### **Book of Abstracts**

for the

Second International Conference on Evolving Cities University of Southampton 22–24 September 2021



Compiled by the Energy and Climate Change Division (ECCD) Faculty of Engineering and Physical Sciences University of Southampton United Kingdom

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#### Preface

The International Conference on Evolving Cities (ICEC) took place as a hybrid event (with both online and in-person delegates) in Southampton, UK from 22-24 September 2021. It brought together leading academics, policymakers, and industry specialists to debate the role of cities in addressing climate change mitigation impacts and accelerating our transition to net-zero carbon. Over the course of three days, there were <u>11 keynote</u>, <u>49 oral presentations</u> and <u>9 posters</u> by delegates from 38 organisations situated within 19 countries. The themes of the conference are shown in Fig. 1 with participants able to discuss and debate ways to develop multi-stakeholder partnerships and implement innovative solutions to propel cities towards low carbon pathways.



Fig. 1: ICEC themes

This document provides a record of the submitted abstracts for the International Conference on Evolving Cities including all oral presentations and posters presented at ICEC 2021.

#### About ECCD

The Energy and Climate Change Division (ECCD) is part of the Faculty of Engineering and Physical Sciences at the University of Southampton. It comprises the Sustainable Energy Research Group (SERG) and the Coastal and Climate Research Group, established since 1990. ECCD/SERG research profiles addresses the University's mission focusing on fundamental understanding applicable to renewable energy studies, energy efficiency and energy for development. ECCD/SERG research <u>supports the United Nations Sustainable Development Goals</u> (SDGs) with fundamental and applied research across our six research themes. These encompass (i) Renewable Energy, (ii) Energy Access, (iii) Cities & Infrastructure, (iv) Buildings & Communities, (v) Behaviour & Modelling and (vi) Climate & Emissions. Please check our website <u>www.energy.soton.ac.uk</u> for further information.

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## **SESSION 1: Conceptualising, modelling and forecasting evolving city infrastructure**

#### Infrastructure and cities ontologies

**L. Varga**<sup>1</sup>, L. McMillan<sup>1</sup> <sup>1</sup>University College London, UK

The creation and use of ontologies has become increasingly relevant for complex systems in recent years. This is because of the growing number of use cases that rely on real world integration of disparate systems; the need for semantic congruence across boundaries; and, the expectations of users for conceptual clarity within evolving domains or systems of interest. These needs are evident in most spheres of research involving complex systems but they are especially apparent in infrastructure and cities where traditionally siloed and sectoral approaches have dominated undermining the potential for integration to solve societal challenges such as net zero; resilience to climate change; equity and affordability.

This paper reports on findings of a literature review on infrastructure and cities ontologies and puts forward some hypotheses inferred from the literature findings. The hypotheses are discussed with reference to literature and provide avenues for further research on (1) belief systems that underpin non-top-level ontologies and the potential for interference from them; (2) the need for a small number of top level ontologies and translation mechanisms between them; (3) clarity on the role of standards and information systems upon the adaptability and quality of datasets using ontologies.

### Distribution patterns and predictive model of solar radiation in urban street canyons with panorama images

**Y. Liu**<sup>1</sup>, M. Zhang<sup>1</sup> and L. Yang<sup>1</sup> <sup>1</sup>*Xi*'an University of Architecture and Technology, China

Solar radiation is the main driving force responsible for adjusting the urban climate and heat balance in street canyons. In this study, the model for predicting urban solar radiation used in RayMan is improved with respect to the reflected radiation and its accuracy is verified in field experiments. In total, 35763 sample sites in Xi'an are generated and categorized using basic urban morphology parameters (building density, average building height, and floor area ratio). The verified model is used to calculate the solar radiation intensities based on Baidu panorama images. The solar radiation distributions in Xi'an are mapped. The patterns of urban morphology affecting solar radiation are investigated. The results shows that solar radiation is affected by street canyons and the morphology of urban plots, as follows. (1) The effect of the width of street canyons on the solar radiation intensity is stronger in the transition and cold season (September to May) than the hot season (June to August), where the influence is stronger when the season is colder. (2) In east–west street canyons, the effects on solar radiation of urban morphology parameters in southern plots are stronger. (3) The relationship between the floor area ratio and solar radiation is strongest and negative.

## Southampton

#### Self-healing in water infrastructure systems

#### L. McMillan<sup>1</sup>

<sup>1</sup>University College London, UK

With infrastructure systems growing increasingly complex and interdependent, the consequences of a system failure have the potential to be more devastating, and impact more users, than ever before. Self-healing systems are those which can independently identify failure or degradation in the network and generate solutions to restore functionality, allowing the continued provision of services. The cycle of self-healing comprises of three processes; maintenance of system health, detection of failure, and system recovery (Ghosh et al., 2007). These processes can be enabled through a variety of techniques, including redundancy-based approaches, forecasting tools, and resource allocation algorithms. The benefits of adopting a self-healing approach to infrastructure network management are obvious and abundant; network quality can be assessed and assured, threats can be swiftly identified and dealt with, resources can be easigned to optimise coverage under fluctuating demand, and consumers can have confidence in the stability of the services they use on a daily basis.

This presentation outlines the potential for self-healing within water infrastructure systems specifically. A systematic review of the topic identifies emerging terminology and methods within the water domain, and the extent to which current research aligns with self-healing methodology is discussed. Finally, a framework for self-healing across the water network is proposed, knitting together existing and developing techniques into a system-wide approach.

### Forecasting future demand and constraints in an already constrained network in Ventnor, Isle of Wight

**E. Ridett**<sup>1</sup>, A. S. Bahaj<sup>1</sup>, P. James<sup>1</sup> <sup>1</sup>University of Southampton, UK

As we make the transition to a net-zero emission United Kingdom, many low-carbon technologies such as Electric Vehicle (EV) charging stations. Heat Pumps (HP) and rooftop solar Photovoltaics (PV) are rapidly being deployed and connected to the network. This is predicted to have a fundamental change to demand, which the current network infrastructure was not originally designed for, and there is risk of faults occurring within the network due to its thermal limits being exceeded. To facilitate this transition, there is a need for highresolution constraint forecasting to assist Distribution Network Operators with effective network planning. This paper provides a methodology to forecast future constraints at the individual substation level for different projection scenarios up to 2050 applied to the Ventnor area of the Isle of Wight, an island off the South coast of the UK. By using actual half-hourly EV charging and HP demand data and solar irradiance data for rooftop solar PV generation in conjunction with annual penetration projections, individual constraint events can be forecasted for different rates of uptake of these technologies. The risk of faults occurring within the network area due to these constraints was then analysed for the different scenarios up to 2050. The methods applied here can be replicated in other areas of the UK or other nations that wish to analyse the risk of faults occurring within the network due to an increasing uptake of the low-carbon technologies considered.



### Integration of industrial and urban symbiosis from renewable energy perspectives $\mbox{D}.\ \mbox{Shang}^1$

<sup>1</sup>University of Cambridge, UK

The world is currently tackling the issues of sustainability and limited resources through multiple different avenues, yet the possibility of using cities as a potential solution has been mostly overlooked. The potential solution, involving cities, is based on the integration of Industrial Symbiosis (IS) and Urban Symbiosis (US) into Urban-Industrial Symbiosis (UIS) through the catalyst of renewable energies. The main ideology of IS and US is to create advantages for the participating community through the exchange of resources, for economic benefit and city metabolism respectively. This research will investigate the impacts of introducing new/additional renewable energies within the IS/US space. It will also explore the possibility of using Virtual Power Plants as a new energy system and/or stabilizing factor to help IS and US integration. The reason for considering this research from an energy perspective is mainly because of the universal need for energy, making it a great connection between different industries, communities, etc. These issues have been acknowledged by the IS and US research community, however research on it has been scarce until recently. As the idea of UIS formation is still at an infantile stage, the methodology for this research is primarily through case study analysis and cross examination, where the cases used include Kalundborg, Kawasaki, Ulsan, Mälardalen, and Guiyang, etc. A literature review was also used as a method to collect secondary data. The expected result from this research will be a framework to help the formation of the UIS system.

This research attempts to fill the gap between the IS and US body of knowledge. It will also expand on the renewable energy topic within IS/US literature as it considers more than the 'traditional' renewable energy systems within literature. Additionally, the framework can potentially increase the utilization & penetration of renewable energy within the city to confront the sustainability issue. The city can also become more interconnected via the systems for resource/information exchange; it will improve the resilience of the city for unexpected situations. Overall, UIS formation will allow cities, which are the foundations of humanity, to positively affect the world.



### **SESSION 2: Municipal responses to local and global challenges**

### Embedding improved health outcomes through inclusive transport networks P. Turton<sup>1</sup>

<sup>1</sup>Portsmouth City Council, UK

South East Hampshire Rapid Transit (SEHRT) will deliver an inclusive, connected public and active transport network, designed to reduce pockets of deprivation and address poor health outcomes experienced within the Portsmouth city region, in the short term, and create a framework to enable sustainable future delivery of housing and employment space in the longer term through policy change.

This £100m programme, developed in partnership across public and private sectors, will create an environment which enables and embeds healthy lifestyles within the urban fabric: Corburn's concept of 'city planning as preventative medicine'.

This talk is formed in four main parts:

The Need for Change

- High levels of congestion and exceedances in air pollution limits,
- poor connectivity and severance
- acute health problems and poor health outcomes: high levels of deprivation, reduced life expectancy

The 'solution'?

• SERHT will deliver the core of a new mass public transport and active travel network which offers a realistic, commercially viable and environmentally sustainable alternative to car travel

Key guiding principles:

- Partnership- Multi agency, private and public partnership, operating as a single team, aware and respectful of the contribution of each stakeholder: the whole, is greater than the sum of its parts.
- Integration of transport and urban planning Breaking down the barriers between planning and transport to ensure sustainable access to developments is a first thought rather than an afterthought, building in sustainable connectivity.
- Community Engagement and Citizen Panels Community Engagement through Insights surveys and the establishment of a diverse citizens panel, ensuring that those who are most disadvantaged by the current transport system are represented.

Conclusion

- Unique opportunity to change: to build back better, to build back fairer (Marmot), and create the foundation of communities that we want to live in
- Outlining implications for policy change: not to rely on old approaches, not retrench into old habits and silos, need for ambition and curiosity to understand different perspectives and different needs, and work in partnership to make a system which truly works for our complex and community.



### Environmental assessment platform for supporting organisations' sustainability pathways

**A.S. Bahaj**<sup>1</sup>, P. Turner<sup>1</sup>, M. Mahdy<sup>1</sup>, S. Leggett<sup>2</sup>, S. Guppy<sup>2</sup>, N. Wise<sup>3</sup>, A. Alghamdi<sup>4</sup> <sup>1</sup>University of Southampton, UK <sup>2</sup>Southampton City Council, UK <sup>3</sup>Winchester City Council, UK <sup>4</sup>King Abdulaziz University, Saudi Arabia

Solar Nationally, 68% of UK cities and local authorities have declared a climate emergency with some setting quantifiable targets to net zero by certain dates. In 2019, Southampton City Council (SCC) and Winchester City Council (WCC) declared climate emergencies and announced ambitious targets for their cities to become carbon neutral and create greener, cleaner cities. The highlighted cities have different pillars to achieve their required targets leading to an overall scope of environmental action plan to achieve these. The pillars or themes are somehow similar and can be exchangeable. In this work, we present an approach to transfer these themes into a structured online environmental tracker that is suitable for most organisations regardless of sector or size. The approach is based on the Analytical Hierarchy Process (AHP) where the themes were transferred to specific criteria with weights agreed by experts to measure relative importance of each theme against each other. The outcome is the Green City Performance Tracker encompassing an assessment matrix that includes carbon accounting and provides ratings for each theme which is combined into quantifiable progress for achieving the committed targets.

