National Centre for Energy Systems Integration

Book of Posters & Abstracts

EPSRC National Centre for Energy Systems Integration

Research Conference 2019

Collaboration across CESI: Crossing boundaries

23 July 2019

Newcastle University

https://www.cesienergy.org.uk

Contents

Thank you from the Conference Chair, Professor Phil Taylor

Director, EPSRC National Centre for Energy Systems Integration
Head, Newcastle University School of Engineering

Thank you to everyone who participated in and helped to organise the CESI Research Conference 2019, making it such a successful event.

Special thanks goes to the Keynote Speakers, Emma Pinchbeck; Professor Stephen McArthur and Professor Keith Bell; Session Chairs, Dr Sara Walker and Professor Simone Abram, and of course to all of those who delivered talks, presented posters and contributed to discussions during the day.

We look forward to welcoming you to CESI Research Conference 2020!

Abstracts

Control Rooms of the Future

Simone Abram, Antti Silvast, Andrew Wright
Durham University

Abstract

Integrating energy infrastructures could have significant implications for operations in the energy system. Despite many years of adherence to political arguments around market provision and competition as the main driver of energy development, much of the UK's energy transmission and distribution infrastructure is still tied into monopoly systems of control. **Control Rooms of the Future** takes a first foray into what integration might mean in relation to system operation by conducting pilot research into control systems for distribution of gas and electricity. The project has two approaches that address regulatory and institutional, as well as operational questions. First, what are the regulatory and institutional conditions under which different energy vectors (gas and electricity) operate, and how might they facilitate or restrict the opportunities for more integrated operations? Second, what are the operational practices in different kinds of control rooms, and what opportunities do they afford for cross-vector co-ordination, and what risks do they present in terms of translating one control room culture to another? The project therefore includes a review of relevant regulatory conditions, alongside empirical research based in distribution control rooms in the respective sectors. It will coordinate with a complementary project to run a simulation exercise with control room staff.

The project allows us to ask how control rooms operate in practice, what the roles of control engineers are, what options exist for integration and what integration might imply for integration of infrastructure or operational practices. The project runs from January to September 2019.

Applying Systems Engineering Concepts for the Evaluation of Whole Energy Systems

Ali El Hadi Berjawi
Newcastle University, School of Engineering

Abstract

Evaluating energy systems performance is a complex task when placed in the social, environmental, economic and political contexts, in addition to the technical factors intrinsically involved. This requires an approach that can bring together different disciplines into the evaluation to account for the different perspectives respectively. The future energy system brings further complications to its evaluation, due to the interdependencies potentially involved in the integration of energy systems, across different energy vectors, infrastructures and stakeholders. This integration is expected to bring about emergent capabilities to the whole integrated energy system, such as enhanced resilience and adaptive flexibility. Hence, an approach that can capture the interactions involved and the systemic properties emerging is also required.

To address those needs, concepts from systems engineering are utilised and a system-of-systems approach is employed. The whole energy system is modelled in a way that would facilitate its evaluation. The conceptual model is based on an architectural framework that was tailored for this application describing the necessary system views. An architectural framework provides a consistent guideline for creating system views to address a specific purpose. This includes in this case defining the energy system boundaries, environment and constituent systems, and identifying the structure, interactions, requirements and functions at different system levels. Evaluation criteria and indicators are then derived from the system model to reflect the performance of the system and its functions towards achieving the identified requirements. The model is developed using the Systems Modelling Language (SysML). The framework is applied to different heat scenarios developed for the Findhorn Ecovillage case study.

Systems engineering is an interdisciplinary field that has been extensively applied to the fields of defence, aeronautics and software engineering, and less so in energy systems evaluation. This led us to a collaboration with a team of researchers in the School of Computing at Newcastle University, led by Professor John Fitzgerald, with expertise around systems engineering and the system-of-systems approach. This approach can support the evaluation of energy systems where existing frameworks fail particularly with the increased energy systems integration. With a more comprehensive and systemic evaluation, results should better serve as evidence for decision making on the benefits of integration.

The North of Tyne as energy systems integration case study

L Brown
Centre Manager, EPSRC National Centre for Energy Systems Integration
H Patsios
Co-Investigator, EPSRC National Centre for Energy Systems Integration

Abstract

The recently formed mayoral combined local authority of the North of Tyne (NTCA) encompasses a varied microcosm of the UK. Coastal, urban and rural communities are all part of this regional grouping. The energy system too is varied. As an ex-heavy industry region it has expansive aging legacy system assets but due to the rural nature of some parts, there are areas not served by the gas network and the power network is relatively weak.

With the primary aim of the NTCA to develop regional economic growth, what benefit or hindrance does the regions energy system provide? Does looking for opportunities for energy system integration provide benefits to how the new region looks as its energy system from a point of view of cost, carbon and security of supply? With two of the three partner local authorities declaring a climate emergency, what role can the regions energy system and its stakeholders play in responding to the crisis?

A study is being performed by the EPSRC National Centre for Energy Systems Integration into these questions. This paper will describe the scope of the project and share some of the very early findings.

Women's Whole Energy Systems Research and Industry Network Werin – We're in!

L Brown
Centre Manager, EPSRC National Centre for Energy Systems Integration
S Walker
Associate Director, EPSRC National Centre for Energy Systems Integration

Abstract

Ever wondered why there aren't more women working, innovating and researching in the energy sector? This is something that is often mentioned but not wholly understood. At the EPSRC National Centre for Energy Systems Integration (CESI), we aim to make inclusion a driving principle of our Centre. And to that end, we bid for and won funding support from the UK Energy Research Centre's Whole Systems Networking Fund (WSNF). Funded by EPSRC, the WSNF aims to improve equality, communications and collaboration between those working in the field of whole systems energy.

In this paper, we will introduce the aims of the Werin network. We will report on the engagement with the innovative member's platform and social media, using data from the platform and twitter analytics. We will then discuss the learnings and contributions gleaned from the networking events held to date, using a reflective learning approach. Finally, we will make recommendations, based on the project outcomes, of the ways in which the energy research community can better support a diversity of voices.

Interdisciplinary collaboration in energy modelling

Chris Dent

University of Edinburgh, School of Mathematics; The Alan Turing Institute

Abstract

This presentation will discuss key areas for interdisciplinary collaboration in energy modelling, and the mechanisms required to achieve this. The material will be based on:

- The speaker's own experience of interdisciplinary research;
- His involvement in scoping studies for Supergen Hubnet, and Centre for Digital Built Britain;
- His experience of developing interdisciplinary research strategy with organisations and initiatives including Durham Energy Institute, the Alan Turing Institute, and the Big Mathematics knowledge transfer project.

It will also present relevant preliminary outputs of The Isaac Newton Institute programme in "Mathematical and statistical challenges in landscape decision making" in which the speaker will be participating in the month of the CESI conference – this is particularly likely to generate new thinking on decision making against very complex backgrounds which is highly relevant to decision support for integrated energy system planning and policy decision making. This INI programme illustrates how many of the deeper methodology and process questions are common across different application disciplines including energy, transport and environment.

There is a strong desire from industry and government for improvements in approaches in modelling approaches. For instance, the 2017 Supergen Hubnet workshop on "Modelling in Public Policy" hosted by Ofgem revealed consensus of need for work in uncertainty treatment, evidence communication, and governance of analysis studies. In government, this is partly driven by the "Aqua Book" which provides an excellent guide to best practice for analysis studies.

