National Centre for Energy Systems Integration

EPSRC Pioneering research and skills

Newcastle University

Durham University

Heriot-Watt University

University of Sussex

The University of Edinburgh

An academic perspective on energy

Laura Brown

MSc CEng MIET

CESI Centre Manager, Newcastle University

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Whole Energy Systems

CESI National Centre for Energy Systems Integration

What Is Energy Systems Integration (ESI)?

- "The process of coordinating the operation and planning of energy systems across multiple pathways and/or geographical scales to deliver reliable, cost-effective energy services with minimal impact on the environment"

CESI Mission

- ***What is the value proposition of taking a whole energy systems approach to energy in the UK?***

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Multi Vector/Sector Energy Systems

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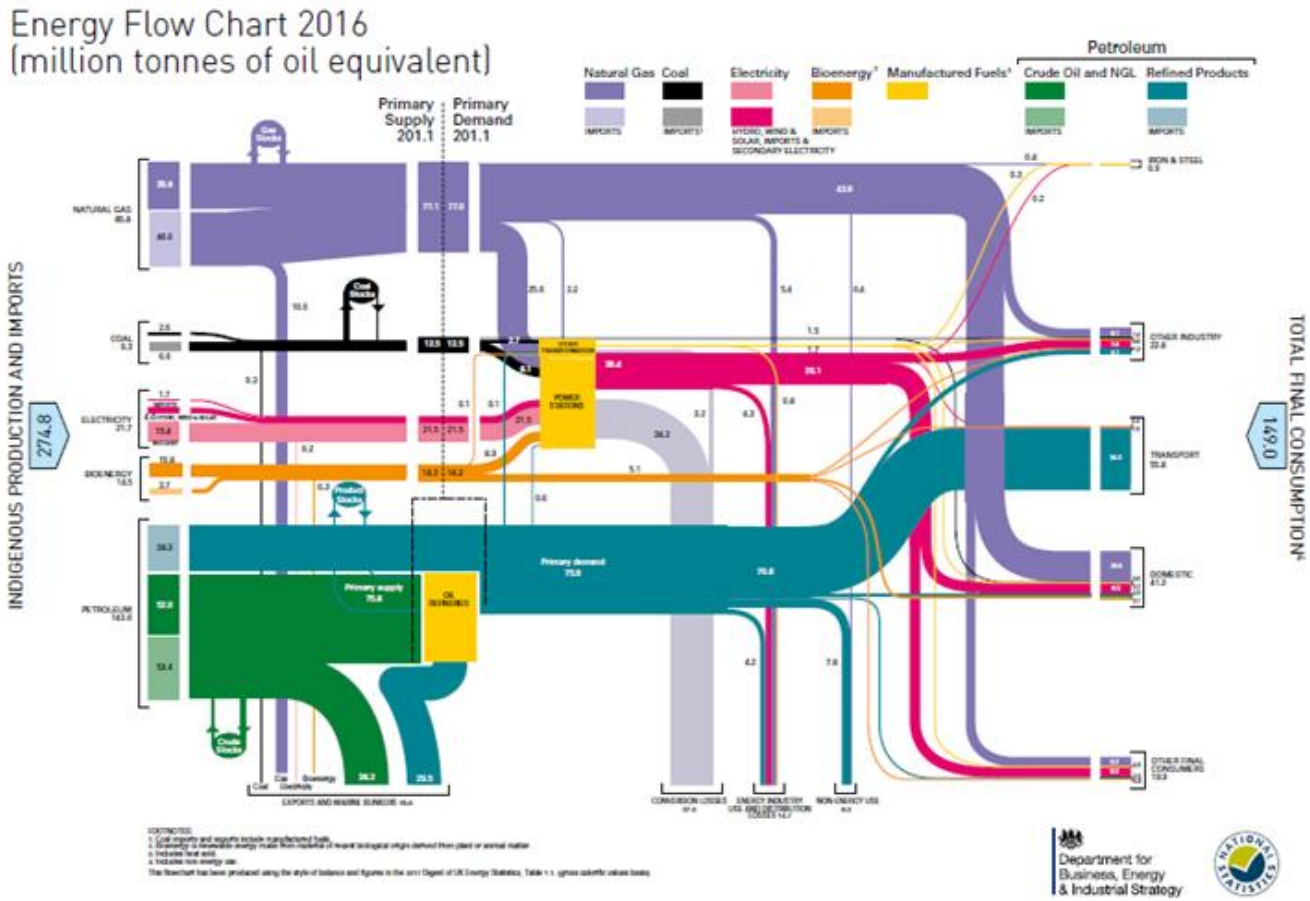
- Whole systems approaches to energy
  - Transport, Heat, Power, Gas, Buildings
- Complementarity , losses, storage, speed, congestion, carbon
- Hybrid/coupling technologies
- Zero marginal cost generation
- Lower cost ?
- Lower carbon ?
- More resilient ?



