from 2004 to 2050 under a range of scenarios. Sensitivity analysis has been used to test the importance of a number of assumptions (eg population and climate). The model and underlying assumptions has been made publicly available to allow exploration of assumptions and testing of alternative assumptions, and could provide an architecture for other EU countries facing similar policy targets.

19. Deep carbon emission reductions in existing UK social housing: are they achievable, and how can they be funded?[26]

A model of energy use, carbon emissions and refurbishment costs has been developed for the existing stock of a large London housing association. Various approaches to stock refurbishment up to 2030 were modelled, and outputs were assessed against four socio-economic scenarios, reflecting uncertainty about future fuel prices and efforts to mitigate climate change. The results indicate that extensive stock refurbishment require a significant increase in net expenditure and are therefore not financially viable for the housing association without extra funding. Two options are explored: increasing rents or selling properties. The option of increasing rents is shown to have some potential, but would require changes in Government policies on permitted rent increases.

20. Energy efficiency and CO2 mitigation scenarios for French dwellings based on retrofitting and best energy demand technologies[27]

This work evaluates various refurbishment scenarios outlook for 2030 of French dwelling stock: Business As Usual (BaU) or accelerate rates, usual technologies or Best Available Technologies (BATs). Emerging technologies (not yet available but with strong potential) are introduced among “on the shelf” technologies. Studied scenarios

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[22] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.093/
[23] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.356/
[24] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_1/1.387/
[25] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.355/
[26] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.201/
[27] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.034/

include energy efficiency actions as well as energy substitution. Estimations of technical investment cost of studied scenarios are presented. The calculations are done using the MIeL « Modelling of the Impact of Energy measures for housing » software, developed by EDF and built following a bottom-up approach.

21. Reducing uncertainty in the refurbishment market: a web-tool that brings together home-owners, housing providers, manufacturers, installers and policy makers[28]

With increasing availability of microgeneration technologies and more conventional energy conservation products, householders face myriad refurbishment options. Yet it is frequently unclear which measures are appropriate for each household. To fill this information gap, the T-ZERO tool has been developed. Utilising a building energy model based engine with over 100,000 modelled buildings, the tool enables users to define their home, then provides them with tailored optimal 'packages' that offer the best performance, measured across eight different parameters.

22. Implementing energy efficiency in Sweden's existing housing stock[29]

This paper analysed changes to building envelopes and to energy supply systems (including power generation and end-use systems as district heating, bedrock heat pumps, wood pellet boilers and electric resistance heaters) and evaluated the impacts on cost, CO_2 emission and primary energy use. It also analysed the economic conditions for Swedish house-owners to implement national economic cost efficient measures, and also what other factors that affect house owners' decisions to adopt new heating systems and concluded that the tax and the currently used investment subsidies in Sweden give relevant incentives to the customers to act according to national policy.

23. TARBASE - Reducing CO2 emissions through refurbishment of UK housing[30] and non-domestic buildings[31]

This paper catalogues interim outcomes from a research project (TARBASE) whose aim is to identify technological pathways for delivering a 50 % reduction in CO_2 emissions of existing UK buildings by 2030. The approach taken was to describe a series of domestic building variants, chosen due to their prominence in the stock as a whole and also by their ability when taken together to describe the range of construction methods. Technological interventions, grouped by building fabric, ventilation, appliances and on-site micro-generation (of both heat and power) as applied to the building variants were investigated. Their applicability was being determined with respect to energy and CO_2 emission savings. The interdependence of the technological interventions was evaluated allowing a series of intervention sets to be depicted for each variant. The non-domestic part of the project has focussed on energy use in offices, retail buildings, schools and hotels. The results make clear that, even within each sub-sector, non-domestic buildings are non-homogeneous. Different solutions apply to different sectors. While the target of 50% carbon savings is possible for many buildings, the changes required should not be underestimated.

24. Savings potential in existing Danish building stock and new constructions[32]

There is a large potential for energy savings in the Danish building stock, 75% of the buildings being constructed before 1979 when the first important demands for energy

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[28] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.227/
[29] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.100/
[30] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.201/
[31] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_7/7.046/
[32] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_2/2035dyrbol/

performance of buildings were introduced. The scope of this study was to investigate and set out the technical and economic potential for energy savings in the Danish building stock and in new constructions. By implementing existing, energy-saving technologies it is possible to reduce energy consumption for space heating to 20 kWh/m 2 p.a. in a block of flats and to 40 kWh/m 2 p.a. in a one-family house.

25. Energy efficiency in the refurbishment of high-rise residential buildings[33]

This paper identifies significant scope for increased energy efficiency in high-rise buildings. The cost-effectiveness of energy savings and avoided CO_2emissions is assessed, and it transpires that the most cost-effective energy savings can be made in the 'old' EU Member States, whilst the most cost-effective CO_2 savings are achievable in the New Member and Accession States. The paper concludes that investment in improving the energy efficiency of the high-rise residential stock should be made, acknowledging that approaches to prioritising this investment still need to be refined.