The Centre for Digital Built Britain research scoping network on "Methodologies for planning complex infrastructure" reached similar very high level conclusions, and further intriguing outputs include:

- The need for information gathering and more detailed scoping work before full scale activity can begin in some areas;
- The need for a more nuanced understanding of success and failure of projects in public debate;
- Communication is a two-way matter – it is necessary for analysts to have a proper understanding of the interests of decision makers;
- How to determine what an appropriate level of resource for analysis is, particularly at the strategic planning stage of a project;
- The value of wider availability of data;
- The need for good design of funding structures, to encourage development of interdisciplinary collaboration.

All of these matters are fundamentally interdisciplinary. Even the technical end of managing uncertainty in modelling requires collaboration between applied system modellers and statisticians. Many of these issues are really about how modelling fits in the wider decision process, and advances in research and practice will require much broader collaboration including social and political scientists.

The presentation will conclude with a discussion of barriers to setting up interdisciplinary collaboration, and possible mechanisms for accelerating development of such collaborations.

Optimization-based Decision Support via Statistical Emulation

Hailiang Du and Michael Goldstein
Durham University, Dept of Mathematical Sciences
Wei Sun, Gareth Harrison and Bravo Vargas Ruben
University of Edinburgh, School of Engineering

Abstract

Computer simulators are widely used to make inferences about complex physical systems such as energy systems, in conjunction with historic observations. In energy systems modelling, optimization methods based on certain objective function(s) are widely used to provide deterministic solutions to decision makers. For complex high-dimensional systems, however, simplifications are inevitable to conduct traditional optimization, which leads to the “optimal” solution being suboptimal or nonoptimal. Whilst the optimization problem is well resolved, it would still be valuable for both operational and long term planning purpose to introduce some flexibility to the solution. A novel statistical methodology is introduced, where statistical emulation and uncertainty quantification are employed to identify candidate solutions and to quantify uncertainties (due to i) observational error; ii) emulation approximation; iii) model discrepancy) attach to each candidate solution. Candidate solutions subject to the objective function(s) provide useful flexibility and attached uncertainty quantification provides extra valuable information for decision support. Furthermore, the proposed methodology is able to estimate the Pareto boundary when there are tradeoffs in the objective functions, which provides valuable information for decision support. If the model is expensive to evaluate, traditional optimization methods will have serious difficulties, whereas the proposed methodology will not be hampered. Multiple applications to various energy system planning problems including wind farms, solar power stations and integrated systems are presented to provide strong demonstration of the use of the proposed methodology.

Techno-Economic—Environmental Evaluation of Integration of Multi-Vector Energy Networks for Meeting Heat Demand

Hamid Hosseini, Adib Allahham, Phil Taylor
Newcastle University, School of Engineering
Charlotte Adams
Durham University, Department of Earth Sciences

Abstract

In order to meet the UK Government carbon reduction targets by 2050, heat demand needs to be decarbonised since around one-third of the GHG emission of the UK is coming from heat demand of different sectors including residential, commercial and industry sectors. In this paper a framework is developed to evaluate the Techno-Economic-Environmental (TEE) performance of different options for meeting the heat demand of a region. The framework provides the basis to compare available and future scenarios for meeting the heat demand in order to make an informed decision to support the most cost-effective and least carbon intensive one. Also, the framework can be used in order to design different components of the heat supplying system including heat pumps and Combined Heat and Power (CHP) units. Additionally, it is possible to implement a layer of control and management over the framework in order to perform control of integrated energy networks of the region. Moreover, business models can be developed in order to deploy the most suitable scenario for supplying heat to the region.

The developed TEE evaluation framework consists of integrated gas, electricity and district heating networks. The available data of Findhorn during a representative winter week, as a case study, was used to populate the framework. Results show that the most operational cost-effective option is to include great share of renewable heating. In this study geothermal heating was considered as the zero carbon renewable heating. However, since great capital cost is associated with deployment of geothermal heating, the next option was deployment of high performance heat pumps.

Integrated Transport Electricity Gas Research Laboratory: InTEGReL

Andrew Jenkins
Newcastle University

Abstract

InTEGReL is a fully integrated whole energy systems development and demonstration facility, providing space for industry, academia, SMEs and government to come together to explore and test new energy technologies, strategies and processes which bring transport, electricity and gas into one place.

The presentation will discuss the how InTEGReL is breaking down traditional barriers between gas, electricity, water and transport sectors to help to deliver a more secure, affordable and low carbon energy system. Existing facilities at the site are highlighted.

Information on the plans and aims of the research facility "Energy Systems Hub for Innovation and Engagement" will also be presented.

An urban-scale, physics-integrated stock modelling approach, calibrated using smart meter data

Peter McCallum, David P. Jenkins, Andrew D. Peacock
Heriot-Watt University, School of Energy Geoscience, Infrastructure and Society

Abstract

All modelling exercises which aim to help us understand, plan and enhance our control of regional or national scale energy systems rely on information regarding how energy demand can be characterised at different spatial and temporal scales. Spatially, there are pertinent energy system modelling questions on a household-scale basis (e.g. time-of-use dynamics and opportunities for demand response and distributed storage), on a neighbourhood scale (where district heating, renewable or storage systems might have application, along with the role of private-wire micro-grids or virtual private-wire networks), and at larger scales, a wide range of traditional operational and planning issues are also present (network constraint issues, long-term strategic policy making around major generating plant). In contrast to traditional approaches to energy system modelling, modern energy systems with significant renewable sources demand must be characterised in a temporally refined manner; depending on the specific objectives, this resolution can be in the range of 1 to 5 minutes, up to 1 hour.

To support energy system modelling, this detailed demand information can be provided through a combination of physics-integrated thermal demand models and electricity demand models. Regarding the former, generating socio-technically rich outputs from a dynamic thermal demand model requires a sensitive approach to calibration. There are a number of different types of model input data for thermal demand models, including a wide range of stock characteristics, physical description of building materials, archetype classifications and characterisation of building user behaviour. The model inputs that have the most significant influence on the ‘daily shape’ of the output response relate to building user behaviour, i.e. schedules that describe occupancy, energy use and heating system controls. This work relates specifically to the calibration of heating system control inputs for dynamic thermal modelling.

This work presents the construction and calibration of a physics-integrated partial stock-model of the North of Tyne Combined Authority. Underpinning this calibration approach is a clustering procedure that identifies routine household behaviour in smart-meter data, which includes links to corresponding demographic data. A series of 2D distributions are generated, from which synthesised heating control profiles are reproduced, which correspond the demographic specific results identified during calibration. As part of the next stage for this work, it is expected that close integration will be necessary with social-science based approaches in demographics mapping and energy practice behaviour.

The HMM-GP model for statistical simulation of electricity demand profile

S.Patidar, D.P.Jenkins, A.Peacock, P.McCallum

Heriot-Watt University, School of Energy Geoscience, Infrastructure and Society

Abstract

To ensure an optimally operating, smart and sustainable energy system, detailed understanding of different components of energy systems such as generation, supply and consumption is essential. The energy performance of buildings can be investigated through physical models as well as data-driven approaches [1] [2]. Physical models can provide a very approximate estimation of building energy use and in general are not suitable for estimating high-resolution demand characteristics of buildings, particularly dwellings. To this issue, several novel statistical/time-series modelling approaches exist in literature. These models are mainly calibrated using detailed information on either or both electricity and household diary data, which is not always easily accessible, i.e., there is a scarcity of data that meets the criteria of being i) high resolution, ii) recorded over long durations (e.g. to capture seasonal variability), and iii) representing a large sample of dwellings accounting for diversity of energy use. In this context, this paper is aimed to present a novel framework of statistical approaches, referred to as the Hidden Markov Model with Generalised Pareto (HMM-GP), that could relax these relatively strict criteria for data requirements through synthetic simulation of electricity demand profiles.

