# The Networks Jigsaw

ETI10 TEN YEARS OF INNOVATION 2007 – 2017

#ETI10

# Welcome and Introduction

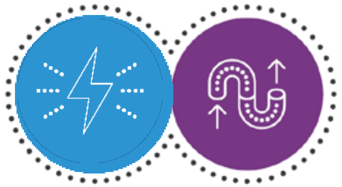
Director – Strategy Development
Jo Coleman

# Agenda

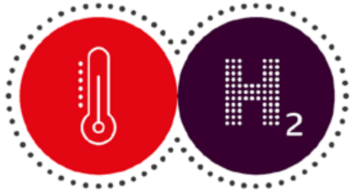
| | |
|---|---|
| **1.30pm** Introduction and welcome | Jo Coleman (ETI) |
| **1.45pm** Programme overview | Rebecca Sweeney (ETI) |
| **2.15pm** Insights overview and modelling capability | Liam Lidstone and Alex Buckman (ETI) |
| **3.00pm** Future Power System Architecture | Eric Brown (ESC) |
| **3.30pm** Break | |
| **3.50pm** Panel debate - 'Challenges facing UK Energy Networks in a Low Carbon Future' | |
| **5.00pm** Final Comments from Jo Coleman and Drinks reception in the exhibition area | |
| **6.00pm** Close | |

# Key challenges facing UK networks

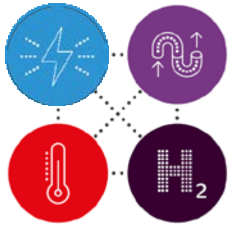
Adapting and enhancing existing networks



Creating efficient and effective new networks

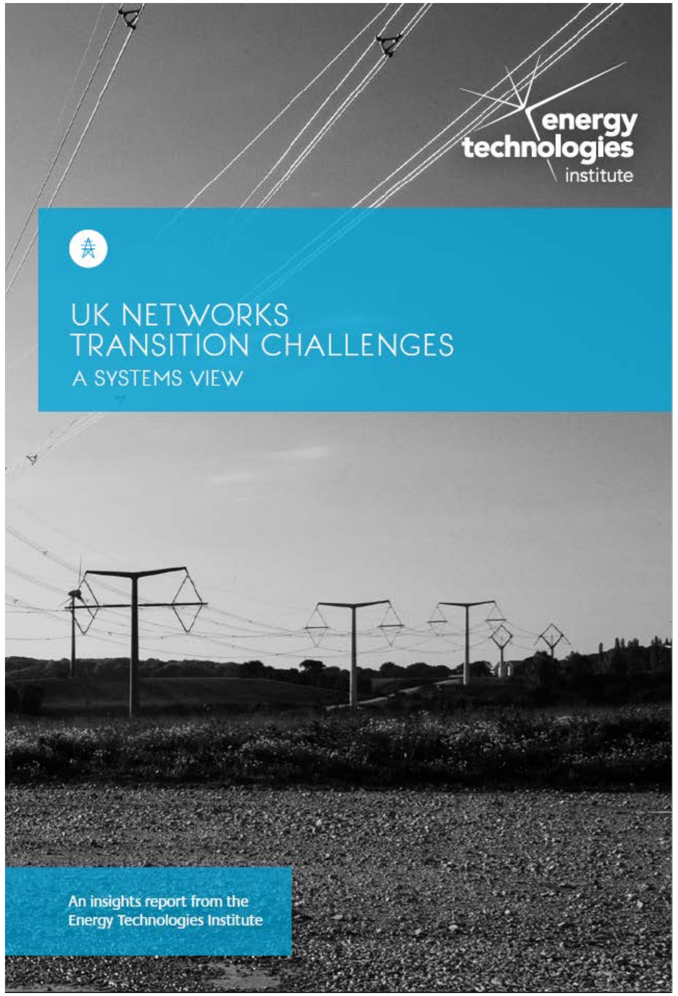


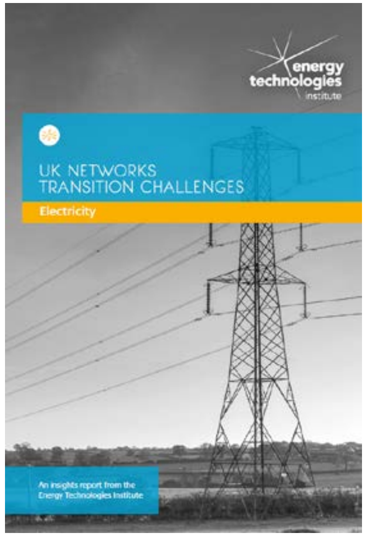
Integrating networks to optimise performance across energy vectors

