INNOVATION IN RELATION TO BUILDING ENERGY DEMAND IN IAMS

AN EXPERT WORKSHOP CARRIED OUT WITHIN THE FRAMEWORK
OF THE FP7 ADVANCE PROJECT, CO-FUNDED BY THE STANFORD ENERGY MODELING FORUM.
LEEUWENBERGH, SERVAASBOLWERK 1a, 3512 NK, UTRECHT, THE NETHERLANDS
20-21 JANUARY 2015

REPORT

Contents

This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No. 308329 (ADVANCE)

Background

IAMs tend to focus on energy supply rather than on energy demand. Still, energy demand is a main driver of emissions and, related to this, energy efficiency can form a major part of mitigation strategies. The ADVANCE expert workshop dug deeper into this topic with a focus on energy efficiency in buildings. It brought together external experts and stakeholders to discuss technological and behavioural options to increase energy efficiency in buildings as well as demand management options to support grid integration of VRE.

Catherine Radford Zoi – Stanford University

Cathy Zoi is a Consulting Professor at Stanford and directs the Energy Transformation Collaborative (ETC). She has spent 30 years in the energy and environmental sectors at the nexus between technology and policy. Cathy served in the Obama Administration as Assistant Secretary and acting Under Secretary at the Department of Energy, overseeing more than $30 billion in energy investments. In the private sector, Cathy has been an energy investor (Silver Lake and Bayard Capital), a board member (Ice Energy, SES, Pacific Solar), and a management consultant (ICF and Next Energy) with bases in the US and Australia. She was the founding CEO of both the Alliance for Climate Protection (established by Al Gore) and the NSW Sustainable Energy Development Authority -- a $50m fund to commercialize technologies to reduce greenhouse gas emissions. In the early 1990s, Cathy was Chief of Staff for the Office on Environmental Policy in the Clinton White House and she pioneered the Energy Star program while at the US EPA. Cathy has a BS in Geology from Duke and an MS in Engineering from Dartmouth.

Getting Innovation in Buildings to Take Hold: Good Technology is Necessary, but Not Sufficient

The potential for improved energy efficiency in buildings was huge 30 years ago – and it remains so. Last week, for example, California Governor Jerry Brown announced a new goal of doubling the energy efficiency of existing buildings across the state. The good news is that building technologies continue to improve: LED lighting, smart windows, evaporative air conditioning, and advanced controls could dramatically reduce energy consumption and associated greenhouse gas emissions, while delivering improved comfort and building functionality. Recent analyses by the New Climate Economy project and others found potential energy savings >50% are achievable. History demonstrates that the rate at which such technical innovation is deployed will be dependent on both commercial and policy drivers. To address timing imperatives of climate change, a combination of policy instruments and business model innovations will be required to seize this future potential: building codes and equipment standards, technology targets, tax incentives and penalties, finance and leasing packages, marketing and education, and of course -- leadership.

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Diana Ürge-Vorsatz – Central European University

Diana Ürge-Vorsatz is a Professor and Director of the Center for Climate Change and Sustainable Energy Policy (3CSEP) at the Central European University (CEU) in Budapest. She has conducted her Ph.D. studies at the University of California (Berkeley and Los Angeles), and has been a Fulbright Scholar. She has worked on and directed several international research projects for organisations including the European Commission, the European Parliament, the Global Environment Facility, United Nation's Environment Programme, the World Energy Council and the World Bank. She has been regularly advising the Hungarian government on environmental, climate change and energy issues.

Dr. Ürge-Vorsatz has authored over 70 publications, and has been serving on several advisory and governing bodies of organisations including UK Energy Research Centre, REEEP (the Renewable Energy and Energy Efficiency Partnership), the, the Hungarian Energy Efficiency Cofinancing Program (HEECP), the European Council for an Energy Efficient Economy (ECEEE), and the Collaborative Appliance Labelling and Standards Programme (CLASP), among others. She has been a Coordinating Lead Author for the Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) for the chapter "Climate Change Mitigation in Buildings", serves on the United Nation's Special Expert Group on Climate Change, and is member of the United Nations Foundation's expert group on energy efficiency advising the German G8+5 process. She has been acknowledged to share the Nobel Peace Prize of 2007 that was awarded to the IPCC.