The patterns of individual electricity demand profiles reflect various regular and irregular activities (attributed to “deterministic” and “stochastic” processes) occurring in the household. The time series decomposition techniques such as STL (a Seasonal-Trend decomposition procedure based on Loess) can be used to simplify patterns in the demand profiles by uncovering different layers of hidden processes and to improve overall modelling accuracy [3]. This paper will demonstrate the performance of an STL-based time series decomposition approach integrated with a HMM-based electricity demand synthesising model. The paper will further demonstrate influence of integrating a GP distribution within the modelling framework (for data post-processing) to improve overall model accuracy in simulating extreme (peak) demand values. The model is applied to a diverse range of dwelling types located in the case study community of Findhorn [4] and the performance of the HMM-GP model in synthesising individual and aggregated demand profiles is thoroughly investigated.

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UKRI Research & Innovation Infrastructure Roadmap for Energy

Zoya Pourmirza, Hamid Hosseini, Damian Giaouris, Sara Walker, Phil Taylor
Newcastle University, School of Engineering
Neil Bateman
Engineering and Physical Sciences Research Council

Abstract

UKRI has been commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) to develop a Research and Innovation infrastructure (RII) Roadmap for the UK. In turn, the EPSRC National Centre for Energy System Integration (CESI) has been commissioned by UKRI and EPSRC to assist in the creation of the UK RIIR for the energy sector that will be required in the UK by 2030.

The presentation discusses the overview and methodology implemented in this project. It demonstrates the wide spectrum of stakeholders and organisations consulted. The findings are presented from Phase 1, which focussed on developing an understanding of the existing research and innovation infrastructure landscape, key statistics relating to the 58 identified RIIs and main messages derived from the landscape study. Finding from Phase 2 are also discussed in terms of future research challenges and RIIs required to address those challenges, and resulting investment priorities. Further strategic messages of both phases of the project are highlighted.

The presentation concludes by highlighting the high impact and benefit of undertaking the UK RIIR project in increasing our understanding of the UK's current capability and planning for the future.

Experience curves of low carbon heating technologies in the UK

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Abstract

Low carbon heating technologies deployment has been acknowledged as one of the main actions toward decarbonising the heating sector. In the UK, several deployment oriented policies have been implemented, such as the Renewable Heat Incentive (RHI). However, there is a lack of data in quantifying the impact of deployment to cost reductions. This issue is addressed in the study by developing experience curves of low carbon heating technologies in the UK. Experience or learning curves, illustrate the development of production costs or product price with the increasing number of products or deployment. Originating in the manufacturing sector, experience curves have been widely used in techno-economic studies of energy technology, such as power plants, wind turbines, photovoltaics, and carbon capture technologies. In this study, the focus is on the following domestic heating technologies: air-source heat pumps, ground-source heat pumps, solar thermal collectors, and biomass boilers. Condensing combination gas boilers are also included in the study to act as the baseline/incumbent technology. We found that air-source heat pumps have the highest experience rate among the low carbon technologies at a 12% rate, while gas boilers have reached the floor price at approximately £30/kW due to its maturity. The resulting experience rates can be used in energy economics models and to inform policy-makers in developing further deployment programs. The latter is particularly imminent with the end of RHI in 2021 and the plan to exclude gas boilers from new build domestic properties from 2025.

Interdisciplinary research for energy systems integration: understanding and promoting good practice

Mark Winskel
University of Edinburgh, School of Social and Political Science
Matthew Hannon
University of Strathclyde Business School
Antti Silvast
Durham University

Abstract

This presentation will report interim findings from a CESI Flex Fund project which is addressing the interdisciplinary challenges and opportunities of energy systems integration (ESI) research. The project is analysing ESI research as a distinctive form of 'whole systems' interdisciplinary energy research (Winskel, 2018). Although systems integration research shares some of the characteristic challenges of whole systems research, in terms of the synthesis of different disciplinary approaches and working across academic-stakeholder communities, it also has some distinctive aspects, in terms of its emphasis on the detailed operation and planning of energy system infrastructures as they evolve over time.

The presentation will discuss the distinctiveness of ESI research within wider whole systems energy research activities, by drawing on a range of evidence generated by the flex fund project to date. These include a desk-based review of ESI and whole energy systems research, a facilitated group discussion among CESI researchers, a workshop which brought together CESI researchers with other whole system research energy researchers and other analysts, and a number of interviews with senior interdisciplinary energy researchers, advisors and stakeholders.

The interim findings will be presented in terms of a number of themes, including overall research consortia designs and interdisciplinary research team working, the development of integrative methods such as scenarios and modelling, and working with non-academic stakeholders. As the project is continuing, the presentation offers an opportunity to test-out some interim findings ahead of final conclusions and recommendations on good practice for interdisciplinary research for ESI, to be published in the Autumn.

References

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A. Silvast, M. Hannon and M. Winskel (n.d.) 'Interdisciplinary Whole Systems and Systems Integration Research: A literature review' working paper for CESI flex fund project, April 2019.

A Novel Planning Method for Multi-Scale Integrated Energy System under CO_2 Force

Jingjie Yang, Wei Sun, Gareth Harrison
University of Edinburgh, School of Engineering

Abstract

The interdependencies of electricity, heat and gas systems have significantly increased in recent years, and their further coupling becomes increasingly important to realize the efficient and secure operation of the future low carbon energy systems. Integration of multi- energy systems at different scales represents an opportunity for overall system improvements using the flexibilities across the distributed local small scale to utility energy network level, bus also poses a new challenge of complexity.

Therefore, a 'whole system' planning approach is essential to capture the synergies and reduce the risks associated with securing an integrated system. Current research on optimal planning for IES lies in different levels, from distributed local small scale to utility energy network level. Optimal design for sizing of hybrid renewable energy system with a battery energy storage systems is presented in [1], for a small-scale residential micro-grid. A comprehensive planning model is introduced in [2] for a distribution energy system with different renewable energy based distributed generation, electric vehicle and energy storage systems. An expansion-planning model for large-scale combined gas and electricity network is developed in [3], with gas-fired generation units as linkages between the two systems.

Some research also make efforts to realize overall planning for multiple IESs. Reference [4] presents an optimization framework that combines the optimal operation and planning of multiple building energy systems with consideration of electric network constraints. An optimal expansion planning model for distribution level gas and electricity energy system with multiple energy hubs are proposed in [5]. However, the multiple IESs are modelled in a single system in existing works in order to get the overall optimal planning scheme for the whole energy system. The centralised planning methods overlook the different ownerships of sub-energy systems, and can lead to impractical in reality as the subsystems are often independently managed.

In this paper, a novel decentralized optimisation framework is proposed to allow a two-level planning integration, which includes the lower-level of multiple local communities and the upper-level of an integrated electricity and gas distribution network. The two levels are both optimised to minimise their own cost respectively while an overall carbon emission budget is set on the entire system under a CO2 force. The distribution optimization is implemented via Alternating Direction Method of Multipliers (ADMM) in order to solve the problem. A case study is also provided to illustrate the application of the proposed framework.