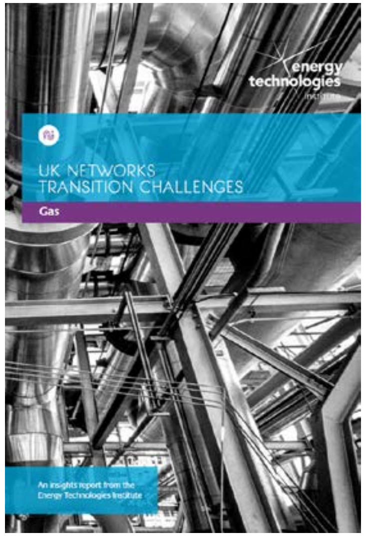


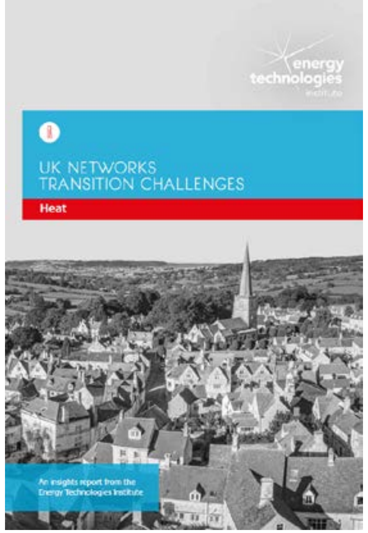
- The next decade is critical to develop the evidence to make informed decisions, through ongoing research and demonstrations at increasing scale

# Insights from the programme

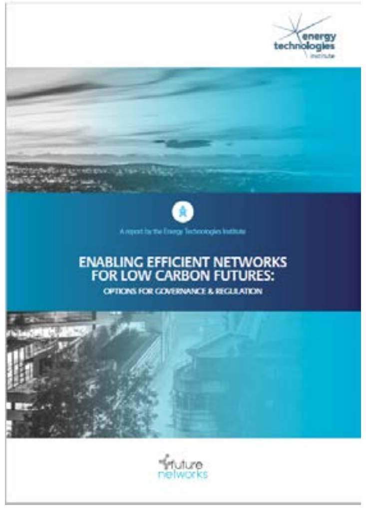






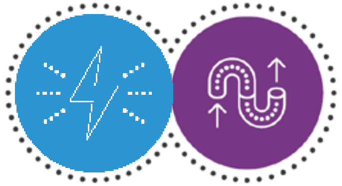

Available at: http://www.eti.co.uk/insights/uk-network-transition-challenges-a-system-view

Or search for: ***ETI network transitions*** or ***network transition challenges***

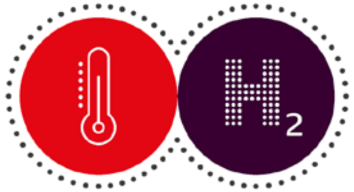
# ESD Programme Overview

ESD Programme Manager
Rebecca Sweeney

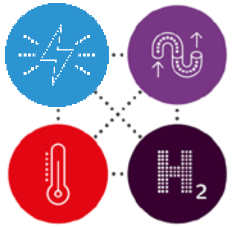
Adapting and enhancing existing networks



Creating efficient and effective
new networks



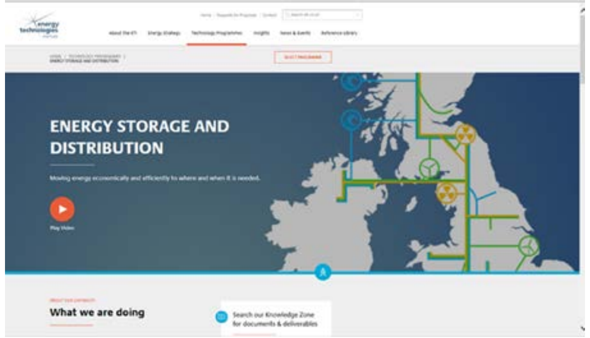
Integrating networks to optimise performance across energy vectors