The paper presents the outcomes from such development – the Green City Tracker – in collaboration with local authorities and city-based organisations and a robust methodology devised to be applied to organisations and cities across the UK and globally. The Tracker was applied to the first 10 SCC city-based institutions. The outcomes are presented in the paper in terms of ratings for each criteria coupled with a combine overarching rating per institution. Such ratings were design to show areas of successes and those that need improvement, providing a basis for needed actions to enhance progress in the themes. The approach highlighted the importance of generating a universally applicable, fair, engaging and time/resource efficient Tracker with less taxing processes in order to incentivise organisation participation. The Tracker and its processes have been developed so that accepted by regional local authorities as they are widely a vehicle to support their sustainability credential and can be adapted to cater for other cities/organisations that declared environmental targets.

### Simulating the consequences of a real time carbon tax at the city and neighbourhood scale

**B. Anderson**<sup>1</sup> <sup>1</sup>University of Southampton, UK

This paper simulates the consequences of a notional carbon tax applied to grid electricity in the City of Southampton using a spatial microsimulation approach. The simulation combines small area Census data with household level half-hourly electricity usage data from a sample of over 4,000 households from the Solent region to produce synthetic half-hourly smart meter data for every home in Southampton in 2018. It then uses this simulation, together with historical half-hourly grid carbon intensity data, to calculate the half-hourly GHG emissions attributable to this electricity use. Finally, the model uses these results to assess



financial implications for different kinds of households of a notional residential carbon tax driven by half-hourly grid carbon intensity.

### An educational awareness program to reduce energy consumption in public institutions: The case of the French Social Security

**T. Marquez**<sup>1</sup>, P. Rostan<sup>1</sup> <sup>1</sup>*Green Soluce, France* 

To achieve ambitious energy efficiency objectives, large institutions face challenges to embark employees and building users. Especially with thousands of people spread over different regions, and in buildings with different characteristics. The French Social Security faces such challenge, with 145000 employees in more than 3000 buildings representing more than 4,5 million sqm of real estate. To meet their energy ambitions, the institution deploys actions to raise awareness among a large number of internal stakeholders, in order to increase acceptance, engagement and responsibility to bring about behavioural change on energy awareness.

The paper presents the results of a large-scale awareness-raising program, named Impulsion2021, which targets 5800 employees within the institution. The program is supported by the Ministry of Ecological Transition and ADEME within the context the Energy Savings Certificate national programme. The program consisted on several phases: a) identification of a sample population to participate in the program, b) develop the learning material to be deployed, c) plan and coordinate the communication campaign across the different departments and branches (e.g. HR, communications, and management), d) deployment and facilitation of learners communities, and e) measure and analysis of results. A specific focus on the adaptation of learning programs is presented: one program targeted to a general user on how to take-up actions on a daily bases (e.g. lighting, hearing, IT), and another targeted to building professionals responsible for building operations and renovation actions needed to also meet new governmental regulations. The results show that of the over 1500 people that have finished the learning program, as of April 2021, the level of awareness has increased. As measure by the level of engagement and exchanges on the topic of energy efficiency within the internal collaborative communication channels, an increase of related content on a weekly newsletter, the identification of over 50 best practices carried out throughout the institution, and the identification of technical solutions that can be potentially implemented on 50 already targeted buildings. The experience shows the opportunities and impact of a common and long-term awareness program and its influence on daily behaviour of users.

**Modelling electric vehicle arrival rates at a charging forecourt C. Axon**<sup>1</sup> <sup>1</sup>*Brunel University, UK* 

The importance of reducing the greenhouse gases resulting from vehicles is widely recognised. Countries are setting rules, targets, and incentives to increase the electrification of transportation. One of the motivations to switch to using electric vehicles is the availability of rapid charging points. An alternative to on-street charging facilities is to create stations functioning in a similar way to a conventional fuel station (forecourt). The UK's first solar EV



charging forecourt was opened recently incorporating a 5 MW on-site battery to store energy from a solar farm and to enable arbitrage for grid services. To enable optimum site operation, predicting the arrival of electric vehicles at different times of the day and hence the load demand, determines the availability of the battery for bulk power supply or fast-frequency response to the grid. We present the outline of a stochastic model for the electric vehicle arrival and charging at the site using the concept of vehicle population-types. Our aim is to mimic EV arrival rates at the site and our model is designed to serve two purposes: 1) to help predict likely site use in the next 24 hour period for planning the battery storage strategy for providing grid services, and 2) to learn about patterns of use to assist in developing future sites. Our model considers the stochastic nature of different parameters controlling the charging process e.g. daily travelled distance, the charging start time and the state of charge at start of the charging session. Exploiting knowledge of vehicle ownership and traffic data, we have implemented local and passing traffic populations. Typical EV arrival patterns for two different days for the residential and passing traffic populations have been obtained. We are gathering operational data to verify our model. The total charging power is used to estimate the energy delivered by the on-site battery. Accordingly, the state of charge, number of discharging/charging cycles and battery degradation rate can be estimated for the optimal operation of the charging forecourt.



#### **SESSION 3: Thermal comfort and energy demand**

### The influence of personality and energy literacy on households' stated acceptance of heat deferral

**P. James**<sup>1</sup>, P. Turner<sup>1</sup>, T. Rushby<sup>1</sup>, S. Gauthier<sup>1</sup>, A. S. Bahaj<sup>1</sup> <sup>1</sup>University of Southampton, UK

The UK's carbon targets, as defined by the Climate Change Act of 2008, specify an emissions reduction of 80% by 2050, which in 2019 the government has revised down to 'net zero' carbon by 2050. In 2017, 17% (64.1 Mt CO2), of the UK's carbon emissions were associated with non-electric use in the residential sector. The majority of these emissions are associated with natural gas space heating, cooking and domestic hot water. In order to meet UK 'net zero' objectives the UK will aim to decarbonise residential heat (currently through electricity and energy efficiency measures), which in combination with electric vehicles could lead to a 200-300% increase in the UK's annual electricity demand introducing serious capacity issues for the electricity system. In the future residential electrical heating or EV charging loads may need to be remotely adjusted to better suit the capacity of the electricity network and maintain substations and feeders within their technical and regulatory limits. Here we present the findings from a survey with a UK energy provider's household customers (N=4.100) which asks whether household would approve of such a scheme and what levels of heat deferral they would be willing to accept at various times of day. The survey also gathers information on the occupier's energy literacy levels personality traits, trust in energy companies, social demographics, thermal comfort and general dwelling information. The survey results were analysed with reference to these topics providing evidence describing if and how these factors influence stated acceptance of heat deferral. These results helped to identify potential pathways for future research, guiding follow-up online focus group interactions to further understand the influencing factors whilst identifying ways to enhance household acceptance. Moreover, these results could be used to inform national energy reduction policies to aid sustainable development.

### Housing retrofits with focus on energy, comfort and well-being L.Bourikas<sup>1</sup>

<sup>1</sup>Lancaster University, UK

Health and well-being are instrumental in promoting motivation, improving self-esteem, engaging in social life and learning. These aspects are critical to personal and social life quality and mental-health. Now more than ever before, our societies need to act collectively to develop social resilience and effective solutions to tackle climate change, air quality, housing and environmental issues. Social housing is an area where big changes can take place in both individual and community levels. But all changes need and should be based on practices of good communication, education, participation and equality. At the same time, social housing providers are required to take dynamic action to achieve energy (and emissions) savings and operational cost avoidance. Such actions often alienate the tenants and the local communities, especially when the expected results are not fully achieved. This points out the importance to include in the evaluation of any social housing interventions, "soft", qualitative factors such as occupants' satisfaction, air quality, healthcare related cost avoidance, the ability to flourish and community welfare. It becomes apparent that "zero carbon ready" as described by the Future Home Standard in the government plans it should not only focus on technical solutions but on the radical transformation of our society and



lifestyles. The aim of this study is to evaluate retrofitting solutions in social housing with focus on energy, comfort and well-being.

#### Displacing cooling loads with solar PV in Saudi housing sector

**M. Alam**<sup>1</sup>, L. Blunden<sup>1</sup>, A.S. Bahaj<sup>1</sup>, A. Alghamdi<sup>2</sup> <sup>1</sup>University of Southampton, UK <sup>2</sup>King Abdulaziz University, Saudi Arabia

Electrical power generation in the Kingdom of Saudi Arabia (KSA) is dominated by fossil fuels. The annual electricity consumption per capita in 2018 is approximately 10.5 MWh representing one of the highest in the world with a commensurate carbon emission. Subsidised electricity tariffs and arid climate, coupled with economic growth have persistently fuelled electricity demand growth in all sectors. The residential sector, which the subject of this research, accounts for over 50% of the total national demand. Cooling loads through the use of air conditioning in the residential sector constitutes about 70% of the total electrical demand, impacting peak daytime loads especially in the summer months. Peak load in the KSA, which has almost doubled in the last decade, is a key challenge for the national grid and is not sustainable.

This research investigates the applicability of building integrated PV systems to (a) serve/dent residential cooling loads, and (b) identify opportunities of such interventions at scale to reduce the burden of peak loads on national grid. The work is linked to KSA's 'Vision-2030' addressing the electricity sector where renewable energy is planned to contribute 50% of the its installed capacity by 2030. Modelling approaches based on simulation of PV systems ranging from 2kWp to 15kWp with and without battery storage were undertaken. Power outputs under KSA weather conditions were determined and linked to monitored household electricity consumption profiles ranging between 2.4MWh and 61MWh annually. Results show that some of the selected PV systems can substantially meet peak cooling loads and are likely to reduce the peak demands on the utility grid if deployed at scale. The paper also presents a techno-economic suitability analyses of such systems both in grid connected and standalone modes. The study highlights that the existing electricity tariff in KSA is likely to create a major barrier of deploying such PV systems at scale, and an appropriately targeted feed in tariff or capital cost subsidy are likely to alleviate such barriers in the short term.



#### **SESSION 4: Planning and policy for net zero development**

#### **Designing policy for cities**

**M. Cavada**<sup>1</sup> <sup>1</sup>Lancaster University, UK

Cities are impacted both by the way we live in them and by policy which is implemented on different scales in city living. For example, in the UK, policy informs cities on a national level, according to the National Planning Policy Framework, on a local level as the Local Plan, and on an international level in the 11th Sustainable Development Goal . Policy also can impact the ways we evaluate the systems within cities, as The Green Book and the Build Back Better describe. Cities and wider urban areas are highly impacted by human behaviour and the unprecedented challenges they face. Human behaviour and challenges cannot simply be supported by a siloed approach to urban policy, because their impact is felt across multiple sectors. Additionally, local initiatives, which are often not part of policy or strategy when designed to reflect local needs and solutions should also play a role in curating local policy. To achieve a clearer picture of designing for policy, a mapping methodology is proposed to document policy which is essential in responding to challenges holistically. Mapping the policy environment will allow exploring where policies converge and where they might contradict. Thus, policy mapping can support policy infrastructure to design policy in cities and urban areas. This mapping exercise will explore and understand the connections across departments and the channels of communications which help to break down the silos of policy that currently exist in cities. One of the expected results of this proposal is to create a model for designing policy infrastructure and clarify policy implications into local practice and local action for cities and urban areas. Furthermore, to understand policy on a local level through implementing initiatives into local policy and strategies.

