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1-020-22: Extended abstract

How dynamic is consumer behaviour? A thought experiment based on agent-based simulations, field studies, and experiments

Christian Klöckner, NTNU, Norway

Panel
1. Dynamics of consumption: less is more?

Keywords
consumer behaviour, dynamic simulations, behavioural change, Behavioural plasticity, Psychological interventions

The energy transition in the European Union, but also societal transitions in relation to energy and consumption worldwide have shifted focus from technological innovation to changes in consumer behaviour and lifestyles. This inevitably raises the question, to which degree consumers are willing to engage in these transition processes, where barriers ly, and not the least, how dynamic these changes in consumption occur. This paper will explore the potential, but also the limits of changes in energy-related consumer choices based on the rich experience from several large-scale research projects: An analysis based on data from 18.000 respondents provided by the ECHOES H2020 project (www.echoes-project.eu) explores the room Europeans from 31 different countries see for behaviour change in energy- and mobility related questions and which factors impact this space of opportunity. The analyses show that the general intention to support the energy transition is high in most European countries, especially in Romania, Turkey, Portugal, Hungary and Malta (less so in Sweden, Czech Republic, the UK, and Latvia). The intention to reduce energy use for heating and cooling follows largely the same pattern, with the exception that people in countries from colder climates are less willing to reduce energy use for heating whereas people in countries from warmer climates are more willing to reduce their energy use for cooling. Intentions to buy electric bicycles and to allow the grid operators to take control about devices to reduce peak loads are lower and there is considerable variation between countries. Regression analyses show that an environmental identity, personal norms and perceived efficacy are the most important predictors of the intention to contribute to the energy transition. Personal norms and identity are also very important for the intention to reduce energy use for cooling or heating. For purchase of electric bikes and allowing control of the grid operator, an environmental identity is less important and personal norms become very important, but also social norms are more important here.

Following up on that, some examples of agent-based simulations of behaviour in relation to social energy innovations will be given from the SMARTEES H2020 project (www.local-social-innovation.eu). In this presentation, I take the case of el Hierro, were a renewable energy project was implemented (a wind-powered hydro-electric power station) and public support was varying. We simulated this varying support and different policy options to improve public support were tested. I present four scenarios, which show that increased positive communication about the hydro plant improved acceptance, especially if it focussed on more than economic benefits, and that guided tours, especially in the beginning of the project could be a powerful tool.

Finally, lessons learned from a large-scale role-out of behaviour science-informed interventions targeting energy efficiency behaviours in millions of European households in the ENCHANT H2020 project (www.enchant-project.eu) show the barriers one meets in everyday live, when trying to implement behaviour science in real live programs to initiate behaviour change. A number of issues occur when rolling out interventions large scale with real stakeholders such as translation problems of behaviour change interventions from the lab to the field, crash with company policies, crash with rules and regulations, or on-response in larger publics.

Together, the experiences from these three projects show both the potentials, but equally the limits of consumer engagement. Large changes can be achieved under the best conditions, but these are often cases where citizens already are engaged and are organized themselves.

1-031-22: Extended abstract

Less struggle and more thrive: How far can justice take us in guiding and understanding energy transitions?

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Panel
1. Dynamics of consumption: less is more?

Keywords
fuel transition, qualitative sociology, Justice, Ethics of care

The moral discourse around energy transitions favours justice as its main virtue, often highlighting injustice in the current system and ways to avoid it. When we aim for justice, our focus is on what is lacking. When we aim for thriving, our focus is on abundance. The current transition away from fossil fuels offers an opportunity to reinvent our energy systems and associated virtues and values. The transition must be fair and the concepts of just transitions and energy justice are a useful guide. But is justice all we should be aiming for? Drawing together theories of virtue ethics and ethics of care (Anscombe 1958, Clement, 1996), we put forward the beginnings of an alternative framework, which does not ignore justice but promotes the virtues of generosity, compassion, care and friendship as the foundations or pre-requisites of it (Beier, 2013). These virtues have the potential to bridge communities with different interests and to broaden who is part of them (Castro, 2021). These alternative virtues have the potential to give rise to new values or to revive some of those lost in the past in pursuit of 'progress' and to initiate an ethical chain that leads to altruism which in turn promotes justice and giving everyone what is theirs (Singer, 2015). Referring to examples from historic energy transitions, we consider the outcomes, ontologies and methods that this alternative framework might have led to. I.e. What outcomes might have resulted from the transition away from burning solid fuels in the home and towards central and district heating systems, had the transition been guided by these principles? Would we have favoured these technologies and how might we have researched and understood them? And what might a guiding framework based around generosity and care mean for the current transition away from fossil fuels?

1-038-22: Peer-reviewed paper

High consumers of energy and resources and the work of being wealthy: towards a research agenda

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Aimee Ambrose, Sheffield Hallam University, United Kingdom
Stephen Parkes, Sheffield Hallam University, United Kingdom
Yael Arbell, Sheffield Hallam University, United Kingdom
Alvaro Castano Garcia, Sheffield Hallam University, United Kingdom
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Panel
1. Dynamics of consumption: less is more?

Keywords
Consumption Reduction, High Consumers, methodology

High consumers of energy and resources in domestic settings make a disproportionately greater impact in terms of their greenhouse gas (GHG) emissions and resource use, with the richest 10% being responsible for around 49% of carbon emissions (Kartha et al, 2020). Moreover, the highest consumers also act as trend-setters and aspirational peers, thus driving high consumption more widely within society. As such, efforts to confine global warming to 1.5 degrees Celsius will be unworkable unless the wealthy change their lifestyles (Gore et al, 2021). We know that the rich have caused climate change (Weidmann et al, 2021) yet there have been limited attempts to define high consumption or what constitutes too much. There also appears to be very limited political will to tackle what might be regarded as excessive consumption and we also find limited direct interest in the issue within research and academia, with attention focussed instead on low or under consumers and more abstracted debates about sustainable consumption. Our work seeks to help address the research gap around high consumption chiefly through the development of deep qualitative methodologies that seek to understand the socio-cultural and structural factors that sustain high consumption. Focussing on the question of: 'why is it so hard to consume less?', our paper reports upon a state-of-the-art review of literature, spatial mapping of consumption data and stakeholder interviews (in the UK) which highlight the need for a greater focus on high consuming households. We also discuss how this work has informed the development of an innovative methodology for exploring the lived experiences of this elusive and hard to reach group, which utilises institutional ethnography to explore and explicate the 'work of being wealthy'.

1-055-22: Extended abstract

(Don't) follow my carbon footprint. Identification and analysis of low-carbon clusters in Germany

Abigail Alexander-Haw, Fraunhofer Institute for Systems and Innovation Research, Germany
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Panel
1. Dynamics of consumption: less is more?

Keywords
energy sufficiency, carbon footprint, consumer behaviour, decarbonisation, domestic energy efficiency, clusters

The 2021 Climate Law requires Germany to be greenhouse gas neutral by 2045. In addition, Germany has set intermediate targets of lowering emissions by at least 65 percent by 2030 compared to 1990 levels, and by at least 88 percent by 2040.

With an average of 7.75 t CO_2e per head in 2019, the carbon footprint in Germany is too high to be compatible with greenhouse gas neutrality in 2045. By definition, lifestyle habits and decisions strongly influence an individual's energy use and carbon emissions. Carbon footprint patterns are thus expected to vary according to socio-economic factors, but also the activity (e.g. electricity use, transport, etc.) in question.

In this paper, we aim to increase the understanding of how individual carbon footprints vary by socioeconomic factors so as to facilitate the development of adapted and targeted policies to address the different groups. To this end, we perform cluster analysis on unique individual carbon footprint and socioeconomic data from a demographically representative survey in Germany (N = 1005) to identify relevant low-carbon clusters. Our carbon footprint calculator distinguishes greenhouse gas emissions related with electricity use, heating, transportation and diet.

We find that clusters of individuals with a relatively low-carbon footprint (compared with the rest of their group) can be found at all income levels. The mean carbon footprint of individuals in low-carbon clusters within lower income categories is markedly lower than its equivalent in the middle and higher income categories, indicating possible energy poverty. Calculating clusters for each income level separately reveals that differences between clusters have different causes between levels. Whilst dietary habits have strong effects between clusters at all levels, heating plays the largest differentiating role within clusters of respondents at higher income levels.

1-086-22: Peer-reviewed paper

The rise of sufficiency in the French energy debate: a comparative analysis of scenarios

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Albane Gaspard, ADEME, France

Panel
1. Dynamics of consumption: less is more?

Keywords
energy sufficiency, long-term scenarios, modelling, lifestyle

The public debate on energy has been fierce in France in the months preceding national elections in 2022, due to the urgent need to prepare the country's energy future. Interestingly, sufficiency has become an increasingly discussed topic, as a solution to achieve climate neutrality and reduce the constraints on the energy supply system.

One reason for this is the publication of several long-term energy scenarios from different institutions and organisations including some consideration of sufficiency. This has been a first time and has contributed to popularise the concept in the media and public opinion. However, has sufficiency been approached and modelled in a similar or different ways in these scenarios?
In this paper, we propose a comparative analysis of four of these scenarios: the 2050 négaWatt scenario, the 'Energy Futures 2050' exercise from RTE (national electricity grid authority), and two of the four climate neutrality scenarios released by ADEME (national agency for ecological transition). We investigate how these studies have been framed, look at methodological aspects to set sufficiency assumptions until 2050, and discuss the results. Last, we provide an overview of how these scenarios have been received and how far they have influenced decision makers.
This comparative analysis allows to better understand the methodological similarities, innovations, and limits of the scenarios. It also helps understanding how such sufficiency-based scenarios can contribute to the public debate process.

1-102-22: Peer-reviewed paper

(What is left of) The potential for lower indoor temperatures - A detailed survey of current heating behaviours of French households

Marie-Hélène Laurent, EDF R&D Département ENERBAT, France
Mathieu Durand Daubin, EDF R&D, France
Pierre Boulin, EDF R&D, France

Panel
1. Dynamics of consumption: less is more?

Keywords
energy sufficiency, behavioural change, behaviour, household consumption, heating, heat controls, residential, energy saving potential

In Europe, heating accounts for the largest part of energy consumption and GHG emissions of the residential sector (EU, 2021). Most of the scenarios aiming at carbon neutrality rely on a combination of improved energy efficiency (EE) and lowered indoor temperatures in a perspective of sufficiency. While many studies and tools, including Energy Performance Certificate, describe the EE of the housing stock, little is known of the current heating behaviours, which are assumed to change toward sufficiency. Before imagining where we could go, we answer the question: where do we stand right now?

This paper describes French households' heating behaviours in 2018, from a representative survey of 4000 people. First, patterns of declared temperature levels, by room and time of the day, reveal a range of spatial and temporal management behaviours. Then a "heating management" typology is analysed in relation with households' demographics and equipment (building, heating system, control devices). Finally, the energy savings potentially resulting from a change of behaviour toward sufficiency is estimated.

Strikingly, most French households do manage temperatures, either manually or through programming devices, achieving a much lower average temperature (in time and space), than their maximum level of comfort. Temperature depends mainly on the heating system quality: poor equipment only allows lower temperatures, while energy-efficient systems produce higher temperatures.

For low-carbon scenarios, this work shows a large part of the potential for lower than 19°C indoor temperature is not available for future energy savings. Moreover, the deployment of heating control devices promoted in energy policies is unlikely to help a temperature reduction, given people without devices already manage their heating. However, the use of these control systems

could mitigate the rise of temperature driven by the spread of more efficient heating systems and could provide controlled flexibility to the electric grid.

1-110-22: Extended abstract

Learning to consume less energy through strategies of sufficiency

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Panel
1. Dynamics of consumption: less is more?

Keywords
learning, practices, everyday life, energy consumption, wellbeing, sustainability, energy sufficiency, sufficiency

Energy consumed in households constitutes a large toll on the total of the carbon emissions. For this reason, it is important to limit everyday consumption through strategies of sufficiency, i.e., bringing the global consumption of resources within the carrying capacity of the planetary eco–systems, while at the same time ensuring a fair resource distribution within and between generations (Spangenberg & Lorek 2019). Sufficiency needs to be addressed especially in countries figuring amongst the main carbon emitters (Wilhite 2013). However, this is a difficult task to pursue, as energy–consuming practices are taken–for–granted, often perceived as non–negotiable and as necessary to achieve wellbeing, which is constantly defined and re–defined through the performance of everyday practices.

In this abstract, we aim to combine learning and practice theories to improve understandings on how changes to more sustainable – and sufficient – lifestyles can be pursued in people's everyday lives, without them experiencing sharp losses in wellbeing. We argue that attempts to reduce consumption involve processes of learning: how is learning involved in the development, adoption and performance of less energy–consuming practices?

Based on a literature review and theoretical discussion, we claim that promoting sufficiency implies changes in how people "practice wellbeing" in their everyday lives. We draw on a practice theoretical perspective conceptualising a practice as a "manifold of doings and sayings" organized by heterogeneous elements such as "rules, practical and general understandings, and prescribed or acceptable ends, projects, tasks, and emotions" (Schatzki 2017: 31). Practices and their elements constitute peoples' daily lives through discourses, actions, beliefs, worldviews, as well as objects and meanings.

Practice theories also help to get insights into how people learn in their everyday life (Schatzki 2017): we approach learning as it occurs through the participation in practices, as a combination of "cognitive and bodily processes" (Lave 1993). This approach offers ideas on how practices can change: in fact, learning can actively engage people in changing the performance of certain practices and so, possibly in changing practices themselves. Shove and Walker (2010: 475) remind us that the practices that are "enduring and relatively stable" persist because "they are consistently and faithfully reproduced, not because they have achieved some kind of closure". In practices' reproduction and performance, Wenger (2010: 181) explains that people contribute to the creation of meaning, and practices themselves are an "active negotiation of meaning": "this meaning–making person is not just a cognitive entity. It is a whole person, with a body, a heart, a brain, relationships, aspirations, all the aspects of human experience, all involved in the negotiation of meaning. [...] Learning is not just acquiring skills and information; it is becoming a certain person – a knower [...]". Similarly, Schatzki (2017: 28) writes that learning a new practice implies taking over a way of being, which implicates something more than the mere acquisition of knowledge: in fact, "it also encompasses the acquisition of habits, feelings, normative convictions and self–understandings". In this sense, learning is understood as a process where individuals can change old practices and acquire new ones – involving new knowledge, but also new identities, new ways of (well)being and so new ways of consuming energy.

Achieving energy sufficiency necessarily implies thorough changes in how we perform our everyday lives, and for that reason, it is important to develop approaches that involve citizens as active participants in creating this transition. Here, a better understanding of the role that learning can play for how we change practices can be decisive for ensuring the transition to "energy light" ways of living without critical losses in wellbeing.

1-116-22: Peer-reviewed paper

The determinants of household energy burdens and their influence on participation in energy-efficiency programs

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Panel
1. Dynamics of consumption: less is more?

Keywords
Energy Equity, energy poverty, residential customers, Energy burden

Providing clean and affordable energy is essential to both economic development and quality of life. And the equitable access to clean and affordable energy is key for eradicating energy poverty and ensuring both energy equity and environmental justice. The use of energy services is a necessity in today's world. Regardless of one's socio-economic standing, the demands and challenges of everyday life in a modern economy require some essential level of energy services. Despite these realities, many households face systemic disparities in their ability to pay for energy and energy-efficient technologies. These disparities limit their access to adequate and clean energy resources. Such disparities are manifested in the energy burdens borne by disadvantaged households and communities. For example, recent studies suggest that 25 % of all U.S. households and 67 % of all low-income households, face either high or severe, energy burdens, representing an estimated 30.6 million households in the U.S. alone. Our ability to address these disparities must start with a comprehensive understanding of the principal sociodemographic factors that shape them.

This paper discusses recent energy equity research examining the influences of multiple sociodemographic factors on household energy burdens and the equitability of participation in energy efficiency programs to better understand the determinants of energy burdens and participation in energy-efficiency programs. The findings are based on recent work performed with a large U.S. utility, providing fresh insights on the influence of income, education, age, race, female-headship, primary language, renter/owner status, and rural/urban location. We conclude with a discussion of how the research findings are being used to address energy inequities and to reduce household energy burdens and energy consumption.

1-124-22: Peer-reviewed paper

Data-driven approach to designing behaviour change communications for achieving Adaptive Thermal Comfort through optimum air conditioner setpoint temperature settings

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Panel
1. Dynamics of consumption: less is more?

Keywords
behavioural change, air conditioning, energy use, residential customers, optimum AC setpoint temperature

With India's sub-tropical climate and rapid urbanization, the penetration of Air Conditioners (ACs) in the residential sector is expected to grow by 37 % by 2037–38 from the current stock of ~40 million units. India Cooling Action Plan underscores the need for a shift in the behavioural attitudes towards Adaptive Thermal Comfort (ATC) practices to reduce cooling requirements and promote a healthy living/working environment. Empirical evidence indicates that acceptable/optimum AC temperature setpoints for Indian conditions lie between 25–27 degrees Celsius. In fact, the Bureau of Energy Efficiency (BEE), the Indian nodal agency for concerted efforts on energy efficiency, has been running the '24-degrees campaign' to steer user behaviour; however, recent surveys indicate that presently approximately 60 % of the Indian households use ACs at 20–21 degrees Celsius. Through 400+ quantitative and qualitative surveys, the present study compares the existing AC usage practices across three metropolitan cities – Delhi, Mumbai, and Kolkata. This includes AC users' perceptions, attitudes, practices, and awareness regarding optimum AC setpoint temperature settings. Approximately 50 % of the households in the sample had at least one AC in their homes and only 1 % of the respondents had maximum five ACs.

The setpoint temperature settings are more clustered (60 % respondents) around lower temperature settings i.e. 18–22 degrees Celsius during summers, while during monsoons, this predominantly shifts between 20–24 degrees Celsius. The findings attribute the observed skewness for lower temperature settings towards preferences for fast and quick cooling, high outside temperatures, humidity as well as adaptability to lower temperatures. In contrast, the concerns for comfort, health, suitability for members of different age groups, and reduced need for frequent temperature changes emerge as the key stimuli driving the respondents to use ACs at

24 degrees Celsius or above. The results further confirm low level of awareness; 26 % and 33 % towards BEE recommended AC setpoint temperature setting and the ‘24-degrees campaign’, respectively.

The study highlights the need to strengthen the campaign with new recommendations for positioning and articulation of the user-centric messaging with respect to the target audience (Who), creative concepts (What), appropriate platform (Where), timelines (When) and distinct goals (Why) and hence informs the design of behaviour change communications to steer user behaviour towards optimum AC setpoint temperature settings. This study can be scaled up across different geographic/climatic zones for crafting a data-driven framework to design behavioural energy efficiency interventions.

1-135-22: Peer-reviewed paper

Household energy usage behaviour - is it mightier than energy efficiency? Accounting for the impact of behaviour diversity on household space heating hourly national power demand

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Marie-Hélène Laurent, EDF, France
Thomas Berthou, Mines Paris, PSL Research University, France
Bruno Duplessis, Mines Paris, PSL Research University, France

Panel
1. Dynamics of consumption: less is more?

Keywords
bottom-up, space heating, household consumption, demand side management (DSM), behaviour, load curve, power demand profile, residential buildings

The potential of residential sector decarbonisation is manifold including the energy efficiency of buildings and systems, household conservation behaviour, increased use of renewable resources along with demand side management. Space heating is known to have the largest share in residential energy consumption and GHG emission; and European carbon neutral scenarios support an increasing use of low-carbon electricity for domestic space heating. Therefore, policy evaluation and future studies must not only evaluate pathways towards carbon neutral targets in terms of energy and GHG emissions, but also assess future power demand and that demand side management potentials could help renewable energy development.

Statistical models are efficient for short term load forecasting; yet, trend breaks, such as behaviour changes, are still hard to predict. This supports the need for explicit bottom-up models despite several scientific and technical difficulties (such as representing diversity at national scale which requires large amounts of data and long configuration and physical simulation time).

The present work consists of evaluating energy efficiency and behaviour change scenarios. Results show the former has a core impact on energy demand, while energy usage behaviour is a main driver of the power demand profile. Load curve warping is analysed under several scenarios including change in heating management pattern, retrofitting, new space heating equipment, etc.

A bottom-up model based on physics simulation is developed for load curve computation of the whole French residential building stock. It relies on a 4,000-household survey, for diversity and

consistency in household energy behaviours. They encompass both temporal and spatial space heating management actions (e.g., night setback, living and sleeping room temperature differentiation)

1-143-22: Peer-reviewed paper

Sufficiency, ethics of care and smart home technology

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Panel
1. Dynamics of consumption: less is more?

Keywords
residential buildings, energy sufficiency, smart grid, practices, ethics

This paper reviews and discusses ethics of care, smart home technology (SHT) and sufficiency, and by bringing these discussions together we point at what a future technology development within SHT should include to help promote a sustainable future. There is a growing agreement that we need to fundamentally change our way of consuming and producing energy, and that efficiency will not be able to secure a sustainable energy future. Sufficiency has been proposed as a concept that raises the issue of how much “enough” is, and how we can define limitations to consumption.

From another angle SHT is promoted by both industry and policy makers as an enabler in a sustainable society, to help control and link together production and consumption of fluctuating renewable energy. In this paper, we will discuss possibilities and limitations of SHT in relation to sufficiency by including ethics of care. We will argue that SHT has its advantages in relation to help control well-defined issues of energy consumption that can be quantified and programmed into algorithms. On the other hand, sufficiency, we will argue, cannot always be defined objectively and quantified exactly.

Concepts like consumption corridors from the sufficiency literature argue for limits of how much we can consume. However, the precise balancing of, for instance, when to turn up or down the heating is also concerned with specific situations and social relations in the everyday life. Sometimes keeping a lower temperature will be fine, whereas in other situations, e.g., when caring for older visitors or when one is sick, it can be a health or comfort issue. Therefore, these situations entail a balancing towards keeping higher temperatures, even if the system may signal a lack of renewable energy at the time. Ethics of care is a concept that is gaining interest within sustainable consumption literature. It includes caring for other people, materiality, and the environment, at the same time as it includes a situatedness, where balancing different concerns cannot be defined objectively and universally.

In this paper, we explore possible implications of ethics of care and sufficiency thinking for the SHT development.

1-202-22: Extended abstract

Analysing co-design methods applied to energy-related smart home technologies

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Vinicius Pereira, University of East Anglia, United Kingdom
Kirsten Gram-Hanssen, Aalborg University, Denmark

Panel
1. Dynamics of consumption: less is more?

Keywords
energy consumption, artificial intelligence, methodology, smart home, co-design

Smart Home Technologies (SHTs) may play an important role in the energy transition due to artificial intelligence-powered appliances that can produce, store, and interpret users' data to support changes in everyday practices such as energy-saving. Despite its disruptive character in householders` everyday life, the development of SHTs have been pushed by the smart tech industry based on a techno-economic perspective, lacking a better understanding of how distinct groups in society engage and respond to such technology (Wilson, Hargreaves & Hauxwell-Baldwin, 2015).

Based on these issues and following a growing body of literature advocating co-created smart technology, we aimed to investigate co-design methods and their use in promoting the development of socially and environmentally sustainable SHTs. Doing so, we intended to answer the following questions: (i) Which theories have been used to explain the collaborative development of SHTs? (ii) What are the prevalent characteristics of co-design among the analysed works? (iii) What are the respective strengths and weaknesses of the methods?

A literature analysis was undertaken through a systematic search in four databases – Scopus, Science Direct, Proquest, and Springer – where 128 peer-reviewed journal and conference articles were retrieved. In the first selection round, the documents were analysed by title, abstract and keywords, retrieving 26 articles for the second selection round that considered the participants' engagement level. Based on the literature on participatory methods (Sanders & Stappers, 2008; Robertson & Simonsen, 2012; Steen, 2013), six characteristics were used to measure the engagement level: (i) participants assuming an active role during the study, (ii) social practices and/or values leading the process, (iii) the deployment of design methods and tools, (iv) leading researchers assuming alternative roles, (v) decision-making power was shared among participants and researchers, and (vi) the indication of a mutual learning process. Then, the studies were divided into three categories: low, moderate, and high level of engagement.

The main results of the literature analysis – focusing on studies with a high level of engagement – have shown that co-design experiences had a substantial effect on making energy visible to householders and effect on reframing their energy-related practices, as they were treated as experts of their own experiences with SHTs and active agents in the process. With regard to methods, all selected studies deployed a set of tools and techniques from multidisciplinary fields, such as focus groups, ethnographies, interviews, prompt cards, personal diaries, web blogs, probes, prototypes, context mapping, etc. Experiences with multi-stakeholders workshops seem to be more efficient for co-created prototypes, incorporating social aspects into the technical process of the product. However, co-design is not limited to a physical object, it can also be applied to design systems and strategies to understand the technical phenomena; its success depends on establishing a collaborative relationship with social groups affected by the product/service being designed.

Further understanding of the methods mentioned above is needed to identify why some provide more engagement than others. The engagement scale can help in the analysis; hence, it is important to make it more robust, crossing it with other participatory frameworks – e.g., the Ten Essentials of Transformative Research (Fazey et al., 2018) or the Arnstein's Ladder of Citizen Participation.

1-213-22: Extended abstract

Households' decision-making on low-carbon technologies through lenses of multiple impacts

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Panel
1. Dynamics of consumption: less is more?

Keywords
multiple benefits, residential customers, photovoltaics, investment decision-making

Energy efficiency and low-carbon technologies are an essential part of the climate-neutrality transition. Apart from decreasing GHG emissions, their scale-up brings about other societal and private financial and non-financial effects – the multiple impacts. Multiple impacts can tip the scales at the decision making for small investors, though a more complex insight into how they are incorporated in the decision-making has been limited.

The paper provides empirical evidence showing how multiple impacts are perceived and included in residential decision-making. We focus on photovoltaics investment in residential buildings in Czechia. Through desk research and 14 in-depth structured interviews with the stakeholder group, we identified 19 factors for decision making, including, e.g., energy and financial savings, technical necessity, comfort or climate goals. The factors were incorporated in a survey among residential decision-makers, with final 363 respondents.

The sample results, which proved to be sufficiently statistically representative, show that while personal financial benefits are the primary motivation for acquiring PV plants, the investors consider the non-financial benefits to the same extent as financial ones. They are less concerned with the level of current investment compared to future cost savings.

The most important factors for respondents entering into their decision to purchase PV include concerns about future energy price increases, household self-sufficiency, cost savings, and environmental benefits. Thus, by acquiring a PV plant, small investors are mainly trying to protect themselves from anticipated future energy price increases. At the same time, they are trying to reduce their current electricity costs and increase their self-sufficiency in electricity supply. At the same time, they are very much aware of the environmental benefits they contribute to through the acquisition of PV plants. By contrast, the decision to purchase PV is in principle not influenced by the increasing presence of PV on the roofs of houses, the perception of PV in the neighbourhood and technical necessity (the remoteness of the dwelling or the unreliability of the electricity supply).

The results further show that the identified 19 factors can be aggregated into five main decision-making pillars, which are personal economic benefits, upfront investment, technical benefits, broader socioeconomic aspects, and perception of the surroundings. The five groups are represented to a varying degree for each investor and allow stratifying the investors into (fairly) homogenous groups with similar motivations and investment preferences. The individual factors within each group "behave" similarly, and investors include them in their decision-making as an aggregate. This aggregation can then be used in further research to identify, for example, individual 'groups' of investors according to their representation in each of the decision pillars. This categorisation will then also allow the typologisation of investors, i.e. it will identify the main groups of investor behaviour.

Additionally, respondents are also installing PV along with other energy-saving measures. They are more willing to become active customers and to take a direct, active role in influencing not only their consumption (e.g. through energy-saving measures) but also their energy production (installation of PV and other systems).
Our results may help fine-tune the current climate policies better to reflect the real investor`s behaviour and motivations.

1-215-22: Extended abstract

Gaps between stakeholders' expectations and everyday life of households in the smart grid viewed through the lens of activity and awareness

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Panel
1. Dynamics of consumption: less is more?

Keywords
household consumption, smart grid, everyday life, social practices, awareness, smart metering

The transition into the future electricity system builds upon the inclusion of more intermittent energy sources in the grid, requiring electricity consumption to adapt to production. Households are pointed out as playing an important role, carrying a potential for being flexible in that their electricity use may be adapted to the supply of the grid. This contribution focuses on how expectations on households from industry and agencies align with reality of everyday life. We explore the relation between expectations and reality through the concepts of activity and awareness, frequently mentioned by stakeholders, and what the concepts imply for households' participation. Results from three separate studies are highlighted: 1) Document analysis of stakeholder expectations on households; 2) Interviews with stakeholders; 3) Interviews with 16 households with a new smart meter.

Results from study 1 and 2 show that stakeholders envisage households to become more active and flexible in their electricity use. However, what this entails is only vaguely expressed. Stakeholders may intend activity to mean time-shifting electricity usage, and that this would be attained if households had detailed information about their electricity consumption. Still, it remains unclear whether the activity of households denotes households temporally, and manually, shifting their chores or whether technology would mediate the shift. In the latter case, technology would serve as a flexibility mediator, possibly through automation. Home equipment, e.g. heat pumps, would be controlled without households' active participation. Concurrently, grid operators signal passivity of households as a benefit – households don't need to bother as the operator promises to take care of everything. Nevertheless, results from study 1 and 2 show that although automated control of household equipment may lessen the burden of manual time-shifting

electricity usage, there is a consensus that households need to be made aware of their electricity use through feedback enabled by a smart meter and mobile apps. Stakeholders indicate an ambivalence in what to expect from households – manual shifting of activities, automation generating the shift, or awareness through feedback on electricity use? Some stakeholders hold that awareness is enough – whereas others hold that awareness only is a means towards an end of time shifting action.

Study 3 shows that some of the interviewed households are indeed active and aware but not in the way that stakeholders envisage them to be, and regardless of their technical interest or energy awareness. For example, some households were active in monitoring their electricity meter to check the accuracy of the electricity bill. They wanted feedback, albeit more nuanced than how stakeholders imagine, e.g., on appliance level and feedback explaining increase in consumption. Some engaged in time shifting by manually unplugging appliances and running the washing machine during night. Some also expressed thoughts on being active in the way that stakeholders imagine: "But [operator] cannot load nor empty my washing machine", indicating that there is more to load balancing than turning on an appliance. However, study 3 mainly highlight the heterogeneity between and within households. Households are active regarding the focus of everyday practices, in which electricity consumption is viewed as a means towards this focus rather than an end. They differ regarding their motivations, use of technology, everyday context, their knowledge, and energy use.

To conclude, our studies point to a gap between how stakeholders view the role of householders in the energy system and the reality of the daily context of householders. To bridge this gap, heterogeneity of householders needs to be addressed. This plays a central part in pursuing democratic values, allowing for citizens to participate on equal terms in a sustainable future grid.

1-218-22: Peer-reviewed paper

The price is not right! Energy demand, Time of Use tariffs, values and social practices

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Panel
1. Dynamics of consumption: less is more?

Keywords
demand response, residential customers, dynamic efficiency, demand patterns

Several governments are opting to move from flat electricity tariffs to Time of Use pricing in an effort to curb peak electricity demand. However, despite the fact that numerous trial studies looking to quantify the effectiveness of pricing schemes have been carried out, these have produced mixed results, and in most cases, the observed temporal shifts in demand in response to the introduction of time-varying pricing are marginal at best. If changes in the timing of energy demand should be of substantial magnitude, marginal behavioural shifts in electricity consumption will not be sufficient. This prompts conceptual efforts to research what constitutes an (in)effective price-driven demand management intervention, and what their implementation may mean for energy demand.

Most failures in price-driven interventions have been interpreted by energy economists in terms of setting the wrong price, which for time-varying tariffs translates into inadequate price ratios between peak and off-peak periods. This view is rooted in principles of economic rational choice theories that assume people will always respond to changes in the price of goods or services in a rational, predictable manner. However, this fails to consider the fact that price is only one of many factors at play when it comes to making decisions that will result in demand for energy.

This paper suggests that more radical reductions in demand for energy and associated carbon emissions can be achieved through approaches that aim to find a better alignment of time-varying pricing and the (value of) social practices which constitute everyday life. The paper concludes by suggesting ways to integrate concepts explaining ToU pricing effects and the timing of electricity demand with methodologies which disaggregate price elasticity, and offer alternatives to the estimation of market and non-market values of practices and time.

1-228-22: Extended abstract

System change by lifestyle change (and vice versa): a multi-stakeholder approach to (policy) intervention design for reducing the consumption of clothing

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Panel
1. Dynamics of consumption: less is more?

Keywords
consumer behaviour, textile industry, system design

The clothing and textiles industries contribute significantly to global greenhouse gas emissions, with substantial energy use going towards the production of textiles. Some studies estimate that a 30% reduction in greenhouse gases emitted by these industries can be achieved through behavior change. As a result, many (policy) interventions have been developed that aim to reduce the consumption of clothing by directly targeting the purchasing, recycling or re-use of clothing by individual consumers.

Studies conducted at a systems level of analysis (e.g. system dynamics, innovation systems or the multi-level perspective) show that the behavior of individuals is often constrained or stimulated by their environment. Yet, approaches to designing (policy) interventions rarely take such interactions into account. The question remains whether targeting individual consumer behavior is the most effective leverage point to effectuate change at a systems level. New approaches should be developed that examine systems and behavior change simultaneously. Yet, few studies analyze the clothing industry from such a perspective and even fewer use their insights to develop interventions that policy makers, NGOs or companies can use to help this industry become more sustainable.

To tackle this literature gap, we have conducted 15 interviews with stakeholders in the clothing and textiles industries (e.g. policy makers, researchers, NGOs, companies), followed by a group model building workshop. These activities will be used to (1) develop a shared understanding of the system dynamics in the clothing industry, (2) select the most relevant leverage points for intervention and (3) foster support for change in the participants.

We also mapped interventions that have been conducted or that are currently being developed by stakeholders in the clothing ecosystem. For each intervention we compared (1) what behavior they target (2) what behavioral and/or system changes they aim to achieve (3) how they aim to effectuate system change (i.e. on what subsection of the whole system constructed in WP1 they focus) (4) what mechanisms/theories they use to substantiate that these effects will actually be realized. Based on this overview, we will select one promising intervention for effectuating system change to evaluate in depth, together with its developers.

1-232-22: Peer-reviewed paper

COVID-19 lockdowns in the United Kingdom: Exploring the links between changes in time use, work practices and energy demand

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Panel
1. Dynamics of consumption: less is more?

Keywords
behaviour, time use, activity patterns, lockdown, energy, appliances, behavioural change

Restrictions on movement and the imposed social distancing and work-from-home rules due to the recent global pandemic have sparked an interest in understanding changes in the timing, duration and sequencing of daily activities. In this paper, we investigate how working from home during the various stages of COVID-19-induced lockdowns in the United Kingdom influenced the timing of in-home, energy-related activities.

We present findings from the analysis of data collected during the first and second UK lockdowns using an online diary instrument developed by the UK Centre for Time Use Research. Based on a weighted average index we show that there were noticeable changes in the start times of energy-relevant activities between the pre- and mid-lockdown periods. Both lockdowns showed a substantial variation in start times of laundering compared to the reference period. The food preparation activities start times varied more during the second lockdown depending on the time of the day. TV watching activities started later and lasted longer relative to the pre-pandemic reference period.

We conclude by discussing how we can account for the associations we have identified between changing energy-relevant activities over the different phases of the lockdown periods.

1-264-22: Peer-reviewed paper

Enhancing Human Nature: Reconnecting humans to the ecosystem

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Panel
1. Dynamics of consumption: less is more?

Keywords
eco-connectedness, transformative experiences, behavioural change, environmental awareness, environmental attitudes, communication, sustainability

We humans are biological beings – we have biological bodies – and as such we are part of the ecosystem and nature. We learned to harness nature and its resources to improve our lives and our wellbeing. By learning to harness nature, we also gradually distanced ourselves from the ecosystem.

We know by now, that we are in fact standing at a crossroads for humanity and that the UN Climate Panel has declared code red for humanity. So far, these facts have not been translated into large-scale actions. However, emotions have shown to be much more likely to spill over into engagement. Handled well, this engagement can potentially be used as a momentum to action. Furthermore, it is known that direct experience of nature has a positive influence on the wellbeing of humans, and that loss of such experiences is a growing concern for humans living in urban environments. Studies have shown that when children have frequent, direct experience with nature, coupled with adult guidance, it contributes to their development of environmental care later in life.

If what is needed to foster large-scale change is not more knowledge, but making us as a collective emotionally aware of the gravity of mankind´s current situation, a pressing research question is how to communicate eco-insights not only to the mind, but also to the heart. As a possible way forward, we suggest a new approach where we explore and challenge what it means to be human by means of bodily experiences of nature.

One inspiration is the so-called overview effect that many astronauts experience spontaneously when they first look down on planet Earth from space. Its experience allegedly results in a permanent transformation of their perspective on the planet, life on earth, and their place in the universe. Seeing the planet from above makes the abstract concrete. “The biosphere”, “The atmosphere” and “The planet” goes from being abstractions to experienced realities. To the astronauts, the planet became real and this changed their perspective on their place in the universe. This may be referred to as a transformative experience. We wish to explore the potential of such technologically enhanced transformative ecological experiences and use this as a first step to communicate eco-insights to the heart. Of course, we do not suggest sending everyone out to watch earth from space, but we would like to test different technologies for this purpose.

A starting point for our exploration is a research project we did on technological body enhancements. As part of a project on mind, body and technology, we built a mechanical artificial human tail that wags with the wearer. Wearing the tail leads to interesting experiences, as it becomes an extension of one´s body. To one of the authors, the most interesting experience related to the tail came when he took it off after having worn it for some time. He then had a very direct bodily experience of being “tailless”.

The experience of “taillessness” was the result of taking something away, in this case the tail that had previously been accepted by the body as an extension of itself. This made the wearer reflect on the role of technology in our lives - that what is experienced as one´s body can include technology. Another approach is through radical exposure to nature, making the unfamiliar familiar, and the familiar unfamiliar. One way of creating a reflection similar to “taillessness” on our bodily relation to nature could be by radically removing us from nature after exposing us to it in an enhanced way. Can this be done by creating sterile artificial environments that make us miss nature? The bodily-emotional experience of missing nature may then be used as a background for reflecting on our eco-connectedness.

As a research agenda this asks for an interdisciplinary explorative research approach, designing for bodily user experiences for reflection in close cooperation with partners from industry, academia, NGOs and the public sector.

1-282-22: Peer-reviewed paper

Gender, expertise and control in Dutch residential smart grid pilots

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Panel
1. Dynamics of consumption: less is more?

Keywords
demand-side flexibility, gender, digitalisation, smart grid, design process

Recent work has shown that technologies to enable residential demand-side flexibility are not value-neutral, that the ability to provide demand-side flexibility is not evenly distributed across societal groups, potentially deepening existing divisions and undermining societal support for the energy and climate transition. One such division relates to gender. Based on work for the IEA User TCP Task on Gender & Energy, this paper aims to contribute to recent discussions on gender and smart grid developments, through a brief literature review and an analysis of empirical materials collected in two Dutch smart grid pilots, where we conducted interviews and focus groups with residential participants.

The paper discusses the gendered differences in the build-up of interest and expertise in household smart grids, in connection to experiences of control, comfort, safety and trust.

Based on a brief literature review and empirical analysis, we show that although other factors such as age also affect the uptake of smart grid expertise, gendered roles in housekeeping stand out because it can result in a situation whereby female household members lose out in terms of control. Consequentially women become more dependent on others for the management of basic energy services in the home than they were before (the introduction of the smart grid solution) – which in cases results in their disengagement and withdrawal. With the advent of residential smart grids, more is asked from in terms of energy literacy, due to an increasing number and diversity in installations for energy generation and storage in and around the home. On top of that, a digital layer consisting of both hardware devices and software to monitor and manage the flows of information and energy within the home and the community is making demands in terms of their digital literacy. Combined, these two developments present a formidable challenge to most household end-users, yet more to women than to men.

While this paper is exploratory, we argue that the challenge arises out of the combined impact of limited energy and digital literacy. For subsequent empirical work, we suggest a further unpacking of the notions of literacy and expertise in relation to gender, in a co-creative approach with both residents and smart grid technology developers. And for policy, as the digitalisation of our energy systems advances, energy transition policies should anticipate unevenly distributed impacts of this digitalisation and attend to how the ability to participate intersects with gender, age and other

socio-economic factors.

1-310-22: Peer-reviewed paper

The expected role of individuals in the transition to net zero: policies and pathways facilitating an active role

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Panel
1. Dynamics of consumption: less is more?

Keywords
individual action, energy policy, scenarios, citizens

Responding to the climate emergency is widely recognised as a priority at all levels of government – from cities up to the EU. However, what this means for individuals is under debate: are individuals expected to be active citizens co-creating the transition, disengaged recipients of net zero policies, or something in between?

This exploratory paper first summarises the debate about whether individual change is a distraction from demanding system change. It concludes that individual change is inextricably linked with system change. Individuals can have roles in the energy system and transition beyond that of the economically-rational consumer. Indeed, characterisation of current energy efficiency policy shows that a variety of conceptualisations of individuals are already present in European and national policy.

Moving beyond efficiency, new ways of engaging individuals - personal carbon allowances, carbon footprints and energy sufficiency - are considered. The most radical is energy sufficiency which encompasses a very broad understanding of individuals, their needs and wants, and their relationship to the natural environment. Looking at various net zero scenarios shows increased individual engagement will be required to reduce / remove reliance on highly uncertain carbon dioxide removal technologies.

This paper builds a picture of how the individual is seen in energy transition research and practice. There are differing expectations according to context, and who is doing the expecting. The paper argues that there are reasons in principle and practice to prefer engaged citizens, and points to policies and pathways which facilitate this active role. Policies which combine multiple levers of change - economic, social and psychological - and/or which move beyond efficiency to sufficiency, will be important in the energy transition.

1-336-22: Extended abstract

Energy efficiency-ing - How energy efficiency is produced in Norwegian industry, research, and policy

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Panel
1. Dynamics of consumption: less is more?

Keywords
industrial energy saving, conservation, energy efficiency policy, research

This paper is a sociological exploration of how energy efficiency is produced in the industry, research, and policy domain in Norway, as seen through the lens of a large industry-research center and public media discourse. More than a technical definition of the relationship between energy input and useful output, energy efficiency is here investigated as the 'work to make energy efficiency (improvements) happen'. The paper draws on an ethnography within a technical research center on industrial energy efficiency in Norway in the period 2017-2021.

The paper shows how rather than enabled through technological innovations, energy efficiency is produced through 1) practices of researching, developing, and implementing technologies with lower energy consumption than its peers; 2) articulating and inscribing these improvements into scientific objects; and 3) the rhetoric and politics connecting these objects to sustainability, as well as other outcomes. This thesis conceptualizes this work to make energy efficiency (improvements) happen as energy efficiency-ing.

Applying this vocabulary, we discuss the forms energy efficiency-ing take in neo-liberal societies, where marketization (of everything) and governmentality through quantifications are dominant discourses. We discuss how energy efficiency-ing is instrumental in its essence, how this instrumentality is articulated through foregrounding differences between 'the efficient' and 'the inefficient', how energy efficiency associates with both conservation and growth, and how it produces legitimacy for technologies, industries, and practices. Following this, we discuss how alternative framings can move us towards a new understanding of the role of energy efficiency in sustainability transitions.

1-339-22: Extended abstract

What is shaping the needs around housing in today's society? A closer look at the drivers of the existing trends

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Panel
1. Dynamics of consumption: less is more?

Keywords
energy demand, behavioural change, wellbeing, building sector, urban planning

The building sector contributes to a high share of the final energy consumption and accordingly, high saving potentials lie in this sector. In the last decades, there has been a significant rise in the average floor area, which directly affects the energy demand. Nevertheless, this increased living space does not necessarily lead to a higher level of happiness and wellbeing of residents. Recent studies focus on the vital role of limiting and reducing the average floor area in decreasing the energy needs and consider this as the ultimate solution to reach the climate goals in the building sector.
It is argued that behavioural changes and practicing a new lifestyle are key for less consumption. However, our lifestyle is largely shaped by the possible ways our service needs could be fulfilled. On one hand, the services and possibilities offered by the neighbourhoods have an impact on the required living space in the buildings. Therefore, innovative urban planning approaches could be an instrument to address the needs of people and influence their behaviour. On the other hand, the shape of cities and communities is highly influenced by the policies in force. Hence designing policy measures that consider the needs and wellbeing of the society is a key towards reaching climate goals.

Making new policies, implementing innovative urban actions, and offering alternative climate-friendly ways for the fulfilment of the needs, could be seen as potential approaches for reducing the service need in the building sector. However, a comprehensive insight into the current living and lifestyle patterns is a prerequisite for these approaches. Thus, the study presented in this paper aims to provide groundwork by exploring the elements that shape the needs around housing and looking at the drivers behind the existing trends.

To this aim, both qualitative and quantitative data sources will be consulted. First, the behaviour of individuals and the motivation for their decision-making in the field of housing, e.g. living location or use of the spaces, will be investigated through reviewing the existing literature. Next, the quantitative data from databases and surveys will be analysed. By evaluating this micro-level data, and through a cluster analysis, different categories of consumers, in terms of needs and current lifestyles as well as living conditions will be identified.

The systematic differentiation of the types of consumers will allow for the exploration of the concrete pathways towards more sustainable lifestyles, through innovative urban planning approaches or tailored policies that trigger the behavioural changes. The results of the paper will thus contribute to the development of sustainability actions and will be a strong basis for the decision-making in which the differentiated needs of the residents are more reflected.

1-340-22: Extended abstract

Social and behavioural challenges in smart communities: a multidisciplinary approach

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Panel
1. Dynamics of consumption: less is more?

Keywords
smart cities, energy communities, energy management, multidisciplinary planning

The transition towards a carbon-neutral energy system is incentivising European citizens to be increasingly engaged in energy management at a community level. Leveraged by the capabilities of ICT, these smart communities can perform activities such as energy generation based on decentralised renewable sources, load management, storage, and trading also contributing to improve the grid efficiency, with economic, environmental, technical and social benefits, such as the capability to promote end-users' energy awareness and to mitigate energy poverty. Recent reviews have shown that these communities are deeply shaped by local tradition and context, but also by the regulatory framework, being mostly focused – namely, in Europe - on renewable generation, self-consumption, and surplus generation trading. The development of smart communities is also influenced by financial aspects (financing schemes, market structure), end-users' enrolment (willingness to participate, awareness and energy literacy), and ICT deployment. This work aims to discuss key social and behavioural dimensions to the success of smart communities that have emerged when modelling energy communities using artificial intelligence tools, as a contribution to multidisciplinary research in this field and to inform a better design of real-world interventions. Preliminary results suggest that community's configuration is not only influenced by self-sufficiency, but also by the participants' profiles concerning costs and revenues sharing, pricing and remuneration schemes, goals and comfort preferences, energy demand patterns, fairness and equity issues, grid requirements, and regulatory framework, thus highlighting the need for collaborative multidisciplinary work to support the design of smart communities.

2-011-22: Extended abstract

Looking beyond the hype: conditions affecting the promise of behaviour change apps as social innovations for low-carbon transitions

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
behavioural change, app, cost benefit, broader social context

Digital tools, specifically smartphone apps, have emerged as enablers of social innovation for the transition to low-carbon societies by using novel data to creatively engage people to act more sustainably, and thus capture the power of collective individual action. Such apps have increasingly been adopted and in real-world experiments have shown their positive impact in the short-term. Despite many studies assessing their behaviour change effectiveness, to our knowledge behaviour change apps have not been looked at through a transformative social innovation lens. A systematic cost-benefit analysis as a policy measure and the contextual conditions that affect their social innovation, namely their capability to support a collective change in carbon emitting practices, have rarely been analysed. Indeed, the rapid uptake of apps may be a hype that does not fulfil expectations, and if not addressed can lead to premature rejection of the technology.

Thus critical reflection is required to look beyond this hype to understand the conditions for longer term impact. We performed a cost-benefit analysis to assess the break-even point in number of users of two behaviour change apps to achieve net-positive impact and discuss relevant technical, organisational, political and financial conditions that enable or impede this impact. These contextual details are often lacking in reporting on intervention effectiveness, even when the experiment is well documented and strict scientific assessment procedures are followed. However, these details are critical to development and scale-up of behaviour change apps, and thus cannot be backgrounded when discussing impact and ultimately deciding whether to invest resources in them, compared to other possible policy interventions. Particularly, the comparison between the costs associated with the apps' development and maintenance and the climate benefits they deliver, is a relevant support for policymaking: if the benefits delivered by these apps are lower than the costs associated with their development and maintenance over time, relying on them as tools to support the energy and climate transition would at least be questionable.

The break-even number of users resulting from the cost-benefit analysis necessitates very significant scale up efforts: approx. 140 – 1,900 times the numbers of participants in the two cases analysed. Such scale up efforts come at a cost, which we did not include in our analysis. Achieving such user numbers appears feasible, as several similar apps were able to achieve considerable app downloads. For instance, GoodGuide, an app providing environmental and ethical information on household products, had over 400,000 downloads one year after the company's formation. And the H2020 project ENCHANT is working on behaviour change interventions, potentially involving smartphone apps, targeting up to 10 million households in six countries.

Our assessment highlights several dilemmas and opportunities for capturing the real transition potential of social innovation. We have revealed several weaknesses in the technical, organisational, political, and financial contexts which limit wide scale-up of the use of the apps, as well as in the scope and conception of the apps to develop long-term financially viable business models, beyond the typical short-lived experiments. We find that the required scale-up in users seems challenging, yet feasible. However, guaranteeing that the supportive conditions are available is vital for the relevance of behaviour change apps as policy interventions.

Understanding which specific conditions can enable or impede the large-scale transformative potential of an app can support the decision about the development of tools, as well as help to innovate for the "long game" of behaviour change, in order to identify viable business models and obtain the suitable (government or other) support that ensures higher chances for the needed long-term scale-up.

2-043-22: Peer-reviewed paper

New times, new policies? Policies to change energy use in the context of zero carbon

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
efficiency, electrification, net zero, demand reduction

Policies to improve energy efficiency have been discussed and implemented since the oil crises of the 1970s. Over this period, a wide range of disciplinary approaches has been used to design and analyse effective policies, with a developing consensus that a policy mix is the most effective approach.

However, the required shift to zero carbon energy systems within a few decades is disruptive. The rates of change in technology and practices implied by global carbon targets are inconsistent with analyses assuming incremental change. Combustion of fossil fuel needs to be largely eliminated, rather than improved. New challenges such as temporal flexibility in electricity use are emerging. Future energy systems seem very likely to be more decentralised, electrified and service-oriented, and therefore involve new actors. With new sets of fuels, technologies and potential actors, it is imprudent to assume that existing policy approaches will be adequate.

The paper starts from an existing assessment of a low-energy, net-zero energy system in the UK (Barrett et al, 2021). It identifies the key implied changes to energy-using technologies and practices. It investigates policy options to promote each type of change and discusses whether these are adequate for the rates of change now needed. Where it appears unlikely that rates of change can be delivered within existing policy frameworks, the paper identifies what new options might be considered.

The paper concludes that changes to the technology, fuels and associated practices required to

increase end use conversion efficiencies will be critical and are largely achievable by adapting policy approaches and instruments that have been used successfully. However, changing the structure of demand for energy services is also needed if demand reduction is to play a bigger role. This will need to draw on a wider set of policy approaches, including policy options not normally considered as part of energy policy.

2-049-22: Extended abstract

Beyond energy efficiency: do consumers care about life-cycle properties of household appliances?

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
household appliances, ecodesign, Sustainable Product Initiative, discrete choice experiment

In the EU, past environmental regulation for household appliances has focused on energy use during usage, such as minimum energy performance standards or energy labels. To achieve EU commitments to become climate-neutral by 2050, recent policy efforts such as the new Battery Regulation and the revised Ecodesign Directive (Sustainable Product Initiative) are broadening the scope of requirements beyond the usage phase and cover lifecycle emissions. In parallel, many companies pledge to decarbonize their value chain by 2050. Previous literature includes engineer-ing-based studies analyzing energy use or emissions at different lifecycle phases of appliances. Socio-economic studies have investigated consumer valuation of energy use during the usage phase. Yet, little is known about consumer preferences for energy use during the production phase of appliances and for other lifecycle characteristics.

In this paper, we elicit individual preferences for lifecycle properties of large household applianc-es, in particular for production-related energy use. We also explore heterogeneity in preferences for various lifecycle properties of appliances. To this end, we employ a representative household survey among the adult population in Germany to study individual preferences for energy-related attributes of household refrigerating appliances. First, we analyze data from a discrete choice experiment on refrigerator purchase; we find that on average, participants value the highest en-ergy class, dislike much higher energy use for production and distribution, and prefer refrigerators with larger volume, longer warranty periods, and higher customer rating. Second, we elicit partici-pants' preferences for information about the energy use that is related to the manufacturing of large household appliances: About 20 percent of participants strongly agree that there should be a label for household appliances indicating the energy use necessary to manufacture them. Third, we investigate to which extent participants consider different lifecycle-related criteria when pur-chasing such appliances. Therefore, we asked participants to indicate how much they typically consider these criteria when making purchase decisions using a

five-point rating scale ranging from ‘no consideration’ to ‘a lot of consideration’. We find that more than half the participants pay a lot of consideration to durability, but only around 15% pay a lot of consideration to envi-ronmentally-friendly materials, recyclability, and energy use necessary to manufacture the appli-ance. To explore the relation of participant preferences for these lifecycle criteria, we estimate multivariate statistical models which include socio-demographic information, environmental and time preferences, and an energy literacy score as covariates. The findings provide evidence that women, older participants (for durability only), less educated participants, participants living in an urban area, participants with higher environmental identity, more patient participants and partici-pants with a higher energy literacy score (for durability only) value lifecycle criteria higher. In comparison, we find no evidence that income or being an owner of the building rather than a tenant explain the preferences for lifecycle criteria.

Our findings also have implications for policy-making. A label on lifecycle properties should not only include information on usage and production-related energy use but also on other lifecycle properties. For production-related energy use it might be sufficient to use only a few categories to distinguish the products. Information about lifecycle properties of appliances should target wom-en, older people, people with below average education, and urban households. Finally, improving energy literacy would lead to a higher share of the adult population to strongly consider durability when purchasing an appliance.

2-068-22: Peer-reviewed paper

From Energy efficiency obligation to carbon savings certificate to achieve carbon neutrality: does it fit the path?

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
energy efficiency obligation, decarbonisation, energy efficiency policy

One way to contribute to carbon neutrality in 2050 is to reduce energy consumption but this will not be enough. To this end, many energy policy instruments (regulations, taxes, incentives, etc.) have been used for many years and well before the goal of carbon neutrality and need to be reassessed to be in line with decarbonisation especially in the context of the EED review.

In many European countries, energy efficiency obligation schemes (EEOs) are used in line with EED article 7. These schemes are usually expressed in terms of primary energy savings as in Italy or final energy savings as in France and to our knowledge only one which has been expressed in terms of carbon as in the UK. Initially the UK EEO was expressed in energy and moved from energy to carbon. However, this movement has not been followed in Europe, even though European policy is increasingly focused on reducing carbon emissions.

There are several ways of integrating carbon into an EEO scheme: from the simplest by considering the carbon content of energy when sharing the level of obligation among obligated parties to the most complex by valuing the certificates directly in carbon units.

By considering both energy and carbon in the same EEO scheme, a double reward is possible to reduce consumption and promote low carbon energy. In this way, new energy savings and carbon reduction potentials could be incentivised, especially in industry and transport in case of fuel switching.

Including carbon in the scheme also means putting a price on carbon in the market, beyond a shadow value for sectors not covered by the historical EU-ETS I without the need to extend the

EU-ETS to the building and transport sectors (EU-ETS II).

This paper aims to challenge this situation and to propose a shift from energy to carbon in an EEO scheme. To do so, we propose to take the case of the French EEO as an example and to assess how this existing scheme can evolve to better integrate the carbon dimension and contribute effectively to the national carbon mitigation strategy.

2-080-22: Peer-reviewed paper

Accelerating the Dutch heat transition by understanding and responding to drivers and barriers of homeowners: practical tools for citizen engagement

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Maaike Roelofs, TNO
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
citizens, homes, empowerment, participation, deep renovations, social, behavioural change

In the Netherlands, 92 % of houses are heated by natural gas. "The Netherlands has the ambition to phase out natural gas consumption in 2050". The biggest challenge is to renovate existing dwellings as these often lack sufficient insulation and use gas-fired boilers. New homes in the Netherlands have a better insulation grade and are since 2017 required to have a natural gas free alternative. Engaging homeowners is specifically important, because they are the sole decisionmakers on what happens (or does not happen) in and around their home. There is currently no law allowing municipalities or other parties to overturn a homeowner's decision. It is therefore very important to understand what drives homeowners towards a sustainable home and what barriers hey face in this process.

In this paper we summarize insights gained from a three-year Dutch research program on how to accelerate the heat transition by involving homeowners and understanding their wants and needs. This program is based on a large body of empirical research, e.g. in-depth interviews with homeowners and civil servants who design and implement the heat transition plans, workshops with municipalities, intermediaries and representatives of the national program on gas free neighbourhoods. As a framework to help municipalities understand and respond to the variety of homeowners' drivers and barriers, we have developed a customer journey towards living in a natural gas free home. We present in this paper the contributions of three specific studies of this empirical research program. First, we discuss drivers and barriers for homeowners in the phase out of natural gas from their homes. In a second study, we clustered the identified drivers and barriers to define main themes, which appear to be essential for home-owner participation during

all the steps of the customer journey. Finally, in our most recent study, we provide practical guidelines for setting up and performing effective citizen engagement. In this most recent study, we identified a strong need for practical support especially among smaller municipalities who often lack sufficient time, knowledge and financing for the (further) development of tailored citizen engagement strategies. To address this need we developed a website as an online tool with practical tips, tools and examples, to be used by these municipalities.

2-095-22: Peer-reviewed paper

Small and medium-sized enterprises: Hard to reach, data poor but rich in creative potential as agents of change for decarbonisation

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
carbon emissions, carbon management, small and medium-sized enterprises, decarbonisation, Hard to reach

Small and medium-sized enterprises (SMEs) are the heart of the UK and EU economies and increasing attention is being paid to their environmental impact. In the UK and EU, the majority of organisations are SMEs (over 95 %) employing the a high percentage of people and accounting for around half (43–53 %) of greenhouse gas emissions by businesses. The SME sector is rich in diversity and challenges, often 'hard to reach' - both in terms of engagement and policy/practical interventions; and 'data poor' in terms of energy and environmental data available to analyse. 'SME' is a large catch-all term for various business organisations from corner shops, industrial units, factories, theatres and galleries. Even though SMEs face challenges due to their diversity, nature of their business operations and legal requirements, they are often characterised by a shared resource limitation compared to multi-national companies which, due to their size and scale, are often the focus of issues around social and environmental responsibility. As such SMEs are an under-researched sector in carbon management with questions remaining surrounding their environmental management and carbon performance, why they implement changes and the barriers to organisational change for decarbonisation.