Challenges to modeling the new frontiers in building energy demand reduction: holistic solutions, integrated options and behavior

The presentation fist provided a systematic comparison of building sector emission and energy demand models produced using IAMs and engineering-economic models. The talk, based on the analysis in and for the Fifth Assessment Report of the IPCC, provided a list of hypotheses that may explain the differences found. The talk highlighted the importance of treating direct and indirect emissions combined when conducting sectoral analyses. Then, the presentation focused on potential game-changing innovations for building energy demand. Within this it reviewed the potentials for upcoming breakthroughs in a few fields of building energy demand. Then, it highlighted the importance of systemic, holistic and integrated solutions and showed examples from the literature that emphasize that the larger reduction opportunities in most end-use sectors for the future are much more likely in such solutions rather than in further perfecting individual technologies where much progress had been made in the past decades. The paper concluded with another angle that may importantly inform building energy modeling: the phenomenon of stabilizing per capita residential energy use.

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Robert Harmsen – Utrecht University

Robert Harmsen (PhD) is Assistant Professor Energy & Resources at the Copernicus Institute of Sustainable Development (Utrecht University). Robert is an expert in energy efficiency and renewable energy policy analysis. His main fields of interest are policy interactions and the built environment. After finishing his PhD in 2000, he worked for COGEN (Dutch CHP association), the Netherlands Energy Research Centre (ECN) and Ecofys Netherlands. As consultant for the European Commission he was involved in the implementation of the CHP Directive and task manager for the development of harmonised reference efficiency values to calculate the primary energy for CHP and district heating. He has led a potential study for renewable heat and cooling in the Dutch built environment and other sectors for the Dutch Ministry of Economic Affairs and initiated a potential study on air/water heat pumps for existing buildings for a consortium of manufacturers. He was involved in a project for the European Climate Foundation (ECF's) to analyse the policy gap for Europe's 2020 energy savings target and to explore design options for binding energy savings targets which may be of particular interest for the non-ETS sectors such as transport and built environment. He was involved in a study for the European Investment Bank in which he analysed the Energy Efficiency Investment Potential up to 2020 for the built environment and other sectors. In 2013 he coordinated a project for the Dutch Ministry of Internal Affairs to study the innovation barriers in the Dutch construction sector. In 2014 he got a grant from the Rexel Foundation to study the role of installers and SME contractors in the renovation market. Currently, he works for the European Commission to provide technical support to the Energy Efficiency Directive regarding cogeneration and district heating. He is also coordinating a TKI STEM project (Dutch top sector research program) that analyses the barriers towards implementation of 300 thousand heat pumps in existing residential buildings in the Netherlands between 2015 and 2020.

Barriers to innovation in new and existing buildings: Dutch experiences

In this presentation insights were presented from three projects recently carried out by Utrecht University on innovation barriers in new and existing buildings. All three studies aim to combine the Technology Innovation System (TIS) approach with complex systems thinking. The first study is on the innovation barriers in the Dutch construction sector. As this study has been subject to an international comparison with Austria and Finland, differences and similarities between the countries are addressed. The second study is about the (changing) role of installation companies in the (energy) renovation of existing buildings. The third study takes a technology perspective and analyses the position of heat pumps in the transitioning of existing buildings into more energy efficient buildings. Insights from these three studies were linked to the field of IAM. All studies show that different scenarios exist to achieve the same (i.e. very efficient buildings), that some scenarios are preferred by stakeholders with vested interests, and that the required effort in terms of type of policy interference to become successful is very different for each of the scenarios.

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Vassilis Daioglou – Utrecht University

Vassilis Daioglou holds degrees in *Mechanical Engineering* (M.Eng, University of Southampton, 2007) and *Sustainable Development – Energy and Resources* (M.Sc, Utrecht University, 2010). At the Netherlands Environmental Assessment Agency (PBL) he helped develop and implement a global residential energy model which investigated the effects of income inequality and technology development on projections of energy access and indoor air pollution. He is currently PhD candidate at Utrecht University and PBL and his research focuses on assessing the long term possibilities of using bioenergy for carbon dioxide emission mitigation. His interests lie in the relations between energy-economy-environment and how models which assess these interactions can be developed and used effectively.