# Energy Storage & Distribution Programme

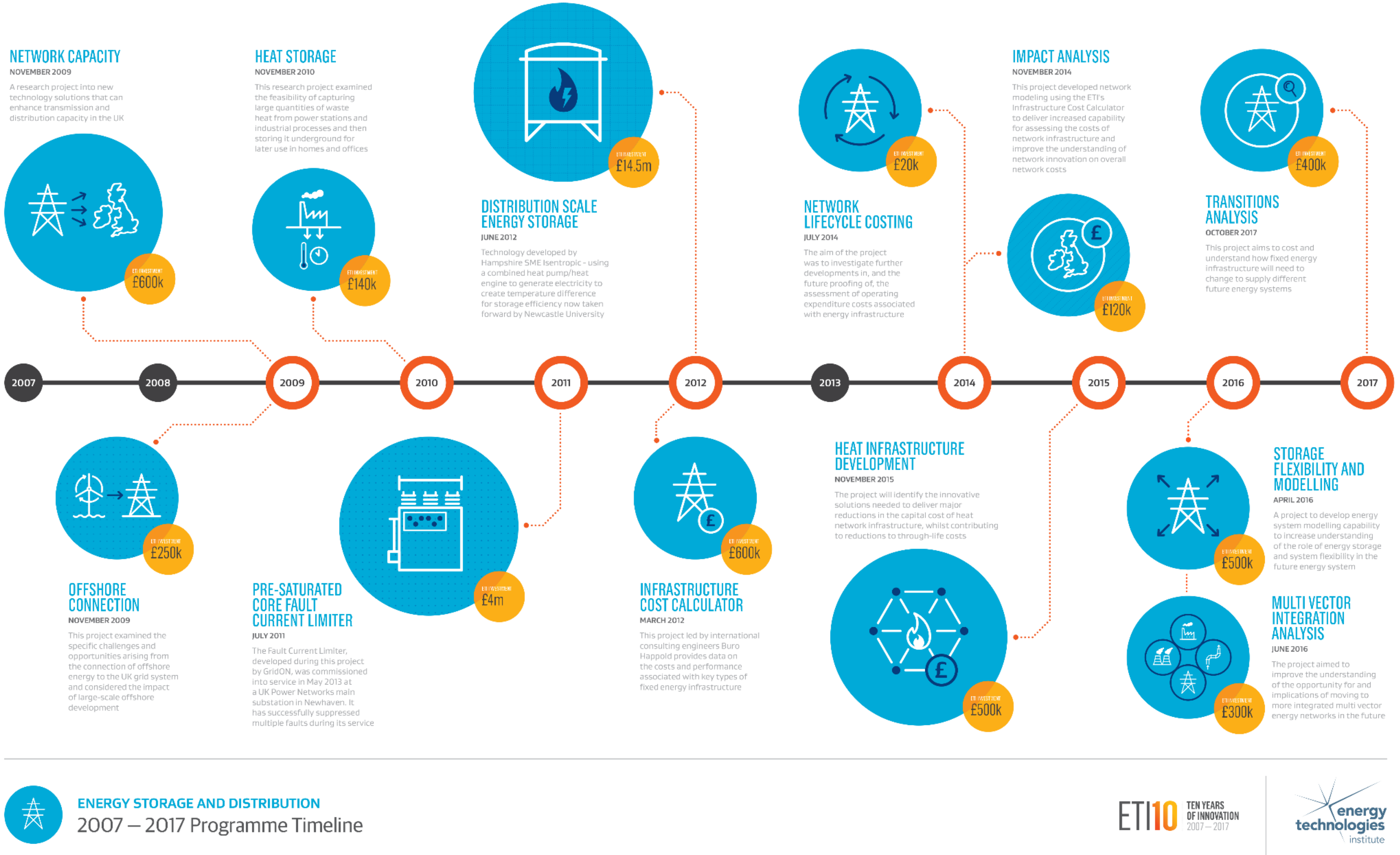
The ETI has invested over in projects in the ***Energy Storage and Distribution*** programme

**£26.9m**



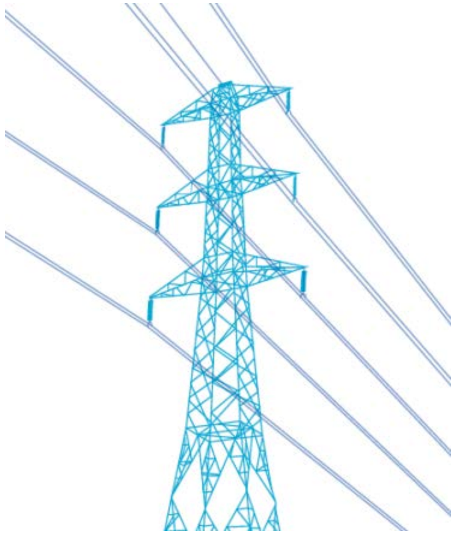

- Fault current limiter development
- Storage and Flexibility Modelling
- Consumers, Vehicles and Energy Integration
- Network Capacity
- Offshore Connection
- Distribution Scale Energy Storage
- Impact Analysis
- Future networks: Multi-Vector Integration
- Infrastructure Cost Calculator
- Heat Storage
- Network Lifecycle Costing
- Heat Infrastructure Development