This research investigates how environmental and carbon performance is managed by SMEs, their motivations, and barriers to implementing carbon management. The paper presents preliminary research findings developed in the context of an European Regional Development Fund (ERDF) Sustainability in Enterprise (SiE) project at Nottingham Trent University, UK, which aims to

support SMEs in Nottingham to reduce carbon emissions by enhancing energy efficiency and reducing resource consumption. This research initially adopted a quantitative approach and a questionnaire survey was used to gather data from SMEs' managers. Findings show SMEs are in the early stages of their carbon management journey. Most SMEs do not measure and monitor carbon emissions for decarbonisation, even though many state having sustainability and environmental policies. SMEs show some evidence of implementing environmental and carbon management actions with targets, but these are sporadic and disconnected from their main organisational goals. Some of the barriers identified are the lack of knowledge & expertise and time & resources. Still, SMEs highlight that reputation, market position, and moral obligation can play a key role in starting their journey to take environmental action. This study contributes to mounting evidence that SMEs face challenges around in-house capacity, resources, access to support and data quality for carbon emissions measurement and management. As a result, the study offers recommendations including a policy recommendation based on Learning Energy Efficiency Network (LEEN) model.

2-104-22: Extended abstract

Smart grid development: Electricity transition through intermediaries?

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
smart grid, intermediaries, renewable energy, electricity

Our electricity systems in Sweden and globally face major changes and one way forward is to have a “smart” grid. Today’s grid is however not smart and was not planned and constructed to be able to meet increased use of intermittent energy sources, higher demand for electricity, a need to reduce the carbon footprint or electrification of transport and industry. With these changes, the electricity grid is facing major challenges, which also constitutes huge opportunities.
Smart grids are seen as a collective term for the new technologies following a vision in which the grid delivers low-carbon electricity more efficiently and reliably while enabling consumers to manage and reduce their energy use and minimize costs to the benefit of all. The smart grid is often seen as the ultimate solution for all the issues of our current electricity grid.
There is previous research that has focused on different visions and imaginaries, pathways or narratives for the future of the electricity grid. What these studies have in common is that they show how powerful visions or narratives are for political ends and to legitimize technological choices.

There are different international activities, as well as national activities in Sweden, like strategic investments at the political level, public research funding or development activities in business. In the design of the smart grid roadmaps, scenarios and other plans are developed. Key actors in these processes are for instance governmental actors at different levels like the Swedish Energy Agency or the Swedish Energy Markets Inspectorate. The often commission different consultancy firms for initiatives or programmes. Thus, there is a rise of consultants’ experts who analyse information to produce and distribute knowledge of the future of the electricity system and smart grids.

These consultancy firms are important knowledge brokers and intermediaries in the development of the smart grid, often providing scenarios and models for policymakers to consider when making decisions. Through their work (e.g. reports on scenarios and roadmaps) the consultants are important influencers for which problems are raised, how they are defined, and what solutions are suggested. Thus, consultants are central players in the future development of the smart grid. The paper aims to improve the knowledge of the role of consultants in designing and influencing the development of smart grids.

We have conducted an actor mapping to identify different smart grid initiatives, programs, and funding in Sweden. As method we conducted a content analysis on the reports of a selection of key consultancy reports for governmental initiatives and programs on the smart grid. We analyzed how the smart grid is materialized in these consultancy reports. Results show that there is no common definition on what the smart grid is and still many uncertainties with regards how the future smart grid will look. Smart grids visions are often technology focused and presented in a positive way. Smart grids are seen as a solution for major problems the electricity grid is facing, not as much highlighting potential problems as for instance handling of data privacy issues, broader sustainability issues like social sustainability (access to smart grid technology) energy justice, democracy or a focus on circularity and resource use. These key actors' roles in developing important societal infrastructure such as the smart grid are important to examine and critically reflect upon to increase transparency, secure a democratic development and make it possible to question assumptions and ideas embedded in the development of the smart grid.

2-155-22: Peer-reviewed paper

Drivers and effects of digitalisation on energy demand in low carbon scenarios

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Tim Foxon, University of Sussex, United Kingdom
Noam Bergman, University of Sussex, United Kingdom

Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
digital, low carbon targets, long-term scenarios, energy demand

The world is currently facing two socio-technical transitions: shifting to a low-carbon society, and a digital revolution. The spread and adoption of ICT does not automatically lead to reduction in energy demand, if this stimulates new energy-using practices or wider economic growth. Despite this policy challenge, the two transitions are often considered separately.

This study examines potential drivers of reductions or increases in energy demand due to digitalisation, as identified in recent leading global and UK net zero transitions scenarios. These include direct effects; indirect and rebound effects relating to home energy use and transport; and effects on economic growth. Specific effects of digitalisation on energy demand are then identified, which reflect projections in the scenarios. These imply that the future pathways adopted for digitalisation will have a significant impact on future energy demand and hence on the feasibility and acceptability of achieving net zero goals. Our main method is coding by searching for quantitative and qualitative statements in the scenarios relevant to digitalisation and energy.

Our initial findings point to a variety of drivers and assumptions that affect energy demand via digitalisation. These include user engagement with technology, consumer awareness and new user roles as prosumers; technological evolution including efficiency and longevity of devices, and changes to number of devices, usage and data; patterns of energy demand; business models and more. In upcoming research, we will engage with stakeholders from business and industry, academia, government and the third sector to consider the plausibility of different drivers of digitalisation, in order to better inform policy. This suggests opportunities for further research and improving policy interactions between these two transitions, and stimulating greater public debate on the different framings for an ICT-driven low carbon transition.

2-180-22: Peer-reviewed paper

What role for energy efficiency auctions in the energy transition?

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Dario Di Santo, FIRE, Italy
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
cost-effective measures, transition, Energy Efficiency Directive (EED), tender, auction, Energy Efficiency First

More and more European countries are turning to energy efficiency auctions as a way of delivering cost-effective energy savings. Germany, Portugal and Switzerland already have auctions or tender programmes in place. In 2021 Denmark launched its first energy efficiency auction, while Greece, Italy, Turkey and the United Kingdom are among the countries considering this mechanism.

This paper draws upon research undertaken for the Horizon 2020 ENSMOV project on the role of energy efficiency auctions in meeting EU Member States' energy savings obligations under Article 7/8 of the Energy Efficiency Directive, assessing the design features that affect eanergy savings, cost-effectiveness and strategic fit within energy efficiency policy frameworks. The paper considers the relative merits of energy efficiency auctions and energy efficiency obligation schemes in the broader context of the energy transition. On the one hand, meeting more ambitious climate change targets requires policy measures that can deliver significant quantities of energy savings. On the other, as energy efficiency measures become more expensive and complex year-on-year and Member States aim to implement the Energy Efficiency First principle, understanding the cost-effectiveness of energy efficiency actions will become increasingly important.

2-183-22: Extended abstract

HeatForAll: a framework for a just transition in household heating services

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Lirong Liu, University of Surrey, United Kingdom
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
heating, fuel poverty, modelling, energy policy

Decarbonisation of building heating is a significant challenge for the UK's 2050 Net-Zero targets: less than 5% of UK households use renewable heating sources, and much of the building stock is relatively old and inefficient. Efficiency retrofits, fuel switches and heating system replacements can be expensive and as many as 13% of households in the UK were already classed as fuel poor in 2019: the 2021/22 energy crisis deepens this problem. The paper comes from a project funded by the UK Government-supported "Network for Heating and Cooling Research to Enable a Net-Zero Carbon Future".

The project is developing a framework to explore combinations of end-use efficiency improvements, low-carbon heat supply investments and policy measures that meet decarbonisation targets whilst minimising fuel poverty, as part of a Just Transition and "HeatForAll".

The project has three modelling layers: bottom-up engineering models of the building stock and occupant demographics; techno-economic optimisation of fabric efficiency and heating system choices; economic models of household expenditure and macro-economic impacts on the wider economy. These are combined with scenario analysis of technology options and policy choices into a single framework, for decision support on local strategies and to inform wider policy development.

The presentation outlines the framework and presents a case study application to 2000 Council-owned properties in the borough of Woking in the county of Surrey in the SE of the UK. Surrey has a target for 61% GHG emissions reduction by 2035. The framework is applied to explore the outcomes of meeting this target for the properties studied, with the current UK policy regime (Business as Usual), or with addition of a new policy measure ("Proposed" scenario). The

energy prices used in the modelling reflect pre-crisis tariffs and forecasts.

Under BAU, existing government incentives leave significant financial burdens on households. Most notably, installation of hot water storage tanks vital to air-source heat pumps are not funded, and financial support for heatpumps is limited to the most inefficient properties, excluding many already in fuel poverty (ie EPC Band D). The Proposed scenario introduces an additional grant, funding insulation measures, ASHPs and electric boilers and applicable to all fuel-poor dwellings.

Preliminary results show that economically optimal choices under BAU lead to emissions reduction of 37% from baseline. Only the least efficient (EPC band E) dwellings install a heat pump. For other dwellings, funding is allocated towards retrofitting insulation measures; relatively high electricity prices lead to gas boilers being the optimal heating system choice. In the Proposed scenario, all fuel poor households install heat pumps and additional window double glazing. This results in an emissions decrease of 67%, achieving Surrey's 61% target. Additional iterations test the effect of forcing the model to achieve Woking Borough Council's own target of Net Zero by 2030.

By targeting limitations of existing policy, the additional grant under the Proposed scenario is successful at promoting decarbonised heating under fuel poverty. However, significant government investment is required. To explore this, macroeconomic effects are simulated in the third layer of the framework. The investments required are treated as external shocks to the current equilibrium in the socio-economic system. Using input-output simulation, changes in GDP, industrial output, government income, indirect GHG emissions of other sectors, and total GHG emissions are assessed. Comparison of the results of different scenarios will provide important information for both local strategy development and for national policy design, supporting development of practical technological and policy solutions to tackle fuel poverty through the transition

2-184-22: Extended abstract

Pay-for-Performance programmes in the EU: Outlining the plan for public authorities

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
Pay-for-Performance, local authorities, energy efficiency financing, advanced metering, business models

The present work identifies and structures the necessary elements and actions to set up Pay-for-Performance programmes in Europe. The motivation is to enable the large scale reduction of building carbon emissions in line with local, national and European policy mandates. Energy renovation activities are currently mostly driven by subsidies or public grants, especially to attract the private residential sector, which is reluctant or does not have the upfront economic capacity. Yet grants might be very restrictive not enough to achieve the expected impact. Examples from the US and research from the H2020 SENSEI project point to promising avenues to achieve energy efficiency goals through business models and programmes based on Pay-for-Performance (P4P).

We study the case of Catalonia as a possible jurisdiction to implement the P4P approach. The study is divided in two large blocks. The first block examines the current starting point and boundary conditions regarding the building stock, energy markets, public policies and regulation. It includes the relevant drivers and enablers, but also the barriers and limitations of a P4P approach that need to be overcome and the changes that must implemented. The second block defines the key aspects of a P4P programme: the architecture of the programme, the definition of M&V baselines, the role of public administration, the relationship with the private sector, and the inclusion of third parties and stakeholders. Emphasis is placed on the role of public administration who defines the legal framework and funding flows based on P4P incentives to attract the necessary groups of projects and obtain the maximum possible performance. With this background, the complementary roles of a P4P programme within the Catalan context are analysed, emphasizing the role of the Aggregator as a meeting point between the administration and investors, end-users and the system operator.

2-194-22: Extended abstract

Factor three emission reduction targets – telling the challenge for Energy Efficiency Programmes

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
intermediaries, saving targets, energy efficiency programmes, evaluation, impact

Emission reduction targets were put forward in the countdown to COP26 as policy makers tried to reaffirm their commitment to prevent climate and ecological collapse. Energy efficiency (EE) is seen as a key strategy to achieve these targets, thus EE programmes (EEP) face mounting expectations.

We conduct a participatory research on a regional EEP to understand how such programmes can address the challenge. In our case, the new political ambition translated into increases by a factor 3 to 100 (depending on the measures) in terms of number of EE measures to be implemented annually, with no additional human resources provided. The intuition was that, as the programme director put it, the EEP had to "rise from lead violinist to conductor" of the regional EE ecosystem.

Indeed, just as a "lead violinist" fuels the orchestra with its energy and experience, EEP typically facilitate the deployment of EE measures with subsidies and, sometimes, technical advice. In practice, EEPs are structured around one or several subsidy schemes and programme staff perform essentially operational tasks (processing applications, estimating and measuring savings, monitoring project implementation…) in order to run them. However, over the course of the workshops, it became clear that this approach will not be sufficient to reach the policy targets. On one hand, it is far from certain that enough potential beneficiaries will be involved with a sufficient degree of ambition in order to trigger the deployment of the required EE measures. On the other hand, the programme would not have the operational capacity to handle the volume of entering applications, should the deployments pick up pace as to reach the targets.

The proposed solution was to rise to a "conductor" role. Drawing on the "transition intermediary roles" introduced by [Kivimaa, 2014], we can understand this as leaving operational roles (e.g., technical support, administration, training…) to contractors or partners while endorsing more orchestral roles (networking, articulation of visions…). It then emerged from further discussions that the EEP had already been fulfilling part of these while developing and launching subsidy or support schemes. We conceptualized the typical path from the development of such schemes, in close contact with a few beneficiaries and installers, to their scaling up and uptake by other intermediaries (energy efficiency specialists, umbrella organizations…).

This scale-up seemed to hit two barriers when it came to the last stage (uptake by partners). First, the EEP's credibility relies on an annual reporting of certified savings, the quality of which could not anymore be guaranteed if the EEP was no more directly tracing individual measures. Second, it turned out to be unclear what other functions the EEP could legitimately endorse, while the staff initially hired to run rather technical subsidy schemes did not have the know-how for networking and communication-related activities. As an example, the EEP does not have any profile on social media.

We suggest that these barriers arise from the fact that EE has become a goal rather than a means, fostering a strongly accountancy-driven approach based on energy or CO2 saving indicators. This also led to neglecting rebound as well as snowballing effects. Instead, the workshops provided the material for the creation of a programme design canvas linking the programme missions and corresponding tasks to encourage reflecting on and valuing the direct and indirect impacts of all the activities of the programme. This impact-aware approach to EEP design is meant to leverage EE as an entry point to achieve a deeper change towards the stated goal of a carbon-neutral society. Just as a conductor is not performing for his orchestra, so should EEPs be aware of their impact on the public.

2-205-22: Extended abstract

Energy efficiency first? The roles of energy efficiency for the decarbonisation of buildings

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
energy policy, district heating, heat pump, decarbonisation, energy efficiency policy, heating, heating temperature

Decarbonisation policies for the buildings sector set a strong emphasis on energy efficiency improvements with its corollaries: high energy standards for new buildings, subsidies for deep renovations and targets for high rates of renovation. Along this line of thoughts, supported by strands of literature on the benefits of efficiency, the EU has adopted the "Energy first principle" as a guiding criterion for its buildings policies. Nevertheless, this strategy has shown mixed results in the last years, or at least has not delivered the expected contribution to the decarbonisation of the sector. While the performance of European new buildings has improved significantly across the last decades, the downward trend of heat demand has stopped since the mid 2010's and only 0.2% of the building stock is being renovated each year to the most ambitious standards. There are growing concerns regarding the capability of the sector to reach high energy efficiency levels in line with political objectives.

More fundamentally, the focus on energy demand reductions bears a strong issue when it comes to decarbonisation. While energy savings are important, reaching a carbon neutral building stock relies primarily on the reduction in the carbon content of energy through the recourse to carbon-free heat sources. The strong focus on energy efficiency hence unnecessarily narrows the scope of approaches available for the decarbonisation of buildings and potentially leads to higher decarbonisation costs.

In this paper, we want to shift the prioritisation of buildings decarbonisation from energy efficiency towards emission reductions via the penetration of carbon-free energy sources. We argue that first considering the needs and prerequisites for the penetration of low-carbon heat sources would be a more effective approach to reaching a carbon-neutral building stock. Starting from this premise, we reconsider the role of energy efficiency as an enabler for the diffusion of carbon-free energy and investigate the role(s) it could play to facilitate this diffusion.

We distinguish between two roles for energy efficiency. On the one hand, it influences the heating temperature requirements in buildings. In turn, low heating temperatures are a condition for a high penetration of clean heating technologies such as heat pumps or decarbonised district heating systems. On the other hand, the electrification of heating, implied by its decarbonisation, will set a great pressure on the power system because of the strong seasonality of the demand in the European context. The energy supply might not be able to cope with a strong peak demand in winter at reasonable costs, while at the same time facing its own decarbonisation challenge. Reductions of winter peak demand would alleviate the challenge to the power sector and therefore its decarbonisation costs.

We find that while some level of efficiency is necessary to reach low heating temperatures, there exist other measures, potentially cheaper, that could cool down the temperatures, and that high levels of efficiency are probably superfluous as far as lowering heating temperatures is concerned. Regarding the second role of efficiency, energy demand reductions clearly have a strong potential to alleviate the challenges posed by the electrification of heat to the power sector. In fact, the main rationale for energy demand reductions may actually be to reduce the peak demand. However, other options could secure power supply with renewable energy, though potentially at higher costs.

2-216-22: Peer-reviewed paper

Finding an optimal district heating market share in 2050 for EU-27: Comparison of modelling approaches

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Şirin Alibaş, Fraunhofer ISI, Germany
Tobias Fleiter, Fraunhofer ISI, Germany
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
district heating, energy model, heating, GIS, spatial analysis

District heating is an important pillar for decarbonizing the heating of buildings, and is most cost-effective in areas with high heat demands. The lower the heating demand in a certain area, the higher the specific distribution costs of district heating. Furthermore, heat generation for district heating needs to be transformed. All of this affects the costs for the generation and distribution of heat to buildings. The question arises, how a cost-effective share of district heating for the heating of buildings in a future climate-neutral energy system can be quantified.

Existing modelling studies report greatly differing values for the future share of district heating. A better understanding of the reasons for such great differences among studies increases the value and relevance of results. Thereby, we present a review of published system analyses studies that aim to model the future evolution of district heating. Based on this, we conduct a case study, using a high spatial resolution modelling approach to determine the most important parameters for analysing the district heating market share in Germany.

We find in the reviewed studies that the resulting shares for district heating vary greatly, even when similar assumptions are used. Some studies identify possible district heating areas with a high spatial resolution. Furthermore, the modelling approaches for the district heating sector differ by cost assumptions, resulting in different shares for district heating. Nevertheless, modelling is a method to indicate future district heating expansion in different European countries.

2-226-22: Extended abstract

A fair share of energy savings for energy poor households

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Samuel Thomas, Regulatory Assistance Project

Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
energy poverty, energy savings, Energy Efficiency Directive (EED), domestic energy efficiency, energy efficiency obligation, fuel poverty

Energy efficiency is the most cost effective, long-term solution to energy poverty. Article 7 (now Article 8) of the Energy Efficiency Directive (EED) is the most important of all European energy efficiency policies; it delivers 50% of the savings needed to achieve the Union energy efficiency target. In the recast of the EED, released in July 2021 and currently under negotiation, the European Commission (EC) has proposed that Member States dedicate a share of the energy savings to be achieved "among people affected by energy poverty, vulnerable customers and, where applicable, people living in social housing." The proposal also increases the annual energy savings obligation target from 0.8% to 1.5% from 2024.

This poster explores the proposals and issues for implementation. The EC proposes that the national ringfences are based on the share of the population in energy poverty reported in National Energy and Climate Plans but very few include this assessment. Alternatively, the ringfence is calculated by taking the average of three Eurostat indicators. The resulting ringfences range from 2.6% in Sweden to almost 23% in Bulgaria. The European Parliament Rapporteur has proposed an alternative calculation which increases the ringfences for almost all countries, with a range of 5.5% and 23%.

What would this mean for countries adapting their national energy savings policies to deliver to energy poor households? The poster draws on experience of countries that have already made provision for energy poor households. In particular, three countries – France, Ireland the UK - have dedicated between 5% and 10% of their Energy Efficiency Obligation Schemes (EEOS) to low-income or energy poor households. EEOSs are a useful lens as they are the most important single policy measure for compliance with Article 7 (now 8), used in 16 Member States, delivering an aggregate 35% of all reported savings. Lessons on energy poverty support through EEOSs is collated from two Horizon 2020 projects SocialWatt and ENSMOV.

First, a ringfence is essential to guarantee policy impact. Five countries incentivise the delivery of savings in target households by administratively increasing the value of the savings rather than ringfencing a share. The uplift alone has been insufficient to overcome the barriers and costs to delivery in the target group. The uplift in Austria (2015-2020) resulted in only 0.66% of savings in the target group. In Ireland the buyout price for energy savings – a proxy for the cost of the savings

– in energy poor households is 15 times higher than in the non-residential sector and over four times higher than other residential savings, illustrating the cost barrier.

Second, targeting support does not rely on a national definition of energy poverty. France, Ireland and the UK all have an energy poverty definition but many countries do not. In practice, proxies are used to define eligibility not a full assessment of energy poverty status under the national definition. Proxies used include income status or access to 'passport benefits', age, low home energy performance or location, eg areas of deprivation.

Third, delivering just the most cost-effective savings – a principle that underpins many energy efficiency programmes - is not the most effective approach for social impact. Energy poor households often need a more complete set of advice, insulation and heating measures. Given the high barriers to and costs of engagement, delivering single or incomplete sets of measures makes poor use of the engagement opportunity. Creative partnerships of utilities, local authorities, social organisations and technology providers can reach more households with a more complete set of support. Experience from France illustrates the value in combining national and local support - the EEOS support and uplift, combined with other national and local funding streams has resulted in more savings for low-income households than the ringfence requires.

2-249-22: Extended abstract

Local Green New Deals: approaches to incorporating environmental and social goals into UK regional economic recovery packages

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
multiple benefits, green recovery, local and regional energy planning, Net Zero, economic development

Many local and city-region authorities across the UK have declared climate emergencies and begun to develop and implement local low carbon energy plans, though acting at varying speeds and with constraints on their ability to act. At the same time, the economic contraction and rise in unemployment due to the Covid-19 restrictions has enhanced the need for investment leading to new job opportunities and skills development across the regions of the UK. This has led many to call for a 'Green New Deal' to achieve these objectives, recognising that delivering this recovery will need to be co-ordinated locally. The pandemic has also shown how many people value local social and environmental benefits, including cleaner air, physical and mental health and community spirit.

This work investigates of the forms of low carbon economic development currently being implemented at a local and regional level, through case studies of the Greater Brighton region in the south and the North of Tyne Combined Authority in the north of England. Plans being examined include the development of a Net Zero innovation-led economic recovery plan (Blue/Green Print) for the Greater Brighton region, launched at a Climate Summit in October 2021, and a Green New Deal Fund for the North of Tyne, aiming to support business growth and innovation.

The paper examines the challenge facing city-region authorities in how to assess and evaluate different choices so as to deliver wider social and environmental benefits, whilst stimulating economic opportunities. It examines how community-focussed and digitally-enabled local green

recovery packages, including energy demand reduction measures, could be targeted, framed and assessed in terms of their wider economic, social and environmental benefits. The focus is on how these relate to the social, environmental and economic values espoused by local people in this context, including through Citizens Climate Assemblies.

2-257-22: Peer-reviewed paper

Future energy retail markets: stakeholder views on multiple electricity supplier models in the UK

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Michael Fell, University College London, United Kingdom
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
governance, stakeholder, interviews, energy suppliers, regulation, supplier hub model, decentralisation, retail

In the transition to smart, low-carbon energy systems, the energy retail market is evolving. Many non-traditional actors are beginning to offer services that can help accommodate distributed supply intermittency. At the same time, they provide greater choice for consumers through new electricity products, such as specialised supply for assets such as EVs and smart appliances, or democratising energy supply, e.g. through peer-to-peer energy trading and community energy schemes. This represents a shift from a supplier-centric energy system to one placing greater emphasis on the role of energy end-users. However, under the current 'supplier hub principle' governing the UK market, domestic consumers' interaction with the energy system is mediated by a single licensed supplier, creating barriers for non-traditional business models.

This paper shares findings from eight semi-structured interviews conducted in summer 2020 with regulators, innovators, energy suppliers, and consumer advocacy groups on the future of the UK's energy retail market and consumers' relationship with it. The research focuses on one alternative to the supplier hub principle; a 'multiple supplier model', which would enable consumers to have multiple electricity suppliers at the same time, engaging with non-traditional models whilst keeping their national-level supplier. Interviewees highlighted peer-to-peer energy trading, and community energy, as well as the ability to bundle supply with technologies such as electric vehicles or smart appliances, as the most transformational use cases that multiple supplier models could facilitate. Although most interviewees felt that the current supplier hub model is not fit to support the energy transition, contention remains around how best to replace it. Findings offer insight into the challenges posed by the supplier hub principle; the advantages and disadvantages of permitting multiple suppliers; and the key aspects of interactions with multiple energy suppliers from the consumer's perspective. This work contributes towards understanding the landscape of future supplier models and the challenges faced in transforming the energy retail market.

2-258-22: Peer-reviewed paper

Segmenting SMEs: net zero opportunities and challenges for UK bakery entrepreneurs

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
energy efficiency action plans, small and medium-sized enterprises, social practices, climate change mitigation, energy management, retail, manufacturing, Climate Change Agreements (UK)

This research generates new qualitative evidence on an important group of relatively energy intensive small enterprises: small bakeries. They both manufacture and retail products so could represent similar activities across the poorly researched broader-small-enterprise-spectrum. The standard market failures and barriers approach to SMEs is not working. There is a big gap between their energy use and a netzero pathway. Granular qualitative detail about sub-groups of entrepreneurs and enterprises may reveal useful patterns of characteristics which could inform further research and policy development.

Small bakery enterprise energy use and the related baking and business practices in the UK are being explored. 12 entrepreneurs and advisers have been interviewed in depth. The researcher also observed and participated in bakery activities. Coding and thematic analysis with the evidence is allowing important themes to emerge from the entrepreneurs themselves.
Initial reporting from participants finds that the entrepreneurs have different objectives and styles, even in the same sub-sector: craft or business; second career or food industry lifer; social climber or sticker, but most enjoy innovating and will prioritise their customers' preferences. The attitudes to peer communities vary, some see them as providing sound advice, whilst others find unwelcome attempts to impose outdated traditions. However, interactions with the local community of residents and consumers are generally seen as positive; they provide energising human contact and acclaim.

It is the perceived consumer preference for fresh bread in the morning that drives the standard night-working-approach of the entrepreneurs. Competition from supermarkets probably influences mid-market enterprises to be more focussed on cost minimisation, including energy expenditure.

Families often provide support, but none of the participants is planning for, or wants their children to take over, so investment follows the business cycle, e.g. new plant to support growth, or making do with old plant because sale of the business is coming up on the horizon. The energy performance of equipment is not a priority and data are not shared by manufacturers, although individual metering is relatively cheap, none of the entrepreneurs have installed it. Entrepreneurs

are often more interested in renewable power supplies than energy efficiency measures. Electricity is the main fuel used by the small bakery enterprises. The entrepreneurs are hostile to bank finance, but paradoxically happy with Government guaranteed loans, equipment-supplier credit and car loan arrangements.

Greater policy emphasis on promoting the use of the most energy efficient plant would be worth considering. Small enterprises are often overlooked by Government policy initiatives for energy efficiency (e.g. UK Climate Change Agreements are not a feasible option), putting them at a, possibly, unfair disadvantage. However, at the same time, small enterprise is often seen as a vital community hub which could support “levelling up”. The opportunities for career and social advancement offered by small enterprises bring a diverse, largely, local workforce into valuable roles in society, compared with the poor access provided by corporate enterprises.

The research provides new qualitative empirical data on a sector of poorly understood entrepreneurs and their enterprises, it could be used to improve energy use across groups with similar characteristics.

2-259-22: Peer-reviewed paper

4D Stock: Adding an organisational dimension to a 3D building stock model

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Rob Liddiard, University College London, United Kingdom
Paul Ruyssevelt, University College London, United Kingdom

Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
strategic decision-making, organisation behaviour, building stock, business models, commercial buildings, tenants, landlords

Building stock models, such as University College London's 3DStock, help us understand energy use across a building stock across time and space. 3DStock is currently used for decision-making and evidence gathering at the national and local policy levels in the UK. A novel innovation proposes to add an organisational dimension to the existing 3DStock model, turning it into a 4DStock model. This conceptual paper articulates some of the anticipated benefits and challenges of this effort, introducing why and how three dimensions could become four. The fourth organisational dimension is eventually intended to incorporate trends in building ownership and usership, with a particular focus on non-domestic buildings and commercial real estate. This organisational dimension is critical for setting agendas, creating agreement, and stimulating action because low-carbon technologies do not adopt themselves. By focusing exclusively on physical buildings and premises, stock models generally omit the human dimension of energy use, including ownership and usership. Organisational characteristics are particularly important in commercial real estate (CRE), which includes 50–75 % of the non-domestic building stock. Different sizes and types of building ownership—for example, large/SME; public/private/listed; owner-occupied or tenanted—have been shown to affect the shape and nature of organisational participation in energy efficiency schemes. Different sizes and types of building usership are also important. The concerns, capacities, and conditions of occupiers have been shown to affect their energy practices and cultures. Understanding these dynamics is essential as we move from theoretical models to practical actions. We need a better grip on both 'achievable potential' (the subset of technologies that are actually installed in practice) and 'social potential' which includes both how these technologies are used and other organisational behaviours. As an initial sketch of this field, the paper concentrates on how a 4DStock model would incorporate both technical and organisational variables related to occupiers. Further developments will be more useful for ongoing carbon accounting and planning in academia, government, and business.

2-292-22: Peer-reviewed paper

Expert views of building retrofit in the UK: residential, non-residential and heritage building renovations

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Tina Fawcett, CREDS, University of Oxford - Environmental Change Institute, United Kingdom

Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
building refurbishment, residential buildings, commercial buildings, sustainability, embodied carbon, retrofit

The retrofit of entire building stocks is a key policy objective at EU and UK level, not least to help meet net zero goals. However, retrofit activity remains much too small in scale everywhere. This paper brings together evidence and expertise from different building sectors – residential, non-residential and heritage – to compare insights across sectors, and to highlight similarities and differences in the challenges faced and potential solutions.

First, an overview of renovation at European level is presented, as are key issues for renovation in each of the building sectors. This is followed by an analysis which combines a broad literature review with the results of five interviews with experienced people in the UK buildings sector. Research findings are presented on cross-cutting themes: the need for better understanding of buildings; the selection and use of metrics; skills training and education; rising public and client interest in 'zero carbon'; roles for government; costs and quality assurance; and the need for cultural change across policy, practice and research.

Experts from all sectors wanted improved regulation and advice and increased roles for local and national government. Understanding at the scale of each building or project is key, especially for retrofit where starting conditions are unknown. The scope for performance loss throughout the process is large, and new processes and roles may be needed to provide feedback, providing learning opportunities at each stage.

Differences between sectors included more specialist professions in the non-residential and heritage sectors, and more expert clients pushing for higher environmental standards. Long-standing concerns about embodied energy in the heritage sector are emerging elsewhere as embodied carbon calculations and discourses in favour of retrofit rather than demolition.

Despite the different time scales, building purposes and characteristics, regulations and contexts,

there are more similarities than differences between these sectors. This opens up options for improvement by better communication and more cross-sectoral learning and research.

2-322-22: Peer-reviewed paper

Multiple benefits of a financial incentive for retrofit in owner occupied houses

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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
building retrofitting, energy efficiency policy, financial incentives, multiple benefits, home working, owner occupied housing

The challenge for retrofitting the owner-occupied sector is enormous. The slow progress not only highlights the need for a radical rethinking of the current financial retrofit schemes but also the need for a new regulatory framework that simplifies the whole retrofit process for the homeowners. The COVID-19 pandemic has fundamentally reshaped the ways in which people work and use their homes. The accelerated trend of home working continues to rise globally after the easing of restrictions in the 'new normal'.

Previous work on retrofit incentives developed an innovative financial mechanism the 'Retrofit Salary Sacrifice' policy scheme to allow employers to provide loans to employees encouraging them to carry out retrofit energy improvements in their 'home office', repaid through the tax system via gross salary contributions. In this working from home was identified as a trigger for a specific subgroup of salaried homeowner employees to undertake retrofit works. The scheme builds on a simple connection between finance, and project management and appraisal to allow overcome a significant deployment barrier increasing confidence and trust to public revenue and private lenders.

In this paper the policy implications of the Retrofit Salary Sacrifice scheme were seen under the lens of multiple benefits framing to capture areas of impact and important points the financial incentive has over five sectors/stakeholders (i.e. Government and Local authorities; Companies and Institutions as employers; Private owned housing sector as employees; Private and public Financial institutions; Supply side companies and Retrofit energy professionals). The authors present an alternative visualisation of multiple benefits framing which draws the connections between stakeholders and the wider impact of Retrofit Salary Sacrifice scheme in energy efficiency retrofit policy. Insights from the analysis show positive economic impacts in all stakeholders that vary from stimulus for a retrofit service and job creation to operational energy use and CO2 emission savings for both companies and homeowners. Social impacts are mainly related to businesses (employers) and housing sector (employees) and concern health, employment and carbon inequality between them. It emphasises an opportunity where the energy efficiency of the domestic sectors can meet to balance the outsourced operations of the non-domestic sector. Environmental impacts are found at high level in governments and local

authorities' energy efficiency and Net Zero strategies as well as in individual companies' environmental targets. Finally, political impacts in government bodies are related to the decision making of financial institutions and supply chain to create retrofit market capacity. Looking the multiple benefit framing of the scheme it helps understand the catalytic role it can have in the retrofit policy mix. It can also help towards more meaningful engagement with full diversity of stakeholders in retrofit sector and to develop better synergies between key roles and functions (e.g. employers, employees and investors, EPC/retrofit assessors, utilities and data companies, lenders, building control, professionals, installers, manufacturers). The analysis here can be used as a first step towards action for trialling the Retrofit Salary Sacrifice scheme. While it also responds to the call for more systematic empirical evidence in governmental policy making and evaluation of the multiple impacts of energy efficiency programmes.

The multiple benefit approach as developed in this paper also demonstrates a different way multiple benefits framework can be applied to support policy design and development of new policy ideas. The alternative visualisation highlights the importance of understanding the role and connections between stakeholders and the shared 'salient benefits' arguments that need to be made to boost retrofit uptake.

2-342-22: Peer-reviewed paper

Seizing Opportunity: A proposal for an Energy Efficiency Coordination Mechanism to boost international environmental conventions

Nils Borg, Borg & Co AB, Sweden
Michael Scholand, CLASP
Hanna Blair, CLASP

Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
appliances, product policy, multiple benefits, environment, Environmental Conventions, Directive on Restriction of Hazardous Substances (RoHS), mercury

The international community has several conventions that bring together large groups of countries to discuss, cooperate and coordinate action on global activities that address mutually agreed environmental priorities, covering issues such as climate, air pollution, hazardous waste, toxic substances, and biodiversity.

While many environmental conventions have been successful in coordinating targeted interventions at the global level within their mandate, to date there is limited focus in most conventions on energy efficiency as an enabler of the conventions' stated objectives. Multiple benefits of energy efficiency could play a much larger role in many environmental conventions, in particular those that aim to mitigate problems caused by the conversion or use of energy, or that regulate contents in products or systems that use energy.

There is also little coordination between the conventions to explore the multiple benefits of energy efficiency in meeting the objectives of one convention while supporting the objectives of another convention.

When speaking about the role of energy efficiency in environmental conventions, the United Nations Framework Convention on Climate Change (UNFCCC) with its Kyoto Protocol and Paris Agreement comes to mind. This is also one of few conventions where energy efficiency is explicitly mentioned, given the key role (fossil) energy use has in global warming.

The primary aim of this paper is out to explore how energy efficiency could support the objectives of a few other environmental conventions. Apart from the obvious UNFCCC, we have selected the Minamata Convention, the Transboundary Air Pollutants Convention, and the Kigali Amendment of the Montreal Protocol for analysis. With Minamata and lighting as the example, we conclude

that energy efficiency can advance the stated non-energy objectives of some of the conventions. By acknowledging and valuing the multifaceted benefits of energy-efficiency measures, we argue that the somewhat disparate conventions could realise and accelerate action on their objectives, while simultaneously reducing energy used by products, equipment and processes. In that respect, the benefits of energy efficiency applied in one convention would support the objectives of another.

The authors argue that the concept of energy efficiency in relation to environmental conventions needs a common “policy and analysis home.” here, energy efficiency synergies could be analysed and addressed properly, timely and with a clear focus that serves the needs of an environmental convention at a given time. Such an international, inter-conventional Energy Efficiency Coordination Mechanism – in short EECOM – could fill this void, as well as promote cooperation and ambition across the various conventions. This mechanism would have three key objectives: (1) facilitate collaboration and coordination of activities between governing bodies, implementing institutions and working groups; (2) serve as a clearing house for data, timely analysis and tracking of product and market innovation; and (3) accelerate the ambition and foster effective implementation across relevant UN conventions.

2-343-22: Peer-reviewed paper

A German, an Italian, a Polish, and an EU official walk into a stakeholder workshop: Supporting energy efficiency policies with the multiple impacts approach

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Giulia Pizzini, Institute for European Energy and Climate Policy IEECP, The Netherlands
Ivana Rogulj, Institute for European Energy and Climate Policy IEECP, The Netherlands
Niklas Mischkowski, Local Governments for Sustainability (ICLEI), Germany
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Panel
2. Efficiency and beyond: innovative energy demand policies

Keywords
multiple benefits, design process, stakeholder, operational tools, energy efficiency policy, policy-making

The EU Commission's Fit for 55 package has outlined the need for increased emission reductions to comply with the Paris Agreement's 1.5 °C target. Incentivising more ambitious action, the multiple impacts approach emphasises co-benefits of energy efficiency, essentially increasing the cost effectiveness of related measures from a holistic perspective. Major EU projects such as ODYSSEEMURE and COMBI have expedited the knowledge base and methodology. However, in spite of significant benefits discovered and various tools created throughout these projects, the approach is hardly applied in policy-making, complexity and a limited applicability to new contexts being central inhibitions.

Therefore, central tenets of the Multiple Impacts Assessment Tool (MICAT) project are the consideration of European, national, and local levels and the involvement of relative stakeholders and policy-makers in the whole development process of the resulting MICATool, in order to better tailor it to their wishes and needs. The involvement will start right from the conception and design phase: in the course of three national and one EU workshops, as well as in an ongoing exchange with three pilot cities, the demands and requirements regarding the design of the tool, the inputs, and the form of the results are discussed with stakeholders and policy-makers - ranging from

European Commission (EC) officials and experts working on climate and energy at EU level, to national officials working in Ministries and other relevant bodies, to local administrators. This will allow the project team to shape and tailor the tool to fit the policy-making process as seamlessly as possible, envisaging the objective to render the multiple impacts approach a paramount aspect of cost-benefit analyses, enabling more ambitious policies to comply with the omnipresent cost effectiveness criterion in EU legislation.

This paper examines how the multiple benefits approach and the MICATool need to be shaped in order to be highly policy-relevant and enable a seamless, ubiquitous, and impactful use in policy-making.

3-016-22: Peer-reviewed paper

Hot air or new energy: Are we seeing signs of improved citizen engagement in district heating schemes?

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Will Eadson, Centre for Regional Economic and Social Research, Sheffielf Hallam University, United Kingdom

Panel
3. Policy, finance and governance

Keywords
stakeholder, district heating, CItizen Engagement, Energy from Waste

District heating schemes linked to Energy from Waste (EfW) and Biomass facilities occupy a contested space in the energy policy landscape. Once viewed as a low carbon solution, their environmental credentials are now questioned and their place in the waste hierarchy unclear. But for many cities across Europe existing waste management facilities and pipe networks occupy an important place in carbon reduction strategies with an infrastructure ripe for development as other energy sources are considered. These schemes are a unique intersection between two key environmental policy agendas - waste and energy - offering a distinctive potential for citizens to impact environmental agendas, and in the future of urban energy infrastructure.

This paper responds to this question by exploring how and to what extent we are seeing greater citizen-focused stakeholders participating in local heat infrastructure decision-making. The benefits of engagement are highlighted in existing literature but there is currently no clear and consistent implementation of stakeholder engagement policy, especially for heat infrastructure. Evidence from qualitative case studies is presented (Nottingham and Sheffield in England and Helsingborg and Malmö in Sweden) to investigate strategies used by heat infrastructure developers and operators to engage with their stakeholders and how this engagement influences the decision-making of the heat network operators. We found limited examples of bottom-up, unplanned moments of citizen engagement and historic partnership arrangements that allow for more formal citizen engagement. The deliberative turn with oft-cited benefits of improved decision-making, greater acceptance and improved environmental citizenship has yet to come of age, certainly with regards to district heating.

3-026-22: Peer-reviewed paper

Applying the Energy Efficiency First Principle based on a Decision-tree Framework

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Stefan Thomas, Wuppertal Institute for Climate, Environment and Energy, Germany
Tim Mandel, Fraunhofer Institute for Systems and Innovation Research, Germany
Heike Brugger, Fraunhofer Institute for Systems and Innovation Research, Germany

Panel
3. Policy, finance and governance

Keywords
energy efficiency first principle, decision-tree framework, demand response, district heating

Energy Efficiency First (EEF) is an established principle for European Union (EU) energy policy design. It highlights the exploitation of demand-side resources and prioritizes cost-effective options from the demand side over other options from a societal cost-benefit perspective. However, the involvement of multiple decision-makers makes it difficult to implement. Therefore, we propose a flexible decision-tree framework for applying the EEF principle based on a review of relevant areas and example cases. In summary, this paper contributes to applying the EEF principle by defining and distinguishing different types of cases - (1) policy-making, and (2) system planning and investment - identifying the most common elements, and proposing a decision-tree framework that can be flexibly constructed based on the elements for different cases. Finally, we exemplify the application of this framework with two example cases: (1) planning for demand-response in the power sector, and (2) planning for a district heating system.

3-035-22: Extended abstract

Scaling the energy transition through effective inter-organisational knowledge sharing: a practical framework for intermediary actors

Helena Lindquist, Lightswitch, Sweden

Panel
3. Policy, finance and governance

Keywords
Knowledge Sharing, Scaling, intermediaries, transition, collaboration

The energy transition requires large-scale system change for which we have no blueprint. Nobody has all the required knowledge to navigate this emerging new landscape. Effective knowledge sharing (KS), horizontally within and between sectors, and vertically between societal levels, is therefore of critical importance to accelerate development. The exponential proliferation of KS initiatives in the energy sector seen in recent years is encouraging and indicates a great willingness by many stakeholders to cooperate to scale energy solutions.

Yet, given the urgency of the energy transition and the great appetite for KS, it is remarkable how little attention – by organisers and participants alike – is paid to key KS mechanisms and preconditions that must be in place for it to be truly impactful. Credible theories of change describing how particular KS initiatives lead to actual scaling of solutions are rare. Instead, many seem to rely on "spontaneous scaling by magic" through one-off events on "hot topics". Scaling is arguably about learning and customisation of ideas and solutions to fit the specific needs of stakeholders in new contexts. With sufficient knowledge of key KS mechanisms, along with practical skills and tools, intermediary actors can play a key role as catalysts for scaling the energy transition – through initiating, designing, and facilitating inter-organisational KS.

There are several interrelated factors to consider when planning impactful multi-stakeholder KS processes; here formulated as questions for intermediaries to seek answers to, in dialogue with prospective KS partners.

WHY: The purpose, vision and concrete objectives constitute the guiding stars for the KS process, and these should be clear to everyone involved. KS is a collective endeavour and development goals should be formulated both for the whole group, as well as for each participating organisation.

WHERE: Any KS process takes place in a specific context, with preconditions (cultural, political, etc.) influencing both the intermediary's and the participants' motivations to engage, as well as the possible impact that can result from the process.

WHAT: This question concerns the subject matter in focus for the KS process, the scope of which can pose challenging trade-offs between the need to solve detailed problems (depth) and the quest for developing a holistic understanding of how different factors interrelate at system-level (breadth).

WHO: The participants' development needs should always be the cornerstone of any KS initiative, but intermediaries also need to consider which stakeholders have what knowledge to share, i.e., understanding the supply and demand of knowledge.

In essence, intermediaries need to solve the puzzle of "who should talk to whom about what and why?". Some parameters may already be fixed, e.g., an existing network of practitioners that want to share experiences, or the intermediary itself wanting to address a concrete sector challenge by means of interdisciplinary KS and co-production of new ideas.

When all the above-mentioned questions have been considered – and calibrated by contextual preconditions and constraints (e.g., resources) – a suitable KS process can be designed, essentially providing a well-grounded answer to the question of HOW knowledge can be shared effectively to meet concrete development needs. The process design should provide a logical structure and tools to help participants explore the chosen focus area systematically. Since KS is effectively a social process of joint sense-making and learning, it is equally important to create favourable conditions for relationships between participants to deepen and flourish, e.g., by promoting an informal atmosphere characterised by high levels of trust.

This extended abstract suggests a new practical framework and tools for intermediary actors to enable effective interorganizational KS as a vehicle to scale the energy transition.

3-058-22: Peer-reviewed paper

Fossil gas infrastructure first, energy efficiency never?

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Jan Rosenow, Regulatory Assistance Project, Belgium
Veit Bürger, Oeko-Institut e.V. - Institute for Applied Ecology, Germany
Sibylle Braungardt, Öko-Institut e.V. – Institute for Applied Ecology, Germany

Panel
3. Policy, finance and governance

Keywords
Energy Efficiency Directive (EED), Fossil gas, infrastructure, gas grid

All major independent studies presenting pathways to meet climate goals show a dramatic decline in fossil gas use, particularly in the buildings sector. Despite these findings, gas distribution companies across Europe are allowed to continue investing vast amounts of money in maintaining, upgrading and even expanding the gas grid. Promises that this infrastructure will be used by so-called green or low-carbon gases have even led to claims that there is less or no need for building improvements and energy efficiency.

In this paper, we look at how energy efficiency is being overlooked in policy discussions around the required transition away from fossil gas. Our analysis is based on detailed conceptual work as part of the H2020 project ENEFIRST and case study analysis of primary data on gas infrastructure investment in Germany. We find that rather than applying the Efficiency First principle, which would require regulators to carefully compare the costs and benefits of new gas infrastructure with the costs and benefits of energy efficiency investments, the current approach is based around an expectation of the continued use of gaseous fuels, or even fossil gas. We develop a number of EU- and national-level policy and regulatory recommendations in order to avoid stranded costs and to prioritise energy efficiency over new supply-side investments.

3-066-22: Peer-reviewed paper

Foundations for gender-sensitive and sustainable public lighting systems

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Giulia D'Angiolini, Econoler, France
Silvia Puddu, AFD, Canada
Sébastien Carreau, AFD
Lina Baldrich, Ecoonoler

Panel
3. Policy, finance and governance

Keywords
gender, street lights, sustainability, developing countries

Urban planning tends to reflect society's dominant values, which are typically neither inclusive nor equitable. Cities have long reflected traditional gender roles and the gendered division of labour, thus marginalising women and girls from public spaces. This is because, historically, cities have been planned and designed by men with little knowledge of or concern for how their decisions affect women. Street lighting systems (SLSs) are an extension of this marginalisation and are still planned and designed without considering gender-differentiated uses of urban spaces. These issues are exacerbated in many developing regions where cities are dimly lit due to the use of non-efficient street lighting technologies, financial challenges, deficient operation and maintenance, and limited in-country technical capacity for planning and operations, among other things.

This paper defines what a gender responsive energy efficient (EE) SLS is: "Gender responsive SLSs encompass resilient and sustainable systems that: (1) Use an intersectional gender approach to consider the gender-differentiated lighting needs of both motorised road users and pedestrians; (2) address women's and girls' urban safety needs by promoting natural surveillance and social integration; and (3) actively enable women's economic, social and political empowerment." Also, the paper identifies five pillars to ensure women's, girls', men's and boys' needs and priorities are considered when designing SLSs: Security and well-being; economic empowerment; voices and rights; gender capacity building; and sustainability including EE.

This paper summarises the main findings of a study commissioned by the French Development Agency (AFD) on the existing inequalities relating to gender and vulnerable individuals in planning and implementing SLS projects in sub-Saharan Africa (SSA). The study was financed by the European Union (EU) under the framework of the Covenant of Mayors in Sub-Saharan Africa (CoM SSA) initiative.

3-085-22: Extended abstract

How committed are utilities to help their clients saving energy without being obliged to do so? An analysis for Switzerland

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Daniel Cabrera, University of Geneva, Switzerland

Panel
3. Policy, finance and governance

Keywords
utilities, collaboration, policies and measures, energy efficiency programmes

Among the many policy instruments introduced around the world to support energy efficiency (EE), we find in several countries Energy Efficiency Obligation schemes (EEO) imposed on energy utilities, which have the advantage of proximity and good information about the end-users' energy needs. In countries where energy utilities are not subject to such legal obligations, there are only few studies on these market agents' relation with EE. We study the case of Switzerland, where the supply of electricity to end customers is ensured by roughly 600 utility companies of different sizes and legal forms. Large differences are found among these companies in their activities to promote EE among customers. This was examined by Blumer and Moser in 2013, along with the associated incentives and constraints. Since then, major changes have occurred in the context, mainly the Paris agreement, the Swiss Energy Strategy 2050, the power shortage risk, and the Swiss withdrawal from the negotiations with the EU which may affect the electricity agreements with neighboring countries.

We collected data of 59 utilities covering 31% of Swiss electricity consumption in the year 2020. Using an EE performance index (PEE) to determine the level of commitment of the utilities, we found that the overall average PEE slightly decreased since 2013, while observing a certain transition towards EE services that are more impactful and drive larger EE savings. In addition, utilities perceive more incentives to promote EE than before. Notably, the incentives of "Improving access to customers" and "Prospects of starting a new business line" have become more prominent, which can be explained by the approaching full liberalization that is pushing utilities towards improving their position in the competitive market. Also, due to the increased national and local ambitions, over half of utilities are now more sensitive to the political goals, especially public ones. At the same time, Swiss utilities perceive more constraints compared to 2013, mainly "lack of capital", and that "EE programmes yield too little financial returns". Even though a solution to such financial issues could be addressed by a national policy framework encouraging utilities saving energy, "the absence of an adequate policy framework" is interestingly not

considered to be a significant constraint. In fact, this resistance towards policies to regulate EE is not only present on utilities' side, but also among policy makers who rejected few motions on the subject. This brings us to the second part of the research, where we study an alternative, voluntary approach for utilities to implement EE Programmes (EEPs) . Building on the recommendations from literature on collaboration between utilities and with other key players for knowledge sharing and implementing common EEPs, we assessed the interest of Swiss utilities in collaborating. The utilities were found to be significantly more open to the idea of collaborating on voluntary basis, by a majority of 70%, than to to be subjected to new policies. The utilities interested in collaboration are mostly small and medium-sized, they reported lack of capital, staff, and time to promote EE and they seem to be primarily attracted by the informational and technical support (knowledge sharing, M&V methodologies). Future research may benefit from understanding the dynamics and roles of key players by analysing the long and successful experience with the "Energy Efficiency Collaboratives" in the U.S., and also by studying their stability in a potentially fully liberalized future market.

3-092-22: Peer-reviewed paper

Utility value of a Pay As You Save inclusive utility investment program for whole home energy efficiency and electrification upgrades

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Jill Ferguson, Stanford University, USA
Ethan Goldman, Resilient Edge, USA
Hassan Shaban, Empower Dataworks, USA

Panel
3. Policy, finance and governance

Keywords
customer finance, energy efficiency financing, financing, electricity savings, energy savings calculation, value, utilities, energy efficiency investments, green investments, inclusive utility investment, Pay As You Save

Inclusive Utility Investment systems such as Pay As You Save® (PAYS®) make it financially feasible and attractive for utilities to capitalize residential energy upgrades to develop efficiency resources and grid flexibility on a scale similar to conventional power plants, rather than managing efficiency programs as cost centres tangential to their core business. This study analysed weather normalized hourly meter data from one of the longest running Inclusive Utility Investment programs, Ouachita Electric Cooperative Corporation's (OECC's) HELP PAYS® energy efficiency and electrification upgrade program based on the Pay As You Save system. Evaluation of billing and utility meter data of participating homes, with subsequent extrapolation to homes that lacked statistically valid weather models, revealed that 369 of the locations in the program's residential portfolio are generating over 1,100,000 kWh of electricity and 250 kW of peak demand reduction per year to the utility (3,200 kWh energy savings and 0.7kW of peak load reduction per home) with a net present value to the utility of $531,900 ($1,350 per home) over the lifetime of the upgrades. Program design reforms instituted half-way through the evaluated period increased average energy saving by 42 %, peak load reduction by 13 %, and offer acceptance rates from 63 % to 80 %. With these improvements and an increased rate of upgrades per year, the net present value for future upgrades is projected to increase by 70 %. Thus, even after considering the cost of capital and program operation costs, OECC's HELP PAYS investment portfolio is generating energy savings for its participants as well as economic benefits for the utility and all its non-participants and is expected to provide even greater benefits in the future. This paper helps make the business case for all utilities across the globe with an approved tariff to use Inclusive Utility Investment to fund building energy upgrades, increasing the scalability and depth of resource efficiency and electrification.

3-094-22: Peer-reviewed paper

Policy design for Energy Efficiency First: taking stock of measures for moving from principle to practice

Tim Mandel, Fraunhofer Institute for Systems and Innovation Research, Germany
Zsuzsanna Pató, RAP (Regulatory Assistance Project), Belgium
Benigna Boza-Kiss, Central European University (CEU)9, Austria

Panel
3. Policy, finance and governance

Keywords
Energy Efficiency First, energy efficiency investments, energy systems, market failures, barriers, EU policy

EEnergy Efficiency First (EE1st) means balancing end-use energy efficiency and other demand-side resources with energy generation, networks and other supply-side resources from a societal cost viewpoint. In parallel with its evolving legal status in EU legislation, a growing literature discusses policy approaches to help implement the principle. However, a theoretically substantiated framework for these policies is not yet established. This paper aims to review and categorize dedicated policy approaches for the implementation of the EE1st principle in the EU. First, we provide a theoretical background to policy design for EE1st by referring to market failure theory and explaining how policies addressing EE1st differ from traditional energy efficiency policies. Second, we link theory and practice by taking stock of potential policy approaches for EE1st, attaching them to individual market failures, and thus providing a comprehensive catalogue of policies for moving from principle to practice. The paper shows that there is no single policy lever for implementing the principle. Instead, EE1st requires a broad policy response that goes beyond the established energy efficiency policy portfolio. We conclude by identifying promising innovative policies warranting more detailed assessment, including electricity market reforms moving towards marginal cost pricing, performance-based regulation for network companies and more.

3-105-22: Peer-reviewed paper

Financing energy efficiency in buildings: an overview of current and upcoming European funding programmes

Giulia Conforto, e-think, Austria
Marcus Hummel, e-think, Austria

Panel
3. Policy, finance and governance

Keywords
financing, building retrofitting, Energy Efficiency Directive (EED), renovation, deep renovations, funding, energy efficiency financing, financial incentives, district heating, cooling, heating, infrastructure

The European Union is among the frontrunners of the global low-carbon transition, with production and consumption patterns undergoing a bold shift. However, its building sector struggles to follow this trend: despite its essential role to achieve carbon neutrality, building renovation rates remain too modest to achieve EU climate targets. Several barriers hinder a deep renovation of the built environment. Among these limited access to funding, which, if lowered, could benefit also other barriers by outsourcing tasks or hiring consultants.

Focusing on the research question “What EU funding programmes can support energy efficiency interventions in buildings?”, this paper gathers a concise overview of financial instruments and, acknowledging their still limited uptake, looks into instruments to counteract market inertia, diving into EU funding programmes. A combination of literature review and desk research provides an up-to-date overarching review of funding programmes offered by European institutions and related entities for energy efficiency in new and existing buildings, including building thermal renovation, efficient heating and cooling, and district heating and cooling. Each funding scheme is listed with details on eligible topics, applicants, budget, duration, and relevant links.

Given the complexity, variety and dispersion of the EU funding landscape, the financial barrier seems to lay less with the availability of funding and more with the limited functionality and accessibility of information for beneficiaries. Raising stakeholders’ awareness of available options, often underutilized, seems a needed step to advance the decarbonization of the building sector. This study tries to fill a research gap by offering a way to discover new instruments and providing tools to guide the reader in what programme could be worth further investigation based on relevant topics, beneficiaries, forms of finance and bankability of eligible projects.

3-119-22: Peer-reviewed paper

Best Practices for Nations: Leading Countries' Efforts to Reduce Emissions through Energy Efficiency Policies and Practices

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Panel
3. Policy, finance and governance

Keywords
energy efficiency policy, CO2 emissions, lessons learned

Many countries have made commitments or set targets to reduce greenhouse gas (GHG) emissions due to the urgency of climate change. Energy efficiency plays a key role in meeting countries' climate goals to reduce overall GHG emissions while also lowering overall energy consumption. Countries that promote investment in energy efficiency and implement supporting policies also reduce air pollution, create jobs, and save money for residents. Analysis from the International Energy Agency shows that energy efficiency has the potential to supply almost half of the necessary GHG reductions to carry out the Paris Agreement's goals by 2040. However, many nations still have a long way to go to decarbonize and incorporate energy efficiency practices into their economies. This paper compares efficiency policies and performance of the top 25 largest energy users in the world, drawing on the findings of ACEEE's 2022 International Energy Efficiency Scorecard. We find that some countries are making significantly more progress than others.

Although European countries often fare well due to compliance with robust European Union (EU) legislation on energy efficiency, countries still have much to learn from one another. This paper examines the policies, practices, and performance in leading EU and non-EU countries to provide lessons learned for nations trying to achieve ambitious climate goals. In particular, this paper identifies best practices and initiatives within the buildings, industry, and transportation sector as well as national commitments to energy efficiency.

3-126-22: Peer-reviewed paper

Energy poverty or vulnerable consumers? An energy-economic method to compare the policy approaches to addressing vulnerabilities in the energy system in Germany

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Ulrich Fahl, University of Stuttgart - Institute of Energy Economics and Rational Energy Use (IER), Germany

Panel
3. Policy, finance and governance

Keywords
investment decision-making, suppressed demand, energy system model, energy poverty, subsidies, energy consumption

Energy poverty results from a combination of overlapping factors including low income, high energy prices, inefficient buildings and appliances, but in Germany the concept is not specifically recognised as separate from overall poverty and not targeted with policies and measures directly. Post-pandemic, energy prices are soaring and households are suppressing demand while stronger action towards decarbonisation demands more urgent action. As consumers of a third of the total final energy consumption in Germany, this puts households both at the heart of the energy transition and key to unlocking the potential to achieve energy and climate change targets while increasing resilience to energy price fluctuations. Yet, the majority of households are not in the financial or decision-making position to undertake the required investments in renewable and energy efficiency technologies. At the same time, households experiencing energy poverty are additionally disadvantaged in terms of meeting their energy demands (suppressed demand) and participating in the energy transition through difficulties accessing and affording resources and technologies. The current policy approach to address vulnerabilities in the energy sector revolves around providing “vulnerable consumers”, defined as social welfare beneficiaries, with subsidisation of electricity and gas consumption. A policy approach to address energy poverty would target the underlying causes through financial support for investments into energy efficiency and renewables. Using an energy system model, this research provides a socio-techno-economic empirical basis for recognising the significance of energy poverty outside of the current vulnerable consumers lens and within the energy transition process. Measures targeting the causes of energy poverty result in 25 % more renewables whereas bill support measures defined under the vulnerable consumers approach result in the persistent reliance on

fossil fuel-based energy carriers for half of their consumption. Subsidies targeting investment support a shift in the energy infrastructure while subsidising consumption maintains the status quo.

3-146-22: Peer-reviewed paper

Energy efficiency finance and multiple benefits – two sides of the same coin?

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Panel
3. Policy, finance and governance

Keywords
multiple benefits, energy efficiency financing, Taxonomy, ESG

Over the past couple of years, the topic of Multiple Benefits of energy efficiency investments has been explored from multiple angles. In the policy context, Multiple Benefits are beginning to be more consistently referred to in the development of regulatory measures and assessment of policy impacts. At the same time, in financial decision-making, non-energy benefits, such as climate resilience, improved comfort, healthier occupiers which are directly linked to the asset value and risk profile, are seldom explicitly targeted, measured or fully considered.