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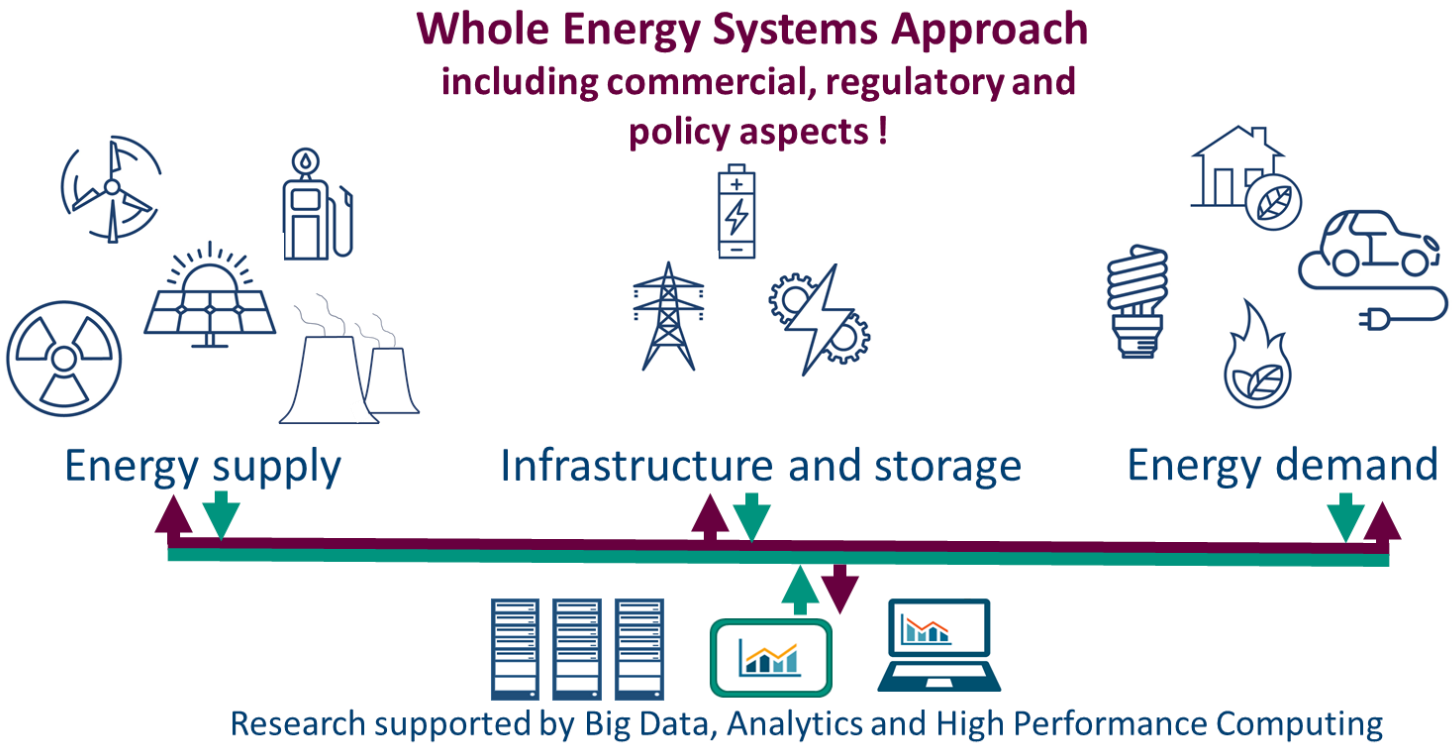
Benefits of Whole Energy Systems thinking

