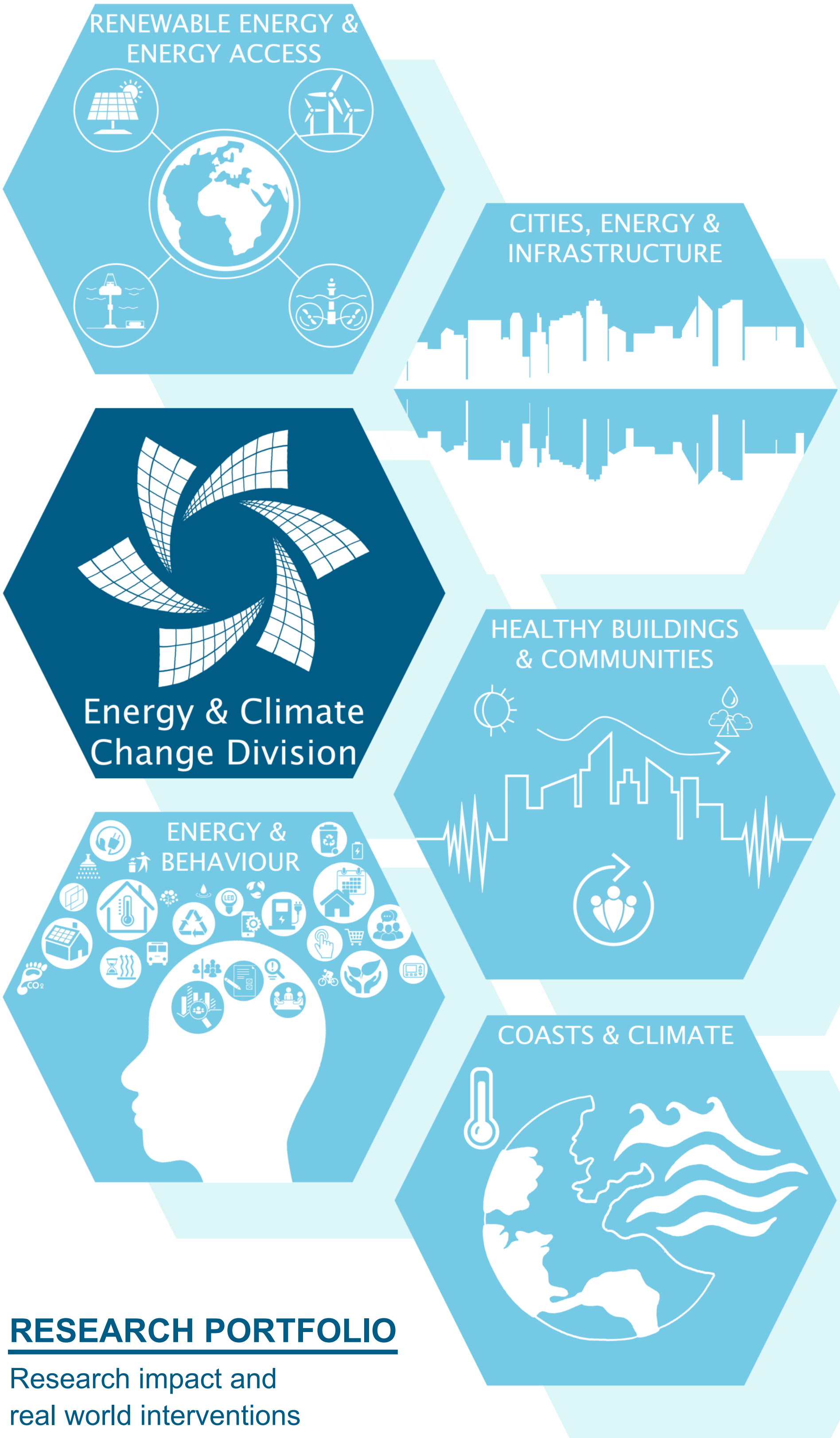
UNIVERSITY OF Southampton

Energy and Climate Change Division

Sustainable Energy Research Group



RESEARCH PORTFOLIO

Research impact and
real world interventions
at the micro and macro scale

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Energy & Climate
Change Division

UNIVERSITY OF
Southampton

Research Portfolio

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Acknowledgements

This book, Report 10 of the Sustainable Energies Series, documents the work of the Energy & Climate Change Division and Sustainable Energy Research Group (SERG). SERG was established thirty years ago with the aim to promote and undertake fundamental and applied research related to the efficient use of energy in the built environment. The content of this book gives a snapshot of the collaborative work undertaken by academics, researchers and PhD students at the University of Southampton.

Contents

Preface

The University of Southampton's mission is '*to change the world for the better*' by building on our global reputation for delivering world-class education, research and innovation that makes a real impact on society's biggest challenges. The University is one of the founding members of the prestigious and research-intensive UK Russell Group, an organisation that brings together the knowledge and resources of the 24 top UK Universities to: protect and improve the quality of University teaching, support and enable innovative research projects, and build stronger links with business leaders and policy makers. The University is a member of the World Universities Network (WUN), comprising 19 research-intensive institutions spanning six continents, a member of the Association of Commonwealth Universities and attracts students from over 130 different countries benefitting from a wide and varied culture.

The University's income in in the 2018 financial year was £583million, with a research grants income of £117million, from the UK Research Councils, UK based charities, the EU, UK Central Government/local authorities/health authorities and hospitals, and from UK public corporations/ industry and commerce. The University has internationally leading experts in designing and managing research programmes. The current value of managed research contracts is over £150M spanning multidisciplinary including engineering, social science and health. Such leadership is attained through developed knowhow, management and processes to deliver projects to the highest standards and required deadlines.

According to the Times Higher Education (THE) World University Rankings by Subject 2020, published 16 October 2019, the University of Southampton is ranked 6th in the UK, 18th in Europe and 76th in the world for Engineering & Technology.

Within the University of Southampton, energy research and development is conducted within the Energy & Climate Change Division (ECCD) encompassing the Sustainable Energy Research Group; (SERG, www.energy.soton.ac.uk), established and led by Prof AbuBakr Bahaj since 1990. ECCD/SERG research profiles include fundamental understanding applicable to renewable energy studies, energy efficiency and energy for development. This booklet provides a snapshot and brief details of some of the current research and development areas within ECCD/SERG. These encompass (i) Renewable Energy & Energy Access, (ii) Cities, Energy & Infrastructure, (iii) Healthy Buildings & Communities (iv) Energy & Behaviour, (v) Coasts & Climate and (vi) a sample of the fundamental research undertaken by PhD Researchers.

The booklets contains web links and details of our contact. If you need, further information on the topics covered or in general, related to sustainable energy and energy efficiency please get in touch.

I hope you find the provided information useful and please check for further details on our website www.energy.soton.ac.uk as well as all the publications available there.

Prof AbuBakr S. Bahaj

Head of Energy & Climate Change Division | Professor of Sustainable Energy, University of Southampton

Renewable Energy & Energy Access

Engineering pathways for reliable and affordable sources of renewable energy to maximise use of regional resources

Marine energy (wave and tidal)

Our research focusses on wave and tidal energy, encompassing resource characterisation, device fundamentals & array planning. It also addresses device fundamentals, device interactions & array siting for optimised energy yields.

The conversion of marine currents (tidal) is a relatively new area of engineering & our work is providing pioneering fundamental understanding of the hydrodynamics applicable to the converters (turbines) & arrays.

Experimental approaches investigate the fundamentals of scaled tidal turbines for a range of conditions (tip speed ratios, pitch and yaw angles). Results provide insights into operation of: (a) single turbines in straight/yawed flows, (b) performance changes due to rotor tip immersion (bathymetry), (c) cavitation inception and (d) interference between multiple rotors. Results validated numerical models including the wake effects & impacts of turbulence.

Resource assessment analysis, array effects & energy yields were obtained for the Channel Islands, Portland Bill & the Isle of Wight. In wave energy, resource assessment through satellite altimetry were conducted, as were the hydrodynamic performance of the Owel & Anaconda devices.