There is a common understanding that Multiple Benefits of energy efficiency have a material impact on investment outcomes. Accounting and realising these additional co-benefits can significantly increase the value and quality of energy efficiency measures. The main challenge faced by financial institutions is that Multiple Benefits remain difficult to communicate, report, track and monetise due to the lack of standardised metrics and lack of market transparency.

This paper presents the main findings of the Energy Efficiency Financial Institutions Group (EEFIG) Working Group on Multiple Benefits. It argues that the translation of Multiple Benefits into actionable and meaningful financial information depends on the ability to assess and communicate these benefits through clear KPIs and quantitative/qualitative evidence. Identifying and assessing the multiple impacts of energy efficiency investments will increase their attractiveness to responsible investors and owners seeking to realise their fiduciary duty to understand and actively manage environmental, social, governance (ESG) and climate-related risks. Linking Multiple Benefits to both the Taxonomy and impact investment framework can provide the required standards and definition of materiality that would facilitate the incorporation of non-energy benefits in financial decision-making.

Building on a short review of the context and relevance of the topic, three aspects will be addressed in more detail: (1) social and health impacts of energy efficiency investments relevant for financial institutions; (2) the role of the EU taxonomy in supporting the articulation of and strengthening the business case for Multiple Benefits; and (3) linking the Multiple Benefits agenda to the impact investment framework. The paper concludes with a list of recommendations addressed to public authorities and relevant market actors.

3-149-22: Extended abstract

Quality control routines for EPC Databases

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Panel
3. Policy, finance and governance

Keywords
energy performance certificates, data monitoring, quality, database

The EPBD emphasizes the role of EPCs as a policy instrument to assess the energy performance of buildings. EPC databases present the huge potential of providing building stock information, that can guide public authorities on the decision making process. Therefore, the stored data must be reliable, trustful and accurate. Currently, in most countries the quality of data stored in EPC databases is not known and systematically assessed. The EU-countries Italy, Greece and Denmark have a well-established EPC database, where building data in XML format is extracted from issued EPCs and stored in the database.

In general, an EPC quality control routine can be carried out in different phases of the EPC issuing process, as for example: emitting warnings and alerts in the EPC calculation software, or validating the EPC data before issuing the EPC. These mechanisms help the new "low quality EPCs" enter the databases. However, many EPCs in the databases have not passed through any quality control routine. Also, it is required to carry out manual checks of EPCs. However, in most countries, the selection of EPCs for these manual checks is based on a random selection of a very small sample of EPCs. This paper sets-up a method to perform systematically a quality control routines in EPC databases. The method is applied in two selected countries (Italy and Greece).
The method builds on different types of rules for the quality check of the EPC parameters. Some of these rules (1st level verification) consist of verifying the completeness of the input data, e.g. if key data like the building cadastral field is empty. In addition, more complex rules were also developed (2nd level verification). They consist of defining the threshold values for specific parameters according to different building archetypes, where the threshold values have been defined based on a statistical evaluation of the database for the building archetypes. It was also part of the method to demonstrate how an analysis of inconsistencies (violated rules) can serve to

improve energy auditors’ practice (and avoid that the same mistakes being repeated).

The method was implemented in a software programmed in Python language and different parts of it have been implemented and tested on the EPC databases. The software allows an interface with the national databases, for accessing the data from different databases. Then, a core module performs the computations using the data retrieved by the interface.

In Italy, almost 2 Mio. EPCs passed through the quality control routine. In the first level verification, 56.1% if the EPCs did not violate any of the rules, while 14.8% violated all rules. The remining 29.1% violated between 1 or 13 rules (from a total of 45 rules).

In the second level verification, 240 building type cluster were identified and for each an threshold values was fixed, using the statistical indicator 99th percentile. In this second level, 75,6% of the EPCs did not violated any rules, showing also no risk. 0,5% presented high risk by violating all rules. Finally 23,9% violated between 1 and 4 (from a total of 11 rules).

Learnings from the exercise showed that it is important to avoid parameter interdependence between the rules, especially in the first check. We can conclude that quality management procedures are highly needed, as they help on gathering more about the quality of the EPCs and also inform assessors and trainers about common mistakes. Furthermore, trustful and reliable EPCs are an important source of building stock information. Prerequisites for the implementation of such routines are: machine-readable format of EPCs and a properly designed and well-established databases. This work has been developed in the frame of the H2020 project X-tendo.

3-162-22: Extended abstract

Place-based business models for Net Zero: a new framework for energy efficiency action

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Tim Foxon, SPRU, United Kingdom

Panel
3. Policy, finance and governance

Keywords
business models, Net Zero, place-based, governance, value

With often competing national and city-level targets for becoming Net Zero, its pursuit embodies multiple transformational shifts, stretching the boundaries between sectors (e.g. digitalisation), our use and understanding of business models and existing forms of governance. Framing Net Zero as a local issue requires undertaking new types of partnerships harnessing new sets of skills, and examining how multiple policy areas, such as biodiversity, carbon off-setting and planning are interacting with each other within a place.

Building on literature from environmental governance, resilience and localism in business models, this paper examines the theoretical and policy emergence of understanding how ecosystems for Net Zero solutions can be developed through geographic proximity, environmental landscape and shared infrastructure. The paper unpacks the interdependent trends in understanding how local value is created through the close integration between firms and local communities and their sense of place. More specifically, the paper examines the multiple ways - location-specific resources and mechanisms, such as 'sense of place', whole systems thinking, as well as just transition and inclusiveness - through which value is created, distributed and captured in place-based business models.

The paper explores a progressive and innovative take on business models thinking as a way of understanding value and the role of context in value creation and capture, through three interdependent vignettes: i) the development of a regional hydrogen economy; ii) nature-based solutions; and iii) developing local skills for decarbonisation, in Sussex, UK. Building on both formal and informal activities and their roles in deep contextualisation, the paper aims to critically evaluate how energy efficiency objectives fit within a place-based understanding of Net Zero and within value creation and capture activities in business models locally. The paper is informed through action-based participation and observation of Sussex-based initiatives and programs, such as the development of a hydrogen strategy for Sussex.

Through the vignette of developing a regional hydrogen economy, the paper discusses five key drivers of hydrogen: i) Geography (natural resources, land and landscape, such as availability of natural resources for the production of energy); ii) Infrastructure: industry, technology and R&I (the level of integration with the energy system, large RES and industrial developments locally, existing transport and port infrastructure, grid capacity; carbon capture utilisation and storage); iii) Policy landscape (the existence of hydrogen specific, interlinked and complementary policies at national and regional level; and planning and policy frameworks for regional incentives and benefits from hydrogen); iv) Opportunities/issues that need to be rectified (areas of higher carbon emissions, lack of energy resources/energy security); and v) Human resources (highly skilled workforce, reskilling and upskilling).

The paper identifies energy efficiency skills and improvements, embedding a whole systems approach, and establishing Regional Hydrogen Energy Hubs as building blocks of the ability of places to progressively reduce the cost of hydrogen and scale up hydrogen production and use. And discusses the importance of developing a broader hydrogen landscape and regional political leadership (e.g. through cohesive and coordinated effort across sectors, governance levels and scales, and Local Area Energy Planning). With a focus on place, energy efficiency skills and improvements take a central role in embedding just transition and inclusion into place-based business models for Net Zero. This is partly done through the introduction of transformational skills, which involve i) whole systems thinking; digitalisation skills; and interoperability skills, and examining their evolving relationships with place.

3-164-22: Peer-reviewed paper

The role of energy demand in policymaking for a just transition to net zero: a comparative survey in the UK, the Netherlands and Germany

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Nick Eyre, Centre for Research into Energy Demand Solutions, Environmental Change Institute, University of Oxford, United Kingdom
Tina Fawcett, Centre for Research into Energy Demand Solutions, Environmental Change Institute, University of Oxford, United Kingdom
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Panel
3. Policy, finance and governance

Keywords
energy demand, energy policy, quantitative survey, just transition, net zero

Historically, energy demand reductions have been the main driver of carbon emission reductions. However, there is concern that this contribution is not recognised, and that policymaking attention remains focused on the supply side. The current and potential future role of demand in energy policymaking is explored via surveys of energy experts and stakeholders in the UK (n>77), the Netherlands (n>54) and Germany (n>80).

In all three countries, the respondents identify some current policy support on the demand side, especially in the context of retrofitting. On the whole, however, they suggest that decarbonisation policies mainly support technological substitution, infrastructure investment and vector switching on the supply side. This focus, to the detriment of funding/finance and changing practices, does not appear conducive to a just transition to net zero. To help energy policy contribute to such as transition, the respondents support the Energy Efficiency First principle which entails a better balance between supply and demand solutions. While German respondents have a strong preference for technological solutions, UK and Dutch respondents support more policymaking emphasis on the demand side, especially through changing practices such as a modal shift to active travel. Overall, German respondents appear broadly content with current policy, Dutch respondents have the greatest faith in policymakers, and UK respondents are neither content with current policy nor do they have faith in policymakers. Despite these discrepancies, trends among responses from all three countries suggest that energy and climate policy solutions appear more suitable for decarbonisation than ensuring justice and fairness of the underlying socio-technical

transformation process. This suggests that both energy and non-energy policies need to be more closely aligned to gain more legitimacy and ultimately succeed in achieving net zero.

3-166-22: **Peer-reviewed paper**

Time to fan the flames of a climate-revolution? Turning care to activism

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Panel
3. Policy, finance and governance

Keywords
action, citizens

More and more experts are explicitly talking about the need to limit consumption. In the research community, efficiency is gradually being replaced by the concept of sufficiency. However, politicians are still hesitant to talk about limiting consumption. Also, we have not even managed to keep consumption on the same level with the current strategy of nudging and efficiency approaches rather than limiting consumption. A recent study showed that politicians do not use research to challenge their own opinions, but to support already made decisions. Hence, the research community does not have the "ear" of the politicians and the need to limit consumption therefore has little chance of becoming part of political agendas. However, after carrying out case studies involving end users, one conclusion is that it may be time for a shift away from the current path of nudging and acknowledge that the necessary shift may well require major societal changes. This paper uses data from studies involving eco-visualization and provotyping to explore citizens willingness to limit consumption. The first study explored the introduction of Automated Meter Reading (AMR) and how to communicate smart grid data to end users. Results showed that visualization may result in reflections, and disruptive communication can induce a willingness to limit consumption. However, it also revealed that when users are presented with the systemic structure of the national electricity net, an initial aha! experience was noticeable. This was then followed by a critical discussion that became quite heated. Hence, when people see the systemic connection, and are exposed to disruptive communication, they do not only understand the system, but also start to question the decisions made at a larger societal level. Results indicate that it may be time to address the citizens rather than the policy makers. A discussion and problematization on the consequences – and opportunities – of this approach follows.

3-187-22: Extended abstract

Energy savings in Article 7 of the Energy Efficiency Directive: What's next? Taking stock of EU institutional negotiations

Marion Santini, The Regulatory Assistance Project, Belgium
Samuel Thomas, The Regulatory Assistance Project, Belgium
Louise Sunderland, The Regulatory Assistance Project, Belgium
Jan Rosenow, The Regulatory Assistance Project, Belgium

Panel
3. Policy, finance and governance

Keywords
Energy Efficiency Directive (EED), energy efficiency obligation, fossil fuel, energy poverty, European Commission

In July 2021, the European Commission proposed a revision of the Energy Efficiency Directive, including significant changes to its cornerstone article, Article 7, on the energy savings obligation. In the revised version, this section is now Article 8.

The proposal would see the annual savings rate that Member States must achieve almost double from 2024 onwards. Significant changes would also affect the eligibility of policy measures, with a restriction from using fossil fuel technologies to achieve energy savings under Article 7/8. In addition, Member States would have to achieve a defined share of their energy savings target through people affected by energy poverty, vulnerable customers and, where applicable, people living in social housing.

The Commission proposed these major policy shifts as a response to the need to align energy efficiency policies with the new EU climate-neutrality objective. Now, EU legislators, the European Parliament and the Council of the EU must all agree on a common text.

We will take stock of negotiations in 2022, analysing the different proposals coming from the Parliament's main committees, as well as the different negotiation texts put forward by the Slovenian and French presidencies of the Council. Our aim is to look at how the options on the negotiation table respond to the EU's climate-neutrality goal.

3-206-22: Peer-reviewed paper

Alternative finance for net zero: the role of citizen finance in social housing retrofit

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Anna Watson, Science Policy Research Unit (SPRU), University of Sussex, United Kingdom

Panel
3. Policy, finance and governance

Keywords
financing, crowdfunding, building retrofitting, local authorities

The Declaration of ‘Climate Emergencies’ means Local Authorities (LA) need to bring forward low carbon infrastructure 'at pace' before 2030. There is also a desire to distribute benefits equitably within local communities to ensure transition'. This creates an impetus for ‘alternative finance’ beyond the traditional channels available to LAs. However, projects have different characteristics, with some directly generating revenue and others without financial returns. Based on recent case studies with two UK local authorities, Lewes and Eastbourne, and a Welsh housing association, this paper will explore and develop a range of alternative finance mechanisms for decarbonisation, including those specifically designed for social housing retrofit. We then explore the prospects for these mechanisms and their policy implications.

3-235-22: Peer-reviewed paper

Towards more Inclusive actor engagement in energy law, policy, and governance for a just transition

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Panel
3. Policy, finance and governance

Keywords
energy efficiency policy, governance, agency, emerging technologies, energy law, transition, sustainability, just energy transition

The climate crisis is a major driver for the just energy transition to smarter, greener, accessible, and fairer energy systems. Greater engagement with key actors in energy systems is an imperative in the regulation and management of energy resources, activities, and investment. Law and policy are fundamental to facilitating this. Managing energy demand is a significant challenge to energy stakeholders. Energy laws, therefore, need to be innovative in engaging all relevant agents in energy systems. It may also be necessary to: broaden the perspective of who the legally-recognised stakeholders are and assess their participation in law-making and policy-formulation processes for enhanced energy efficiency and sufficiency strategies. This raises key questions on managing energy demand for a decarbonised energy future: Who is legally mandated to enter into binding arrangements for energy efficiency and sufficiency? What are the energy law and policy objectives? Would more inclusive decision-making processes make current energy law frameworks more effective? Who has the capacity for sustainable energy investment? Should emerging 'smart' technologies gain legal recognition as regulated entities? Are emerging technological innovations discordant with law and policy developments? Traditionally, nation states and governments have been the designated sovereign entities that formulate energy law and implement policy. However, there is an expanding range of emerging influential actors in energy systems. New energy efficiency and energy sufficiency collaborations could be crucial to sustainably reformulating aspects of modern life like housing, transportation, and industry. The Covid-19 pandemic demonstrates the need for enhanced multi-stakeholder co-operation and behaviour change. This paper proposes that law, policy, and technology are major tools for accelerating decarbonisation strategies and must, therefore, evolve to include new agents of change.

3-250-22: Peer-reviewed paper

Italian white certificates: a first glimpse on the effects of the new guidelines introduced in 2021

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Livio De Chicchis, FIRE - Italian Federation for the Rational Use of Energy, Italy

Panel
3. Policy, finance and governance

Keywords
tradable white certicates, white certificates, energy efficiency obligation, energy efficiency policy

The Italian White Certificates scheme (WhC) was introduced in 2001 and has been effectively working since 2005. It has been characterised by the coverage of all sectors and energy efficiency solutions, and many flexibility options in place (e.g. non-obliged – a.k.a eligible – parties, tradable market for white certificates, bankability, flexibility on obliged parties targets, etc.).

With more than 29 million tonnes of oil equivalent (toe) of energy savings cumulated by the end of 2021, it has considerably contributed to the national energy efficiency targets.

The scheme has undergone important changes first in 2012, then in 2017, both for the targets and the operating guidelines. These modifications, combined with energy market developments, resulted in a reduced capability of producing the expected certificates and in an increasingly shorter WhC market that resulted in rising prices, thus putting at risk both the compliance with the targets and the operation of the scheme itself.

For this reason, a deep revision of the scheme was introduced in 2021, trying to solve and overcome the risk of collapse and to relaunch the scheme in accordance with the National Energy and Climate Plan.

The paper will illustrate the main changes of the scheme guidelines, the reason why they were adopted, and the first results of their application over one year from their introduction.

3-262-22: Extended abstract

Are economic assessments provided in the EPBD and EED compatible with long-term climate targets?

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Mariangiola Fabbri, BPIE, Belgium
Marcus Hummel, e-think, Austria
Iná Maia, TU Wien, Austria
Andreas Müller, e-think, Austria
Hélène Sibileau, BPIE, Belgium
Jan Steinbach, IREES, Germany

Panel
3. Policy, finance and governance

Keywords
cost benefit, cost-effective measures, Energy Efficiency Directive (EED), Directive on Energy Performance in Buildings (EPBD)

The EPBD and the EED ask Member States to carry out economic calculations to frame their energy efficiency policies: the EPBD foresees cost-optimality calculations for setting energy performance standards; the EED requires Member States to carry out a comprehensive assessment of efficient heating and cooling, including a cost-benefit analysis. In this paper we will analyse and discuss the following question: Is the way how these calculations were carried out by different Member states (in different periods) compatible with and supportive of the target of full decarbonisation and associated principles such as energy-efficiency-first? Do they need to be revised and reframed in order to ensure compatibility with the overall policy framework? Are the cost-optimality and cost-benefit analyses provided in the EPBD and EED as such compatible with the overall, long-term policy framework?

We start with identifying key principles that can be derived from the existing long-term policy framework. One of them is that a scenario reflecting a system still relying on fossil fuels is not a reference point compatible with a decarbonised future. As a second step, we carry out a comparative analysis of underlying assumptions in the economic calculations being done in selected countries. Third, we show the impact of some of these assumptions by exemplary calculations by the means of sensitivity calculations. Preliminary results show that in a significant number of the past economic assessments carried out in the EPBD and EED fossil fuels still play a strong role as reference scenario. The assumptions on fossil energy prices and possible CO2-prices frame the results. We discuss the implications of a fully renewable reference system in the framing of the economic analyses and the possible impact on policy conclusions. We close with recommendations on the further development of these provisions, also discussing the newly adopted revisions of both directives in this context.

3-265-22: **Peer-reviewed paper**

Climate City Contract as an innovative governance tool for the Mission on Climate-Neutral and Smart Cities

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Emina Pasic, Energimyndigheten, Sweden
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Panel
3. Policy, finance and governance

Keywords
governance, climate policy, climate action plan, climate city contract, Climate-Neutral CIties

Climate transition puts the traditional organization and governance of our societal institutions as well as our democratic system on the edge. To cope with the radical transition that we need in a short amount of time, the EU Mission Climate-Neutral and Smart Cities emphasizes the need for increased cooperation between local authorities, citizens, businesses, investors, as well as regional and national authorities. Therefore, the Mission aims to deliver 100 Climate-Neutral and Smart Cities by 2030 and ensure that these cities act as experimentation and innovation hubs to enable all European cities to follow suit by 2050.

To achieve these aims the Swedish Innovation Programme Viable Cities has developed the Climate City Contract as a tool for system transformation and governance innovation. The Climate City Contract is a signed agreement of joint forces by local and national authorities. Starting with nine Swedish cities signing the Climate Contract in 2020, there are now 23 cities that together with the Swedish Energy Agency, Swedish Innovation Agency (Vinnova), the Swedish Research Council for Sustainable Development (Formas), the Swedish Agency for Economic and Regional Growth and The Swedish Transport Administration work in a co-creative and interactive learning process to find joint ways to accelerate climate transition.

Cities are the place where decarbonization strategies for energy, transport, buildings and even industry and agriculture coexist and intersect. The climate emergency must be tackled in a holistic view including health and social aspects within cities and by engaging citizens who are not only voters but also users, producers, consumers and owners.

These new forms of multi-level governance and co-creative collaboration processes put research and innovation into a new role aiming to build a common ability to meet major societal challenges and to unlock our full potential as people at a time of both digitization and automation. In this paper we will present our first experiences and learnings working with the development of Climate City Contract as a new innovative governance tool.

3-284-22: Peer-reviewed paper

From Kyoto to Paris and Glasgow: overview of international climate agreements and regimes, their limitations, and the role on energy efficiency and sufficiency

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Panel
3. Policy, finance and governance

Keywords
climate change mitigation, international negotiations, Kyoto Protocol, Paris Agreements, energy efficiency action plans, energy sufficiency, Climate justice

In 1988 the UN General Assembly defined climate change a “common concern of mankind”. In 1990, the IPCC’s first Assessment Report (AR) highlighted the impact of climate change and the need to have an international coordinated response. The United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992 established the United Nations Framework Convention on Climate Change UNFCC), and the subsequent regular Conferences of the Parties (COP). A major step forward in international climate agreements was Kyoto Protocol in 1997. The Protocol was based on the principle of "Common but Differentiated Responsibilities", with obligations only for developed countries. A rapid increase in emissions by fast growing countries, showed the limitations of the Kyoto Protocol. The Paris Agreement reached at COP 21 2015 is a major step forward in climate change negotiation with global engagement to limit global warming to well below 2 C. The Paris Agreement departs from the top-down approach of the Kyoto Protocol; it adopts a bottom up approach in which each country determines its contribution to reach the global target, through national determined contributions (NDCs), which shall be revised with the view of increasing the ambition every 5 years. Other important elements of the Paris Agreement are: the increased role of climate finance for developed countries, the role of non-state actors, and the “rule book” for GHG monitoring. Despite the Paris Agreement, the global emissions have continued to increase till 2020 and the current set of NDCs are not compatible with a 2C pathway.

The paper presents the key elements of the international climate agreements and their limitations, the lack of ambition of NDCs, the current conflicts and the latest agreement reached in Glasgow in 2021. Particular focus is on the role of energy efficiency and energy demand options including sufficiency in the global effort for GHG reduction and temperature stabilisation at 1.5 C.

3-285-22: Extended abstract

Moving Positive Energy Neighbourhoods beyond pilot projects

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Jessica Glicker, BPIE, Germany

Panel
3. Policy, finance and governance

Keywords
social innovation, urban planning, cities, climate policy, smart cities, community energy systems

The EU aims to be climate-neutral by 2050, which requires a full decarbonisation of our urban environments. A priority is to redesign and retrofit our buildings and neighbourhoods, making them future-proof, ensuring no adverse impact on climate change and with a minimised environmental footprint. One novel solution is Positive Energy Neighbourhoods (PEN), piloted in several EU funded projects, which are highly energy-efficient and flexible urban neighbourhoods, in which buildings, energy systems and mobility infrastructure work in harmony to achieve a surplus of renewable energy.

While there are several barriers holding back the development of PEN, there is a broad consensus they will play a key role in the transformation of our built environment. PEN needs to go from being a niche idea to become the new normal within the next decade. A successful PEN implementation builds on an integrated, engaging, and neighbourhood-based approach, bringing together multiple actors and objectives. Experiences from EU projects show that preparing and implementing PEN requires a high organisational capacity, which often is lacking in small and medium-sized cities.

This report provides an analysis of the current policy, legal and financial framework needed to enable the development of PEN, beyond EU pilot projects. It also discussed the role technical assistance (TA) can play in enabling local actors to carry out PEN. Given that PEN is a relatively new concept and involves a high degree of expertise to understand and implement, TA for local authorities will be essential in moving the idea from niche to normal.

The assumptions will be tested on the experience of two ongoing EU funded PEN pilot projects, (i) the OpenLAB project, which develops PEN innovation living labs in the cities of Genk (BE), Pamplona (ES) and Tartu (EE), and (ii) the Syn.ikia project which develops sustainable PEN demo cases in Santa Coloma de Gramenet (ES), Oslo (NO), Uden (NL) and Salzburg (CH).

3-298-22: Extended abstract

Energy efficiency auctions: a deep dive into the auction design

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Barbara Schlomann, Fraunhofer Institute for Systems and Innovation Research ISI, Germany

Panel
3. Policy, finance and governance

Keywords
governmental support, tender, cost effectiveness, cost efficiency, energy efficiency, auction

Market-based instruments (MBIs) for energy efficiency (EE) have started to gain traction in the EU and worldwide. So far, the two most commonly applied MBIs are energy efficiency obligation schemes (EEOSs) and auctions. While EEOSs have already a long track record, EE auctions are a rather emerging policy instrument. Thus, the existing literature focuses mostly on the comparison between EEOSs and auctions. Most studies of EE auction design are conducted on the country level, while general analyses on the impact of design choices are scarce.
Our presentation aims to close this gap by providing an overview and comparison of several EE auction designs and to derive first conclusions on the effects of design elements based on auction theory and on experiences of renewable energy (RE) auctions. In our analysis, we include EE auctions from Canada, Germany, Portugal, Switzerland, the UK, and the US.
EE auctions are employed by governments to allocate (investment-based) support for energy or electricity saving measures. Most countries opt to auction a certain budget, in contrast to RE auctions, where capacity is the major auctioned product. In EE auctions, support is usually paid out as a certain percentage of CAPEX. Furthermore, the support is usually capped at a certain percentage of CAPEX, e.g. 30% in Switzerland. To increase actor diversity, several segments in EE auctions exist. For instance, Switzerland has two different auction budgets, one for projects, i.e., larger, individual EE actions and programmes, which aggregate several smaller measures.

Usually, static, sealed-bid auctions are used, while pay-as-bid is the preferred pricing rule. While some countries have used multi-criteria auctions in the past, most countries switched to price-only auctions, which tend to lead to lower awarded prices. Price-only auctions usually award projects with the best cost-effectiveness, i.e. lowest support required per unit of saved energy. Furthermore, most countries require a certain minimum payback period (without support) for participating projects to ensure additionality of the support. The minimum payback period varies between 2 (Denmark) to 4 years (e.g., Germany). Although most EE auction schemes include a ceiling price, which ensures low prices even in absence of competition, the design varies significantly: in some cases, it is the absolute amount of support (e.g. in Switzerland or Germany), while sometimes it is defined as a bid price. In contrast to RE auctions, strict (non-performance) penalties are absent from most EE auctions, which can lead to low realisation rates of projects. Another characteristic design element of EE auction is the automatic volume adjustment. This mechanism adapts the auctioned budget/volume downwards to create competitive pressure in case of few submitted bids.

We find that many EE auctions lack competition, which leads to two challenges: the low competition can lead to higher awarded prices (close to the ceiling price), as well as to low effectiveness, i.e., governments might not be able to procure the targeted energy savings. To increase competition, policymakers should abolish "outside options", i.e., parallel funding opportunities and decrease the minimum payback period to increase the number of eligible EE projects. While volume adjustments increase the level of competition (artificially) in the short-term, the mid- to long-term effects need to be further investigated. Research in RE auctions shows a negative impact on the overall project supply and thus on the effectiveness in the longer term. Another challenge of EE auctions are the low realisation rates. Therefore, policymakers should consider carefully introducing non-performance penalties and financial prequalification criteria in EE auctions, a common design element in RE auctions. With regard to the practical implementation of the energy first principle, we also recommend to examine joint auctions for energy efficiency and renewable energies.

3-303-22: Peer-reviewed paper

Organizing energy sufficiency: a framework to envision and foster energy sufficiency at a territorial scale

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Julie C Mayer, Ecole polytechnique, France

Panel
3. Policy, finance and governance

Keywords
sufficiency, territories, organization designing, scaling up, energy policy

While energy sufficiency is acknowledged as a cornerstone of the energy transition, the potential paths and conditions for its development at a large scale remain mainly unknown. Existing attempts to operationalize sufficiency often exclusively focus on reducing energy consumption at the individual level (e.g., by promoting eco-gestures for domestic households). This calls for a more holistic approach to energy sufficiency, to help policy makers envision and deploy the potential of energy sufficiency at an aggregative level.

Drawing on the theory of organization designing, we develop a framework that defines energy sufficiency as a way of organizing energy uses by searching for enough-ness. We show that organizing sufficiency encompasses the designing of three dimensions: i) desirability conditions that reflect a collective understanding of what “enough” means; ii) organizing practices that foster the moderation of energy uses; and iii) mechanisms of value creation that generate, capture and distribute the positive effects of sufficiency.

We illustrate how this framework can help define, implement and evaluate energy sufficiency in the Ile-de-France territory. We apply our three dimensions to reveal the territorial characteristics and dynamics that can lead to a “desirable” vision of sufficiency; the variety of potential practices triggered by various stakeholders; and some concrete strategies that generate economical, social or environmental value for the territory.

Our framework contributes to reveal the underlying conditions for the dissemination and scaling-up of energy sufficiency, while integrating concerns of social justice. This paper calls for better efforts to bring coherence between territorial roadmaps, by envisioning sufficiency beyond energy and climate policies (including urbanism, mobility, agriculture, industry, education, employment). It provides practical insights to federate a plurality of actors toward a shared project of energy sufficiency.

4-012-22: Peer-reviewed paper

Identifying the case for next generation energy performance certificates

David Jenkins, Heriot Watt University, United Kingdom
Sally Semple, Heriot-Watt University, United Kingdom
Peter McCallum, Heriot Watt University, United Kingdom

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy performance certificates, Energy Performance of Buildings Directive (EPBD), energy assessment

The 2003 Energy Performance in Buildings Directive (EPBD) resulted in EU member states formulating standardised responses to grading and assessing the energy performance of their building stock. The 2018 update of the EPBD raised the possibility of using Energy Performance Certificates (EPC) for new metrics and applications, placing the challenge of upgrading our built environment under greater scrutiny. This includes attempting to quantify the "smartness" of buildings, as gauged by a "Smart Readiness Indicator", but it also raises the question of where EPCs should go next – and, by extension, what can we reliably do with current EPC frameworks across Europe? Can new challenges, and targets, of a decarbonised building stock be met within the current scope of EPCs?

The €2M Horizon2020 crossCert project aims to test a sample of buildings across Europe using the responses of different countries to the EPBD. In doing so, the project will i) identify differences in approaches to EPC assessment, ii) report on the impact of these differences for the same building sample, iii) use this analysis to propose new, "next generation" EPC approaches and iv) test out these new approaches with target user groups to better understand their potential.

This study will document the current variations of EPC frameworks across Europe and compare those with proposed next-generation EPC approaches from a range of European projects, including the above. To understand the argument for a different approach, this research will reflect on the changes that have occurred since the EPBD was first introduced, including improved access to high-performance building simulation and empirical energy data, new (e.g., heating) technologies reaching mass market, and the requirement of these simple energy rating calculations to enforce mandatory action, rather than provide advisory guidance.

4-015-22: Peer-reviewed paper

Effective energy saving policy requires causal evidence

Kees Vringer, PBL Netherlands Environmental Assessment Agency, The Netherlands
Daan van Soest, Tilburg University, The Netherlands
Mirthe Boomsma, Tilburg University, The Netherlands

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
evaluation methods, smart metering, energy policy, impact evaluation, causal evaluation practises, residential energy conservation

Residential energy use is the source of 15–20 % of CO2-emissions in the Netherlands. Reaching the Dutch and European climate goals is impossible without a substantial decrease in household energy consumption. Previous research documented that feedback on one's household's energy use, based on smart meter data, can induce energy savings. However, effective energy savings due to the wide enrolment of the smart meter were in the Netherlands much smaller than expected: about 0.9 % for only natural gas (the main source of residential heating in the Netherlands) and no savings for electricity, compared to a predicted 3.5 % reduction for both. To close this gap of about 2.7 % savings, the Dutch government and energy companies decided to improve the already widely used Home Energy Reports (HERs), a form of feedback, delivered bimonthly via mail or email. Unfortunately, the revised monthly HER did not lead to higher energy savings, as proven by a large Randomized Controlled Trial (RCT). To illustrate the importance of methods to get robust insights into energy saving effects like RCTs for evidence based policy making, we present in this paper impact estimates of three different feedback mechanisms – an app, email, and an In Home Display (IHD). Impacts were measured using RCTs, implemented in the Netherlands. Our results confirm earlier findings that feedback is effective if it is real time and continuously visible. For a simple IHD applied in the Netherlands we found savings of more than 2 % for electricity and nearly 7 % for natural gas. Our research also illustrates that impact estimates from observational studies and field-experimental evidence are sensitive to the country-specific environment, as impacts measured abroad can differ substantially from those that are materialized in the Netherlands. The use of causal ex-ante impact analyses, like RCTs, implemented in the country context and among the target population, is indispensable for evidence based policy making.

4-034-22: Peer-reviewed paper

Use of energy performance certificates for realistic prognoses – A method to calibrate the national calculation procedure by the average actual consumption

Tobias Loga, IWU - Institut Wohnen und Umwelt (Institute for Housing and Environment), Germany
Britta Stein, IWU - Institut Wohnen und Umwelt (Institute for Housing and Environment), Germany

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy performance certificates, existing residential buildings, metering, energy efficiency gap, statistics, prognosis model, calibration

The calculation models of Energy Performance Certificates (EPCs) are designed for energy rating and for proof of compliance with regulations. Their principles are comparability, replicability and verifiability. To ensure this, a national EPC procedure typically uses the same boundary conditions for all buildings, similar to a test bench in a laboratory: From the variety of indoor conditions found in practice a specific set is selected and applied. Particularly in unrefurbished old houses also the thermal characteristics of components are uncertain so that many assumptions are needed for the performance calculation. In consequence, larger differences between theoretical and actual energy consumption can be expected for single buildings, and also systematic deviations, when a large number of existing buildings is considered. The idea of this article is to quantify the deviations and use this information to calibrate the EPC output and thus provide realistic estimates of the actual consumption.

The empirical basis of the proposed method is a building sample of various energy performance levels. For all buildings the floor-related values of the calculated and of the measured energy use are combined to pairs. Since the absolute consumption variance of unrefurbished houses is much larger than that of refurbished, a precondition for linear regression is not fulfilled. In consequence, a logarithmic transformation of the variables is applied in the forefront of regression. The implementation of such analysis on a sample of about 2800 residential buildings in Germany is presented. The result is a function that assigns the average actual consumption and the typical spread to a given EPC calculation result. Examples show how the model can be used to interpret different actual consumption values resulting from different household sizes and utilisation

intensities in similar unrefurbished buildings and to estimate the probable span of energy consumption after refurbishment for these different cases.

4-052-22: Extended abstract

Ex-post evaluation of neighborhood projects within the German National Climate Initiative

Katja Schumacher, Öko-Institut, Institute for Applied Ecology, Germany
Victoria Liste, Öko-Institut
Dominik Jessing, ifeu
Lisa Muckenfuß, ifeu

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
evaluation, community, information, climate policy, neighborhood projects

The German National Climate Initiative (NCI) is part of Germany's climate strategy. It aims at stimulating behavioral change and investment in different target groups and areas that have not yet been tapped by other instruments. It covers a wide range of projects ranging from direct investment support for technologies to informational and educational programs.

This paper presents the evaluation of the support program "shortcuts to combatting climate change" which is funded by the NCI and addresses initiatives to conduct climate change projects at the neighborhood level. It funds collaborative activities for everyday actions of citizens by bringing together different actors, initiating local initiatives, reducing barriers and setting examples for multiplication and imitation.

Between 2016 and 2019, more than 100 projects in Germany were funded with just over €9 million. The evaluation reveals a high transformation potential for these projects resulting from the involvement of local actors and target groups and the direct reference to everyday activities. Many activities are able to continue beyond the funding period on the basis of the acquired skills and structures. One obstacle to successful implementation is the high administrative burden, especially for grant recipients with no previous experience in applying for funding.

The importance and success of the program is widely accepted and qualitatively shown by the evaluation. Yet, the evaluation of the quantitative impact on GHG emissions reduction faced severe challenges. Reasons include lack of data, complex impact chains and lack of monitoring capabilities and capacities by the mostly volunteer-based project implementers. GHG reduction effects were thus only calculated for a limited number of projects, specifically for cargo bike initiatives and food sharing projects. The question remains how to scientifically assess and communicate the contribution of these project to climate change mitigation.

4-070-22: Peer-reviewed paper

Assessment of perceived legitimacy in policy evaluation applied to Dutch Regional Energy Strategies

Astrid Martens, Netherlands Environmental Assessment Agency, The Netherlands
Kees Vringer, Netherlands Environmental Assessment Agency, The Netherlands
Jarry T Porsius, Netherlands Environmental Assessment Agency, The Netherlands

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy policy, transition, perceived legitimacy, policy acceptance

Large-scale changes in society are needed to achieve the policy goals for a transition to a sustainable energy system in the Netherlands. In a democratic system such goals can only be achieved when policy is accepted by the population. Most previous studies have investigated which factors influence the acceptance of local wind farms where self-interest can play a dominant role. But for national policy it may be just as important to better understand which policy characteristics affect citizens' perceived legitimacy, based on public interest, of plans to generate more solar and wind energy at the national level. In the present study we examined this in the context of the Dutch Regional Energy Strategies (RES). The RES are local decision processes to determine where wind turbines and solar parcs are going to be placed in 30 Dutch regions before 2030. We identified 7 factors that may affect the perceived legitimacy of the RES plans. We tested the effects of the 7 actors in a vignette study with a representative sample of Dutch citizens (n=2729). The results show that 6 out of 7 factors had a statistically significant effect on the perceived legitimacy of the presented plans in a random intercept model. The strongest effects on the perceived legitimacy were observed for citizen participation (B=-0.89 for full participation vs. no participation) and the impact on landscape (B=-0.87 for low impact on cost vs. low impact on the landscape) on an 11-point scale (1=fully unacceptable, 11=fully acceptable). The model-based estimated legitimacy score for the least legitimate scenario in the eyes of citizens was 3.75 vs. 7.57 for the most legitimate scenario. This implies that if policy makers find the perceived legitimacy of local sustainable energy generation to be important, they should consider the set of criteria for policy legitimacy we have studied. This study also showed that our approach is feasible for (ex-ante) policy evaluations, taking into account a broad set of evaluation criteria.

4-074-22: Peer-reviewed paper

How to ensure proper participation in the monitoring of a voluntary scheme: The example of energy efficiency networks in Germany

Clemens Rohde, Fraunhofer Institute for Systems and Innovation Research, Germany
Lisa Neusel, Fraunhofer ISI
Miha Jensterle, adelphi
Anton Barckhausen, adelphi

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy efficiency networks, voluntary agreements

Monitoring and evaluating of energy efficiency policies is crucial to understand their impacts. These impacts can be the direct impacts, in particular on energy use but can also cover wider impacts such as changes in corporate culture and decision making.

Over the last years, energy efficiency networks have become a successful instrument to integrate energy efficiency into corporate culture and to foster the uptake of energy efficiency measures in companies. Building on the leading example of Switzerland, Germany has become the largest operator of energy efficiency networks in the World. The German approach is built on a voluntary agreement between the major industrial organisations and the federal government. The monitoring is carried out by an independent institute.

As the scheme is completely voluntary (compared to other "voluntary" schemes, which offer counter-values for the participation), monitoring has its specific challenges. For the participating companies, the added value of participation in the monitoring process is often unclear. The motivation to provide detailed data can be rather low. In particular, when it comes to a detailed verification of the implemented measures,significant efforts have to be made to stimulate an active contribution. The Corona crisis with its multiple impact on business has not made the process easier.

Within our paper, we will describe and analyse the challenges of the monitoring process with regard to the specific conditions of a purely voluntary scheme. We will also show the impact of the Corona crisis on the operation of the energy efficiency networks based on a survey conducted among participating companies. Finally we will present the results of the monitoring process and analyse them with regard to the aforementioned boundary conditions.

4-083-22: Peer-reviewed paper

Load monitoring at a short time step to set up actions: a feedback from the USER project on the Réunion Island

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Guillaume BINET, EDF R&D, France

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
Specific electricity, Power demand monitoring, evaluation methods, efficiency

The context of the French overseas territories is particular. Those territories are off the main grid. This implies relying on an expensive and CO2 rich energy mix for electricity generation. Nevertheless, the tariff equalization mechanism keeps the price of the kWh exactly the same as the one in France mainland. The difference is covered by a tax paid by all the French consumers.

In such a context, the benefits of reducing the consumption of electricity are even more relevant. To do so and set up the appropriate actions and policies, a local knowledge is needed.

USER (Usages Spécifiques de l'Electricité à la Réunion) is a three-year project (2019-2022) funded by the French environmental Agency ADEME. USER aims at improving the knowledge about the households' use of electricity for their appliances on the Réunion Island. A deep understanding of the Island households is the path to success for relevant actions that will be accepted and preserve as much as possible the wellbeing and the local ways of life.

In this paper, we will present the project and discuss the main results of two of its parts. A quantitative survey focusing on the knowledge of the Reunion households' appliances and a monitoring campaign conducted on a sample of 45 Réunion Island households. Their cold appliances were targeted in the first place because they remain a major electricity consumption but not only. Up to five appliances were separately monitored for each participant. Active power was recorded every six seconds during a whole month. In contrary to simple energy measurement, this short time step allowed us to see precisely what is really happening at the appliance scale: is there a malfunction? Is the use intensity too high?... Results from these analyses provide insights for local decision-makers (ADEME and EDF Réunion) to address households in a tailored manner. Main intervention included replacing the appliance or giving the right advice to optimize its use.

4-087-22: Peer-reviewed paper

Minimizing free riders, supporting home-owner associations and reaching low-income households: an evaluation of a Dutch subsidy scheme

Vera Rovers, TNO, The Netherlands
Renee Kooger, TNO
Casper Tigchelaar, TNO
Lydia Geijtenbeek, CBS

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
subsidies, homeowner associations, free riders, low income, energy efficiency measures, residential buildings, microdata analysis, insulation, energy poverty

The Dutch Subsidy scheme for Energy Saving in Privately Owned Houses (SEEH) supported home-owners and home-owner associations (HOAs) to insulate residential buildings and ran between 2016 and 2020. When a plot of land, or an existing building, is divided into different apartments a home-owners association (HOA) is automatically set up in the Netherlands. The individual apartment owners automatically become members of this HOA. We evaluated the scheme on various aspects using different methodologies, including data analysis, micro data analysis and the use of in-depth interviews in order to distil valuable lessons for the design of subsidy schemes in general.

Using data analysis, the effectiveness of the scheme was evaluated to calculate the total energy efficiency savings and CO2 emission reductions. 65,000 home-owners and 363 HOAs received a subsidy for installing energy efficiency measures. The theoretical energy savings from these measures have been calculated using a building physics model. Altogether, these measures have, and will continue to save 0.9 petajoule more then would have been the case without the SEEH. This results in annual emission reductions of 52 kiloton CO2.

Three specific elements that policy makers put in the Dutch SEEH scheme stand out: minimizing free riders by setting stricter criteria, supporting home-owner associations and reaching low-income households. In this paper we will discuss how successful the scheme was in relation to these elements and we will provide recommendations for policy makers for designing successful future subsidy schemes.

Free riders in this case are home-owners that planned to install insulation measures regardless of whether or not subsidy is available for them. These home-owners would have saved energy and

reduced emissions with or without the subsidy, so there is no or less additional effect of the subsidy on energy consumption. Our analysis shows that the share of free riders in the SEEH scheme has been limited to 38 % by requiring at least two measures with a minimum surface area to be taken in order to be applicable for subsidy. These strict requirements were implemented after an ex-ante study showed that otherwise the additional effect would have been negligible. Based on this experience we recommend to always make a detailed analysis before a subsidy scheme is implemented to increase its additional effect.

In-depth interviews with representatives of HOAs revealed that the SEEH scheme by itself was often not enough to realise energy efficiency investments in multi-family buildings. Most HOAs were only able to undertake energy efficiency measures when combining the subsidy with a government loan initiative. Also, the process for approving energy efficiency measures within HOAs takes years, and the time period for implementation allowed by SEEH was considered very short by the HOAs. A better tailored set of financial instruments, available over a longer period of time, therefore seems to be key to support HOAs in the implementation of energy efficiency measures.

Finally, we collaborated with Statistics Netherlands (CBS) who has many datasets available at the level of individuals, businesses and addresses. These microdata can be combined with external data which we have done in this evaluation by linking tax statements to applicant data of the subsidy scheme. This microdata analysis improved our understanding of the dataset and provided new insights into the inclusiveness of the scheme. The analysis showed that lower income households were less likely to apply for subsidy. Home-owners in the highest income decile applied for the SEEH subsidy twice as much as households in the lowest decile. If a subsidy scheme wants to target low-income households, for example to reduce energy poverty, it should be investigated how the conditions of the scheme affect different target groups and how low-income households can best be supported. Options that could improve participation by low-income households include raising awareness, providing services, increasing the subsidy amount and offering assurance in advance on how many subsidy one will receive.

4-093-22: Extended abstract

How climate change affects the energy use for space cooling in Dutch dwellings

Vera Rovers, TNO, The Netherlands
Robin Niessink, TNO
Marijke Menkveld, TNO

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
space cooling, residential buildings, air conditioning, climate change, cooling behaviour

The Netherlands are not well known for high temperatures during summer. However, the country has experienced numerous hot days in the past couple of years leading to a sharp increase in the purchase of air conditioners. Recent numbers suggest that an air conditioner is already present in at least 15% of Dutch households. Information, however, is lacking to determine the actual cooling demand as well as the resulting energy use for space cooling, now and in the future. TNO has therefore started to research two aspects related to this: the change in future cooling demand due to climate change and the cooling behaviour of residents.

In cooperation with the Royal Dutch Meteorological Institute we determined an outdoor temperature profile on an hourly basis for the year 2030 and 2050. These climate scenarios were added to a physical heat balance model that calculates cooling profiles of houses. The model translates the outdoor temperature and solar irradiation to an indoor temperature and, when it rises above a certain threshold, into a cooling demand for the building. First results indicate that the cooling demand of a newly built terraced house with a set point temperature of 24 °C would rise 7% in 2030 and 17% in 2050.

To translate the cooling demand into an estimate of the energy use for space cooling, the model requires information about residential cooling behaviour. In the autumn of 2021 we conducted a survey asking participants if and how they used cooling appliances, like an air conditioner or a borehole heat pump, at home. Questions included which rooms they cooled, at what time of the day and at what temperature they set the system. Households that don’t have cooling yet were asked under what conditions they would consider purchasing a cooling system. Results of the survey are currently being analysed.

4-100-22: Peer-reviewed paper

Toward residential upgrade savings guarantees: An AMI-based diagnostic interface

Ethan Goldman, Resilient Edge, USA
John Theurer, Zither Labs, USA
Stephen Bickel, LibertyHomes, USA

Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
advanced metering, analytics, weatherization, HVAC

Residential weatherization and HVAC programs often struggle to deliver 100 % realization rates, but Inclusive Utility Investment programs such as Pay As You Save® (PAYS®) face a steeper challenge: to ensure that, barring changes in behaviour or new load, participants will all enjoy net bill cost savings. There are five primary reasons that expected savings are not fully realized even after weather-normalizing and adjusting for fuel cost changes: 1) changes in usage behaviour, 2) installation of appliances, 3) overestimated savings, 4) upgrades were not properly installed, 5) unrelated equipment failure. Even programs that deliver high energy savings realization rates will, due to the unavoidable occurrence of causes 1 and 2, will include projects where post-upgrade net energy savings are less than estimated and do not fully cover the fixed cost-recovery payments that are a feature of these programs. Although PAYS programs do not offer a savings guarantee, future Inclusive Utility Investment programs that wish to do so will need a means to manage that risk or at a minimum quantify the associated monetary risk so that it can be accounted for in program budgets.

In their quest to ensure that all participants are saving money, a rural electric cooperative is testing a new diagnostic tool designed for residential upgrade programs. The system is built on top of the open standard CalTRACK methods and provides physically meaningful model outputs such as changes in heating and cooling loads and balance points. This paper opens the hood of this new tool, showing how it analyses the hourly electric AMI data to generate charts and metrics that can automatically flag projects for review and help to identify what types of issues could be impacting performance. This paper also explains how the diagnostic system can identify early signs of potential deficiencies, such as misconfigured HVAC controls, determine if a fix is needed, and verify that any such issues are effectively remediated.

4-142-22: Peer-reviewed paper

Five actions fit for 55: streamlining energy savings calculations

Kelsey van Maris, VITO, Belgium
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Carlos Patrão, Institute of Systems and Robotics, Dep. of Electrical and Computer Engineering, University of Coimbra, Portugal
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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
Energy Efficiency Directive (EED), Art. 3 and 7 EED, energy saving assessment, energy savings calculation, deemed savings, energy efficiency obligation

The "energy efficiency first principle" is key when defining energy policies and making relevant investment decisions within Europe to encourage actions in energy efficiency and energy demand management. In a first round, the H2020 project streamSAVE targeted five Priority Actions or measures with high energy savings potential and being considered as priority issues by the Member States. The project streamlines energy savings calculations, in frame of Article 3 and 7 of the Energy Efficiency Directive (EED) covering energy efficiency targets and national energy savings obligations, respectively. Given the importance of deemed savings approaches in Member States' EED reporting, streamSAVE focuses on bottom-up calculation methodologies of standardized technical actions.

Despite their high energy savings potential, policy officers indicated that a lack of experience, practices and reliable data sources is hindering the adoption of the following Priority actions by several Member States: Heat Recovery; Building Automation and Control Systems (BACS); Commercial and Industrial Refrigeration Systems; Electric Vehicles and Road Lighting. The project developed standardized calculation methodologies and provided EU-wide indicative values for each of these Priority Actions. These bottom-up approaches for calculating energy savings consider all essential impacts on the energy consumption of an appliance or system (e.g., equipment efficiency, operating hours) and compare the baseline scenario with the situation after implementation.

This paper presents the developed methodologies, considering Article 3 and Article 7 reporting requirements as well. Moreover, lessons learned, collected during the testing and validation of the

methodologies when translating the streamSAVE methodology guidance into Member States' EED practices, are explained to illustrate the role of standardized calculations in supporting energy efficiency policy.

4-181-22: Extended abstract

Can energy social innovation improve energy justice and energy equality standards? An evaluation of ten European cases

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
social innovation, energy justice, energy equality

A just energy transition requires due consideration of the potentially negative social implications that vulnerable groups might suffer in the process of transitioning from fossil fuels to renewable energy sources in European societies.

In order to counterbalance these possible negative outcomes, innovative policy schemes delivering simultaneously social and environmental co-benefits could be devised to favour a locally inclusive transition.

The H2020 SMARTEES project (2018–2021) has researched energy social innovations (SIs) across several case clusters regarding sustainable mobility, energy efficiency and energy poverty in neighbourhood regeneration, and renewable energy in islands.

The qualitative and quantitative data collected through semi-structured interviews, workshops and surveys were analysed in an energy justice perspective centred on the concept of energy equality.
We evaluated the interventions carried out in the SMARTEES SIs cases of Malmø, Stockholm, El Hierro, Samsø, Aberdeen, Timisoara, Vitoria-Gasteiz, Barcelona, Zurich and Groningen and while we found that SIs schemes appeared to increase energy justice and energy equality generally, some critical areas were identified, which led to outline several policy recommendations aiming at strengthening procedural, distributional and recognition justices through suitable energy SIs designs.

Regarding distributional justice, in the SMARTEES cases, financial resources played an important role in enabling the SI's, in the sense that if the necessary public funding was lacking, the actions taken would not be possible, and the SI would not be started or implemented. Thus, appropriate financial solutions should consider a differentiated pattern of managing and consuming energy between low- and high-income households. In this regard, it is worth distinguishing between financial resources benefiting low-income households directly and indirectly; both are useful, but the former has a greater impact in addressing distributional injustices and should always be included in any social innovation project that wishes to address effectively such injustices. Hence improving distributional justice through SIs requires adequate public finances and carefully considering socioeconomically diverse target groups.

In terms of procedural equality, the social innovation cases considered show that substantial benefits can be accrued from the active participation of citizens in the social innovation, particularly when citizens are consulted or even involved in a co-creation process. A process of consultation and co-creation generates a better understanding of the aims of the SI and gives citizens the chance to make their voices heard, and their preferences stated. It allows promoters to understand underestimated barriers or neglected citizens' needs to be addressed to develop a successful SI project. Therefore, strengthening procedural justice in SIs schemes necessitates local policies encouraging citizens' early-stage consultation and co-creation and providing seed funding for fostering citizens-led SIs.

Recognition justice, or the fair representation of vulnerable groups, implies knowledge about the specificities of groups living in neighbourhoods. First of all, it requires acknowledging the needs, rights and experiences of vulnerable individuals, households and groups affected by energy decisions. Some particular social groups require greater amounts of energy to satisfy their basic needs than other groups, such as the elderly or disabled. Secondly, attention must be paid to which groups are "privileged" and which are "ignored". Hence, improving recognition justice in energy SIs entails vulnerable groups having their needs recognised and accounted for and, if necessary, adopting targeted approaches of engagement that are mindful of cultural and social differences.

4-182-22: Peer-reviewed paper

Residential energy and carbon management system for a city and a nation

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Misaki Fujiwara, Osaka University, Japan
Toshiki Nakanishi, Osaka University, Japan
Yohei Yamaguchi, Osaka University, Japan
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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy management system, simulation, statistics, smart metering, national energy efficiency action plans (NEEAPs), bottom-up simulation, residential sector

A digital twin model for energy and carbon management of the building sector, both nationally and at the city level, is developed. The model consists of the following three tools: 1) a bottom-up, end-use energy simulation model that replicates the energy demand determination mechanism, 2) individual statistical data that explain the relationships between household/building characteristics and appliance ownership/energy-saving behavior, which enables the model to consider the heterogeneity of households and buildings, and 3) smart meter data that can be used to analyse the energy efficiency progress of households and buildings. The concept of an energy/carbon management system is introduced and the progress of the Japanese Plan for Global Warming Countermeasures (PGWC) is assessed. A distinctive feature of the Japanese PGWC is that it clearly identifies the target diffusion amounts for each countermeasure technology. To simulate Japan's residential sector, a representative sample of 0.03 % of Japanese households is randomly selected, and various characteristics, including the number and attributes of household occupants, the thermal performance of the residential building, occupant ownership and use of home appliances, and the type of water heater and space heating equipment, are used to accurately reflect population heterogeneity. With these data, together with weather data for the target years, the annual energy demand of the Japanese residential and non-residential sectors is simulated for 2013-2019. In the residential sector, the impact of differences in weather conditions is found to be substantial, reaching a maximum of 50 %. For the non-residential sector, the effect of weather differences is relatively small. The effect of the government's energy efficiency measures as estimated by the simulation is smaller than the government estimates for both the residential and non-residential sectors, and is well below the government’s 2019 target.

4-185-22: Extended abstract

Global assessment of appliance energy efficiency standards and labelling programmes achievements 2021

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
minimum energy performance standards (MEPS), energy labelling, energy efficient products, multiple benefits, policy evaluation, energy efficiency policy

Energy efficiency standards and labelling programmes have been cornerstones of many countries' energy efficiency policy for several decades. Over 120 countries have implemented or are developing mandatory standards and labels for a range of appliances and equipment. This retrospective study draws on a global review of nearly 400 published reports, studies and papers covering more than 100 products – representing one of the most comprehensive datasets assembled on the topic to date.

It confirms that improvements to the energy efficiency of appliances and equipment are some of the lowest-cost options available today for reducing energy consumption and associated emissions, with typical society benefit/cost ratios of 4:1. Programmes that have been operating the longest, such as those in the United States and the European Union, are estimated to deliver annual reductions of around 15% of total current electricity consumption. These programmes provide net financial benefits to individuals and the community. Other benefits, including employment, product innovation, water savings, improvements in air quality and the reduction of public expenditure on health, add to the case for stronger standards and labels.

This study shows that EES&L programmes deliver large energy and cost savings, enabling the transition to a cleaner energy future. Evidence shows that EES&L programmes can deliver annual electricity demand savings on a par with the current annual production of renewable energy. Reflecting the increasing recognition of such benefits, EES&L programmes have continued to grow in quantity to a greater number of countries and in scope to include a wider range of appliances and equipment.

As products currently covered by these programmes replace the existing stock, the size of EES&L savings will grow naturally. By this process, even a 2% annual improvement in stock energy efficiency will result in almost a 50% reduction in energy consumed over a 30-year period.

For this to occur, policy makers must regularly update EES&L policies to keep them in step with technological improvements. This demands adequate resources to ensure due diligence, including industry consultation. As indicated by the benefit/cost ratios, governments can expect multiplicative returns on their investments in programme planning and delivery.
This assessment of the impacts of EES&L programmes are based on an examination of several hundreds of detailed programmatic evaluations across many countries. Further EES&L impact assessments that involve 'normalising' the results across different countries and programme types would be greatly improved if future programmatic evaluations were more uniform in both methodology and reporting.

In particular, we found that:
• The number of high-quality ex-post evaluations identified was rather limited, and these tended to be from those programmes that are longer running with good ongoing data collection strategies and a clear policy of undertaking ex-post evaluations.
• Many reports that appeared relevant could not be used for the more in-depth analysis because quantitative data was not reported at all or was only reported in a way that could not be converted into a form suitable for international benchmarking and comparisons.
• Few reports examined in any detail the issue of attribution of claimed energy savings. Attribution can be quite important where there are several programmes that overlap and/or where there is rapid technology change driven by factors unrelated to energy efficiency.

In order to address some of the issues raised about inconsistencies in programmatic evaluations, 4E is currently producing an 'Evaluation Guidebook'. This is aimed at assisting those commissioning the future evaluation of EES&L programmes to encourage the consistent use of best practice and more transparency in the reporting of results.

4-188-22: Peer-reviewed paper

Recognition justice and the evaluation of low carbon innovation projects

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
evaluation, low carbon technologies, energy poverty, sustainable communities

Evaluations of energy system innovation projects serve multiple purposes. They inform funders and stakeholders of project performance against key indicators and targets; assess value for money; document lessons learned; and provide insights for future innovation initiatives. Against the backdrop of the climate emergency, issues of equity and inclusion are being increasingly incorporated into living laboratory projects, reflecting a broader shift in energy discourse and governance towards concern for a just transition. Evaluators are key actors in assessing the justice implications of energy innovations, representing those voices and perspectives with less influence in innovation discourse and governance. However, their success in doing so depends on a range of internal and external factors. Internal factors include those frames of reference, motivations and methodological practices which vary amongst different kinds of evaluators, while external factors include the availability of data, access to users and participants, and the prioritisation of justice and inclusivity by project partners and funders. This paper draws on evidence from three energy system innovation projects in the United Kingdom to analyse the practice of evaluation as a key determinant of recognition justice. The projects, of strategic national importance, involve trials of innovative technologies and practices, including on-street electric vehicle charging, heat-pumps with load-control, and neighbourhood-scale flexibility. Each has explicit aims to address issues of energy justice, including tackling energy poverty and demonstrating the potential for demand-side practices to contribute towards grid balancing. We discuss examples of how the motivations, methods and expertise of particular evaluators influences the ways in which users are represented and issues of justice addressed, as well as practical barriers such as gathering quantitative data on electricity usage and vehicle charging data. Given the changing nature of evaluation for energy innovation, we highlight the need for critical reflexivity amongst evaluators, relating to their positionality, motivations, capabilities and limitations. Evaluation is an essential, but under-acknowledged, component of energy innovation and effective policy making. This article highlights its potential to address issues of energy justice and calls for further research and policy attention.