## The role of renewable energy in sustainable economic growth for the urban and peri-urban poor in line with post-COVID19 pandemic E. M. Biririza<sup>1</sup>

<sup>1</sup>UN-BABITAT, Kenya

Context: In light with the COVID-19 pandemic, countries are trying to cope with recommended measures to curb the spread of the virus. The measures that are highlighted by WHO include tele-working and restricting movements. House occupancy rates during the 24-hour span has increased the use of energy through such services as cooling and heating, lighting and powering Information, Communication & Technology (ICT) equipment. Decentralized renewable energy options can play a greater role in enhancing power supply to support these domestic services. Solar-photovoltaics can be used for lighting and other ICT equipment while solar-thermal can be used to provide water heating services especially in tropical regions. At the same time other productive activities in the commercial and public sector in the urban poor need to continue in a sustainable manner.

Possible interventions: The possible interventions may include the use of renewable energy sources such as solar PV for electricity generation for the domestic, commercial and institutional applications. Bioenergy can also play a role in supporting domestic and productive uses. In developing countries, notably, in Africa, Asia and Latin America, some peri-urban areas are installed with agro-processing facilities such as rice mills, the husks can be used to generate electricity and heat for applications in the productive sectors. As



the pandemic will be with us for some time, it is also important to promote energy and resource efficiency measures in the built environment by designing green buildings and retrofitting existing buildings to promote natural lighting and ventilation.

Support mechanisms: For this to happen, a combination of support mechanisms need to be instituted. The governments need to consider revisiting their policies and regulations to address these challenges, especially inherent to this COVID 19 pandemic. Enabling environment (policies, regulation, financing) need to be made available so as to crowd-in private sector investments. Capacity building need to be done in different groups of stakeholders including public, financing institutions, individuals, and private sector players. Creating partnership in the uptake of low carbon energy systems.

# Stakeholder engagement in energy data collection: a case study on the implication of landlords and tenants to comply with the French obligation to reduce final energy consumption

T. Marquez<sup>1</sup>, **C. Bouverat-Bernier**<sup>1</sup>, Y. Blennoun<sup>1</sup>, T. Marquez<sup>1</sup>, <sup>1</sup>*Green Soluce, France* 

Reducing the energy consumption in the tertiary sector is key to transition to net-zero carbon cities. Today, much attention focuses on policies and technologies. Nevertheless, it's the individuals who are to implement the required actions. In 2019, the French decree on "Obligations to reduce final energy consumption in service sector buildings" requires all landlords and tenants of buildings over 1000m2 to implement actions to reduce consumption by 40% by 2030. The actions and consumption must be declared each year; thus, an early implication of landlords and tenants becomes a determining factor to achieve the objectives. The paper analyses the implication of landlords/tenants to respond to the decree. As the two actors have access to different energy data, ways to collect it, and responsibilities to comply. Although landlords take charge of the process, they only have access to the consumption of the buildings' common parts, whereas tenants are responsible for their private consumption but must share this information. To assess the implication between the two, a methodology was proposed to: a) assess their knowledge level, b) increase awareness on their responsibility, c) create material on the legal and technical implications, and d) organise events among stakeholders. The methodology aimed to increase the level of acceptance and thus the response rate for data collection. Based on the analysis of around 5.000 landlord and tenants throughout 7,000,000sgm of buildings, we observed a difference in acceptance between single and multi-tenants' assets. Single-tenants are inclined to share data due to having one energy supplier for the whole building, and few stakeholders involved. In contrast, multi-tenants share common space with other tenants, are less involved in the building's operational activities, and thus feel less responsible for its energy performance. The results highlight the challenge to get tenants on board, i.e. understand the decree, sign mandates for data automation, and collect historical bills. Nonetheless, an appropriate engagement campaign increased the response rate on data collection to 90% (office buildings) and 75% (shops) over 8 months.

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#### **SESSION 5: Planning and policy for net zero development**

### Optimisation of integrated systems: the potential of power and heat sectors coupling in decarbonisation strategies

**J. G. Arenas**<sup>1</sup> <sup>1</sup>Université Libre de Bruxelles (ATM ULB), Belgium

In order to reach the goals of the Paris Agreement on climate change, the European energy supply is aimed to be fully decarbonised by 2050. For the power sector, a massive deployment of decentralised renewable technologies will be required to provide carbon-free electricity. However, other energy intensive sectors such as gas, heat, transport and industrial sectors are more challenging to decarbonise since they mostly rely on liquid and gaseous fuels. Considering this, exploiting the synergies between energy vectors in an integrated, multi-energy system represents an opportunity for a cost-effective transition towards a carbon-free energy economy compared to the independent management of energy sectors.

The objective of this study is to provide insights on sector coupling in Belgium by developing a techno-economic tool able to optimise the interactions between energy carriers such as electricity, hydrogen, methane and heat in order to supply the Belgian power and residential heat demands in a centralised multi-energy system.

Three main conclusions were drawn from this analysis. First, compared to the individual management of energy systems, the central planning and operation of an integrated system could induce an annual cost reduction of owning and operating the system of 16% in 2050, along with a 69% CO2 emissions avoidance while only focusing on minimizing the annual costs. When applying environmental constraints such as net zero emissions and limited renewable curtailment, the annual costs increased but were still 8.5% less than business-as-usual. Then, it was concluded that Belgium could not be able to achieve an independent energy transition and will therefore need to rely on imports of carbon-free energy. In fact, the land use to generate the necessary intermittent renewable energy infeed is up to 2.7 times the available space. Finally, it was shown that nowadays, the investment costs of coupling technologies are certainly not competitive enough to reduce the total costs relative to energy supply and, while substantially improved for 2030, the results were still not sufficient to meet the EU emissions reduction targets without additional supportive energy policies.

Energy transition in France: urban communities smart grids integration case J. Arkhangelski<sup>1</sup>

<sup>1</sup>University Paris-Est Créteil, France

This research presents an example of the energy transition process application on conventional French urban communities and particularly, its possible integration into the Urban Communities Smart Grids (UCSG). For this, it was chosen one of typical urban community – Alfortville (94140), Paris region, France. The aim is to define all UCSG components and the adapted UCSG structure for the further Day-Ahead Optimal Power Flow (DA-OPF) efficient, renewable, economic and resilient energy management, giving the opportunity to get additional distribution grid flexibility. The integration of UCSG's DA-OPF management requires the centralized control and involves the integration of centralized battery storage systems (CESS) and distributed PV generation. The community data was to



process and the distribution map of the residential electricity delivery point number (< 36kVa) also as the electrical residential consumption zones were defined. It was determined the optimal penetration rate and size of distributed PV generation. Further, this data was deeply processed by the percentile notion of Bayesian credible intervals to define the optimal size of CESS. Also, it was studied the ENEDIS statistics of the average outage duration in the Middle Voltage (MV) and Low Voltage (LV) DG, to define the required CESS minimum value to supply the community in full consumption for this duration. The CESS and PV units' distribution was considered throughout the commune consumption zones. The MV scheme of Alfortville DG was brought to the simplified form. The final considered UCSG simplified scheme and its components was defined. Finally, the efficient DA-OPF management strategy was applied on the obtained community scheme. The DA-OPF is based on a data forecast system that uses a deep learning long short-term memory network. The OPF problem is formulated as a mathematical mixed-integer nonlinear programming model. The real data simulation UCSG showed significant benefits and an electricity price reduction for the considered urban community compared to a conventional case, as well as the easy applicability of proposed method. The efficiency and versatility of this research allow its easy application to others similar urban communities under UCSG integration (77% of the French population).

#### African off-grid housing

**P. Cascone**<sup>1</sup>, M. Laddaga<sup>1</sup>, B. Lau<sup>1</sup>, R. S. Phan<sup>1</sup>, M. C. Georgiadou<sup>1</sup> <sup>1</sup>University of Westminster, UK

Today, 600 million people in Africa do not have access to electricity and 900 million lack access to clean cooking facilities (International Energy Agency- 2019).

With this premise the paper will explain the research agenda of the African Off-grid Housing project on how to design and build off-grid and affordable housing solutions for the African Sub-Saharan context. Such agenda intends to re-consider the question of producing an innovative knowledge able to bridge traditional and advanced construction technologies in response to the urgent need of affordable housing in the region. Therefore, the research by design methodology is informed by the interrelations between the following aspects:

- a critical understanding on how climatic and social dynamics are affecting African housing
- the study of vernacular dwellings taxonomies of Sub-Sharan Africa

According to such analysis the most flexible and affordable vernacular genotype was selected and evolved through a design methodology based on a parametric approach. Therefore, the form finding of this initial housing genotype was informed by the negotiation between the site-specific climatic conditions, the spatial and energy needs of local users and the material systems available on-site. The performative criteria of the form finding were including the question of self-sufficiency in relation to energy, water and food accessibility.

The evolution of such initial prototype has generated a catalogue of possible variations (global geometry, spatial configurations, materiality etc) able to respond to different site specific conditions and requirements. The catalogue of possible configurations is the result of a comparative design methodology based also on environmental testing and physical prototyping. The best negotiation between the different criteria, has been selected and developed forward as a paradigm to generate a design protocol and a construction kit open to possible variations in terms of scalability and incrementality.





The research project has been discussed also with Arch, Vincent Kitio (Chief, Urban Energy Unit – UN-Habitat) with the aim to define innovative policies for effective actions in African countries, which could eventually be adapted to suit other specific Global South's contexts.

#### Moving towards renewable and grid-supportive district energy systems – experiences gathered from design to operation of a case study in Germany J. Hahn<sup>1</sup>, C. Rust<sup>1</sup>, W. Jencsh

<sup>1</sup>Centre for Energy Efficient Buildings and Districts, Munich University of Applied Sciences, Germany

The population living in urban areas worldwide has grown continuously over the last decades and will further increase in the future. In contrast to single and multi-family dwellings, it is very challenging, to cover the entire energy demand of multi-floor and highrise buildings, with local renewable energy sources. However, large buildings with a combination of various uses are most common in cities. In Germany residential and nonresidential buildings consume about 35% of today's final energy. The oral presentation will provide insights from a practical case study (+EQ-Net: Grid-neutral residential and nonresidential building "puls G" in Geretsried) in the suburb of Munich, Germany. The recently built high-efficiency district building is scientifically accompanied from early design stages to real operation. Seven storeys combine 66 residential, seven commercial units and a fullrange supermarket. In addition to the various uses, the energy system also has a wide spectrum of sources. Heat pumps with geothermal ground collectors and heat recovery from the exhaust air as sources, as well as cogeneration units form the basis. Electrical and thermal storages installed between energy supply and consumption by the users allow a temporal decoupling and therefore an optimization of sources. A large rooftop solar system supplies electric energy to operate the heat pumps or appliances in the units. Furthermore, heating and cooling applications are combined to save energy purchases from the public grids. The aim of this research is to design a district building, which should be as gridsupportive as possible and driven by a high amount of local renewable sources. To increase efficiency, synergies between various uses are analysed and subsequently integrated into the innovative energy concept. In the project, only current available technologies are applied. Against the background of fluctuating renewable sources, efficiency and occupant comfort, the interaction and control of all technical systems as well as temporal variations in energy use are key factors to meet the set objectives. The presentation will cover important aspects of design and construction as well as findings from the scientific technical monitoring and evaluation.