The Perspective of IAM models: Buildings in IMAGE-TIMER

Energy demand for buildings has been included in the IMAGE model by investigating the residential and service sectors separately. The presentation outlined the method adopted in order to model the energy demand of the residential and service sectors. The level of disaggregation, demand functions and key drivers were explained. Following, a number of important issues and difficulties were highlighted and knowledge gaps were identified.

The useful energy demand of specific energy function (cooking, lighting, space cooling/heating and appliances) has been related to economic indicators. Technologies and fuels which can deliver these services compete based on relative costs, while changes in efficiency may be exogenously set or a reaction to energy prices. The model is calibrated to historic data for these sectors. Key knowledge gaps include uncertainty on the drivers of energy choices, the possibilities of game-changing technologies and the elasticity of demand.

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Carrie Armel – Stanford University

Dr. Carrie Armel is a research associate at Stanford's Precourt Energy Efficiency Center (PEEC) where she investigates the diverse ways in which an understanding of human behavior can lead to improvements in energy efficiency. For example, the application of behavioral principles can produce significant energy reductions through interventions implemented at the policy, technology, built environment, media/marketing, and organizational/community levels. Dr. Armel co-chairs the Behavior, Energy, and Climate Change Conference; oversees Precourt Institute's Behavior and Energy Bibliographic Database and Website; and teaches courses on behavior and energy at Stanford.

In addition to these initiatives, Dr. Armel develops specific energy efficiency interventions that apply behavioral and design principles, and develops measures to evaluate the efficacy of such interventions. Her most recent project involves a collaboration between academic and non-academic organizations to design and evaluate a technology that takes advantage of smart meters to provide feedback to residents on home electricity use.

Dr. Armel completed a Ph.D. in Cognitive Neuroscience from the University of California at San Diego, and postdoctoral work in Neuro-Economics at Stanford. In these programs she employed behavioral, psychophysiological, and neuroscientific methods to investigate how affect and motivation influence behavior. She most recently completed postdoctoral work at Stanford's School of Medicine, translating intervention techniques used in health promotion work into the domain of energy efficiency.

Behavior change programs

This talk provided a survey of Stanford's ARPA-E Sensor and Energy Behavior Initiative as an illustration of the diversity of behavior change programs. The goal of this initiative is to develop a comprehensive human-centered solution that leverages the widespread diffusion of energy sensors to significantly reduce and shift energy use. The initiative has several parts: (1) a software platform that enables behavioral programs to be implemented at scale; (2) behavioral interventions to reduce and shift energy use; (3) data modeling that incorporates behavior into prescriptive engineering and economic analyses; and (4) an extensible energy communication network to enable future innovation. The behavioral interventions include technology (behavioral analytics, human-centered computational infrastructure), media (interaction design, social networking, games and feedback interfaces), policy (behavioral economic incentive programs) and community (schools, NGO's, utility and social organizations).

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Robert Lowe – University College London

Robert Lowe is a physicist with a broad interest in the field of buildings, energy and sustainability. Until 2006 he was at Leeds Metropolitan University, where he directed numerous studies relating to climate change and the energy performance of housing, culminating in the Stamford Brook Project. In February 2006 he joined UCL as Professor of Energy and Building Science. Since 2004 he has been a member of the FMNectar Consortium supporting DCLG in the development of UK building performance standards. He is currently the Deputy Director of the UCL Energy Institute and Director of the UCL-Loughborough Doctoral Training Centre in Energy Demand Reduction in Buildings.

Behavioural options in buildings – a socio-technical perspective

A socio-technical system is one in which the human and the material are closely coupled, giving rise to the potential for complex whole system behaviour. This presentation reviewed two case studies that demonstrate such behaviour, and offer some tentative conclusions. First that predictive modelling needs to be informed by an expanding body of high quality and data-rich case studies on a wide variety of buildings. Such data, generated and interpreted from a socio-technical perspective, may help modellers to identify contingent combinations of variables likely to be involved in the deployment of relatively novel packages of technologies at scale. Secondly, that the complexity in such systems is not restricted to end users, but also involves people working in the supply chains that deliver packages of technologies to end users.