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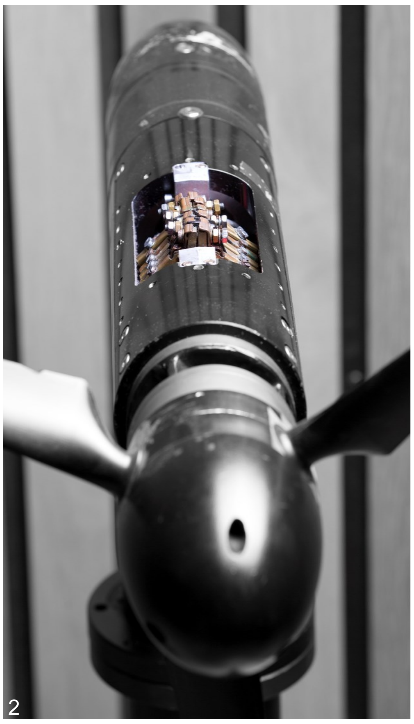
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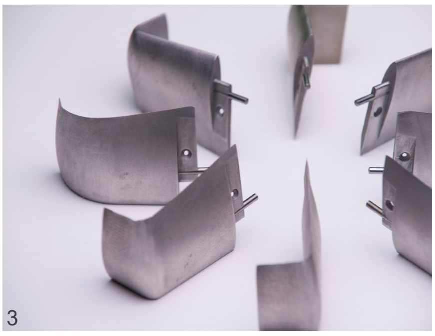
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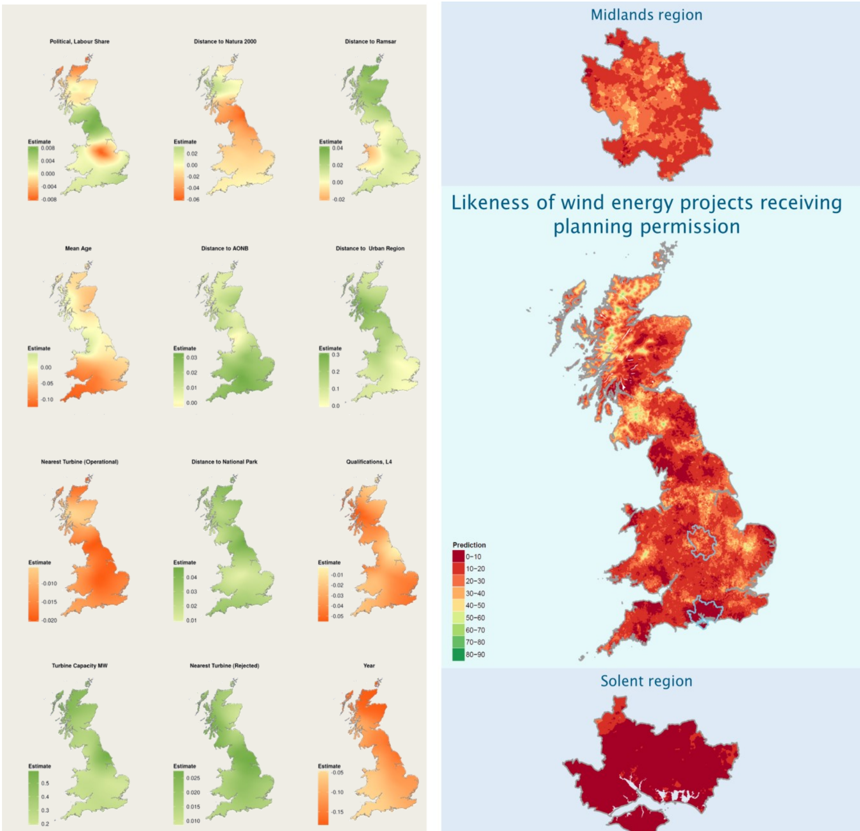
Wind energy

Research in wind energy is undertaken at various scales – urban, onshore and offshore. The first addressed UK field trails with turbine capacities >5kW (micro wind turbines), the 2nd was geared to identify factors that may influence the planning acceptance of onshore wind, whilst the latter mapped offshore wind energy resources and energy yields in the Middle East providing a blue print for sites development in the region.

In the UK national trial on micro wind turbines, the Energy and Climate Change Division team played a pivotal role in the monitoring and analysis of the results from 75 test sites (*Fig.6*) across the UK. This has resulted in guidelines for such turbine utilisations.

In onshore wind, research undertaken aims at identifying factors that may influence planning acceptance, integrating the results into a spatial model of onshore wind energy providing the most likely suitable locations for "least resistance" development (*Fig.5*).

In offshore wind, research addresses wind energy potential with a particular focus in the Middle East, where there is a paucity of information around the resource, its locations and infrastructure needs. This seminal research is based on the development of new, more accurate estimates of available resources and predicted energy yields, taking into account appropriate constraints such as shipping lanes, nature reserves, electrical grid etc, presenting the first mapping of the potential for offshore wind energy in the region (*Fig.7*).



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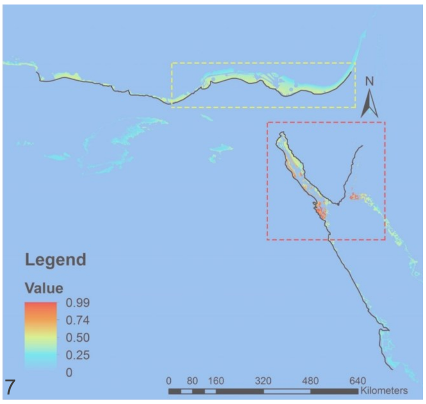

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Renewable Energy & Energy Access

Engineering pathways for reliable and affordable sources of renewable energy to maximise use of regional resources

Energy for development

The energy for development (e4D) research addresses energy (electricity) access. The e4D programme installed 6 solar photovoltaic (PV) mini grids in Sub-Saharan Africa (*Fig.8&11*), invigorating villages and poor off grid communities. Studies on community level power is augmented with research on solar home systems and how they can be optimised with efficient appliances.

Energy for Development (e4D) undertakes research and development in many fields related to the provision of energy (electricity) in poor and sparsely populated areas in rural Africa. Activities include mini grid system design, analysis and implementation. The work also addresses AC and DC approaches with emphasis on unlocking the promise of high efficiency appliances and low maintenance cost. In addition, the e4D programme is also carrying out research on electrical network resilience of mini grids exploring options to cluster these to form wider networks with greater stability and utilisation. The work also studies connecting these to the national grid including the support of end of line in the national network. This research inevitably investigates intermittent islanding operation of mini grids and demand side management approaches for network stability.

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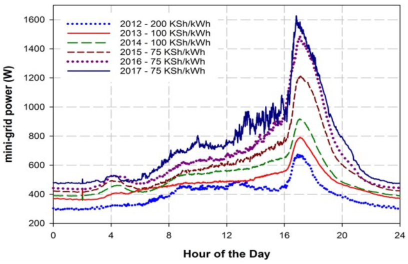

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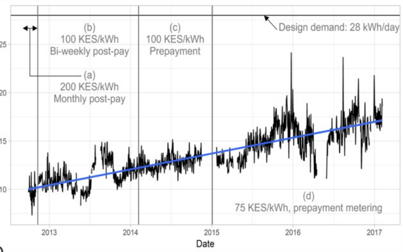

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Solar photovoltaics (PV)

Solar photovoltaics (PV) convert sunlight to electricity and is now the most utilised renewable energy technology globally. PV research focuses on ways to optimise power output from solar systems in real world situations. It covers fundamental understanding of solar PV, focussing more on applications in buildings, cities, villages, refrigeration and in energy access.

PV research focuses on buildings as power generators at city scale (*Fig.30*), the supply of power to invigorate rural villages in Africa (*Fig.14*) as well as unique examples of building integrated PV (BiPV) deployed at the university (*Fig.13*), with linkage between power generation from PV and behaviour in social housing.

PV for refrigeration was deployed on a Sainsbury's working articulated trailer for the delivery of perishable food, a world first (*Fig.14*).

In addition, we work on the utilisation of PV on carports shading in Kingdom of Saudi Arabia (SA) as car parking footprints in many institutions in KSA represent more than 50% of their area, creating possibilities for large power production at point of use. One of the research foci is understanding appropriate combination of cleaning options to mitigate dust accumulation which reduces energy yield of such PV arrays (*Fig.15*).

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Cities, Energy & Infrastructure

Developing engineering solutions for the planning and management of sustainable, resilient and inclusive cities

Heat networks

Heat networks provide a high efficiency, low cost option for energy supply based on combined heat and power concepts. Analysis of heat networks performance and deployment of smart heating technologies are mainly applied in heat networks in social housing settings within the cities of Southampton and Portsmouth (*Fig.16*).

Developing and improving heating networks is key to reduce energy bills and reduce carbon emissions. Through an EU €5.5M project (*Fig.17*), research includes the following:

- Monitor & analyse the efficiency of domestic heat networks (*Fig.19*).
- Contribute to the wider deployment of advanced building heating technologies, increasing the energy efficiency of residential buildings.
- Develop control optimisation strategies, and identify residents' needs assuring their comfort.

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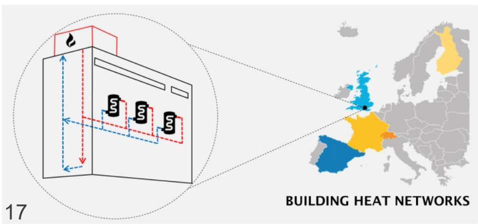

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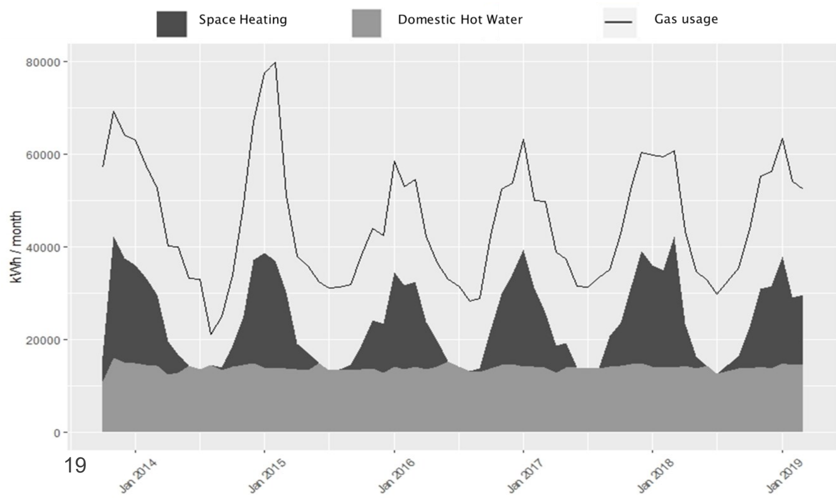