4-203-22: Peer-reviewed paper

Energy poverty and health: the effect of poor housing on people's wellbeing

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy poverty, domestic energy efficiency, health

Energy poverty is traditionally and historically identified mainly with an issue of inadequate heating of homes, which arises when people, due to economic hardship, are unable to heat their homes to a satisfactory level of comfort at an acceptable cost. However, following the progressive increase of the importance of the topic and the effects connected with climate change and evolutions in the behaviours and needs of families, it is necessary to extend the analysis of the phenomenon to the overall climatization of the buildings. This implies that also cooling, and other essentials services (such as mobility, being able to cook hot meals or have hot water available for personal hygiene purposes or use essential electric appliances) shall be included. Moreover, energy poverty represents a social issue, subject to the attention and study both by European and national governments. This is also shown by literature, where the correlation between energy poverty and health has already been studied in some European countries (e.g. France and the U.K.). The main health outcomes are an increase in the probability of contracting respiratory and cardiovascular diseases, as well as favouring the onset of psychiatric diseases or aggravating already existing ones. In this paper, after an introductory literature review on this topic, a methodology is proposed and applied to a case study on Turin city. Among the results, it emerges that energy poor individuals have a 7% higher risk of premature death than non-energy poor, for causes related to the above-mentioned diseases. Energy poor have also higher risks of hospitalization for these pathologies, with probability increases between 5% for ischemia to 27 % for Chronic Obstructive Pulmonary Disease (COPD). In the last part of the paper, the extension of the methodology to the whole country is proposed, with a preliminary estimation of the impact of such increased rate of diseases on the National Health Service.

4-214-22: Peer-reviewed paper

Identifying drivers of residential energy consumption by explainable energy demand forecasting

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
smart buildings, domestic energy efficiency, energy demand drivers

Reducing primary and final energy demand is crucial for substantially decreasing Greenhouse Gas (GHG) emissions and reaching global and European climate targets. To understand what drives energy consumption behaviour is crucial for decision-makers to design policies effectively. Most current studies focus on smart meter data and sensor data. These data should be complemented by contextual, sociological, and behavioural data (acquired for example through surveys), which allow to study more precise user profiles. Integrating user profiles may reveal more valuable information, at the same time too much redundant information may also harm the prediction accuracy. How to select the crucial drivers is still understudied, but has direct impacts on the performance of the prediction.

This paper presents an explainable three-step forecasting method, which identifies long-term as well as seasonal trends and the most important drivers of household energy demand. In the first step, times series analysis (Bayesian Structural Time Series - BSTS) is applied to decompose energy demands into long-term, seasonal and residual components. In the second step, features are selected through a hybrid machine-learning approach (combining Extreme Gradient Boosting - XGBoost and Random Forest - RF), which reveals the key drivers of energy consumption. Finally, the energy consumption for each household is predicted with a deep-learning algorithm (Long Short Term Memory - LSTM). Furthermore, drivers of household energy demand – covering energy usage, building information and user profiles – are extracted and validated by domain experts. We apply this approach to a real-world dataset collected in eight German cities. The results demonstrate significant improvement in the prediction accuracy of electricity demand and interpretability of drivers.

4-227-22: Peer-reviewed paper

Process matters: Assessing the use of behavioural science methods in applied behavioural programmes

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
low income, small and medium-sized enterprises, methodology, behavioural change, survey, testing

Behavioural science methods have significant potential to help policy makers, practitioners and energy programme managers design, implement and evaluate behavioural campaigns addressing hard-to-reach (HTR) energy users. But when facing budget and logistic constraints, how many real-life programmes actually follow through? How are behavioural science methods actually applied in a real-world setting? This paper presents a scientific process for behaviour change programmes – the “Building Blocks of Behaviour Change” – and analyses 19 case studies from seven countries to see how many are actually utilising these methods in practice. The case studies focus specifically on HTR energy users and the authors also share their perspectives in feasibility and acceptability of utilising such a process in their work.

We found that most programmes utilised some behavioural science research methods, but few followed a full scientific “best practice” process. Limitations of this study include selection bias (the case studies for analysis were chosen by country experts), design issues and some missing data in the cases with regards to exact methods employed. But it is the first study of its kind, to our knowledge, that takes a look at the extent of how scientific methods are being applied in the real world with HTR energy users. Based on this comparative analysis of the cases and feedback from the case study authors, we present recommendations on how programmes can continue to realistically integrate best practice methods into their programmes while also meeting budget, competency, and timeline constraints.

4-233-22: Extended abstract

Leveraging non-energy impacts to ensure equitable benefits of energy efficiency

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
multiple benefits, non-energy benefits (NEBs), equity, underserved, domestic energy efficiency

Utilities in the U.S. and Canada are increasingly prioritizing more equitably serving their customers with energy efficiency programs. These efforts include a renewed focus on historically underserved audiences such as income eligible, low-English proficient, and indigenous energy users. A binational group of utilities has joined forces to collectively analyze how non-energy impacts (NEIs) can help achieve equity objectives. This abstract details early findings from the collaborative work underway across these organizations to ensure that NEIs are more fully accounted for in valuing energy efficiency programs. This work began in 2021 at the Consortium for Energy Efficiency (CEE), a consortium of utilities whose 70+ members direct approximately 70 percent of the $9.2 USD billion dollar energy efficiency industry in the U.S. and Canada.

Administrators of energy efficiency programs increasingly recognize the importance from an equality standpoint of ensuring that all customers have easy access to the value of their energy efficiency programs. The challenge is that many underserved customer groups often use little energy, and it can be expensive to reach these energy users, making it difficult for utilities to achieve significant energy savings from these programs. Better quantifying and valuing NEIs is key to fuller engagement of underserved audiences, given that programs serving these customers may otherwise fail the cost-effectiveness tests common in U.S. and Canadian programs. In addition, underserved customers may be more motivated to participate in utility programs if they perceive benefits beyond energy savings, in areas that may be of higher priority to them. Yet quantifying NEIs is often difficult and expensive. Energy efficiency program administrators have begun collaborating to better understand approaches to quantifying and valuing NEIs in the U.S. and Canada. This collaboration will include an assessment of which NEIs may most benefit program equity.

To better understand energy efficiency program administrator priorities and approaches to quantifying NEIs as related to equity in the U.S. and Canada, CEE conducted a survey among these program administrators and also held a series of discussions to seek input from North American utility staff on these topics. Overall, CEE led 6 roundtables between June 2021 and April 2022, which included participation from 37 utilities in the U.S. and 5 utilities in Canada.

In total, 19 program administrators responded to the survey. Questions focused on which NEIs were of highest priority to better understand and quantify, and also sought input on how these topics could most effectively be addressed collaboratively. Though these are preliminary data, three NEIs rose to the top. The first NEI of high interest was economic benefits to underserved groups, such as low-income energy users, with 16 of 19 respondents asserting this was a priority or high priority. Environmental impact-related NEIs (such as outdoor air quality or conservation improvements) were also highly valued, with 15 out of 19 respondents identifying this as either a priority or high priority. Finally, health and safety related outcomes (such as improved indoor air quality and improved living conditions) were mentioned by 14 of the 19 respondents as priority or high priority. Despite the small sample size, this initial data provides an early glimpse into U.S. and Canadian priorities for how better accounting for NEIs to fully value programs may go hand-in-hand with equity objectives.

4-260-22: Extended abstract

Assessing the impact of energy efficiency programs driven by an electricity utility provider

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Imane Fouiteh, University of Geneva, Switzerland
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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy efficiency programmes, evaluation methods, impact evaluation, electricity savings, local utilities

Utility providers are key players for the energy transition. They are in the privileged position to speed up the process thanks to the direct relationship they have with end-users and their knowledge about the end users' historical energy consumption.

As one of the largest utilities in Switzerland, the cantonal utility in Geneva launched in 2009 an ambitious portfolio of Energy Efficiency Programs (EEPs) addressing mainly electricity for all segment customers. Since then, the EEPs have been successfully implemented and significantly expanded to other utilities. To quantify their impact in terms of energy savings, the University of Geneva developed and applied a set of complementary evaluation methods (ex-ante, ex-post, bottom-up and top-down). One of the main challenges for the evaluators was to assess the actual impact of the program on top of the policies (i.e. the savings that would not have taken place if the program did not exist).

During the start-up period of the EEPs, the set of the necessary information for the evaluation was identified and the data collection procedure was coordinated with program managers. Special attention was paid to optimizing evaluation costs and information directly extracted from program administration files was used for the evaluation.

For small consumers (annual consumption lower than 30 MWh/y - most of them residential customers), ex-ante methods based on deemed savings per replaced appliance allowed to evaluate the impact as soon as the actions were deployed. For some appliances (e.g. light bulbs), the estimates were based on the average power of removed light bulbs, allowing to update the baseline that was continuously changing due to the improvement arising from policies (e.g. ban of inefficient light bulbs). In addition, a large database with historical billing data for all residential customers allowed to apply a bottom-up ex-post method. Those who didn't participate in any program constituted the reference group. A top-down method, based on cantonal statistics, complemented with a survey among customers, accounted for the spill-over effect.

For medium consumers (communal areas of buildings and small to medium enterprises SME between 30 to 500 MWh/y), online ex-ante online tools were used by practitioners to estimate the savings. Annual billing data helped later to validate or eventually adjust the ex-ante calculations. For the communal area of buildings, a top-down analysis, supported by interviews among practitioners, helped to estimate the spill-over savings. Unfortunately, the top-down analysis for SMEs didn't give reliable results.

For large consumers (mainly tertiary sector companies consuming more than 500 MWh/y), every single energy efficiency measure, implemented by the participant companies, benefited of a report containing information about the measures taken and the resulting savings. Small actions were evaluated ex-ante while the important ones were done using the IPMVP protocol. A larger part of the savings were accounted ex-post.

In 2009, the utility aimed to reduce the total electricity consumption by 5% by 2013. This goal was finally achieved in 2017. The potential initially identified was quite realistic, but the time required was underestimated, as it was an innovative task for the utility to convince the customers to implement the proposed measures, train and certify practitioners about energy efficiency, build the management and communications tools, and finally put in place the energy efficiency measures.

4-266-22: Extended abstract

Beyond energy savings – quantifying the multiple impacts of energy efficiency improvements

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
multiple benefits, cost benefit, impact evaluation, social impacts of energy efficiency

There is still significant potential to improve energy efficiency in all sectors. Facing the often cited "energy efficiency gap", even the profitable potential is not fully exploited. Highlighting and quantifying the additional values of energy efficiency measures and investments considering the multiple non-energy impacts could help closing this gap and facilitate energy-relevant decisions and policy-making. A main barrier to the systematic consideration of Multiple Impacts (MI) of energy efficiency in policy design is the fact that these are often quantified with comprehensive modelling approaches, which may be time and resource consuming. New tools for the quantification of MI are thus required which are easy to use, flexible enough to adapt to different evaluation purposes and applicable at different governance levels. Further, they must be based on a sufficiently sound scientific basis to provide reliable and accurate results. Finally, a tool must cover the most relevant indicators in the overarching categories economic, social and environmental impacts.

The H2020 project Multiple Impact CAlculation Tool (MICAT) aims at the development of a scientifically-sound online-tool that addresses these needs and is available for free. The tool will be flexible enough to enable a quantification and monetisation of MI at three different governance levels (local, national and EU) to address a broad target group, allowing impacts analyses to be carried out ex-ante and ex-post and on the basis of top-down scenarios and bottom-up data (e.g., derived from specific energy efficiency policies). Finally, the MICAT tool will include the option for the tool user to perform a comprehensive Cost-Benefit Analysis (CBA) from a societal perspective.

MI analysed in MICAT range in the social impact category from energy poverty alleviation to human health effects due to improved indoor climate and reduced outdoor air pollution. Impacts in the economic category are differentiated by microeconomic (e.g., industrial productivity, import dependency, energy security) and macroeconomic impacts (e.g., GDP and employment effects, public budget impact, energy intensity). Environmental impacts include in particular material resource savings, reduction in air pollution and GHG savings.

Due to the high flexibility requirement of the MICAT tool, the specific MI will be quantified based on impacts factors or functions, i.e., for each indicator assessed a specific impact factor or equation is developed, which is directly linked to input parameters (e.g., energy savings, investments, stock data of technologies) of the respective scenarios or policies assessed. In order to aggregate impacts with different physical units, compare their magnitude, and integrate them into CBA, the conversion into one common (monetary) metric is necessary. The objective is to monetise as many MI as possible and to include them into the CBA.

The approach for impact quantification is exemplified looking at selected indicators in the social dimension for energy poverty and health. An example of health impact is avoided asthma cases due to the reduced exposure to indoor dampness. A large number of studies show that there is a consistent association between indoor dampness and asthma cases. To attribute asthma prevalence to the exposure to dampness, the standard method for assessing the Environmental Burden of Disease (EBD) is applied. In addition, assumptions are made between potential indoor dampness reduction and each retrofits type based on expert judgement. In terms of energy poverty impacts, the approach focuses to assess the positive financial and physical effects of residential building renovations on energy poor households using a set of established indicators. Adjustable assumptions are made to account for the crucial role of policy frameworks and market conditions for the distribution of building renovations and their costs and benefits.

4-271-22: Peer-reviewed paper

Social innovation in energy transition: Evaluation challenges and innovative solutions

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
social innovation, impact evaluation, community energy systems

TThe climate crisis needs urgent solutions and potential agents of change are cooperatives, citizen initiatives, start-ups etc., which form social innovation initiatives. Social innovations in energy transition (SIEs) are defined as "(combinations of) ideas, objects and/or actions that change social relations and involve new ways of doing, thinking and/or organising energy. " (Wittmayer et al. 2020, iv). This is how the H2020 project SONNET defines SIEs, on which this paper is based on.

The aim of the paper is to illustrate how challenging the evaluation of the success of those diverse types of SIEs is and what approaches were and can be applied. Evaluating whether SIEs are successful means to understand whether SIE-initiatives have been successful in achieving goals and which types of SIEs are more successful in achieving certain goals than others. We differentiated between the aims held by SIE-initiatives themselves (SIE-aims), aims which are shared by the EU and SIEs (shared-aims), and aims of the European Energy Union which are not shared by SIE's (EU-aims). The aims of the SIE-initiatives were based on literature review and a survey among the empirically studied SIEs in SONNET.

We find that many of the studied SIE-initiatives do not monitor their impacts as resources are scarce. Some of the impacts occur in people's mind (such as impacts on "thinking"), and even the impacts which can and have been monitored are hard to compare across different initiatives, due to their diversity. Therefore, our surveys only capture the perceived contributions of SIEs to the different goals.

Based on the surveys we find that SIE-initiatives achieved significantly higher contributions towards SIE-aims than towards EU-aims or shared-aims and that the perceived contribution is stronger for those aims with higher importance. The SIE-aims with the highest contributions were "improve social acceptance of renewable energy production" and "strengthen local community". The shared-aims with the highest contributions were "increased renewables production" and "reduced greenhouse gas emissions". The perceived contribution towards other EU-aims or

shared-aims was rather low. Looking at the different SIE-types, in general SIE-initiatives focusing on “Thinking”-type of activities seem to achieve slightly lower contributions for many of the aims we assessed than the other types of activities (“Doing”, “Organizing”). Regarding the social relation, contributions towards shared aims were significantly higher in case of SIE-initiatives working on a “Competition” setting, and significantly lower in case of SIE-initiatives that were in “Conflict” than for the other types of social relations (i.e. “Cooperation” and “Exchange”).

Our conclusion was that not one evaluation method fits all SIEs and we explored in a workshop how innovative approaches such as media analysis (news databases, websites, social media) and web tracking (google analytics/facebook) might be used for future evaluations of SIEs.
evaluations of SIEs.

4-275-22: Peer-reviewed paper

Spatial interaction model of energy demand of buildings and satellite thermal imageries using Geographically Weighted Regression analysis

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy performance certificates, Landsat 8 satellite imageries, GIS based spatial analysis

The Energy Performance Certificate (EPC) is an important information tool to improve the energy performance (EP) of buildings. However, establishing the EP of building is tedious, time-consuming, and numerous input parameters are required in its estimation. However, the usefulness of EPC for the implementation of customized solutions by the supply-side actors require that EPCs are available for all buildings, easily accessible, credible, and recent. However, this is not the case at present. This could be addressed by employing remote sensing dataset along with GIS based spatial analysis techniques. In the present study, the spatial regression analysis technique is implemented in identifying the spatial relation between the input variables and the EP of selected 4541 buildings within Växjö municipality, Sweden.

The input variables used in the study include the land surface temperature (LST) maps of summer and spring of 2020 derived through the thermal band of Landsat 8 satellite data, built-up and openland neighbourhood maps prepared from the land use/land cover map 2020 of the study region. Building topology including year of construction, type, category, and complexity of buildings are also used to identify the relation between the input variables and the EP of those selected buildings. Results of spatial regression analysis reveal a significant positive relation between the LST and EP of buildings (regression co-efficient are 0.86 and 0.95 in spring and summer respectively).

The stronger correlation in summer could be because of the availability of higher intensity of solar radiation which gets absorbed by the built-up regions. Results suggest that the LST maps derived from satellite imageries could provide information on the EP of buildings. This could be beneficial to local decision makers and policy regulators in identifying the buildings with lower EP with better accuracy with less dependence on EPC data which are sometimes not available or not updated. The results could also be beneficial to investment bankers, real estate companies during the purchase and sale of a building. Policy makers and renovation companies could get benefited with

the results in preliminary identification of the potential hotspots for district energy renovation where the EP of buildings is poorer. This could help achieve the goal of sustainable urban planning targeting energy reduction, climate adaptation, through implementation of effective energy management strategies in the building sector.

4-280-22: Peer-reviewed paper

Monitoring the impact of energy conservation measures with artificial neural networks

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy conservation measures, measurement and verification, artificial neural networks, IPMVP

Energy Conservation Measures are mandatory in order to improve buildings' energy performance by using upgraded technologies, systems and installations. However, the lack of accurate techniques for Measurement & Verification (M&V) imposes insurmountable barriers towards their extended financing. The development of precise M&V techniques to estimate energy savings is a critical issue that can be tackled through the adoption of predictive models for the adjusted baseline energy consumption in the reporting period.

The most commonly used M&V practices to date are reported in the International Performance Measurement and Verification Protocol (IPMVP), where the most widespread techniques per case for calculating energy savings are defined. More specifically, the IPMVP indicates the adoption of linear regression methods to predict the adjusted baseline energy consumption of a building, exploiting outdoor temperature and heating degree days.

In this paper, utilisation of Deep Learning for training energy consumption predictive models is examined, as vast amount of data from Internet of Things devices are available nowadays. Thus, the feedforward Artificial Neural Network (ANN) is proposed for predicting the adjusted baseline energy consumption, using the hour of the day, the day of the week and weather data as training features. The proposed models incorporate both linear and non-linear relationships, in contrast to linear regression methods.

To validate the proposed method, an experimental application is implemented, applying the developed models on an educational institution in Latvia. The building has been renovated regarding its heating supply and ventilation system, as well as its enclosing structures insulation. The predictions from the ANN models are compared with the ones from the traditional degree days method, indicating that ANN achieves higher accuracy in energy savings estimation for electricity and diesel fuel consumption.

4-335-22: Peer-reviewed paper

Diving into the energy consumption of Germany’s tertiary sector: From company data towards energy end-use balances

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
tertiary sector, end-use consumption, energy consumption, monitoring, modelling

Usually, the tertiary sector is an undifferentiated residual in energy balances. This is due to the variety of activities covered by this sector. They include, among others, the operation of public and private services, trade, commerce, manufacturing and small industries, but also schools, universities, hospitals, hotels and public swimming halls. In Germany, the tertiary sector’s energy demand amounts to a non-negligible share of 14,6 % (AG Energiebilanzen 2019) in the countries’ entire energy consumption. However, the overall sectoral aggregate makes any evaluation and assessment of energy saving potentials difficult.

An allocation of the energy to the energy uses such as process heat, process cooling, lighting, mechanical energy, hot water, air conditioning, space heating and ICT would thus be helpful. For this purpose, a representative survey among 2000 companies in Germany’s tertiary is combined with a modelling approach. It is a combined bottom-up as well as a top-down approach to get detailed statistics and information of the fuels and district heating as well as the electricity in the shares of the energy uses. Using the different drivers of the energy uses like floor area, employees or water area (in the case of swimming halls), the survey can be extrapolated. In addition, special attention to new applications such as data centers and ICT is paid. We will present the underlying methodology as well as results from the modelling exercise.

With this representative breakdown of the energy consumption allocated to the subsectors in a detailed and comprehensive way the relevance of energy efficiency management and federal incentive programs can be monitored and evaluated.

4-344-22: Peer-reviewed paper

Evaluating multi-measure schemes for enhancing energy efficiency: The German Energy Efficiency Fund

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
evaluation methods, impact evaluation, evaluation

The Energy Efficiency Fund established in 2011 was the largest cross-sectoral funding source for improving energy efficiency in Germany. It provided financing to more than 20 national policy measures from across all sectors. Earlier publications have covered methodological aspects related to the evaluation of the Fund and the measures within. This contribution focuses on the overall impact of the Fund and seeks to point out aggregation issues in such a multi-measure scheme. For this purpose, a nine step process is followed to evaluate and aggregate quantified measures within the Fund. In terms of net results in 2017, the Fund achieved at least cumulated savings in terms of GHG emissions of 0.92 million tonnes CO2-eq., final energy savings of 2.7 TWh and annual reductions of energy costs of 171 million Euro. This is after adjusting gross savings for free-rider, pull-forward and follow-up effects and under the consideration of interactions between individual measures. In terms of aggregation issues, experience from the evaluation underlines that transparent impact models, clear views on interdependencies of measures and well-defined targets are helpful assets in the evaluation of multi-measure schemes. In addition, it is underlined that despite the harmonization of the evaluation process, differences in the implementation can hardly be avoided. Thus, transparency on the chosen implementation practice is advisable when presenting the results of such multi-measure schemes.

4-345-22: Peer-reviewed paper

Ex-ante impact evaluations of energy efficiency measures – how to increase their transparency

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
evaluation methods, impact evaluation, monitoring, energy efficiency policy

Both at European and national level, the requirements for reporting on measures introduced to achieve EU-wide and national energy efficiency and climate targets have increased considerably in recent years. While ex-post impact evaluation of policies and measures is nationally as well as internationally rather well documented, ex-ante reporting processes are still very inconsistent. The goal of this presentation is to develop a consistent methodology for a good practice for ex-ante impact evaluations, which provides a common methodological guideline for the design and monitoring of energy efficiency and climate policy measures and programmes.
In our presentation, we derive the key factors to be taken into account for a transparent ex-ante impact evaluation of energy efficiency policies. The following factors will be discussed:

1. Relevant assessment criteria:
The most important assessment criterion for an ex-ante evaluation of energy efficiency policies is their climate protection effect, which is reflected in the effect on energy savings and greenhouse gas (GHG) reduction achieved by a measure as the main indicators. However, we will also briefly address other important criteria as e.g. economic effects (such as effects on energy costs, investments, employment or value added), distributional impacts, as well as acceptance and diffusion.

2. Assumptions on key framework data:
In order to consistently calculate the indicators for the energy savings impact of a measure, certain framework assumptions must be made. For bottom-up impact assessments, these include the following aspects in particular: Energy prices, lifetimes, emission and primary energy factors as well as the underlying reference development (baseline).

3. Methodological approach for determining gross impacts of the measure:
In principle, a distinction should be made between gross and net savings when reporting savings by means of indicators. The indicator values "influenced" by the measure are called the gross

effect of a measure. Following the procedure of an ex-post evaluation, the impact model should first be determined also for an ex-ante evaluation. Such an impact model contains the idealised assumption of the impact of an action (here: implementation of a measure) in the sense of a causally justified sequence. However, a generally binding definition of how to determine the gross impact of a measure is not possible, as the individual policies are too heterogeneous and the method chosen depends on the specifics of each policy measure.

4. Effect adjustment approach for the calculation of net effects:
The net effect addresses the criterion of the effectiveness of a The question is to what extent the evaluated measure was "causal" for the determined gross impact and to what extent "additional" savings were achieved. To determine the net effect, it is necessary to adjust the gross values for corresponding effects as e.g. free rider, rebound or interaction effects.

5. Requirements for a transparent handling of uncertainties
Uncertainties exist at all described stages of the ex-ante evaluation process. In this context, it seems useful to distinguish between uncertainties regarding implementation and allocation of a policy measures as well as technological and political uncertainties. In our presentation, we will address some methods to reduce uncertainties which are used in practice. However, since inherent uncertainties cannot be completely avoided in ex-ante impact assessments, it is important to transparently present not only the assumptions on which the evaluation is based, but also the associated uncertainties.
In our presentation, we will not only discuss these criteria, but also illustrate them by a catchy policy example from the building sector.

4-349-22: Extended abstract

Impact of COVID pandemic on energy efficiency in the EU: A quantitative assessment

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Panel
4. Monitoring and evaluation for a wise, just and inclusive transition

Keywords
energy savings calculation, transport, decomposition analysis, impact of Covid pandemic

In response to the COVID pandemic which has drastically affected the European economies, the EU countries have implemented recovery plans sometimes supporting investment for ecological transition. In the meantime, we observed in 2020, a reduction of 6% and 5.6 % of the primary and final energy demand respectively, which finally (and fortunately) allows the EU to reach its 2020 energy efficiency targets. In 2020, the resulting energy intensity has increased of +0.5%, after 6 years of regular decrease.

Therefore, for energy policy analysts, the question arises to evaluate the relative contribution of the economic depression versus the energy efficiency on the target achievement in the recent years.

In general, energy efficiency deteriorates in periods of deep recession in productive sectors (industry, services and freight transport): indeed, energy consumption does not follow the reduction in economic activities because of lower use of industrial capacities, or lower load factor for trucks, leading to an increase of indicators of specific consumption and a lower “efficiency”, not from a technical viewpoint but from an operational viewpoint.

The so-called “decomposition analysis” (see ISO 500047) methodology allows to perform such evaluation. However, this data demanding methodology relies on detailed data which are only available at n-2 or n-3 years, refraining its use for our 2020 issue. To overcome this methodological barrier, we have developed a new methodology so called “early estimates of the energy efficiency Index“ as it is used for elaborating the recently published ECEEE energy efficiency scoreboard.

After some quantitative observations on the impacts of the COVID crisis on activity and energy demand, this paper will present and discuss the methodology used to assess the impact of the COVID crisis. We will apply this methodology through two case studies: 1) at EU level for all sectors allowing to evaluate the level of energy savings; 2) An in-depth analysis of the transport sector in

France (the most impacted sector, due to lock down and travel restrictions) and for which detailed end-use data are available. Finally, as a conclusion, we will compare the impact on energy efficiency between the 2008 financial crisis and the COVID crisis.

5-006-22: Peer-reviewed paper

Incentives and barriers to flexible operations of industrial processes and district heating production to increase intermittent renewable electricity production – an interview study with involved actors

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Panel
5. Towards sustainable and resilient communities

Keywords
demand response, district heating, industry, renewable energy, interviews, flexible operations

The Paris Agreement sets a framework to reach a goal of limiting the increase in global average temperature to well below 2°C above pre-industrial levels. Actions to reduce greenhouse emissions include increasing the share of renewable electricity production and improving energy efficiency.

However, this implies challenges related to the intermittent nature of wind and solar power. One way to enable an increased share of intermittent electricity production is to increase flexibility on the demand side. A district heating system that includes centrally controlled heat pumps and combined heat and power plants, together with load management of industrial processes, can provide a platform for an increased share of intermittent renewable power generation.

Previous studies have analysed technical potentials for flexible operations that can increase the share of intermittent renewable electricity production. However, the view of the actors involved has not been analysed. Therefore, the aim of the present study is to analyse the industry's and the energy sector's perceptions of the potentials and challenges related to flexible operations.

Actors from industry and energy companies in Sweden were interviewed to appraise and evaluate how they perceive the potentials and challenges regarding sector coupling and flexible operations. Challenges identified are trade-offs between balancing the electricity grid and cost-optimisation at company level, and that the strategy requires a smart control system and targeting regulations.

The results from the study can guide policymakers when formulating policies that can stimulate

marketplaces for flexible operation that will enable an increased share of intermittent renewable electricity production and reduce the risk of power capacity shortages.

5-037-22: Peer-reviewed paper

Strategic heating and cooling planning to shape our future cities: Survey on success factors and challenges of heating and cooling planning in Germany

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Panel
5. Towards sustainable and resilient communities

Keywords
local and regional energy planning, urban planning, heating, sustainable communities, cities

Strategic heating and cooling (H&C) planning has proven to be an effective tool to drive the decarbonisation of H&C in cities. In this paper, success factors and key challenges of strategic H&C plans are analysed based on semi-structured interviews and an online survey with stakeholders from Germany. The 241 participants of the online survey see CO2 neutrality as the main objective of strategic H&C plans. The most important success factors are good communication and data availability. Particularly challenging are having common goals, enough staff as well as data availability. Targets and guidelines are more important if the city is obligated to strategic H&C planning. In general, the instrument is seen as effective and suitable to tackle climate change in cities by the participants. The results of this paper can help policy makers and stakeholders to develop successful H&C plans and, thus, to tackle decarbonisation of H&C in cities.

5-047-22: Extended abstract

Stakeholder support in early decision phase for positive energy districts

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Panel
5. Towards sustainable and resilient communities

Keywords
renewable energy, energy performance, community energy systems, alternative energy systems (AES), CO2 reduction, Positive Energy District, Carbon Neutrality

INTRODUCTION
Positive Energy Districts (PED) are a piece of the puzzle for the goal of carbon neutrality in the coming decades. PEDs are contributing to the ambitious targets of the European Strategic Energy Technology Plan. The goal is to deploy 100 Positive Energy Neighbourhoods by 2025.

An important stakeholder is the administration and the political representatives of a city or municipality. They are involved at the very beginning of site development and are the ones who can set requirements for the energy performance of buildings and mobility and type of energy carrier through instruments such as zoning plans, development plans or building regulations.

The first steps towards plus-energy districts were taken in the city of Melk, which is a small town with around 6,000 inhabitants situated in the UNESCO world heritage of Wachau. Two individual sites were examined by means of spatial energy analyses, calculation of energy need and potential renewable energy supply. Possible approaches to set legal binding requirements were analysed. Through the active participation of the city of Melk as well as the property owners and developers involved, acceptance is to be ensured as a preparation for implementation and a concept for PEDs that is as practical as possible.

METHOD
Stakeholders in the context of neighbourhood development, especially the municipality, need a long-term perspective on the planning and construction of a district. After all, such a process takes around 10 to 20 years and needs to be planned far ahead. A roadmap in relation to Positive Energy Districts is therefore helpful.

Existing roadmaps were analysed to define support for PED development: the "Smart City Guidance Package" helps with a broader scope. This package is aligned with the UN Sustainable Development Goals. In "Co-Creation of Positive Energy Blocks", more attention is paid to the development process and the involvement of residents. The "Guidelines for Positive Energy District Design" covers the scope well and focus on the planning process. A good quality mapping of the process from start to operation of a Positive Energy District is provided by the Cities4ZERO initiative, which was used as the basis for the Roadmap for Positive Energy Districts.

ROADMAP

This PED roadmap consists of the stage's strategy and initiation phase, planning phase and implementation phase up to operation. In addition to these phases, individual steps are concretely defined and presented in a specific order. In early development phase, steps from strategy phase are relevant: 1. Set PED vision, 2. Engage people, 3. Analyse relevant data, 4. Set up working groups, 5. Formulate specific objectives, 5. Define acition plans, 7. Integrate in general administration work. This sequence is not always followed according to the proposal. In different settings, the series of steps can be adapted accordingly.

For the city of Melk, the objectives, the participants and the measures were defined for each of the individual steps, so that the roadmap can be used as a guide for future action.

CONCLUSION

It is important to inform relevant stakeholders in the cities at an early stage about the dimensions and steps of the development of PEDs. At the same time, it must be mentioned that current urban development areas have no other option than to become energy and climate neutral. In the field of urban development, long-term planning is needed; decisions are being made now for the next 20 years.

The early involvement of stakeholders is the key to successful implementation. By designing an active participation process, fears and resistance can already be reduced in the first steps and a common goal can be achieved.

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5-075-22: Peer-reviewed paper

Engaging households in energy efficiency action at the local level: A case study of Energy Efficient Scotland

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Panel
5. Towards sustainable and resilient communities

Keywords
domestic energy efficiency, local authorities, attitudes, pilot projects, Engagement

High standards of energy efficiency in buildings are critical for achieving a low carbon and just society. In Scotland, energy efficiency was designated a National Infrastructure Priority in 2015. Domestic properties account for 13% of Scotland's total greenhouse gas emissions (Heat in Buildings Strategy, 2021), and owner-occupied properties constitute the largest proportion of these. Engaging private householders in significant upgrades to their homes has proved to be challenging, but is crucial for achieving climate targets. Local authorities have been recognised as having a vital role in enabling energy transitions by bringing local property owners, businesses and social enterprises together and acting as key agents of change (Webb & Tingey, 2020). This paper focuses on the role of local authorities in engaging private householders in energy efficiency measures, using the case study of the Energy Efficient Scotland programme. Set up by the Scottish Government, this programme tested mechanisms for improving energy efficiency in all homes, business and public buildings during 2016-2019. As part of the programme, local authorities piloted different citizen engagement strategies including: mail-outs (postal or electronic), in-home visits and high-street 'energy hubs' (or drop-in centres).

We present findings from a social survey, which examined householder attitudes towards, and outcomes of, these different engagement strategies. Questions were designed to establish the extent to which the strategies affected domestic sector engagement with, and investment in, energy efficiency measures. In total, 490 households responded across eight Scottish local authorities. The returned data were anonymised for privacy and confidentiality. The key descriptive statistics and themes were analysed, and triangulated with data from previous Energy Efficient Scotland pilots.

Our findings demonstrate that overall, the Energy Efficient Scotland programme had a positive impact on Scottish households through the provision of advice which stimulated action: 61% of homeowners installed, or planned to install measures to improve the energy efficiency of their homes after engagement. In addition, respondents regarded energy efficiency advice from local authorities as trustworthy, which supports proposals for such advisory services to become a

statutory duty for local authorities, given their key influencing capacity within the local community (Hofman et al. 2021). The provision of a drop-in centre was the strategy that stimulated the most positive response in terms of useful advice, and resulted in the most plans and actions. By acting as a point for dedicated, face-to-face interaction which can lead to increased trust in, and momentum from, services, this strategy served as an effective tool for householder action.

Barriers to householder action included cost, which reinforces related proposals for increased, long-term funding for homeowners to retrofit property. The lack of new, more specific information was also a barrier to household action. Whilst the provision of information through the programme was beneficial, national-led programmes need to enhance services with more detailed information tailored to household type, including for properties in conservation areas. Appropriate funding, skills and staff resources are also needed for local authorities to catalyse effective change. In conclusion, we consider the drop-in centre as an innovative community engagement tool which resulted in the most change in the Scottish pilot localities. Particularly from a local authority perspective, this strategy should be further examined as a long-term means to stimulating citizen engagement in energy efficiency.

5-101-22: Extended abstract

Citizens as co-owners of energy systems: prosumerism in cities

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Panel
5. Towards sustainable and resilient communities

Keywords
prosumers, citizens, municipal utilities, district heating, co-ownership, financing

More than three-quarters of the EU's total population live in cities and suburban areas. Most urban areas continue to gain population and become ever more important sources of greenhouse gas emissions. The trend of increased urbanisation implies that cities are key for addressing climate change. Energy prosumerism can contribute to mitigating greenhouse gas emissions in cities. Energy prosumerism describes the active participation of citizens in the energy system. It can be implemented through individual and collective prosumerism. While individual prosumerism is restricted to single-family houses, collective prosumerism can cover a more comprehensive range of projects. This includes investments in energy technology and infrastructure on-site, for example, in or on top of an apartment block, or off-site, such as a photovoltaic plant near a community or large-scale heat-pumps connected to (small) district heating.

We assess the current status and possible impact of prosumerism in cities using a literature review, expert discussions and case studies. We categorise, introduce and evaluate prosumer concepts for on-site and off-site electricity generation and infrastructure as well as decentral and district heating in cities. Three examples of collective prosumerism from European Member states are presented. Athens' first energy community, "Hyperion", enables members to consume electricity from collectively owned ground-mounted PV plants outside the city by using virtual net-metering. Each member owns a share of the electricity generated equivalent to their share of equity. The share of the electricity generated is accounted on the energy bill. In Greece, prosumers in virtual net-metering schemes must pay for all taxes and other levies, e.g. grid fees, which make the investment only financially profitable if generation costs are below electricity procurement costs. Another collective prosumerism case exhibits the citizens founded cooperative „BürgerEnergie Berlin", which bid for ownership and operation of the city's elec-tricity grid, though faced several legal obstacles. The concession was finally awarded to "Berlin Netz", a city-owned company founded for the purpose of running the grid. The Berlin govern-ment examines how to enable citizens to participate in grid ownership. Offering co-ownership to a cooperative like BürgerEnergie Berlin is one of the options envisaged. As third example, “Hvide Sande Fjernvarme AmbA” is a consumer-owned energy company operating a district heating network with RES heat generation from direct electrified sector coupling technologies utilising renewable electricity from the community owned wind turbines. The Danish District Heating Association, a stakeholder group promoting nationwide collective prosumption models in the heating sector, initiated the company’s founding in 1963.

Based on this analysis, the following policy recommendations for key stakeholders are developed: Municipalities can persuade utilities co-owned by local governments to involve citizens in energy planning and emphasise citizens' involvement in setting terms and conditions for awarding concessions of energy infrastructure to initiatives that enable citizens to participate in decision-making processes. Integrated energy planning should be developed hand in hand with citizens in a participatory process, especially for heat planning and charging infrastructure. Local governmental institutions, e.g. energy agencies or business support agencies and networks can facilitate access to information for potential prosumers, function as aggregators or "one-stop-shop" service providers to all interested parties.

Municipalities can also provide space on public buildings or redevelopment areas to local energy communities to deploy power plants, e.g. PV, or develop a sustainable energy district or offer opportunities for integrated energy districts, for example when areas within the city are redeveloped or new areas are added.

5-118-22: Peer-reviewed paper

Piloting Home Energy Assessment Toolkits (HEAT kits) to empower hard-to-reach energy users

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Panel
5. Towards sustainable and resilient communities

Keywords
energy poverty, pilot projects, community, behavioural change, hard-to-reach energy users, vulnerable households

The government of Aotearoa NZ is targeting widespread energy hardship with the Support for Energy Education in Communities Programme (SEEC). The purpose of this fund is to deliver community-level energy education to help households in need. As part of the Hard-to-Reach Energy Users Task (HTR Task) by the Users TCP by IEA, we have received SEEC funding to undertake a field research pilot on hard-to-reach (HTR) energy users in Wellington.
The pilot tests the value of Home Energy Assessment Toolkits (HEAT kits) as a tool for HTR households to empower themselves to manage household energy when introduced by a trusted community-based contact. The community "Middle Actors" (MAs) include those working with households from health, social support, and budgeting sectors. Their primary mandate is not necessarily to provide energy advice to their clients. The pilot thus trains them in the Home Performance Advisor: Making Energy Work for Whānau (Families) programme. This builds the capacity of MAs to have informed conversations with households, so they can "play" with the HEAT kit to help understand their energy bill, how they use energy, and options to change (elements of their house and how they live in the home) to improve health and wellbeing.
The HEAT kit content was co-designed with community workers and technical experts. The MAs complete in-home assessments using the HEAT kits to gather monitoring and behavioural data. The kits include activities, such as quizzes and games, and engagement is rewarded with solutions that target the issues highlighted by HEAT kit audit tools (e.g. LED light bulbs, tap aerators, secondary glazing, door snakes).

MAs are already managing extremely complex work with very limited resources: this makes them quite HTR for policy makers, programme managers and researchers. Thus, anyone relying on MAs for recruiting and engaging HTR energy users, first need to build trusted relationships, and find ways to work alongside existing programmes and be responsive to their needs.

Even though household recruitment for this pilot is still underway, we have gleaned several important insights already:
- (Mis)trust is one of the main barriers why vulnerable households are so HTR with standard

programmes and policies (Rotmann, 2021).
- Using trusted community providers to recruit households and provide in-home advice is thus crucial. But:
- They are also extremely HTR and under-resourced.
- Offering (paid) training and compensating them well for their time is only one way to engage them.
- More important is building trusted relationships, and being referred by other trusted partners.
- Co-design is a crucial element when working with community partners, so is listening to, and incorporating their expertise.
- Following behavioural science "best practice" (see Karlin et al, 2022) is a good way to ensure adequate data is collected to evaluate process and impact. However:
- In the real world, there are often inadequate resources to collect, analyse, and triangulate quantitative and qualitative data.
- Focusing on qualitative insights, including stories, is good practice in real-life applications.
- A focus on kWh or financial savings can have perverse outcomes for vulnerable energy users - e.g., if they are already in a "heat or eat" situation.
- Energy education and communication needs to be simple, clear and fun, and focus on the most important energy services.
- Effective advice is personalised to a home and the people living there.
- HEAT kits can be a useful addition to trained community providers of in-home advice and support. But:
- Simply loaning the kits out via libraries is not enough to engage HTR and/or highly-vulnerable whānau.

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5-150-22: Peer-reviewed paper

IIs ‘the social’ forgotten? Aspirations and understandings of Energy Communities

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Panel
5. Towards sustainable and resilient communities

Keywords
community energy systems, small-scale energy systems, transition management, Energy equity, Energy communities

Energy communities (ECs) is a concept which has been around for decades in various forms, but which has not been explicitly defined or regulated by policymakers until the introduction of the Clean Energy for all Europeans package in 2019. Since then, the EU provides a legal framework for ECs which will guide the creation and management of ECs within member states. From a policy perspective, an EC is regarded as a way to organize collective energy actions in an open and participatory way to provide benefits for members of local communities and opportunities for citizens to get engaged with the transformation of the energy system. In a broad sense, the aim is formulated in terms of enabling a transition towards a "clean and fair” energy system. The policy aspirations for ECs seem to be many and diverse, including technical, economic, social and organizational, referring to a set of different values such as effective use of resources, social equity, and ecological sustainability. In technical and economic terms, EC's are supposed to enable clusters of actors to collectively invest in technology for renewable energy systems and share coordination benefits of more diverse energy use patterns, energy storage solutions and production units. Socially, ECs are expected to increase the acceptance of and support for the transition towards a renewable energy system by involving and empowering citizens, thereby helping to address issues such as poverty, social equity and “energy segregation”. Moreover, within the EU policy discourse, ECs are conceived as policy instruments for implementing EU’s energy goals, as actors on energy markets and as a part of civil society and local communities at the same time.

Evidently, ECs are expected to produce a multitude of societal benefits, but the extent to which these policy aspirations are heard and translated into practice remains unclear. In this paper, we present a mapping of how the concept of ECs is understood and reported in the research literature, published from 2015 until 2021. The aim is to categorize and assess existing understandings of ECs, and to show which aspects have been considered when ECs have been discussed and practiced. More specifically, we pose the question of whether the policymakers' social aspirations of ECs have been forgotten.

5-152-22: Peer-reviewed paper

Enhancing value creation in Energy Communities through flexibility management and network ancillary services provision

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Panel
5. Towards sustainable and resilient communities

Keywords
Energy Communities, Virtual Power Plants, smart grid, demand response, artificial intelligence, renewable energy

The Clean Energy for all Europeans policy package has opened the way for a major transition of the European energy landscape towards customer empowerment and local energy markets development. The European Green Deal, the Fit for 55% package and the European Directives revision are pushing forward Renewable Energy Communities, which will disrupt the energy sector and overcome limitations of existing rigid energy markets. The rise of distributed energy technologies is fostering the development of customer-centered services such as peer-to-peer energy trading. However, adequate tools and business models to interface and engage with energy markets are still lacking.

The H2020 FleXunity project is addressing the emerging market needs by developing a technological platform, that combines advanced artificial intelligence algorithms, blockchain technology and demand response services, to exploit new business models that could value the aggregation of small-scale energy assets. Although the concept of these platforms is relatively well known, their real-world implementation and validation is still at an early stage. This paper presents the FleXunity0 project's main objectives, details of the Virtual Power Plant managing Platform under development and the characteristics of two distinct real world pilot Energy Communities already deployed in the UK and Iberia. It also presents an analysis of the role that Demand

Response activities and independent aggregation could play in Energy Communities, and specifically explores the role of Demand Response in the balancing markets of Finland, UK, Spain, and Portugal. Focusing on the pilot markets, the project also identifies the most promising balancing services to be provided by Energy Communities, by surveying and framing the existing regulatory qualification requirements.

5-169-22: Peer-reviewed paper

Challenges and drivers for Positive Energy Districts in a Swedish context

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Gireesh Nair, Umeå University, Sweden
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Panel
5. Towards sustainable and resilient communities

Keywords
positive energy district, transition, energy, workshop, challenges, drivers

A Positive Energy District (PED) is an inclusive, energy efficient district with optimized energy flows and a local production of renewable energy, with an annual surplus of energy that can be exported to other areas. Most of the municipalities in Sweden have ambitious climate neutrality goals and implementing PEDs in cities could be one way to contribute to the achievement of those climate goals. However, PED is an innovative concept which is still ambiguous for many stakeholders, and many uncertainties remain. To understand the perspectives of Swedish stakeholders towards PEDs, a three hour long online workshop was organized in December 2020. Representatives from city officials, universities, energy utilities and real estate companies participated in the discussion groups. The groups discussed three topics related to PED, namely; 1) Definition of PED, 2) Challenges and drivers for PEDs and 3) Replication of PEDs.

Most of the discussion groups agreed to the importance of viewing PEDs as a part of the larger energy system and to find holistic solutions and promoting collaboration between actors. Most groups considered leadership and stakeholder engagement as important drivers for PEDs. Further, participants discussed that the slow decision processes in municipalities could be a challenge for PEDs. Even though there was consensus on most challenges and drivers, one aspect where participants had conflicting opinions was the PED definition. Some groups thought that the PED definition needs to be clearer and more narrow, while others saw it as a potential barrier if it becomes too technology focused. During discussions on replication, most groups stressed the importance of knowledge sharing and the results highlight that different stakeholders can play different roles in facilitating replication for PEDs. The study highlights the importance of a regional perspective when developing the PED definition, since the Swedish stakeholders had different viewpoints on PED that could be used to adapt the definition.

5-199-22: Extended abstract

Energy citizenship in rural communities. Place making, third places and physical structures.

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Pasi Aalto, Norwegian University of Science and Technology (NTNU), Norway
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Panel
5. Towards sustainable and resilient communities

Keywords
energy citizens, sustainable communities, local and regional energy planning, consumer involvement, transition

The city is the dominating spatial entity in the green shift discourse, as measures and efforts related to densification, increased investment in public transport and micro-mobility, to mention some, are usually not developed with rural communities in mind. Rural areas in Norway experience demographics showing an older, diminishing, and often male-dominated population. On the other hand, citizens in rural places often have a strong sense of belonging, place attachment and community feeling. The distance from decision to action is short, networks are already established, and local know-how and initiative can produce contextual and fitting alternatives in the green shift.

Getting young people of all genders to stay or move back after studying is challenging as rural areas often offer a narrower spectre of job opportunities, difficulties getting affordable and up to standard housing, and meaningful leisure activities. Home, work, and leisure are often far apart and require private transport to get between.

Citizens' proximity and access to physical environments that provide quality of life and facilitate social behaviour is central to achieving the green shift, and affects citizens' travel patterns, transportation options, and overall living conditions. These informal social spaces to gather, engage and interact outside the home and workplace, are commonly referred to as ‘third spaces’, and can function as places for citizen’s participation and local democracy. By investigating opportunities to combine social spaces, such as shared neighbourhood facilities and activities, with housing and workplaces, we aim to increase awareness of energy citizenship and create more room for sustainable, low-emission lifestyles in rural areas.

The spaces that citizens use as their homes, workplaces, and social spaces are, at the same time, some of our biggest energy consumers. Globally, buildings account for approximately 40% of our total energy use. Even in a country with good building standards and well-built hydropower capacity, buildings still account for 15% of national emissions. Optimising the use of buildings has proven to be very complicated, as their intrinsic technical, cultural, social, and physiological aspects are not aligned. Utilising participatory strategies to involve local citizens, with knowledge of local potentials and challenges, is an alternative route to develop context sensitive solutions instead of externally developed one-size-fits-none.

Our study investigates context-specific measures supporting the green shift combining local competence and solutions with construction expertise and academic knowledge, establishing key enablers for local participation rather than overarching frameworks. Through participatory methods, we target age- and gender dimensions in the rural community Overhalla in Norway to develop social meeting places, new and innovative forms of housing aiding a low-emission lifestyle, including transport. In this approach, we investigate the interplay in the local community between place, architecture, and energy use.

This Norwegian Citizen Action Lab (CAL) is one of 9 CALs across Europe that put energy citizens at the core of the innovation process. The research is part of the DIALOGUES project, a Horizon 2020 funded project aiming to produce an operational concept of inclusive energy citizenship that accounts for diversity and empowers groups currently at the margins of the energy transition to take a more active role in supporting the objectives of the Energy Union. We seek to nurture the engagement necessary for citizenship to emerge and consolidate by understanding and facilitating active local participation.

5-239-22: Peer-reviewed paper

An innovative approach to achieve positive energy districts in Italy

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Panel
5. Towards sustainable and resilient communities

Keywords
smart cities, decarbonisation, renewable energy, sustainability, district heating, energy consumption, building retrofitting

Public and private sectors are nowadays focusing their interest on new solutions to fulfil climate-neutral goals by 2050. Indeed, due to global demographic development, cities produce 70% of global CO2 emissions, and consume two thirds of the total available energy supply, therefore energy consumption in buildings requires particular attention. A promising approach is moving energy performance targets beyond individual buildings towards an urban district level that has a zero, or even positive, energy balance. Such a solution must be investible whilst providing co-benefits to the citizens and local authorities. The positive energy district (PED) concept highlights the importance of all these features. A PED combines sustainable mobility, energy production and consumption to increase energy efficiency and reduce greenhouse gas emissions to create an added value for citizens. Furthermore, a PED also requires integration between buildings, users and energy network, mobility, and IT systems. This new urban development shifts the focus from the simple building to energy blocks and thus to a new level of sustainable urban development and energy transition in smart cities. Hence, to achieve a PED it is necessary to improve the efficiency of the buildings to reduce the energy needs and thus the quantity of energy production needed to cover it. As such, PEDs have become an integral part of sustainable urbanization strategies. This paper aims to provide a method for quantitative, qualitative, and cost-benefit analysis for the development of a positive energy district with renewable energy and energy efficiency solutions. As case study, a realistic district based in Milan has been designed via a Building Information Modeling software to simulate buildings energy consumption profiles and the impacts of efficiency measures, resulting in 15 GWh of saved energy and 2,209 tons of not emitted CO2. Finally, two cost-effectiveness scenarios were developed.

5-248-22: Peer-reviewed paper

High-resolution transformation strategies towards carbon-free heat supply in German municipalities

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Panel
5. Towards sustainable and resilient communities

Keywords
municipal utilities, renewable energy, Energy Efficiency Directive (EED), cost benefit, district heating

The decarbonization of the heating sector has become a major focus of energy policy in recent years. Almost 50 % of final energy consumption in Germany is accounted for heating, hot water or process energy with only 15 % share of renewable energies. District heating infrastructure provides an opportunity for municipalities to reduce GHG emissions significantly by developing large scale renewable energy heating technologies, such as geothermal, heat pumps or solar thermal plants. However, the potentials for these technologies are often locally limited and can only be used in a spatial proximity to the heat demand. Therefore, municipal heat planning plays a decisive role by taking regional characteristics into account.

As part of the reports for the European Energy Efficiency Directive (EED), we were commissioned by the German Federal Environment Agency to analyse the potential for efficient heating and cooling at municipal level in order to derive transformation strategies for municipalities. First, we analysed the locally available potentials of renewable heat in the over 4,500 German municipalities and compared them to the municipal heat consumption. The results are prepared in a GIS online platform for local stakeholders and used for the development of transformation strategies at municipal level. These can fulfil the energy efficiency target of a 30% primary energy reduction by 2030 and the minimum renewable share of 40 % in heat supply.

Second, a cost-benefit analysis was performed to evaluate all available technologies for each municipality from both a micro- and a macroeconomic perspective. The latter considered socio-economic and environmental factors and the well-being of society as a whole. Compared with the reference development, the transformation strategies have lower costs and lower greenhouse gas emissions. The results of this paper can help local actors for an initial assessment of local potentials by accessing the developed GIS online platform and thus serve as an important basis for the implementation of carbon-free heating strategies.

5-256-22: Peer-reviewed paper

Neighbourhood-level energy retrofits driven by intermediary actors: what are the prospects?

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Panel
5. Towards sustainable and resilient communities

Keywords
building retrofitting, neighbourhood-scale, intermediaries, literature review

Energy retrofits of existing buildings are one of the current priorities to tackle climate issues. A potential way of boosting the currently low rates of retrofitting could be by pursuing neighbourhood-scale retrofitting approaches. However, the existing literature does not offer a comprehensive analysis of neighbourhood-scale retrofitting and the role of intermediaries in it. Therefore, this research aims to determine the prospects of neighbourhood-level retrofitting driven by intermediary actors based on an extensive literature review, whereby: (1) state of the art, opportunities and challenges of neighbourhood-level retrofitting are presented; (2) intermediaries that serve as facilitators of retrofitting and the business models under which they operate are discussed; (3) governance of existing neighbourhood-level renovation projects are investigated. As a result, this study determines the key characteristics of neighbourhood-level retrofitting. Moreover, we suggest differentiating between intermediaries primarily engaged in intermediation and those who take on the roles aside from their main activities (e.g. municipality). Finally, the findings indicate that although many authors highlight the benefits of neighbourhood-scale retrofitting, they are hindered by the complex governance of engaged stakeholders. Intermediaries that could serve as facilitators and coordinators of these projects are still not very prominent in the actual pilots of neighbourhood-level retrofitting.

5-263-22: Peer-reviewed paper

A just energy trading platform – or just an energy trading platform?

Marten Boekelo, DuneWorks, The Netherlands
Jordan Young, DuneWorks, The Netherlands
Sylvia Breukers, DuneWorks, The Netherlands
Ruth Mourik, DuneWorks, The Netherlands

Panel
5. Towards sustainable and resilient communities

Keywords
community energy systems, design process, environmental justice, digital divide, user-friendly, flexibility services

This paper draws attention to the challenge to develop energy flexibility platforms that are understandable, usable and equitable. This challenge merits attention given the growing recognition of the strategic potential of energy communities to create and retain value locally, and in so doing, accelerate the transition towards a sustainable energy system. ICT platforms with features like energy management services and smart energy apps are mobilized to unlock this potential. They enable access to the flexibility market, facilitate energy trade and promote community members' engagement.

However, these platforms are also a sign and accelerator of the increasing complexity of energy provisioning. With this complexity come new uncertainties, dependencies and risks of exclusion. As part of our participation in three major EU H2020 demonstration projects for community-centred energy flexibility – Hestia, Lightness and NRG2peers – we draw on the environmental justice framework to develop a co-creative design process capable of addressing these issues. The main challenges include recognizing and designing for a diversity of users' needs and capabilities and creating a space for communities to be able to translate their social values into flexibility business models and matching technological architecture.

In the paper, we draw on our interviews and focus groups with pilot participants to identify the issues users face. We then report on our interventions in one of these pilots, where we focus especially on a co-design workshop, through which we try to align the participatory design process with justice principles. We argue that this combination can bolster and enrich user-centred design practices, which will help ensure not only that flexibility technology is fair, but also effective. We conclude the paper by evaluating outstanding challenges in realizing that promise.

5-273-22: Peer-reviewed paper

Evaluating domestic demand side response trials in UK dwellings with smart heat pumps and batteries

Rajat Gupta, Oxford Brookes University, United Kingdom
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Panel
5. Towards sustainable and resilient communities

Keywords
demand response, existing social housing, monitoring, survey

Smart heating and battery technologies are beginning to be deployed in UK homes to alter the timing of domestic energy demand to enable residential demand side response (DSR). This paper empirically evaluates the impact of DSR trials on grid electricity import and household experience regarding disruption to routines, thermal comfort and noise disturbance in 17 thermally efficient social housing dwellings (Barnsley, England) with air source heat pumps, 5 kWh smart batteries and solar photovoltaic panels (1.3–3.0 kWp). Four DSR trials were run during the latter part of the heating season of 2021 to shift electricity demand away from peak times using automated control of battery and heat pumps to impose two-hour 'turn-down' interventions during peak times and two-hour 'turn-up' interventions at expected times of local surplus renewable generation. The turn-down trials were driven by price signals (time of use tariffs) and grid carbon intensity. While during turn-down interventions grid electricity import was minimised, it was increased through battery charging and heat pump use during turn-up trials. Internet of Things based sensors recorded time-series data on grid electricity use, battery charging-discharging and heat pump electricity use. Telephone surveys were conducted with residents following the trials.

All turn-down interventions reduced grid import electricity. or time of use trials, grid import was reduced up to 1.7 kWh per household (85 %) between 5–7 pm and controllable load was reduced up to 4.3 kWh per household. For the turn-up trials, grid electricity import was increased up to 3.6 kWh per household and controllable load was increased up to 2.6 kWh per household between 1–3 pm. Household surveys revealed general concerns about the project related to fuel costs, indoor temperature and hot water temperature. Although a few households noticed battery noise during the trials, no one reported it as a concern. For 77 % of responses, trial changes were acceptable even amongst households who noticed changes in indoor temperature and battery noise. The general acceptability of automated DSR, under thermal comfort limits and manual override, are promising for the wider application of domestic DSR driven by price signals, although a continued focus on individual user support regarding the deployment of new technologies is needed. Additionally, individual dwellings may show different levels of demand response depending on the levels and patterns of electricity consumption.

5-281-22: Peer-reviewed paper

Creating superpowers: capable communities in smart local energy systems

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Panel
5. Towards sustainable and resilient communities

Keywords
social capital, information and communication technologies, community energy systems, smart grid

Trends in electrification of heat and transport plus connection of battery storage and renewable generation on electricity distribution networks are creating new challenges for network management as well as new opportunities for households, businesses and communities. Smart Local Energy Systems are a sociotechnical response to these trends, aiming to: a) tackle network constraints by balancing supply and demand at the local level using flexibility, b) create local markets for energy services, c) create efficiencies and social and environmental benefits. To participate in SLES, and capture benefits from them, households, businesses and communities need technical, economic, social and knowledge-based skills and capabilities. The wider energy system must also provide the right regulatory and policy context for SLES to be viable. Therefore, we can think of requisite capabilities as attributable to individual actors, to communities and to "system" levels of the energy system. As network constraints at low voltage levels are created by the collective actions of end users, collective solutions are often (but not always) necessitated and community level capabilities must become accessed and deployed. For example, a community connected to a constrained part of the low voltage network should possess the technical and social capabilities to aggregate flexible energy demand from a threshold number of households in the community - and to configure this flexibility into various network services (e.g. a "peak management" service) which can then be traded in a local energy market. Drawing on learnings from implementing an ambitious smart grid project in the UK (Project LEO) we explore the essential capabilities that communities require and can develop when their activities are coordinated. We consider what sharable skills and resources are needed and accessible through various forms of social capital (bonding, bridging, linking) and ask whether building social capital is an appropriate policy response for promoting SLES. Finally, we highlight energy equity issues arising from unequal distribution of community level capabilities.