**Displacing University campus fossil fuel power supply with solar PV in Saudi Arabia S. Alsulamy**<sup>1</sup>, A. S. Bahaj<sup>1</sup> <sup>1</sup>University of Southampton, UK

The Kingdom of Saudi Arabia is committed to replace its reliance on fossil fuel electricity generation through expansion of renewable energy technologies such as solar photovoltaic (PV) and wind. The need to reduce greenhouse gas emissions has led the country to target 40 GW of PV power generation by 2030. The development of projects to achieve this target needs to be augmented with research to overcome the challenges faced in the technical capability of the country. This work aims to investigate the impact of solar photovoltaic PV



electricity supply in a university campus, to displace the current fossil fuel systems. The work is focused on the main campus of the University of Jeddah where load profile data and power expansion needs are known. The university campus covers 5 million m2 of which 300,000 m2 has potential for PV utilization representing 6 % of the total campus area.

The methodology presented encompasses modelling of a multi-MW solar photovoltaic systems in including options for building integrated and ground mounted systems, taking into account weather conditions, actual consumption data of the university and different development scenarios based on conducted surveys.

University smart meter electricity data is used to build a full year load profile in kW per half hour for the year of 2019. The analysis of the weather and consumption data showed that air conditioning loads are responsible for 72% of the campus load. Evaluation of the load profile and peak consumption hours was important to design the appropriate size of PV system. Different scenarios were considered in the system design. The results show that a combined PV and grid connected scenario to supply the campus will decrease the total cost of electricity over the next two decades by a 20 to 30 percent respectively. This corresponds to a reduction of the current carbon emissions of campus by half.



#### SESSION 6: Planning and policy for net zero development

#### Sources, behaviour and mitigation strategies influencing indoor air quality

S. Gauthier<sup>1</sup>

<sup>1</sup>Universty of Southampton, UK

The average person in the UK spends more than 90% of their time indoors, and indoor air quality related emissions can contribute significantly to total air pollution exposure. Exposure to indoor air pollutants, such as particulate matter, volatile organic compounds, carbon monoxide and biological materials can cause a range of health conditions. Despite this, relatively few studies focus on indoor air quality compared to outdoor air quality. This research focuses on indoor sources (cooking, cleaning and mould). Using the UK Time Use Survey, daily household cooking and cleaning activities were reviewed to establish a day typical schedule. This schedule was used to undertake experiments in a controlled environmental room to characterise indoor air pollution exposure. Then, the results from these experiments were used to develop and validate a CFD model. Finally, this CFD model was used to explore many behavioural activities and mitigation strategies. The results of this research have implications to building management and public health policies.

### Evaluating occupant perceptions of their presence and energy-use patterns in shared office spaces

**M. K. Annaqeeb**<sup>1</sup>, E. Azar<sup>1</sup>, D. Yan<sup>1</sup>, V. Novakovic<sup>1</sup> <sup>1</sup>*Norwegian University of Science and Technology, Norway* 

Occupant Behavior (OB) is a complex phenomenon, and has several facets, ranging from occupant comfort, presence, movement, habits, and the associated energy-use patterns of each. While OB has been recognized as a driving factor in building energy performance, this complexity is not captured in building simulation models and design criteria, most of which rely on static/fixed schedules. A significant gap in the research on OB and its models is the exclusion of social influences as a parameter. Recent studies have pointed out the need of incorporating social influences in order to achieve a more holistic view of OB.

Evaluating social influences is usually conducted with the use of the Theory of Planned Behavior (TPB), which recognizes three factors in social influences: perceived behavioral control, subjective norms, and personal beliefs/motivations. Based on TPB, this study assesses the perceptions of occupants about their own presence. This is done in the form of hourly schedules for presence, motivations, and energy-use patterns of plug loads in a shared office space, which were gained through a survey. The perceptions are then compared to the actual measurements, which were derived from monitoring these occupants with regards to their presence, environmental parameters, and plug loads for a period of six months using different sensing modalities. This enabled a comparative analysis that evaluates the correlations between perceived presence, actual presence, and standard schedules from ASHRAE. In addition, the plug loads were monitored with respect to each device, which enabled the investigation of occupant's motivations and intentions regarding energy-use habits and their influences on actual energy-use. The results from this study can be used for developing social models for OB, by defining influence factors for different parameters of social influences.



### Valley city ventilation under the calm and stable weather conditions Z. Cao<sup>1</sup>

<sup>1</sup>Xi'an University of Architecture and Technology, China

For valley cities, the high frequency calm and stable weather conditions caused by terrain barrier and temperature inversion will result in very unfavorable diffusion conditions and limited environmental capacity, leading to frequent haze and heat waves. In this case, the interaction of two mesoscale circulations, slope flow and urban heat island circulation, is the basic model of valley urban ventilation, which dominates the dissipation of heat and pollutants in urban areas. At present, some studies have been conducted to understand the above process. A critical review of relevant studies will be presented from research methods and research contents, respectively. Meanwhile, shortcomings of existing researches will be discussed in order to explore new research directions in the field of valley city ventilation

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### Assessment of environmental comfort in educational buildings. Case study in the north of Spain in winter conditions

**A. Arriazu-Ramos**<sup>1</sup>, A. Monge-Barrio<sup>1</sup>, N. Martin-Calvo<sup>1</sup> <sup>1</sup>University of Navarra, Spain

The improvement of energy efficiency in educational buildings has to ensure adequate indoor thermal conditions and a good level of air quality, that is especially relevant in these buildings due to the high occupancy of the classrooms and its relation to the sense of tiredness and lower school performance of the students. Buildings built almost 50 years ago present additional difficulties because they have thermal envelopes with low energy performance, heating systems without adequate regulation and control (with high energy consumptions and high CO2 emissions) and without air ventilation systems. Before defining and designing rehabilitation measures, an in-use assessment of the building is required, monitoring and analysing energy consumption and environmental conditions, and surveying students and teachers. Therefore, measures without cost or with low cost can be studied in order to improve the building performance. In this Case Study, an in-use assessment of a High School with almost 1000 students with ages between 12 and 17 years old, in Pamplona (North of Spain) is presented. 9 classrooms were monitored during the first 15 days of March 2020 (6 of them considered representative of the classrooms of each course, and 3 of them with different constructive conditions). In addition, surveys-in-time were done in two of them (in different wings and floors of the building). These surveys were answered at the beginning and at the end of three classes (first class, the class after the break, and the last one), and 204 responses were obtained. The adolescents were asked about thermal sensation (TSV). thermal preference of change (TPV), sensation of stuffy environment and tiredness among others, and responses were matched with monitored values of temperature, relative humidity and CO2 concentration. Analysis of results allows to verify how adolescents are sensible to inadequate environmental conditions that should be improved in order to increase their concentration and academic performance. In addition, this study has allowed the detection of problems related to heating regulation and the need of establishing regular patterns of natural ventilation that improve environmental condition and reduce the sense of stuffy environment and tiredness in the students.

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### Investigating inter-generational factors on behaviour and human building interaction

**G. Sewell**<sup>1</sup>, S. Gauthier<sup>1</sup>, P. James<sup>1</sup> <sup>1</sup>University of Southampton, UK

Residential buildings in the UK represent twice the energy consumption when compared to all industry and services. Moreover, this is consistently increasing despite national and international policies. Within the home, space heating is responsible for over 60% of this total, thus representing the greatest potential for change. Many factors influence the occupant's behaviour towards heating usage; some outside the occupier's control such as weather, building fabric and energy cost, but occupier thermal comfort is the obvious driver towards heating usage. However, a user's energy literacy and personality type may also influence occupants' heating behaviour. These traits, along with perceived thermal comfort, can significantly vary with differing cultures and demographics. Demographics such as age (both younger and older than the main occupant) have seen little research into their respective influences on the main occupant's behaviour, but may be considerable factors in the overall use of domestic heating usage. These factors could include sub-conscious health concerns for older relatives or pressure from the ever-increasing environmental awareness of children. It raises the question; do other generations affect occupants' heating behaviour, in particular the frequency and type of interaction with the heating system in the home? To address this question, a survey engaged a pool of 26,000 dwellings in the UK. The survey also gathered information on the occupier's energy literacy levels, personal traits, social demographics and general dwelling information. Analysis initially divided the participants' homes between those with a younger generation, older generation or those with both. A second contrast was drawn between those homes that saw an increase or a decrease in heating usage within these groups. The survey results were analysed with reference to these contrasting groups. Then the analysis provided evidence describing if and how intergenerational factors influence occupants' heating behaviour and human building interactions. These results helped to identify potential pathways for future research; leveraging these inter-generational influences to reduce household energy consumption. Moreover, these results could be used to improve the future engagement of public health and national energy reduction policies to aid sustainable development.



#### SESSION 7: Artificial intelligence and policy for net zero development

## Multivariate monthly water demand prediction using classical, ensemble and gradient boosting tree-based machine learning techniques

P. Banda<sup>1</sup>

<sup>1</sup>Royal Melbourne Institute of Technology, Australia

Short, medium, to long-term water management planning, requires reliable and accurate water demand forecasting. Water demand prediction is affected by climatic, socio-economic, and demographic variables. This paper investigates urban monthly average water demand prediction, using gradient boosting tree-based ensemble machine learning techniques. For this predictive task, classical (decision trees), ensemble (random forest), and gradient boosting (LightGBM, AdaBoost, and XGBoost) machine learning models were developed based on the available monthly water demand, climatic, economic, and demographic data. Three data train-test split schemes on the water demand timeseries were considered to determine the effect of data size on water demand prediction. Sensitivity analysis was employed to reduce input feature dimensionality while maintaining model accuracy. A univariate timeseries (water demand only) produced R2 values of up to 0.91, which increased to 0.94 with the addition of calendar and climatic features. Increasing the training data size from 70% to 90% resulted in improvements in the RMSE and MAE scores by ensemble and gradient boosting methods. The random forest and the AdaBoost models showed improvements of up to 69%. Sensitivity analysis revealed successful input feature dimensionality scheme from a potential 17 input attributes to only seven. The most current water demand and climatic observations were influential in improving monthly water demand prediction for Melbourne city. Reducing the number of inputs is favourable because it increases model efficiency and reduces data collection expenses. The gradient boosting group of models showed robust and faster execution time, especially with the increase in training data, which is attractive for medium-term urban water demand forecasting.