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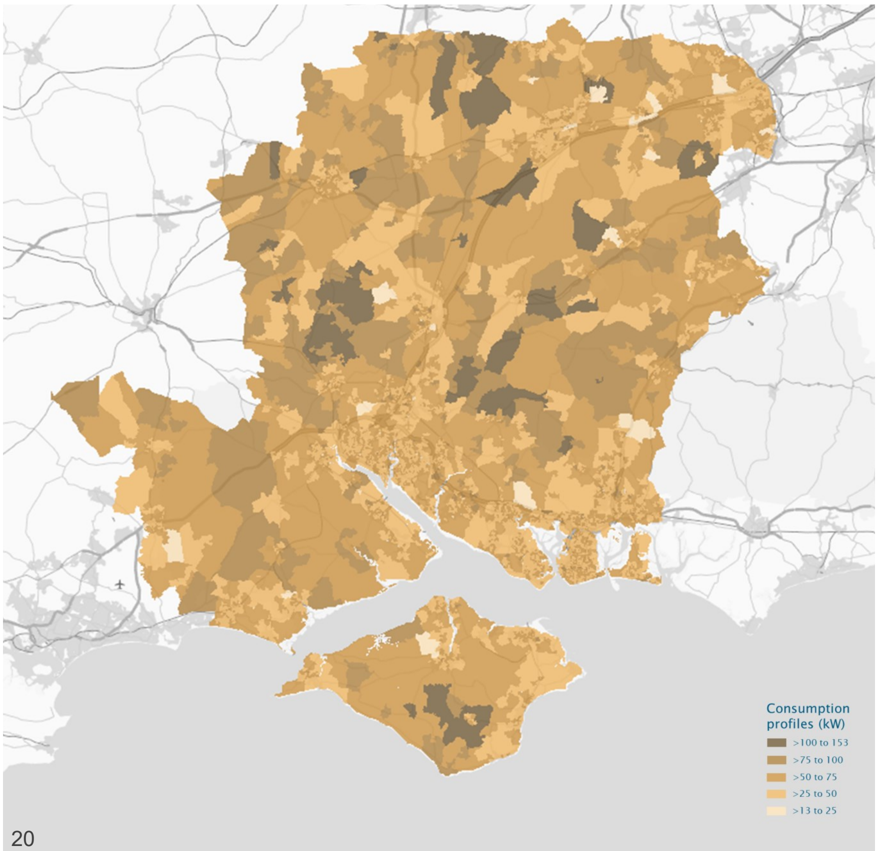
Demand modelling for infrastructure resilience

Demand modelling based on randomised control trials of over 4000 households' (F*ig.22*) monitored electricity consumption coupled with longitudinal surveys to test the efficacy of energy efficiency measures and understand their impact on the network operator's infrastructure.

This £10.3M Ofgem Low Carbon Network Fund (LCNF) project - Solent Achieving Value from Efficiency' (SAVE) primarily focused on the Solent region and the key output from the project was the Network Investment Tool: a suite of models to improve the simulation of low-voltage distribution networks, informing future investment strategies of operators across the UK.

The SAVE project created a large-scale, representative sample of households and their electricity consumption (*Fig.20-22*). The industry leading sample underpins spatial microsimulation modelling, used to predict residential demand profiles for small geographical areas. Using data from randomised control trials of behavioural interventions, the model provides demand under 'baseline' and 'intervention' scenarios to predict response in heterogenous areas or populations, identifying house types based upon a combination of heat source, household size and dwelling size (*Fig.23-24*).



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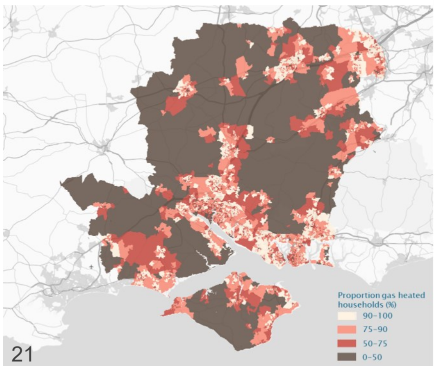

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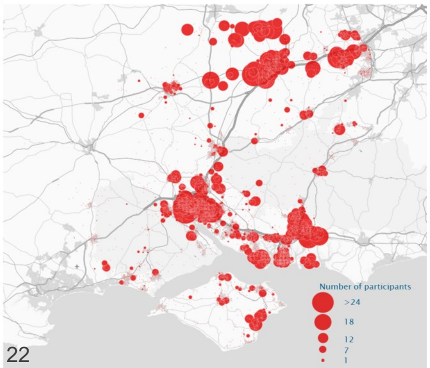

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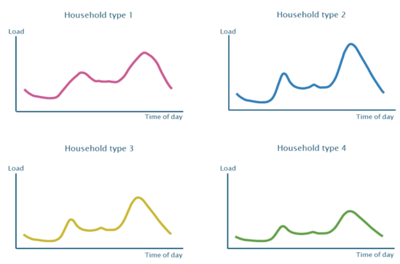

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Cities, Energy & Infrastructure

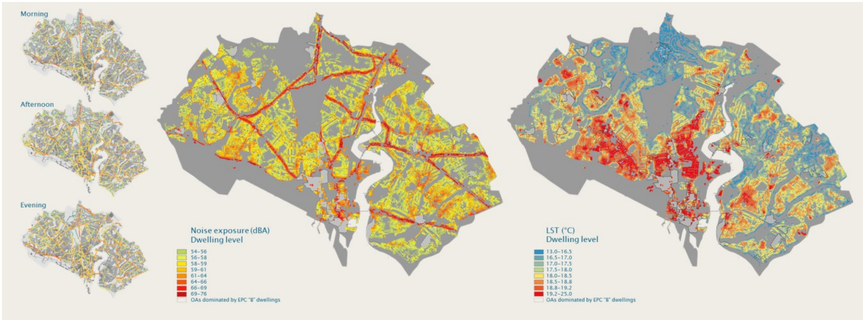
Developing engineering solutions for the planning and management of sustainable, resilient and inclusive cities

Rezoning and environmental impact modelling

The research takes into account city infrastructure change opportunities looking at future city pathways to address negative conditions such as sound and air pollution, fragmentation, ghettoization and impoverished areas.

Active and virtual monitoring of cities is undertaken with modelling of factors such as noise, land surface temperature (LST), accessibility and density (*Fig.25&28*).

Once key research areas have been identified, solutions are formulated and presented to local authorities with real world interventions being deployed and tested (*Fig.26-27*). This assists local government in formulating sustainable future city plans.



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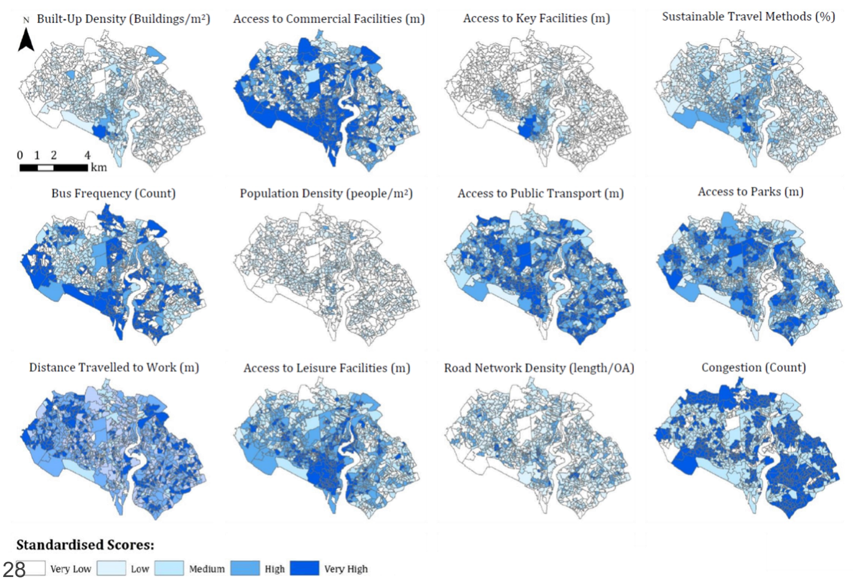

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Energy and cities

Research encompasses engineering analysis, developing evidence and providing advice to Southampton City Council and Portsmouth City Council. The work includes citywide analysis of building performance, providing evidence on required investment for building refurbishment as well as potential solar PV power production from all buildings in the city.

In Southampton, this study (and others) is now the building stone for the recently announced Green City Charter. In Portsmouth, various studies that resulted in policy changes and informed decisions around infrastructure investment. The work resulted in new tools to assist UK's local authorities for future investment planning and carbon target setting.

Engineered on geographic information systems (GIS), a building physics model was developed to allow refurbishment options to be applied and modelled, providing estimates of energy savings as a result of specific interventions. Furthermore, the model automatically identifies suitable roof areas for deploying solar systems - photovoltaics, or thermal, using high-resolution raster data collected by remote sensing. The result is a highly detailed 3D model of the entire city (*Fig.29*), rebuilding constructions and trees on a virtual environment. The model is able to accurately simulate solar radiation of building surfaces, taking into account factors such as shadows on roof surfaces at different times of the year. The model is able to combine multi-layer analysis and then identify suitable buildings that are feasible for installing solar systems (*Fig.30*).