5-297-22: Peer-reviewed paper

Social fingerprints: Social characterization of a neighbourhood as design frame for sustainable communities

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Carina Wiekens, Hanze University of Applied Sciences, The Netherlands
André Faaij, University of Groningen, The Netherlands

Panel
5. Towards sustainable and resilient communities

Keywords
local and regional energy planning, survey, neighbourhood, citizen participation

IIn this study, survey data were collected for a neighbourhood in the municipality of Pekela, The Netherlands. The neighbourhood takes part in a national programme aiming for natural gas-free neighbourhoods as Living Lab. The study demonstrates how social data can complement economical and technical data to inform the energy planning process. With these data, both the choice for specific measures and the way in which plans should be implemented can be adjusted to the specific features of a community. A theoretical model was developed in which relevant resident and neighbourhood characteristics were identified based on the existing literature. Demographic, community, individual, socio-historic context and participation factors were identified as key concepts. Part of these concepts are related to energy, such as attitude towards energy transition and the willingness to take energy measures, and part of these concepts are more general in nature, such as the social contacts between neighbours. A total of 25 factors within those 5 key concepts were measured for the neighbourhood. With these data, a so-called 'social fingerprint' was constructed, a unique set of scores on the variables that represents the neighbourhoods' identity in a concise manner. The social fingerprint, presented in a graph, can be compared with other neighbourhoods in a way that mutual differences become easily apparent. Notable characteristics for Pekela are the low institutional trust and low scores on neighbour interactions while showing strong neighbourhood connectivity. The social fingerprint can be interpreted for application in the planning practice. Overall, tangible indications can be given for the technical measures to be chosen, the communication with citizens, the degree of citizen participation and the cooperation with third parties.

5-301-22: Peer-reviewed paper

A model, for the local agents of change, on how to construct projects and procurements of energy efficiency in renovations

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Maria Lindman, Recorded Value AB, Sweden
Jens Johansson, National Agency for Public Procurement, Sweden

Panel
5. Towards sustainable and resilient communities

Keywords
initiatives and solutions, public procurement, collaboration, building refurbishment, energy saving potential, energy efficiency agreements

Over the past decades there have been various programmes available to enhance energy efficiency in buildings. However, it is difficult to engage building managers in public organisations to work on long term projects on a large scale in their entire building portfolio. Market failures such as lack of knowledge, financial resources, collaboration, trust and split incentives, are some of the obstacles that constrain national energy efficiency programs that can be implemented at the local level. The latest Swedish programme for energy efficiency in 2016–2018 reached 15 % of the potential targeted buildings (RIR2019:25). The targeted buildings being rental apartment buildings in low income areas. The Swedish energy efficiency target is to reduce energy use by 50 % by the year 2030. The potential for energy efficiency is large; there are in total about 2.8 million apartments in Sweden and 80 % of them were built before 1980 and most of them have not undergone any renovation with focus on energy efficiency .

This paper describes the findings from the project EnOff (Energy efficiency in public sector), focused on developing a model to purchase energy efficiency measures in public buildings and systemise it for a whole building stock. The project members were not satisfied by the current concepts on the market and they wanted to find a more purchaser driven concept. The EnOff concept was developed in the project and tested in the city of Enköping.

This paper describes the purchaser driven model (for making exiting buildings more energy efficient) that was developed by the EnOff project. We emphasise the role of procurers as facilitators and not only as administrators. The by law regulated process of public procurement is perceived by many building managers as complicated and as a threat to rational purchasing. This is a hurdle that needs to be overcome, otherwise a majority of energy efficiency programs in the public sector risk to fail. The EnOff model helps to overcome this hurdle.

5-302-22: Peer-reviewed paper

Municipal climate action managers: Effectiveness in funding acquisition and GHG mitigation

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Hesse Tilman, Öko-Institut, Germany
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Panel
5. Towards sustainable and resilient communities

Keywords
climate, climate action plan, climate policy, impact evaluation, municipal utilities, funding

Germany has approximately 11,000 municipalities which can make a significant contribution towards achieving climate targets. The Local Authorities Funding Guideline (LAG) of the German National Climate Initiative (NCI) has supported municipalities in designing and implementing climate action since 2008.

One of the funding components of the LAG is the funding of a position for climate action management (CAM). Since 2008, more than 800 climate action managers have been funded. The positions are funded for three years and can be renewed for a further two years. Often the positions are made permanent and firmly anchored in the administration after the funding period ends.

The tasks of the climate action managers are very diverse. Their main task is to implement investments in energy efficiency and climate action measures. They often apply for further funding for this purpose or advise and support others in the application process. However, measuring their impact presents a challenge. Determining the impact of a policy instrument such as the funding of a climate action staff position is essential, on the one hand to be able to justify the expenditure of funding, and on the other hand to create a knowledge base for the continuation and further development of the instrument. This study contributes towards such an impact analysis.

The aim of the study is to analyse the effect of the work of the CAMs on the call for funding and to quantify the greenhouse gas reductions achieved through the implementation of funded climate action measures. The analysis was carried out as a comparison group analysis: The acquisition of subsidies in municipalities with climate action managers is compared to that in municipalities without. The associated greenhouse gas reductions are quantified. Data from 11 funding programmes were evaluated.

In addition, in the group of cities with climate action management (CAM), funding calls before the introduction of CAM were compared with funding calls after the introduction of CAM. Both comparisons were made for small and medium-sized municipalities.

The results show that more funded climate action measures are implemented in municipalities with CAM than in municipalities without. The funding volume with CAM is also significantly higher than without, and greenhouse gas reductions are correspondingly higher. With the results presented here, the impact of municipal climate action managers on the reduction of greenhouse gas emissions in municipalities can be proven. For municipalities with CAM, it can also be shown that more projects are implemented after the establishment of CAM than in the years before the climate action manager was hired.

The survey results can be used to demonstrate the importance of climate action managers for municipal climate action and for the implementation of climate protection measures. The aim should therefore be to increase the number of municipalities with climate action managers.

5-315-22: Peer-reviewed paper

Low-carbon commons: changing property rights for urban retrofits

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Panel
5. Towards sustainable and resilient communities

Keywords
retrofit, urban planning, traffic management, new paradigm, public space, neighbours, social innovation

This paper develops a analysis of challenges to urban low carbon urban retrofits, caused by the scarcity of urban space and the presence of pre-existing property boundaries. There is growing evidence that the spatial characteristics of a city influence the environmental footprint of its citizens and that this creates a range of context specific challenges for the governance of low carbon transitions in cities. On the one hand, more compact cities are associated with lower carbon lifestyles. But on the other hand, more urban space allows for more retrofit options, e.g. for external insulation, installation of more renewables and accommodation of more active travel infrastructure (e.g. bike lanes) or green space to provide nature based solutions. But it is not only the existing urban morphology, street design and housing types that shapes the options for low carbon interventions. The city is a dense network of rigid property boundaries and old rules about access to and use of space, and existing literature pays limited attention to the ways and extent to which this can hamper the adoption of more efficient and equitable low carbon investments and behaviours, especially when many homes are privately owned by their residents. Through real world examples, this paper seeks to characterise these property barriers and spatial constraints, and organise low carbon interventions into a generic set of options to change property archetypes – typically away from exclusionary private control towards a better low carbon utilisation of scarce urban space. Focusing on substantive urban issues in the UK (i.e. concerning millions of households), this paper highlights how the existing landscape of allocated private rights (from user right to exclusionary ownership) creates significant inefficiencies in deploying low carbon interventions in particular parts of the city, and discusses what (in terms of property rights) would need to change in order to overcome these inefficiencies and achiever faster and deeper decarbonisation of existing houses, streets and neighbourhoods.

5-320-22: Peer-reviewed paper

Secondary school student participation in Carbon Footprint Assessment for Schools

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Oliver Wagner, Wuppertal Institut, Germany
Dieter Seifried, Büro Ö-quadrat, Germany
Lotte Nawothnig, Wuppertal Institut, Germany
Lena Tholen, Wuppertal Institut, Germany
Amelie Straßen, Wuppertal Institut, Germany
Amelie Vogler, University of Graz, Austria
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Panel
5. Towards sustainable and resilient communities

Keywords
schools, greenhouse gas emissions, tool, Carbon Footprint, self-efficacy

More and more cities are setting themselves ambitious climate protection targets, including CO2 neutrality. Schools are important institutions of cities and therefore they have to play a central role in achieving this goal.

With the investment backlog building up and pressure from the Friday for Future movement increasing, the Wuppertal Institute and Büro Ö-quadrat have initiated the project Schools4Future, aiming to support secondary schools to become climate-neutral. In cooperation with secondary school students and teachers, the project team evaluated the existing situation of the participating schools and developed GHG-balances and feasible climate protection concepts. For this purpose, an Excel-based carbon footprint (CF) assessment tool for schools has been developed which is freely available. The tool covers all important emission areas, including heating energy, electricity use, travel to and from schools, school trips, the school canteen and paper consumption. The students were found capable to conduct the CF assessment with the guidance of the teacher, information materials and support of the researchers. So far, six pilot schools have completed their CF assessment with emissions ranging between 335 and 944 kg CO2 per person.

In this paper we present the tool and compare the CF assessment of some schools. We further elaborate on how the tool and project has increased the climate awareness and self-efficacy of students and even stimulated measures by the school board.

5-337-22: Extended abstract

The role of aggregators in energy communities

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Marta Lopes, ESAC / INESCC, Portugal
Carlos Henggeler Antunes, DEEC / INESCC, Portugal

Panel
5. Towards sustainable and resilient communities

Keywords
community energy systems, end-use flexibility, aggregators

A successful energy transition depends on multiple inter-related factors of different nature and scale, including the decarbonisation of key sectors, smart use of energy, design of development paths for more sustainable and resilient cities, optimal integrated management of energy resources (including load control, renewable local generation and storage), change of energy behaviours, and deployment of energy communities. Considering that cities are responsible for a big share of global energy consumption and emission of greenhouse gases, it is urgent to mitigate their negative impact on environment and climate change. Energy communities can play a decisive role to foster energy transition in cities. A key issue to make energy communities active players in the management of power systems contributing to energy transition is the ability to leverage demand-side flexibility. Aggregators act as intermediaries between energy communities and markets / grid operators contributing to collect and manage energy communities' flexibility, which can provide valuable system services with multiple positive impacts. Once gathering a flexible portfolio of energy resources, aggregators use optimization techniques to address different purposes, such as participation in the provision of ancillary services, including load-frequency control, or the scheduling of resources considering economic, environmental, and quality of service objectives with benefits for different players. From a market perspective, the participation of aggregators in the electricity market contributes to increase competition and liquidity. There are, however, regulatory and policy level barriers that need to be addressed to capture the full potential of aggregators. The aim of this work is to give an overview of the role and potential of aggregators to support energy communities, as well as existing barriers and recommendations, while discussing existing market models in place in the European Union.

6-002-22: Extended abstract

Requesting control and flexibility: A mixed methods case study on user perspectives on smart charging

Frans Libertson, Lund University, Sweden

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, smart charging, flexibility

Smart electric vehicle charging and user flexibility have been proposed as potential remedies for future imbalances in energy consumption. Smart charging programs, which integrate information, communication technologies, and energy networks, seek to maintain equilibrium between supply and demand within the boundaries of renewable energy production. They seek to allocate charging so as to avoid overloading the energy system at peak hours while reaping the benefits of charging during off-peak hours.

The success of smart charging programs, however, requires close collaboration between users and system operators. In smart charging schemes, users are expected to relinquish their control over charging while also being more flexible in their energy use. From an electric vehicle user perspective, flexibility can be defined as adapting one's charging in time, space, or intensity to accommodate someone else's need for electricity. However, providing flexibility will not only imply adapting current charging routines, but it may also come at the expense of the user's own flexibility in mobility. In essence, providing flexibility may to some extent entail giving up one's ability to accommodate all one's mobility needs.

This study increases the understanding of how users respond to this new approach of energy use and adds to the body of knowledge on user perspectives on smart charging. In order to do so, the study focused on the functional, symbolic, and societal attributes that users ascribe to the technology. Furthermore, the study added the layer of flexibility capital to highlight the discrepancies between user attitudes toward SC and user's actual flexibility capacity.

In general, the respondents were positive toward smart charging as a concept. However, reliability and the possibility to accommodate one's mobility needs were found to be important factors, as the utility of smart charging was associated with a certain level of uncertainty. Participation in smart charging schemes was associated with altruism, and SC was understood as a natural development of the energy system and a new market form that could safeguard future energy supply. Smart charging was deemed to imply grid stability and better renewable energy source integration for society.

Participating in SC schemes requires the capacity to be flexible, and this capacity should be regarded as a form of capital, similar to cultural and social capital, which may be converted into money under certain conditions. The factors that enable or limit a user's capacity to be flexible are complex and embedded in daily life. The results of this study confirmed this by showing that providing flexibility was perceived by the respondents as something partly beyond their direct control. Instead, user flexibility capacity was deemed to depend on external factors, such as working patterns, home conditions, technical knowledge, EV type, and access to charging stations. That being so, the implementation, optimization, and success of SC schemes rely more on societal structures than on user attitudes.

This study thus concludes that integrating SC schemes in daily life is far more complex than merely a matter of individual choice. Rather than focusing on general economic incentives to advance participation, future policies should be customized to individual conditions to compensate for any differences in users' capacity to be flexible in energy use in order to avoid unfair flexibility markets.

6-008-22: Peer-reviewed paper

Optimizing the utilisation of EV light goods vehicles for supermarket delivery services

David Wallom, University of Oxford, United Kingdom
Cheng Zhang, University of Oxford, United Kingdom

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
logistics, electric vehicles, transition

With the rise of online grocery shopping, a centralized delivery model has the potential to improve sustainability. Growing demand though brings challenges to grocery retailers' net-zero targets with many retailers' sustainability plans detailing the transition to electric vehicles (EV) within logistics as essential. In this study, a feasibility analysis on replacing internal combustion engine vehicles (ICEV) with EVs for Sainsbury's grocery delivery business in Oxfordshire was conducted. As grocery delivery has stricter timing requirements and considerations must be made for EV charging and load management, several methodologies were proposed and used in simulations.

Using Genetic Algorithms combined with Dynamic Programming for vehicle fleet route optimization, we were able to achieve optimizations of 48.8 % under the 4h Saver slot and 20.8 % under the 1h Standard slot. Furthermore, strategies were developed to optimise the number and type of EVs deployed at each store and the location of EV charging stations (EVCS). The optimal strategy provided a reduction of 458.8 km for daily fleet operation under the Saver slot. Emissions analysis shows that the initial deployment of the EV fleet results in 303.5 tons more greenhouse gas (GHG) than the ICE fleet. However, during operation, the accumulated GHG emissions of the ICE fleet exceed those of the EV fleet after the 4th year of deployment. Due to the battery and EVCS installation costs, the upfront cost of the EV fleet is €474,600 higher than the ICE fleet but would see operational cost savings of €609698 due to the lower cost of electricity. Technical, environmental, and economic analysis proved the feasibility of EV fleet deployment for Sainsbury's grocery delivery business based on the specifications of existing electric vehicles and the current technologies & standards of EV charging. Increasing carbon prices and decreasing carbon intensity of electricity generation would expand the benefits of EV usage even further in the future.

6-009-22: Peer-reviewed paper

Investigating In-Route Energy Consumption Profiles of battery-electric buses using open-source transportation simulation

David Wallom, University of Oxford, United Kingdom
Sabrina Gao, University of Oxford, United Kingdom

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
public transports, Rural population, Bus, electric vehicles

IIn the context of ambitious net-zero targets and decarbonisation of transport, bus fleet electrification has emerged as a likely significant transformation. This study proposes a multi-step model for investigating the effect of route structure on electric buses' energy consumption. Initial bus fleets were selected based on the route demand and characteristics, using a Multi-Criteria Decision Matrix. Energy consumption modelling of buses was differentiated into auxiliary and powertrain components to consider select operational characteristics. Travel flow analysis was conducted using the Simulation of Urban Mobility (SUMO) software through importing transport networks, defining bus stop locations and routes. A case study of Oxfordshire's existing bus system was conducted given worst-case seasonal temperatures including optimized electric bus selection for five selected routes, and a flow simulation to determine the energy consumption patterns of different route types.

Powertrain modelling showed strong monotonic relationships between route length and propulsion energy consumption, ranging from 19.1 kWh to 105 kWh for the shortest and longest routes respectively. Higher levels of congestion, proxied through average inter-stop speeds, correlated with lower instantaneous energy increases. Overall, auxiliary systems constituted a maximum of 11 % of total energy consumption across all routes simulated. Auxiliary system modelling also showed that total energy consumption and the proportion spent on auxiliary services were only weakly influenced by route length; instead, stronger correlations were observed with the total number of stops, due to a significant impact on door opening times. Future work could investigate the optimised location of depot and in-route charging infrastructure to best support electric bus fleets considering additional constraints of grid congestion. These findings contribute to research on the infrastructural needs of a zero-carbon bus fleet by providing local authorities with a high-level understanding of e-bus energy demands across the region.

6-032-22: Peer-reviewed paper

Electrifying trucks and other fleets: Utility infrastructure will be critical

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
fleet operators, utilities, electric vehicles, electricity grid

As electric grids get cleaner, the use of electric vehicles becomes a central decarbonization strategy; this means trucks as well as passenger vehicles. In the U.S., buses and freight trucks account for less than 5 % of vehicles but about 28 % of greenhouse gas emissions. Many trucks are part of fleets, including delivery vehicles, buses, garbage trucks and tractor-trailers. Discussions with electric truck manufacturers indicate that a large barrier to fleet electrification is having adequate power on-site to charge vehicles. Fleet charging can require several megawatts of power, with loads of 20 MW or more in some applications; fleet depots can have power needs similar to many factories. In order to supply this power, utilities need to assess customer charging needs and incorporate findings into the planning of local distribution grids. Needed updates will often include new transformers, sometimes include new feeders, and at times require substation upgrades. In the U.S. a few utilities are taking a proactive approach to prepare for fleet electrification, but most utilities have barely started. This paper characterizes this emerging issue and provides case studies on how several leading utilities are preparing for electric fleets, providing models for other utilities.

6-079-22: Peer-reviewed paper

Comparison of electric vehicle charging efficiency with IEVCC and a typical EVSE

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Marco Silva, Coimbra Polytechnic - ISEC and INESC Coimbra, Portugal
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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, EVSE, load management, charging efficiency

More than a fashion trend, EVs (Electric Vehicles) are here to stay and present themselves as a solution for combating climate change. In addition to the TCO (Total Cost Ownership) reductions, these vehicles are much more efficient than their equivalent ICE (Internal Combustion Engine) counterparts. Even if all the energy used to charge an EV comes from renewable sources, one of the points in the energy transfer chain, where efficiency can be optimized is in the charging process, whose efficiency depends on the charging power. This results from the fact that the EV internal charger has a fixed minimum power consumption to operate. Charging with a higher power results in less time charging, so less time is spent wasting energy on the EV internal charger. EVs come equipped with an internal charger whose charging power can be controlled by an external charge controller, commonly known as an EVSE (Electric Vehicle Supply Equipment). Manufacturers typically supply EVSEs with a fixed charging power setting, so they can be used on a household plug without any safety issues concerns. Usually, this power is set to around 2.3 kW for 230 V, but it is not uncommon to find values around 1.84 kW and very rarely 2.76 kW (which corresponds to currents of 8~12A). Often these EVSEs, due to the low charging power, do not always allow the users to restore the total charge used on a common day. In addition, the use of energy in a house is conditioned by the contracted power, which, if exceeded, triggers the main switchboard of the house. This requires some scheduling to manage an EV charging session in conjunction with other house appliances usage. The use of an EVSE that considers the instantaneous house consumption and adjusts the EV charging to the maximum available power, allows to maximize the charging efficiency. A new EVSE that implements these functionalities has been developed and is addressed in this work. This EVSE, which is called IEVCC (Intelligent Electric Vehicle Charger Controller) is compared with a fixed EVSE, and the results show greater efficiency in the charging process.

6-099-22: Extended abstract

Addressing flying-as-default setting in India’s IT companies to reduce their climate pollution

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
aviation, information and communication technologies, sufficiency, greenhouse gas emission reduction

The aviation industry is the most complex and challenging industry to decarbonize. The Indian aviation market is the world’s fastest growing and it’s Information Technology (IT) sector is severely dependent on Air Travel; it accounts for 25% of its annual GHG emissions and are rising 7% per year while emissions from electricity declined by 0.8% for India’s 2 largest IT Companies. This study first examines barriers to reduction of excessive flying that allow the issue to be recast as one plagued with lack of choice or one that will be addressed by breakthrough ‘green-aviation’ technologies in the near future. In terms of socio-psychological barriers, it examines the perceptions of: uncleanliness of other modes of travel (eg. rail travel), prestige of air travel, productivity, inequity felt by average employees upon whom air-travel restrictions are imposed while top executives continue flying unhindered. In terms of intra-industrial factors it interrogates the influence of 'sacrosanct' business principles such as the necessity of personal contact to retain customers, prejudiced insurance policies favoring air travel vs. perceived unsafe models of travel (eg. rail). ‘Greenwashing’ discourses explored are aviation industry claims of hydrogen fuel technology, electric aircrafts, Sustainable Aviation Fuels, Carbon Offsets.

The paper presents preliminary results of an ongoing Pilot Program (FairTravel, FT) to mainstream sustainable air travel policy and practice through India’s IT Industry. It employs the participatory concept of ‘carbon reduction action groups’ (CRAGs) within IT companies, that set their own air travel reduction targets and develop an implementation roadmap. FT supports them through the process, providing training, behavioural change facilitation and decision support tools. The program concludes by examining CRAGs reductions vs. average employees (i.e. ‘control’ group). Insights will be used to advocate for change with IT Industry Regulatory Authorities.

6-114-22: Peer-reviewed paper

Understanding the gaps and addressing the potentials of energy sufficiency in "catching-up" European economies

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
energy sufficiency, policies and measures, CEE countries, modelling, transport sector

While the role of energy sufficiency as an essential driver towards reaching climate goals has been discussed in the European context for a few years, it still faces obstacles to making its way towards policy agendas. On one hand, existing policies tend to focus on energy efficiency and the development of renewable energies, which are more clearly identified, thoroughly assessed and integrated into available scenarios. On the other hand, energy sufficiency is commonly perceived as a limitation to individual needs and thought of in terms of willingness for behavioural change, although the concept has also to be considered at the policy level, resulting in infrastructural changes. This paper addresses reasons and ways to bridge this gap in understanding energy sufficiency and its role in strengthening the climate mitigation actions, with a focus on two “catching-up” economies in Central and Eastern Europe: Hungary and Lithuania. It summarises results from the CACTUS project, which analyses the integration of sufficiency in the sectors with the highest energy consumption shares, namely building and transport. First, the paper examines the potentials of energy sufficiency regarding energy and climate policy goals in the transport sector and discusses the building of energy sufficiency assumptions in the perspective of a European convergence. Then, considering the crucial role that scenario development plays in framing climate policies, it analyses the methods and challenges for integrating these assumptions in scenario models. The paper also explores the path towards more ambitious mitigation strategies by providing exploratory quantitative and qualitative analysis of sufficiency

potentials. The results of the project are expected to pave the way for the development of sufficiency policies by raising the awareness of policymakers on the sufficiency concept and its mitigation role.

6-144-22: Extended abstract

Pro-environmental self-identity and compensatory beliefs in moral self-regulation affecting the performance of pro-environmental behaviours

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
spillover, identity, behaviour, regulation, electric vehicles

Pro-environmental behaviour is often viewed as a mixture of self-interest and (altruistic) concern for others and/or the ecosystem. As such, it is a goal-directed behaviour where an individual consciously chooses to minimize his/her actions' negative impacts on the environment. Being purposive, pro-environmental behaviour is regulated by a cognitive process through monitoring and assessing the contextual and intrapersonal variables resulting in self-reaction. Except for situations where contextual forces are extremely facilitating or inhibiting, people are often inclined to possess some control over their feelings, motivation, thoughts, and actions. In most cases, self-regulation, therefore, mediate the effects of most external influences while providing the very basis for purposeful action.

Research on spillover effects has suggested that an individual's active moral self-regulation during and after performing a pro-environmental action would account for the degree to which he or she further engage in other pro-environmental behaviours. It is believed that the recent pro-environmental action could make the individual's self-concept of being a pro-environmental person (i.e., pro-environmental self-identity) salient. In line with the identity theory, when this identity is in the foreground (salient) it will more likely predict behaviour when the meaning of the behaviour corresponds to the meaning of the identity. That is, the performance of pro-environmental behaviours is best predicted by pro-environmental self-identity that is made salient. On the other hand, doing something 'enough' already, may liberate the individual from an obligation to act virtuously when the next chances occur. Put in another way, past good deeds can compensate for the individual's divergence from subsequent behaviour corresponding to the individual's pro-environmental self-identity. It is understood that compensatory beliefs are used as balancing stock by offsetting the adverse impact of a transgression on one's self-concept.

Based on the above reasoning, it is proposed that whether people are more, less, or equally likely to perform other pro-environmental behaviours after an initial pro-environmental act depends upon their active balancing of pro-environmental self-identity and compensatory beliefs. Using survey data (N = 587) collected in 2019 among owners of recently registered battery electric vehicles (BEV) in Norway, a multiple indicators and multiple causes (MIMIC) model, where the effect of pro-environmental self-identity on the performance of pro-environmental behaviours is moderated by the compensatory beliefs controlling for some demographics (i.e., age, gender), is tested. Prior to the MIMIC modelling, a two-parameter logistics (2PL) model is applied to a battery of 23 pro-environmental behaviour items to obtain performance scores. The results show that both the measurement model and MIMIC model without interaction fit the data well. The MIMIC model with compensatory beliefs' moderating effect shows a slightly better model fit. As hypothesised, pro-environmental self-identity exerts a strong and positive effect on the performance of pro-environmental behaviours. The compensatory beliefs not only have a negative and moderate impact on the behaviours but also moderate the effect of pro-environmental self-identity on the behaviours. Age and gender, which are included in the model as covariates, are also found to influence model constructs.

The results of data analyses thus demonstrate a moral self-regulation process occurring under the performance of pro-environmental behaviours. Meanwhile, it seems that compensatory beliefs cannot entirely offset the heightened sense of pro-environmental self-identity, in situations where the initial behaviour is costly and difficult. It appears therefore that once an individual is committed to cracking a hard nut will there be a little hindrance to reaching low-hanging fruits.

6-159-22: Extended abstract

Stakeholder expectations as a barrier or success factor for alternative drive technologies – the case of ehighway systems in Europe

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
heavy-duty transport, stakeholder, innovation, fuel transition, actors, qualitative study

Catenary trucks and infrastructure, so-called eHighways, present one option to decarbonize the growing heavy-duty road transport sector. EHighways enable electric vehicle charging through overhead lines during driving. This makes them an energy-efficient solution as the trucks do not have to carry large and heavy batteries. However, the technology requires adjustments on the vehicle side and a large initial build-up of catenary infrastruc-ture. To achieve such a far-reaching system change, not only techno-economic aspects are relevant but coordination and negotiation between relevant stakeholders as well.

Activities around eHighways continue to be dynamic. In addition to the concluded field trial in Sweden, Germany plans extensions of its three trials and additional countries are getting involved. This suggests that the technological innovation system (TIS) around the technology is growing. However, market development and a diffusion of the technology beyond the field trials necessitates a wider market acceptance and many vehicle manufacturers remain critical of the technology. To shed light on potential roadblocks our aim is to identify industry-perceived success factors and barriers for a market development of eHighways. Literature on sustainability transitions and innovations puts forward joint visions as a crucial aspect for the success of niche technologies and TIS (Scherrer et al., 2020). We therefore ask: (1) which expectations and visions do truck manufacturers have for eHighways and (2) how do these expectations and visions align or differ from those within the field trials?

We conducted a qualitative study using interview and document data in Germany. We interviewed representatives from five truck manufacturers, an industry association and a government programme association. We then triangulated this data with actor statements in newspapers articles and press statements. The material was coded according to the pre-identified categories of different actors and expectations. Sub-categories were then inductively developed based on the material.

Manufacturers' expectations highlight their perceived barriers for the potential success of eHighways.They expect the technology to be met with opposition due to its disruptive aesthetics, centralized nature, maintenance requirements, and lacking integration into EU regulations. They also expect that it will be difficult to standardize the technology across borders and to achieve a market competition that is as dynamic as the one already developing for fast, stationary charging.

A key difference in visions shows in the expected relationship between the alternative technologies. In the research projects, eHighways are considered one type of charging infrastructure that can be compatible with multiple vehicle configurations, including fully BEV. Such "synergetic" vision has, for example, been put forward by a Task Force in Germany (NOW, 2021). Manufacturers outside the trials consider eHighways to compete with BEV and focus on the early PHEV configurations. Further differences show in the expected future USP of eHighways. In the field trials, the technology is expected to retain its usefulness as it avoids stationary charging and the associated space and time requirements. Interviewed trial-external manufacturers expect the technology to lose its USP and only remain in specific niche applications if battery technologies continue to develop at current speeds and fast stationary charging is established.

The results show that in order to gather market acceptance, eHighways need to be set in context with rapid development around BEV and fast, stationary charging. Further factors are currently being analysed in a second coding round showing that acceptance seems to hinge on actors and processes in addition to technology specifications. Further analysis will account for these factors based on literature on technology legitimacy (Binz et al., 2016; Geels & Verhees, 2011).

6-161-22: Peer-reviewed paper

Intervening me softly - Modeling nudging interventions to change EV user preferences

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
consumer behaviour, electric motors, energy model, demand response, smart grid, feedback, social and economic pressure

The charging of an increasing number of electric vehicles (EVs) leads to load peaks in the distribution grid. Controlled charging can reduce these peaks, but could also impair the mobility needs of the EV owners. Financial incentives are a frequently discussed measure to stimulate grid-friendly consumption, but they are limited in their attractiveness for the consumers. A more intuitive approach is the so-called nudging interventions, which influence the decision-making of consumers through a change in their environment.

The design of nudging interventions, such as social comparison and normative feedback, is investigated in the literature but – so far – not simulated. A translation of nudging interventions, into a modelling environment would, however, capture effects beyond a theoretical setting. We address this research gap - for the case of EV charging - by setting up an agent-based simulation that models the decision-making of and interaction between EV users.

Our model displays the effect of nudging interventions on the preferred EV battery state of charge (SoC) for each agent. Based on social networks, we model how interventions spread within the agent population. The selected interventions, social comparison, and normative feedback aim to minimize the preferred SoC. The model captures different sensitivities of agents towards the interventions, different sizes, and structures of the networks, frequency of interventions, as well as the boomerang effect.

Our results show an overall reduction of the SoC for all interventions. The strongest impact can be allocated to the normative feedback. Our findings thus indicate that nudging interventions cause agents to accept a lower SoC. Correspondingly, a larger share of the flexibility potential provided by EVs would be made accessible for controlled charging. While our model is theoretical, it can be substantiated with empirical data on consumer preferences and combined with the modelling of controlled charging on the household, grid, and electricity system levels.

6-174-22: Extended abstract

Are synthetic fuels a promising option for ships and trucks? An investigation of actors and acceptance of renewable methane in Germany

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
commercial transport, stakeholder, technology acceptance, technological innovation system, renewable methane

Introduction
In the transport sector, synthetic methane from renewable energies represents a new option for decarbonising energy-intensive applications, like road freight transport and shipping. Whether renewable methane will succeed on the market in the future depends largely on how efficiently and cost-effectively it can be produced. In addition, a new technology such as renewable methane must receive support from various social actors in order to become established.

Research questions
The following questions are examined: 1) Which types of actors are currently active in the innovation system around renewable methane (and specifically in the truck and ship applications) in Germany? 2) How do the actors perceive the potential of renewable methane in general and in both applications?

Data and methods
A media and publication analysis of 279 German newspaper articles and publications and 12 guideline interviews with German stakeholders from the shipping and trucking sectors form the empirical base. To answer the first research question, actors were identified by means of the media and publication analysis. Subsequently, an overview of the actor system for synthetic methane was created with the help of an actor systematization (Hekkert et al. 2011). For the second research question, potential interview partners with a market focus around both applications were selected and interviewed about their assessment and acceptance.

Results
Regarding the first research question the results show that renewable methane has so far been discussed almost exclusively in specialist circles. At the same time, a wide range of actors, especially from research and industry, are already active in the field. Only few actors were

identified around the usage of synthetic methane in ships and trucks. This reflects the early stage of development. In addition, there is a large number of supporting organizations and an absence of critical voices. The interviewed stakeholders (second research question) are more positive towards renewable methane for ships than for trucks since energy-efficient solutions for large ships are scarce and LNG (Liquefied Natural Gas) has proven to be a viable option. Among ship actors, the technically straightforward conversion from LNG to synthetic methane is strongly emphasized. This can help overcome the long lifetimes of ships as a barrier to switching to alternative fuels or propulsion systems.

The truck actors, on the other hand, see other options, such as electric drives, as more promising. Some interviewees, however, continue to see gas drives as a bridging technology for the next few years (fossil gas) or with a longer-term potential for specific applications such as heavy-duty long haul transport (electricity-based gas).

Despite these differences, similar challenges for future market development were identified for both applications, such as e.g. resource competition and generation of renewable electricity, development of costs, regulation, slow development of infrastructure (incl. generation plants), lack of willingness to invest and lack of political support.

Conclusion and outlook

For the application of ships, it can be expected that the political pressure to reduce greenhouse gas emissions will increase further in the future. On a German national level there are also drivers for a further market development of LNG and in the long term synthetic methane (Timmerberg et al. 2021). In addition to renewable methane, however, the interviewees also see other promising options. As far as the truck sector is concerned, however, it will be a major challenge for synthetic methane to establish itself as an option. Here, both generation plants would have to be built and sufficient renewable energies would have to be available, as well as legislation that would classify gases produced in this way as climate-neutral. Only through a cost advantage over fossil fuels, a market opportunity for synthetic methane can emerge.

6-177-22: Extended abstract

How Norway's largest distribution company deals with electrical vehicles

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Alf Inge Tunheim, Elvia, Norway
Hans Christian Bolstad, Sintef Energi, Norway

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
batteries, smart water heaters, flexibility, smart grid

The Norwegian electricity distribution grid is conventional, inflexible and it has few solutions for remote measurements, monitoring and control. From a system perspective, it is important to demonstrate innovative solutions on a large scale so new technologies and systems become a real alternative to conventional solutions.

Norway is the country with the highest share of electrical vehicles, and the challenges we see today, is expected to come in Europe within 8 years. Analysis of the electrical grid for the Norwegian Distribution System Operator (DSO), Elvia, indicated that more than 2000 distribution transformers in the grid stations are in overload. This number is expected to increase in the future. Calculations also show that voltage drops >10% is a problem for a significant proportion of the end customers in the electrical distribution grid.

Elvia is testing if they can compensate for under voltage and overload in the low voltage grid by using batteries or consumer flexibility in form of smart water heaters (SWH) and smart electrical car chargers. SWH are deployed in 20 regular households and 40 cabins (with high variability of use). The hypothesis of the pilot is that grid batteries and smart water heater control can raise the min. voltage in the low voltage grid, and thereby defer necessary traditional investments to the grid. A close collaboration between the DSO, technology supplier and customers can contribute to a sustainable solution.

The key outcome of the demonstration is:
• Practical experience with smart water heaters, smart electrical chargers, electrical grid batteries, and consumer flexibility and associated contractual frameworks.
• Evaluation of how solutions can solve the challenges of under voltage and overload in the low-voltage grid.
• Cost comparisons for the solutions and verification of cost reductions

We will present the first results, learnings and experiences of this ongoing pilot. The project is 1 of 4 pilots in the project IDE led by the Norwegian Smartgrid Centre.

6-179-22: Peer-reviewed paper

Mobility and sustainability practices in Viva, a sustainable residential building complex in Gothenburg, Sweden

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Sandra Hillén, Gothenburg University, Sweden

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
individual mobility, car buying patterns, car transportation, parking, mobility services

In a relative central area in Gothenburg Sweden there is a tenant-owner complex with 132 apartments. The complex was built in 2018–2019 with the ambition of being Sweden's most innovative and sustainable apartment building complex. Sustainability, in all its dimensions, guided the construction process and design from installing solar panels, energy storage facilities, facilitating recycling and providing sharing opportunities both for space and goods. From a mobility perspective no residential parking places were constructed and instead tenants are offered access to mobility services such as electric car-sharing, electric bikes and cargo bikes, larger bicycle garages and facilities for bike repair and care. We have followed the residents of Viva through interviews and surveys, before and after moving in the apartment, to assess the impact of moving to Viva has had on their sustainability practices with a special focus on mobility. We find that not having any residential parking does not imply that it is a car free housing. Both the before and after surveys show that there is a fair share of households that have retained a car, some of which reducing from previously having two. From the survey results we don't find that gender or environmental interest has any correlation with deciding to keep the car. However, car owners are slightly older than those without cars. From the interviews we find that other issues such as the ease of making everyday life work are more influential. One household with kids, e.g., was prepared to pay for parking in an adjacent parking lot for a year prior to the move, to be sure that they could retain the car. While another household, also with kids, found a large freedom in not owning a car and the financial opportunity to purchase an apartment in a relative central part of town. In general, the tenants perceive that Viva has facilitated a more sustainable living.

6-201-22: Extended abstract

Potential of micro mobility to reduce car trips and greenhouse gas emissions

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Mascha Brost, Institut of Vehicle Concepts, Germany
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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
Micro Mobility, Light Electric Vehicle, greenhouse gas emission reduction

The targeted climate goals and also the reduction of emissions of noise, pollutants and local heat can only be achieved with a worldwide change in transport behavior, supported by technological progress and fundamental changes in vehicle concepts. One contribution to reducing greenhouse gas emissions may be made by using very small and light electric vehicles (LEV).
These efficient vehicles have a favorable ratio of vehicle weight to payload (passengers or goods), and in addition to low vehicle weight, the most efficient use of electricity for propulsion contributes to environmental sustainability regarding vehicle operation. As with electrically powered passenger cars, local emissions from a combustion process are eliminated. In contrast to the large and heavy passenger cars, however, the traction batteries in LEVs could be considerably smaller, so that the consumption of critical raw materials is also reduced, thus lowering also production-related greenhouse gas emissions.

In order to quantify the theoretical potential of emission reduction, we want to present an interdisciplinary study that was carried out to determine what proportion of the trips currently made by car could, in purely theoretical terms, be covered by small and light electric vehicles (LEVs). We present a scenario, in which a major modal shift away from trips with full-sized passenger cars to LEVs has taken place. This analysis assumes today's patterns of mobility are maintained, but using full sized cars only for those few trips which are very long or include many occupants. The work employs Germany as a case study for potential savings, given the national importance of cars as both a means of mobility and an economic sector.

In order to determine the proportion of trips made today by car that could theoretically be made by LEVs, the national household survey MID 2017 was analyzed. We use the characteristics of vehicles (e.g. speed, range, number of seats) and trips (e.g. distance) to determine which trips may be conducted in LEVs, and thus derive a total for substitutable car kilometers. Many different types of vehicles, from e-scooters, cargo bikes and pedelecs to three- and four-wheeled light electric vehicles, are considered. Together with an assessment of greenhouse gas emissions per vehicle kilometer for both LEVs and the replaced vehicles (considering production via life cycle analyses and energy for vehicle use), a theoretical, calculative potential of greenhouse gas emissions savings is derived for Germany.

The results of the analyses show that 75% of all car trips and 50% of car mileage could theoretically be substituted by one of the LEVs considered. Regarding the CO_2eq saving potential an overall saving of 44% of entire car emissions can be assumed. This is equivalent to a reduction of 57 Mio tonnes CO_2eq per year.

6-222-22: Peer-reviewed paper

Evaluation of sustainable scenarios on extra-urban passenger mobility in Italy

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Anna Realini, RSE
Francesca Bazzocchi, RSE
Marco Borgarello, RSE
Carlo Caruso, Tandem
Edoardo Redaelli, Tandem

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
mobility, energy scenario, decarbonisation, environmental impact, long-term strategies, energy efficiency policy

The role of transport sector in achieving European decarbonisation goals through, among others, energy efficiency, is continuously growing: according to the Green New Deal transport-related greenhouse gas emissions must be reduced by 90 % by 2050 compared to 1990 levels. This makes transport the second most important sector after the residential one, ahead of industry and the tertiary sectors, in the framework of the European decarbonization strategy. The actions required to achieve such a goal must include a progressive abandonment of fossil fuels and the adoption of new approaches to the problem of sustainability in transport from both an extra-urban and urban mobility point of view. This paper is focused on reconstructing and modelling inter-zonal extra-urban passenger mobility in Italy, and exploring future evolution scenarios to explore long-term pathways toward a deep decarbonization of the transport sector in Italy. First, a multimodal model to evaluate the choices among four modes of transport (road, railway, high-speed railway, and airplane) was developed, based on an origin/destination matrix obtained from the cellular network TLC data. This constitutes the reference scenario representative of the current mobility demand. Then, six scenarios were created to evaluate the adoption of sustainable mobility measures and strategies, regarding lifestyle changes and policy and infrastructure interventions both from the demand and supply point of view in the expected post-pandemic framework. Moreover, the energetic and environmental impacts of each scenario are calculated and evaluated. Finally, possible applications of the model to other cases are discussed.

6-224-22: Extended abstract

Are Norwegian car users ready for a transition to Vehicle-to-grid technology?

Milad Mehdizadeh, Norway
Alim Nayum, Norway
Trond Nordfjaern, Norway
Christian Klockner, Norway

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, behavioural change, energy efficient technologies, electricity grid, attitudes, quantitative survey

Vehicle-to-grid (V2G) is a technology where electric vehicles (EVs) are able to transfer electricity back to the power network. The V2G technology allows energy systems to balance renewable energy, thus contributing to climate change alleviation. Employing a self-report online survey among Norwegian car users (n=929) in November 2021, the study aims to investigate how perceptions and beliefs towards the V2G system motivate both EV users and non-EV users (combustion engine car owners) to utilise the V2G technology in the future. Understanding similarities and dissimilarities in future intentions of V2G use across two groups of car users (i.e., EV and non-EV users) may facilitate segment-specific marketing. The core theoretical framework in the study is a hypothesised model based on the Technology Acceptance Model and the Theory of Reasoned Action. The results show that the theoretical framework substantially explains future V2G use intentions. The model showed that behavioural beliefs related to the use of V2G technology and varying concerns and benefits about this system (e.g., concern over vehicle battery, usefulness in terms of financial and environmental benefits) explain V2G adoption among the groups. A multiple-group structural equation model showed structural stability in associations between the model constructs and intention across EV and non-EV users. However, non-EV users had lower means on central variables (i.e., trust in V2G, perceived ease of use, vehicle battery concern, perceived usefulness, subjective norm, and intention). As a result, non-EV users are not equally likely to adopt V2G, but if their values on the central variables could be increased, then the effect would be the same as for the EV users. The study concludes that both groups of car users are ready for a transition to V2G technology. When it comes to behavioural change campaigns, the same measures could be taken into account for both groups of car users. Non-EV users, however, should receive more attention in such campaigns.

6-246-22: Extended abstract

The new normal: modelling electricity demand and the potential for flexibility from EVs in a post-COVID, energy demand-conscious future

James Dixon, CREDS, University of Oxford - Environmental Change Institute, United Kingdom
Jack Flower, University of Strathclyde, United Kingdom
Jonathan Bowes, University of Strathclyde, United Kingdom

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, car transportation, passenger vehicles, electricity system flexibility

Demand-based policies are crucial to delivering decarbonisation in Global North countries, and the UK is no exception. The Centre for Research in Energy Demand Solutions (CREDS) have published Low Energy Demand (LED) scenarios, from which it was reported that the UK could reduce final energy demand by up to 50% without compromising quality of life via 'steer', 'shift' and 'transform' policies. However, the CREDS work considered only the magnitude of demand, and not its all-important temporal variation.

This work will undertake modelling of the implications of these reductions for the temporal variation in electricity demand from electric vehicles (EVs – in this case referring to private passenger cars) and the potential for flexibility to support an increasingly high proportion of variable renewable energy in the generation mix.

This work will take outputs from the CREDS LED scenarios for mobility, and use the CREDS findings to synthesise credible travel patterns based on an established means of synthesing EV charging behaviour from travel diaries – in this case from the UK National Travel Survey (NTS). CREDS analysis of post-COVID demand scenarios will also be included in the analysis. The conclusions to be taken from this work will be changes in future electricity demand projections and the temporal variation in EV charging demand based on credible changes in personal mobility following the realisation of the CREDS LED scenarios. The findings are important and relevant to the quantification of i) the level of demand that will be placed on UK infrastructure and ii) the contribution from controllable electrical load in supporting the decarbonisation of the electricity system, which will be crucial in supplying the demand-conscious future energy system.

6-267-22: Extended abstract

Evaluation of a major EU climate and energy initiative: the Covenant of Mayors

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Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
climate change mitigation, climate change adaptation, policies and measures, local and regional energy planning, local authorities

Cities and local authorities are key players in addressing climate change. The Covenant of Mayors for Climate and Energy (CoM) has been the first initiative of its kind addressing local authorities to endorse their efforts in the implementation of sustainable energy and climate policies and to provide them with a harmonised data compilation, methodological and reporting framework, supporting them in translating mitigation goals into reality. This paper provides the highlights of the last scientific assessment of CoM regarding mitigation and adaptation. The assessment covers the Climate and Energy Action Plans submitted by participating cities (more than 7000 cities), examines planned and implemented policies and measures (about 180000 for mitigations and 10000 for adaptation). It gives an overview on the progresses in terms of energy consumption reductions though energy efficiency, renewable energy generation and overall GHG emission reductions as reported by the cities in their regular monitoring reports, based on about 3000 monitoring reports. The risk and vulnerability assessment by cities is also presented together with the adaptation measures. The key findings show that the overall commitment to reducing GHG emissions by signatories is 30% by 2020 and 47% by 2030, compared to baseline emissions projected to 2005, with many cities committing to climate neutrality in advance of 2050 and the climate induced hazard presently and in future faced by cities.

6-306-22: Extended abstract

The interplay between infrastructure and gender roles in electric mobility transition

Josephine Tröger, Fraunhofer Institute for Systems and Innovation Research, Germany
Sabine Preuß, Fraunhofer ISI, Germany

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
gender, electric vehicles, mobility, individual action, individual mobility, environmental attitudes, identity, infrastructure

People drive electric cars when they perceive a high compatibility of the electric vehicle with their personal values and needs in everyday life (i.e., Rogers Diffusion of Innovation Theory, 2003). However, studies on early adopters show that mostly men drive electric cars. Based on gendered roles and gender differences in green behaviour and identities (Bloodhart & Swim, 2020), it is likely that current e-mobility infrastructure seems much less compatible with women's needs and values than those of men. One of these need differences maybe intertwined with the fact that men more often perform full-time jobs in their "breadwinner-role" whilst women perform part time jobs when they are put into the "caregiver-role" (Tammelin 2018). We argue that it is necessary to understand these interrelations and integrate needs and mobility patters of diverse groups into infrastructural planning in order to increase transformation and guarantee a just and gender-equal mobility transition.

Our study explores gender effects in perceived compatibility of needs and values in dependence of e-mobility and charging infrastructure at people's workplace. We invited Fraunhofer employees across Germany (minimum N = 200) taking part in an online survey before and after installation of semi-public charging infrastructure close to their workplace. We analyse interrelations between paid working time distribution, perceived gender identities, need and value compatibility as well as further variables determining acceptance and adoption of electric vehicles. Results will be presented and discussed.

6-307-22: Peer-reviewed paper

The role of energy demand reduction in achieving net-zero in the UK: Transport and mobility

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Jillian Anable, University of Leeds, United Kingdom
Greg Marsden, University of Leeds, United Kingdom

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
energy demand, mobility, scenarios

Decarbonising the transport sector is arguably the most challenging given ever increasing demand for mobility, heavy fossil fuel use, reliance on carbon-intensive infrastructure, and deeply embedded car-dependent lifestyles. Aviation, shipping and heavy goods transport are hard to decarbonise because realistic zero carbon technologies are limited for longer distances. This paper investigates the contribution energy demand reduction in the transport sector could make to climate mitigation efforts. Here we use a bottom-up modelling framework that comprehensively estimates the potential for mobility-related energy demand reduction at a country level. Replicable for other countries, our framework is applied to the case of the UK where we find that reductions in mobility energy demand of up to 61 % by 2050 compared with baseline levels are possible without compromising on citizens' quality of life. This translates to total lifecycle carbon emissions reductions of up to 72 % by 2050 compared to 2020 levels, with about half of the reduction coming from mode shifting and avoiding travel and moving goods. The other half comes from vehicle energy efficiency and electrification as well as downsizing of the vehicle fleets. Our findings show that energy demand reduction in the transport sector can make it easier to meet sectoral carbon budgets and reduce reliance on more drastic car use restrictions further down the line. There are big potential co-benefits from reducing energy demand as we avoid unnecessary travel, become more multi-modal and electrify a smaller vehicle fleet. Active travel and less air pollution from burning fossil fuel will all improve health. Reducing energy demand may also lower household travel bills, reduce business costs, improve energy security, and transform the job market away from the incumbent fossil fuel economy.

6-308-22: Peer-reviewed paper

Increasing walking rates during the Covid-19 pandemic in the UK and the window of opportunity for modal shift.

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Jillian Anable, University of Leeds
Greg Marsden, University of Leeds
Iain Docherty, University of Stirling

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
COVID19, travel, consumer behaviour, Shopping behaviour, mobility, individual mobility

The COVID-19 pandemic, and the associated lockdowns and travel restrictions significantly impacted transport systems worldwide. Cities saw reductions in car use, reductions in public transport patronage and increases in active travel (walking and cycling). This prompted many to speculate about what travel might look like after the pandemic, and whether increases in active travel would lead to more permanent modal shifts away from car use, and towards a more sustainable transport system. However, as restrictions have been lifted, many countries have reported car use rates returning to, or close to, pre-pandemic levels, with public transport patronage being lower than pre-pandemic levels, and active travel rates reducing since initial lockdowns. This poses the question, has the window of opportunity for sustainable travel post-pandemic gone? This paper examines this question further by focusing on walking rates during the pandemic. Using data from a longitudinal panel survey this paper addresses the following questions: how have walking levels changed during the pandemic in the UK? What are people walking for? and what impact could these changes have on greenhouse gas (GHG) emissions? Findings show walking is the only transport mode to increase during the pandemic and have more people walking regularly than pre-pandemic. This increase has been for mixed purposes, not solely for leisure purposes, and in June-21 17.4 % of the sample who eligible to drive, increased the frequency they walked and also decreased their car use. This paper argues there is still opportunity for policy makers to encourage a continuation of walking, and for some modal shifts from car use to continue post-pandemic.

6-316-22: Peer-reviewed paper

Innovation Diffusion Theory – Identifying behavioural heterogeneity in the EV and V2G markets

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Masao Ashtine, University of Oxford, United Kingdom
Scot Wheeler, University of Oxford, United Kingdom

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, transportation, Innovation Diffusion Theory, Vehicle-to-Grid

The electrification of road transport is crucial for the net-zero ambitions of decarbonising countries, by reducing energy demand through improved efficiency and the utilisation of low-carbon fuels. The UK government aims to accelerate this transition through its ban on new sales of conventional vehicles by 2030. However, this transition is inhibited by inter alia a lack of clear insights into consumer demand, which precludes effective public policies and disincentivises industry investments. Recognising the behavioural heterogeneity of vehicle purchasers, our work focuses on the application of the Innovation Diffusion Theory (IDT) on the vehicle market. IDT provides a bottom-up analysis to forecast the level of public readiness through the identification of swing consumer groups, enabling effective and targeted policies. With potential vehicle purchasers segmented into categories – based on their appetite for innovative technology – IDT also sheds light on the electric vehicle (EV) market landscape for auto- and policymakers. Additionally, the consumers likely to be left behind by the UK's top-down mandate – predominantly used-vehicle purchasers – are identified. Besides the 'who', the 'when' can also be determined with this methodology. Market sizes of customer groups are used to determine tipping points and phases in EV diffusion. These results could then identify windows of opportunity for vehicle-to-grid (V2G). By utilising plugged-in vehicle batteries to respond to the power grid, V2G enables the UK's twin goal of transport and power sector decarbonisation. However, typical non-V2G compatible EVs will likely inhibit V2G development, due to competing demand for consumers and technology lock-ins. To realise the benefits of V2G, IDT is used to identify industry pioneers for V2G development, enabling targeted collaboration for these projects. With the success of transport decarbonisation contingent on EV and V2G uptake, IDT can provide invaluable insights into consumer behaviours for policymakers and vehicle manufacturers.

6-323-22: Peer-reviewed paper

It's (not) a match! The role of compatibility for the use of public charging points and the adoption of electric vehicles

Sabine Preuß, Fraunhofer Institute for Systems and Innovation Research, Germany
Josephine Tröger, Fraunhofer Institute for Systems and Innovation Research (ISI), Germany
Daniel Hanß, Darmstadt University of Applied Sciences, Germany

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
electric vehicles, compatibility, adoption, public charging points

Electric vehicles help private households to reduce their carbon footprint in the transport sector. Although the adoption of plug-in electric vehicles (PEV) has recently increased, market shares still fall short of political goals. Therefore, examining factors that may influence the adoption of PEVs can provide valuable insights for promoting a transition of the transport sector and for mitigating climate change. Recent research shows that compatibility, i.e. whether (or not) the innovation matches the user's needs and values, often constitutes the driving factor for the adoption of PEVs and plays a crucial role in the use of other low-emission transport options (e.g., car sharing). Since the availability of public charging points (PCP) is often discussed in the context of PEV compatibility and PEV adoption, the current paper addresses the following research questions: Does the compatibility of PCPs influence the adoption intention of PEVs in non-PEV users? Does the established relationship between PEV compatibility and PEV adoption also apply to PCPs?

We conducted two non-representative studies in two German cities (total N=470 participants), one focused on the future generation of potential PEV users in a suburban context and the other one on people who live or work close to a PCP in a city. Results of Study 1 replicate that PEV adoption intention is predicted by PEV compatibility. Moreover, our analyses reveal an indirect effect of PCP compatibility on PEV adoption intention via PEV compatibility. Specifically, the more compatible PCPs are perceived, the more compatible are PEVs, and if people consider PEVs more compatible they also tend to have a stronger intention to adopt PEVs. Study 2 replicates and extends the results of Study 1. It indicates that the relationship between compatibility and using intention not only applies to PEVs, but also to PCPs. That is, the higher the compatibility of PCPs, the higher the use of them. We conclude that the perceived compatibility of PCPs plays a relevant role in the intention to adopt PEVs as well as for the use of PCPs. Our findings inform transport and urban planning, for example, with regard to the provision of charging points in public spaces.

6-341-22: Extended abstract

Energy labelling for light vehicles

Selma Elmgren, Swedish Energy Agency, Sweden
Carlos Lopes, Swedish Energy Agency, Sweden

Panel
6. Energy-efficient and low-carbon mobility for all

Keywords
life cycle analysis, energy labelling, consumer information, CO2 emissions, passenger vehicles, light commercial vehicles, electric vehicles

The Swedish Energy Agency has been directed by the government to review the possibility of implementing a guide to buyers of light vehicles with information on fuel consumption, CO2 emissions and air pollution with a lifecycle perspective, with inspiration taken from EU energy labelling. Points of discussion include which indicators a scale can be based on (eg. tailpipe emissions do not differentiate between EVs), how a scale can handle when a vehicle can be driven on more than one driveline or fuel type, how primary energy can be included and based on what calculations. Data pertaining to vehicle use (primarily fuel LCA) is readily available, and policy questions arise with regards to which driveline, and which fuels can and should be promoted in such a guide. Electrification of the transport sector is widely accepted as key to reducing emissions, but such an increase in EVs leads to a shoot in demand for resource-intensive batteries, which means that the manufacturing phase of a vehicle's lifecycle must be addressed. LCA data for the manufacture and EoL of vehicles is however not consistently available or standardized and hence cannot easily be included. Other issues to review are how to stimulate use of biofuels and what recoil effects that in turn could have. Sweden has in general a heavy fleet, and therefore the correlation between weight and environmental impact is an important fact to convey in a guide. Many manufacturers are investing in various "green" solutions, eg. green steel. These initiatives should be promoted, but there are difficulties in how to measure and standardize such investments in a way that they can be conveyed in a guide that enables the buyer to compare. We hope that this can be an inspiration for a vehicle label on EU level. The Swedish market is not big enough for a national label to have a significant push/pull effect, and in order to obtain LCA data from manufacturers, an EU-wide framework would likely need to be put in place.

7-005-22: Peer-reviewed paper

iBRoad2EPC – Upgrading EPCs to support Europe's climate ambitions

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Alexander Deliyannis, SYMPRAXIS Team, Greece
Alice Corovessi
Eleftheria Touloupaki

Panel
7. Policies and programmes for better buildings

Keywords
building energy certification, building design, building envelope, energy performance certificates, deep renovations, building renovation passport, stepwise renovations, audit programme, auditor tool, energy audit, audit guidelines, building refurbishment, building retrofitting

Energy Performance Certificates (EPC) and Building Renovation Passports (BRP) will play a central role in the roll-out of EU's Renovation Wave, as the instruments are key to trigger renovation demand and ensure targeted renovations. The EPC is the basic element that informs about the energy performance of buildings. Thus, it raises interest for energy performance and makes it part of building assessment in the market. Millions of EPCs are issued every year across the EU. BRPs were introduced in the Energy Performance of Buildings Directive (EPBD) to "provide a clear roadmap for staged renovation over the lifetime of a building, helping owners and investors plan the best timing and scope for interventions."

The Horizon 2020 project "iBRoad2EPC" aims to bridge the BRP with the EPC. It is building on the results of the iBRoad project (2017-2020) which developed, tested and delivered a model for the BRP supporting homeowners with personalised advice to facilitate stepwise deep renovation. This bridging will make EPCs more useful and provide tailored advice for stepwise deep renovation.

The aim is to improve reliability and effectiveness of EPCs, thereby establishing the next generation of EPCs that will support Europe's decarbonisation ambitions. This will be done by clustering the project's activities around four main pillars:

1. assess the needs, potential and practicability of merging the EPC with the BRP in a new form: the iBRoad2EPC;
2. adapt the iBRoad concept to become part of EPCs;
3. test and evaluate the applicability of iBRoad2EPC in six countries (Bulgaria, Greece, Poland,

Portugal, Romania and Spain), including training for energy auditors and EPC issuers and 4. facilitate the adoption and exploitation of the iBRoad2EPC model across Europe. Implementing authorities in the six countries are directly involved in the process of conceptualisation, development and testing of iBRoad2EPC to become an integral part of existing relevant schemes. Targeted communication, dissemination and exploitation activities will support further acceptance and uptake.

This paper presents the conceptualisation and design of integrating BRP elements into EPCs according to pillar 2. This comprises the question of information depth in the iBRoad2EPC which is determined by the targeted market coverage on the one hand and by the effort that the required added information causes on the other hand. As the aims of EPCs differ slightly across the Member States, information depth of the iBRoad2EPC has to adapt flexibly to the specific country requirements. The paper also presents the BRP and Building Logbook developed in the predecessor project iBRoad.

7-010-22: Extended abstract

Home-meanings framework to analyse and promote the diverse benefits of low-carbon dwellings

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Panel
7. Policies and programmes for better buildings

Keywords
building retrofitting, low/zero carbon homes, motivation, emotion

One important strategy to reduce operational energy use in dwellings and mitigate climate change is to motivate homeowners to retrofit. Building research and policy typically consider the rational reasoning behind such motivations in terms of health and well-being considerations, climate concerns and altruistic behaviours, and financial considerations, i.e. returns on investment and savings on energy bills. However, this focus on rational reasoning neglects emotional aspects of how homeowners themselves make sense of the potential benefits of low-carbon dwellings.

To complement this focus, the thematic analysis in this paper collates insights from: (i) 8 interviews with homeowners from the SuperHomes network, who achieved significant carbon emission reductions through retrofit activities; (ii) 10 interviews with homeowners, who did retrofit of different depth and have expertise in energy retrofit or access to such expertise; (iii) a workshop with 36 participants, representing various actors interested to advance domestic energy retrofit activities in the UK, such as actors from industry, government, academia, non-for-profit organisations and other intermediary actors.