### The operational cost of infrared thermographic detection of faulty photovoltaic solar modules using deep learning

**A. Klink**<sup>1</sup>, A. S. Bahaj<sup>1</sup>, P. James<sup>1</sup> <sup>1</sup>Universty of Southampton, UK

Solar photovoltaic (PV) energy generation is rapidly becoming the power generation technology of choice. The International Energy Agency (IEA) predicted in 2000 that there would be 18 GW of global solar photovoltaic capacity by 2020. At the end of 2020, the IEA estimates that global capacity reached at least 760 GW. This rapid growth has been driven by falling manufacturing costs, as described by Swanson's law. Labour and maintenance costs have remained relatively static in comparison and now represent more than 50% of the costs of PV in utility-scale farms in the UK. Due to this, reducing the costs of labour and maintenance is vital to further decrease the price per kWh of PV and hence increase PV adoption. This work presents a deep-learning computer-vision algorithm that can automatically detect faulty PV solar modules using non-destructive imaging. The algorithm uses deep convolutional neural networks that learn how to classify PV modules as faulty/non-faulty based on pre-labelled "training" data. We compare and contrast the algorithm's performance and operational cost when using this method for the following applications:

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- close-up using electrolumiscent imaging,
- close-up using drone-mounted infrared thermographic (IRT) imaging, and
- long-distant using drone-mounted IRT imaging.

Long-distant drone-mounted IRT imaging is the cheapest and safest to operate out of our tested applications. Despite long-distant imaging having the lowest resolution images, our preliminary findings show that our algorithm performs very well, indicating that this has the ideal price-to-performance impact for most operations.

#### Carbon reduction strategies for existing public buildings – an interpretable datadriven approach M. Manfren<sup>1</sup>

<sup>1</sup>Universty of Southampton, UK

The average person in the UK spends more than 90% of their time indoors, and indoor air quality related emissions can contribute significantly to total air pollution exposure. Exposure to indoor air pollutants, such as particulate matter, volatile organic compounds, carbon monoxide and biological materials can cause a range of health conditions. Despite this, relatively few studies focus on indoor air quality compared to outdoor air quality. This research focuses on indoor sources (cooking, cleaning and mould). Using the UK Time Use Survey, daily household cooking and cleaning activities were reviewed to establish a day typical schedule. This schedule was used to undertake experiments in a controlled environmental room to characterise indoor air pollution exposure. Then, the results from these experiments were used to develop and validate a CFD model. Finally, this CFD model was used to explore many behavioural activities and mitigation strategies. The results of this research have implications to building management and public health policies.

### Data driven anomaly detection in office environmental measurement

**F. Montet**<sup>1</sup>, L. Rychener<sup>1</sup>, J.-P. Bacher<sup>1</sup>, J. Hennebert<sup>1</sup> <sup>1</sup>*HEIA-FR*, *Switzerland* 

In smart buildings, digitalisation is at the core of evolution. The vast amount of produced data induces an entropy in the systems to monitor and increases the difficulty to create context-aware anomaly detection systems generically. In this study, we explore the use of server monitoring methods to improve the fields of predictive maintenance and wellbeing of building users. Our method takes the use case of a CO2 level anomaly detector in a six desks office. At first, presence, noise and CO2 levels are collected and pre-processed for forty days. Then, a Facebook Prophet model is trained including various meta-features like holidays and weekends. Finally, the model's prediction is used as a baseline to compute an error on which warnings are signalled if they don't pass a statistical test. The results show that data-driven approaches can be used to analyse environmental signals where human stochasticity is present with little expert knowledge. Furthermore, to base the error on a model output allows capturing many types of anomalies with a single system. Finally, the genericity of the developed system allows for a potentially wide range of use cases.



# Efficient modelling framework of urban heat island effect and generating hourly weather data for outdoor comfort assessment: a case study of Shenzhen P. Shen<sup>1</sup>

<sup>1</sup>Harbin Institute of Technology Shenzhen, China

Urban heat island (UHI) is an outcome of urbanization and conglomeration of human population, which exerts impact to local microclimate and thermal comfort. Since China is going through a rapid urbanization process, the microclimate of its urban context is facing challenges brought by UHI effect. In this research, an information-collection framework based on map capturing and unsupervised clustering technique for building type classification is developed to gather input parameters for UHI model. Urban Weather Generator (UWG) is utilized for UHI modeling in a center city area of Shenzhen, China. The proposed framework together with a differential-evolution-based calibration procedure is implemented to the development of the UWG model for the selected urban tissue. The model is calibrated by metered weather data and used to morph the typical meteorological weather (TMY) data. The evaluation of outdoor thermal environment using UTCI under the impact of UHI is conducted. When the effect of UHI on thermal comfort is taken into consideration, the percent of time comfortable accounts for 50.377% all year round, and it is remarkable that the percent heat stress increases by 2.49%.



### **SESSION 8: Energy, emissions and buildings**

### Energy consumption of system-built versus cavity wall construction in the social housing sector

**L. Blunden**<sup>1</sup>, A. S. Bahaj<sup>1</sup>, P. James<sup>1</sup>, A. Waggott<sup>2</sup> <sup>1</sup>University of Southampton, UK <sup>2</sup>Portsmouth City Council, UK

'Non traditional' (or 'system-built') houses are a category of dwelling built in the UK in the post Second World War period, from approximately 1945 to 1970. There are a number of construction methods falling into this category and include elements such as in-situ or precast concrete; steel or timber frames and cladding. These types of houses are thought to have poorer thermal performance on average than traditional cavity brick/block types due to the use of lower quality materials and rapid construction in response to housing shortages. However, there is lack of published data on the actual difference in energy performance between traditional and non-traditional construction dwellings.

In 2013 Portsmouth City Council received funding from the Department of Energy and Climate Change to replace gas boilers in 525 of its properties with new efficient condensing units. The replacement programme was focussed on vulnerable and low-income households in line with the Government's fuel poverty priority groups. Approximately half of the dwellings were of the system-built type. As part of the programme, historic meter readings were obtained for the affected households. In combination with energy performance certificates (EPC) for the dwellings and tests the hypothesis that system-built houses have poorer energy performance. The results have implications for improving the targeting of local authority funding for energy efficiency upgrade programmes.

### Operational emissions in prosuming dwellings: a case study research comparing different sources of grid CO2 intensity values in South Wales

**J. P. Fernandez Goycoolea**<sup>1</sup>, G. Zapata-Lancaster<sup>1</sup>, C. Whitman<sup>1</sup> <sup>1</sup>Welsh school of Architecture, Cardiff University, Wales

The paper presents an analysis of operational CO2 emissions from electricity consumption and exports in 4 on-grid photovoltaic (PV) prosumer dwellings in South Wales (SW). The study aims to identify and quantify the variation of operational CO2 emissions when different data sources are used for the calculations and explores the possible relevance of grid interaction metrics for the results. Monitoring data from four urban dwellings obtained during a year-long period (April 2020 to March 2021) was used. Three different sources for the grid's CO2 intensity data are considered: 1) UK average values, 2) SW regional values and 3) DEFRA's CO2 Emissions Factor (EF) for the study period. UK and SW grid CO2 intensity were obtained on a 30-minute resolution, whereas EF is a year constant. All carbon emissions calculations were performed on a 30-minute resolution. Results showed that total CO2 emissions from grid imports for the study period using SW regional data were the highest across the four dwellings: between 67.5% and 69.2% higher than using UK values; and between 41.1% and 45.1% higher than using the EF. When a net emissions calculation approach was taken, the difference between the higher and lower result for each dwelling ranged between 62.3% and 103.1%, with no consistent order of datasets across the different dwellings. The results suggest that CO2 reduction effectiveness of on-site PVs depends



significantly on the calculation methods and data source. Similarly, the findings suggest a relation between the grid CO2 intensity and operational emissions, highlighting the potential of the time-of-demand management to maximise CO2 emissions reductions.

### The contribution of decentralized photovoltaic systems to energy poverty alleviation in La Pila, Slp, Mexico

**R. C. Soares**<sup>1</sup>, J. Hamhaber<sup>1</sup>, M. A. Siller<sup>1</sup>, J. Z. Gutierrez<sup>1</sup> <sup>1</sup>ICLEI South America, Brazil

The nexus between deprivation of access to modern energy, poverty and the environment has been in evidence in international sustainability projects and studies. The use of microscale renewable energy technology has been promoted not only for its environmental benefits but also for the potential co-benefits of its applications.

This research analyses how decentralized photovoltaic solar energy systems (DCPV) contribute to the energy poverty alleviation of La Pila Delegation, a vulnerable peri-urban community located in San Luis Potosi, Mexico. Adopting a multidisciplinary method based on secondary data, this study executed an energy poverty diagnosis, a policy analysis and built six different scenarios of the application of DCPV under distributed generation schemes. An impact assessment for social, environmental and financial aspects was applied in each scenario. Its results indicate that the application of grid-connected DCPV contributes to the local energy poverty alleviation by providing security and more affordability to the electric energy chain that is responsible for delivering part of the community's fundamental energy services. Further, it was discovered it positively impacts aspects of the energy vulnerability, precarity, injustices and fragilities of the socio-energy system that collaborates with the existence of energy poverty in the location. Environmentally, it supports climate change mitigation due to the avoidance of greenhouse gas emissions and water consumption in energy generation, also having the co-benefit of distributing financial savings to different governmental institutions and local households. Recognizing its limitations, this research concluded that this type of application represents a step further towards positioning technology in service of people's fundamental needs in coherence with the planetary boundaries.

Beyond green: mainstreaming sustainable material choices in Jordanian residences M. Razem<sup>1</sup>

<sup>1</sup>University of Cambridge, UK

While environmental policies for greening the built environment are making headway in Jordan in the form of codes and voluntary rating systems, they have not produced the aspired change in number of buildings. Architects are key to achieve transition to decarbonized buildings. However, for this transition to take place, there is a need to look beyond mere 'education of professionals' as most viable path to change, and instead gain a deeper understanding of collective routines of architects' practices that have become unchallenged and historically embedded. This study focuses on disruptions to the norm when green building materials are selected compared to local conventional choices, in Jordanian residential buildings, from architects' and clients' perspectives. Guided by a practice-based approach, semi-structured interviews with thirty architects and the resident-



families of two green homes aimed to unearth normative meanings associated with materials to identify which of these meanings led to unsustainable material choices. Findings reveal achieving compliance in the material section in the rating system was the most challenging for three reasons. First, compromised execution of materials due to incompetence of material suppliers' market, construction workers, and some professionals. Second, prevalence of certain cultural, gendered, and social beliefs that derail sustainable choices. These have been historically shaped and deeply embedded material choices around clients' progressive or conservative identities, ensuring privacy, and expressing status. Third, aesthetic tendencies of some architects to legitimate their practice draw on Western disciplinary images and doctrines. Thus, contrary to conventional policy orientation of assuming that green design training and the offering of green materials would incur change, the study highlighted the role of the deeply lodged collective norms that challenge rating systems rhetoric and practice. Based on these findings, localized policies for sustainable material choices would be more effective when they holistically intervene; to enhance competences within the construction market culture, provide sustainable materials that match clients' aspirations, and re-acquaint architects to local and vernacular solutions as alternatives to what has been long obscured by training-instilled Western ideologies.

### Does design-for-deconstruction increase upfront embodied carbon? Life cycle assessment of a deconstructable building.