26. Deep Energy Reductions in Existing Homes: Strategies for Implementation[34]

This paper addresses the importance of developing a foundation to cut energy use in existing North American homes by 70%-90%. Properly implemented, the deep energy reduction paradigm offers the potential for reduced energy vulnerability and environmental impact over the life of a dwelling, while enhancing comfort, indoor air quality, and durability. However this requires a "beyond technology alone" strategy and must encompass behavioural choices and community-based strategies. While some experience gained from housing, energy, and utility programmes supports implementation of the deep energy reduction paradigm, other residential energy efficiency traditions make it more difficult to obtain large energy savings.

27. House Owners' Perspectives on Implementing Energy Efficiency in Existing Residential Areas[35]

There is a significant potential for increased energy efficiency in Swedish residential areas by improving the existing building stock. However, successful implementation of changes requires them to be sufficiently attractive for consumers to adopt. The authors analyse the economic conditions for house owners to change their heating system and to implement energy-conservation measures in a Swedish context. The most important factors for house owners were found to be the annual heating cost, the functional reliability, the investment cost and the indoor air quality.

28. CO2 emissions reduction potential from space and water heating in the Hungarian tertiary buildings[36]

This paper describes an ongoing project which examines the mitigation potential from space and water heating in the Hungarian tertiary buildings and summarizes its results for the public buildings. The project relies on a bottom-up approach of determination of mitigation potential. The different abatement options are selected from a set of currently commercially available technologies applicable to Hungarian context, assessed on their CO_2 mitigation potential and cost-effectiveness. The options include high performance building envelope components, heat controls and efficient space heating technologies and reduction of demand for hot water for existing buildings and passive house standard for new buildings. Preliminary results that the most cost-effective abatement options in the Hungarian public buildings are reduction of demand for water heating through

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[33] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_2/2123guertler/
[34] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2008/Panel_10/10_333/
[35] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2006/Panel_2/p2_16/
[36] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.352/

switching off recirculation when the buildings are unoccupied, and temperature management through installation of heat controls followed by improving the thermal building envelope.

29. Energy use in commercial building in China: Current situation and future scenarios[37]

This research evaluates the impact of a variety of scenarios of GDP growth, energy elasticity and energy efficiency improvement on energy consumption in commercial buildings in China using a detailed End-use Energy Model. Official energy statistics have limited information on energy demand by end use; further, China uses a different classification system for energy reporting, so official sectoral energy breakdown has long been questioned. The results suggest that commercial energy consumption in China's current statistics is underestimated by about 44 %, while energy efficiency improvements will not be sufficient to offset the strong increase in end-use penetration.

30. Evaluation of building envelope retrofit techniques for reducing energy needs for space cooling[38]

This paper is based on some preliminary results of the IEE project KeepCool. It presents a methodology for bottom-up assessment of the energy savings related to "sustainable summer comfort" solutions; case studies of buildings with good summer comfort and low energy consumption performances; and case studies of "comfort policies" adopted by public and private bodies to ensure summer comfort with low energy consumption (e.g. commitments to give priority to heat load reductions instead of introducing mechanical cooling, relaxed dress codes, low thermal insulation chairs, local air velocity increase).

31. Energy Efficiency in U.S. Buildings: What's Worked; What Might Be Better[39]

This paper reports findings of a new assessment of the techno-economic potential of the US building stock. The project assesses impacts of previous policies and programmes on building energy use in North America, and estimates future impacts of potential new efficiency policies for existing buildings. This paper summarises the results and provides insights into lessons learned though the broader global review of best practices to improve the energy efficiency of existing buildings.

32. Sensitivity analysis of cost effective climate protection in EU building stock[40]

The impact of the EPBD for EU-25 was analysed and demonstrated to be highly cost-effective for demand reducing measures in the building stock, with insulation measures of existing buildings offering the main saving potential. Coupling energy-efficiency measures with general maintenance and retrofit measures in the building sector, these measures are highly cost effective. A sensitivity analysis was carried out with five energy price scenarios. The effects of these scenarios on the cost effectiveness of insulating a pitched roof of a residential building in a moderate climate based on a reference building were calculated.

Non-energy benefits

33. Counting good: quantifying co-benefits of improved efficiency in buildings[41]

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[37] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.312/
[38] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_7/7.403/
[39] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2006/Panel_8/p8_26/
[40] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.072/

A review of global research findings on the quantification of cost-effectiveness of opportunities through improved efficiency has highlighted that there is a major shortcoming in the vast majority of such calculations. It is common that such studies normally consider only direct costs in their assessment. Whereas there have been several trans-national efforts to quantify external cost, external "benefits", or non-energy benefits, are rarely monetized and included in cost-benefit analyses. Since several studies have attested that these benefits often amount to more than the direct energy benefits, the omission of these values severely distorts the results of such assessments and, therefore, it is of utmost importance to consider these for in global and national policy-making and target-setting. The aim of the present paper is to assist in laying the foundations for this process, and demonstrates this on the case of the building sector.