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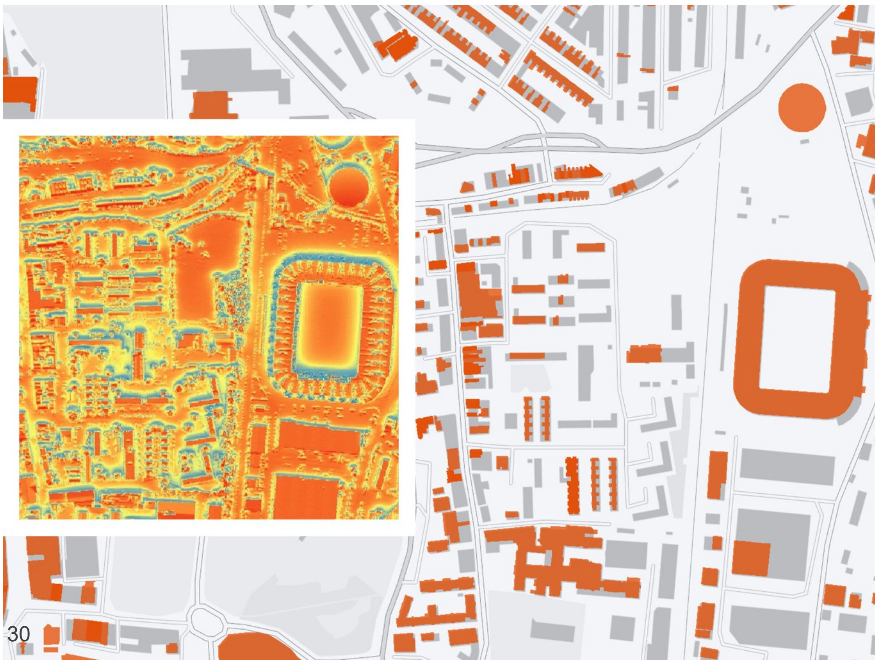

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Healthy Buildings and Communities

Designing and evaluating healthy indoor and outdoor environments for human settlements

Heating and energy performance

Reducing energy demand in dwellings is an important component of meeting carbon reduction targets. The drivers of such demand reduction are linked to occupant practices, varying greatly between people and locations.

This research shows that occupants' thermal preferences (*Fig.33*) can adapt to prolonged high indoor air temperatures, raising their expectations. It also points out that in absence of communal heating charges, several households are unlikely to be able to afford to heat their homes to the recommended healthy standards.

A human – centric approach is required to achieve energy savings without compromising people's health and well-being.


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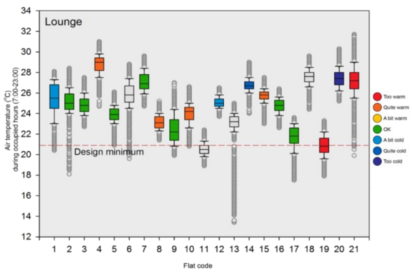

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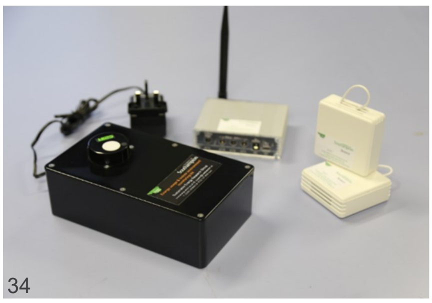
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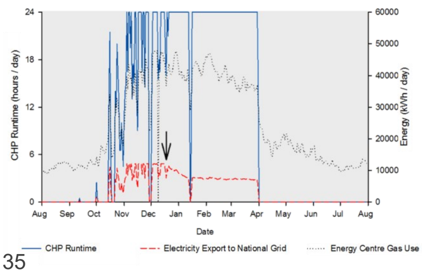

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Thermal comfort

Heating, is the main component of energy demand in dwellings in the UK and is often associated with thermal comfort. In order to achieve thermal satisfaction, occupants may interact with the building systems and controls to adjust their living environment.

Smart buildings are seen as key in reducing energy consumption and emissions due to their improved operational efficiencies. The prevalence of the Internet of Things and reduced costs of modern sensing technologies (*Fig.34*) heralds the application of such systems to provide real-time, dynamic control and automation in buildings. Clearly, such transformative approaches will also need to be augmented with building occupants' perception of comfort and space functionality to succeed.

Post occupancy evaluation (POE) and continuous feedback (*Fig.37-38*) can provide some of the tools required to design and manage low-energy buildings with controls and occupants as direct actuators of adaptation.

Part of our thermal comfort studies are contributing to the activities of the International Energy Agency's Energy in Buildings and Communities Programme (*Fig.39*).

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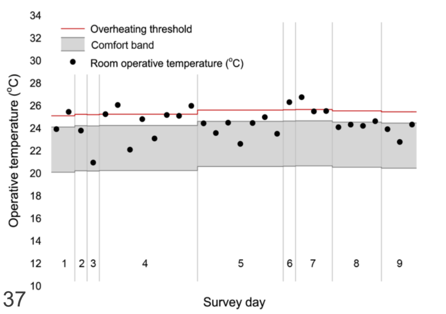

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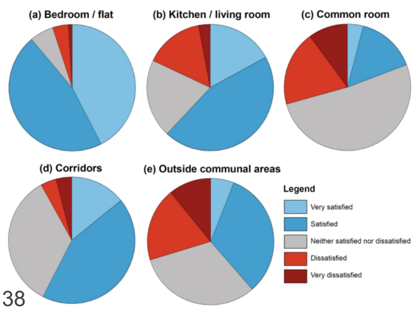

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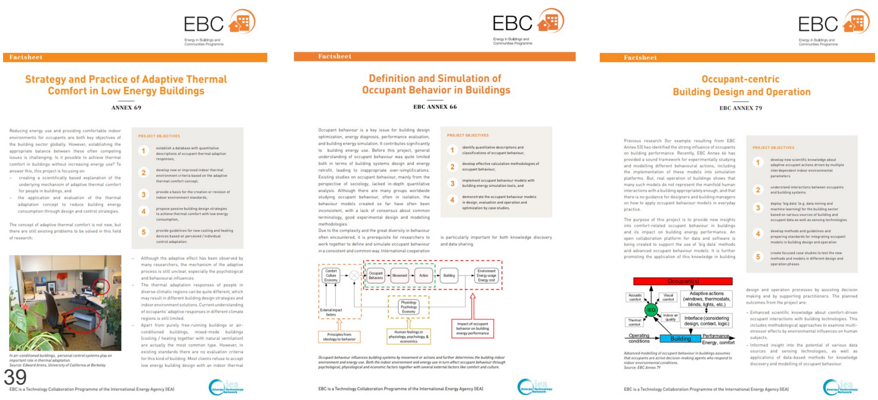

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Healthy Buildings and Communities

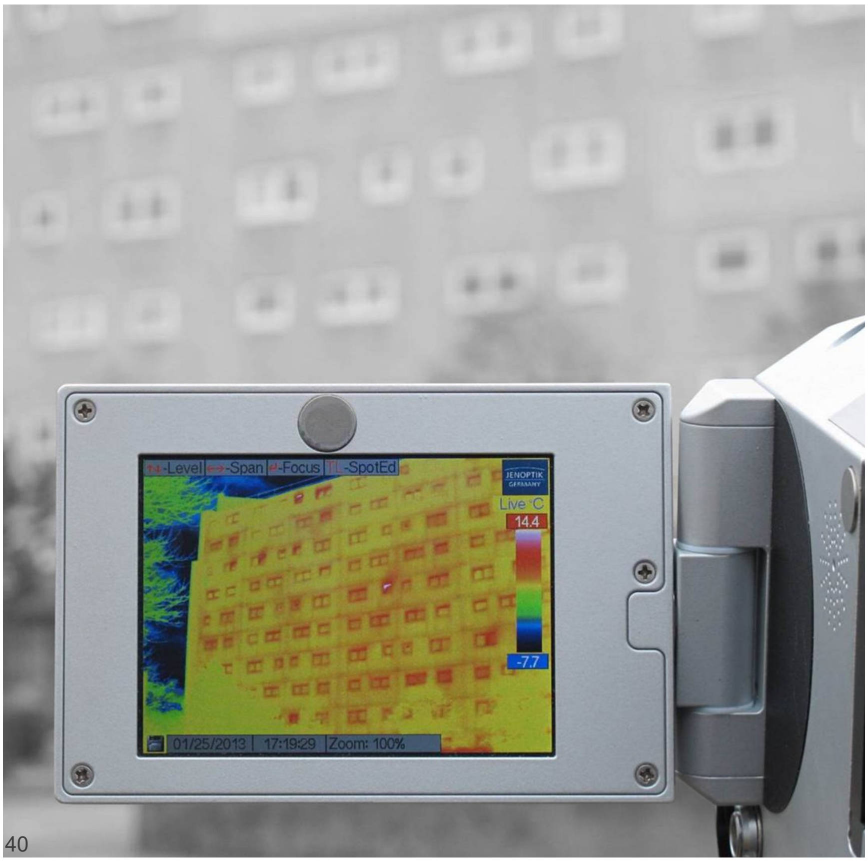
Designing and evaluating healthy indoor and outdoor environments for human settlements

Building and indoor air quality

Our research investigates how domestic buildings and their occupants use energy and how they interact with building systems in order to adjust their comfort.

Ventilation rates are a key missing element in the prediction of domestic energy performance. Off the shelf energy monitoring systems do not monitor CO_2 levels. The CO_2 decay profiles for typical building types are attributed to a combination of user behaviour and the theoretical technical performance of the buildings. Airtightness in dwellings is not simply predicted by the energy rating of the dwelling, underlining the need to understand people's behaviour in order to predict energy performance in-use.

The interpretation of data within the context of specific building properties and occupancy (*Fig.43-44*) can inform design and policy regarding domestic building retrofits and managing demands on the electrical distribution network.