**M. Roberts**<sup>1</sup>, S. Allen<sup>1</sup>, D. Coley<sup>1</sup> <sup>1</sup>University of Bath, UK

The construction industry produces 140 million tonnes of waste and consumes 400 million tonnes of raw materials annually within the UK. The concept of a circular economy allows materials to be retained in the value chain, thus reducing waste production, raw material extraction and their associated environmental impacts. Design-for-Deconstruction (DfD) helps enable a circular economy by considering buildings as material banks, and ensures buildings can be deconstructed and reused or reconstructed. The benefits of DfD are challenging to quantify as they are realised at end-of-life, which possesses the greatest uncertainty in a building's life cycle. A life cycle assessment (LCA) of an educational building in Swansea, UK has been conducted to investigate how DfD strategies influence a building's embodied impacts. The case study building has been designed to be deconstructed in 2026. The DfD strategy will enable the building to be fully disassembled, with the potential to be reconstructed in the same configuration, at the end of its service life. The building incorporates on-site energy generation and storage technologies allowing the building to respond to fluctuating grid carbon intensity. The Global Warming Potential (GWP100) is reported for the following life cycle stages: cradle-to-gate [A1-A3]; transportation [A4]; construction [A5]; replacement [B4]; and, operational energy use [B6]. When assessed over a 60-year period, the A1-A5 impacts account for 60% of the building's total GWP100, B4 impacts account for 25% and B6 impacts account for 15%. The energy generation and storage systems contribute 18% of the building's A1-A3 impacts. The results demonstrate the importance of the embodied carbon of building services in buildings that employ on-site generation and energy storage technologies. For the case study building as a whole , DfD strategies have been implemented while keeping cradle-to-gate impacts 25% below current 'business-as-usual' target values for the UK. The case study demonstrates that, when implemented effectively, DfD strategies can produce net-reductions in whole-life GWP100 impacts while providing end-of-life benefits to help enable a circular economy.



#### **SESSION 9: Advances in materials and technology**

### Utilisation of buildings rooftops for PV power generation in Saudi Arabia A. Alghamdi<sup>1</sup>

<sup>1</sup>King Abdulaziz University Saudi Arabia

The electricity demand in the Kingdom of Saudi Arabia (KSA) is almost entirely dependent on fossil fuels for generating power. The hot climate made it necessary to use air conditioning in buildings, which consumes a lot of power. The increase in power demand makes it essential to use the natural resources, such as solar and wind energy, to meet part of this demand.

This paper addresses the utilisation of buildings' rooftops for PV power generation in KSA and presents findings from monitoring the electricity consumption of two typical domestic buildings (villas) in the city of Jeddah. The electricity consumption observations were associated with indoor environmental conditions to study how and when cooling demand affects final demand. The study investigated options to serve the observed demand profile of the villas with simulated power generation from arrays of PV panels installed on the two buildings' roofs. Finally, a model of dynamic solar radiation simulation was developed to assess the hourly electricity generation, and a cost-benefit analysis was conducted for different capacity PV systems scenarios. The results indicate that locally used rooftop PV output could reduce the household electrical demand from the grid. more so when combined with building refurbishment solutions. The economic analysis discusses the implications of a proposed feed-in tariff with the associated payback periods and ROI, as well as proposals for PV system deployment at a large scale on the roof of buildings in KSA.

Encouraged by the findings of this study, further research has recently set of to implement buildings' rooftops PV power generation on 20 houses, with 40 more houses as control, in Jeddah city. The research will incorporate different technology interventions in houses tied with thorough analysis, which will give clear understanding of the consumption profile and the intervention impact. The collected data will provide dataset, which will provide guidance to planning and inform policy. These interventions can provide understanding of how this local PV power generation impacts networks. This project is sponsored by the Ministry of Education of Saudi Arabia as an international collaboration between King Abdulaziz University and University of Southampton (Energy.soto.ac.uk).

Thermal performance of advanced material in intelligent concave and convex building façade in semi-arid climate of low-rise residential building

**Z. H. Baiz**<sup>1</sup>, C. Atakara<sup>1</sup> <sup>1</sup>Cyprus International University, Cyprus

Building energy consumption, creating a comfortable indoor environment, and enhancing building thermal performance, from its construction until demolition, are the major issues nowadays. Many strategies and different designs are used to obtain a comfortable environment. These issues are considered as factors of emerging fields of intelligent building. Sometimes, an intelligent building does not require technology. Many old buildings offer intelligent features. Also, it is not supported to define the constructions that are not working well as intelligent buildings even if they are well equipped. Although various intelligent façades are seen worldwide, the context and climate vary from different places. Yet, fewer attempts to create an intelligent façade in a semi-arid climate available. The aim



is to create a building that provides a more comfortable indoor environment with less energy demand. By the use of different intelligent building materials and show its response, according to different concave and convex building façade. The subject will be done in three steps, firstly, reviewing the existing and recent studies that determine the factors affecting building thermal performance. Then, study advanced material that could be used in the facade in the semi-arid climate zone. Finally, it investigates the adaptation of the advanced material on the intelligent building façade in the low-rise residential building by testing samples of concave and convex building façade in the semi-arid climatic zone. It will show how these samples, perform thermally to get suitable concave and convex building façade. The results will show that, for the same climatic condition, the different shapes of the buildings will provide various thermal performances.

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## Optimized battery thermal management system using PCM composites- forced convection: experimental and numerical investigation M. Karkri<sup>1</sup>

<sup>1</sup>Paris-Est Créteil University, France

The development of photovoltaic systems and electric vehicles is dependent on the development of Li-Ion batteries. Efficient thermal management of Li-Ion batteries is necessary to ensure better performance, autonomy and optimal lifespan. Active cooling systems (air/liquid) are the most widely used thermal management systems. However, these systems are costly in terms of energy consumption, investment and maintenance. The use of phase change materials (PCM) to absorb of heat generated by Li-Ion cells can represent an alternative solution. However, PCMs have a low thermal conductivity which limits heat exchange capacities and reduces the kinetics phase change. In order to increase the heat exchange capacity between the battery and the PCM, a metal foams can be added. Indeed, metal foams have specific characteristics such as high porosity (between 0.8 and 0.98), high thermal conductivity and a large contact surface. This qualifies them to be a good solution to intensify heat transfer. In this work, thermal management of Li-ion batteries using PCM-Metal, Foams composites has been studied experimentally and numerically at the cell scale. Firstly, a Metal foam-PCM composites were developed and characterized. In a second part, and in order to understand the transfer mechanisms during solid-liquid phase change, a numerical and experimental studies were carried out. The morphology and properties of the foam on the PCM kinetics phase change was studied. The results obtained allowed to classify RT27- Aluminum Foam composite as the best candidate to keep the temperature of a Li-ion cell within the desired temperature range (15°C- 30°C). The last part was devoted to the study of thermal phenomena in a typical Li-ion cell: 18650, and implementation of a passive thermal management system for Li-ion batteries. Experimental and numerical results [1-2] proved that the addition of an aluminum foam allows a more efficient thermal management of the cell.

## Analysis and evaluation of CT transformation error for non self-contained smart meters installed in smart cities

**C. Ndung'u**<sup>1</sup> <sup>1</sup>Kenya Power, Kenya

Smart cities in recent time have attracted numerous attention from investors due to reliable and stable power supplies sourced from various power distribution generation resources.



Consequently, heavy industries and large power consumers are rapidly increasing in smart cities. To measure accurately the energy consumed and demand, non-self-contained smart energy meters are installed at point of common coupling (PCC). Load factor for most of large power consumers are relatively low due to production schedule (week days and weekend) and market dynamics. This paper aims to answer a question whether or not the current transformer employed in non-self-contained smart energy meter adversely affect energy and demand measurement when it operates below ankle point and/ or above knee points. Current transformer, commonly abbreviated as CT, is an electrical instrument transformer that is designed to produce an alternative current in its secondary winding which is proportional to the current being measured in its primary circuit. It plays two main key roles; (i) Electrical isolation between measuring devices and high voltage conductors and, (ii) Current sensor for a transformer operated (non-self-contained) energy meter. Analysis of energy and demand measured by smart energy meters from sampled large power end users in a smart city when compared with energy captured by Ampcoder (current primary logger) revealed that the energy and demand captured are correct despite CT secondary current being below ankle or above knee points. This was also confirmed in the laboratory setup using a CPC-100 equipment (current generator equipment) where the CT accuracy was found to be well within accuracy error limits even when the CT was subjected to a primary current as low as <0.05% of CT nominal current and as high as >150% of nominal current of CT.

### The effect of enhancing super insulation aerogel for future building façades in north of Iraq

**Z. H. Baiz**<sup>1</sup>, C. Atakara<sup>1</sup> <sup>1</sup>*Cyprus International University, Cyprus* 

Aerogel is a sort of engineered porous substance. It has unique chemical and physical properties with different types of opaque and translucent. Thus, it is considered one of the most encouraging materials in various applications such as spacecraft, electronic devices, and buildings. In building, translucent aerogel uses for window construction. It plays a vital role in increasing energy saving and enhancing the building acoustically. Unfortunately, though its high cost, aerogel is a brittle material that makes it hard to produce large-sized free crack windows and prevents the window from being operable. Also, it is not optically transparent, which isolates the occupant from the outside view. All the mentioned limitations restrict the designer and architect from putting aerogel windows on the building facade. Thus, enhancing the aerogel window system by making it more flexible and less brittle can get the better efficient glass with larger size and transparent glass that experiences the natural quality of the light and outside view. As a result, it may give the building a more functional façade that can fulfil people's needs in the future. So, the study will evaluate the efficiency of façade in the future. Therefore, the study's main aim is to predict the capability of improved aerogel in creating a facade that fulfils a human need while increasing the efficiency of the building from different perspectives. This study examines improved aerogel windows and their role in enhancing current residential buildings in the north of Iraq. Ecotect and Dialux software used as a research tool. The paper concluded that the capability of improved aerogel will give the building a new facade that is more environmentally friendly and provides human comfort while still transparent compared to the current façade

## Southampton

#### **SESSION 10: Local responses to sustainability targets**

#### To what extent has the climate emergency strategy adopted by Southampton City Council met the objectives set for it?

S. Leggett<sup>1</sup>

#### <sup>1</sup>Southampton City Council

This oral presentation will analyse the extent to which the climate emergency strategy adopted by SCC has been successful reflecting on the successes and failures during the period from mid-2018 to current day. The presentation will outline key council policies were that were developed, identifying, and analysing the main factors that have combined during the adoption and implementation of council's climate emergency strategy and green city agenda. The areas identified are political factors, economic factors, and key stakeholder relationships. Case studies will be reviewed in these three areas. The case study in the political factors section will highlight the power dynamics at play during the easing of lockdown from the Covid-19 pandemic and the roll out of a key transport policy. The case study in the economic factors section will identify how a proven track record of successful project delivery enabled the council to attract greater funding opportunities. The case study in the key stakeholder relationships section will highlight how a damaged or broken relationship can place the council's key polices at high risk of failure.

#### A study of energy consumption for office buildings in Vietnam for sustainable energy and climate change mitigation

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This study used survey data to evaluate the current status of electrical energy use of commercial office (CO) and governmental office (GO) buildings in Hanoi and Ho Chi Minh City (HCMC) in Vietnam. Main data used in the analyses including floor area and monthly electricity consumption which were gathered from the questionnaire survey for 57 CO and GO buildings in two cities – conducted by the Vietnam Clean Energy Program in 2015. The basic statistical analysis techniques were used to evaluate the electricity consumption intensity of office buildings and preliminarily analysis key factors affecting the energy consumption of these buildings. The results generally showed that CO buildings consumed significantly more electricity than GO buildings in all months of the year and the variation and trend of mean monthly electricity consumption intensity of the buildings strongly depend on that of ambient air temperature. In addition, the energy use intensities (EUIs) of CO buildings, GO buildings, and both buildings (CO+GO) in HCMC (in a hot climate all year round) were higher than those in Hanoi (in a climate with four distinct seasons). The mean EUIs of these buildings in Hanoi, HCMC and both cities were 105.9, 116.4, and 109.6 kWh/m2 floor.year. The findings of this study are useful information on the status of energy use and energy efficiency of CO and GO buildings in Hanoi and HCMC, thereby contribute scientific bases to the development of policies and solutions to promote the energy efficiency of CO and GO buildings in the coming years and urgent actions for sustainable energy and climate change mitigation in Vietnam.