The lens used in the analysis integrates: (i) the homeowner individual frames on the meaning of low-carbon dwellings, that underpin their motives; (ii) the home-meanings framework, developed around the concepts of affordance, practice and perezhivanie (emotional and cognitive experience) to explain homeowner individual frames.

Three themes are found to capture the emotional aspects of how homeowners make sense of the potential benefits of low-carbon dwellings: (i) Happy – a low-carbon dwelling is a better platform to be in control of one's environment, and subsequently, be happy in one's home. The concept is linked to the feelings of comfort, ease, relaxation and love, which are closely associated with the perception of an ideal home. (ii) Caring – a low-carbon dwelling is an expression of one's environmental identity and involves caring for the immediate community, future generations and the whole Earth. The concept is linked to the notions of self and identity, community cohesion and the feeling of belonging. (iii) Future-resilient – a low-carbon dwelling is a place with greater resilience, including more durable building components, financial resilience to volatile energy prices, resilience to the changing political environment that is transitioning towards tightening requirements for energy use and carbon emissions, and resilience to climate change. The concept is linked to the feelings of safety, security and control.

This research proposes integration of the benefits of low-carbon dwellings in a single frame, and their promotion as a single package – Home for the Common Future (HCF). The abbreviation can simultaneously be used to describe motivations involving rational reasoning – Health and well-being, Climate and Financial concerns; as well as motivations involving emotional reactions – Happy, Caring, Future-resilient.

The proposed individual frame – Home for the Common Future – together with the home-meanings framework can be used to develop a range of motivational narratives that are emotionally compelling to the homeowners. For instance, for a family with young children a message about one's happiness and wellbeing could include a picture of children playing in front of a big triple-glazed window (practice), and enjoying themselves (perezhivanie), while there is heavy rain and wind outside. Yet, the weather does not distract the children from their game, as there is no sense of cold air flow in the proximity of the window (affordance).

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7-017-22: Peer-reviewed paper

Sufficiency in the building sector in France: its contribution towards carbon neutrality by 2050

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Bruno Lafitte, ADEME
Philippe Leonardon, ADEME

Panel
7. Policies and programmes for better buildings

Keywords
buildings, sufficiency, energy sufficiency, energy demand, emissions scenarios

The deep decarbonation of the buildings stock requires all transition levers to be activated. ADEME, the French Environment Agency, carried out a foresight exercise called Transition(s) 2050 to document four pathways to carbon neutrality for France, each giving a different weight to sufficiency, efficiency, decarbonation and carbon storage. This paper presents these pathways for the building sector (residential and commercial), answering the question: Which are the different ways in which the building sector can contribute to carbon neutrality in France in 2050?

Among the different levers available for the building sector, some (efficiency, decarbonation of energy…) have been widely studied. Sufficiency, however, is rarely introduced in foresight scenarios. This paper presents two levels of sufficiency actions. First level, the buildings stock (building less, limiting average space per person, turning back vacant dwellings and holiday homes into main residences, transforming vacant offices into dwellings…). Second level, the building itself (increasing the intensity of use of existing buildings, cutting down on the number of devices, better sizing them, limiting their use, developing the infrastructure to make sufficiency possible…). Exploring sufficiency paves the way to new and innovative buildings policies that are complementary to renovation or "nearly-zero" standards and will help deliver much deeper reductions in carbon emissions from buildings.

This paper addresses specific questions, trying to quantify the impact of sufficiency: How much energy and carbon can be saved in the buildings stock in France through sufficiency measures? For instance, how can optimizing occupancy help reduce the need for new dwellings and the overall footprint of the buildings stock (beyond in-use operational energy demand)? How can sufficiency help mitigate the energy consumption needed for news uses such as air conditioning or data centres? How much more should other levers be activated if sufficiency is not?

7-019-22: Peer-reviewed paper

Who is paying for decarbonizing the Dutch residential sector? A detailed cost-benefits analysis of the Dutch ambitions to phase out natural gas

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Vera Rovers, TNO, The Netherlands
Arjan Zwamborn, TNO, The Netherlands
Evie Cox, TNO, The Netherlands

Panel
7. Policies and programmes for better buildings

Keywords
built environment, decarbonisation, cost benefit, cost effectiveness, inclusiveness, deep renovations, phase out natural gas

The Netherlands, in which 92 % of houses are heated by natural gas, has the ambition to phase out residential natural gas consumption completely by 2050. Municipalities are tasked to draw up plans for each neighbourhood on how and when they transition to become carbon neutral. Minimizing societal costs is the main criterion for selecting technical strategies.

Societal costs reflect effects on society as a whole, but they do not reflect the actual costs and benefits for each individual stakeholder. We determined these costs and benefits for homeowners, tenants, landlords and the national government. This resulted in a large dataset for a variety of dwelling types which are split based on typology, construction period, energy performance, ownership and energy behaviour.

Based on analysis of this data, we conclude that none of the strategies to phase out natural gas are cost effective for homeowners in 2020. Actions to stimulate cost reduction and changes in energy taxation help to improve this for 2030. We concluded that different decarbonisation options do not receive equal support from the government. Explicit and implicit benefits favour district heating and renewable gas options over all-electric options. Regulations, not necessarily designed with the energy transition in mind, have a large effect on the distribution of cost and benefits between actors. Investments in energy efficiency for example are uneconomical for landlords, since rental laws prevent them from increasing the rent to compensate for their costs.

The most economical way to reach the goal of 1.5 million natural gas free dwellings in 2030 is to prioritize well-insulated dwellings over inefficient dwellings, since the cost and benefits for installations are more favourable in these houses. Using this approach, it is more cost effective to reach large numbers of renovations quicker. However, investments in energy efficiency serve

multiple purposes, such as alleviating energy poverty and reducing the demand for scarce (renewable) energy sources. Consequently, a different prioritization than one from a pure financial standpoint may be desirable.

7-021-22: Peer-reviewed paper

Reforming the EPB certification and the property tax incentive to encourage additional investments in energy efficiency

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Panel
7. Policies and programmes for better buildings

Keywords
investment decision-making, interviews, energy performance certificates, New European Bauhaus, property taxation

The EU member states have implemented energy performance of buildings (EPB) minimum requirements for new constructions, while in Flanders an additional property tax incentive is offered if higher standards of energy performance are achieved. The current paper aims to investigate whether the property tax incentive played a role in encouraging additional investments in energy efficiency in new constructions. It also aims to understand the mechanisms of the EPB certification process, including the decision-making between the client, the architect, and the EPC certifier, and the interplay between the implementation of the EPB regulations and the property tax incentive. For this purpose, in-depth, semi-structured interviews with EPC certifiers operating in Flanders were undertaken. Findings show that the property tax incentive plays an important role in additional investments, principally when the levels required by the property tax are close to the minimum standards as in recent years. The most commonly used methods to achieve lower E-levels than the minimum requirements are PV systems, followed by efficient ventilation systems, heat pumps and airtightness test to a lesser extent. Investments in systems are motivated by a common practice of making the EPB certification after the building permit was released; therefore, changes in the design are problematic. At this stage sufficiency or efficiency design strategies are difficult to be implemented and thus additional investments in systems are preferred. Only EPC certifiers who are the architects of the project have a more holistic approach and make EPB simulations at an earlier design stage. Requiring the EPB certificate before the building permit would encourage the engagement of the energy expert from an earlier design stage and a closer collaboration between the architect and the EPC certifier. Breaking the silos between the energy experts and the architects, as well as a holistic design are in line with the New European Bauhaus principles.

(1) According to the calculation system implemented by the Flemish Energy Agency, the E-level (E-peil in Dutch) depends on the following parameters for dwellings: thermal insulation, airtightness, compactness, orientation, insolation, ventilation losses and systems (for heating, hot water, ventilation,

cooling and renewable energy). A better performing building has a lower E-level.
Keywords: investment decision-making, interviews, energy performance certificates, New European Bauhaus, property taxation.

7-023-22: Peer-reviewed paper

Deep Renovation: shifting from exception to standard practice in EU policy

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Rutger BROER, BPIE - Buildings Performance Institute Europe, Belgium

Panel
7. Policies and programmes for better buildings

Keywords
deep renovations, definition, efficiency standards, EU policy, Directive on Energy Performance in Buildings (EPBD), affordability

The Renovation Wave, the strategy published by the European Commission at the end of 2020, sets the objective to at least double the annual energy renovation rate by 2030 and to foster deep energy renovations. But what are these? While the concept is high on the EU political agenda, clarity has long been missing in the legal framework, where no definition of Deep Renovation was provided before the 2021–2022 revision of the Energy Performance of Buildings Directive (EPBD).

The absence of common understanding and lack of consensus of what deep renovation is and what it should deliver, has led to a mushrooming of concepts at national level, and to an EU policy ecosystem which is not fit to deliver on it, missing on energy savings to multiple other benefits for individuals and society. The current annual deep renovation rate only stands at 0.2 % on average in the EU. But to achieve the EU 2030 and 2050 climate targets, it should increase to 3 % by 2030. A paradigm shift on deep renovation is therefore essential. This paper investigates existing conceptualisations of deep renovation, and deep dives on ways to define it, based on an overview of national examples, from which best practices and key parameters are extracted. While the concept is multidimensional, defining it should be guided by the overarching objective of achieving climate neutrality by 2050, setting a path for every building to be climate proof, while addressing affordability aspects. The paper suggests both a definition and delivery approach to deep renovation. At the same time, it considers the EPBD recast proposal from the European Commission, assesses the quality of the definition suggested and provides recommendations. But beyond giving an EU-wide legal definition to the concept, it is crucial to shift the deep renovation paradigm and practice from an exception to the default approach, and to recalibrate the EU renovation ecosystem of policies. The paper explains why this change is so important if the EU is to reach its climate targets and address energy poverty. It considers the ongoing revision of the EPBD and the extent to which this shift towards deep renovation is triggered.

7-024-22: Peer-reviewed paper

Splitting energy costs between landlords and tenants: What can Sweden and Germany learn from each other?

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Panel
7. Policies and programmes for better buildings

Keywords
buildings, heating, landlord-tenant problem

The legislative framework for splitting heating costs between landlords and tenants can influence the efficient use of energy in buildings. While landlords are typically responsible for investments in thermal retrofit measures, tenants can reduce energy consumption through energy-saving behaviour. In view of the shared responsibility, the question which contractual arrangements for splitting energy costs between landlords and tenants support energy efficiency is controversial. Our paper addresses this question by analysing the legislative framework in two countries with opposing approaches: In Sweden all-inclusive rents are common practice, where the landlord is entirely responsible for paying the heating costs. By contrast, in Germany, heating costs are fully borne by the tenants and individual metering and billing has a long tradition. Recently, several approaches for partially introducing all-inclusive rents in Germany following the Swedish example are in the discussion. At the same time, Sweden is currently strengthening the role of individual metering and billing in view of the requirements of the energy efficiency directive and the professional property owners' resistance towards individual metering and billing remains very strong. Our analysis provides a comparison of the approaches that are currently discussed in the two countries and derives recommendations on how to combine the best of two worlds to provide a favourable framework for supporting energy efficiency.

7-028-22: Peer-reviewed paper

Building typology of the non-residential building stock in Germany – methodology and first results

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Panel
7. Policies and programmes for better buildings

Keywords
non-residential buildings, building typology, representative sample survey

In contrast to residential buildings, the stock of non-residential buildings (NRB) in Germany is not fully represented in any official statistics. This is surprising given the economic importance of this sector. Not only the increasing relevance of climate protection makes it seem reasonable and necessary to capture the scope and characteristics of this important economic sector more precisely.

The gap in official statistics could be closed by a survey based on a representative sample of building footprints and unbiased extrapolations to the whole stock, a completely new approach in the German NRB stock (Hörner 2020). The goal was to provide statistically valid data on the stock for the first time. This results in an estimated number of thermally conditioned NRBs in Germany that are relevant under the Building Energy Act (BEA) of NBEA =1.9081 ± 0.152 million, considerably less in number but bigger in size than previous estimates (BMWi 2020 S. 30).

To map the characteristics of the building stock in an appropriate manner, a NRB typology was developed, comprising mean values of U-values, building component areas etc. and absolute frequencies of NRBs. The most important feature of the type definition is the concept of "synthetic average buildings", whose values are unbiased extrapolations from the sample to the whole stock. They are "mean estimators" in terms of estimation theory. The areas of the components of the building envelopes (e.g. facades, roofs and floor slabs) were determined from geospatial data of the sample buildings. The survey provided additional geometric values like window area fractions and roof types as well as further monitoring variables such as insulation thicknesses and the current equipment with technical systems. The great diversity of NRBs and their values were summarized in 33 types differentiated according to 11 building functions and 3 building age bands. Model input variables for building energy simulations (e.g. U-values of building components and energy expenditure factors of the heat generators) were derived from monitoring variables of the survey and age-specific properties, similar to the TABULA project for residential buildings (Loga et al. 2012).

Typologies are used to calculate the energy demand of building stocks with reasonable effort, in order to evaluate the impact of climate protection policies and to take the building stock into account adequately in scenarios. In addition, more sophisticated building stock models can be validated. So far, the current stock of non-residential buildings in Germany was mapped to a typology. Future analysis will add structural measures for energy-related modernization and calculations of the energy demand.

7-042-22: Peer-reviewed paper

Socio-ecological transformation of residential heating in Berlin

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Katja Schumacher, Oeko-Institut, Germany
Julika Weiß, IÖW, Germany
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Panel
7. Policies and programmes for better buildings

Keywords
energy use, buildings, energy poverty, affordable housing, costs and benefits

About half of Berlin's carbon dioxide emissions stem from energy use in buildings, primarily for heating. Reducing the heating demand through energy-efficient building refurbishment and shifting to renewable energy and waste heat for heating are the two central components of mitigation of Berlin's buildings. The considerable investment required is offset by benefits resulting from, for example, lower heating costs after refurbishment.

Costs and benefits are distributed among various groups of stakeholders such as the public sector, building owners and tenants. At present, there are conflicting opinions among these stakeholders on the question of the social compatibility of energy-saving refurbishments, the design of energy policy regulations in the context of rent increases and the development of energy costs. The degree to which households are affected differs: Low-income households and those at risk of energy poverty in particular need to be protected and supported.

This paper aims to enhance the existing debates on affordability of housing and climate policy in large cities, such as Berlin, with scientific analyses on the effects of existing instruments such as income support programs, investment subsidy programs and informational programs. Specifically, we look at the distribution of costs and economic benefits of refurbishment and conversion of heating systems for different stakeholder groups, take a deeper look at the effects on low-income households, and derive recommendations for policy makers to implement social and economic solutions to achieve climate targets in the buildings sector.

7-044-22: Peer-reviewed paper

Taxonomy Regulations – An incentive to improve the building stock built before 2020 in Sweden

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Tommy Sundström, CIT Energy Management, Sweden

Panel
7. Policies and programmes for better buildings

Keywords
financial incentives, building energy certification, top 15%, taxonomi, building codes

The European Green Deal aims for the EU to reach no net emissions of greenhouse gases by 2050. The Taxonomy Regulation is one action that is planned to implement the European Green Deal. The Delegated Regulation specifies the technical screening criteria under which certain economic activities qualify as contributing substantially to climate change mitigation and climate change adaptation. For acquisitions and ownership of buildings, the delegated regulations include those within the top 15 per cent in terms of energy performance on a national or regional scale. The criteria imply that buildings built before 31 December 2020 will be included if they are within the top 15 per cent of the national or regional building stock, expressed as operational Primary Energy Demand (PED). This study aims to define the top 15 per cent of residential and non-residential buildings in Sweden by using the national database of Energy Performance Certificates. The paper explains how PED can be calculated from previous building regulations and how to analyse the data to obtain a representation of the top 15 per cent in different building categories.

The analysis shows that a calculation of PED ought to be based on the building regulations in force for primary energy efficiency with normalised consumption of hot water and the number of buildings registered in the database for energy performance certificates (EPCs). The building stock ought to be divided into multi-residential buildings, different categories of non-residential buildings, and single-family houses, while the division is not relevant for year of construction or climate zone.

It needs to be easy for banks and other investors to assess if a building is in the top 15 per cent of best buildings. Based on these criteria and established limit values for primary energy efficiency for the different building categories, a direct assessment can be made from an EPC issued after 1 September 2020.

The limit values for primary energy efficiency correspond to the energy efficiency classes in the Swedish EPC system. To be in the top 15 per cent of best buildings, multi-residential buildings need to have energy efficiency class A, B or C, while non-residential premises may include some buildings of energy efficiency class D. For single-family houses, energy efficiency class A or B

applies and a few buildings of class C.

The limit values for multi-residential buildings and non-residential premises are produced based on data that include the main building stock in the analysis. The result for single-family houses is significantly less reliable as only 21 per cent of the building stock is represented in the data.

The data that are used and the analysis contain some uncertainties that need to be taken into account when determining the limit values for primary energy efficiency for the different building categories. These uncertainties can be reduced in a future analysis with a new extract from the database with EPCs.

The taxonomy aims to provide an incentive for sustainable investments, which in turn provide an incentive to improve the building stock. As buildings become more energy efficient, the limit value to be in the top 15 per cent of best buildings will gradually improve. Limit values for primary energy efficiency will thereby need to be updated annually if the taxonomy is to contribute to meeting the aim of the European Green Deal.

7-051-22: Peer-reviewed paper

Distributional impacts of CO2 pricing - focus on the buildings sector

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Sibylle Braungardt, Öko-Institut
Johanna Cludius, Öko-Institut
Benjamin Köhler, Öko-Institut
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Panel
7. Policies and programmes for better buildings

Keywords
buildings, distributional impacts, climate policy, housing, CO2 pricing

The building sector is responsible for 16 % of GHG emissions in Germany and its contribution to meeting Germany's climate targets is correspondingly high. Effective climate protection in the building sector can only be achieved with a broad mix of instruments. One important instrument in this mix is CO2 pricing of fossil fuels. In Germany, a CO2 price for the building and transport sector was introduced at the beginning of 2021. This paper analyzes the social impacts of CO2 pricing in Germany and looks into alternative models for revenue recycling. We focus in particular on redistributing revenues by reducing the renewable energy surcharge and thus household electricity prices. Additionally, we consider how the impacts change when efficiency investments are taken in response to the pricing scheme.

Our analysis shows that CO2 pricing in Germany in combination with revenue use for reducing electricity costs has clear positive distributional effects at the level of households. Limiting the pass-through of CO2 cost from landlords to tenants both reduces the burden on tenants and increases incentives for landlords to invest in energy-efficient refurbishments. For households in the first three income deciles, reductions in electricity cost outweigh the CO2 costs incurred. Although high-income households also benefit from an abolition of the renewable electricity surcharge, the costs incurred from CO2 pricing cannot be completely offset. We find, however, adjustment actions such as investing in more efficient, zero-carbon energy solutions results in net reductions also for these households.

Besides limiting cost pass-through to tenants, we conclude that a carefully chosen approach for revenue recycling is important to protect vulnerable households. Taking into account the practical implementation as well as transaction costs, this results in a favourable assessment for electricity price reduction as a redistribution mechanism compared to a lump-sum rebate of the same revenue amount. These findings can inform the ongoing discussions of introducing an EU-wide carbon pricing mechanism for buildings and transport as proposed by the European Commission.

7-056-22: Extended abstract

Preferences for thermal retrofits in co-owned buildings: A discrete choice experiment with landlords and owner-occupiers in France

Carine SEBI, Grenoble Ecole de Management, Univ Grenoble Alpes ComUE, France
Marie-Charlotte Guetlein, Grenoble Ecole de Management, France
Valeria Fanghella, Grenoble Ecole de Management, France
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Panel
7. Policies and programmes for better buildings

Keywords
energy saving potential, financing, private condominiums, split incentive, building retrofitting, discrete choice experiment

Thermal retrofit of existing buildings is a major challenge for the energy transition in France. While the country aims to reach a nearly zero energy level for all buildings by 2050, the share of existing buildings that have been retrofitted remains low. This is particularly true for the private condominium sector (28% of French building stock) where thermal retrofit decisions involve multiple actors and potentially conflicting incentives between different types of owners within the same building. Against this background, this paper elicits landlords' and owner-occupiers' preferences for thermal retrofits in condominiums using a discrete choice experiment on a representative sample of the French population (N = 1268). In particular, we examine to what extent an unequal distribution of energy savings affects their propensity to engage in thermal retrofits. We also investigate preferences for different financing mechanisms.

Our results from mixed logit models show that both types of owners prefer retrofits that lead to higher energy savings in absolute terms and in comparison to other owners of condominiums in the same building. For financing schemes, both types of owners dislike long-term loans and are indifferent between financing the retrofit through an increase in condominium fees or through credit payments.

Finally, the propensity to engage in retrofit increases if loan can be transferred to the next owner in case the condominium is sold. We then investigate preference heterogeneity using a latent class model. We identify three classes with different preferences for the attributes of the thermal retrofit: Class 1 (64% of the sample) and Class 2 (31%) are in favour of implementing the renovation; however, they differ in terms of preferred financing mechanisms: while class 1 prefers charges and loans payment, class 2 prefers cash payment. Class 3 (5%) oppose to the renovation. We explain class membership using respondents' socio-demographic characteristics and

preferences (such as debt aversion). Our results have implications for the design of policies for thermal retrofits, particularly for the financing mechanisms.

7-069-22: Extended abstract

Pre-commercial procurement for upgrading buildings to be self-sufficient on 100% renewable energy

Mehmet Börühan Bulut, empirica, Germany
Georg Vogt, empirica, Germany

Panel
7. Policies and programmes for better buildings

Keywords
renewable energy, renovation, pre-commercial procurement, public procurement, public buildings

Pre-commercial Procurement (PCP) is an EU instrument to promote innovation by using public procurement to challenge the industry to develop and test innovative solutions while providing companies with a first customer reference. The EU Horizon-funded PCP project procuRE brings together the cities of Istanbul (TR), Barcelona (ES), Nuremberg (DE), Vila Nova de Gaia (PT), Velenje (SI) and Eilat (IL) to jointly procure R&D services to renovate three schools and three office buildings to become energy self-sufficient on 100% renewable energy. Given that the cities own and operate around 21,000 of public buildings, they are looking for a versatile Renovation Approach that is replicable to be applied to any of their buildings. The resulting Renovation Packages for specific buildings are expected to take into account the needs and the expectations of key stakeholders that interact with the building, including users and maintenance personnel, and be developed through a Co-Design process in dialogue with these stakeholders. Continuous Commissioning is also a key aspect of the project, where suppliers are expected to ensure good monitoring, diagnostics and verification, as well as preventive maintenance.

A Call for Tender with specific requirements, shaped by the market input through Open Market Consultations (OMC) and the demands of the procurers, was published to select six suppliers that will propose their renovation approach that is applicable to any school or office building in Europe. The PCP has three phases; in the first phase, six suppliers enter an innovation funnel and develop rough designs for each building based on their innovation approach; in the second phase after the first call-off, four suppliers further develop their solutions and provide detailed designs of the proposed solutions; in the third phase after the second call-off, two suppliers finalise their designs and each test them in three buildings, including at least a school and an office building.

Value of co-benefits from energy saving ventilation systems – Contingent valuations on Swiss home owners

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Panel
7. Policies and programmes for better buildings

Keywords
co-benefits, investment decision-making, willingness to pay, domestic energy efficiency, health, willigness to accept

Previous efforts exploring options to increase residential sector's energy efficiency have overlooked that highlighting co-benefits associated with energy efficiency may represent a promising strategy to draw attention from decision makers. For instance, buildings equipped with energy saving and comfort ventilation (ESV) system provide, in addition to savings in energy costs, co-benefits such as improved indoor air quality (IAQ), thermal comfort, and noise reduction. These co-benefits are difficult to appraise by a person that has not experienced ESV. In the economic literature, an experience good is a good difficult to appraise prior to its usage –i.e. such appraisal is feasible only after it has been experienced. By interacting with an experience good, consumers learn the good's attributes –which include co-benefits– only after buying and consuming. This description holds for an ESV system. As co-benefits from an ESV are not a component of everyone's daily life, their appraisal is difficult. For instance, an individual that has experienced poor air quality most of his/her life would find difficult to ponder the value of an improvement in indoor air quality unless he/she experiences such an improvement. Therefore, an appraisal of ESV's co-benefits must rely on preferences reported by people that have experienced such co-benefits.

With this paper we want to contribute to the nascent literature on the value of co-benefits of energy efficient investments in the residential sector. To the best of our knowledge, co-benefits analysed in this paper have been the focus of five previous studies – Spetic et al. (2005); Banfi et al. (2008); Chau et al. (2010); He et al. (2019); Golbazi et al. (2020). From those studies, only Chau et al. (2010) and Golbazi et al. (2020) have considered that these co-benefits are attributes of experience goods, exploring preferences of, respectively, apartment residents in Hong Kong and students in USA. Indeed, there is space for research when it comes to exploring values of co-benefits from energy efficiency investments once a resident has experienced such co-benefits.

Consequently, we have estimated the value of ESV's co-benefits by analysing answers that owners of Minergie houses – which are equipped with ESV – have provided to a contingent valuation

protocol. Via a single-bounded dichotomous choice question, we have gathered monthly willingness to accept (WTA) compensation to hold off on using ESV. Average monthly WTA is estimated at CHF 181 – a value dominated by IAQ. WTA protocols may deliver overestimated values. Consequently, this paper estimates willingness to pay (WTP) on a sample of owners of houses that are not equipped with ESV. Average monthly WTP is estimated at CHF 163 – a value dominated by presence of allergies at home, an approximation to relevance of IAQ among respondents that have not experienced ESV. A back-of-the-envelope cost-benefit analysis informed with our estimates suggests that monthly co-benefits from ESV can be as much as twice the costs.

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7-088-22: Extended abstract

Local authority capacities for strategic action on energy efficiency and heat decarbonisation – a Scottish case study

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Jan Webb, University of Edinburgh, United Kingdom

Panel
7. Policies and programmes for better buildings

Keywords
institutions, innovation, local authorities, capacities

Existing approaches to energy efficiency and low carbon heat in buildings are failing to deliver change at the speed and scale necessary to meet climate targets. Local and regional planning is a potential route to faster action, but innovative policy instruments are needed. We examine the emerging innovation in Local Heat and Energy Efficiency Strategies (LHEES) in Scotland. The intention is to create area-based, costed and prioritised, 20-year strategies for upgrading energy efficiency and decarbonising heat in all buildings. Scottish Government have positioned local authorities as key agents of change through the proposal to make LHEES a statutory duty, with all councils having a comprehensive Strategy by 2023. This paper analyses empirical material collected in a 3-year (2017-2020) evaluation of LHEES pilots. It presents original data from interviews with local authority officers coordinating the pilots, alongside analysis of the LHEES reports generated. A capacities framing is used to explore the potential for effective institutional innovation through this proposed local responsibility. The analysis considers how political authority, finance, personnel and knowledge capacities shape and constrain local authorities' ability to deliver. The paper highlights the inter-linkages between different local authority capacities and the tensions that may restrict councils' ability to deliver LHEES. This shows that innovations in governance are essential to achieving net zero emissions from buildings, and area-based strategies are likely to be one effective instrument. However, central government intention to innovate through new local responsibilities is insufficient when local capacities are weakened by long term reductions in public finances. Only through concerted interaction across central and local governments, and across sectors and building owners, to plan, and to organise the essential resources, will innovation happen.

7-098-22: Peer-reviewed paper

Pay As You Save system of inclusive utility investment for building efficiency upgrades: Reported and evaluated field experience in the United States

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Stephen Bickel, Clean Energy Works, USA
Harlan Lachman, Energy Efficiency Institute, Inc., USA
Paul A. Cillo, Energy Efficiency Institute, Inc., USA
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Panel
7. Policies and programmes for better buildings

Keywords
domestic energy efficiency, utilities, energy efficiency financing

From 2002-2021, 23 U.S. utilities in 10 states gained experience offering building efficiency and electrification upgrades through investment programs that are uniquely inclusive, primarily because they are accessible to occupants no matter their renter status, income, or credit score. All of these utilities have used the Pay As You Save® (PAYS®) system, which is a set of consumer protections and design parameters that have become the basis of the Inclusive Utility Investment approach. With Inclusive Utility Investment, any utility with an approved tariff can pay for site-specific upgrades and recover the full cost at each site over time through a charge on the bill that is less than the estimated savings. In short, Inclusive Utility Investment makes it financially possible and attractive for utilities to capitalize building efficiency upgrades that generate savings on the same scale as conventional power plants with similar assurances for cost recovery on a site-specific basis. Through 2021, the U.S. utilities with experience have cumulatively deployed more than $50 million for building efficiency and electrification upgrades to nearly 6,000 locations, and more than $170 million is committed for similar deployment over the next three years. This paper summarizes field data on Inclusive Utility Investment programs using the PAYS system as reported by each of these sponsoring U.S. utilities through the year 2021. These utilities have capitalized upgrades to rental and owner-occupied housing in both single family and multi-family categories as well as commercial and municipal buildings. Of the utilities that have reported the fraction of customers accepting the utility's upgrade offer after receiving a savings assessment, each reported that over two thirds of customers accepted the offer. That metric is six times greater than participation rates in traditional debt-based upgrade programs. Across these utilities, the average cost recovery rate exceeds 99.9 %. Of the utilities that have completed evaluations of their investments in building efficiency upgrades, the net present value to the utility ranges from $1,000 to $3,000 per upgraded location. In other words, even after taking into account all program costs, the Inclusive Utility Investment programs using the PAYS system are

generating net economic benefits for the utility and its owners in addition to generating benefits for participants. Altogether, the field data presents a striking picture of a utility investment solution that can reach underserved markets even in areas of persistent poverty. It also provides examples for more states, utilities, regulators, policymakers, and communities internationally that want to expand participation in the clean energy economy, a requirement for rapid reduction of greenhouse gas emissions from the buildings sector.

7-108-22: Extended abstract

Confronting systemic neglect of the cooling needs of India's urban poor through mobilizing participatory design process and women's cooperatives

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Vinita Rodrigues, cBalance, India
Hasan Ul-Banna Khan, cBalance, India
Anusha Mohan, cBalance, India

Panel
7. Policies and programmes for better buildings

Keywords
passive cooling, comfort, energy sufficiency, human-centered design, informal housing

Only 7.5 % of India's built-space is constructed involving architects; most of India 'builds itself' through self-constructed informal housing' where most its population lives. It is therefore unsettling that most building policies, bilateral aid programs in India have neglected their desperate energy and comfort cooling needs. Our studies of thermal conditions in informal settlements in India Mumbai and Pune have revealed roof temperatures in excess of 500C even when air temperatures are a moderate 30 0C. They therefore suffer intense thermal stress which is compounded by lack of adequate sleep since its too hot to inhabit their home before midnight. The situation is profoundly unsettling when power cuts and the inability to operate fans during summer nights are accounted for; further aggravating the human misery. This paper presents the results of a pilot program in 2 Indian cities to directly address this social inequity related to unacceptable energy access disparity and concomitantly mitigate potential greenhouse gas emissions from the legitimate cooling needs of this largely neglected rights-holders. The program is working with vulnerable communities, through dialogical methods of active listening and participatory design, to address thermal stress in poorly constructed informal dwellings. We present the outcomes of co-created, fabricated, and pilot tested through full-scale installation in 30 homes, low-cost and easily implementable passive design retrofit solutions to achieve thermal comfort with minimal energy use and GHG emissions. The paper finally presents long-term models being develop and advocated, that are aligned with social obligations: of the municipal government, corporate CSR programs, official mandate: of city utilities to operate demand-side-management program, and financial incentive: developing financial 'products' for women-owned small-scale cooperatives that provide thermal comfort solutions within communities as a low-cost service.

7-111-22: Peer-reviewed paper

100% targets mean reaching everyone: The imperative for inclusive financial solutions

Holmes Hummel, Clean Energy Works, USA
Jill Ferguson, Stanford University, E-IPER Program, USA
Stephen Bickel, Clean Energy Works, USA
Jill **Grey Ferguson**, Stanford University

Panel
7. Policies and programmes for better buildings

Keywords
energy efficiency financing, financing, customer finance, building envelope, efficiency, distributed energy resources (DER), economies of scale, utilities, Equity, Inclusion

With more countries urgently seeking a path to 100 % decarbonization targets, scaling up building energy upgrades is imperative, yet most financial solutions for capitalizing these essential upgrades have not proven to be fiscally sustainable or scalable to even remotely approach those aims. In the U.S., most households are systematically disqualified from participation in the clean energy economy by pervasive barriers like upfront cost or the split incentive between renters and landlords. The resulting clean energy divide is a painful and polarizing artifact of policies that advantage affluent households with discretionary income and larger tax liabilities. In a search for remedies, several U.S. states have sought to popularize consumer loan products for energy upgrades. Four of the best performing state-backed consumer loan programs for energy efficiency upgrades have reported reaching a maximum of 0.1% of the eligible households in any year, and among the beneficiaries, 90% of the households had credit scores that were prime or better. These results reflect rules in the financial services sector that were never meant to serve everyone. Meanwhile, ten U.S. states have at least one utility offering Inclusive Utility Investment with strong consumer protections. They are harnessing a century-old social compact already in use by utilities across the globe to assure that a combination of funding and financing can reach every building regardless of income, credit score, or renter status of the occupant. California, Illinois, and New York have each concluded that access to financing is a significant barrier to efficiency, electrification and on-site solar upgrades necessary to reach state decarbonization targets, and now each have policy proceedings underway that could result in introduction of Inclusive Utility Investment by some of the largest utilities in the U.S. This paper will explain how Inclusive Utility Investment policies are expanding access and investment, with potential for replicability in more countries.

7-133-22: Peer-reviewed paper

The development of local long term renovation strategies in Flanders

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Kelly Cautreels, Sweco Belgium, Belgium

Panel
7. Policies and programmes for better buildings

Keywords
renovation, local administrations, local authorities, long-term strategies, deep renovations, energy efficiency action plans, energy saving potential, energy savings potential, tool, visualisation, data

Between November 2020 and August 2021 and in collaboration with eight pilot municipalities, the LIFE project "Belgium Renovates for Energy Efficient Living!" (BE REEL!) worked together with the company BUUR Part of Sweco (BUUR PoS) to develop general guidelines to support municipalities in Flanders (Belgium) to develop drafts for their own local long term renovation strategies (LLTRS). Besides these guidelines, they also developed eight inspirational roadmaps with the pilot municipalities to support thae development of their LLTRS. To ensure maximal diversity in the different cases, the pilot municipalities range from mid-sized and larger municipalities to towns and larger cities. This paper summarizes the key findings of the development process for governments and other organizations seeking to develop similar strategies.

This collaboration was a process consisting of multiple cocreation phases ranging from desktop research and surveys with local authorities, through in-depth interviews and workshops, to the development of the final output and lessons learned. In tandem with BUUR PoS's co-creative process, a visualization and monitoring tool was developed by Climact, an engineering consultancy firm, to support the development of the LLTRS with robust data and clear information. This tool served to map out and clearly indicate the zones with maximal energy reduction potential within a municipality's building stock. At the end of the co-creation process, each municipality received general guidelines, a specific draft roadmap for their municipality, data from the tool about their building stock, and a list of possible measures.

7-147-22: Peer-reviewed paper

Who builds the energy transition? Actors and networks in a German research initiative

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Elisabeth Dütschke, Fraunhofer Institute for Systems and Innovation Research ISI, Germany

Panel
7. Policies and programmes for better buildings

Keywords
networks, technological innovation system, actor analysis, building sector

The transformation to a nearly climate-neutral building sector requires the interaction of different actors at different levels. In Germany, the federal research initiative "Energiewendebauen" aims at enhancing the knowledge base in the building sector by bringing together actors from research and practice. Within the programme, funding of several million Euros is provided for research, development and demonstration for energy-efficient buildings and neighbourhood. The intention behind building such a knowledge network is to ensure that sustainable innovations are taken up broadly. This takes up the notion put forward by conceptual frameworks on the diffusion of innovation and on socio-technical transitions that argue that knowledge and actor networks are an important precondition to change. In this paper, we therefore examine the actor structure of the projects funded as part of the research initiative to evaluate in how far the programme succeeds in this regard. A data base of 314 projects including 572 different actors is analysed applying network analysis. The findings were validated and extended in a workshop with experts from the community under study.

We categorise the actors participating in this programme based on a scheme from the technological innovation system (TIS). Within the network, the categorisation helped discover which types of actors often interact but also whether the network is open for a diversity of actors affected by the transition of the sector. As to be expected, actors in research and development play an important role, in particular technical universities and research institutions. They act as key agents of change as they connect many of the other actors through a variety of projects. As such they may be crucial to including other types of actors which are not yet well represented, e.g. municipalities and end-users.

7-156-22: Extended abstract

Stuff, Skills and Stories: Social practices of secondary school sustainability in the UK

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Panel
7. Policies and programmes for better buildings

Keywords
social practices, schools

School buildings will play an important role in the UK net-zero emissions strategy. Schools represent an opportunity for both demand reduction and decarbonisation, with the UK Department for Business, Energy & Industrial Strategy identifying the education sector as a priority for cost-effective energy savings. School communities are also demanding support for sustainability, with over 750 school leaders joining the “Let’s Go Zero” campaign, led by the charities Ashden and Global Action Plan, in which they declare their aspiration to operate with zero carbon emissions by 2030.

Schools are places of teaching and learning, with school climate action empowering future generations and positively impacting the surrounding community. The UNESCO model of whole-school sustainability emphasises the relationship between the facilities, classroom learning, and preparing young people for the future, with environmental and sustainability educators referring to the five Cs of climate education: curriculum, campus, culture, community and careers.

This qualitative study of secondary schools in England involves stakeholder interviews and student focus groups at twelve schools in Greater London and the Thames Valley Region (Berkshire, Buckinghamshire, Oxfordshire). School sustainability is explored through the lens of social practice theory, with teachers, students, parents, governors and school staff (leadership, facilities, finance) reflecting on the stuff, skills and stories that enable more or less sustainable activities in terms of energy, transport, food and waste.

This research provides insights for schools that aspire to decrease their environmental impact while engaging young people and other school stakeholders with climate and nature both inside and outside the classroom. It also reveals a potential divide between state (government funded) and independent (privately funded) schools when it comes to environmental and sustainability education, empowerment and action.

7-168-22: Peer-reviewed paper

Energy efficiency first policy landscapes for buildings: case studies in Germany, Hungary and Spain

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Panel
7. Policies and programmes for better buildings

Keywords
energy efficiency first, deep renovations, Energy Efficiency Directive (EED), Directive on Energy Performance in Buildings (EPBD), overcoming barriers

Recognizing the value of energy efficiency improvements as the biggest domestic energy resource in the EU, Energy Efficiency First (EE1st) is a cross-cutting principle of EU energy policy. It is set out in the recast Energy Efficiency Directive, supported by a set of practical recommendations. Implementing EE1st challenges the way we compare demand-side and supply-side options, assessing the basis for and practicalities of prioritising demand-side options.

The Renovation Wave as part of the Green Deal emphasizes the importance of acting on energy efficiency of buildings. Implementing the EE1st principle here benefits the entire energy system, as buildings are able to reduce the energy demand and thereby have a direct impact on infrastructure needs.

This paper reviews EE1st implementation for the building sector in German, Hungary and Spain showing a diversity of preconditions. The overall buildings policy frameworks are analysed to determine if the two examples of EE1st policies discussed in this paper could be best suited for transferability in the realm of the institutional, financial and policy system. Germany has an already strong building code, which could still be strengthened to overcome barriers identified, such as silo thinking. Spain has strong renovation funding programmes which could be defined in terms of composite indicator instead of primary energy to lead to an EE1st approach. Hungary should increase the overall building code stringency and should integrate energy requirements into funding schemes. EE1st aspects coupled with rapid improvements in the decision-making process, in collaboration among decision-making and implementation bodies, as well as efficiency criteria in many, but at least in grant decisions could result in economic, social and climate benefits. The findings have been validated through expert consultations in the three countries through the ENEFIRST project.

7-172-22: Peer-reviewed paper

Using joint procurements and green financing to increase the renovation rate of Swedish single-family houses

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Panel
7. Policies and programmes for better buildings

Keywords
homes, renovation, green investments, funding, procurement, single-family homes, energy efficiency

Like in many other European countries, the energy end-use in the Swedish single-family housing stock is significant and causes considerable greenhouse gas emissions. It is estimated that single-family houses are responsible for 40 percent of the energy end-use in buildings and 36 percent of the greenhouse gas emissions. The EU Commission’s strategy "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives" aims to double the annual energy renovation rates in the next 10 years. Trying to live up to these expectations, owners of single-family houses are a very important but hard group to influence. The EU taxonomy will also impact the energy renovation rate.

The current low renovation rate of single-family houses can be attributed to several different factors like personal financial opportunities, varying degree of technical knowledge, and individual priorities. Contractors and installation companies also consider owners of single-family houses to be a difficult and costly client group to work with due to the house owners’ varying technical knowledge and the limited size of an individual renovation project.

This paper investigates the extent to which the combination of green financing and joint procurement of renovation measures, specifically through the Swedish Energy Agency’s network for energy-efficient single-family houses (BeSmå), could lead to higher energy-efficiency renovation rates, more extensive renovations, and increased profitability, primarily for house owners but also for contractors, through the possibility for the homeowners to acquire green financing either for the measure itself or for the total loans on the house.

If this approach can meaningfully increase the scale, depth, and value of energy-efficiency measures, the impact will extend beyond housing stock, freeing up important capacity in the

electricity grid and production plants needed for the ongoing rapid electrification of other sectors such as transport and industry, and at the same time improve home health.

7-190-22: Peer-reviewed paper

Pathways towards achieving a climate-neutral building stock in Germany

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Panel
7. Policies and programmes for better buildings

Keywords
greenhouse gas emission reduction, building refurbishment, renewable energy, Climate neutrality, building stock, Energy system models

The German Climate Change Act (KSG) defines a sector specific reduction target for the building sector for 2030 of 67 million tonnes CO2eq achieving climate neutrality by 2045. In a scenario analysis this paper examines the extent to which greenhouse gas emissions (GHG emissions) in the building sector in Germany can be reduced by 2045 through current and additional policy instruments. Therefore, a trend scenario is modelled to quantify the target gap by 2030 and 2045. Second, a cost-optimal transformation path for complete reduction of GHG emissions until 2050 from a sector-coupled perspective is modelled (target scenario). For the trend scenario the bottom-up simulation model Invert/ee-Lab is used to map the exploratory development of the building stock based on the current political framework and individual decisions of building owners. The target scenario is modelled with an optimisation approach using the energy system model REMod, which represents the whole energy system and determines a target system considering CO2 reduction targets and the remaining CO2 budget. Coupling both energy models enables a comparison between the simulation of actors' decisions and the resulting diffusion of heat supply systems and building renovation with the target system, in order to identify possible field of actions to reduce GHG emissions. In the third part, additional policy instruments are suggested for closing the gap between trend- and target scenario with the impact being modelled in a policy scenario. In the trend scenario a gap of 21 million tonnes of CO2eq results in 2030 compared to the target defined in the KSG. In 2045, 31 million tonnes of CO2eq remain, which is 91 % less than in 1990. The target scenario outlines a pathway to achieve decarbonisation of the building stock by 2045, already reducing GHG emissions to 52 million tonnes CO2eq until 2030. The ambitious target requires a consistent change to renewable heat supply and heat grids as well as an increase in renovation rates.

7-193-22: Peer-reviewed paper

Harnessing energy performance certificates for deep energy renovation: Policy recommendations and evidence from testing

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Panel
7. Policies and programmes for better buildings

Keywords
energy performance certificates, deep renovations, Energy Performance of Buildings Directive (EPBD), nearly Zero Energy Buildings, Deep Energy Renovation Platform

To achieve the EU's energy efficiency targets, both the rate of building energy renovation and its depth, i.e., the amount of energy savings post renovation need to be improved. Energy Performance Certificates (EPCs) are key to make energy efficiency measures transparent for the building market and to promote the energy efficiency of buildings through renovation. The revision of the Energy Performance of Buildings Directive (EPBD) is seen as a pre-condition to meet the Renovation Wave objectives and to reach a highly energy efficient and decarbonized building stock by 2050. One focus of the current revision of the EPBD is therefore the improvement of EPCs. QualDeEPC – High-quality Energy Performance Assessment and Certification in Europe Accelerating Deep Energy Renovation, funded under the EU's Horizon 2020 programme, is a project that aims to improve EPCs. Following an EU-wide review of existing EPC schemes, and extensive stakeholder discussions in the seven partner countries, QualDeEPC found that EPCs and EPC schemes need to enhance particularly in the following three ways:
1. Establish a close link between EPCs and deep energy renovation
2. Improve the quality of EPC schemes, i.e., both the EPCs and their data, and the processes of assessment, certification, verification
3. Improve cross-EU convergence of EPC schemes.

Therefore, QualDeEPC developed an enhanced EPC scheme by improving seven elements of

existing EPC schemes across the EU and tested their applicability and convergence potential for their EU-wide uptake. They include improved renovation recommendations consistent with deep energy renovation, high user-friendliness through an improved EPC template, mandatory regular training or examinations for EPC assessors, and four other measures to facilitate better implementation and compliance by Member States and market actors.

For testing the tools on renovation recommendations and user-friendliness in the enhanced EPC scheme, 98 pilot buildings were selected from seven partner countries. For all the pilot buildings, standard EPCs were prepared as per existing practice, and enhanced EPCs were prepared using the enhanced EPC scheme. Three further priorities – Online tool, Deep Renovation Network Platforms, and Advertisement Guidelines – were tested for their effectiveness by means of a questionnaire to building owners and other stakeholders.

The results show significant potential for improvement and convergence between various member states, and are discussed in the present paper. In most countries, the number of recommendations and their ambition increased in the enhanced EPCs that provide a clear list of options, and on average, almost 50 % of energy savings potential was suggested in the enhanced EPCs. Based on the analysis, tools developed, and evidence from testing, the paper summarizes the conclusive policy recommendations by the QualDeEPC project, to inform the further EPC policy process at EU level and particularly the EPBD revision.

7-196-22: Extended abstract

Agent-based modelling of private household energy retrofitting behavior

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Panel
7. Policies and programmes for better buildings

Keywords
building retrofitting, energy efficiency policy, simulation, behavioural change

Heating of private household use 16.5% of all final energy use in EU. Energy retrofitting is the most efficient way to reduce this energy consumption. However, research regarding what leads a household to retrofit is difficult to directly translate to clear policy suggestions and effects on energy saved. Additionally, in the authors' opinion, existing models do not sufficiently integrate the existing behavioural research on which factors lead people to retrofit. Therefore, we built the 'Household Energy Retrofit Behavior' model, an agent-based simulation of household energy retrofit decisions based on leading retrofit behavioural research, allowing us to estimate different policies' impact on energy use. In the model, households transition in decision-making stages based on the latest psychological research on energy retrofitting behaviour, and ultimately conduct retrofits on the households over a period of 100 years. As the insulation also decays over time, households must continuously retrofit to maintain an energy standard. All individual households in the model are based on two Norwegian national surveys (n = 2605 and 3797).

Most currently existing and newer policies can be implemented in the model, and the policy's effect on individual and aggregated levels can be observed. We tested the aggregated effect of four different policy scenarios. The current Norwegian energy retrofit subsidies reduce the 100-year cumulative energy use of a household by 34.7 MWh. Lowering the threshold for receiving these subsidies further reduced energy consumption. Marketing certain energy standards have no positive effect. Motivating households seriously considering retrofitting has an effect as long as both outreach and motivation change is sufficient.

Additionally, we tested observed freeriding's effect on future energy consumption. To our surprise, more freeriding on energy retrofit subsidies is associated with less energy use in the future. This somewhat unintuitive result is because subsidies have little effect when there is a high willingness to retrofit in the population. People do not need subsidies to be motivated. Thus, a high free-riding could signify a highly motivated population.

Agent-based modeling of energy retrofitting based on behavioral research rather than economic theory serves as a valuable tool in policymaking. By basing the simulation on what households do, a more accurate picture of policies' effectiveness can be achieved. Finally, the method can be adapted to assess the effectiveness of other policies.

7-209-22: Extended abstract

What role can minimum energy performance standards play to fully decarbonise the stock?

Louise Sunderland, RAP and Independent, United Kingdom

Panel
7. Policies and programmes for better buildings

Keywords
domestic energy efficiency, Energy Performance of Buildings Directive (EPBD), energy performance certificates, building regulations, minimum energy efficiency standards

The European Commission has proposed new minimum energy performance standards (MEPS) in the recast of the Energy Performance of Buildings Directive, published in December.

The proposal targets the worst performing buildings, defined as those with an Energy Performance Certificate class F or G, on an A-G scale. G class non-residential buildings are to be improved to F by 2027, then F class to E by 2030. Homes follow the same steps but three years later, with G class improved to F by 2030 and to E by 2033. The Commission's proposed design follows several international examples that focus on the worst performing buildings and aim to bring them up to a minimum 'decency' standard. Examples are found in Australia, New Zealand, France, Flanders, Belgium and the UK.

The current context, however, requires new thinking. The need to swiftly cut gas use – the dominant fossil heating fuel – and reduce carbon emissions from the buildings sector by 60% by 2030 paves the way for a redesign of MEPS. Rather than improve buildings to just the next worst performing EPC class, the regulations should put every building on a pathway to full decarbonisation through one or two stages of renovation.

The destination for all buildings before 2050 is a suitable level of energy efficiency of the envelope and a heating system that uses a zero emissions source, individual or shared. To guide buildings along this path, the MEPS regulations should require each building to be renovated to a minimum envelope energy efficiency standard that enables decarbonisation of the heating system concurrently or at the next step.

This standard should be defined as the energy efficiency and heat distribution system requirements that enable the building to be heated using lower temperature water and for the heating schedule to be operated at flexible times without compromising comfort. Heating with lower flow temperature water in radiators or underfloor systems is always more efficient, whatever the heat source. It will be particularly important for heat pumps - a primary heat solution - as they work more efficiently when delivering lower flow temperatures. Enabling homes to be heated flexibly is essential to allow new electrified loads from heating to be absorbed efficiently by the electricity system.

This new MEPS can support the different pathways to phase out fossil fuels for heat. It can be used in conjunction with the phase out of the gas grid, as underway in the Netherlands, in advance of a phaseout of fossil boilers as proposed in several European countries, or in conjunction with an EPC-based standard requiring individual buildings to be decarbonised using a carbon metric.

The Netherlands is the frontrunner in this field. In 2021 the Government defined a standard for home insulation to 'future-proof' homes. The intention is to ready buildings to be heated with sustainable heat sources that deliver water at lower flow temperatures compared to the grid gas, defined as 50 degrees or below. The standard is presented for four archetypes, distilled from an investigation of 16. It is currently guidance with no decision made on making compliance compulsory.

In Scotland, the Government has also made steps in this direction by setting out its intention to combine a minimum fabric efficiency standard (equivalent to EPC C) with a requirement for fossil boilers to be replaced with zero emissions systems. A recent Existing Homes Alliance Scotland (2022) paper explored how the minimum efficiency standard could be redefined to ensure lower flow temperature and flexible heating.

In Germany, where a phase out of fossil boilers is planned from 2026, analysts (Ifeu 2021) explored the insulation and heat distribution characteristics that would define a 'low temperature-ready' standard to ensure that the homes can be heated at a maximum flow temperature of 55 degrees. These examples and assessments provide invaluable starting points for the definition of a standard in the EPBD.

7-219-22: Peer-reviewed paper

Pieces of the jigsaw: Minimum Energy Performance standards in practice

Catrin Maby, n/a, United Kingdom
Louise Sunderland, RAP and Independent, United Kingdom

Panel
7. Policies and programmes for better buildings

Keywords
minimum energy performance standards (MEPS), existing housing stock, building energy certification, boiler phase out, fabric first

The COP26 meeting in Glasgow has heightened awareness of the climate challenge across the globe. In Scotland, the host country, the devolved government is pushing ahead with plans to decarbonise buildings, one of the areas in which they have power to legislate. The age and slow replacement of the housing stock, combined with high levels of owner-occupation, make the owner-occupied existing housing stock a high priority for action. It is also a very difficult and sensitive sector to tackle. In 2019, the Scottish Government consulted on setting minimum energy performance standards for owner-occupied homes, and in October 2021 published their Heat in Buildings Strategy, signalling a pioneering approach to this challenge.

This paper describes the approach under development in Scotland, and the range of legislative, technical, social, commercial and practical barriers and opportunities that this raises. These include concerns for homeowners about the costs and disruption of works, energy bills and quality assurance for works. Other major consideration are the practicalities of different trigger points, and the links to effective enabling structures, as well as burdens upon local authorities and impacts on the housing market more generally. A framework is proposed, to bring together the many pieces of this complex jigsaw.

The paper is informed by current research underway with stakeholders in Scotland, as well as studies with a wider European perspective on the fuel poverty and social justice issues involved in decarbonising homes.

7-220-22: Extended abstract

Bioclimatic: Buildings providing comfort with low energy needs in warm climates

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Lorenzo Pagliano, Politecnico di Milano, Italy
Asmae Khaldoun, Al Akhawayn University, Morocco
Silvia Erba, Politecnico di Milano, Italy
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François Garde, University of La Reunion, France

Panel
7. Policies and programmes for better buildings

Keywords
Energy Performance of Buildings Directive (EPBD), bioclimatic, Local constructions Materials, low-energy summer comfort, passive cooling, policies and measures, case studies

Buildings play a central role in a decarbonised & zero-emissions future. Projections indicate a doubling of population by 2050 in Africa, which implicates expanding already insufficient the building stock. New buildings should be designed according to concepts that will make them robustly comfortable against climatic changes and with low energy needs. However, globalisation trends in building design resulted in inadequate solutions for warm climate regions, performing poorly energy & comfort wise.

Analysing and documenting the best sustainable solutions for warm climates is crucial to popularise these concepts and support communities, local construction & manufacturing. The solutions involve a bioclimatic approach, passive cooling techniques, and local low embedded energy construction materials. These concepts and designs already exist in Africa, needing to be identified, documented, standardised and adapted to new conditions & technical possibilities. A recent publication from UN in COP26 presented a series of cases studies documenting worldwide proven options to help cool cities. Strikingly, there were no examples from African cities listed, even though several techniques and designs are flourishing in the region. ABC 21 project aims to fill this gap & promote exchange of best practices between Africa & Europe.

The goal is to present the project's recent findings regarding operative case studies in both regions that follow the bioclimatic and energy efficiency principles for achieving comfort in warm climates. Besides, we will also address how do local geo-bio-based constructions materials and techniques contribute to energy-efficient buildings. How policies and regulations can support and facilitate the dissemination of these techniques and the capacity building in the construction sector, public calls & regulation? The exchange between Africa & EU will contribute significantly to the increased use of adequate locally adapted and climate-resilient buildings.

7-229-22: Peer-reviewed paper

A retrofitting obligation for French dwellings – A modelling assessment

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Panel
7. Policies and programmes for better buildings

Keywords
subsidies, fuel poverty, modelling, retrofitting obligation

Retrofitting obligations are gaining traction among policy makers to overcome the sluggishness of energy efficiency improvements in residential buildings and the low effectiveness of most incentive programmes in changing this. Such an obligation was for instance the flagship proposal submitted by the Citizens' Convention for Climate to the French government. What are the costs and benefits of this little-studied measure? We examine this question using Res-IRF, a building stock model of French dwellings with endogenous retrofitting dynamics. We find that a retrofitting obligation is essential in allowing a net-zero energy target to be met in the residential sector. Crucially, the obligation makes up for the failure of most other programmes (subsidies, white certificate obligation, zero-interest loan, energy taxes) to trigger retrofits in private rental housing. As a result, the obligation is the most effective measure to eliminate the least efficient dwellings (EPC labels G and F) and its impact on energy savings and fuel poverty alleviation is twice that of all other existing measures combined. Against these benefits, we find the obligation to increase annual investment needs by 4 to 6 billion Euros.

7-236-22: Peer-reviewed paper

Occasions for energy-efficient renovation: A targeted approach to stimulate homeowners' uptake of energy advice

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Henning Ellermann, DENEFF, Germany
Christian Noll, DENEFF, Germany
Laurenz Hermann, co2online, Germany
Dana Ifflaender, Dana Ifflaender, Germany
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Panel
7. Policies and programmes for better buildings

Keywords
counselling, home energy audits, homes, detached houses, energy advice

To achieve a climate-neutral building stock, almost every building in Germany must undergo deep renovation and remaining heat supply must switch to renewable energies. However, many homeowners remain unaware of the need to renovate their homes. Despite recent improvements, uptake of energy advice and renovation rates fall far short of the necessary.

This paper analyses how opportunities for renovations like change of ownership, repair measures or biographical changes can be used for a more targeted approach to activate homeowners for energy advice. The study focuses on owners of detached or semi-detached houses in Germany.

We identified and prioritised occasions that could trigger energy advice and renovation and linked them to target groups. So-called personas illustrated core target groups with their motives, needs and obstacles. Focus groups validated the identified occasions and motives and added new insights. Customer journeys then illuminated particularly relevant occasions as well as their possible links to energy advice and allowed us to identify promising communication approaches.

As a result, we found that owners want trustworthy, holistic and independent advice on their property that goes beyond pure energy issues. While climate protection and ecological motives are relevant arguments to owners, they are not central drivers for measures. Furthermore, there is a lack of information about qualified energy consulting services and their benefit to homeowners. For communication of subsidised energy advice, we identified a necessary shift in three respects:

(1) by linking promising occasions to customer journeys and using multiple touchpoints to target groups; (2) by addressing the owners' wishes for advice that goes beyond pure energy issues and (3) through aligning the communication for energy advice with the actual motives of the target groups. Accordingly, a broad bundle of measures is necessary.

7-252-22: Peer-reviewed paper

Shining a light on energy poverty in the European private rented sector

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Manon Burbidge, University of Manchester, United Kingdom
Stefan Bouzarovski, University of Manchester, United Kingdom

Panel
7. Policies and programmes for better buildings

Keywords
energy poverty, energy efficiency policy, indicators, good practice

The Fit for 55 package stipulates a fair, competitive and green transition by 2030 and beyond. As part of this, increasing attention is given to the decarbonisation of the building stock: only 1 % of buildings in Europe are retrofitted each year, a number which must double if the EU is to meet its 2050 targets. Significant energy efficiency investments are needed, whilst the planned expansion of the EU-ETS to the building sector in 2026 will likely pass the carbon cost onto the consumer. This will increase the cost burden placed on low-income households, exacerbating energy poverty, if these two strategies are not counterbalanced by adequate policies and support mechanisms.

The European Private Rented Sector (PRS) is often side-lined by policymakers when implementing energy efficiency policies to tackle energy poverty. As many as 1 in 10 Europeans spend 40% or more of their income on housing costs, with those in the PRS struggling with energy-related problems, such as poor energy efficiency and maintenance, to a much greater degree than the general population. Understanding these challenges and creating targeted policies is of critical scientific and policy importance.

To date, a pan-European policy on how to address energy poverty and energy efficiency improvements in the PRS is lacking; current European Union instruments to address such issues (including the Fit for 55, and the Clean Energy Package that preceded it) lack a dedicated approach towards the complex structural issues embedded in the European PRS. What is more, there is a limited understanding of the character of energy poverty in such residential dwellings, as well as policies to address energy injustices. We therefore examine current and historical disparities in energy poverty between the EU's PRS tenants and the general population by analysing a variety of quantitative indicators which reflect different dimensions of energy poverty. We then take stock of the policy landscape, identifying energy efficiency policies tailored to alleviate energy poverty in the PRS and common challenges. We subsequently interrogate possible solutions, drawing on existing good practice policies. In so doing, we aim to reduce the sector's political invisibility by addressing the lack of disaggregated, targeted data and dismantling barriers that currently lead to the PRS being disproportionately affected by energy poverty.