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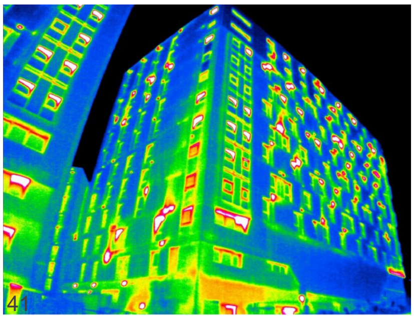

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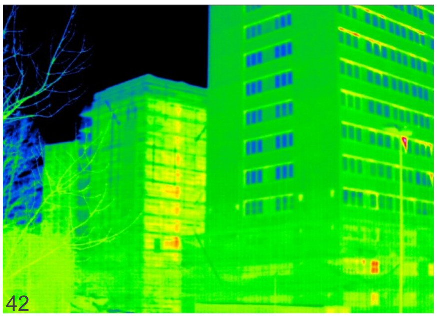

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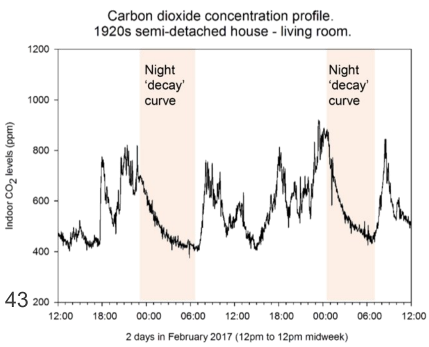

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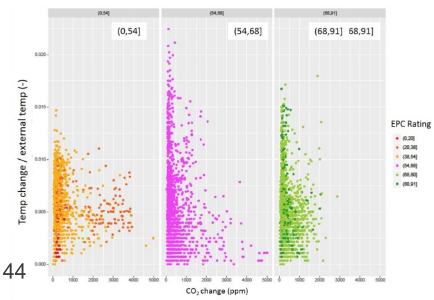

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Energy and behaviour change

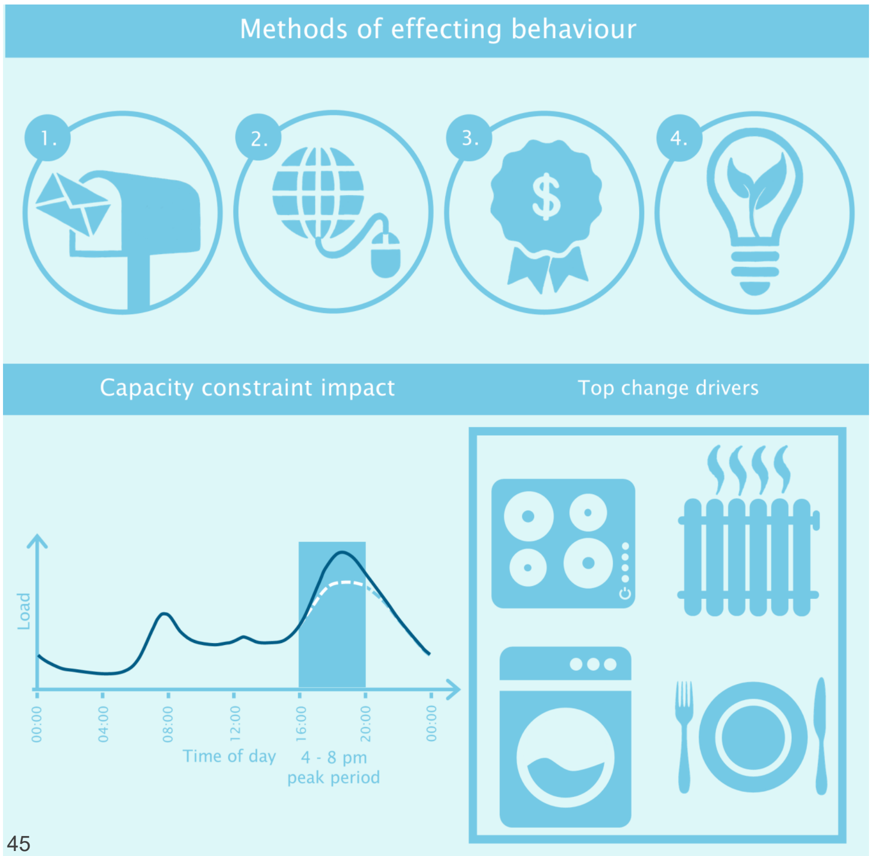
A key output from the Solent Achieving Value from Efficiency (SAVE) project mentioned on *demand models for infrastructure resilience (Fig.20-24)* was the Network Investment Tool: a suite of models to improve the simulation of low-voltage distribution networks, thus better informing future investment strategies.

Trial aim: to test a number of behavioural interventions aimed at reducing electricity demand during the network peak hours (4 to 8pm).

Design: a large-scale randomised controlled trial (4,000 households).

Methods: Data-informed messaging (postal & online), financial rewards, banded pricing (peak-hours rebate), energy efficient lighting upgrades.

Data: electricity demand, socio-demographic, appliances, time-use diaries.



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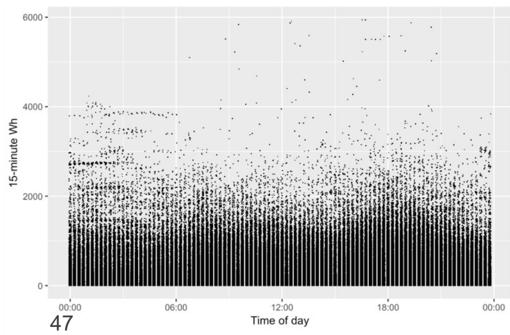

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SAVE clamp data 2017-01-16 to 2017-01-22
Households: 3,893 - Observations: 2,538,508


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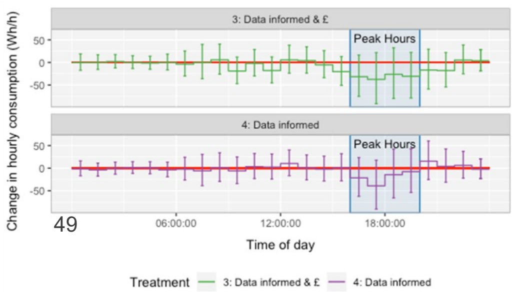

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SAVE sample households: 2017-11-13 to 2017-11-26
Sample size: Control = 861, Treatment = 794 & 791
Error bars indicate 90 percent confidence interval for estimates

Energy and Behaviour

Understanding individual perceptions and behaviours to advance adoption of sustainable energy initiatives and technologies.

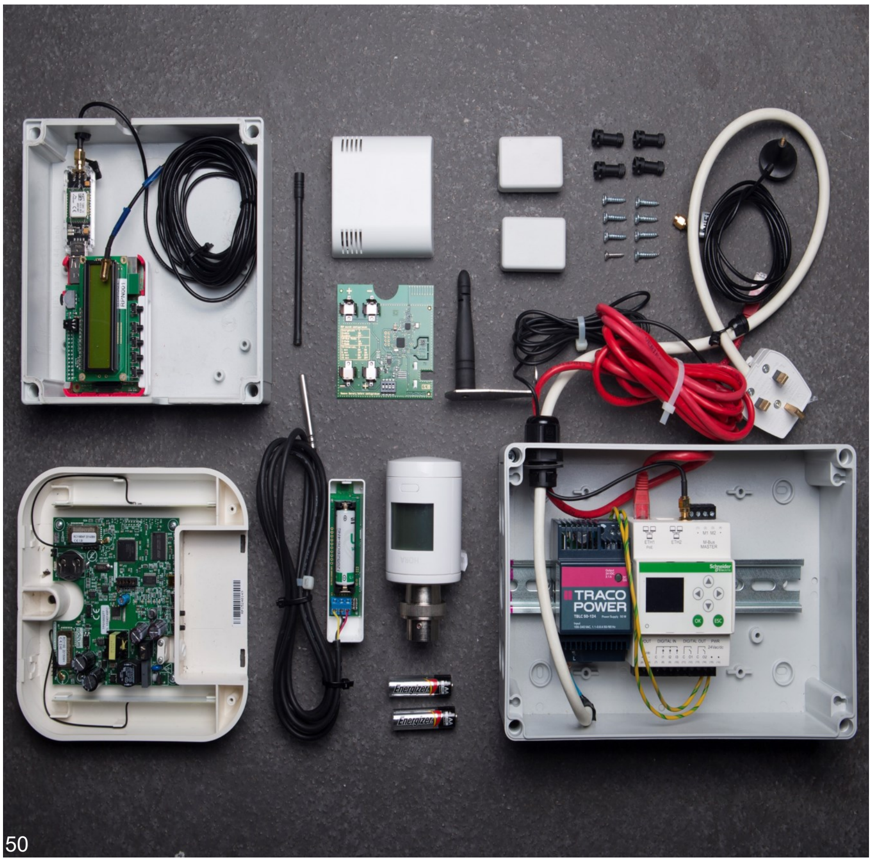
Energy usage behaviour modelling

Monitoring of user's energy related behaviour to establish patterns, motivations and constraints to inform energy efficiency strategies in social housing.

Through an EU €5.5M (THERMOSS) project (*Fig.17)* we are monitoring social housing residents, particularly their heating usage and the reasons behind it.

With a combination of monitoring sensors (*Fig.50*) and social surveys, we can infer energy usage patterns and their determinants, as well as understand user's motivations and constraints (*Fig.51*).

This is a pathway to securing their thermal comfort needs, reduce consumption as well as tackling with fuel poverty.