### A methodology for optimising electric vehicle charging, ensuring access to all citizens – a case study in Winchester District, UK

**M. Mahdy**<sup>1</sup>, P. Turner<sup>1</sup>, A. S. Bahaj<sup>1</sup>, N. Wise<sup>2</sup>, H. Ricketts<sup>2</sup> <sup>1</sup>University of Southampton, UK <sup>2</sup>Winchester City Council, UK

Electricity charging points for cars are the main factor to reduce the carbon emissions in the transport sector, especially to encourage electrical vehicle (EV) private car use. Many drivers are unwilling to invest in an EV without knowing whether they can access convenient charging points. Therefore, to help encourage the uptake of EVs a methodology is required to determine the optimum siting of charging infrastructure to inform local authorities' deployment plans.

The paper presents an approach to determine the optimum spatial siting of EV charging point locations within Winchester District, UK. The methodology is based on the Analytical Hierarchy Process (AHP) linked to site spatial assessment in a Geographical Information System (GIS). The assessment considered key criteria such as road type, road access, on-road parking availability, road slope hazard, proximity to fuel station/current charging point/future charging points/car parks/Low voltage electrical network, EV ownership distribution, and population distribution. The process contains two filters, in the first filter all restricted roads were excluded from further analysis, the Boolean Mask filter reduced the potential road segments from over 9000 to around 2000. The second suitability filter was applied to settle on a suitable 44 EV charging points, which was verified using Google Earth® determining the most suitable locations for EV electricity distribution infrastructure.

### Evaluation of electric scooters as an alternative transportation mode for home-work trips in France

T. Marquez<sup>1</sup>, **Y. Bennouna**<sup>1</sup> <sup>1</sup>Green Soluce, France

In France, the transportation sector is responsible for a third of greenhouse gas emissions. Moreover, according to the French Institute of Statistics, in 2020, 72.8% of nationwide homework trips were made by car. This presents a challenge on how to reduce the emissions associated and an opportunity for cleaner modes of transport, for example e-mobility options such as electric scooters. Where a modal shift of car-users towards e-scooters should result in improved environmental benefits. The paper presents the results of a pilot project in Paris, France, which aims to evaluate the influence of micro-mobility to reduce the environmental footprint of home-work trips. Part of this research is carried out within the framework of a French supported energy savings program, Mobiprox, and other industry association partners. The paper shows the methodology and actions taken to evaluate the program: a) selection of over 500 users for the pilot experimentation, b) analysis of technical specifications and GPS monitoring of e-scooters, c) continuous anonymous user-surveys to understand travel habits, and d) the development of an analysis tool to monitor and assess the environmental impact compared to other forms of transportation. In addition, the results are analysed based on the following measured indicators during the experimentation period energy consumption (kWh), CO2, NOX and PM10 emitted, the observations from the surveys and gathered GPS data. The project aims to contribute with a case study on e-



mobility by comparing the results from electric scooter as mode of transport with existing alternatives and identify user-behaviour challenges and opportunities in the shift of transportation modes.

# Beyond productivity and housing supply: why should the performance of the UK housing sector be assessed differently in the 21st Century, and how can we do it? D. Carun<sup>1</sup>

<sup>1</sup>Queen Mary University of London, UK

For decades, successive UK governments have used narratives of housing supply, more recently measured through net additional dwellings, or productivity, expressed as GDP, for describing the performance of the UK housing sector. Other aspects of performance such as creating great places, climate resilience, safeguarding the environment, and creating and supporting sustainable and inclusive communities, to name but a few, although also reported as priorities in housebuilder visions and mission statements, have not gained as much traction or honest adoption and management. There is limited literature on how the housing sector collectively perceives, defines, and assesses its non-financial performance, and what actions, if any, it has been implementing to align it with frameworks such as the Sustainable Development Goals (SDGs). The research therefore aims to study the sector's views on its performance for insights on whether there is a case for assessing it differently, and whether and how the technological context of the Fourth Industrial Revolution in which Artificial Intelligence (AI) plays a major role can be leveraged for the purpose of improving its performance. A qualitative methodological approach was adopted for this research and data was collected through semi-structured interviews and a survey questionnaire, where questions were structured around the strands of perceptions of performance, quality, and productivity; innovation; organisational culture; and organisational AI-readiness. The results show that due to the fragmented nature of the housing sector, there are huge issues with estimating the hours worked, and measures like productivity, therefore, are not meaningful performance metrics in the context of the current structure of the UK housing sector. Shareholder return is the most dominant metric amongst Volume Housebuilders and that, combined with a lack of purpose for the housing sector, is producing homes that are not fit for the future. On establishing a consensus on why UK housing sector needs a different way of assessing its performance, the paper presents a framework for one, and also recommends an action plan for the adoption of this framework.



### **SESSION 11: Energy cities and buildings**

### A survey on multilayer networks modelled to analyse robustness in infrastructure systems

#### Z. Mahabadi<sup>1</sup>

<sup>1</sup>University College London, UK

The development of modern societies places particular demands on the consistent performance of infrastructure systems. So, the robustness of these complex systems that contain several interconnected and interdependent components is necessary to unceasingly provide essential services. Since multilayer network models are capable of representing the relational connections among infrastructure components, they have been used to study and analyse the robustness of infrastructure systems. The present study is a systematic review of papers that reported on the robustness of infrastructure systems modelled as multilayer networks, published in a 10-year interval since 2010. This review found that almost all papers aimed at optimising the physical structure of the systems to strengthen infrastructures against failures, rather than evaluating decisions and strategies toward robustness. Percolation theory was the most popular method used in about 70% of papers to assess the robustness of infrastructure using a multilayer network model. Regarding the properties used in network-based models of infrastructure systems, coupling strength and communities were the most common whilst directed links and feedback conditions in interdependent connections were scarce. We identified the following gaps which provide opportunities for further research. Models adopted different types of networks to represent infrastructure rather than representing infrastructures using real data. Real-world infrastructures have unique properties that are highly simplified in models. Models that are better digital twins of the real world would provide more accurate and actionable insights. None of the papers considered all potential properties, and the effect of boost or weaken the effect of other properties. By considering all properties, the importance of different properties on the robustness of infrastructure systems can be quantified and compared in future studies.

### Solar net metering for industrial prosumers to support renewable electricity expansion in Bangladesh

**M. Talut**<sup>1</sup>, A. S. Bahaj<sup>1</sup>, P. James<sup>1</sup> <sup>1</sup>University of Southampton, UK

Bangladesh has severe land scarcity due to high population density and has little scope for installing large-scale renewable power plants. Moreover, the consistent renewable power supply is not affordable to date, ascribed to the high price of energy storage devices. Therefore, net metering seems a very timely and effective technique to enhance this country's green power generation prospects, tackling the major challenge of land unavailability and the deployment of expensive energy storage systems. Being a developing country and a global leader in producing certain commodities like garments, jute, and food, Bangladesh has a considerable number of medium to large manufacturing plants across its landscape, occupying a substantial portion of its scarcely available land. Using statistically distributive extrapolation and geographic mensuration tools, the study estimated that the total extraditable solar power from such premises is around 5 GWp with a corresponding energy of 7.5 TWh. This amount could contribute more than 6% of Bangladesh's current consumption in a greener way without putting extra concern on managing land for such a



venture. The findings may be considered a strong proponent readily available now towards a sustainable power system in the future for the country when land and energy storage become critical in that connection.

#### Supply chain readiness for solar PV expansion in Saudi Arabia

**N. Alghamdi**<sup>1</sup>, A. S. Bahaj<sup>1</sup>, P. James<sup>1</sup> <sup>1</sup>University of Southampton, UK

Saudi Arabia has been relying on fossil fuel since its discovery in commercial quantities in early 1950's. The energy Sankey diagram shows the energy mix for Saudi Arabia as of 2018. However, it is going through an intensive wide range utilisation of Renewable Energy (RE) according to the Saudi 2030 Vision programme. More than 68% of the 58.7GW planned renewable energy projects by 2030 is based on the Solar PV technology. The current Saudi Arabia renewable energy supply chain does not seem to fulfil the local content\* targets. Combining the outcome of 11 different surveyed entities, simulation scenarios and cases studies from other countries, a set of informed recommendations and policy suggestions will be presented to the respective Saudi governmental entities.



### POSTERS

### Static and dynamic setpoint optimization in residential heat pumps based on learned user behaviour

**M. Ardnt**<sup>1</sup>, P. R. Adam<sup>2</sup>, S. Erkel<sup>3</sup>

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Commercial residential heat pumps mainly work on static, manually adaptable setpoints for heating and hot water generation. Often, these setpoints remain at the standard factory settings. Thus, there is potential to reduce the energy consumption by individualizing and dynamizing these setpoints.

In this paper we describe the development of two methods to adapt the hot water temperature setpoint statically and dynamically by learning the user behavior and the installation conditions. The methods were then evaluated by system simulations. The optimal hot water temperature setpoint depends on the building type, the hot water demand and the inlet temperature to the heat pump. Therefore, in our approach, the heat pump will first run with various settings for a limited learning period. From the collected data, the resulting energy consumption for each hot water heat up cycle was calculated. Thus, at the end of the learning period, a dataset existed, which was used to find the optimal hot water temperature setpoint under given circumstances.

Method 1 calculates, based on this dataset, one individual optimal hot water temperature setpoint for one specific heat pump installation and user profile. This new static setpoint was then used in the simulation.

Method 2 generates categories (e.g. periods like day, night, working day or weekend) and calculates an optimal setpoint for each of these categories. Using a schedule, these setpoints were then used dynamically in the simulation. A variation of method 2 uses an additional demand prediction algorithm, to further improve the energy efficiency.

The energy reduction potentials for method 1 and 2 were finally quantified using a building simulation system which includes a TRNSYS Building model (Type 56), randomized and normed (DIN EN 16147) user hot water consumption and a reference model of the hot water tank and the heat pump. The simulation results show an energy reduction potential of 3.5% for method 1 and at least 6.5% for method 2 compared to the factory settings. The presented concept could reduce the carbon footprint of heat pumps, as it can be implemented by adaptation of the control software of existing residential heat pumps.