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Robin Roy - Natural Resources Defense Council

Robin is Director of Building Energy and Clean Energy Strategy at the Natural Resources Defense Council (NRDC), and Founder and Director of Next Energy. He has worked for three decades to help meet society's need for secure, economic, and environmentally sound energy. His work often focuses on the nexus between the practicalities of effective public policy, the capabilities business, and the opportunity created by technological and institutional innovation. As a member of NRDC's energy and climate senior management team, Robin identifies and pursues new directions for federal energy policy for buildings including federal efficiency standards and codes, as well as strategies for clean energy development. While focusing on federal opportunities, he contributes to strategic opportunities for advancement of building energy and clean energy policies at the state, regional and international level.

He is also co-founder and director of Next Energy, a Sydney-based adviser to government, industry and environmental organizations on energy policy and strategy, often delivering on that advice with operational and project management services. Robin was formerly Project Director & Fellow at the United States Congress Office of Technology Assessment, where he advised the Congress on energy efficiency initiatives in the federal government and housing sectors, competition in the electricity market, vulnerability of electricity systems to terrorism and natural disaster, and nuclear industry issues.

Prior to that, he was with the Pacific Gas and Electric Company, focusing on demand management and strategic planning. Robin received a PhD - Civil Engineering, MS - Engineering-Economic Systems and BS - Electrical Engineering from Stanford University.

Grid-interactive consumer appliances for an increasingly decarbonized, economic electricity system: The case of water heaters, and beyond

Utility control of electric water heaters has long been used for energy storage, shifting demand to low-cost, low demand times. With increasing uptake of low-emissions, variable output generation such as wind and photovoltaics, the benefits of such customer-side energy storage will likely continue to grow. Further, fast two-way communications and control systems that allow use of consumer equipment for ancillary grid services are rapidly emerging, offering further economic and environmental benefits. In some cases such as water heaters, there can be a significant trade-off between energy efficiency and grid interactivity. Economic and environmental analysis is nascent, and much more work is needed to support good policy-making.

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Marissa Hummon & Doug Arent - National Renewable Energy Laboratory

Dr. Marissa Hummon is a senior scientist in the Energy Forecasting and Modeling Group at the National Renewable Energy Laboratory (NREL). Since joining NREL in 2010, her areas of expertise include: Integration of demand-side resources in grid simulation and optimization models, Parallel computation of power system models, and Quantitative/statistical analysis and modeling. Before joining NREL, she was a Research Associate with Harvard University, Analyst with Ecos Consulting, and Consultant and VP Operations with Apogee Strategies. Marissa has a PhD in applied physics from Harvard University and a BA in physics from Colorado College.

Dr. Doug Arent is Executive Director of the Joint Institute for Strategic Energy Analysis at the National Renewable Energy Laboratory (NREL). In addition to his NREL responsibilities, Arent is Sr. Visiting Fellow at the Center for Strategic and International Studies, serves on the American Academy of Arts and Sciences Steering Committee on Social Science and the Alternative Energy Future, is a member of the National Research Council Committee to Advise to U.S. Global Change Research Program (USGCRP), and is a Member of the Keystone Energy Board. Arent was recently invited to serve on the World Economic Forum Future of Electricity Working Group, and is a member of the International Advisory Board for the journal Energy Policy.

Arent was a Coordinating Lead Author for the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). He has been a member of Policy Subcommittee of the National Petroleum Council Study on Prudent Development of North America Natural Gas and Oil Resources, served from 2008 to 2010 on the National Academy of Sciences Panel on Limiting the Magnitude of Future Climate Change, and also served on the Executive Council of the U.S. Association of Energy Economists. His research interests are centered in energy and sustainability, where he has been active for more than 30 years. He has published extensively on topics of clean energy, renewable energy, power systems, natural gas, and the intersection of science and public policy. Arent has a Ph.D. from Princeton University, an MBA from Regis University, and a bachelor's of science from Harvey Mudd College in California.

Modeling Demand Response for Integration Studies

Modeling flexible demand for integration studies requires new techniques. Demand can provide capacity, energy, and reserves for the system. This talk demonstrated the NREL approach to developing a data set and modeling techniques to measure the value of demand response. NREL applies this model of flexible demand to the western interconnect in the United States, in concert with solar and wind annual power production ranging from 30 to 55% of annual generation. The talk concluded with a look toward integrating flexible demand in integrated assessment models.