7-255-22: Extended abstract

Why renovation obligations can boost social justice and might reduce energy poverty in a highly decarbonized housing sector

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Panel
7. Policies and programmes for better buildings

Keywords
renovation, energy poverty, renters, buildings, CO2 abatement

Achieving the 1,5 °C target will require almost complete decarbonisation of the building sector even until the year 2040 in EU countries. Previously developed decarbonisation scenarios did not explicitly show how this transition process will be possible considering affordability and social inclusiveness. While CO2-taxes are included in almost all proposed future policy packages as a key instrument, it is not clear how a CO2-tax might affect low-income households and how different institutional settings affect the level of target achievement. We will deal with following research questions: (1) Is a CO2-tax sufficient to achieve decarbonisation in the Austrian housing sector, considering different structures of housing provision and low-income households? (2) Which impact would a CO2-tax imposed on the housing sector have on low-income households for the case of Austria? (3) What is the impact of regulatory policy instruments like a renovation obligation in combination with a CO2-tax, in particular on low-income households? Key structures of housing provision are the starting point of our analysis, e.g. the distinction of rented vs. owner occupied, and considering (age classes and income classes of households. We integrate these structures in the building stock model Invert/EE-Lab through different constraints and decision rationales. After having modified the model in this way, we model following scenarios: (i) a base case scenario achieving decarbonisation through strong regulatory measures and a CO2-tax, (ii) a scenario without a renovation obligation, (iii) a scenario without renovation and RES-H obligation. We conclude that CO2-taxes alone are not sufficient for achieving decarbonisation targets and that they may lead to adverse effects for low-income households. Mandatory, well prepared and accompanied long-term targets for building renovation, can compensate for these negative effects and make sure that the CO2-tax can unleash its full impact.

7-294-22: Peer-reviewed paper

Framework for stepwise climate work with Climate impact KPIs for the operation and management of buildings built before 2020

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Panel
7. Policies and programmes for better buildings

Keywords
operation, built environment, key performance indicators (KPI), climate action plan, asset management

In 2019, the City of Malmö adopted a local roadmap called LFM30, in connection with Sweden's climate goals. The roadmap implies a climate-neutral construction sector in Malmö by 2030 and will be reached by commitments of participating organizations. To measure the improvements and that the commitment has been fulfilled, a new framework with clear key figures has been developed by researchers and property owners of existing buildings. The framework is used to determine a building's climate status and to practically guide managers and technical managers to systematically and continuously work on climate-adapting operations and management and to analyze the profitability and climate effects of technical measures. Within the framework, 27 Climate impact Key Performance Indicators, CKPI have been identified, key figures that show a building's current climate status. With the CKPIs a building's improvement over time can be showed within a property management, but also for comparing buildings with each other. To improve the CKPIs a tool with about 150 relevant climate actions for operation, management, building, building services systems and user engagement has been developed. The focus is on climate action, but these must not adversely harm other environmental and health factors, which the operation and management should continuously control. The climate actions are formulated as questions that can be answered with yes or no, each is rated in 1–5 depending on how cost- or time-efficient they are to implement. The framework also includes a process guide for the improvement work to be structured and that climate actions are implemented in the right order to avoid sub-optimization of climate effects and the economy. The guide helps managers and technical managers to implement climate actions that are relevant based on the building's conditions and the financial conditions. The property owners' commitments to LFM30 are to report annually from 2023 what proportion of their buildings have reached stage 1, step 2, etc. LFM30 is a good example of how property owners create pressure on themselves and collaborate with other organizations to get climate work started for real.

7-305-22: Peer-reviewed paper

Solar shading as a cost-effective means to stop rising air-conditioning needs in Europe

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Markus Offermann
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Panel
7. Policies and programmes for better buildings

Keywords
passive cooling, mitigation options, summer comfort, air conditioning, decarbonisation, long-term scenarios, building envelope, European Commission, Energy Performance of Buildings Directive (EPBD), policy recommendations

Active space cooling in buildings is projected to rapidly grow until 2050 in Europe. The IEA estimates air-conditioning (AC) in Europe to rise from 115 million units in 2020 to 275 million units by 2050. A comprehensive analysis has been conducted on the extent an uptake of external dynamic solar shading devices on windows could mitigate the predicted additional energy use and associated GHG emissions of AC units in Europe. Results show that dynamic solar shading can effectively stop the predicted trend of rising needs for AC. This means significant reductions of electricity use for AC, net-cost-savings and GHG emissions. In order to get dynamic solar shading a fair chance amongst options for most cost-effective building configurations, the European Energy Performance of Buildings Directive (EPBD) could pave the way by explicitly introducing the energy efficiency first principle as the mandatory guiding principle for setting up minimum energy performance requirements. For new buildings and retrofits a mandatory due diligence for overheating should be introduced, stipulating to first apply solar shading and only then consider active AC if still needed. Furthermore, the EPBD should enable to adequately map the bivalent character of dynamic solar shading – being an element of the building envelope and of building automation and control systems (BACS) at the same time - to the EPBD articles.

7-338-22: Peer-reviewed paper

Distributed data for distributed power. How data ownership and feedback can enable change.

Philipp Grünewald, ECI - Energy Group. Environmental Change Institute, University of Oxford, United Kingdom

Panel
7. Policies and programmes for better buildings

Keywords
heat pump, smart metering, building retrofitting, consumer information, customer feedback

Thus far smart meters have mostly helped utilities to ‘bill better’ or remotely disconnect customers, once they fall behind with their bills. It is time that smart meter data serve those who supposedly ‘own’ them -—the user.

We argue that customers lack easy access to reliable and impartial data to inform difficult choices. The difficulty in obtaining data access rests in the centralised nature of data governance, which requires military grade security procedures to safeguard personal and system sensitive data from unauthorised access or manipulation. We propose a distributed data solution, following the principle of subsidiarity. The default is for data to be processed locally and only to be shared as and when required. This approach gives easier data access for end users and (with their consent) for service providers, who can develop better data driven services than are currently available.

As a case study for the power of personal data to improve feedback and empower better user decisions we discuss heat pumps. Changes in gas and electricity demand before and after replacing a gas boiler with a heat pump can inform important insights into diversity of system performances. This can help to explain why performance varies so dramatically, from one to five units of heat per unit of electricity. Identifying common factors that result in better performance can have profound impacts for a range of stakeholders:

1. End users can use their historic gas consumption data alongside other explanatory variables to get personalised advice on the best heating solution for them
2. Fuel poor households can be protected against unexpectedly higher bills from a change in heating system
3. Industry can develop standards based on the best performing systems and offer recourse in case of underperformance
4. Policy makers seeking a large-scale adoption of heat pumps can target the most suitable early adopters and put in place appropriate measures, such as retrofit, to prepare later adopters in a cost effective manner
5. System operators benefit from better estimation of winter peak demand

The successful roll-out of heat pumps will critically depend on a public actively seeking undergo a major change to their home heating system. Trust and accountability are essential. We will present models and approaches that can inform and reassure adopters ahead of installation and provide accountability over the lifetime of the system.

All that is needed is ready access to one's 'own' smart meter data. We will comment on the challenges and opportunities in this space.

8-003-22: Peer-reviewed paper

Long-term trends in connected thermostat performance

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Abigail Daken, U.S. Environmental Protection Agency, USA
Leo Rainer, Lawrence Berkeley National Laboratory, USA

Panel
8. Innovations in products, systems and building technologies

Keywords
thermostat, indoor temperature, heating systems, cooling, control and monitoring devices

Internet-connected thermostats (CTs) control heating and cooling systems in about 30 % of North American homes, and capture half of annual thermostat sales. In 2017 the U.S. Environmental Protection Agency created a program to certify the performance of ENERGY STAR® Connected Thermostats. To demonstrate compliance with energy-saving criteria, thermostat vendors must submit performance summaries for a representative sample of up to 1250 homes. Vendors must then re-submit results from a new, representative sample every six months in order to maintain their ENERGY STAR certification.

This procedure has created a unique record of each thermostat's long-term performance in response to changes in weather, customer demographics, building stock, and algorithms. Our analysis covers submissions from 13 different vendors, who submitted data up to 7 times over four years. We found that these semi-annual samples generated relatively stable trends for comfort temperatures and Heating, Ventilating and Air Conditioning (HVAC) runtimes over the study period. However, some vendors achieved consistently more energy-conserving comfort temperatures and shorter HVAC runtimes than others. The most recent submission runtimes averaged 700 hours for heating and 1,300 hours for cooling, but some vendors achieved runtimes as much as 17 % below the mean. This implies lower energy consumption is due in large part to more successful algorithms and control strategies used by those vendors.

8-007-22: Peer-reviewed paper

Challenges of heat pumps coupled with building to make them a flexibility tool for the electricity network

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Kevin Attonaty, EDF
Laure Meljac, NIBE
Cong-Toan Tran, Mines ParisTech
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Panel
8. Innovations in products, systems and building technologies

Keywords
heat pump, demand response, control, grid flexibility, energy storage

The EU is setting increasingly ambitious energy and climate targets and is aiming at carbon neutrality for buildings by 2050. In the building sector, this objective implies restrictions on the use of fossil fuels in favour of, among others, electricity. Buildings will then become an interesting tool for grid flexibility, particularly to absorb and store electricity from renewable sources. Furthermore, heat pumps, whose market is booming, constitute a very efficient electrical heating technology and will become a pillar of the electrification of buildings in the coming years. Heat pumps will be a key component of buildings, used as a tool for balancing the grid.

This study presents a comprehensive literature review on flexibility potential. It constitutes the first step of research works aiming to develop a tool dedicated to the flexibility of heat pumps in buildings that will optimize and control the entire heat pump and storage system according to the characteristics of a building to meet a demand for flexibility from the grid.

This literature review shows that heat pumps can offer basic flexibility functionalities such as self-consumption of locally produced renewable electricity and adaptation to electricity tariffs, and can receive single orders from the grid. This study also highlights that, due to the wide variety of configurations and expectations, performance indicators are numerous but not always comparable and not suitable for an objective of optimizing response to various grid orders. In addition, we propose an overview of the different categories of controller addressing flexibility. This study concludes on the future works to be carried out to make the heat pump an efficient flexibility tool for balancing the grid.

8-025-22: Extended abstract

Identifying the Lock-in Effect in the Decarbonization of Residential Sector

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Thomas Haupt, Hochschule Ansbach, Germany
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Panel
8. Innovations in products, systems and building technologies

Keywords
lock-in effect, prosumager, residential buildings, system optimisation

Decarbonization of the residential sector relies on the households' investment decisions, including renovating the building for higher thermal efficiency, replacing fuel boilers with heat pump, adopting electric vehicle instead of gasoline cars, etc. Besides, investment in PV (and battery) systems can bring households profit by generating "free" electricity and earnings from feed-in tariff. Furthermore, combined with smart energy management systems, the household consumers become prosumagers, and can maximize the synergies among consumption (notably heat pump), PV generation, and energy storage (thermal tank and battery) for lowest overall energy cost.

However, the perfect combination of renovation package and technologies may not come naturally, because all these long-term investment decisions do not happen at the same time, and the households also face budget constraints. As a result, a household can be locked with a gas boiler even when it has the chance to switch to a heat pump. Because it cannot install a PV system, or the thermal efficiency of its building is not high enough to use heat pump while it cannot afford the renovation cost.

In this paper, we try to identify such "lock-in effect" based on an hourly optimization model that covers all the aspects of energy consumption of a household, including electric appliances, space heating, space cooling, hot water, PV, battery, and (electric) vehicle. For any combination of renovation package and technologies, the model optimizes the hourly operation of technologies under given conditions (outdoor temperature, radiation, energy prices, and feed-in tariff), and gives the minimized operational energy cost. Then, by comparing the "minimized cost" of different combinations, we can see the cost change of changing any single renovation package or technology given any existing combination. Furthermore, we can also see potential "lock-in" situations by adding the information of investment cost and budget constraint.

8-029-22: **Peer-reviewed paper**

Rejection of innovations: The discontinuance of low carbon digital products and services

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Panel
8. Innovations in products, systems and building technologies

Keywords
diffusion, user behaviour, covid-19, climate change mitigation, post-adoption

DDigital consumer innovations offer low-carbon alternatives to mainstream consumption practices. Examples include smart home technologies for controlling heating, lighting and appliances and domestic electricity generation with storage for co-ordinating personal consumption and peak demand.

Whilst innovation literature predominantly focuses on processes for encouraging adoption; we address a lack of research on the factors influencing post-adoption decisions of discontinuance for this important class of innovations. We conducted a repeat survey with UK consumers (n=995) in 2019 and 2020 to investigate 16 digital products and services across homes, energy, mobility, and food domains. Our survey captured temporal changes in adoption, personal and contextual characteristics, communication, social influences, innovation experiences and perceived attributes. We compare responses of participants who discontinued an innovation with two control groups: 1) participants who continued adoption and 2) those who remained non-adopters. We also provide a unique contribution by assessing the impacts of Covid-19 on post-adoption processes, domain behaviour and information flow.

Our results indicate that discontinuance is associated with 1) services more than products; 2) perceived functional attributes not met by experienced attributes; 3) a lack of positive social influence, including word-of-mouth; 4) a lack of social network connections to other adopters; and 5) a decline in an individual's financial situation. Covid-19 was not found to be a significant factor influencing innovation discontinuance. Findings highlight generalisable insights for industry and policy regarding issues that need addressing to overcome discontinuance. For example, while digital services offer low-carbon promise, continued adoption is sensitive to their strong performance attributes. There is a need for continued innovation to sustain market position relative to more familiar incumbents.

8-057-22: Peer-reviewed paper

Energy efficiency policy for small network equipment

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Panel
8. Innovations in products, systems and building technologies

Keywords
energy labelling, minimum energy efficiency standards, small network equipment, product policy

Energy consumption of small network equipment (SNE) continues to grow as more products are connected to the Internet and use more data-demanding services such as video download and gaming. Previous studies estimate global SNE energy consumption of 179 TWh in 2020, increasing to 215 TWh in 2030. Much of this energy consumption could be avoided; researchers estimate that efficiency improvements – especially power scaling – could decrease energy consumption of SNE by 20 to 50 %. Current energy reduction efforts for SNE, however, are scarce and mostly of a voluntary, industry-led nature, such as the SNE Voluntary Agreements in the US and Canada or the Broadband Code of Conduct in the EU. These approaches are complex and tend to follow business as usual instead of driving innovation.

This paper explores options for mandatory energy efficiency measures, such as minimum efficiency requirements or energy labelling, for SNE based on a functional approach. Our analysis of SNE power data shows that products with similar functions can differ in power consumption, indicating that efficiency improvements exist. In addition, the analysis provides insight into the impact of various components (functions) on product power draw and builds a model to establish a reference value for the power consumption. An energy efficiency index (EEI) is then based on the reference value and can be used to set minimum requirements through ecodesign and an energy label. The minimum requirements assure that the least efficient products are banned from the market, while the energy label, through public procurement and green taxonomy, will stimulate the uptake of the most efficient products.

8-060-22: Extended abstract

pump:chic – on getting comfortable with heat pumps

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Panel
8. Innovations in products, systems and building technologies

Keywords
heat pump, adoption, electrical heating, consumer preferences, digital

This presentation will introduce pump:chic, an online project set up to help people get comfortable with the idea of living with a heat pump. In many European countries (such as the United Kingdom, the Netherlands, and Germany), domestic heating energy demand is dominated by natural gas. To meet decarbonisation targets, these countries are therefore putting substantial focus on promoting highly efficient electric heat pumps. However, the technology is still unfamiliar to most residents. While cost is a significant barrier to uptake, other factors have been shown to play a role, such as concerns about comfort, noise, and appearance. The pump:chic website demonstrates approaches which could be used to support quicker and wider uptake.

"Trialability" is recognised as a potentially important component in the adoption of innovations. However, heat pumps do not easily lend themselves to trialling. In an attempt to address this, the "Test Drive" option gives users a chance to feel, hear, and see how a heat pump might fit into their home. The "feel" option relies on reducing flow temperatures of existing condensing gas combi boilers. "Hear" uses a Bluetooth speaker to play a heat pump recording, calibrated for volume using a smartphone app, that can help in pump positioning. The "see" option has two strands. One is an easily constructible frame users can assemble and use to try out positions for their pump. The other is an augmented reality app that offers a similar experience without the need for physical kit. Finally, a "boiler escape plan" gives simple next steps for users who aren't ready to move to a heat pump straight away, but would like to in future. The presentation will include a demonstration of these test drive facilities.

A second strand focuses on the aesthetics of heat pumps. Users are given the opportunity to rate the attractiveness of different heat pump installations, including how they are landscaped into their space. The aim here is to show what people like, and inform tips about effective landscaping. ECEEE attendees will have the opportunity to add and rate pump photos for themselves. The presentation will also cover next steps for the project, along with reflections about what is working well (or not so well) so far.

8-062-22: Peer-reviewed paper

Evaluation of the energy saving potential through systematic data collection of the electricity consumption and heating in the building sector

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Panel
8. Innovations in products, systems and building technologies

Keywords
evaluation, domestic energy efficiency, resource consumption of digitalization, user behavior

The digital measurement of electricity and heat consumption of households and buildings offers the opportunity to systematically identify previously hidden energy efficiency and saving potentials in real time. But the required measurement and processing of the data is associated with negative environmental impacts, through the hardware of the devices and the data transmission and processing. The DETECTIVE project aims at quantifying the net saving potential of digital consumption metering for electricity and heat.

In the electricity sector, the framework for a wide smart meter rollout in Germany has been set up, but the installations have been running modestly since 2019. Soon, smart meters will create the technical infrastructure for the digitalization of the energy transition, which will enable and facilitate the integration of renewable energies, sector coupling and prosumer models. In the heating sector, digital metering of primary energy consumption is used by energy savings contractors to optimise the operation of the heating system.

In this paper, we analyse measured data from households and buildings, in which digital applications for electricity consumption and online monitoring of the heating system operation are installed, and evaluate the changes in energy consumption. We estimate the additional electricity consumption of the necessary digital devices and data flows to compare them with the energy savings. This enables a net balance between energy expenses and savings in order to quantify the ecological benefits.

In view of the upcoming large-scale smart meter rollout, this is essential information in order to

regulate digitization in such a way that the greatest possible environmental benefit can be achieved.

8-078-22: Peer-reviewed paper

"Energy transition modules" – adding efficient living space on the top of existing buildings with pre-fabricated modules

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Panel
8. Innovations in products, systems and building technologies

Keywords
energy efficient technologies, building design, cost efficiency, efficiency, energy transition, pre-fabricated modules

Especially in densely populated cities, living space is scarce and rents are increasing dramatically. But there are options to tackle this problem. Many roofs of the building stock are suitable to be topped up with living space by adding floors, thus increasing space and energy efficiency. Within a pilot project, we developed innovative modules that can be used for this purpose.

We call these modules "energy transition modules". They are highly energy-efficient, use wood as their primary building material while having a supply unit using solely renewable energy. This unit supplies heat to the surrounding rooms centrally via wall heating, concentrates technology in one module part, thus allowing favourable transportation from the manufacturing to the building site, and enabling a flexible floor plan arrangement. In order to check which system technology should be used to supply heat and domestic hot water to the modules, energy analysis, life cycle assessments, and cost calculations were carried out to obtain an optimal result.

Different variants of energy transition modules were developed in order to prepare for various applications and circumstances, including adding a floor to car parks, office buildings or other non-heated buildings. The energy transition module can either supply a building with heat and energy (self-sufficient), share only a part of its energy with the building (symbiont), or be supplied by the building (profiteer). By arranging different modules, a “village on the roof” can be created.

The project, which is presented in this paper, is unique in several ways: We planned and simulated the heating system and developed concepts for an architectural implementation. We analysed the changes in legislation required to increase the number of rooftop designs. In addition, we determined how many energy transition modules can be used for rooftop designs in Germany, and finally realised the module on top of an office building in Southern Germany.

8-081-22: Peer-reviewed paper

Fit for renewables through low temperature readiness of buildings

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Panel
8. Innovations in products, systems and building technologies

Keywords
renewable energy, district heating, heat pump, low temperature, Fit for renewables, renovation, building envelope, system optimisation

When oil or gas boilers break down, they are often substituted by yet another generation of oil or gas boilers. However, once a fossil heating system is installed, the next chance for a change to renewable energy will occur only in 15 to 20 years. One problem is that in practice not every building is ready for renewables – particularly for heat pumps. The required high temperatures in the heating system frequently block the switch to renewable energy.

Most existing buildings do not have to be completely modernized to be heated with heat pumps or low temperature district heating. Usually, a few targeted measures enable lower system temperatures: insulation of specific envelope components and improvements to the heat distribution. This paper proposes a new "standard" that combines efficiency measures and the optimization of the heating system to open the door for renewable heating: "Fit for renewables through low temperature readiness (LT ready)".

We will demonstrate how we developed the LT ready standard based on static and dynamic building calculations, what benefits it has in terms of enhanced capacity of buildings to include renewables, increased seasonal efficiency, lower load demand, and higher resilience of the building. For a definition, we suggest that buildings are LT ready when insulation measures, heating circuit optimization, or efficient domestic hot water supply have been optimized such that the room temperature required by the users is ensured with a maximum flow temperature of 55°C. LT readiness is not a final target standard, but an intermediate step in the renovation biography of a building towards carbon free buildings.

The paper will also present how LT readiness and "Fit for renewables" can be incorporated into energy audits, building roadmaps, funding schemes, and regulation, as exemplified in the "Building Energy Act 2.0" developed as a blueprint of a revised building code.

8-096-22: Peer-reviewed paper

Optimal sizing of solar photovoltaic and lithium battery storage to reduce grid electricity reliance in buildings

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David Wallom, University of Oxford, United Kingdom
Malcolm McCulloch, University of Oxford, United Kingdom

Panel
8. Innovations in products, systems and building technologies

Keywords
renewable energy, optimisation, hybrid, photovoltaics, electric storage

In alignment with the Paris Agreement, the city of Oxford in the UK aims to become carbon neutral by 2040. Renewable energy help achieve this target by reducing the reliance on carbon-intensive grid electricity. This research seeks to optimally size solar photovoltaic and lithium battery storage systems, reducing Oxford's grid electricity reliance in buildings. The analysis starts with modeling the electricity demand. The model uses Elexon electricity settlement profiles, and assembles them into the demand profile according to the quantity and types of buildings in Oxford. Then, solar generation is modeled using Pfenninger and Staffell's method. Solar photovoltaic and lithium storage systems are sized using a hybridized analytical and iterative method. First, the method calculates the solar system size search range, then iterates through the range. At each solar size, the method calculates and iterates through the storage system size search range. Within each iteration, the renewable system is simulated using demand and generation data with a simplified system setup and the conventional operation strategy. The method outputs combinations of solar system capacity, storage system capacity, and grid electricity import. Each combination's levelized cost of electricity is calculated, and the lowest cost combination is the optimal sizing. Solar and storage system costs are projected from 2019 to 2100, and the optimal sizing is calculated for each year. The result shows that solar photovoltaic is economically competitive, but lithium storage cost is still too high. As solar and storage prices continue to drop, they will take up greater portions of the energy system. However, there will always be a need

8-103-22: Peer-reviewed paper

Living with demand response: Insights from a field study of DSR using heat pumps

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Jenny Crawley, UCL, United Kingdom
Michelle Shipworth, UCL, United Kingdom
Cliff Elwell, UCL, United Kingdom

Panel
8. Innovations in products, systems and building technologies

Keywords
heat pump, demand response, case studies, comfort, practice theory

Demand response with domestic heat pumps has gained interest in recent years. It is seen as a possible solution to the need to balance electricity grids that are sourcing a higher proportion of their electricity from variable low-carbon electricity sources. Although many modelling studies suggest that demand response with heat pumps will be successful, we have little knowledge of their real-world impacts, including the impact on indoor conditions and the perception of these.

This study compares what happened in three homes of early adopters of heat pumps with demand-side response (DSR). In the three households, the operation of the heat pump was constrained from 4pm to 7pm to provide demand response. Drawing on technical monitoring, we report on indoor conditions in the home and heat pump operation. Drawing on interviews and informed by social practice theory, we explore how comfort at home is experienced and achieved. The focus of the study is on the indoor conditions as the material background for daily practices, and on how these are sensed, interpreted, and created through comfort practices.

The analysis of the results revealed that air and surface temperatures dropped during demand response (air temperature dropped 0.3–1.1 degrees in 3 hours). However, these changes were sensed and interpreted differently by different participants: (1) not perceived, (2) noticed but tolerated without affecting DSR or (3) not tolerated. Although material adjustments were common in (2) and (3), the nature of the adjustment depended on the know-how of the participants and the meaning associated with temperature changes; for example, (2) adopted new materials (e.g., clothes) while (3) changed the operation of the heat pump to produce more acceptable indoor conditions.

The findings challenge conventional modelling assumptions that demand response is unnoticed by people if the indoor temperature remains within the limits of steady-state models of thermal comfort and reveal how demand response is negotiated and incorporated into daily practices.

8-115-22: Peer-reviewed paper

Field testing of the next-generation residential space conditioning system

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Sara Beaini, Electric Power Research Institute, USA
Ammi Amarnath, Electric Power Research Institute, USA

Panel
8. Innovations in products, systems and building technologies

Keywords
residential buildings, domestic energy efficiency, demand response, summer comfort

Residential heat pump systems at the minimum efficiency standard can use high quantities of energy, resulting in higher greenhouse gas emissions, higher bills for customers and electric grid congestion. This project evaluated a variable capacity heat pump system with additional heating and cooling innovations that could provide high efficiency space conditioning for residential conditions. The heat pump system integrates advanced HVAC technologies including: a variable capacity compressor, inverter driven indoor blower, automated demand response capability, low GWP refrigerant, intelligent dual fuel heating, integrated ventilation, and zonal control. The heat pump system was tested in 3 residential homes located in California, US. Our tests showed that heat pump systems can provide heat for >90 % of hot and dry climate zones, like California, since they can meet almost all loads in the heating season without backup. While the system's dual fuel functionality (electric heat pump with gas furnace back-up) adds versatility, gas and electric utility rates are primary drivers for incentivizing heat pump usage. The field evaluation saw positive customer feedback, with users appreciating how quiet the units were, how quickly they cooled or heated the space, and their ability to control the temperature in individual spaces. Utility bills from the customers were used to compare this new heat pump system against the typical residential space conditioning baseline of air-conditioner with fossil fuel furnace. The project team worked extensively with the manufacturer and the homeowners to understand the impact of such next-generation devices, and the field evaluation results provide valuable information on the customer's energy burden holistically. This is critical in ensuring the equitable adoption of advanced HVAC technologies, which encompasses both the economic burden on customers, perceived comfort for the customers, and value for the utility industry.

8-127-22: Peer-reviewed paper

Lowering Building Energy Use by Improving LAN Energy Efficiency

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Panel
8. Innovations in products, systems and building technologies

Keywords
Wi-Fi, energy model, Directive on Energy Performance in Buildings (EPBD), local area network

Improving ICT wired and wireless Local Area Network (LAN) energy efficiency will lower building energy use, in particular commercial buildings. With a growing reliance on LANs for the use of Internet of Things (IoT) building management applications, the need for networks to be as energy efficient as possible is only going to be greater. The energy savings is estimated using the Total Energy Model (TEM).

The TEM, developed for the International Energy Agency 4E Electronic Device and Network Annex, models Internet network and device energy use. The TEM reveals that LANs, within the commercial and residential sectors, are one of the highest energy consuming components of the Internet. Opportunities to improve LAN efficiency are currently technically feasible in the commercial sector, while further development is required for LANs in the residential sector.

The Energy Efficient Ethernet (EEE) amendment to the Institute of Electrical and Electronic Engineers (IEEE) 802.3 standard was intended to dramatically reduce LAN energy use. And while the potential remains, it appears that relatively few LANs take advantage of this option. The Wi-Fi Power Save (PS) mode enabled connected battery-powered devices to reduce power consumption. However, despite the development of PS mode, there has been little effort to improve the overall energy efficiency of Wi-Fi networks.

LAN energy efficiency could be enhanced by enabling connected Wi-Fi networks to enter a low power mode. One way of achieving this is to amend the relevant LAN standard to enable an Ethernet network to inform a connected Wi-Fi network that it is in Low Power Idle (LPI) mode, thus allowing the Wi-Fi Access Point to enter a similar mode.

Based on the conservative assumptions outlined in the paper regarding implementation of the proposal, the TEM estimates that by 2030 the energy saving in commercial buildings, compared to the BAU case, would be in the order of 34 TWh annually. The paper also explores additional technical options to increase the efficiency of Wi-Fi LANs in the residential sector.

8-128-22: Extended abstract

Integrating energy labelling with a quality assurance process: a new quality seal for planning, installation and commissioning of VAC systems

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Panel
8. Innovations in products, systems and building technologies

Keywords
energy label, ventilation, air conditioning, energy labelling scheme

In non-residential buildings, ventilation and air-conditioning (VAC) typically account for a significant share of energy consumption. Often owners might not even be aware of the VAC's high energy footprint due to missing meter and sensor technology in medium and large size systems. Ecodesign and energy labelling have contributed to raising the energy efficiency of the components of new VAC systems. However, the ultimate energy consumption depends to a large extent on an appropriate sizing and efficient operation of the complete system: e.g. an over-sized system that ventilates unused rooms wastes energy even with an efficient fan.

From planning to operation of a VAC system, a number of pitfalls regularly result in waste of energy: e.g. missing information about probable use; insufficient sensors and actuators for adaptation to changing demands; too few time allotted to commissioning; lost information for energy efficient operation when responsibility passes to the user.

Here, we present a new approach that combines energy labels with a quality assurance process for new VAC systems. The concept transfers the EU energy label to a bespoke systems label and introduces an independent auditor to accompany the planning, installation, commissioning and operation. In a three step process, the auditor checks energy efficiency, sizing, sensor technology, plans for commissioning, instructions and training for operators, and more.

The voluntary process works as an exchange between auditor, building owner and planning offices involved: asking the right questions and the right moment, making sure no information is lost and plans are implemented correctly. At each step, the auditor reflects the current status via an

energy label. To create the labels, an especially developed software algorithm rates the yearly energy demand. Energy labels help the auditor to visualise and condense information on energy efficiency in a way that is easily understood by customers.

At least six months after commissioning, a last check of the operation conditions and settings ends the process.
Successful completion of the monitoring process is rewarded with a Seal of Quality for Ventilation and Air Conditioning ("Qualitätssiegel Raumlufttechnik"), issued as a certificate for a building's entirety of ventilation and air conditioning system. A manual provides guidelines and minimum energy requirements for the award.

The Seal of Quality for Ventilation and Air Conditioning transfers the well-established energy labels for products to a complex system, including planning, installation and operation. Additionally, it showcases how to combine energy savings and energy efficiency with quality assurance. The design of the process as a support in information flow for all involved parties - while setting clear energy efficiency requirements - offers acknowledgment for good work to planners and installers, as well as assurance of a high energy efficiency of the complete VAC system to customers.

The concept was commissioned by the German Environment Agency and is shortly expected to be available to the public. While counting on positive feedback from industry stakeholders, a broad implementation requires additional steps: currently the concept is under consideration by the relevant standardization committee in Germany.

Generally, the challenges regarding planning, installation/commissioning, operation and their relevance for energy savings are not unique to VAC systems. Therefore the concept could be transferred to other complex building related systems, such as heating. In the future, linking energy efficiency quality assurance to subsidies or regulations for new buildings is desirable, possibly including heating as a further step.

8-140-22: Peer-reviewed paper

Pandemic-related behavioural changes – does EU Ecodesign policy making need to react?

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Panel
8. Innovations in products, systems and building technologies

Keywords
behavioural change, energy labelling, information and communication technologies, household appliances, Pandemic, Smart Home and Products, EU policy

The global COVID-19 pandemic has brought far-reaching changes for our society. Suddenly, millions of people spent the majority of their time at home - either due to a lock down or by switching from office to working remotely. This paper offers a literature review regarding pandemic-related behavioural changes and a first mapping of likely consequences for EU Ecodesign regulations. These impacts are considered for product groups that are already regulated by EU Ecodesign or are under discussion for future regulation. Furthermore, potential for smart home applications are analysed exemplarily.

We identified which behavioural changes have the potential to become established in the long-term. This might need to result in adaptions for regulations under the Ecodesign Directive and EU-Energy Labelling regulations to better reflect the recently appeared usage profiles. It might require different priority settings regarding the product groups to be regulated and communicated to users, due to online shopping proliferation, to be updated.

Changed behaviour can be observed in product groups such as ICT, consumer electronics and household appliances. Examples include the increased use of laptops and tablets for digital teaching, use of gaming devices and office equipment in private households (IT, printing and network devices) and changed cooking behaviour. This resulted in increased sales of some product types. Online sales became even more important than in-store sales, which also means that consumers are increasingly informed online about energy efficiency. More do-it-yourself (DIY) home projects result in more frequent – not yet regulated – DIY power tool use and over the long run might stimulate the need for (semi-)professional tools. The changes in behaviour patterns also

offer the opportunity to optimize consumption by means of smart homes and smart products. However, the control of networked household appliances requires additional energy for standby states and data exchange. As an illustrative example, we discuss the conflict between higher energy consumption for smart system components and the possible optimization of consumption in private households.

8-145-22: Peer-reviewed paper

Architects as agents of change – designing to support a sufficiency-oriented dwelling practice

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Ann Bosserez, Thomas More Research
Elke Knapen, Hasselt University
Nick Van Loy, Hasselt University

Panel
8. Innovations in products, systems and building technologies

Keywords
building design, architectural education, domestic energy efficiency, energy sufficiency, heating practice

Since the implementation of the EPBD in 2006, architects are trained to design for energy efficiency to meet the requirements in their country. However, the focus of the EPBD is highly object-oriented, meaning that architects have learned to design energy-efficient buildings, of which the performance is evaluated for standard climate conditions and standard occupant behaviour (Bosserez, 2020). The aspect of energy sufficiency, which demands much more a user-oriented design perspective stimulating a sufficiency-oriented dwelling practice, is still completely absent in architectural design education (Verbeeck & Bosserez, 2021). This results in architectural students assessing their recently built, EPBD compliant parental houses as highly energy efficient (in kWh/m^2 floor area) and thus good examples, while completely ignoring the actual high energy consumption in these houses (in kWh). For the sample of 182 parental houses (academic years 18-19, 19-20, 20-21), the average energy efficiency is 140,6 ± 87,3 kWh/(m^2,year), whereas the average energy consumption is 33.595 ± 21.096 kWh/year and the average CO2 emissions 6,0 ± 3.4 ton/year for heating and electricity consumption. This high energy consumption despite a reasonable energy efficiency is often a consequence of the large size of the houses (on average 258,1 ± 110,7m^2 floor area), the open design, the non-climate responsive design and the often luxurious lifestyle.

The passive design approach in the first steps of the Trias or Penta strategy for (nearly) zero energy buildings however allows the inclusion of design measures to steer residents towards a much more sufficiency-oriented dwelling practice. A spatial design method for sufficiency has already been presented at eceee2021 (Verbeeck & Bosserez, 2021). This spatial design approach can be complemented with a sufficiency-oriented heating practice. Currently heating in dwellings is mostly designed in terms of heating systems (object-oriented) and much less in terms of heating practice (resident-oriented) (Van Loy et al, 2021). Efforts are undertaken to increase the energy efficiency of heating systems by means of the use of more efficient heating systems and more sophisticated control systems, but the aim is still to provide a comfortable room temperature by

acclimatising complete rooms, often regardless of the actual spatial and temporal occupancy. A sufficiency-based heating practice on the contrary focuses on providing thermal comfort to the residents by heating people instead of rooms. This can be realized through a reduction of the overall room temperature in combination with a higher clothing level and, if needed, localized dynamic personal heating.

In recent years this sufficiency-oriented design approach has been integrated in architectural education at our faculty, both in theoretical courses and design studios. In the bachelor course on Climate Responsive Design, the chapter on strategies to reduce energy consumption in buildings has been extended with a critical reflection on energy efficiency and a presentation of the design method for energy sufficiency, and students have to evaluate their parental house on both energy sufficiency and energy efficiency. In the master course Zero Pentathlon students combine the design methods for sufficiency and efficiency in a design assignment on the renovation of existing houses (in academic years 19-20 and 20-21 on large, underused houses, in academic year 21-22 on social houses). Furthermore, master classes on sufficiency-oriented design are planned for the future for practicing architects, in order to introduce this concept more in architectural practice.

8-158-22: Extended abstract

Safety and energy performance of photovoltaic equipment: the case of the the Brazilian labelling program - PBE PV

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Panel
8. Innovations in products, systems and building technologies

Keywords
photovoltaics, safety, energy labelling, mandatory requirements

Renewable energy capacity addition set another record in 2021, driven by solar PV, and despite pandemic crisis and rising costs of key materials, solar PV is expected to continue setting new records, growing faster than in the previous 5 years (IEA, 2021).

However, for this growth to be sustainable, there is a must to consider issues such as equipment safety, system performance, electric grid, environmental impacts, and others, which must be addressed by governments together with stakeholders.

Many countries have established legislations for the qualification of PV equipment, and recently EU is examining the conditions for adopting an energy labelling scheme. In order to contribute to the debate, we present the experience of the Brazilian PV Equipment Labelling Programme (PBE-PV), whose initiative complete 20 years in 2022.

Since 2002, Inmetro, a national regulatory agency, has been working with the issue of PV equipment, under the aegis of the Brazilian Labelling Programme (PBE). In 2008, Inmetro launched the first edition of PBE PV, as a voluntary certification scheme, in 2011, adopted a mandatory labelling approach, and in 2022, launched a fully improved programme, of mandatory declaration of conformity, which is the case presented here.

PBE PV stablishes technical, marking, declaration of conformity and labelling requirements for PV equipment, with mandatory compliance to market products in Brazil. All suppliers are subject to premarket controls, such as registry and imports approval, and market surveillance.

For PV modules, the regulation covers products of nominal power ≥ 5 W, of silicon cells, thin films, or heterojunction. It stablishes performance (power determination, conversion efficiency) and electrical safety (insulation, current leakage in wet conditions) requirements. The evaluation is by family of products, covering 5 tests of IEC 61215. After all, module’s efficiency is calculated and classified from “A” (>20%) to “E” (<14%).

For charge controllers, the regulation covers PWM and MPPT types. It stablishes performance (self-consumption, internal power loss) and electromagnetic compatibility requirements. The evaluation is by model, and the tests are based on Inmetro's own procedures, covering self-consumption, internal losses, setpoints, overvoltage, reverse polarity and short circuit protections.

For batteries, the regulation covers electrochemical technologies of lead-acid, nickel-cadmium, lithium-ion, and others. It stablishes performance (capacity, charge cycles, self-discharging) and electrical safety (management system, overheating, overload) requirements. The evaluation is by family of lead-acid or by model of lithium batteries, and the tests are based on NBR and IEC standards, covering real capacity, charge cycles, self-discharge, overload, overcurrent, and overheating controls.

For inverters the regulation covers off-grid, grid-tie, and hybrid inverters ≤ 75 kW. It stablishes performance (euro efficiency), electrical safety (polarity inversion, insulation resistance, arc fault, mechanical disconnection), grid stability and compatibility (harmonic distortion, supportability and immunity) and electromagnetic compatibility (radiofrequency disturbances) requirements. The evaluation is by model, and the tests are based on NBR and IEC standards, covering polarity inversion, insulation failures, harmonics distortion, over/under voltage, over/under frequency, unintentional islanding, conversion efficiency and radiofrequency emissions.

PBE FV has currently 13.176 registered products, being recognized as an important regulation to protect national market from unsafe and underperforming equipment. Although the recent regulatory process involved a tough and complex negotiation with stakeholders, it was possible to achieve good levels of commitment, and to introduce new requirements, anticipating risks faced by other countries such as blackouts, arc faults and radio frequency disturbances related to PV equipment.

8-173-22: Peer-reviewed paper

Lower Efficiency but a Higher Efficiency Rating? A Case Study in Air Conditioner Circumvention under the ISO 16358:2013 Calculation Method

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Panel
8. Innovations in products, systems and building technologies

Keywords
air conditioning, energy label, Cooling Seasonal Performance Factor, Circumvention

Identifying and rewarding more efficient products is a key goal of energy efficiency labeling programs for air conditioners. Towards that end, many countries around the world, from Brazil to India to Thailand, have adopted energy efficiency standards and labeling policies based on variations of the ISO 16358:2013 calculation method, which is designed to estimate the energy performance of inverter air conditioners over the course of the year, in the form of the Cooling Seasonal Performance Factor (CSPF) metric. These policies have been crucial in creating a global market shift towards more efficient inverter air conditioners, reducing energy demand and CO2 emissions in the process. However, there is a major loophole in the ISO 16358:2013 calculation method that has allowed some manufacturers to achieve a better CSPF with a less efficient product.

This paper examines a case identified by the Brazilian National Institute of Metrology, Quality, and Technology (Inmetro) where some manufacturers operating in Brazil achieved a higher CSPF by substantially reducing their product's efficiency during one of the tests used in the calculation of that metric. We explain how reducing efficiency during the testing process can exploit a loophole in the calculation method when using the option test point, as well as how policymakers can address this issue in a cost-effective manner in order to ensure that their energy efficiency policies are indeed promoting the most efficient products

8-198-22: Peer-reviewed paper

Reducing post-harvest food losses through innovative, affordable, and sustainable cooling

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Panel
8. Innovations in products, systems and building technologies

Keywords
affordability, innovative technologies, cold supply, post-harvest loss, shelf-life extension

Though India is a leading producer of food grains and horticultural crops globally, it stands 101st among 116 countries on the Global Hunger Index 2021. One leading reason for this paradox is improper post-harvest practices leading to rejection at the farm gate and delays in the distribution process, which wastes EUR3.7 billion every year. For fresh produce, the post-harvest losses are estimated at 35 % from production to consumption during harvesting and post-harvest activities. The high volume of losses, if reduced, can generate significant value and address food security concerns. Awareness of appropriate post-harvest processes, adoption of proper packaging, and access to affordable cooling can bring better remuneration to the producers and affordable prices to the consumers. Understanding the relation between post-harvest shelf-life extension and cooling requirement is essential to reduce post-harvest losses. The shelf-life extension through conventional cooling systems comes with energy, environmental, and monetary costs. The authors firstly emphasise optimum (minimum) temperature reductions for key tropical fruits and vegetables to ensure their fresh supply to the end consumers while minimising the energy requirements. Evaporative cooling in dry regions with lower relative humidity levels offers a sustainable solution to meet the challenges of reducing post-harvest losses. Evaporative cooling reduces air temperature to within a few degrees of the wet-bulb temperature of the outside air and is frequently used in dry climatic regions for comfort cooling. The natural conditions of the lower dry-bulb and the water temperature prevailing at night and early morning time provide an opportunity to use evaporative cooling for pre-cooling effectively. In lower night-time air temperatures, the harvested produce can be cooled to some degree by ventilation alone. The authors propose cooling the harvested produce by recovering the coolth from the night air and water through evaporative cooling to pre-cool the produce in an insulated cabin mounted on the tractor-trailer or a similar vehicle commonly available near farms. It is an innovative and versatile solution to extend the post-harvest shelf-life with easy access to cooling at an affordable cost to the farmers. The night temperature of underground well water (generally used for irrigation purposes) is also cooler, further helping the evaporative cooling to reduce the produce temperature by 5 °C lower than the harvest temperature. When mounted in the tractor-trailer a mobile pre-cooler can easily pre-cool the produce to up to 25 °C or lower, thus extending the shelf life and freshness of the produce by 1 to 2 days. This increased shelf life by a few days will support

small farmers to sell the produce to better prices in the market. The avoided post-harvest losses of a mere 5% translate to feeding nutritious fruits and vegetables for 2.7 million hungry people daily every year.

8-204-22: Extended abstract

Enabling shared ground heat exchange in cities

David Barns, University of Leeds, United Kingdom
Catherine Bale
Fleur Loveridge
Saleh Salavati Meibodi
Alice Owen
Joshua Turner
Peter Taylor
Simon Rees

Panel
8. Innovations in products, systems and building technologies

Keywords
low-carbon buildings, district heating, urban planning, governance, cities, local and regional energy planning, local authorities

Shared ground heat exchange (SGHE) could be critical in the transition to net-zero, tackling the hard-to-decarbonise heat in buildings sector. SGHE comprises heat pumps using ground-sourced heatand alow temperature heatnetwork serving multiple households. Heating and cooling can be shared across the network and balanced through ground thermal storage. SGHE is viable in dense urban areas where individual heat pumps are not and addresses some of the challenges inherent in classic high temperature district heating.

The combination of heat pumps and low temperature DH is recognized as key to European heat and electricity sector decarbonisation. Whilst the SGHE technique is established, deployment is highly concentrated in just three countries, Switzerland, Sweden and Germany, but remains niche in many others including the UK. Unlike conventional fossil-based heating, SGHE is net-zero compatible as the electricity grid continues to decarbonise. However, as a result of the technology and its interplay with the complex institutional, policy and regulatory environment, greater deployment is dependent on detailed policy measures which will translate national goals into local and regional plans and policies.

This work brings together interdisciplinary research from across the University of Leeds on technical aspects of SGHE, consumer perceptions, the planning and regulatory environment, as well as perspectives from municipal authorities and private developers involved in developing SGHE. Through a comparative case study we have established how city governments operating under the same regulatory framework can use powers and tools at their disposal within the municipal planning function to support deployment.

These findings are applicable across technologies and internationally. The work incorporates outcomes of engagement with national and local policymakers on a set of policy recommendations to support the deployment of shared ground heat exchange in cities.

8-211-22: Extended abstract

Transforming the global motors market with new policy guidelines and model regulations for MEPS and HEPS for eco-efficient electric motors and motor systems [Inc. pumps, fans, compressors]

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Paul Kellett, UNEP, France

Panel
8. Innovations in products, systems and building technologies

Keywords
electric motors, energy systems, minimum energy performance standards (MEPS), efficiency standards, efficiency classification, market transformation, regulation

The development and implementation of energy efficiency and environmental policies will drive the transition to energy efficient motor systems globally and reduce the global electricity demand by motor systems by 20-30 per cent in 2030. With a solid basis of energy efficiency testing and classification standards for motors and driven applications (e.g., pumps, fans, compressors) over 40 countries have implemented minimum energy performance regulations for motors.

Especially during the last decade, the energy savings results have led to an increase in countries implementing MEPS for motors. An extra driver is the notion that absence of such policies may cause them to become the destination for inferior motors that are not acceptable elsewhere.
An international public-private partnership, United for Efficiency, has first published Policy Guidelines and a Model Regulation on Minimum Energy Efficiency Requirements for electric motors. This integrated policy approach includes supporting tools like best practices, green procurement, labelling, finance and financial delivery mechanisms and monitoring, verification and enforcement.

The USA, the European Union and China have well founded experience with MEPS covering e.g., fans, pumps, air compressors, VSDs and circulators. These MEPS for 'electric motor driven units' enable governments to harvest an even larger portion of energy savings by including efficient technologies and e.g., extending the scope of the covered products.

Recent work by the international public-private partnership into developing an updated set of Policy Guidelines and Model Regulations on motors and motor systems targeted to enable emerging and developing economies to take on this proven instrument. The approach is to build off existing test standards and MEPS that exist – and are proven – in other countries and regions.

At the Summer Study first results will be presented and discussed, with a special focus on outreach to the key stakeholders.

8-245-22: Peer-reviewed paper

Accelerating market uptake of heat pump systems: Challenges, visions and steps for change – results from a stakeholder process in four European countries

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Thomas Friedrich, ISOE - Institute for social-ecological research, Germany

Panel
8. Innovations in products, systems and building technologies

Keywords
renewable energy, heat pump, market barriers, stakeholder, combined cooling

Electrification of heating via heat pumps is one important step to improve the building sector and to achieve the European Commission's 2030 target of a 40 % share of renewables in the energy mix. While the use of heat pumps increased steadily in most European countries, the market share of heat pumps still varies strongly between market segments and countries. According to EurObserv'ER 2018, heat pumps are well established in new constructions. In the renovation market with multi-family buildings, the share of heat pumps is much lower, reaching only around 10 % in Germany, Austria and France (EurObserv'ER 2018).

The contribution will present results from a stakeholder process, which was carried out to better understand the conditions of market uptake of innovative heat pump systems in different European countries. The analysis was carried out as part of a Horizon 2020 funded research project on trigeneration systems based on heat pumps (https://www.tri-hp.eu/).

The objective was to investigate key social and contextual factors that influence the social and market acceptance of renewable heating and cooling systems. The analysis included a literature review and in-depth interviews with change actors in the heat pump markets in Germany, Switzerland, Spain and Norway. Among others, the perspective of heat pump manufacturers, HVAC planners, installers and building owners were taken into account.

As a result, we could identify important barriers, drivers and incentives for the adoption of heat pump systems in general and innovative trigeneration heat pumps systems. systems. Besides economic factors, such as high upfront costs, issues of practical implementation and feasibility

emerged as important topics. Organisational factors, such as the cooperation between different trades on the construction site, or country specific heating cultures also turned out to be important issues.

In the contribution, we will link these findings to the outcomes of a series of workshops, in which steps to actions were discussed with key stakeholders on a national and European level.

8-253-22: Peer-reviewed paper

PCMs based thermal storage devices for enhancing energy efficiency

Vincenzo Bianco, Università degli Studi di Genova, Italy
Federico Scarpa, Università degli Studi di Genova, Italy
Luca Antonio Tagliafico, Università degli Studi di Genova, Italy

Panel
8. Innovations in products, systems and building technologies

Keywords
thermal storage, domestic energy efficiency, energy saving technologies, Phase Change Materials

To improve the integration of thermal renewables in buildings, the utilization of thermal storage is of fundamental importance. The timing mismatch between thermal energy generation (e.g., for domestic hot water) and utilization is usually a limiting factor in the spread of thermal renewables, such as solar thermal panels. Traditionally water based thermal storage devices are used for accumulating the generated thermal energy to use it during the day. Such a solution has the advantage to be easy and cost-efficient, but in terms of effectiveness, it is not optimal. In the last years, new materials appeared on the market and they can be efficiently employed in thermal energy storage systems. Among these phase change materials (PCMs) can be certainly included. The present contribution aims to quantitatively evaluate the impact that the utilization of PCMs within thermal storage can achieve. A practical case on a domestic application for the city of Genoa (Italy) is proposed. Specific attention will be also devoted to the Life Cycle Analysis of the proposed case with particular attention to the impact that the embodied energy may have on the system. Based on the results obtained, a generalization is proposed and an overall analysis of PCMs along different dimensions (e.g., technical effectiveness, economics, environmental impact, circularity, etc.) is developed to evaluate their potential for large scale applications.

8-288-22: Peer-reviewed paper

Understanding peak periods of electricity use in Indian urban dwellings with and without air-conditioning

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Anu Antony, Oxford Brookes University, United Kingdom

Panel
8. Innovations in products, systems and building technologies

Keywords
residential, electricity profile, monitoring, smart metering

To meet the recently-established net zero target by 2070 in India, national electricity grid needs to be rapidly decarbonised using renewables. This requires a deeper understanding of the timing and peak periods of residential electricity use which is expected to increase by five times by 2032. This paper uses statistical clustering techniques to develop representative daily electricity use profiles and determine peak periods of electricity use in the summer, monsoon and winter seasons, using time-series data. Smart meters recorded electricity use data at 30 seconds for 9–11 months (2018) across 89 urban dwellings in India representing different climatic zones. About 54 out of 89 dwellings owned at least one air-conditioning (AC) unit. An unsupervised clustering technique was used to group electricity use curves with similar patterns using a combination of hierarchical and k-means algorithm, to characterise the diurnal and seasonal variations. The maximum point difference was used to identify the daily peak usage period.

Three distinct clusters emerged. The first cluster with largely AC dwellings had a prolonged night time peak of the highest magnitude, while the second cluster had a mix of AC/non-AC dwellings and experienced a late evening peak. The third cluster with predominantly non-AC dwellings experienced a short morning peak of lowest magnitude. The duration and magnitude of peak periods in the two AC clusters were different, indicating use of multiple AC units. Seasonal variation in electricity use was prevalent at the sample (89 dwellings) and sub-sample (54 AC dwellings) level. Mean daily electricity use of AC dwellings (n:54) in the summer and monsoon seasons was found to be around 13kWh/day which was twice that of non-AC dwellings (n:35, 6.4kWh/day). For AC dwellings mean daily electricity use in the cooling season (summer and monsoon) was double that of the non-cooling season (winter), while such seasonal variation was subtle in non-AC dwellings. It is evident that daily electricity profiles of all three clusters indicate potential for reducing the magnitude and duration of peak electricity use in urban Indian dwellings.

8-291-22: Peer-reviewed paper

Opportunities for Minimum Energy Performance Standards (MEPS) for electric motors in Ghana

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Antoine Durand, Fraunhofer ISI
João Fong, University of Coimbra

Panel
8. Innovations in products, systems and building technologies

Keywords
minimum energy performance standards (MEPS), energy efficiency policy, industrial energy saving

High electricity tariff levels pose a challenge for economic development for the productive sector in Ghana. Electric motors have poor energy efficiency, facing maintenance issues and hard environment. The overall energy consumption of electric motor is estimated to account for around 4 TWh per year. The United for Efficiency initiative estimates the potential annual electricity savings for electric motors at 230 GWh by 2040.

The government of Ghana has been a pioneer in West Africa and also in the African continent in general, in regard to energy efficiency standards and labelling. Electric motors might follow next, as Ghana included the elaboration of standards and labelling for electric motors into the National Energy Efficiency Plan from 2015. However, standards for electric motors have not yet been developed in Ghana. Already implemented standards for appliances in Ghana but also in other sub-Saharan countries were mainly developed using a policy benchmarking approach. This paper summarises an independent, academic work, which investigates the opportunity of setting Minimum Energy Performance Standards (MEPS) for electric motors in Ghana as well as the level of requirements and the impact of such a regulation. The work carried out follows the principles of the well-established EU Methodology for Ecodesign of Energy-related Products (MEErP). The MEErP will allow a better and more detailed consideration of the local context than a benchmarking approach. Since Ghana has a large second-hand market of electric motors, the work will also cover second-hand electric motors, as only approximately 60 % of the imported products on the Ghanaian market are new. This paper will present the main development and results of the study. Beside the technical aspects, policy options will be suggested to foster energy efficiency of electric motors. Finally, the paper will present the possible impacts of the policy on the electricity and greenhouse gas savings in Ghana.

8-296-22: Peer-reviewed paper

Additional Dwelling Units: Can they finance energy renovation?

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Krushna Mahapatra, Linnaeus University, Sweden
Brijesh Mainali, Linnaeus University, Sweden

Panel
8. Innovations in products, systems and building technologies

Keywords
space heating, building design, housing refurbishment, detached houses, elderly-friendly, social innovation, design innovation

In Northern Europe, Single Family Housings (SFH) constitute a large share of the total building stock. In Sweden, more than 52% of the population lives in SFH. Most of these houses were built between 1960-80 and are currently needing renovation. Most of these houses are owned by older adults whose kids have moved away, and thus they live in housing over-dimensioned to their needs with a large share of energy consumption for space heating. Furthermore, these facilities are neither elderly-friendly nor energy-efficient, deeming major renovation.

This paper applies a case-study approach to explore options to better utilize and reduce the living area per capita through the generation of Additional Dwellings Unit (ADU) within the existing building stock owned by the elderly. The case study SFH owned by an elderly couple is located in Kronoberg Region, Sweden, and is a typical SFH built during the 1970s. We redesign and restructure the underused space to create an ADU that can be rented out, which in turn may economize the high investment costs of energy-efficient renovation. The energy efficiency renovation measures considered were improvement of the building's climate shell (envelope), extra insulation in the walls and attic, and better performance doors and windows. Energy simulations and life cycle cost assessment of the energy efficiency measures, and space redesign showed that it is possible to reduce energy use by 61% compared to the existing condition of the reference house and a payback time of 59% compared to the application of the energy measures alone. The proposed intervention is aligned with the aging in place strategy, tackling it from a space sufficiency perspective. The proposed intervention reduces the living space per resident by 40% and energy consumption per capita by 62% compared to just the energy renovation of the reference house while creating cash inflows that motivate the houseowner to uptake an energy renovation. The improved energy performance of the building may generate better indoor living conditions for a healthier life for the residents.

8-311-22: Peer-reviewed paper

Overcoming deficits of the new EU energy label

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Dieter Seifried, Büro Ö-quadrat GmbH

Panel
8. Innovations in products, systems and building technologies

Keywords
appliances, energy labelling, household appliances, cost efficiency, life cycle cost (LCC)

Efficient household appliances represent a huge energy-saving potential but that requires innovative approaches to realise. In a study for the German Journal “Energiewirtschaftliche Tagesfragen”, the authors showed that the life-cycle costs (i.e., combined purchase price and lifetime running cost) of highly efficient appliances are often lower than those appliances in lower efficiency classes. This implies that, by choosing the right appliances, households can save money and reduce their carbon footprint.

In March 2021, the new EU energy label was enforced with scales ranging from A to G again for 5 product groups (namely, fridges and freezers, dishwashers, washing machines and washer-dryers, electronic displays including televisions and lighting) with other product groups carrying EU energy label to follow in the coming years. This apparent improvement has come along with some misconceptions. For most appliance categories the top efficiency classes are deliberately left empty and for some sub-categories like undercounter refrigerators a class E-product can be the best on the market. At the same time some categories of appliances like washing machines already have a significant share of A-rated products. However, information on the distribution of efficiency classes is not available, neither to consumers nor to sellers. The result is that consumers can no longer tell intuitively whether an appliance is amongst the most efficient appliances currently on the market or not.

In this paper, the authors will offer solutions on how the existing confusion can be eliminated through an innovative online application based on the EPREL database along with an appropriately designed app and an online service, which can provide assistance to consumers in choosing high-efficiency household appliances.

With these instruments, a double climate protection effect can be achieved: Households save CO2 (and money) by purchasing energy-saving appliances. By shifting demand, manufacturers will respond to the need by producing more energy efficient products. Without an improvement of the EU-label, the potential for improving the efficiency of household appliances will be undermined.

9-013-22: Peer-reviewed paper

Industrial high temperature heat pumps – Can they deliver the promise of meeting the deep decarbonization goals?

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Baskar Vairamohan, EPRI, USA

Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, Directive on Energy End-use Efficiency and Energy Services (EEES), industrial energy saving, industrial processes

According to the U.S. Department of Energy, it is estimated that approximately 35% of industrial energy input for process heating is lost as waste heat in the form of exhaust gases, cooling water, and heat loss from product heating. Recovering waste heat from industrial processes can be an effective strategy to help in the deep decarbonization of industrial processes. For heat recovery to be economical and effective, an industrial facility must have a waste heat source and a simultaneous need for heating elsewhere in their facility. Low-temperature waste heat streams account for most of the industrial waste heat inventory. The waste heat inventory in the industrial sector in the United States was analyzed and is estimated to be on the order of 1500–3000 Trillion Btu per year. This paper focuses on novel heat pumps that are being developed in the United States and other parts of the world. Details of a project funded by the California Energy Commission will be presented. This work effort is aimed at developing an industrial heat pump that can capture low-grade industrial waste heat (around 70 – 80 degree C) and transform it into high-temperature useful heat, specifically in the form of steam. The paper will also discuss low Global Warming Potential refrigerants that can provide a temperature lift of at least 40 degree C, thereby producing steam, with coefficient of performance greater than 3.4. Industries such as food processing, chemicals, paper and textile industries can make use of this steam. Such heat pumps enable deep decarbonization by reducing steam production from fossil-fuel based boilers, as well as reusing the heat which would have been otherwise wasted. The paper will share the latest developments from the laboratory testing to commercial applications.