National Centre for Energy Systems Integration (CESI)

- Encourages the development of a more **flexible energy systems** for future **security**
- Enables efficient **integration of renewable energy** onto the system and hence **reduce carbon emissions**
- Provides an **integrated platform** for multi-vector solutions to the power, heat and transport fuel future challenges
- Significant **cost saving efficiencies** can be realised as a direct consequence of these flexible solutions



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CESI National Centre for Energy Systems Integration

- brings together experts to investigate the energy network, understand and demonstrate future supply and demand for the UK

5 Leading Research Universities

Newcastle University
Durham University
Heriot-Watt University
University of Sussex
The University of Edinburgh

Leading Edge International Scientific Support

Nanyang Technological University
NREL National Renewable Energy Laboratory
CenSES Centre for Sustainable Energy Studies
UKERC UK Energy Research Centre
i-STUTE
The Alan Turing Institute
Skoltech Skolkovo Institute of Science and Technology
iESI International Institute for Energy Systems Integration
Centre on Innovation and Energy Demand
ITRC mistral
CIE-MAP Centre for Industrial Energy, Materials and Products
DTU
enzen
EPRI Electric Power Research Institute
The Faraday Institution Battery Storage Technologies
UCL Energy Institute
Imperial College London

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The Centres Industrial Partners

CESI National Centre for Energy Systems Integration

- Lead Industrial Partner

SIEMENS
Ingenuity for life

- Government Support

Department for Business, Energy & Industrial Strategy
The Scottish Government
CATAPULT Energy Systems
Research Councils UK Energy For a Low Carbon Future
Department for Transport
ofgem
Innovate UK

- Leading Energy Industry Partners

Ørsted
centrica
SCOTTISHPOWER
nationalgrid
NORTHERN POWERGRID
Northern Gas Networks
Scottish & Southern Electricity Networks
triphase
redT energy storage
End Use Energy Demand Centres
Reducing Energy Demand | Research Councils UK
gentoo It's how you live
Newcastle City Council
Durham County Council
NEA Action for Warm Homes

Supply

Infrastructure and Storage

Demand

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National Centre for Energy Systems Integration

The Centre Leadership

Director

Professor Phil Taylor Newcastle University

- Deputy Pro Vice Chancellor of SAgE Faculty & Head of the School of Engineering
- Siemens Professor of Energy Systems
- An internationally leading researcher and industrial expert in energy systems, electrical distribution networks, smart grids and energy storage integration and control.

Associate Directors

Professor Jon Gluyas
Dong/Ikon Chair in Geoenergy, Carbon Capture & Storage
Durham University

Professor Gareth Harrison
Bert Whittington Chair
Director of Research
University of Edinburgh

Professor Gordon Mackerron
Professor Of Science And Technology Policy
University of Sussex

Professor Tony Roskilly
Director, Sir Joseph Swan Centre for Energy Research
Newcastle University

Dr Sara Walker
Director of Expertise
School of Engineering
Newcastle University

Dr David Flynn
Associate Professor
Director of Smart Systems Group
Heriot Watt University

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CESI Work Package Streams

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WP1 

Commercial, regulatory and policy aspects

- Energy Policy
- Sector Regulation
- Social interaction
- Commercial
- Behaviour

WP2

Energy supply

- Multi –Vector Generation
- Interconnection
- Spatio-temporal

WP3

Infrastructure and storage

- Systems modelling
- Storage
- Networks and Infrastructure

WP4 

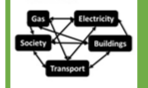
Energy Demand

- Multi-vector Consumer Demand
- Buildings
- Transport
- Highly temporal

WP5 

Demonstration and Validations

- Cross-vector demonstration
- Validation within living labs
- Real-time data

WP6 

Multi-Scale Architectures

- Whole systems planning tool
- Co-evolution cycles
- Integration of models
- Stochastic optimisation

Bounded together by WP7 - Impact, engagement and management

How is the Theory contributing to the Practice?

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Place in the innovation cycle

- Universities (in the main) carry out three forms of research in energy
  - Pure research on Energy Materials (NECEM) (usually with other Institutions)
  - Applied research on Energy Products, Technology and Systems (usually with Industry)
  - Socio-Economic and Policy Research on how people use, pay for and make decisions about energy (usually with government (local/central), housing associations or Commercial entities.
- The findings from this research:
  - Provide answers to academic questions which lead to future academic research
  - Help companies develop better and/or new products for market
  - Inform policy makers with independent research and evidence

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Where is the Centre's research positioned?