National Centre for Energy Systems Integration

Posters

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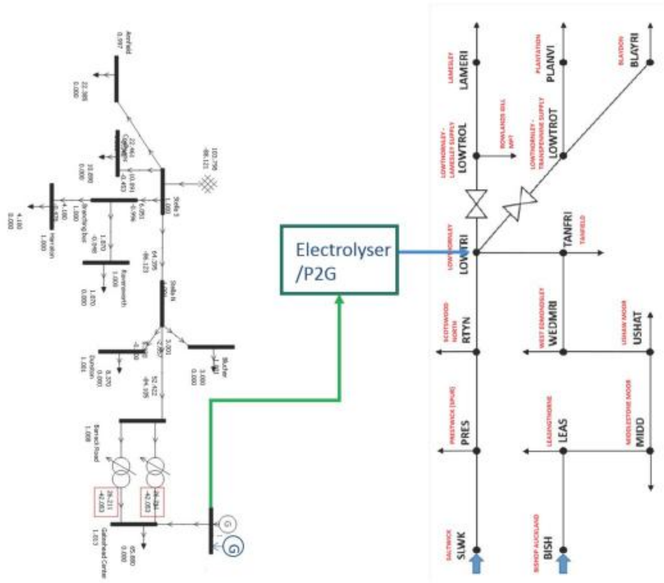
CESI National Centre for Energy Systems Integration

Control Rooms of the Future

Curtail or use?

Rather than switch off a turbine when there's no load, what if it were used to power an electrolyser? What if the hydrogen produced could be fed into the gas network? How would the electrical and gas networks need to communicate with one another? Would control rooms have to change?



Control Room Integration

As well as regulatory and institutional issues, we look at 'control room cultures' - routines, expectations, and norms in respective control rooms, to see how these might affect future integration.

Step 1: Regulatory and institutional review
Step 2: Control room observations and interviews
Step 3: Simulation exercise with InTEGReL
Step 4: Systematic study design

Integrating Vectors

Active network management is a means to balance generation and load in a distributed system. In an integrated system, who will do that load-management? What kind of control will be required? Are today's control rooms right for future integrated active management? What are the rules for control room operation? Which regulations might need to be amended? Should integration happen at Transmission or Distribution level? How many sites have curtailed generation near to gas access? How big will hydrogen input have to be before it requires changes in gas control operations (given current experience with smaller biomethane production)?

Areas for further research include:

Network Entry Agreements would be required; what would they look like?
Both vectors work with legacy systems based on earlier philosophies that are only gradually aligning with current issues. How can imaginaries of future systems enhance the alignment during a transition?
If the interests of the two vectors do not align, what kind of new network code will be required?
If hydrogen production is owned by third parties, what kind of network agreement will they have to sign up to, to ensure efficient working and maintenance?
At what pressure (what section of the pressure regime) should hydrogen be introduced?
Should hydrogen be controlled by the DNO/DSO's or by National Grid?
How much of the control could be automated?
How will commercial and operational decision-making be coordinated?

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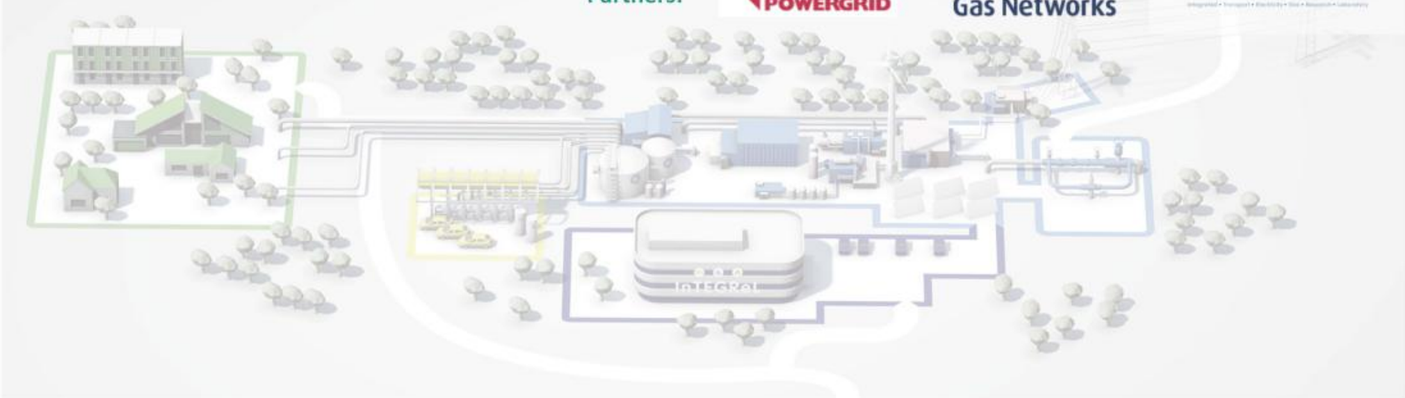

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National Centre for Energy Systems Integration

An Interdisciplinary Framework for Evaluating Whole Energy Systems

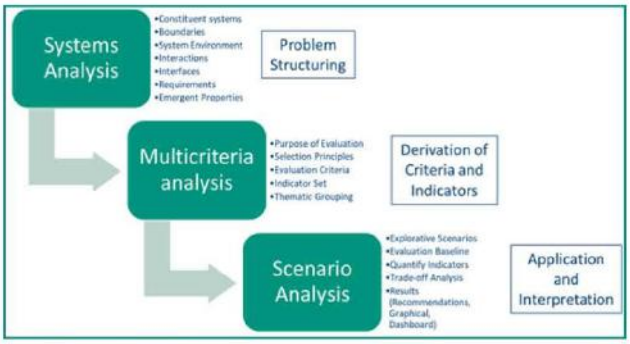
1. Future Energy System

- Combined perspectives & multiple objectives
- New interactions and interdependencies
- Emerging properties of the whole system
- Integrated energy system architecture

2. Evaluation Requirements

- Multidimensional
- Multivectoral
- Systemic
- Systematic
- Futuristic
- Applicable

3. Evaluation Framework



4. Case Study: Findhorn EcoVillage

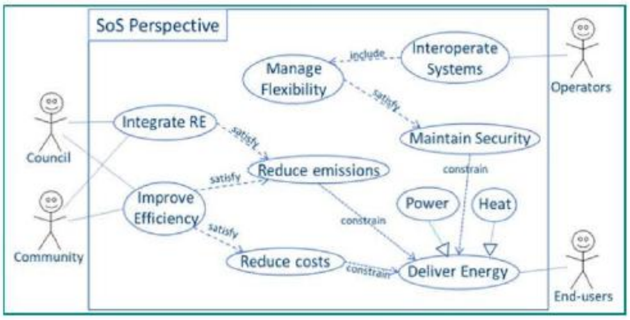
Test Scenario

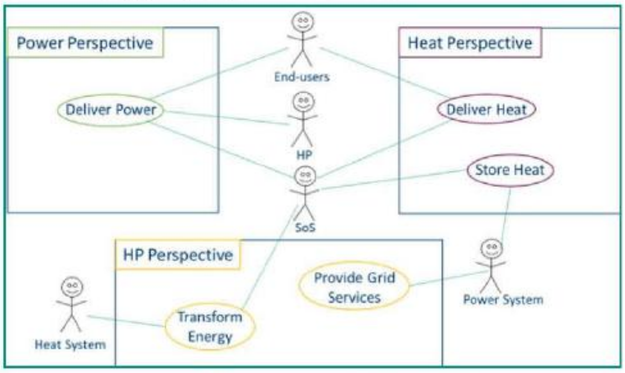
- Integrated Power and Heat Systems
- Power network fed by transmission grid
- Local wind farm and rooftop solar PVs
- District heating network: ground-sourced heat pumps, thermal storage and electric heaters