9-018-22: Peer-reviewed paper

Demand response capabilities of industrial refrigerated warehouses: Experiences in practical implementation

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Panel
9. Deep decarbonisation of industry

Keywords
buildings, demand response, industrial energy saving, industrial internet of things (IIoT)

As the amount of renewable electric power generation increases, so does the need to find end uses that can vary their demand to follow supply availability. Storage capacity inherent in certain end uses can be leveraged to enable flexible demand response (DR) to offset power generation intermittency. One such opportunity is in industrial refrigerated warehouses, which are used by logistics operations for storing food products as they move from production facilities to consumers. California hosts the largest amount of refrigerated space in the U.S., with refrigeration load of about 120,000 tons of refrigeration (TR) [422 MWth] and associated electric power consumption of about 360 MW. A recent study by Lawrence Berkely National Laboratory estimates the DR potential of refrigerated warehouses at 0.575 kW / TR [0.163 kWe/kWth] by storing thermal energy in the refrigerated/frozen products, corresponding to at least 69 MWe. An EPRI-led team investigated the potential of automated DR at a large industrial refrigerated warehouse in California. Using open standards based on the OpenADR 2.0b protocol, the team could reliably transmit DR signals from a virtual top node all the way to the end use, to increase or decrease the power used by the facility by up to 30 % during a DR event. This was achieved without adverse consequences on the food products stored in the warehouse. The team found that detailed understanding of heat transfer processes in the warehouse, along with an understanding of the refrigeration control system, was necessary to obtain the response desired. The team also found that the desired response with little or no extra energy cost with correct control design. Conversely, an inaccurately tuned control action produces unreliable response and high energy cost. This experience indicates that practical implementation of flexibility measures is best achieved by integrating flexibility with existing cost optimization services, that already use detailed modeling of the facility to minimize operating costs. Beyond storing thermal energy in the product warehouses, other DR opportunities exist through control of resistance floor heaters and charging electric forklifts used to move product within the facility.

9-033-22: Peer-reviewed paper

Analysing the feasibility of industrial decarbonisation pathways through electrification and zero carbon fuel (ZCF) applications

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9. Deep decarbonisation of industry

Keywords
energy-intensive industry, zero carbon fuels, industrial processes, electrification, Industrial SME

Industrial decarbonisation is one of the most significant hurdles as we move towards a global net-zero CO2 emissions target. Processes requiring high temperatures and heavy-duty transport are major complications, with cost and feasibility of implementation of zero carbon methods often significant barriers, especially for medium sized or smaller businesses. This study shows that decarbonisation of business processes through electrification as well as on-site green ammonia generation, is possible and can be profitable for this scale of company. Mühlendorfer Kreidefabrik, used as a case study, is an Austrian chalk processing factory that emits approximately 4680 tonnes of CO2 per year whilst spending EUR664,000 on energy.

Different decarbonisation scenarios were investigated, based on the general concepts of electrification and zero-carbon fuel (ZCF) generation. The study leveraged simulation algorithms in conjunction with past usage data of the company in order to model supply and demand in future years. 4.7 MW of solar PV panels as well as one 3 MW wind turbine are required in a pure electrification scenario. Including the replacement cost of fossil-fuel by electrified equipment and an estimated lifetime of 20 years, this system is expected to cost ~EUR512,000 annually. A larger electricity generating system of 13.7 MW solar PV panels and one 3 MW wind turbine is required in a ZCF scenario, along with a 3.9 MW alkaline electrolyser connected to an air separation unit and Haber-Bosch equipment. This system will produce ~1887 t of green ammonia per year, sufficient to replace both natural gas and Diesel currently used in the factory, requiring only adaptation of current plant and machinery instead of replacement. Costing ~EUR714,000 annually, this option is more expensive, however has further advantages in minimising interference in factory operations. This pathway seems also preferable due to the uncertainty in availability of a pure electrified solution even with the extra costs.

9-036-22: Extended abstract

Global green steel opportunities surrounding high quality renewable energy and iron ore deposits

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Panel
9. Deep decarbonisation of industry

Keywords
system optimisation, renewable energy, green steel, green investments, energy systems

The steel sector's foreseeable decarbonisation demands reconstruction of not only production processes, but the entire iron and steel supply chain. This study involved a global industrial relocation analysis of the most economically and energetically efficient steel supply chains in the projected 2030-2050 timeline where all energy is derived from renewable electricity and green hydrogen. A facility-level optimisation model was developed, largely dependent on the two key inputs to primary iron- and steelmaking: high quality iron ore and energy. The shift from fossil-based to renewables-based steel production necessitates a comprehensive geospatial approach to industrial change as the power potential of renewable energy and iron (Fe)-content of the nearest iron ore deposit are locally unique. Furthermore, energy and ore costs account for about 20% and 25%, respectively, of the levelised cost of steel (LCOS), so strategic location of decarbonised iron and steel-making facilities will be indispensable for competitive zero-carbon steel. Historically competitive steel regions, commonly located nearby coal mines and natural gas reserves, must be re-evaluated in a decarbonised context.

This study investigated the simplest steel supply chain, where iron ore was upgraded to highest possible value (i.e. steel) at source (i.e. deposit), for transportation to the nearest port for export. It was hypothesised that iron ore producers should, considering energetic and economic efficiency benefits, play a more central role in a decarbonised steel industry. The bottom-up approach also established clear foundations for more complex trade strategies. Initially, the top-12 iron ore producing countries (by fraction of global output) were assessed, in addition to Guinea (a location with high quality yet untapped iron ore resources). All 185 iron ore deposits in these countries (Schulz & Briskey, 2005) were investigated, aggregated into 39 regions to allow regional renewable energy profiles to be used for modelling in combination with the region-specific Fe-content of iron ore deposit.

The importance of high-quality iron ore inputs is often neglected in decarbonised steel literature, a gap this study begins to address. Green hydrogen-based direct reduction of iron is likely to dominate primary steel production in a zero-carbon future (Mission Possible Partnership, 2021), which demands an even higher quality ore (67% Fe-content) in comparison to the traditional blast furnace route (65% Fe-content) (Barrington, 2018). The average Fe content of extracted ore varied across these countries from 20% to 71%, with a global average of 62% (U.S. Geological Survey, 2022).

A linear optimisation model was developed for lowest cost green steel production with hourly temporal resolution. The key outputs were the LCOS, energy consumption, and renewable energy infrastructure capacity for each regional facility with a 1 Mtpa steel capacity, located adjacent to the ore deposit, and powered by 100% solar and onshore wind energy. The islanded energy system was optimised to balance infrastructure capital expenditure with load factors, through the dynamic management of renewable energy supply, storage infrastructure and production processes.

The results revealed competitive market conditions alongside favourable producer locations for the decarbonised steel market. Machine learning techniques were then applied to the results to derive a simplified green steel investment model and expand the utility of the study. This enabled expansion of the global assessment from 39 regions to 306 deposits and laid the foundations for future work where more complex supply chains will be assessed, including the trade of hydrogen and hot briquetted iron, and delivery to demand markets.

9-048-22: Extended abstract

Deep decarbonisation of the steel industry: a regional perspective

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Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, regional transition, society, industry, steel, hydrogen, CO2 emissions, interviews

Deep decarbonisation of the steel industry is crucial in achieving Germany's CO2 emission reduction targets and becoming greenhouse gas neutral by 2045. The steel industry is responsible for 30% of industrial and 6% of total national emissions. At the same time, as a basic material industry, it is an integral component of national as well as regional value chains. Despite the resulting economic and societal importance of the steel industry for neighbouring regions, e.g. in terms of employment or regional identity, there is only limited research on the societal aspects of industrial low-carbon transitions from a regional perspective. With this study, we aim to contribute to this field by examining the wider societal perspective on transition processes in the steel industry on the regional level.

As part of a case study on the transition to hydrogen-based steelmaking in Germany, we conducted 16 in-depth interviews with selected representatives of industry actors, associations, knowledge institutes and regional actors. The selection of the interview partners was informed by previous data collections with experts within the project team and focused on relevant actors in Germany and the region under study. The interviews were semi-structured and the field phase was between September and October 2021. Based on the interview study, we investigate perceptions on opportunities and risks of decarbonising the steel industry using hydrogen direct reduction. Furthermore, assumptions on the societal impacts of the studied transition process on neighbouring regions are derived. Finally, we provide insights on drivers and barriers for successful regional transition processes in the steel industry.

We find that, overall, the interviewed actors assess the future transition to hydrogen-based steelmaking positively. Main opportunities stated in the interviews are its contribution to emission reduction and to securing the future of the steel industry in Germany and the respective regions. Regarding the societal impacts on neighbouring regions, the interviews provided mixed results: Some respondents emphasized the risk of carbon leakage if industry relocated to other countries. In this case, negative economic impacts on the regional level are anticipated. Others perceived the transition as a necessary step to secure competitiveness of the site and the local industry in general. Some interviewees further described the transition as a flagship project that provides positive marketing for the region. This assists the recruitment of new types of employees, which is necessary, since old and new facilities will be operated in parallel, resulting in a simultaneous

need for employees for both systems.

Further findings from the interviews identify the drivers for the transition on a national and regional level. Nationally, pressure from society, politics and consumers is regarded as a main driver. For a successful regional transition process, the support by federal and municipal governmental actors is seen as an important factor. Barriers, on the other hand, are seen in terms of the availability of green hydrogen and resources as well as the lack of profitability in the starting phase of the transition. Furthermore, the (local) acceptance of the infrastructure for hydrogen-based steelmaking as well as the support of employees and unions is considered as crucial. Since the acceptance by these actors cannot be assessed conclusively on the basis of this interview study, further research should thus take a closer look on these groups and their perceptions on transition processes in the steel industry.

9-059-22: Peer-reviewed paper

Demonstrating Net Zero: the Next Generation of Science-Based Targets for Industry Decarbonization

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Panel
9. Deep decarbonisation of industry

Keywords
industry, greenhouse gas mitigation, climate policy, financing, science-based targets, net zero, voluntary guidelines, corporate strategy, regulation, harmonised accounting

Net zero presents a challenge and opportunity for the industrial sector, which has seen emissions growth over the past couple decades. The emissions intensiveness of industrial production combines with policy insularity and established vested interests to create an orientation toward status quo approaches. On the other hand, new company targets and emerging technologies create opportunities for industrial sector low-emissions transformation. This paper outlines the components of net-zero, science-based targets for industry that will play a central role in achieving climate stabilization.

9-089-22: Peer-reviewed paper

The material impacts of an energy transition based on sufficiency, efficiency, and renewables

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Panel
9. Deep decarbonisation of industry

Keywords
materials, circular economy, efficiency, sufficiency, industry, resources, Negawatt, transition

For two decades now, the négaWatt Association has published and updated a comprehensive energy transition scenario for France showing how the country could switch to a 100 % renewable supply with the support of energy efficiency and sufficiency to curb demand.

Recurrent questions were often heard about the material impacts of such a scenario, e.g. on the risks of potential depletions and how sufficiency and circular economy principles could be applied to material resources. To answer such interrogations, the scenario experts have undertaken a considerable modelling work and developed a calculation tool called 'négaMat'.

This paper describes the objectives and approach of négaMat. It specifies in details its methodological step and illustrates them by results obtained through its application to the French négaWatt scenario.

It shows for instance that buildings and civil works represent the largest tonnage of material use, and moderating the need for new buildings would have a substantial impact. Sufficiency could also reduce the consumption of other goods (paper, electronics, vehicles…). The calculation module reveals how these drops in consumption could be offset by smart relocation of some manufacturing sectors in the country, leading to a relative stabilisation of the total industrial activity.

NégaMat can also provide insights on which material resources could be put under pressure by energy transition. Iron is not really an issue, but copper deserves special attention in the development of a 100 % renewable grid. Electric mobility is also a source of concern, as a one-to-one electrification of current vehicles would lead to significant difficulties with respect to lithium. Only a scenario in the négaWatt spirit with sufficiency efforts (less distance travelled, substantial modal shift, higher carpooling and a mix of sustainable motorisations) could mitigate the risks on the resource.

9-113-22: Extended abstract

More for less: the case for demand flexibility to support business decarbonisation and competitiveness

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Panel
9. Deep decarbonisation of industry

Keywords
demand response, renewable energy, energy-intensive industry, decarbonisation, competitiveness

Industry is reshaping the market by demanding more renewable energy. One of the key market innovations has been the emergence of corporate renewable power purchase agreements (PPAs) with over 100 Australian organisations signing deals in the last five years. Innovative businesses are now using demand flexibility to get more out of their PPAs.

This research investigated three case studies to show how businesses can unlock greater cost savings, and reduce risk and emissions, as they become more energy literate. The key findings are outlined below. These businesses had engaged with a retail model of wholesale price exposure combined with a retail PPA and demand response. The hypothesis was: Offsite PPAs can be the catalyst for increased energy literacy and complementary on-site demand flexibility.

AGRANA Australia manufactures fruit-based products in NSW. AGRANA Australia has signed a combined wind and solar PPA with wholesale price access and is actively participating in the Australian Reliability and Emergency Trader (RERT) demand response program. These products helped AGRANA Australia's cost of energy drop by 10% in 2019. This is largely due to its well-designed PPA, which matches over 75% of its demand with a mix of solar and wind generation. The site can also use onsite diesel generators to respond to RERT requests for additional revenue. Significant untapped energy flexing opportunities still exist for the business such as rescheduling processes, or using more onsite generation, at times of high renewables and/or low spot prices.

The City of Sydney is home to almost 250,000 people. The City signed a PPA with wholesale price access in 2019 to meet its commitment to purchase renewable energy that matches 100% of energy it uses from the grid. Deals with local governments are often different to commercial businesses, as they have multiple goals for their procurement. For example, the City used its deal to be the first PPA to include a community energy project. The City also has a high (>80%) demand match, mostly from wind given its peak demand is driven by street lighting. Smoothing its spike in demand from 4pm could offer additional savings.

Pernod Ricard Winemakers is the second largest wine, spirits and Champagne company in the world. The business' energy journey in Australia is well advanced, having accessed the wholesale price since 2016. The business now has: an >80% demand-matched PPA; 3MW of onsite solar; an innovative storage system; and participated in the RERT program. Pernod Ricard Winemakers is industry-leading how it flexes its energy including: ramping down key loads, such as wastewater and refrigeration; aggregating equipment that is complementary to its onsite solar generation using "Virtual Net Metering"; and unlocking flexibility through a novel thermal energy storage system.

Three key lessons that are shared across the case studies were:
1. Matching the energy consumption profile with a mix of renewable energy generation is a key step to a successful PPA. It significantly reduces the "market buy", which increases the certainty of electricity costs. The cases showed that a >75% match provided 8-10% energy cost savings in 2019.
2. In addition to demand matching, most untapped demand flexibility opportunities minimise unmet demand or surplus generation. There are multiple options for businesses to access these opportunities including rescheduling processes, activating onsite generation, or investing in energy storage (both electrical and thermal).
3. Both AGRANA Australia and Pernod Ricard Winemakers demonstrated that demand flexibility can deliver financial benefits without compromising operations. In particular, dispatching onsite generation or rescheduling non-critical processes (e.g. wastewater treatment) are easy to activate and have little to no impact on core business. New technologies (e.g. storage and remote control) will provide more low-risk options.

9-136-22: Peer-reviewed paper

Still alive, but different in the future? Decarbonisation of industrial steam boilers from a multi-dimensional perspective

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Panel
9. Deep decarbonisation of industry

Keywords
industrial steam systems, electrical heating, heat pump, hydrogen, decarbonisation, food and drink, paper industry, chemical industry, boilers, industrial processes, multi-dimensional analysis

The first steam applications were already invented two millennia ago; due to its versatility, industry will still need steam in the future. In view of the current climate targets, a shift towards carbon-free steam-generation is required while it is still mostly based on fossil fuels today. Future alternatives that are based on the direct use of renewable electricity or green hydrogen are not yet economically favourable or they are still under development, also due to the comparatively high electricity prices. This paper therefore investigates CO2-neutral steam generation in two respects: First, compared to the current state of the art, which electricity-based technologies are available for steam generation and what is their development status? And second, how are the technologies evaluated in comparison to the current fossil reference technology from a multi-dimensional perspective encompassing ecological, economic and technical criteria? In this paper, these questions are addressed along three applications for steam generation in the paper, food and chemical industries. For this purpose, a concept for a multi-dimensional analysis with a perspective up to the year 2050 is introduced and applied. The required data was obtained from literature, a quantitative model and 19 semi-structured interviews with industry representatives, manufacturers and research institutions. The results indicate that various alternative technologies (electrode boilers, heat pumps, hydrogen-fired steam boilers) are available, but their technology readiness level varies. To contribute to their widespread deployment in industry, policy making will have to ensure competitive economic as well as ecological and infrastructural framework conditions with a long-term perspective.

9-137-22: Peer-reviewed paper

Beyond basic material production: The feasibility of CO2-neutral process heat generation in Germany's industry

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Panel
9. Deep decarbonisation of industry

Keywords
energy-intensive industry, process heat, decarbonisation, economic model

Deep decarbonisation of the European industry by 2050 requires action in all stages of manufacturing. Many publications focus on a few selected highly energy intensive basic materials such as high value chemicals, steel or primary aluminum. However, around half of the energy consumption for industrial process heating in the EU27 and the majority of installations and companies is outside these main processes.

Here, we conduct a broad analysis of the opportunities to switch to CO2-neutral process heating for 34 applications across all energy-intensive subsectors but focusing processes so far less-investigated. In total these processes account for a third of industrial process heat use in Germany. We assess the technical maturity, energy efficiency and economics of CO2-neutral process heat generation and compare it to the fossil-based status-quo. We create a set of techno-economic data of conventional and new technologies and model their competition and resulting diffusion under transformative economic conditions. The data set describes Germany but the concept and insights can be relevant for the entire EU27.

We find that some of these often overlooked applications have access to the necessary technologies which, with medium- to high-ambition economic measures, can be economically competitive. In particular, about 55 % (78 TWh) of the investigated energy demand, primarily consisting of steam generation and glass production, can decarbonize by 2040 or are close to it – given the ambitious measures applied in this analysis. Another 2 % (2 TWh) in highly specialized applications (hardening, carburizing, heat treatment of copper) lack economically attractive options in 2040. About 43 % (60 TWh) have economically attractive options available, but are unable to implement them fast enough to reach decarbonisation by 2040 or 2050. This group, challenged by long lifetimes of installations, mainly consists of steel processing and clinker production. For them, early price signals can support the transition. We conclude though, that

some applications might require regulatory law, as even strong price signals do not sufficiently incentivize decarbonisation.

9-138-22: Extended abstract

Low pressure steam from industrial heat pumps – State of development and market perspectives

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Panel
9. Deep decarbonisation of industry

Keywords
waste heat recovery, steam generating heat pumps, high temperature heat pumps

Heat recovery is common in industrial processes within the limits of the economic framework conditions found up to now. However, the framework conditions are changing, therefore additional heat recovery is becoming attractive. It is often easier to implement heat recovery measures first before converting large parts of the energy supply system. High temperature heat pumps play a special role as heat recovery devices, as they upgrade low temperature waste heat such that it can be re-used in industrial processes. Therefore, they increase the energy efficiency, enable electrification including decarbonisation and make a significant contribution to reducing CO2 emissions. Annual industrial heat demand in EU28 sums up to about 1950 TWh, about 30% is needed in the temperature range up to 200°C. (Heat roadmap Europe 2017)

High temperature heat pumps are available on the market from single manufacturers with limited maximum supply temperatures. Also numerous research and development projects address this technology development including supply temperatures up to 200°C. Industrial heat pumps are a cross-cutting technology which can be implemented in new and existing industrial process operations. (de Boer 2020) The generation of low-pressure steam is a very attractive field of application here. Steam is one of the most important energy carriers in industry, it is used both for heat transfer as well as a process reactant and the integration into existing steam networks is possible.

The contribution gives an insight into the state of development and shows both open and closed loop systems for steam generation with heat pumps. It shows the basics of the technology and its effects in industrial processes. Basic distinguishing characteristics are described, and the advantages of the types are presented. Furthermore, different views of the future market for industrial heat pumps and the share of steam generating heat pumps are presented. (Marina et al. 2021; IEA 2021) In the H2020-project BAMBOO, EDF Électricité de France and AIT Austrian Institute of Technology cooperate for the application of steam generating heat pumps in industrial environments. The use of high temperature heat pumps is also considered in the context of BAMBOO with regard to flexibilization of industrial energy supply systems. (Villanueva and Meneghello)

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9-139-22: Extended abstract

Decarbonising the building value chain of the European Union: A systematic overview of circular economy measures and their potential impact on basic materials

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Panel
9. Deep decarbonisation of industry

Keywords
circular economy, buildings, decarbonisation, basic materials

The relevance of Circular Economy measures for the reduction of greenhouse gas (GHG) emis-sions is increasing due to the growing material demand on the one hand and the advancing climate crisis on the other hand. The basic industry is of particular importance as it is responsi-ble for a large share of the emitted GHG (about 20% of the EU emissions). Moreover, the miti-gation of these emissions is challenging and often very expensive with technological change alone. Consequently, the reduction of material demand is crucial. Typical end-use goods and the related basic materials have to be considered since the impact of a Circular Economy measures can be seen along the entire value chain.

Accordingly, this contribution describes the building sector - as one of the main contributors to steel and concrete demand - and gives a systematic overview of relevant circularity measures. Thus, we answer the following research question: How to compare and prioritize relevant Circu-lar Economy measures in the building sector? On the one hand, the aim is to identify promising options for the decarbonisation of the building sector and related basic materials in the Euro-pean Union based on pre-defined criteria. On the other hand, a database is developed for the consideration of these Circular Economy measures in further research.

For this purpose, relevant measures are pre-selected from three major publications in this field. The selection is based on the expected impact on GHG emissions as well as the applicability. The applicability is limited to the building value chain and specifically the materials steel and concrete.

Five measures that have a high impact are analysed in greater depth. For these, fact sheets are developed via an additional literature research. They describe the measure, the rele-vant material, the affected value chain stage, the categorization according to the 9R framework, the impact, the applicability and limitations. Moreover, the measures are compared using a weighted sum model considering ecologic (change in GHG emission), economic (change in cost) and technical criteria (change in material and energy demand). These criteria enable a ho-listic view and finally, a prioritization of the measures.

In this way, we determine which of the Circular Economy measures are most promising in light of the aforementioned criteria. For example, the optimization of space use in residential build-ings, which decreases cost, material demand and GHG emissions, can have positive impact. At the same time this measures is challenged by constraints during the practical implementation. In contrast, the reduced over-specification of building components can reduce demand for the energy-intensive basic materials steel and concrete. However, this requires the adaption of re-spective regulations and standardisation. Overall, the collected data can support stock-driven material flow analyses and thus be taken into account in transformation pathways for industry decarbonization. Nevertheless, the research showed that the quantification varied significantly between literature sources. Consequently, the actual exploitation of the potentials of a Circular Economy depends on an efficient policy framing.

9-141-22: Peer-reviewed paper

A framework to build decarbonisation pathways for the industrial sector: application on the French pulp and paper sector

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Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, bottom-up, energy model, pulp and paper industry, technology dissemination, simulation, demand analysis, industrial processes

The challenge of deep decarbonization is putting the industrial sector under unprecedented pressure, while so far most industries have been protected from the strictest regulations. Industries would need to act quickly considering their long reinvestment cycles and their ageing assets. However, no clear path appears: a wide range of mitigation options, ranging from electrification to changes in demand, are available. In response to this issue, this paper presents a new theoretical bottom-up framework to assess different long-term pathways of the industry in terms of energy demand, CO2 reduction and investment needs. This framework is built following a microeconomic view. Industrial assets are progressively replaced by the best available or disruptive conventional technologies according to their economic interest. The basic model is enriched with an explicit representation of demand, representing the entire value chain. An original database of existing French industrial assets, including energy and production data, was used, providing an explicit representation of industry turnover. This framework is applied to the French Pulp & Paper sector. This sector could be at the core of a new bio-energy system and thus both incremental and breakthrough changes are considered. This novel assessment reveals that, depending on the hypotheses, the CO2 emissions could decrease by 55–90 % by 2050. This would mainly depend on if early incentives like an early development of innovative technologies or a rapid evolution of commodity prices are in place. Those would allow the sector to seize the next decade to replace a great part of its equipment’s avoiding any fossil fuel lock-in.

9-151-22: Peer-reviewed paper

Energy efficiency services as “change agents” for the industry on its path to net-zero by 2050

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Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, industry, role of energy efficiency measures and services, empirical research, energy efficiency policy

The deep decarbonisation of the industry is as necessary as it is challenging. It is complex, it is subject to uncertainties, not least technological ones, and it is expensive. The European climate protection regulatory framework has become more concrete. A comprehensive Clean Industry Package was prepared in the context of the “Fit for 55” policy. While the industry’s commitment is encouraging and growing with the increasing regulations and the tightening of climate goals, still the one single path towards the deep decarbonisation of European industries has not yet been identified. Apart from expanding the use of renewable energies, energy efficiency is essential for achieving the European and national climate goals. In this context, this paper argues that energy efficiency services can act as the “change agents” the industry needs for its transformation towards climate neutrality.

The German Federal Energy Efficiency Centre (BfEE) has monitored the market for energy efficiency services and measures for over five years. Together with a scientific team from Prognos AG, ifeu institute and Kantar the BfEE examines issues, such as applied energy efficiency measures and technologies as well as the conjunction with energy efficiency services. It studies the role of energy efficiency for different key customer groups, inter alia the German manufacturing sector that is represented by 700 enterprises annually in the survey.

Based on our surveys this paper discusses the following questions: How does the relevance of energy efficiency differ across industry sectors? How far is climate change integrated in business strategies? How does the usage of energy efficiency services drive corporations to implement more comprehensive energy efficiency measures and to invest more in energy efficiency? Finally, the paper demonstrates how energy efficiency services can make a distinct contribution to the deep decarbonisation in the industry and how these can be supported effectively by policies.

9-176-22: Extended abstract

Co-Creating Transformative Policy Mixes for Energy-Intensive Industries in Germany and the UK

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Panel
9. Deep decarbonisation of industry

Keywords
stakeholder, energy-intensive industry, climate policy, transition management, socio-technical, long-term scenarios

In view of the long-term climate targets of Germany and the UK, their industry sectors need to be geared to a pathway towards climate neutrality rapidly, which requires radi-cal process innovations in energy-intensive industries such as the production of steel, cement and basic chemicals. There are various techno-economic scenarios how to achieve this, but there is also a long-standing debate on the usefulness of model-based transformation pathways for informing policy makers. The main reasons are that the models usually do not address certain socio-technical aspects (Wesseling et al. 2017) and that the tacit knowledge of stakeholders is not taken into account. One proposed solution is the co-creation of transformative policy mixes with stakeholders, extending the model-based pathways to socio-technical scenarios with qualitative assessments of the transformation pathways (Rogge, Pfluger, and Geels 2020). In particular, the identi-fication of central bottlenecks can raise awareness of the challenges to be tackled by policies and be integrated in future modeling exercises (Geels, McMeekin, and Pfluger 2020).

In our contribution, we describe the conceptual background for co-creating transforma-tive policy mixes with key stakeholders (cf. Wachsmuth et al. 2021b) and provide first steps towards an application to the energy-intensive industries in Germany and the UK. Koasidis et al. (2020) have considered the decarbonisation of these industries from a sectoral innovation and system failures perspective. According to Koasidis et al. (2020), the carbon intensity of production has been relatively constant in these sectors. So the transformation to a GHG-neutral economy as targeted by both countries is still in an early stage for the energy-intensive industries, although various industry associations have recently embraced the vision of a transformation to GHG neutrality.

Elaborating on Koasidis et al. (2020) and an analysis of EU industry policy by Wachsmuth et al. (2021a), we come up with an indicative list of key bottlenecks and a first elaboratation of elements of a suitable transformative policy mix for the energy-intensive industries in Germany and the UK.

Furthermore, we outline how to map the relevant stakeholder groups and provide an outlook on the further elaboration of the transformative policy mix in stakeholder workshops to take place in summer 2022.

9-208-22: Extended abstract

Industry 4.0 and energy efficiency: How digitalisation can support decarbonisation

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Panel
9. Deep decarbonisation of industry

Keywords
Energy Efficiency Directive (EED), industry, digital, decarbonisation

The energy transition for the industrial sector is not limited to a reduction in energy consumption: the real issue is to combine sustainability with growth, by mixing the two ingredients (the rational energy use and the industrial growth) which are not always compatible. The New Green Deal policies have the goal to promote an economic development as well as the environment sustainability and social inclusion.

RSE has investigated the role of the national incentive plan “Impresa 4.0” (currently “Transizione 4.0”, equivalent to “Industry 4.0”) as a measure to promote the energy transition, analysing whether and how is it possible to combine economic development with energy efficiency.

Originally, it was developed to increase the competitiveness of industrial sector, but, progressively, it was also used to promote energy efficiency and sustainability.

A survey was carried out by RSE on about 300 companies that implemented innovation and digitalization interventions, monitoring the effects and impacts that the "4.0 choice" has determined on energy consumption, on their environmental externalities and, in general, on other costs. Moreover, some case studies were collected, together with a database of “Impresa 4.0” application, that supported technical and economic evaluations. The impact of these measures on energy performance of the companies was estimated from the analysis of actual projects and from interviews and discussions with the operators.

In this paper, the results of the survey are presented and the outcomes are analysed in comparison with the Italian manufacturing sector performance, in order to establish the potential of “Impresa 4.0” policies in supporting the decarbonisation process and reaching 2030 environmental targets.

9-217-22: Peer-reviewed paper

Carbon Contracts for Difference as essential instrument to decarbonize basic materials industries

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Panel
9. Deep decarbonisation of industry

Keywords
climate policy, energy-intensive industry, steel, chemical industry, cement, EU Emission Trading Scheme (EU ETS), energy policy

Contracts for difference are an instrument to provide security in case of volatile or unsure price evolvement. They have been successfully used in the context of market opening for renewable energies. The contract guarantees the agreed contract price and thereby basically funds a price gap between market prices for a good and its actual costs for the project developer.

Project-based Carbon Contracts for Difference (CCfD) are now being discussed as a means to advance the adaptation of breakthrough technologies, i.e., to incentivise emission intensive basic industries to shift to low-emission production processes. In Germany, the federal government committed itself to deploy a project-based pilot funding program for such CCfDs, for the steel, ammonia, cement, and lime sectors. The basic idea is simple: to cover incremental costs between a novel climate-friendly technology and its conventional baseline, while considering existing and evolving CO2 prices and other relevant risks. The implementation as a CCfD might also encompass paybacks in case CO2 market prices (in the EU ETS) exceed the contract price, depending on the design of the instrument. The detailed design of this policy instrument, contrariwise to the basic idea, can be rather complex. Important questions are: how to set a suitable reference for the project to be contracted in terms of costs and emissions, which kinds of costs and revenues to consider, how to allocate funding and determine which projects are awarded, and how to consider the interaction with the ETS – and many more.

The paper presents preliminary findings from a research grant from the German Federal Ministry for Economic Affairs and Climate Action (BMWK), considering the aforementioned questions of policy design in the context of the expected German pilot program, and discusses their respective trade-offs. It outlines explicitly how a CCfD payment can be derived considering the difference costs between a climate friendly and a respective reference production as well as the effective CO2 price based on market price and free allocation. In a broader perspective, it addresses how

CCfDs are embedded in the existing and anticipated policy framework for carbon intensive industries in Germany and in the EU such as, e.g., CBAM.

9-231-22: Extended abstract

Industrial clusters as agents of change? Results from a rapid evidence assessment

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Panel
9. Deep decarbonisation of industry

Keywords
energy-intensive industry, clusters, decarbonisation

This paper presents the results of a rapid evidence assessment of the approaches being used internationally to drive the decarbonisation of industrial clusters and critically assesses the role of industrial clusters as agents of change. Industrial activity accounted for 26% of global CO2 emissions in 2020 and substantial reductions are required to meet climate targets. One pathway for change is to prioritise interventions into areas of energy intensive industry, or clusters. Clusters have the potential to accelerate industrial decarbonisation in a variety of ways. Co-location of new infrastructure reduces upfront investment, offers economies of scale and de-risks development by providing a broad customer base. Geographical proximity offers the potential for stakeholders to investigate opportunities for industrial symbiosis. The networks built through regional specialisation have the potential to stimulate learning and innovation and generate knowledge spill-overs, delivering new technological breakthroughs.

However, these outcomes are not certain. A significant amount of literature points to the potential for industrial clusters to lead on the decarbonisation of industry, however many cluster decarbonisation initiatives are recent and empirical data are lacking. Studies drawn from economic geography suggest different places have different capabilities to engage with change and that historical context is often the key factor. Agglomerations of mature industries may lead to technological and political lock-ins which impede progress rather than accelerate it. The potential for clusters to act as pathfinders for broader industrial decarbonisation initiatives is therefore unclear. Nor is it apparent which configuration of policies, technologies, sectors and actors might best support this work.

This paper presents the results of a rapid evidence assessment on industrial cluster decarbonisation. It finds that studies on industrial decarbonisation clusters presently focus upon techno-economic assessments of the feasibility of CCUS and hydrogen deployment and neglect the importance of non-technical factors such as leadership, vision and strong networks which have historically been noted as key determinants of cluster success. It provides an overview of emerging exemplar clusters, including an overview of the range of approaches to funding; governance and integration with broader decarbonisation initiatives; alongside an assessment of

the contextual information which may have influenced the ways these cluster have evolved. It notes that work to date concentrates on flagship projects in coastal clusters in North-West Europe and North America and argues that while these places are significant sources of industrial emissions, the lessons learned may have limited relevance for inland and dispersed industrial sites. It concludes that if clusters are to have a role as agents of change then a holistic approach incorporating a range of abatement approaches should be integrated into their strategies.

9-238-22: Peer-reviewed paper

Similarities and differences between energy efficiency and circularity approaches in industrial transition processes targeting manufacturing SME

Carina Hermandi, Hochschule Ruhr West, Germany
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Panel
9. Deep decarbonisation of industry

Keywords
transition, circular economy, overcoming barriers, industrial SME, manufacturing, efficiency

Several large basic industries and original equipment manufacturers (OEM) have started to develop strategies and measures for a Circular Economy (CE). However, the whole circular potential in the value chain of manufacturing industry can only be seized if small and medium enterprises (SME) are not neglected. SME often do not have a clear perspective when they are asked what they could contribute to and to which extent they could benefit from the transition towards a CE. They often need support in identifying and realising circular potentials.

Therefore, following an action research approach, the project ‘Prosperkolleg’ has analysed, developed, tested and evaluated concepts and tools supporting SME on their way to a CE. It particularly focuses on manufacturing SME in the state of North Rhine-Westphalia (NRW), Germany, and is carried out in close co-operation of Hochschule Ruhr West (University of Applied Sciences) with Efficiency Agency of NRW, two local economic development agencies (WiN Emscher-Lippe GmbH; City of Bottrop) and the association Prosperkolleg e. V.

The paper analyses, to which extent the development of supporting measures, concepts and tools targeting SME with regard to a CE can learn from the long-term experience in the field of energy efficiency in SME. On the one hand, there are several similarities regarding benefits and opportunities, barriers and obstacles, antecedents, drivers and facilitators, monitoring and evaluation as well as management. In both fields, understanding the situation of the SME, their market situation, motivations and challenges, and approaching them by personal communication is a key. Therefore, the design of strategies and approaches, concepts and tools, communication, co-operation and networking approaches can learn from relevant measures targeting energy efficiency in SME. On the other hand, while many energy efficiency activities in mostly less energy-intensive SME are cross-cutting measures that hardly touch the company's core value creation processes, a key difference is that several circular strategies directly affect the SME's core business by rethinking the business model, redesigning products and reorganising

production, purchasing, logistic, distribution and service processes. For the implementation of these changes, contextual factors are much more important than for energy efficiency activities. Therefore, the focus of CE support activities should be to support the willingness and capability of the SME to implement changes in the core value creation processes of the firm and beyond in co-operation with other actors along the whole value chain.

9-242-22: Peer-reviewed paper

Pathways to a near carbon-neutral German industry sector by 2045: A model-based scenario comparison and recommendations for action

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Panel
9. Deep decarbonisation of industry

Keywords
industry, electricity, hydrogen, bottom-up analysis, Germany, 2030 sector target

In 2018, emissions from the industrial sector in Germany amounted to around 190 million tons of CO2 equivalents, the majority of which were caused by companies in energy-intensive industries. According to Germany's reduction target for this sector, these emissions must fall to 118 million metric tons by 2030. Its high dependence on fossil fuels, technical restrictions and hardly avoidable process emissions pose major challenges for the sector. In order to achieve near climate-neutrality in 2045, these challenges require a profound transformation in the basic materials industries. This contribution presents the results of a comprehensive bottom-up assessment comparing four technology pathways to a near carbon-neutral German industry sector until 2045.

The analysis was carried out using the bottom-up energy demand model FORECAST, which is characterized by a high degree of technology and process detail. Its results show that the goal of a nearly carbon-neutral industrial sector in 2045 is possible, but will require enormous efforts. Large amounts of CO2-neutral secondary energy carriers like electricity and hydrogen will be needed in addition to improvements in material and energy efficiency. Depending on the technology focus, the amount of electricity used nearly doubles from 226 TWh up to 413 TWh in 2045. In the case of a "hydrogen economy," the industrial use of hydrogen as a feedstock and as an energy source increases up to 342 TWh in 2045. The time horizon to 2030 is crucial if the transition to a near climate-neutral industry sector is to succeed by 2045. It must be possible to scale up CO2-neutral processes from the pilot and demonstration stage to industrial level by 2030 and enable their economic operation. This contribution therefore also places particular emphasis on the period up

to 2030 and discusses those options for action in this time frame which have proved to be robust in several scenarios. The need for additional action is also elaborated based on the scenario results.

9-261-22: Extended abstract

Steel decarbonisation in China – a top-down optimization model for exploring the first steps

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Panel
9. Deep decarbonisation of industry

Keywords
China, steel, industry, decarbonisation

China produced 1065Mt of crude steel in 2020, accounting for 56.7% of global production. This production caused about 15% of total Chinese GHG emissions. In September 2020, China announced its national climate target to "peak emissions before 2030 and achieve carbon neutrality before 2060." For the steel industry, China in 2021 signaled the ambition to peak emissions already in 2025 and reduce them by 30% by 2030. These targets were never officially adopted and in 2022 the target of peaking steelmaking emissions by 2030 was adopted by the Chinese government. Despite this, some steel companies have maintained their earlier targets to peak even before 2025 (e.g., HBIS and Baowu). In addition to climate targets, China has adopted several targets to reduce air pollution from steelmaking (e.g., for particulate matter, sulfur dioxide and nitrogen oxides). Although there are often synergies between reducing carbon emissions and other pollution it may have implications for the geographical location and timing of measures if one is prioritized over the other.

Strategies for reducing carbon emissions and pollution must also be understood in the context of overcapacity which is currently estimated at 130-350 Mt in China and the steel demand in China is expected to decrease in the coming decades. In the short term, a key measure to reduce both carbon emissions and pollution is by switching to scrap-based secondary steelmaking through electric arc furnaces (EAFs). The share of secondary steelmaking in China is currently much lower than in other countries but it is likely to increase as the economy matures.

Tackling these challenges not only need national target set by the central government, but also need provincial governments to coordinate. Local governments have rights to design local policies, allocated targets could make national goal achievement more effective.

Recent studies have explored long-term breakthrough technology options for China as well as short term strategies (where scrap-based EAF steelmaking is the main option) but so far only at the national level and without attention to the recently announced climate ambitions.

Furthermore, most studies are focused on either carbon dioxide emissions or other pollutants. Over time, the policy focus on local air pollution problems has been extended to also include greenhouse gas emissions.

In this study we built a top-down optimization model to assess the potential future regional allocation of production capacities and secondary steelmaking for meeting the previous climate ambitions for 2025-2030, and at the same time reduce capacity. For the purpose of understanding the pollution implications of a cost optimal strategy for reducing carbon emissions we compare it against a strategy for minimizing pollution .

Our analysis shows that peak carbon by 2025 and 30% emission reductions by 2030 is possible but scrap availability will be a challenge. The overall cost for our two scenarios is roughly the same but lead to different patterns of demand for scrap over time. If reducing pollution impact was the main objective, it would lead to 26-32% less pollution impact than when optimizing on abatement costs and a different geographical distribution of production capacity.

The results show that China may have been overly cautious when setting the target to peak steel industry emissions in 2030. The limited scrap availability highlights need for China to increase quality scrap collection or scrap imports. Furthermore, policy should consider the balance between accelerating the introduction of scrap based EAF steelmaking versus reducing overall capacity. Also, the results indicate that policy should pay attention to the trade-off between cost optimal mitigation and pollution impact. Policy must also consider strategies for the long term and how a shift to secondary steelmaking can be followed by a shift in primary processing technologies to reach the 2060 goal of carbon neutrality.

9-268-22: Peer-reviewed paper

Increasing the voltage – sequencing decarbonisation with green power & efficiency

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Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, decarbonisability factor, industry, energy systems, energy supply and demand

The quickest and easiest way to eliminate GHG emissions as a business is to green energy and compensate the remaining emissions. An issue however is that following this path, very quickly all renewable energy is off the market, prices for renewables would increase quicker than additional capacity can be built with similar effects applying to compensation schemes.

As sectoral coupling, i.e. electrification of processes and transportation, as well as decarbonising industrial processes – that all need large amounts of additional renewable energy – are simulatenously advancing, neither existing nor planned generation and transmission infrastructure will suffice to meet the expected short term demand.

Therefore it is necessary to get an understanding how much of the GHG savings companies plan to achieve through improvements on-site. Determining this 'decarbonisability'-factor is crucial to 'switch on the light' in the black box of knowing how much additional off-site generation capacity and transmission is needed to decarbonise industry and when and through this identify the degree of demand overshoot.

Data gathered from approximately 900 manufacturing companies globally (predominantly Europe) indicates that – despite COVID – companies on average plan to avoid 22% of their 2019 GHG emissions by 2025 and 27% by 2030. Even though 60% of these measures are bound to be on-site (energy efficiency, process decarbonisation & on-site generation), the data calls for expanding planning authority capacities and rapid expansion of green generation.

9-272-22: Peer-reviewed paper

Key strategies to achieve deep decarbonisation of the industry sector. Insights from a meta-analysis of recent climate neutrality scenarios for Germany

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Panel
9. Deep decarbonisation of industry

Keywords
energy-intensive industry, zero-carbon technologies, long-term scenarios, industrial processes, electrification, deep decarbonisation

The EU aims to become the first climate neutral continent. To achieve this goal, the industry sector needs to reduce its GHG emissions to net zero or at least close to net zero. This is a particularly challenging task due to the high energy demand especially of primary materials production and the little potential to reduce this energy intensity when switching to other production processes based on electricity or hydrogen. In order to identify robust strategies for achieving a net-zero-compatible industry sector, the paper at hand analyses the transformation of the industry sector as described by a number of recent climate neutrality scenarios for Germany. Apart from overall industry, a focus is set on the sectors of steel, chemicals and cement. The analysed scenarios show very deep GHG emission reductions in industry and they appear to be techno-economically feasible by the mid of the century, without relying on offsets or on shifts from domestic production to imports. The scenarios agree on a suite of core strategies to achieve this, such as direct and indirect electrification, energy efficiency and recycling as well as new technological routes in steel making and cement. The scenarios differ, however, regarding the future mix of electricity, hydrogen and biomass and regarding the future relevance of domestic production of basic chemicals.

9-274-22: Extended abstract

Deep decarbonization of industry

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Frank Wubbolts, TNO, The Netherlands
Remko Detz, TNO, The Netherlands

Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, chemical industry, greenhouse gas emission reduction

The deep global decarbonization of our lives can only be realized through massive deployment of renewable electricity generation and robust value chains for circular carbon. As a consequence, a new paradigm will develop, which is linked to two key ingredients produced directly from the sun's energy: renewable electricity and biomass. The electricity, the bio-energy and the bio-materials find their way to consumers through the intricate structures of industry.

Many useful materials consist of carbon-based molecules. These products are all to be produced from circular-carbon resources: biomass, recycled waste and captured CO2 from industrial processes or from the air. The processing of these carbon-based resources generally requires energy of high quality.

For the Netherlands it should be foreseen that a considerable share of its energy demand cannot be generated as electricity within its own territory and therefore has to be provided by import of electricity through grid connections and through activated' CO2, water and nitrogen in the form of biomass, hydrogen, ammonia and methanol.

This paper looks in particular at the transformation of the petrochemical industry in connection with the phasing out of fossil carbon and re-programming of the current 'thermo-catalytic cascade' of fuels and materials co-production. We explore taking carbon-efficiency towards materials as a guiding principle for the transformation. Chemistry and catalysis is then used to drive carbon preferentially into products instead of emitted into the air and to assess if one could identify new and scalable value chains and conditions for them to emerge.

While e-fuels and batteries may eventually displace most fossil-based energy carriers, for most chemical products there are no alternatives imaginable for carbon-based chemicals & materials. Taking the current 'cracker' platform chemicals as a basis, this paper elaborates and discusses the technical options for chemical conversion and possible consequences when chain carbon-efficiency and energy-efficiency in the materials are prioritized over cost of transformation. In this way, existing value chains can adapt to the new boundary conditions by making modifications to current operations.

The paper will discuss the elements of this restructuring of the chemical industry and the challenges that have to be met to make a more energy efficient and low carbon industry, both technological and in terms of policies, together with their estimated impact.

We will illustrate the case for the Netherlands, a country with large clusters of refinery and petrochemical industry and sketch the corresponding roadmap that can be expected from the guiding principle of carbon-efficiency towards products.

9-277-22: Extended abstract

Setting the scope of industrial decarbonisation

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Rod Janssen, Energy Efficiency in Industrial Processes, Belgium
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Panel
9. Deep decarbonisation of industry

Keywords
decarbonisation, supply chains, scope, product carbon footprint

Devising an effective pathway to decarbonisation - both from a company and policy maker per-spective require an understanding on where companies are at the moment (i.e. awareness of their Greenhouse gas footprint (GHG), energy consumption across fuel sources and energy effi-ciency potentials), but also on where they want to go by when.

With an increasing number of 'net-zero'-pledges, it is necessary to assess net-zero in what dimen-sion (CO2, CO2+ or GHG emissions) and also on what scope (i.e. Company facilities & vehicles (Scope 1), Purchased energy (Scope 2) or in respect to the Up- & downstream supply chain (Scope 3)).

As the product carbon footprint gains in importance in a number of sectors, driven through large original equipment manufacturers (OEMs), supply-chain decarbonisation is of increasing interest to companies. What approaches do companies undertake to get their supply chains to address their Scope 1 and 2 emissions and what policy measures would boost decarbonisation action?

This extended abstract will illustrate first aggregate findings of the 2nd data collection of the Energy Efficiency Index of German Industry in 2021 in which approximately 900 manufacturers of all sec-tors, sizes and energy intensities share their plans, situation and assessments. It will showcase where companies stand, what scopes they focus on, whether the product carbon footprint plays a role and what is undertaken to decarbonise the supply chain. It will further give insights on a num-ber of policy statements, such as emission pricing, plannability and the role of energy efficiency in decarbonisation.

A special focus in the current survey was on the areas (scope 1, 2 and 3) in which the companies want to decarbonise, reaching from company facilities and -vehicles, purchased energy and all other emissions, including upstream and downstream supply chain. Around three quarters of companies are already on track to decarbonise all three scopes, with scope 3 still being in the early stages because of its complexity. Decarbonising the emissions of the upstream and downstream supply chain is particularly challenging because this is often largely beyond the direct control of companies.

The reason why so many companies are committed to eliminating upstream and downstream emissions becomes clear when one considers that almost 70 % of companies are working to offer their own products with net-zero emissions, including a large majority of smaller companies. It can be assumed that some of this motivation is the result of increased expectations from customers, investors and politicians. Many companies strive to implement this by imposing requirements in supply contracts, however many also pursue other strategies, such as cooperation via decarboni-sation networks.

Companies thus seem to be surprisingly committed to decarbonisation action, however, results also show that policies that boost this process are desired. Most companies (66 %) consider regu-latory policies necessary to achieve climate targets in the industrial sector. Less surprisingly, over 70 % of those surveyed desire implementation assistance and funding in this regard. Considerable, yet not overwhelming number of companies (59 %) fear loss of competitiveness on international markets.

Summing up, large parts of the manufacturing industry in Germany are intensively working on how they can contribute to a climate-neutral economy. Doing this successfully, however, requires from companies to be aware of their goals and timelines in that respect. On part of policymakers, especially setting the course in respect to shortened planning times and standardised emission pricing for more plannability is crucial according to participants. Furthermore, investment risks have to be reduced and the availability of renewable energy and skilled labour needs to increase.

9-283-22: Extended abstract

Towards CO2-neutral concrete; Industrial scale-up of a closed-loop recycling process of end-of-life concrete (CIRCO2BETON project)

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Panel
9. Deep decarbonisation of industry

Keywords
circular economy, concrete, cement, carbonation, low carbon industry, pilot projects

Concrete and cement production are responsible for 6-8 % of manmade CO_2 emissions. Still, concrete is one of the most environmentally friendly material due to its unique properties such as low embedded energy, durability and easiness of production and application. Faced with the challenges of climate change and carbon neutrality by 2050, the French cement industry has set itself the goal of reducing its emissions compared to 2015 respectively by 24% in 2030, then 85% in 2050. This industrial scale up project, called CIRCO2BETON®, is part of the pathway. It is based on advanced recycling of end-of-life concrete, carbonation of recycled concrete fines and utilization of the materials produced in cement and concrete production as a way towards CO2-neutral concrete.

CIRCO2BETON® project
The concept behind the project comprises 4 novel technologies: I) selective separation of the end-of-life concrete enabling production of high-quality recycled aggregates, recycled sand and recycled cement paste (RCP); II) using a part of the RCP as a CO2-free raw material for clinker production partially replacing limestone and hence reducing its CO2 emissions; III) using another part of the RCP for CO2 mineralization from the clinker production process, further lowering the emissions associated with clinker production; IV) using the re-carbonated RCP as a cement constituent and replacing clinker to produce a new low-CO2 composite cement. The concept, whose underlying assumptions have already been experimentally proven, aims at lowering the CO2 emissions associated with cement production to less than 1/4 of the current level and enables fully circular economy in concrete production.

The CIRCO2BETON® project has received funding from the French Government as part of the Investments for the Future program which is coordinated by ADEME. It includes a dedicated recycling platform to perform the advanced concrete recycling process and a CO2 reactor integrated into a cement plant to perform the CO2 mineralization of RCP.

a) Selective separation
Contrary to the common practice based on size reduction and utilization of crushed concrete as a road base or for earth works (cf. downcycling), the selective separation aims at providing high quality aggregates and sand. This is accompanied by significant amounts of normally unwanted fines. Today, these fines are the mix of fine aggregates and hydrated cement paste. This feature neither allows for their extended use in clinker production nor as a cement component. The project will scale up to industrial level a novel technology to achieve high yields and qualities of all components and especially of the RCP.

b) Carbonated recycled concrete paste used as cement constituent
The RCP targeted is a mixture of partially carbonated cement paste (~20%) with small amounts of fillers, fines from sand and fines from aggregates produced during the downstream processes. The RCP will be mainly used for CO2 mineralization to sequester CO2 from the cement kiln gases in a process called “re-carbonation” (potential ~80%). During re-carbonation, silica alumina gel is formed which has pozzolanic properties and is therefore suitable for cement production [2]. The project includes the installation of a CO2 reactor at the Ranville cement plant (FR) to optimize and demonstrate the industrial feasibility of the process under normal and continuous production conditions.

Closed loop economy of concrete
The challenge of the CIRCO2BETON® project is to demonstrate the economic and environmental benefits of the closed loop of concrete. In addition to the direct technological challenges, one must add to the project indirect challenges such as the large-scale roll-out of selective deconstruction to improve the quality and homogeneity of demolished concrete while making easier the access to this resource, the access to land plots near cities to perform advanced recycling process, and traceability throughout the value chain.

9-287-22: Peer-reviewed paper

Voluntary agreements in Flanders: quo vadis?

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Panel
9. Deep decarbonisation of industry

Keywords
voluntary agreements, roadmaps

Flanders, Belgium is renewing its Energy Policy Agreements, voluntary agreements on industrial energy efficiency. The current ones will expire at the end of 2022.

First, the paper assesses the current Energy Policy Agreements as they are the basis for the new ones. They are relevant as they cover the lion's share of the Flemish industry and contribute to Flanders' obligations under the European Energy Directive. However, their effectiveness is revealed to be low and shows a declining trend, indicating that the voluntary agreements are losing momentum. Their cost-efficiency is also low; the specific reduction cost is estimated at €900/ton CO2.

Secondly, the paper discusses the design aspects of the new Energy Policy Agreements. A climate component is added, but it is limited to short-term investments only. Only a mandatory, indicative roadmap prepares the participants for climate neutrality by 2050. The duration of the new Energy Policy Agreements is shortened to four years, which does not stimulate the participants for long-term planning and acting. This means that a modest improvement of the effectiveness of the new Energy Policy Agreements can be expected. The current benefits are maintained, meaning that the cost-efficiency will remain low.

Third, the paper presents the conclusions of an international workshop on renewing voluntary agreements on industrial energy efficiency. There is a clear trend of adding a climate component in all European countries, but there are mixed opinions on whether a hierarchy of actions should be respected and on the number of targets to include. Some countries have experience with roadmaps as a tool, but these roadmaps have not been effective in driving the industry towards more sustainable products and processes.

The paper concludes with policy recommendations to improve the effectiveness and cost-efficiency of the new Energy Policy Agreements. Their objective should be to stimulate the participants committing to ambitious climate actions. In that respect, they should be aligned with international initiatives, such as the Science Based Targets initiative, that have the same objective. Also the benefits, granted to the participants, should be reformed; rebates on fossil energy and carbon costs should be replaced by funds stimulating innovation amongst the participants.

9-293-22: Peer-reviewed paper

Renewable microgrids covering the heat and electricity needs of industrial parks

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Panel
9. Deep decarbonisation of industry

Keywords
microgrids, decarbonisation, climate change mitigation, combined heat and power (CHP), business strategy, energy policy, optimal techno-economic and environmental sizing methodology

The industrial sector, undoubtably, has a key role to play in the reduction of global greenhouse gas (GHG) emissions. However, the diversity of processes involved, coupled with the uncertainties around the affordability and the reliability of climate-neutral solutions, make decarbonization in the industrial sphere a complex challenge. They could enable industries to reduce part of their GHG emissions by using climate neutral alternatives, ensure the resiliency of factories to future climate change impacts, and represent an economic opportunity, by deploying profitable and efficient energy management actions. However, many questions remain on how to best implement microgrids from both a technical and financial perspective. Obviously, from an investment perspective, minimalizing the overall size of the grid is essential as this prevents extraneous investment in unnecessary and costly capacity. In this paper we address some of the technical and economic questions on grid sizing. We present an optimal sizing methodology for heat and power microgrids. These grids were composed of solar PV panels, Li-ion batteries, and a biogas fired CHP unit. We go onto assess the financial, environmental and resiliency potential of the solution and use a multi-factor optimization (considering both economic and technical factors) to address the problem. A case study renewable microgrid was designed based on a real-life dataset of an industrial park, located in the UK and used to show significant carbon footprint reductions through the implementation of our model.

9-331-22: Peer-reviewed paper

Future hydrogen demands from industry transition towards 2030 - a site-specific bottom-up assessment for North-Western Europe

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Panel
9. Deep decarbonisation of industry

Keywords
energy-intensive industry, industry, hydrogen, transition, alternative fuels, re-investment

Industry decarbonisation is currently high on the agenda in the EU and its member states, as this sector has substantial shares in overall GHG emissions while it faces serious challenges to decarbonise. Hydrogen based on renewable electricity can have a key role in the transition towards a CO2-neutral industrial production since its use as an energy carrier as well as a feedstock in various industrial process routes is promising. To scale-up hydrogen infrastructure in North-West Europe, a deep systemic understanding with a detailed spatial perspective is required. With industry representing a high-priority sector for the use of CO2-neutral hydrogen, a site-specific analysis of hydrogen demands from industry is essential.

Here, we conduct an analysis of the potential demand of hydrogen for the industrial transition in North-West Europe (Netherlands, north-west Germany, Belgium, northern France, Luxembourg). The region is a centre of the European heavy industry value chain and is seen as a pioneer region for industry transition. Our method is based on a techno-economic scenario approach that considers 515 individual industrial plants allocated to 185 sites. We calculate transformation pathways based on re-investment cycles and plant age.

We present the resulting hydrogen demands by sector and spatially distributed at the level of sites and NUTS3 regions. Limiting the use of hydrogen to feedstocks and high-temperature process heat, we calculate a total technical demand potential of about 250 TWh/a based on 180 individual plants. Considering re-investment cycles and plants due for re-investment until 2030 shows a potential hydrogen demand of 55 TWh/a. Aggregating the hydrogen demand by NUTS3 region, we identify 12 regions with a total technical demand potential of 10 TWh/a or more mainly

concentrating around the large chemical and steel clusters.

The resulting data set is available for download and can be used in energy-systems studies to improve the resolution of industry sector.

9-348-22: Peer-reviewed paper

Modelling pathways towards a climate-neutral EU industry sector

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Panel
9. Deep decarbonisation of industry

Keywords
industrial processes, decarbonisation, chemical industry, steel, electrification, hydrogen

To attain climate neutrality by 2050, the European industry must achieve significant reductions in greenhouse gas emissions. The EU's Green Deal with the new 55 % reduction target by 2030 and the 'Fit for 55' package set the frame for the transition. The Fit-For-55 package is accompanied by an impact assessment that includes scenario analyses for the development of the EU energy system until 2030. A perspective Beyond 2030 is not published, but essential to understand the need to achieve climate neutrality by 2050.

Here, we develop two scenarios for the industry sector to benchmark the scenarios published by the EU. We extend our scenarios towards 2050. One scenario reflects current policies (not yet including the proposed fit-for-55 package) and a second scenario that is in line with meeting climate neutrality by 2050 (Mix95). We use the industry-sector simulation model FORECAST. The model calculates energy demand and GHG emissions pathways based on assumptions about policy instruments like CO2 prices or investment grants with a high technology detail.

Results show that the current policy scenario is not in line with the Green Deal target and is far

from reaching climate neutrality by 2050. The Mix95 Scenario achieves ~95 % GHG reduction by 2050. To meet this reduction, various strategies are necessary. A fast and comprehensive switch to electricity and hydrogen is driven by higher CO2 prices and OPEX support. Driven by the electrification of process heating, electricity demand increases significantly to ~1600 TWh by 2050 starting from 1018 TWh in the year 2018. Also, hydrogen sees a rapid uptake to reach 811 TWh by 2050 prioritizing use in steelmaking and chemical feedstocks. CCS and CCU are used to capture the remaining process emission in the cement and lime production resulting in 75 Mio. t CO2 captured in 2050. Effective instruments for circularity and material efficiency reduce the production of energy-intensive goods and thereby the demand for CO2-neutral energy carriers.