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Michael Hogan - The Regulatory Assistance Project

Mr. Hogan is a Senior Advisor to the Regulatory Assistance Project on matters relating to power industry decarbonization in Europe and the US, in particular matters of wholesale market design, the role of demand response, and integration of intermittent renewable generation. Previously he was based in The Hague directing the European Climate Foundation's power sector programs; in that role he initiated and led ECF's influential "Roadmap 2050" power sector decarbonization project. He began his career in 1980 with GE's Power Systems business marketing large fossil and nuclear power systems in the US, the Middle East and Latin America. Beginning in 1988, he helped build the J. Makowski Co. in Boston into a leading U.S. private power developer. After selling the company in 1994, he and other JMC executives founded private power developer InterGen. He spent the next seven years in London leading the growth of InterGen's regional business unit, successfully developing, financing, building and operating over 8,000MW of greenfield power plants across the U.K., the Netherlands, India, Egypt and Turkey. He returned to the U.S. to lead the restructuring of InterGen's 3,700MW North American business in 2001 and 2002, after which he joined Centrica's North American affiliate Direct Energy, based in Toronto, as head of its upstream gas and power unit, where he oversaw a mid-sized Western Canadian gas exploration and production business and built up a 1,300MW power plant portfolio in Texas over the course of three years. He earned an MBA from Harvard and an ScM from MIT in Urban Studies and Planning, and a BA in Philosophy and a BS in Aerospace Engineering from the University of Notre Dame.

Demand Management Options to Support VRE Grid Integration

Demand management in buildings has the potential to reduce dramatically the cost of integrating intermittent renewable energy sources into the energy system. This potential breaks down into two broad categories:

1) *Energy efficiency reduces the quantity of production capacity needed to meet the demand for energy services; given that most renewables are highly capital intensive the economic benefits of energy efficiency are more front-loaded (and thus greater on a present value basis) where large new investments in renewables are planned.*

2) *Demand response, in the form of shifting consumption of electricity and other energy inputs from periods of scarcity to periods of surplus, is among the most technically feasible and economically efficient means available to mitigate the intermittency of renewable energy production.*

The focus of the presentation was on the latter category of benefits. Much of the discussion around demand response has tended to focus on active management of consumption by building owners/lessees in response to various forms of dynamic pricing signals, with advanced metering systems being a key enabler. In reality this is unlikely to be the case for a number of reasons, including:

1) *Savings on bills from even the most assiduous attention to price signals are unlikely to be enough to drive the sustained commitment in time and resources required of the average building owner, and they would struggle to evaluate the expected return any needed investments.*

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2) *As the share of renewables grows on the system the timing and pattern of periods of scarcity and surplus will become less predictable, rendering mechanisms such as time of use and critical peak pricing less effective and increasing risk for consumers exposed to real-time retail pricing.*

3) *The most valuable services DR can provide are of more immediate value to system operators than to consumers, few of whom are in a position to exploit them in any case; consumer benefits will come in the form of lower overall costs to manage a system with high shares of renewables, something individual building owners have little or no ability to evaluate.*

As a result, demand management in buildings is only likely to come anywhere close to its full potential, and to deliver tangible and material benefits to building owners, via energy services aggregators acting as intermediaries between building owners and retail and wholesale market operators. In this model building owners strike a commercial deal with service providers, be they evolved offerings from traditional suppliers or services offered by new third-party market entrants, in which the full range of benefits to be derived from building energy management (from simple arbitraging of real-time prices to the sale of ramping and balancing services to grid operators) are monetized in some sort of fee-for-services arrangement that dramatically eases the burden on the building owner and makes the benefits readily apparent. These deals can include needed investment in kit such as thermal energy storage equipment. Possible candidates for new entrants to provide these services include Internet and telecom service providers, electric vehicle manufactures and thermal appliance retailers. One other implication is that the "smartness" of meters is likely to play a more limited role in facilitating all of this than is often assumed. While interval metering will continue to be a key enabling function – and ToU and CPP rate options can serve as useful intermediate measures – the actuation of the most valuable end-use management functions is more likely to occur via the Internet.