- Work in partnership with Energy Systems Catapult and Industry
- Feed the energy innovation and ideas conveyor belt to solution development

Technology Readiness Levels (TRL)

Industry (large and SMEs)
Test, Development and Commercialisation

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Simple Examples

- **Congested Electrical Distribution Network or outage on electrical network with DG**
  - Power to gas
  - Blend Hydrogen
  - Transport in gas network use for heat, transport or back to power where electrical network heavily loaded, EVs ?
  - Decarbonises both electrical and gas systems
- **Expensive Electro-chemical storage at limited scale**
  - Gas network is inherently a large storage system
  - Explore if and how to use this ?
- **Dual Fuel Appliances**
  - Demand side response options become much more exciting and realistic and less time limited

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Future Whole Energy Systems for Transport, Heat and Electricity

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Traditional Generation and infrastructure

Nuclear

Power Transmission and Distribution

Natural Gas for Power

Centralised Coal fired electricity generation

Prosumers, Low Carbon and Multi Vector Production

CHP

Rooftop PV

Low Carbon Vehicles

Solar Farms

Wind Farms

Fuel Cells and Electrolysis

Geothermal Heat and Power

Electrical and Thermal Storage

Consumers

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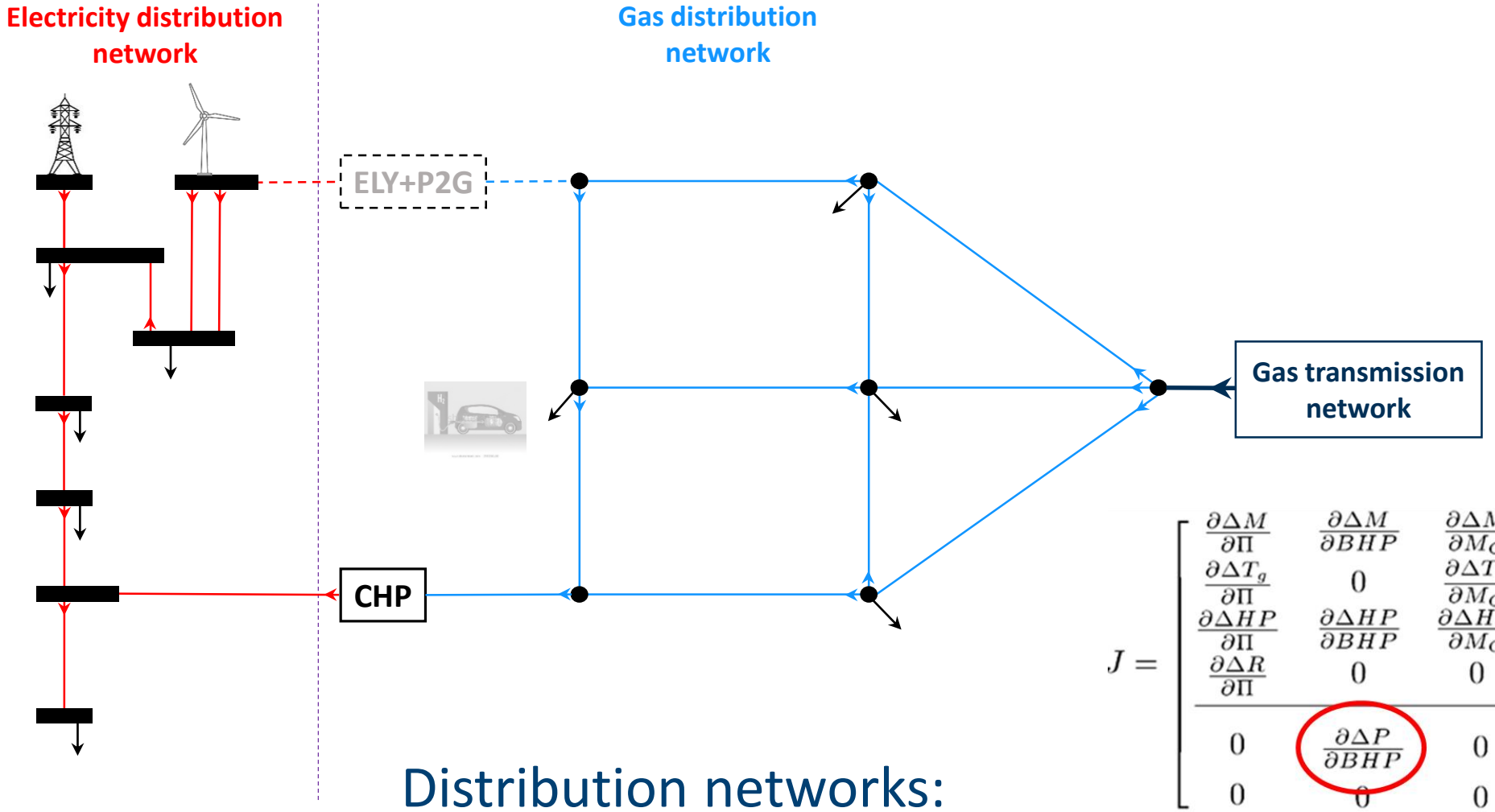
Early Output Highlights – Multi Vector Modelling