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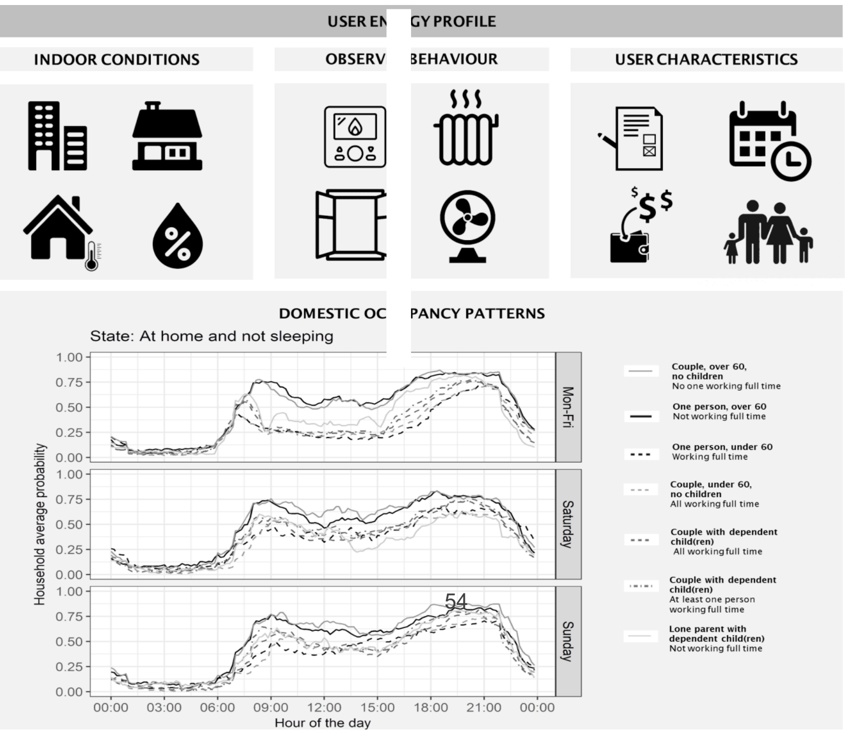

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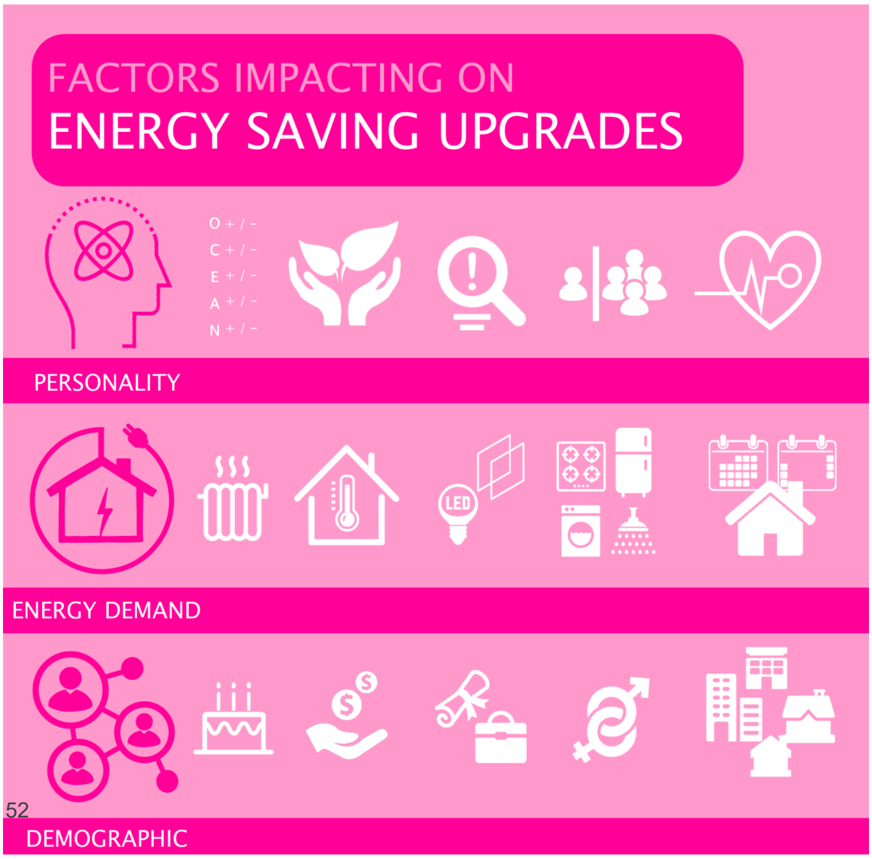
Energy investment behavioural studies

The research is aiming to develop a new approach to providing energy services to residential customers, further understanding how to increase uptake of energy saving upgrades.

Working in partnership with Igloo Energy, research is undertaken to establish the influencing factors (personality, energy demand and demographic/contextual) affecting the uptake of energy-efficient household appliances (*Fig.52*) which in the UK are below expected levels.

While research has shown the economic market failures, psychological factors are also a key influencing factor (*Fig.55*), in particular personality traits (Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism).

Research with online focus groups (*Fig.53*) is being undertaken in order to determine whether personalised messaging based on an individual's personality will enhance uptake of energy saving upgrades such as smart thermostats or hybrid heat pumps (*Fig.54*).



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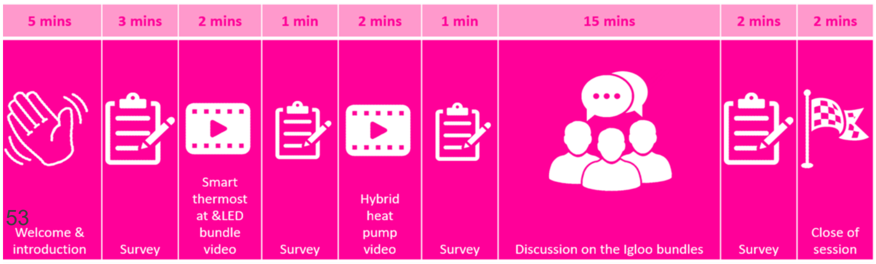

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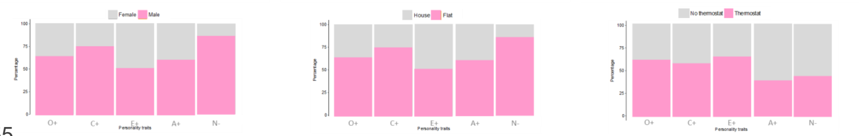

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Energy and Behaviour

Understanding individual perceptions and behaviours to advance adoption of sustainable energy initiatives and technologies.

IoT approach for independent living

The CareTeam project incorporates background environmental sensing (*Fig.56-57)* to unobtrusively monitor and predict behaviour of those receiving care to help provide reassurance and detect changes in condition.

As part of the adult digital health support platform developed under CareTeam, the research proposes the introduction of soft warnings, based on the continuous evaluation of the occupancy behaviour, care conditions and the home environment (*Fig.58-59*).

Results have shown that the care needs of a person are key determinants of occupancy behaviour. The work is also integrating a probabilistic approach to the occupancy profiles and evaluating the merits of different machine learning approaches (*Fig.60*).

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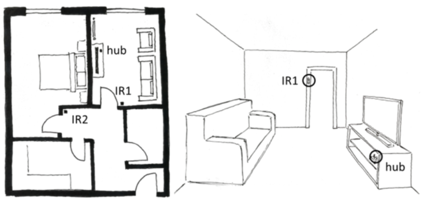

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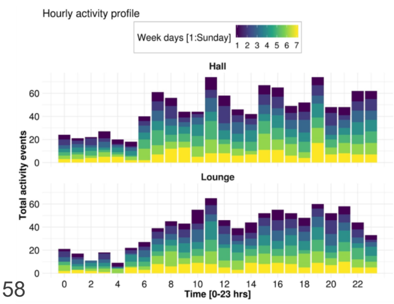

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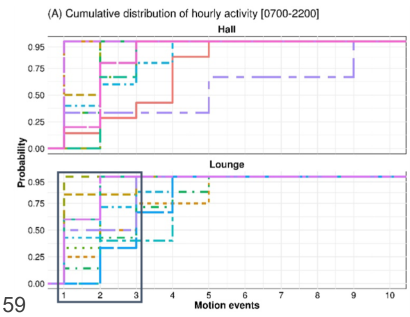

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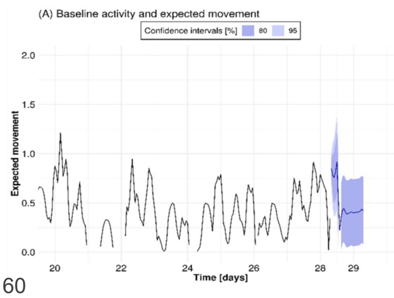

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Caring for the community

The CareTeam project in partnership with industrial partners Nquiringminds, Southampton and Portsmouth city councils aims to provide more efficient care services to help adults who currently *receive* care to remain independent, comfortable and active in their own homes for longer.

CareTeam comprises an app and background environmental sensors (*Fig.50*) providing a non-intrusive IoT approach geared to generate proactive care-awareness.

The app provides functions such as secure group messaging, contacts, a calendar and a 'to do' list (*Fig.64*) providing the means to raise concerns and recommendations regarding the wellbeing of the supported person.

The sensors which measure temperature (*Fig.62*), relative humidity and movement (*Fig.63*) of people allows carers to check remotely and identify potential issues/ concerns such as the home being too cold or there being no movement for a prolonged time.