# Evidence base



# Network Capacity

- Research project into new technology solutions that can enhance transmission and distribution capacity in the UK
- Assessing the feasibility of technologies to provide improved management of power flows and increased capacity
- Seeking to enable the increased deployment of low carbon energy sources in the UK

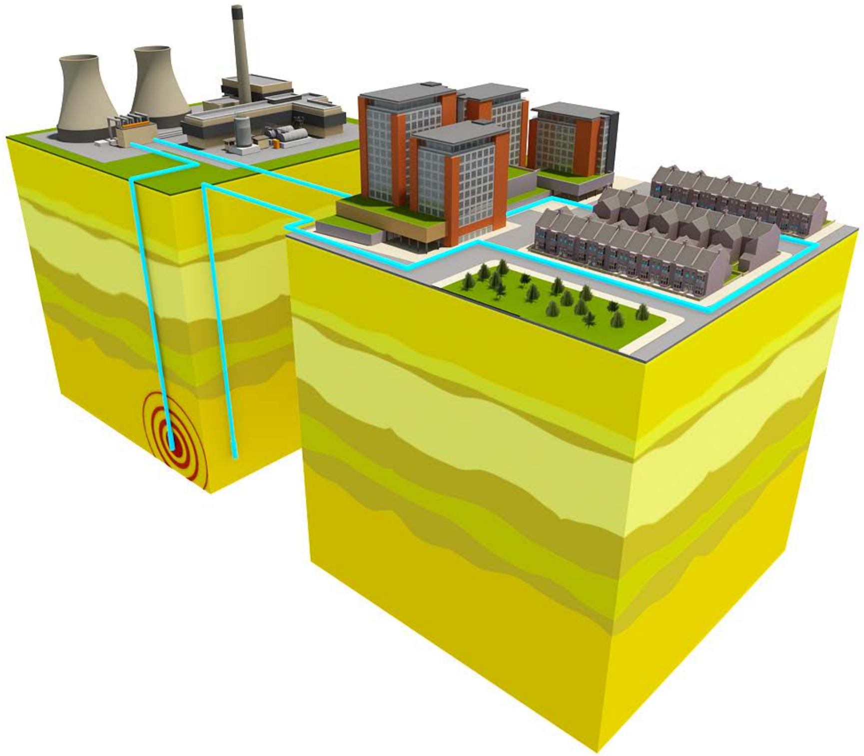


£600k

MOTT MACDONALD

# Heat Storage

- Examination of the feasibility of capturing large quantities of waste heat from power stations and industrial processes then storing it underground
- Investigation into the cost effectiveness of storing large quantities of heat for long periods of time
- Evaluating the practicality and technology needs of such storage schemes



£140k

BUROHAPPOLD ENGINEERING

# Pre-saturated Core Fault Current Limiter

- Development and demonstration of a 10MVA pre-saturated core fault current limiter
- Product design offers advantages of a non-superconducting pre-saturated core fault current limiter with instant response and recovery, a small footprint based on established transformer design and build process
- Commissioned into service in May 2013 at a UK Power Networks primary substation in Newhaven
- 2nd unit installed on a WPD network


£4m GridON
Protecting the Grid. Wisely.

# Infrastructure Cost Calculator

- Developed to allow users to calculate and compare network transition costs
  - across a number of scenarios
  - across a number of energy vectors

- Provides users with access to a robust, centrally stored database of infrastructure costs based on current industry data

£600k

BUROHAPPOLD ENGINEERING

# Distribution Scale Energy Storage

- Pumped heat electricity storage technology
- Intended for use on the distribution network
- Reduce the need for upgrades and reinforcement
- Complements the £20m EPSRC National Centre for Energy Systems Integration which is led by Newcastle University

£14.5m

Newcastle University

# Consumers, Vehicles & Energy Integration

- Develop understanding on how to enable a cost-effective UK energy system for Ultra-Low Emission Vehicles, and to validate them through a Mass-Market Trial with real users

- The project outputs will:
  - help inform UK government and European policy
  - help shape energy and automotive industry products

£5m

TRL

# Heat Infrastructure Development

- This project is a knowledge based study of opportunities to reduce the costs and impact of implementing heat infrastructure
- Aim to identify a combination of improvements which will reduce implementation of Heat Networks by ~40%
- Considering new techniques and industry best practice