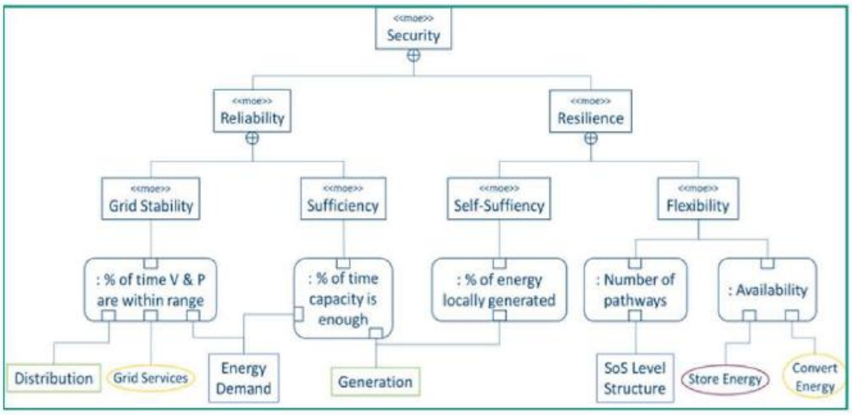
System Boundary

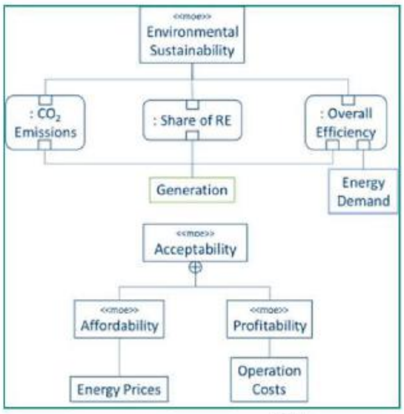
- Energy Supply and Infrastructure

5. Systems Analysis









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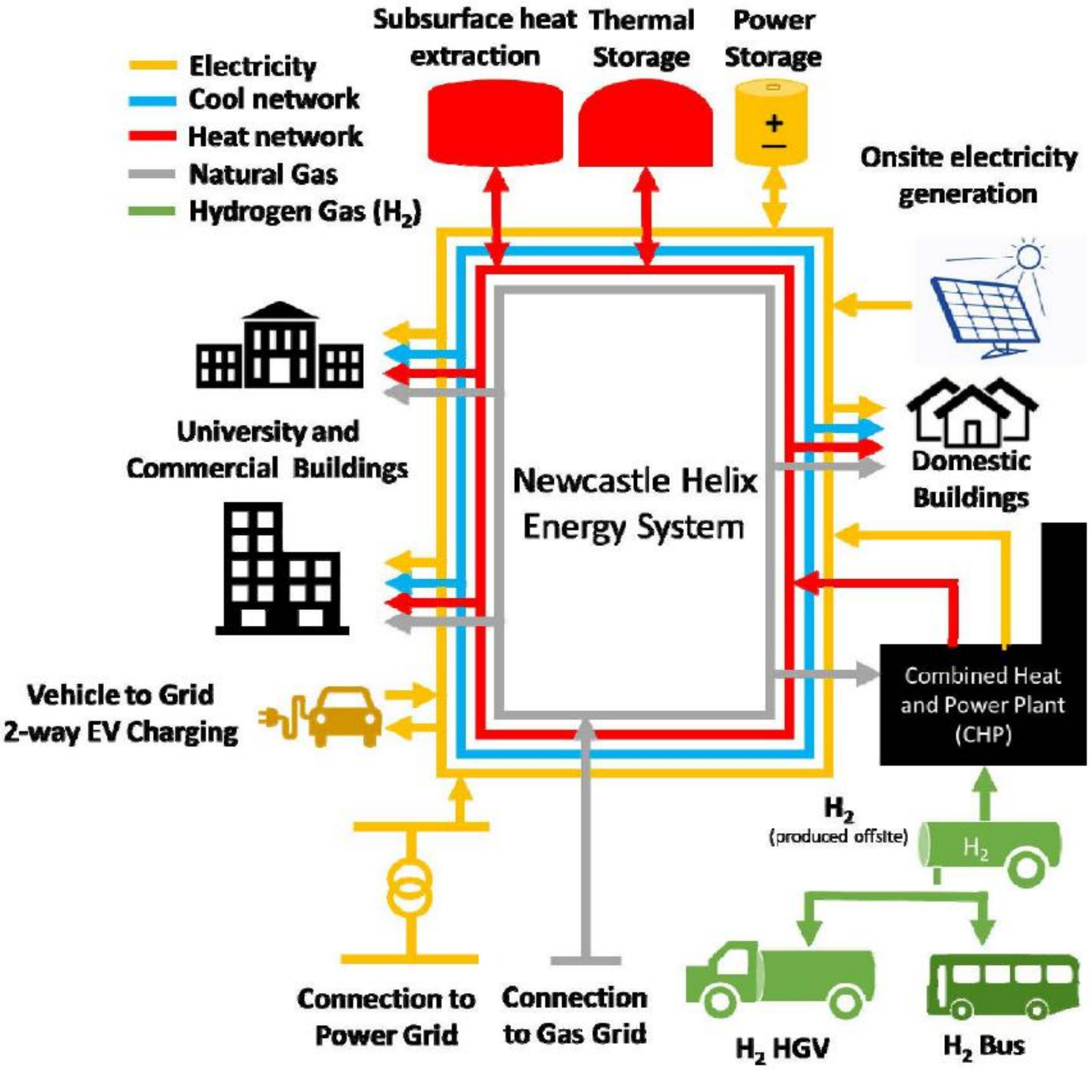
National Centre for Energy Systems Integration

Envisaging a NetZero Newcastle Helix Energy System

- A landmark 24-acre hybrid city quarter in the centre of Newcastle, built for international tech and science businesses, the local community and residents.
- Smart grid with energy efficient, smart buildings and a district heating system fuelled from an on-site energy centre
- Home of the Urban Sciences Building (USB)
- Newcastle Helix and USB are CESI demonstrators



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National Centre for Energy Systems Integration

Women's Whole Energy Systems Research and Industry Network

We're in!
www.werin.org.uk

Working Together	Waving the flag for women in the Sector	Network Building	Signposting
A coherent, inclusive and comprehensive network of female academic and industrial research personnel working in the energy systems field within the UK	An events series that is inclusive, flexible and focused on engaging with the entire energy systems community regardless of geographical constraints	Aiming for new collaborative research opportunities to be established by members as a direct result of meeting new contacts through the network	Interactive membership platform with user-generated content providing sector information via blogs and details of relevant events

Some of the themes and partners of our past events

The Future of Electric Vehicles

Benefits of gender parity in preparing for the energy transition

What innovative approaches are needed to deliver Net Zero by 2050?

Networking lunch with Panel and Audience Discussion

Joanna Das: Joanna.das@ncl.ac.uk, **Dr Sara Walker:** Sara.Walker@ncl.ac.uk, Newcastle University

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Supergen | Energy Networks

Supergen Energy Networks Hub: An Overview

Bringing together the vibrant and diverse energy networks community to gain a deeper understanding of the interactions and inter-dependencies of energy networks

What is the EPSRC Supergen Programme?

The Supergen programme was set up in 2001 to deliver sustained and coordinated research on Sustainable PowER GENeration and supply. The UK has ambitious energy and environmental targets and policy goals. It is hoped the fourth stage of the Supergen programme will contribute to meeting these through its world class research.

What is the Supergen Energy Networks Hub?

The Supergen Energy Networks Hub is a £5 million, 48 month investment from EPSRC. The hub's research focuses on how different energy networks can work together to adapt to challenges from societal shifts, environmental changes and technology on energy networks.

The hub also includes a range of industry partners. This is essential for meeting our purpose to understand, shape and challenge the whole energy network infrastructure.