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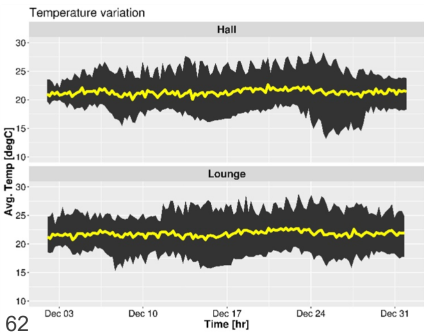

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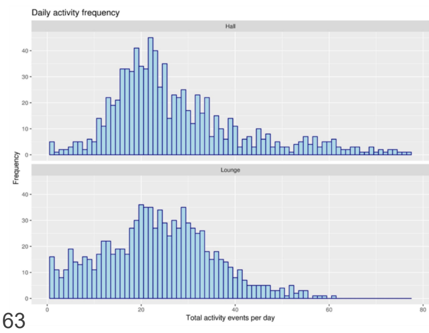

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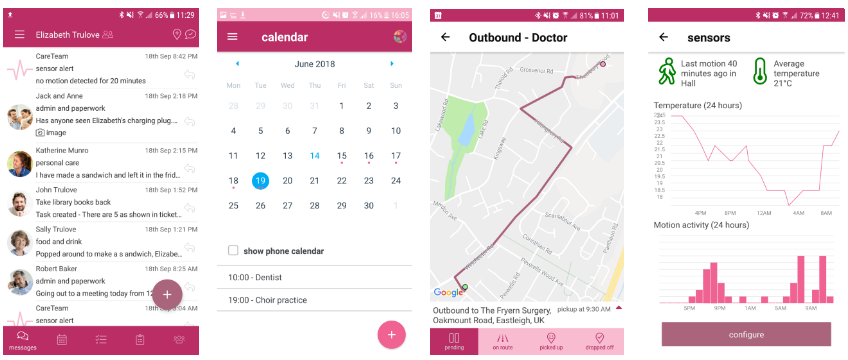

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Coasts and climate

Research into coastal engineering and management includes the modelling and societal responses to flooding, erosion and sea level rise.

Coastal engineering

Our work estimates flood risk and standards of protection at global and local scales. For instance, in the UK, coastal flooding is widely recognised as potential risk for civil emergency, with potential consequences including fatalities, damage to property and infrastructure, interruption of essential goods and services, and environmental damage including natural infrastructure.

Results indicate that there are large uncertainties in predicting the consequences of flooding due to the lack of or poor data availability, such as on coastal defences (*Fig.65-68*). The work also quantifies extreme water levels, which are set to change as a result of sea-level rise. This means that there is a great risk that defences, where present, may be overtopped under storms and sea water to propagate inland leading to flooding.


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Coastal management

Coastal zones are popular places to live (*Fig.69*), and have competing pressures on land for those living, working and holidaying by the coast. The research provides analysis on how coasts are managed today, and the implications of the competing interests that may exert, today and in the future.

Global studies have been undertaken in the broader context of climate change and sea-level rise including analysing the risk from erosion or flooding (*Fig.70*), and how to address them. This research uses a holistic perspective, using mixed methods from physical science, engineering and social science disciplines. One of the outcomes from this is the need for a more collective approach in coastal management, involving stakeholders at different level of government, and the need to include communities in decision making.


69

The research also addresses understanding of the complex processes affecting the environment and rural populations living within one of the world's biggest deltas. This includes identifying and examining synergies and trade-offs in achieving a number of United Nations Sustainable Development Goals (SDGs) for example, within the Sundarban Biophysical Reserve in the Ganges-Brahmaputra delta. A whole systems approach is applied to modelling the interrelationships between local governance, climate change, land use, hydrology, socio-economics and rural livelihoods.


70

Coasts and climate

Research into coastal engineering and management includes the modelling and societal responses to flooding, erosion and sea level rise.

Climate change impacts

Sea-level rise could be in excess of 1m in 100 years, creating significant impacts on coastal zones. We have studied impacts at global and continental scales, and in specific environments, such as deltas or small islands. For example, research across the Ganges-Brahmaputra delta indicated what areas are at risk from flooding now and in the future. The outcomes are supporting plans to reduce the number of people exposed to coastal flooding (*Fig.71-72*).

Research on small islands is undertaking risk and impact assessments, advising government and other stakeholders on how to adapt to sea-level rise (*Fig.73-74*). In the Solomon Islands, for example, research is being undertaken into community relocations in the context of rising sea-levels. Adapting to sea-level rise is not just an engineering problem, but also a societal challenge. So our research takes a diverse, whole systems approach to understand how to instigate change.

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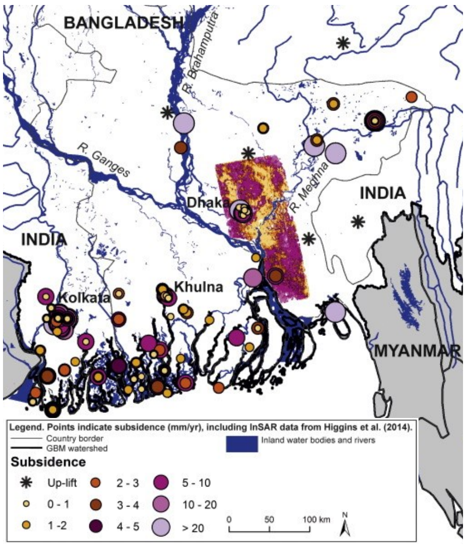

72 (Brown and Nicholls, 2015)

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Coastal vulnerability

Coastal vulnerability is assessed through analysis of coastal zones that are vulnerable to change (*Fig.74*), such as through rising sea-levels or wider coastal change. The research includes analysis of natural heritage sites to determine how and why they are vulnerable, and how vulnerability manifests itself. Providing evidence to governments and non-government organisations to understand how to reduce vulnerability and help them achieve that.

For instance, one of our projects analyses shoreline change on UNESCO natural heritage sites to determine whether shorelines have accreted by depositing sediment, or have been recessional leading to erosion (*Fig 75*).

Although these coasts are in pristine condition, results indicated that many sites are severely impacted by human behaviour outside of the sites boundaries. This is being followed up by interviews with coastal managers to determine how they are responding to shoreline change.

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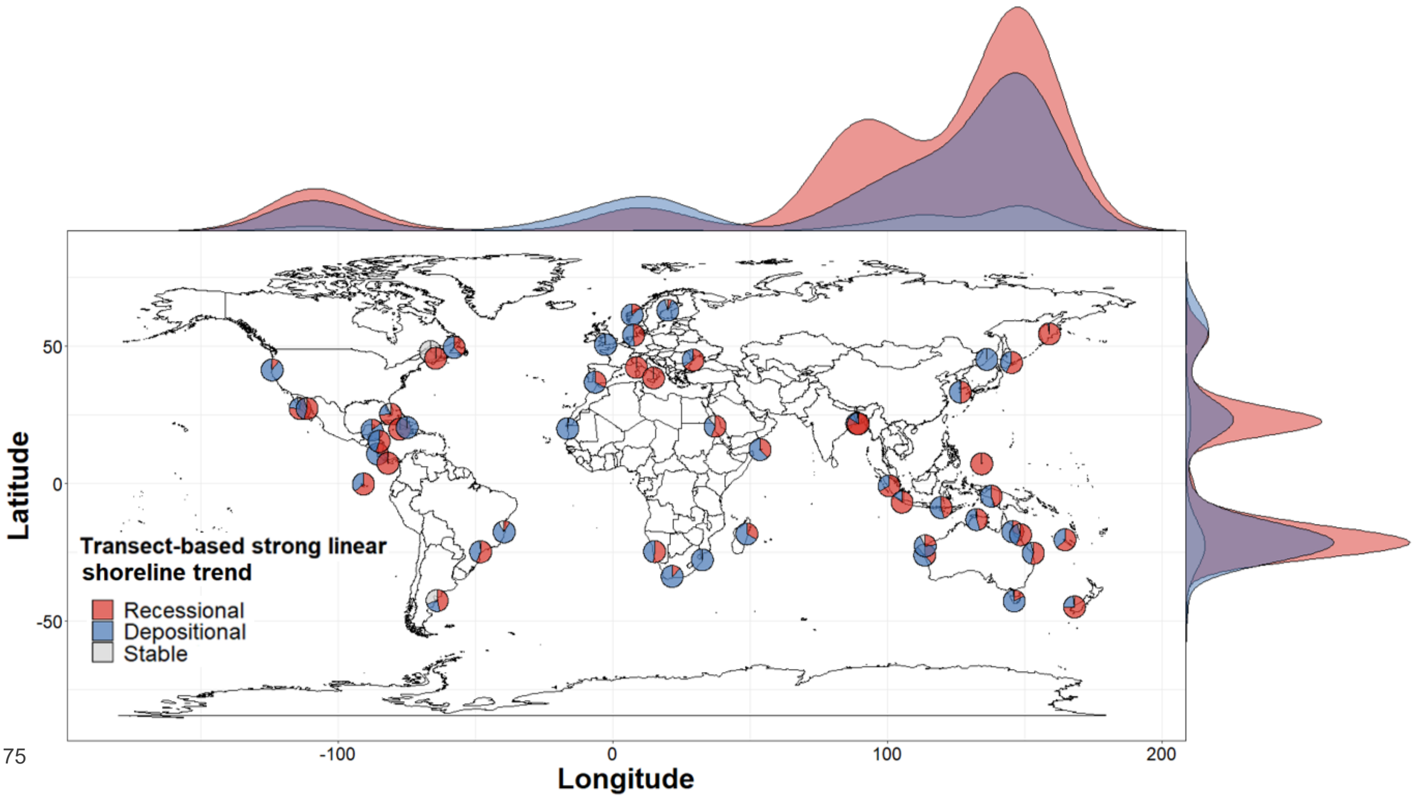

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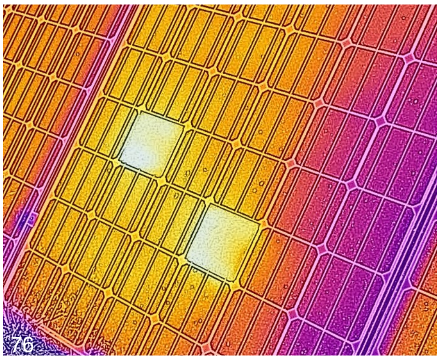
Further Fundamental Research

Further fundamental research to augment the 4 research themes of the Energy and Climate Change Division

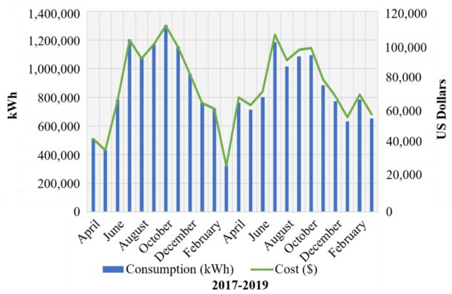
Artificial intelligence in renewable energy systems

Photovoltaic (PV) solar energy production is the fastest growing form of renewable energy, with forecasts of generation doubling by 2024. This growth is led by a decrease in capital cost, causing the relative cost of PV maintenance to increase, from ~50% of the total cost of UK's large-scale PV farms in 2019, to ~67.5% in 2030. Because of this, research is being undertaken into optimising solar PV maintenance using automated fault detection using AI. In this work, infrared thermography (*Fig.76*) is used to capture an image of the temperature of a solar PV module. State-of-the-art deep-learning-based image-classification algorithms are then used to detect if there is a fault and the type of the fault providing warning to farm operator.