$$J = \left[\begin{array}{ccc|ccc} \frac{\partial \Delta M}{\partial \Pi} & \frac{\partial \Delta M}{\partial BHP} & \frac{\partial \Delta M}{\partial M_C} & 0 & 0 & \frac{\partial \Delta M}{\partial \Delta P_{\text{gen}}} \\ \frac{\partial \Delta T_g}{\partial \Pi} & 0 & \frac{\partial \Delta T_g}{\partial M_C} & 0 & 0 & 0 \\ \frac{\partial \Delta HP}{\partial \Pi} & \frac{\partial \Delta HP}{\partial BHP} & \frac{\partial \Delta HP}{\partial M_C} & 0 & 0 & 0 \\ \frac{\partial \Delta R}{\partial \Pi} & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & \frac{\partial \Delta P}{\partial BHP} & 0 & \frac{\partial \Delta P}{\partial \theta} & \frac{\partial \Delta P}{\partial V} & \frac{\partial \Delta P}{\partial \Delta P_{\text{gen}}} \\ 0 & 0 & 0 & \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial V} & 0 \end{array}\right]$$

Distribution networks: Base Case

Early Output Highlights – Multi Vector Modelling

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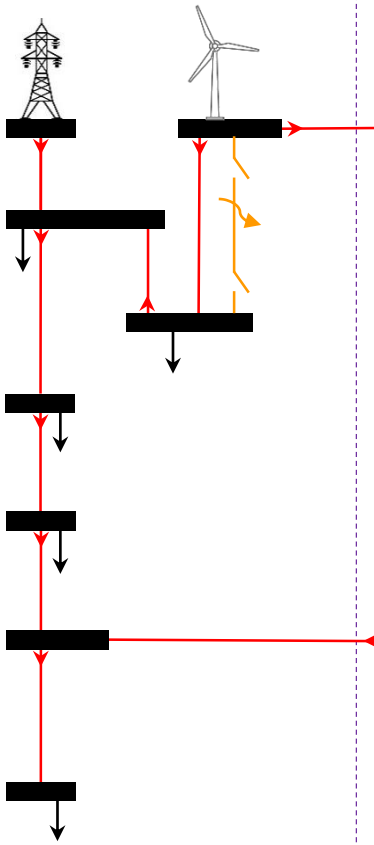
Electricity distribution network

Gas distribution network

Rather than curtail the generation, utilise to generate Hydrogen to blend into the gas network