Example of engagement we have done so far:

Our Team:

Our leadership team is made up of six academic core partners based at five different universities, along side Research Associates and Professional Services staff:

Our Industry Partners

Supergen Energy Networks Hub includes crucial partnerships with gas and electricity utility companies; government, industrial and international organisations; trade association bodies; and data/ICT/cyber experts:

Our Industry Advisory Member organisations

Areas of Research and Networking Activities

Sara Walker	**WP1: Understanding, Shaping and Challenging** Answers "What is the value of a whole systems energy networks approach?" by brining all work packages together	**Equality Diversity and Inclusion** To become a beacon of EDI by enhancing equality of opportunity and create a flourishing, safe and inclusive environment for everyone associate with the Hub
Jianzhong Wu	**WP2: Energy Network Infrastructure** Looks at multi-vector energy infrastructure and will build on existing research in energy networks	**Demonstrators** Supporting validation of approaches through demonstration at a range of scales
Vladimir Terzija	**WP3: ICT and Data** Addresses and investigate practical and validated approaches for integration of big data	**Industry** Enable close collaboration with UK and international industry in supply, demand, infrastructure, transport, ICT and storage sectors
Peter Taylor	**WP4: Policy and Society** Targets the creation of flexible policy that can meet the long-term challenges of energy networks	**Policy Interface** Activities including policy briefings, involving decision makers in workshops, joint briefings, collaboration with other hubs, and media
Furong Li	**WP5: Markets and Regulation** Develops holistic techno-economic tools, commercial and regulatory innovations to promote efficiency and resilience	**International/ Horizon Scanning** Promote international applicability of UK energy networks research through keynote and research presentations
Robin Preece	**WP6: Risk and Uncertainty** Establishes how uncertainties propagate through interconnected and interdependent energy networks	**Early Career Researchers** Support ECR mobility and access to fulfil their potential as the next generation of energy researchers

Dr. Chris Dent, School of Maths, University of Edinburgh
Turing Fellow at the Alan Turing Institute
Co-Director, Centre for Energy Systems Integration

CESI National Centre for Energy Systems Integration

Interdisciplinary collaboration in energy modelling

Hubnet "Modelling for energy policy" workshop , May 2017

- Hosted by Ofgem, sponsored by Supergen Hubnet
- CESI involvement: Dent, Wilson, Copeland, DEI, Mackerron
- Key message was need for cross cutting work, e.g. managing uncertainty, communication, modelling within overall policy process
- Role of government Aqua Book a key issue

The Aqua Book:
guidance on producing quality analysis for government

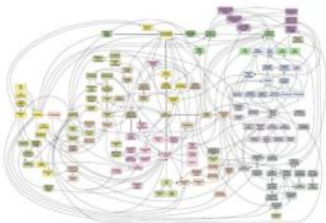
cdbb
Centre for Digital Built Britain

CDBB "Methodologies for planning complex infrastructure under uncertainty"

- July to December 2019, CESI staff in core team: Dent, Mackerron, Du, Tehrani, Gibson
- Key conclusions
  - Need for preliminary info/scoping work
  - Nuanced understanding of success and failure
  - Communication from decision makers to analysts
  - Level of resource for strategic planning
  - Value of wider availability of data
  - Good design of funding structures

INI "Mathematical and statistical challenges in landscape decision making"

- July 2019, Dent and Goldstein invited
- Examples of topics covered
  - Decisions against very complex backgrounds
  - Common methodology core across applications
  - Explainability of models
  - Integrating analysis and overall decision process
  - HM Treasury Green Book and natural capital
  - Links to large NERC/DEFRA programme



Isaac Newton Institute for Mathematical Sciences

Department for Environment Food & Rural Affairs

Conclusion: need for collaboration

- I have interacted directly with many subjects
  - From engineering and maths to philosophy
  - All have important things to contribute
- Some key challenges in linking disciplines
  - Funding can end up with 'usual suspects'
  - Do best people have application track record?
  - Reward for interdisciplinary research and KT??
  - Challenge of KT with unfamiliar methods
  - Need to work together from early stage
- Picture is optimistic if we can make these links

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Techno-Economic-Environmental Evaluation of Integration of Multi-vector Energy Networks for Meeting Heat Demand

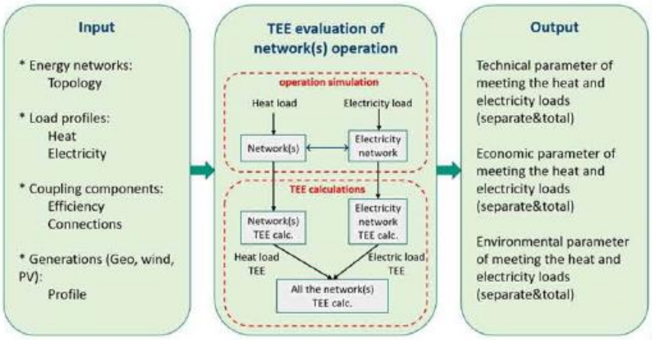
Introduction

- Decarbonisation of heat demand is a priority to meet the UK government 'Net Zero' target.
- A framework is required to evaluate the Techno-Economic-Environmental (TEE) performance of different options for meeting the heat demand of a region.
- The framework needs to provide the basis to make an informed decision to support most cost-effective and least carbon intensive one.
- The framework can be used to design different components of the heat supplying system.
- It is possible to implement a layer of control and management over the framework.
- Business models can be developed to deploy most suitable scenario for supplying heat to the region.

Research question

How to evaluate different options for meeting the heat demand in terms of Techno-Economic-Environmental (TEE) parameters in integrated multi-vector energy networks?

Algorithm of Techno-Economic-Environmental (TEE) evaluation framework



Test system

- District heating network has the same topology as the electricity network, i.e. the heat source is just next to the electricity network substation (slack bus).
- The geothermal pump, the heat source electric heater, the CHP in different scenarios are all at the heat source/slack bus.
- The gas boiler and heat pump in the scenarios are at the nodes corresponding to the zones.
- Data for the week in winter (w/c 23.2.2015) used.

Scenarios

Scenario 1: all electric
Scenario 2: all gas
Scenario 3: gas and electric heat pumps
Scenario 4a: high temperature geothermal & DHN *
Scenario 4b: low temperature geothermal & DHN
Scenario 5: high temperature geothermal, CHP & DHN
Scenario 6: CHP & DHN

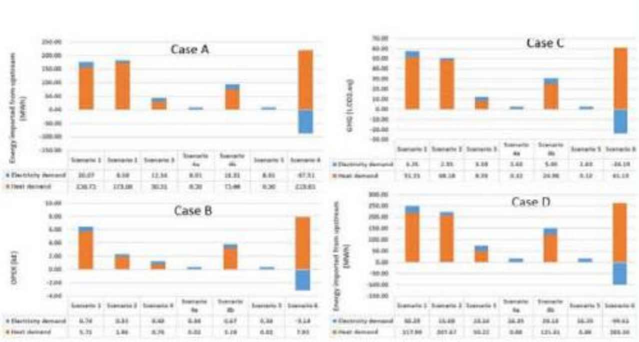
* DHN: District Heating Network

Cases for loads and generation levels

	Load w.r.t. Case A	RES generation w.r.t. Case A
Case A: Base case	--	--
Case B: Peak load	120 %	100 %
Case C: High renewables	120 %	140 %
Case D: Low renewables	120 %	60 %

All the scenarios were simulated in all the Cases for loads and generation levels.