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Wilfried van Sark – Utrecht University

Wilfried van Sark is associate professor at the Copernicus Institute of Utrecht University. He has over 30 years experience in the field of photovoltaics, ranging from thin film silicon and III-V solar cell experimental and modeling development and testing to solar cell processing development, out- and indoor performance of solar cells, policy and cost development. His current activities focus on employing spectrum conversion (down/up conversion) using nanocrystals to increase solar cell conversion efficiency for next-generation photovoltaic energy converters as well as performance analysis of PV systems in the field, in particular linked to the development of smart grid systems in the built environment.

Demand side management: we need electric mobility!

With increasing penetration of variable renewables in the residential sector such as photovoltaic solar energy, matching of demand and supply is a challenge. The University of Utrecht studied demand side management options in a neighborhood setting and found only limited beneficial effects on shifting demand. Local storage, especially using batteries of electric vehicles in conjunction with bidirectional charging/discharging is shown to improve the balance of demand and supply: self-consumption can be >80% with proper energy management algorithms and adequate solar forecasting.

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Hans Christian Gils – Deutsches Zentrum für Luft- und Raumfahrt (DLR)

Hans Christian Gils studied physics with emphasis on astronomy, particle physics and security policy at the Universities of Konstanz, Padua and Hamburg. In 2010, he joined the department of Systems Analysis and Technology Assessment of the German Aerospace Center (DLR) as a doctoral candidate. His main fields of scientific interest are the modeling of energy systems and the integration of high temporal and spatial resolution data into energy system models. Specific research foci are the role of load management and enhanced sector coupling in future energy supply systems with high renewable energy share.

Model-based Assessment of Potential Future Demand Response Utilization in Germany – Selected Results and Implications for Integrated Assessment Models

Demand Response (DR) measures have been identified as one of the options available for meeting the increasing power system flexibility needs arising from the fluctuating power generation of variable renewable energies (VRE). To what extent DR can contribute to a higher VRE integration has however not yet been thoroughly investigated.

The presentation briefly introduced the implementation of electric load shifting into the cross-sectoral energy system model REMix. The deterministic linear optimization model REMix is designed for the preparation and assessment of energy supply scenarios based on a system representation in high spatial and temporal resolution. In the following, selected results of a case study for Germany were presented. It is focused on a scenario assessment of the competition and interaction of DR with alternative balancing options in integrated European energy supply systems predominantly relying on renewable energy sources. Indicators regarding the DR impact on VRE integration were discussed, including back-up capacity demand, VRE curtailment and annual load shift. The presentation concluded with a derivation of implications of the REMix results for integrated assessment models and an outlook on future research.

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Discussion points and conclusions

The expert workshop "Innovation in relation to building energy demand in IAMs" looked into the key issues of future residential energy demand and more specifically into: mitigation potential; impact of behavior; relationship between integration of VRE and residential energy demand. By means of expert knowledge on these topics, participants could draw conclusions on how to represent these issues in integrated assessment models.

IAMs, which are used to advise policy makers on overall mitigation strategies in the next decades, need to be as much as possible consistent with the information provided by detailed case studies. However, the interpretation and use of detailed information from case studies for integrated systems and, eventually, implementation in global long-term models remains one of the greatest challenges. Also, further discussion is needed to clarify to what degree energy demand may be covered by endogenous or exogenous assumptions in the models. In any case, to better represent energy demand functions in the models there is a great need for additional data, especially on regions beyond the OECD.

Experts during this workshop have indicated that demonstrated by EE models and bottom-up studies, there is a very high potential for energy savings and clearly IAM models still have major problems with representing these energy saving opportunities. Again, the level of detail, but also the availability of data, appears to be a major obstacle. The need to cooperate for collecting information and data on building stocks' age structure, efficiency of buildings, end-use energy consumption was supported by several participants.

The buildings sector offers great potential to shift energy demand in time and thus results being very suited for VRE integration. Several presentations showed potential for using residential energy (e.g. water heaters, air conditioning, heat pumps, and vehicle batteries) allowing higher intermittent use (much more attractive than central storage). These options seem to be too specific for IAMs, but a possibility would be to create a more generic option to peak shift or battery (depending on location, climate/culture etc.). Hereby it is important to research the trade-offs between load demand management and energy efficiency improvements in more detail.

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