ELY+P2G

CHP

Gas can be used to Fuel Vehicles

Gas transmission network

$$J = \left[\begin{array}{ccc|ccc} \frac{\partial \Delta M}{\partial \Pi} & \frac{\partial \Delta M}{\partial BHP} & \frac{\partial \Delta M}{\partial M_C} & 0 & 0 & \frac{\partial \Delta M}{\partial \Delta P_{\text{gen}}} \\ \frac{\partial \Delta T_g}{\partial \Pi} & 0 & \frac{\partial \Delta T_g}{\partial M_C} & 0 & 0 & 0 \\ \frac{\partial \Delta HP}{\partial \Pi} & \frac{\partial \Delta HP}{\partial BHP} & \frac{\partial \Delta HP}{\partial M_C} & 0 & 0 & 0 \\ \frac{\partial \Delta R}{\partial \Pi} & 0 & 0 & 0 & 0 & 0 \\ \hline 0 & \frac{\partial \Delta P}{\partial BHP} & 0 & \frac{\partial \Delta P}{\partial \theta} & \frac{\partial \Delta P}{\partial V} & \frac{\partial \Delta P}{\partial \Delta P_{\text{gen}}} \\ 0 & 0 & 0 & \frac{\partial \Delta Q}{\partial \theta} & \frac{\partial \Delta Q}{\partial V} & 0 \end{array}\right]$$

Distribution networks:
Scenario1: Fault in the electricity network

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Early Output Highlights – Energy and Emissions Efficiency in Marine Transport

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- Power management of batteries in Thames Boat Taxis
- Intelligent sensor network
- Incorporating propulsion and standby batteries
- Integrated via a Dynamic Resource Monitor (DRM) sensors to the other electrical equipment including engines and generators

http://82.223.33.73/

Intelligent Transport

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£35m InTEGRel - Integrated Transport Electricity Gas Research Laboratory

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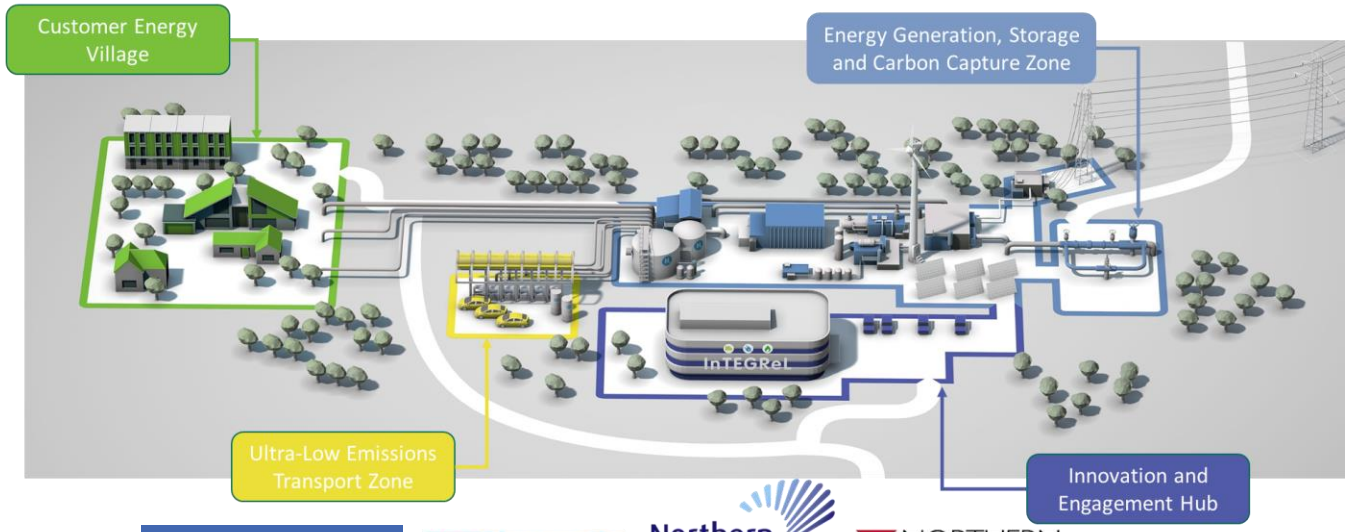
- **UK's first multi-vector industrial networks research centre**
- Collaboration between CESI, Northern Powergrid and Northern Gas Networks
- Development of a world-leading **emerging sector** in Gas and Electricity Network **integration**

1. Customer Energy Village for testing of innovative solutions to energy challenges e.g. Hydrogen as a Heating Fuel, **Low Carbon Heating**
2. **Innovation Hub** for engagement and skills development and training
3. Energy Generation, Storage and **CCS** Zone
4. Ultra-Low Emissions Transport Zone e.g. **H_2**, V2G, **Low Carbon Freight**

https://www.northerngasnetworks.co.uk/ngn-you/the-future/integrel/

InTEGReL Future Vision

InTEGReL
Integrated • Transport • Electricity • Gas • Research • Laboratory



hefce Higher Education Funding Council for England
Newcastle University
Northern Gas Networks
Northern Powergrid