Results



Key findings

- The performance of the TEE evaluation framework is verified and can be used for well-informed decision making on design choices of future energy scenarios since it has produced sensible results.
- The most operational cost-effective and least carbon intensive options for heating are, in order:
  - High temperature geothermal
  - Electric heat pumps at zones that follow the load
  - Low temperature geothermal boosted by heat pump
  - CHP
  - Gas or electricity networks (depending on RES levels: electricity network at higher RES, gas network at lower RES)

  Decreasing cost effectiveness and increasing carbon emissions
- The higher the renewable levels, the less energy imported from upstream networks, more cost savings for both network operator and customers and cleaner air.
- The TEE framework can actually assist in quantifying the impact of different technology mixes as well as load and RES levels on comparing different options for meeting the heat demand.

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National Centre for Energy Systems Integration

InTEGReL

Integrated • Transport • Electricity • Gas • Research • Laboratory

InTEGReL today

InTEGReL is a fully integrated whole energy systems development and demonstration facility, providing space for industry, academia, SMEs and government to come together to explore and test new energy technologies, strategies and processes which bring transport, electricity and gas into one place.

The initiative creates a first-of-a-kind facility exploiting, and significantly enhancing, the existing co-location of:

- An electricity distribution system
- A gas distribution hub
- A gas distribution system control room

Through collaboration with industry and academia, InTEGReL is breaking down traditional barriers between gas, electricity, water and transport sectors to better utilise their assets to deliver a more secure, affordable, and low carbon energy system.

The existing and proposed future InTEGReL facilities are summarised in Figure 1. The core partners of InTEGReL do not seek to retain IP from innovations developed using the facility, and see their roles as predominantly facilitative. **Therefore InTEGReL is open to researchers to use the facilities in their research.**

Proposed ESHIE research facility at InTEGReL

Newcastle University are developing the £22m Energy Systems Hub for Innovation and Engagement (ESHIE) facility to provide an open, flexible, 'whole-systems' energy research and demonstration facility at the InTEGReL site.

It will support expertise to catalyse effective energy solutions developments, and will address the skills gap for research and innovation in energy systems integration. Within ESHIE will be an industrial research lab with the ability for any energy conversion equipment to plug-and-play with; electricity, natural gas, hydrogen, hot heat, cold heat and compressed air.

Newcastle University are working to close the £17m funding gap in order make the ESHIE facility, shown in Figure 2, a reality.

Figure 2: Artists impression of ESHIE

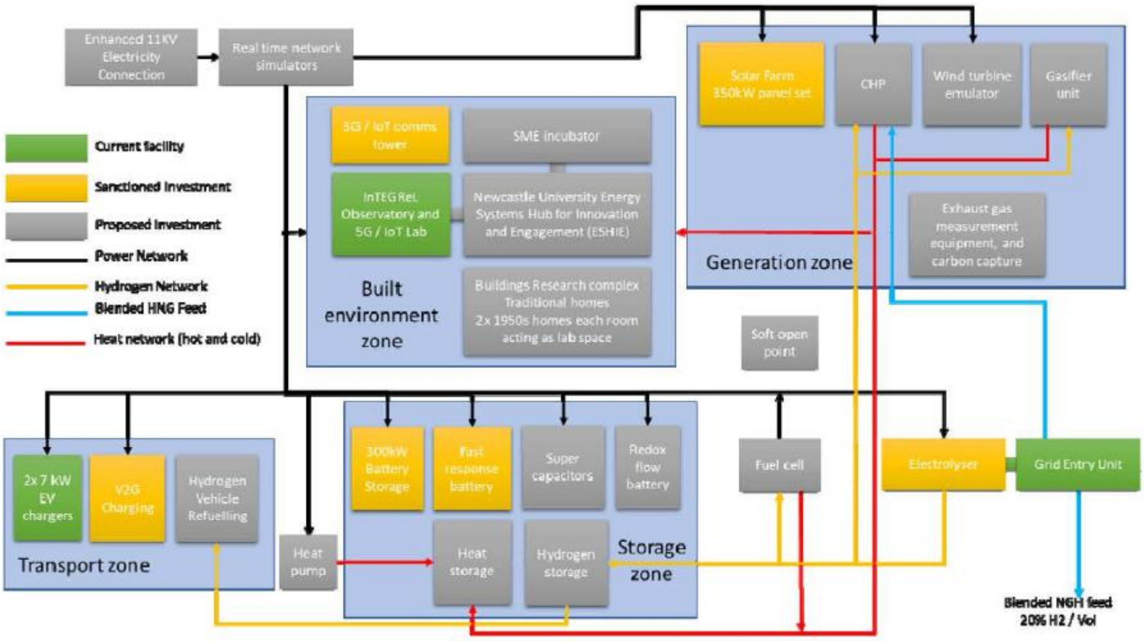

Figure 1: Proposed InTEGReL energy assets and development projects

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An urban-scale, physics-integrated stock modelling approach, calibrated using smart meter data

— Our partners —

EPSRC Pioneering research and skills | Newcastle University | US University of Sussex | Durham University | THE UNIVERSITY of EDINBURGH

— Urban-scale energy demand modelling —

This work presents the construction and calibration of a physics-integrated stock-model of a residential district within the North of Tyne Combined Authority (Shiremoor, North Tyneside).

— Characterising socio-technically rich energy demand patterns —

Overall, our collective whole-system modelling efforts aim to help us understand, plan and enhance our control of regional or national scale energy systems. This relies on socio-technically rich characterisation of energy demand, at different spatial and temporal scales.

Spatially, there are pertinent energy system modelling questions:

- on a household-scale basis (e.g. time-of-use dynamics and opportunities for demand response and distributed storage);
- on a neighbourhood scale (district heating, renewable or storage system applications, along with the role of private-wire micro-grids or virtual private-wire networks);
- and at larger scales, a wide range of traditional operational and planning issues are also present (network constraint issues, long-term strategic policy making around major generating plant).

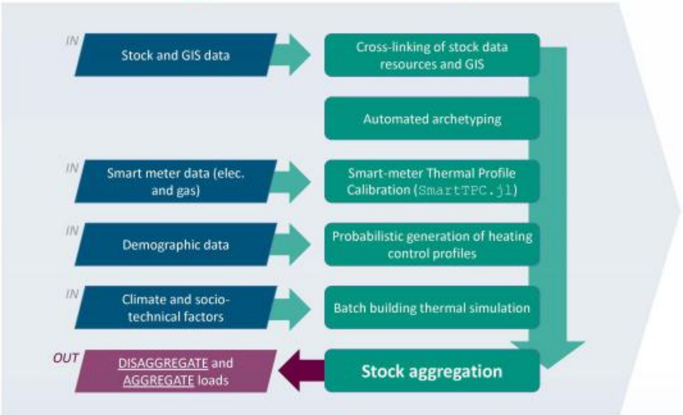
Temporally:

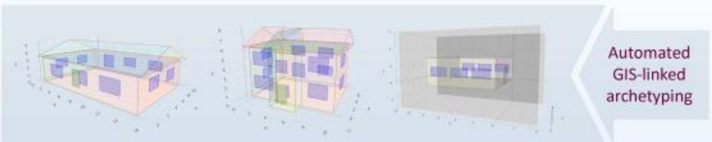
- modern energy systems with significant renewable sources demand must be characterised in a temporally refined manner; depending on the specific objectives, this resolution can be in the range of 1 to 5 minutes, up to 1 hour.