Impact of solar PV penetration on city grids in the Kingdom of Saudi Arabia

Saudi Arabia has announced plans to build 20GW of photovoltaic (PV) electricity generating capacity by 2024 and 40GW by 2030. Solar PV total installations by 2020 will reach 2.5 GW. KSA 300 MW PV project expected to operate by November 2019, holds one of the records for low tariff for PV of US Cents 2.3417/kWh. This research studies the impact of PV penetration on the grid of the University of Jeddah Campus (*Fig.77*), knowledge generated will support analysis on a medium size city in KSA to displace fossil fuel power supply currently been used. The relationship between the consumption, economics, social and environmental aspects as well as grid impact will be assessed through different scenarios in both cases.



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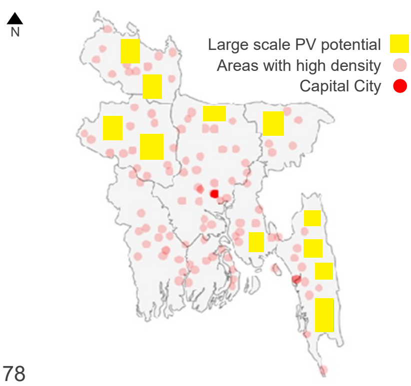
Transitioning Bangladesh to renewable power

This research addresses what are the policies required to guide Bangladesh through its sustainable energy infrastructure transformation to support its aspiration of becoming a developed country by 2041. A regression-based simulation model will be developed to exhibit the effects of influencing factors on the transition pathways. Based on the model outcomes, the research will suggest what renewable share in the energy mix should be progressively elevated in accordance with the future escalation in financial affordability and technical advancement of the overall efficiency of suitable renewable systems for the country. This work also aims to help policymakers and energy managers to understand better the dynamic interrelationships between different transition factors and plan the wide-scale implementation of renewable energy systems according to the available resource and fiscal potential of the region.



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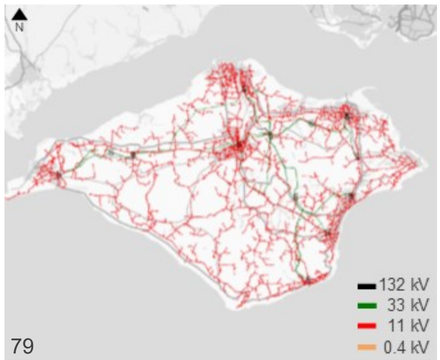
Realising the Isle of Wight's aspiration for renewable energy power generation and local consumption

In the UK, the Isle of Wight (IoW) wish to become self-sufficient in electricity from renewable sources, which is likely to be achieved through the deployment of utility-scale solar PV farms augmented with roof-top solar PV systems. However, the required expansion is constrained due to an insufficient network capacity, which has resulted in the curtailment of current generators during times of peak generation. The research undertaken explores the potential options to develop the IoW's renewable power generation by looking at opportunities for local consumption demands, energy storage systems, demand response strategies and smart grid solutions (*Fig.79*). The resulting methods and concepts will be tested on real-world conditions and will not only support the IoW Council's aspirations, but also have national and global applications as we make the transition to a low-carbon future.



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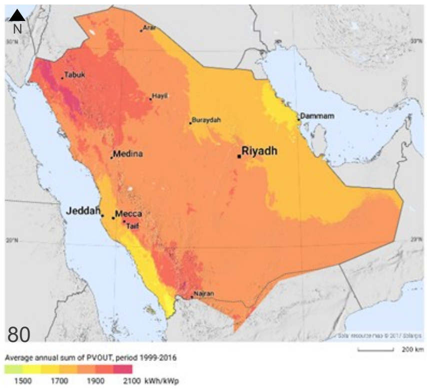
Supply chain readiness for renewable energy expansion in the Kingdom of Saudi Arabia

Saudi Arabia is aiming to intensify the adoption and the advocacy of their renewable energy sector, to localise 30% in the short term and 60% in the long term of its value chain. To achieve this, a local content market should be large enough to supply the planned 27GW capacity contained with 35+ renewable energy farms by 2024 with additional capacity of 59GW by 2030. Although Saudi Arabia has excellent natural wind and solar resources (*Fig.80*), the current skills are not adequate for planned future expansion in renewable energy. The research aims to identify means to reduce this skills shortage and proposes practical recommendations as to how to achieve this through robust research on KSA's supply chains and how this can be adapted and augmented to support the above targets.



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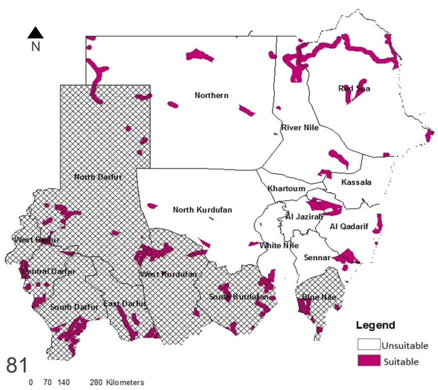
Site suitability analysis for renewable off-grid systems using GIS-MADM in Sudan

This research aims to investigate the potential for implementing clean off-grid energy systems for rural electrification in Sudan. Analysis using the GIS (Geographic Information System) -MADM (Multiple Attribute Decision Making) method will identify sites suitability for renewable off-grid electricity systems. The methodology includes four main strands of work: (a) assessment of renewable energy availability in Sudan, (b) identifying suitable weighting criteria for site selection, (c) location of appropriate sites that fulfil the criteria via MADM-GIS, and (d) performing experts' NGT (Nominal Group Technique) via AHP (analytic hierarchy process) - SAW (simple additive weighting) to select the most suitable sites in rural Sudan (*Fig.81*).



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Recent Projects

THERMOSS

SAVE

Low Carbon Cities

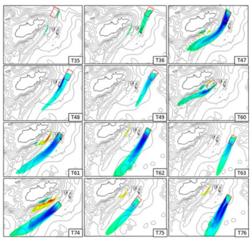
Fortis Unum

SENSE

DC Mini-Grid

Solar Home Systems

Energy Acess & Energy Efficiency



Marine Energy

Solar Shaded Car Park

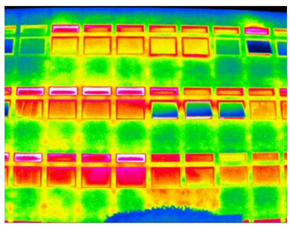
CareTeam

Marine Renewables

Energy for Development

Liveable Cities

International Centre for Infrastructure Futures



Community Initiatives in Energy Saving

Home Energy Management

APERIO: Low cost facade management

Dynamics of Energy Mobility and Demand

PhD & MSC Research

Outreach

International Conference on Energy and Cities (ICEC)

July 2019

More than 90 delegates from 21 countries and 40 organisations attended the International Conference on Energy and Cities 2019 (ICEC2019) from 10 to 12 July 2019 in Southampton, UK. Hosted by the Energy and Climate Change Division the occasion was the second in the series of academic fora promoted by the International Academic Alliance for Low Carbon Cities, Neighbourhoods and Buildings (IAA-LCCNB).

Keynote speakers

5th African Mini-Grid Summit

June 2019

Prof AbuBakar Bahaj, head of the Energy and Climate Change Division at the university of Southampton, chaired the 5th African Mini-grid summit held in Nairobi, Kenya . The Summit was part of the World Bank engagement on energy access, bringing together academic, government and stakeholders.

Key Cities Meeting - City and the Environment

Feb 2019

The Southampton City Council joined forces with the University of Southampton and hosted a Key Cities Meeting addressing challenges on air quality, energy efficiency, transport, and infrastructure development. In a united effort to highlight the green agenda the meeting urged local authorities to adopt a "healthy and prosperous" vision towards air quality and energy efficiency in towns and cities across the UK.

Saudi Arabia International Symposium on Progress in Solar Energy Applications

Feb 2019

Under the auspices of the King Salam Chair for Energy Research (KSCER) at King Abdulaziz University (KAU), Jeddah, Saudi Arabia, academics from KAU and the University of Southampton, Energy and Climate Change Division and the Sustainable Energy Research Group participated in an International Symposium under the title Progress in Solar Energy Applications, which was hosted by KAU and UoS and opened by the President of the KAU, Prof Abdulrahman Alyoubi and KSCER's Dr Abdulsalam Alghamdi.

Recent Publications

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