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£65M Faraday Battery Institution

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- **UK's independent national battery research institute**
- Established as part of the government's £246 million investment in battery technology through the **Industrial Strategy**
- Significant investment in the important area of **battery energy storage**
- CESI Director, Professor Phil Taylor is a founding member
- Newcastle University involved in 2 of the 4 fast start projects (£42M)
  - **Extending battery life**
    - 10 university partners including

University of Cambridge, Newcastle University, WMG University of Warwick, University of Strathclyde

  - **Recycling and reuse of batteries**
    - 8 university partners including

University of Birmingham, Cardiff University, Newcastle University, The University of Edinburgh

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£9.8M InnovateUK e4Future

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- **Flagship Vehicle-to-Grid Industrial Research collaboration**
- Part of the government's £30 million investment from the Office for Low Emission Vehicles and Innovate UK
- Large-scale demonstrator targeting **1000** Vehicle-to-Grid (V2G) installations
  - evaluating **commercial offerings** to electric vehicle fleet customers to supply important grid services to the electricity network
  - Aim to **reduce the total cost** of ownership of EVs
  - Support the electricity system in a more **efficient** and sustainable way
  - Supporting the uptake of electric vehicles and batteries **manufactured in the UK**

NISSAN Innovation that excites

Newcastle University

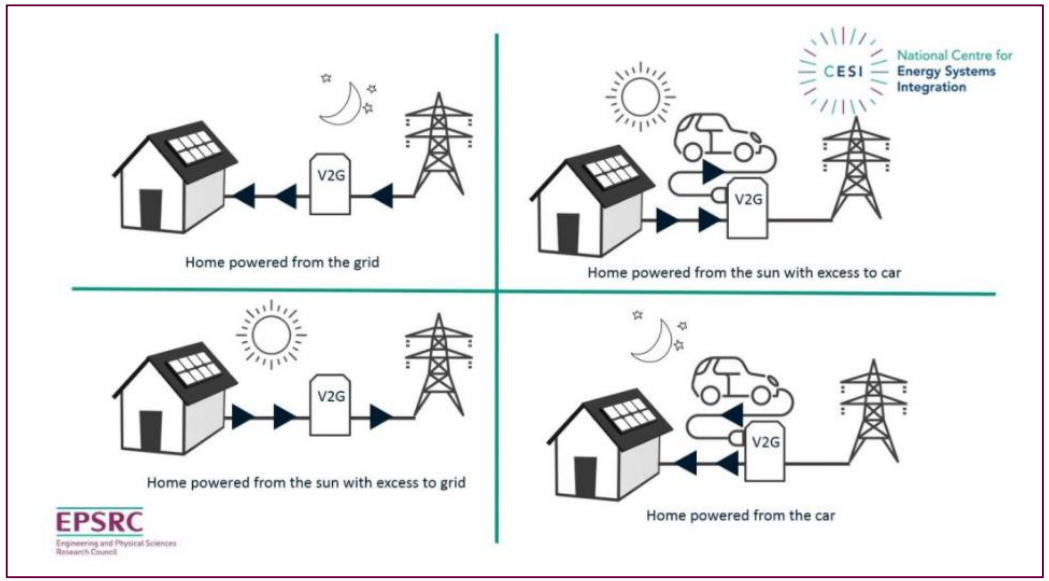
NUVVE

NORTHERN POWERGRID

nationalgrid

UK Power Networks

Imperial College London



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£10M - inteGRIDy - Isle of Wight full scale demonstrator