### Solar PV and hybrid energy storage virtual power plant for smart energy communities: an optimal parallel services concept

**R. Garner**<sup>1</sup>, G. Jansen<sup>1</sup> <sup>1</sup>Brunel University, UK

Renewable Distributed Energy Resources (DER) are becoming more popular as governing bodies introduce ambitious climate policy objectives to curb emissions production. The Virtual Power Plant (VPP) concept can be used to increase the visibility of DER and provide grid support services to the grid, as well as promote the continual increase in renewable energy usage and additional revenue to participants. In this model, a prosumer Energy



Community is constructed consisting of surplus PV solar generation, flexible loads, and a hybrid battery and Hydrogen Fuel Cell (HFC) Energy Storage System (ESS). A non-linear optimisation strategy based on a Genetic Algorithm is used to find the optimal day ahead energy dispatch to ensure optimal revenue for each participant within the VPP. Excess energy storage provides internal peer-to-peer remuneration as well as peak demand management and frequency control services to the grid. Hybridising battery and HFC provides optimal synergy between the technologies, making use of the strength of each technology by allowing the battery to provide short duration storage and fast response for frequency control, while the HFC can provide long duration storage, and improve the overall resilience and economic performance of the ESS. The hybrid storage is sized to reduce the Levelised Cost of Electricity (LCOE) by finding the optimal battery and HFC capacity ratio. Specific social, regulatory, and technical barriers to implementation are presented and discussed in relation to the proposed VPP concept. Further research of the system's economic performance and potential business models in combination with this work could prove the commercial feasibility of the Energy Communities concept.

### Creating multi-domain urban planning indicators using a knowledge graph: a district energy use case in Singapore

**S. A. Grisiute**<sup>1</sup>, H. Silvennoinen<sup>1</sup>, Z. Shi<sup>1</sup>, A. Chadzynski<sup>2</sup>, S. Li<sup>1</sup>, M. Q. Lim<sup>2</sup>, F. Sielker<sup>2</sup>, A. von Richthofen<sup>1</sup>, P. Herthogs<sup>1</sup>, S. Cairns<sup>1</sup>, M. Kraft<sup>2</sup> <sup>1</sup>Singapore-ETH Centre, Singapore Council, Singapore <sup>2</sup>Cambridge Centre for Advanced Research and Education in Singapore, Singapore

In Singapore, decision-makers from multiple ministries and government agencies participate in urban planning and management. This often results in siloed datasets, different data formats and domain specific software: a lack of interoperability that hinders the integration of (big) data in planning. Semantic Web Technology (SWT) can help to solve data interoperability issues. With SWT, computers can infer semantic relationships between heterogeneous data that are linked using ontologies (i.e. 'common languages'). Knowledge Graph (KG) data structures allow such linking, and thus support SWT applications. The Cities Knowledge Graph (CKG) research project uses a KG to facilitate the use of multidomain data in city planning. We present a use case that demonstrates how KGs enable the creation of planning indicators, building on various openly available datasets in Singapore. The first step was to transform datasets containing geospatial and regulatory data on zoning, parcels and buildings to CityGML. Then it was loaded into a KG structured using a CityGML-based ontology. Retrieving raw data values or composite metrics (essentially manifold combinations of queries on different datasets) was done using SPARQL. However, our goal was to develop indicators that could benefit urban planners examples include 'GPR potential' (unused Gross Plot Ratio per zone) or 'allowable programmes per plot' (which uses could exist on a plot, given its zone). These and other indicators have many potential applications, including in urban energy modelling. For instance, we developed an indicator for district cooling potential based on geometric parcel data as well as zoning and density data. We demonstrated how these indicators can be used to analyse a part of downtown Singapore, and visualised the results. We show that KG technology allows planners to analyse cities through multi-domain indicators, which would be difficult to develop based on individual datasets. Another benefit of KGs is highly malleable data architecture, allowing data to be updated, expanded or created. Future work includes integrating new datasets into our CKG and developing new analyses. Ultimately, these could be carried out autonomously by a multi-agent system.



### Large scale energy storage in Uppsala, Sweden: an analysis of voltage fluctuations and a service stacked portfolio

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#### 1. Subject, motivation and objectives

Extensive electrification of several sectors of the society has created an increased demand of electricity, considering both energy and power. As a result, a handful of regions in Sweden indicate a critical lack of distribution capacity to larger urban areas. One of these regions is Uppsala, where the DSO Vattenfall has decided to connect a 5MW/20MWh Li-ion battery energy storage system (BESS) to temporarily ease the congestion issue. Additional applications of high relevance are flexibility services and frequency support to ensure safe and efficient distribution of high-quality electric power. As of the connection of the BESS, it is also of great interest and importance to investigate how the power quality in the area will be affected by the operation of the BESS. For this study, the voltage stability of the grid and variations over time would be of most particular interest. Furthermore, an optimal operation strategy of the battery would also be of interest by combining the services of interest.

#### 2. Method and approach

By measuring the local voltage level over time, it is possible to indicate how the power quality is affected by the operation of the BESS. The local grid voltage level will be measured before, during and after service provision of the BESS. Further, by considering a smart planning of the BESS operation it enables the feature of combining two or more services in parallel to increase the benefit of the energy storage unit during and between seasons.

3. Results and conclusions

Results from the measurements indicate very small or no voltage fluctuations during neither flexibility nor frequency response service provision. The next step in the verification process is to test more stressful services like fast frequency response (FFR) which requires approx. 30 times shorter activation time of the storage. Also, it is also of interest to further investigate and implement service stacking in an intra-day and intra-season timescale. Energy storage in distribution grids will certainly become an important tool for distribution system operators as the market evolves even further.

### Sustainable operation of district heating systems using dynamic hierarchical optimisation

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District heating is expected to play an essential role in the cost-effective decarbonisation strategy of many countries. However, resource-optimised management of district heating networks needs to consider a wide range of factors, including demand forecasting, flexibility of the heat provision mix, and volatile market conditions. While traditional approaches often rely on static models and rather simple heuristics, dynamic cross-domain interoperability that allows the consideration of all these factors is essential to holistically optimise thermal grid operations.



A hierarchical optimisation approach based on the merit-order principle is developed and embedded in a model predictive control framework to allow the system to incorporate most recent information and react to disturbances promptly. Solving the unit commitment and load dispatch problem using a heat merit-order stimulates the inclusion of (industrial) waste heat and intermittent renewable energy sources by increasing transparency on marginal generation cost from different sources. Simulation-based optimisation is used to determine the short-term heat generation mix based on data-driven gas consumption models and dayahead forecasts for the energy demand and grid temperatures. Seasonal autoregressive integrated moving average models with exogenous predictor variables (SARIMAX) are found to be sufficiently accurate and precise. The forecasting errors of the best-fitting SARIMAX models are shown to have no decisive influence on the generation optimisation results when compared to actual historical data. A detailed sensitivity study is conducted to identify key design criteria and input parameters and assess the impact of anticipated changes in regulation and market conditions. The effectiveness of the approach is demonstrated for an existing heating network of a midsize city in Germany, where a reduction of approximately 20% and 40% compared to baseline operational data is obtained for operating cost and CO2 emissions, respectively. Scrutinising real industry data has revealed several severe data quality issues and emphasises the importance of a semantic representation to foster cross-domain interoperability between heterogeneous data and allow for automatable artificial intelligence applications. This work demonstrates early progress towards a knowledge graph-based approach to heat generation management within a broader semantic digital ecosystem for municipal utilities.

## Can different urban information systems speak to one another? – An innovative use case of the knowledge graph technology for Singapore's energy planning

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As governments and cities aspire to be 'smarter' and 'more digital', the knowledge graph technology aims to advance these aspirations for optimal planning outcomes by solving the lack of interoperability between different urban information systems such as Building Information Management and Geographic Information Systems. This poster presents the results of the 'Consumer Energy Usage Data in Smart City Development' funded by the Singapore National Research Foundation, and provide evidence of the opportunities to use knowledge graph technology to link different data systems.

In an era driven by digital innovation, technological tools, like cloud computing and big data, offer cities new possibilities in tackling the complex environmental and socio-economic challenges of today. Despite the potential of digitalisation, governments at all levels across the globe are not prepared to fully use the opportunities of digital developments into their planning systems. Considering the diversity of urban information systems available, interoperability and level of detail remains the key obstacle, resulting in barriers such as lack of universal standards, coordination, and expertise. Moreover, different levels in the planning system requires different detail and scope of data. For example, energy planning requires the geo-spatial coordinates for the power grids at a national level and consumer switch rooms at a neighbourhood level. Thus, the existing siloed urban management approaches impede cities and planning systems from capitalising on the latest technological developments to encourage good data practices and sharing, while providing more efficient higher quality services. This poster showcases the use of knowledge graph technology as



a solution to the interoperability issue through 'The World Avatar' project in Singapore. The knowledge graph represents a network of interlinked descriptions for real-world entities – objects, events, or concepts. We present how the knowledge graph can be used as a one-stop solution platform to correspond between various urban information systems through the case of energy use in Singapore. Specifically, this poster demonstrates the proof-of-concept when 'The World Avatar' project is integrated with three planning technologies – Building Information Management, Common Information Model and Geographic Information Systems – to address planning issues.

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## Automatic building inspection techniques through drones and transfer learning on fused thermal and colour imagery of building facades H. Sharig<sup>1</sup>

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The building sector is responsible for 40% of overall global energy consumption. Building defects such as heat losses, moisture, and air leakages account for inefficient space heating and cooling that results in excessive energy consumption and the associated greenhouse gas emissions. Building inspections and energy surveys are performed to detect and diagnose these building defects, however, recent inspection methods have been highly labour intensive, time consuming, and not suitable for large-scale audits. The research and development in this paper aims to automate building inspection techniques through artificial intelligence (AI). A drone-based low-powered embedded machine learning (ML) system is proposed and implemented that utilises pre-trained model via transferring learning (TL) on fused thermal and colour imagery of facades to detect and identify faults. The experiment sets were performed and compared on heat losses around windows through (a) only thermal imagery and (b) on fused thermal and colour data set. Results showed a 20% higher accuracy of successful fault detection on the fused data set compared to applying ML on thermal data alone. The use of transfer learning in building facade survey allowed the ML model to be run on a low-power embedded microcontroller, which provide massive future scope for an autonomous drone-based building survey at large-scale with automated and real-time fault detection on building façades.

A Systems Approach to More Resilient Data Management for Municipalities J. Zou<sup>1</sup> <sup>1</sup>University of Victoria, Canada

Throughout the last year, city leaders have increasingly been focused on ensuring the safety of their citizens and adapting city planning functions to support the delivery of critical services during unprecedented circumstances. To support operations and data-driven decision making during this time, city staff have increasingly relied on data collection, management, and producing insights from data. The process of which is easier said than done, requiring significant infrastructure for data collection, data governance and processing expertise, and the tools necessary to produce insights from this information. To this extent, this poster submission will highlight best practices and outcomes from UrbanLogiq's work supporting City Halls across North America to facilitate more streamlined data management and analytics functions to inform decision making and policy.



Poster contents will detail applications of Urban Logiq's technology: our Data Platform, a feature-rich data lake that leverages multiple regional, local, and private data streams for more informed city services. This includes illustrating our work with municipal agencies such as the City of San José, California, the City & County of Honolulu, Hawaii, and the City of Ottawa, Ontario, to institute data management best practices and derive outcome-oriented insights. Highlights will focus on tangible quick wins that municipal agencies can implement to collect data that's easier to consume, processes for transforming data, and what city officials should be considering when scaling data collection and analysis functions. In addition, the presentation will showcase outcomes from recent projects, such as a data analytics project completed with the City of San José Department of Transportation, which used machine learning to project road safety patterns over a 5-year period so as to direct city planning resources more efficiently and effectively to save lives.











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