34. Valuing low energy offices: the essential step for the success of the EPBD[42]

Under present valuation methodologies, energy efficiency of offices is rarely taken into account. Those properties that might be categorised as 'low energy' are undervalued; the market for them is stagnant. This research argues the property investment benefits of low energy offices, namely the prospect of both increased rental return and increased future investment worth. Despite difficulties gathering empirical valuation data the work reaches important conclusions regarding data availability, energy assessment and market stimulation. This paper highlights the current inability to demonstrate the investment benefits of low energy offices under current practices, and emphasises the reduced risk for owners that ensure their properties comply with energy efficiency best practice.

35. Commissioning in public sector building – Non-Energy Benefits (NEBs), not savings, are the selling point[43]

As part of a broader study to examine cost-effectiveness of commissioning public buildings, the authors examined the non-energy benefits from a sample of buildings, including schools, offices, and prisons. Phone surveys were used to gather data to measure both positive and negative benefits, and values were computed based on multiple measurement methods. Results showed the highest-valued non-energy benefits are: changes in comfort, indoor air quality, productivity, light quality, safety, reduced tenant complaints, fewer operational deficiencies, and improved knowledge for operating and maintenance staff. Non-energy benefits add significant value above and beyond the direct (energy & cost) benefits, and are often stronger selling points than energy savings.

36. Why Energy Efficiency Retrofits Are Undervalued[44]

For comparing efficiency programmes to conventional supply investments, metrics such as the "total resource cost" (TRC) are used. Such comparisons of costs and benefits have provided a generally accepted decision framework. However, sometimes that framework may disadvantage particular types of programmes and lead to long-term lost opportunities for energy savings. This paper focuses on the case in which the TRC methodology is used to evaluate comprehensive whole-house retrofit programmes such as those of the national Home Performance with ENERGY STAR® initiative.

Energy Performance Contracting

37. Energy performance contracting – An incentive for improving the energy performance of the building envelope in existing commercial office buildings[45]

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[41] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_1/1.316/
[42] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_2/2009guertler/
[43] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.313/
[44] http://www.eceee.org/conference_proceedings/ACEEE_buildings/2006/Panel_7/p7_12/

Energy performance contracting (EPC) is used to remove some of the barriers to energy efficiency by providing a delivery mechanism that enables access to commercial financing, improves access to technical information and reduces project risks for the end user. In commercial buildings EPC has traditionally been applied to the substitution or retrofit of end-use technologies for lighting or heating ventilation and air conditioning (HVAC) services, whereby third party financing of the energy efficient improvement or measure is provided on the basis of *shared* or *guaranteed* savings contracts. Its application to tenanted buildings has largely been confined to government leases and educational facilities. This paper examines the role of EPC as an incentive for improving the energy performance of the building envelope for buildings occupied by commercial tenants. Two case studies are presented for buildings located New Zealand). Contractual relationships in traditional owner/tenant type lease agreements are compared against the "green leases" schedule developed in Australia.

38. Comprehensive refurbishment of buildings with energy services[46]

Energy Performance Contracting (EPC) projects, if implemented properly, have successfully delivered guaranteed savings since they were first established in Europe about 1995. In this paper, the authors propose and describe models how to integrate building refurbishment measures into EPC-models. They examine three different basic models for the implementation of comprehensive refurbishment projects. Factors for applicability of the models (especially for the public sector) are described.

39. Contracting and building renovation – does it work together?[47]

Renovation is an important point in the life cycle of a building that makes it possible to achieve both environmental and climate protection goals and a higher quality of living of the inhabitants. However, lack of money often leads to a renovation that covers only the basic requirements, whereas measures that are valuable in a long term perspective like energy saving measures are not realised. Energy performance contracting (EPC) is widely used as an instrument to reduce long term operating costs significantly by guaranteed energy savings. It is the aim of this paper to investigate the possibilities to incorporate construction measures like building envelope insulation into EPC.

40. Energy Performance Contracting: An opportunity for the private service building sector or a tool for public buildings only?[48]

Since 1997, Energy Performance Contracting (EPC) has become a frequently used tool in modernising more than 1000 public buildings in Austria. However, private building owners seem to lack either knowledge of, or confidence in EPC as a tool, despite the huge energy saving potential in this building sector. Up to 50% of the operating costs are energy-related, and, on average, 20% of these costs can be saved by using EPC. This paper describes the current situation in the Austrian EPC market, especially in the tertiary sector, where the implementation of EPC seems to be much more complex than in the public building sector. It discusses the barriers that prevent building owners from using EPC as a tool, as well as the barriers for Energy Saving Companies (ESCOs) and financial institutions. Finally, the means Austria is developing to overcome these barriers are presented as basis for discussion.

41. Improving energy efficiency in buildings under the framework of facility management and leasing financing[49]

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[45] http://www.eceee.org/conference_proceedings/eceee/2009/Panel_4/4.064/
[46] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.039/
[47] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.200/
[48] http://www.eceee.org/conference_proceedings/eceee/2005c/Panel_2/2080grim/

Non-residential buildings see a big variety of building management and financing schemes. The success of two approaches, Leasing Financing and Facility Management, quickly gaining share in the Austrian market are described.

[49] http://www.eceee.org/conference_proceedings/eceee/2007/Panel_5/5.179/