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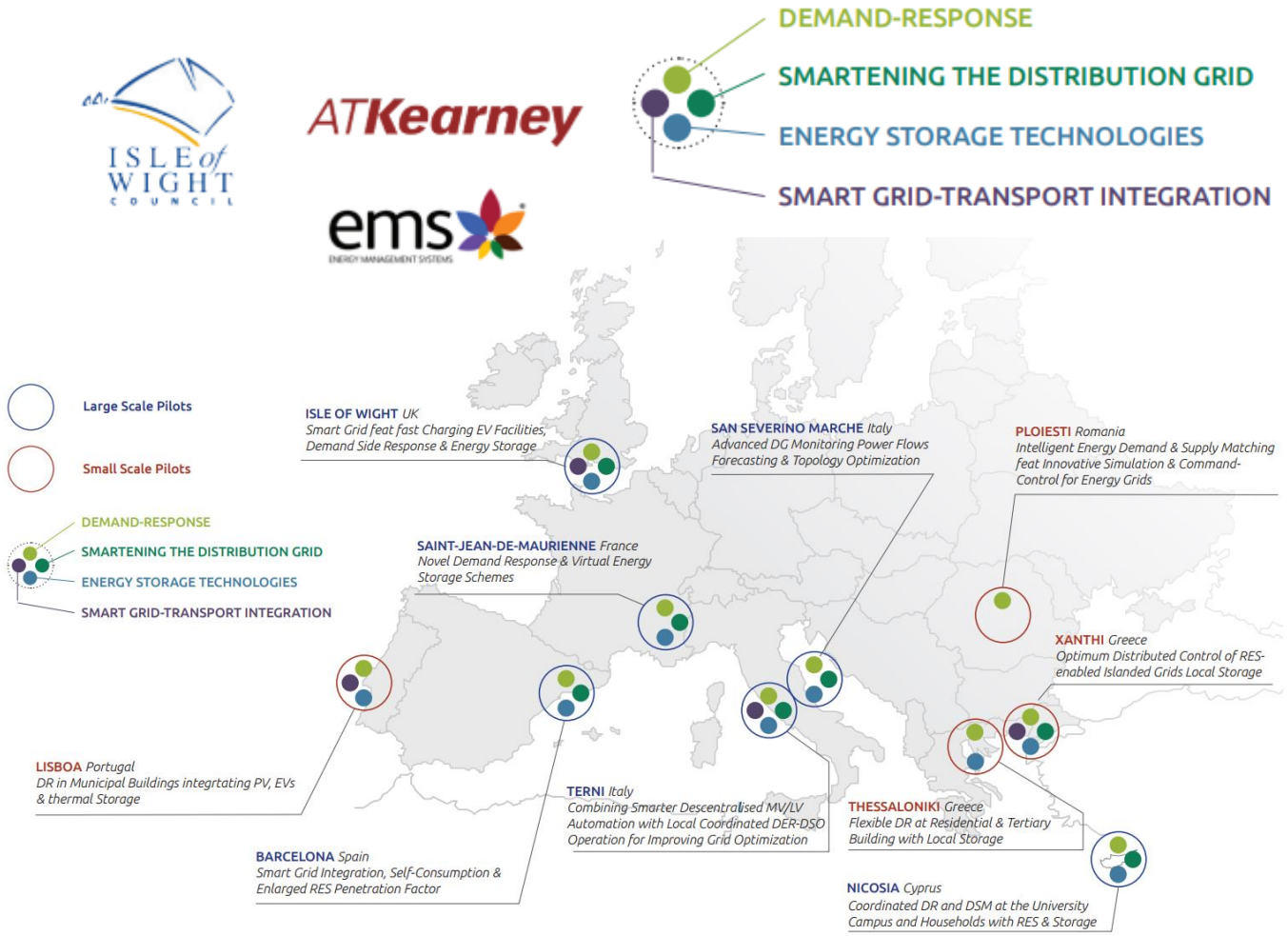
- **Largest H2020 project of it's kind – involves 8 countries including UK**
- UK pilot of large-scale industrial research to improve the grid design, storage, EV penetration and RES installation on a self-sufficient island

Minus 7 a heating revolution · SIEMENS · Teesside University · Newcastle University · Isle of Wight Council · AT Kearney · ems Energy Management Systems

- use network data and predictive analysis to develop a smart grid architecture
- Enabling **removal of grid constraints** to become self-sufficient in low carbon power generation
- technologies will be demonstrated at **scale**
- home heating system utilising **thermal storage** provided by Minus 7 (M7)
- a **rapid EV charging system** that provides energy storage, **DSR** functionality and building energy management provided by EMS (UK) Ltd
- **IoT-based** BMS system provided by **Siemens**



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