To model urban-scale thermal demand, our goal becomes:

- **to generate socio-technically rich outputs from a dynamic thermal demand model**
- **this requires a sensitive approach to calibration**

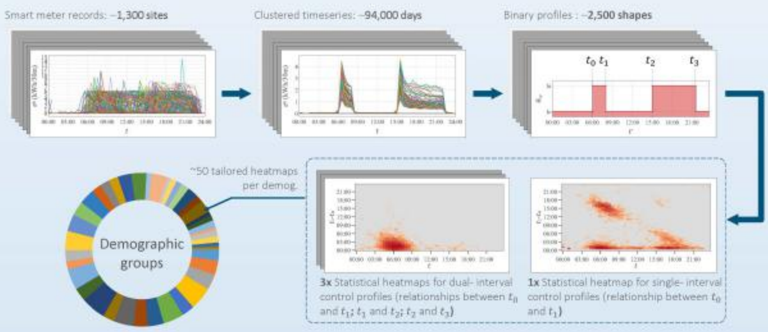
— Energy demand model design —





— Case study (Shiremoor) —

— Heating control calibration (smart-meter based) —



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The HMM-GP model for statistical simulation of electricity demand profiles

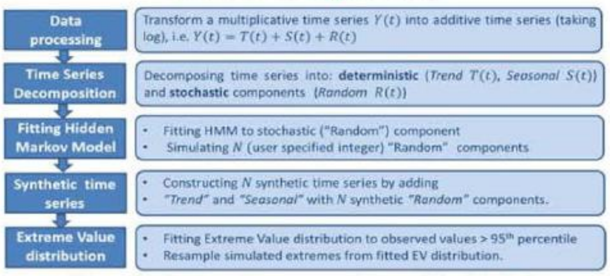
Designing a robust and reliable energy system

High resolution (5 min or below) electricity demand profiles can be statistically analyses to understand the specific energy demand characteristics occurring at a specific time, such as peak load, in a building. The individual demand profiles can be aggregated to provide quantifiable impacts of these specific events have on aggregated energy demand of the community. However, at present, simultaneous availability of high-resolution energy demand data that are recorded over long durations (e.g. to capture seasonal variation) and across a large sample of buildings (accounting diversity of energy use) is not available. *HMM-GP model is developed to meet some of these challenges.*

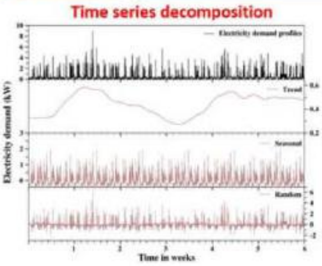
Case study—Findhorn

HMM-GP model has been applied to simulate five minutely electricity demand data collected over a period of six weeks (15 Feb 2015 to 28 March 2015) for a sample of 14 buildings located in Findhorn community.

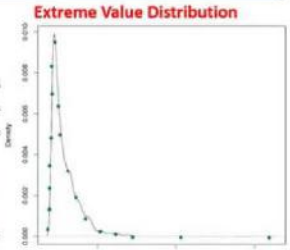
HMM-GP modelling framework



Time series decomposition

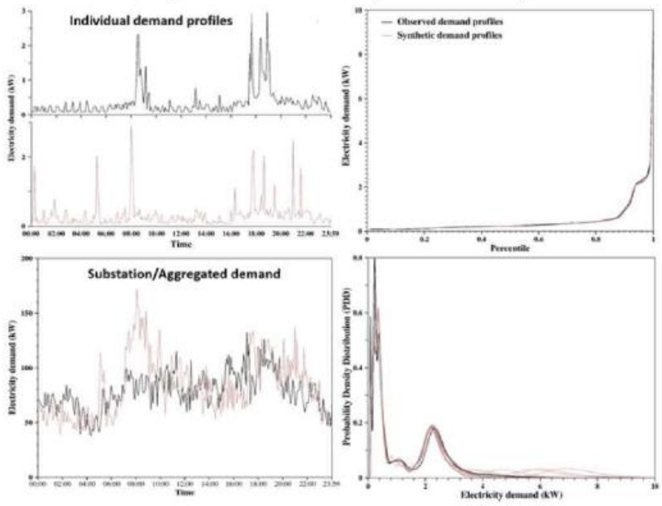


Extreme Value Distribution



Model Performance and validation

The HMM-GP model applied to sample of 14 buildings (weighted appropriately) to generate aggregated synthetic demands of 181 buildings (served by substation). Key statistical properties of observed/synthetic demand profiles compared.



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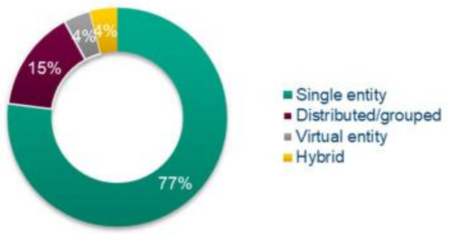
Research and Innovation Infrastructure Roadmap for Energy Sector

Introduction

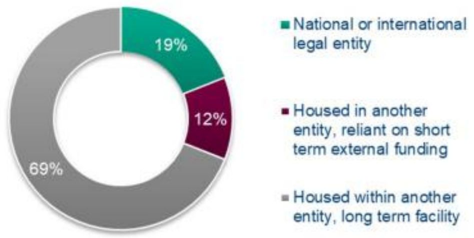
The EPSRC National Centre for Energy Systems Integration (CESI), have been commissioned to assist EPSRC and UKRI to develop a **research and innovation infrastructure roadmap.(RII)** of the Energy research and innovation facilities that will be required in the UK by 2030. It is intended to increase our understanding of the UK's current capability and **guide future planning.**

The distribution of RIIs

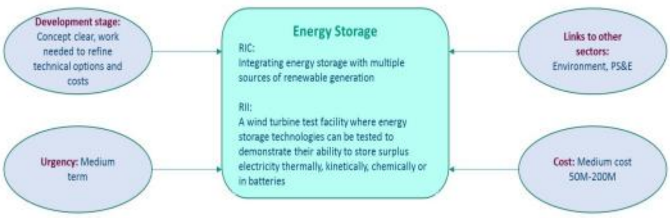
RIIs are grouped according to whether they are single entities, grouped/distributed entities or virtual (digital).



RIIs are grouped according to their legal structure.



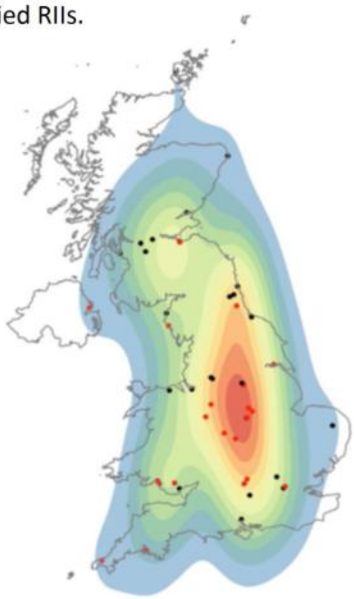
Example of a challenge in energy storage sub-section and the infrastructure required to address the challenge.



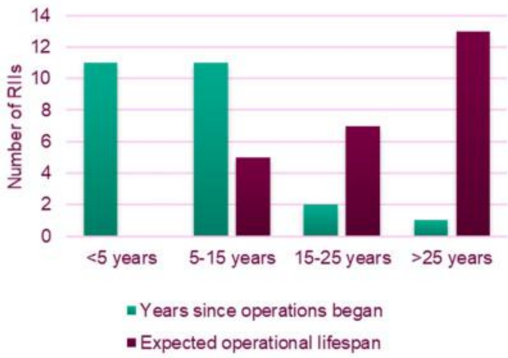
The geographical location of RIIs

Based on our expert elicitation exercise and studying the existing key reviews, **58 RIIs** have been identified across energy sector.

The contour map below shows **the geographical location** of the identified RIIs.



RIIs are grouped according to their years of operations and their expected operational lifespan .



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