AECOM

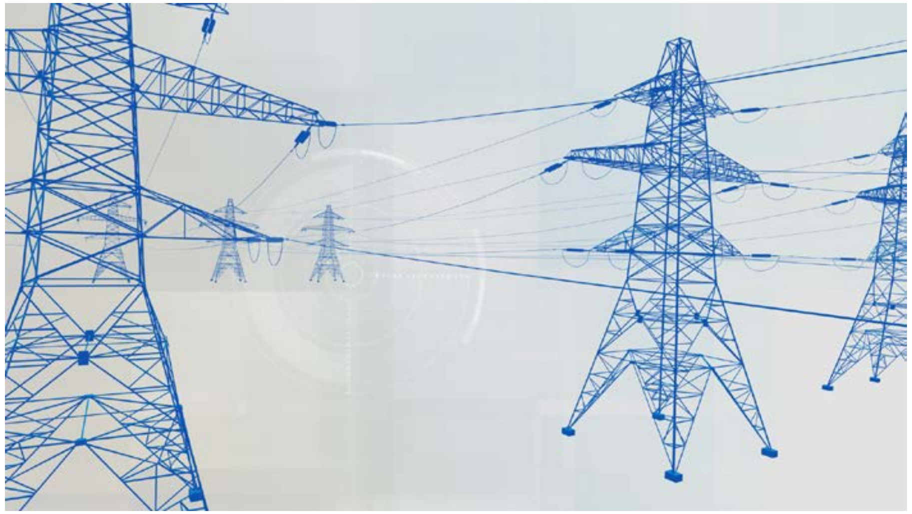
Total Flow

COFELY GDF SUEZ

£500k

# Storage & Flexibility Modelling

- Developing energy system modelling capability to increase understanding of the role of energy storage and system flexibility in the future energy system
  - Whole systems view
  - Cross-vector flexibility
  - Assess value of energy storage

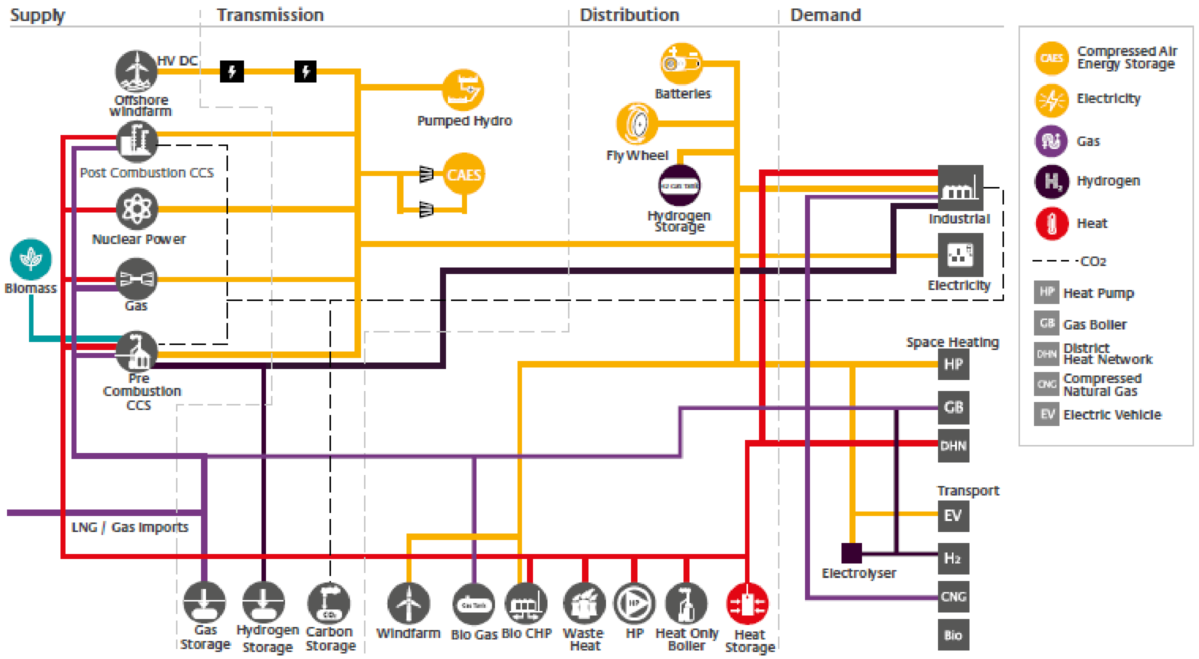


£500k

Baringa
Brighter together

# Multi Vector Integration Analysis

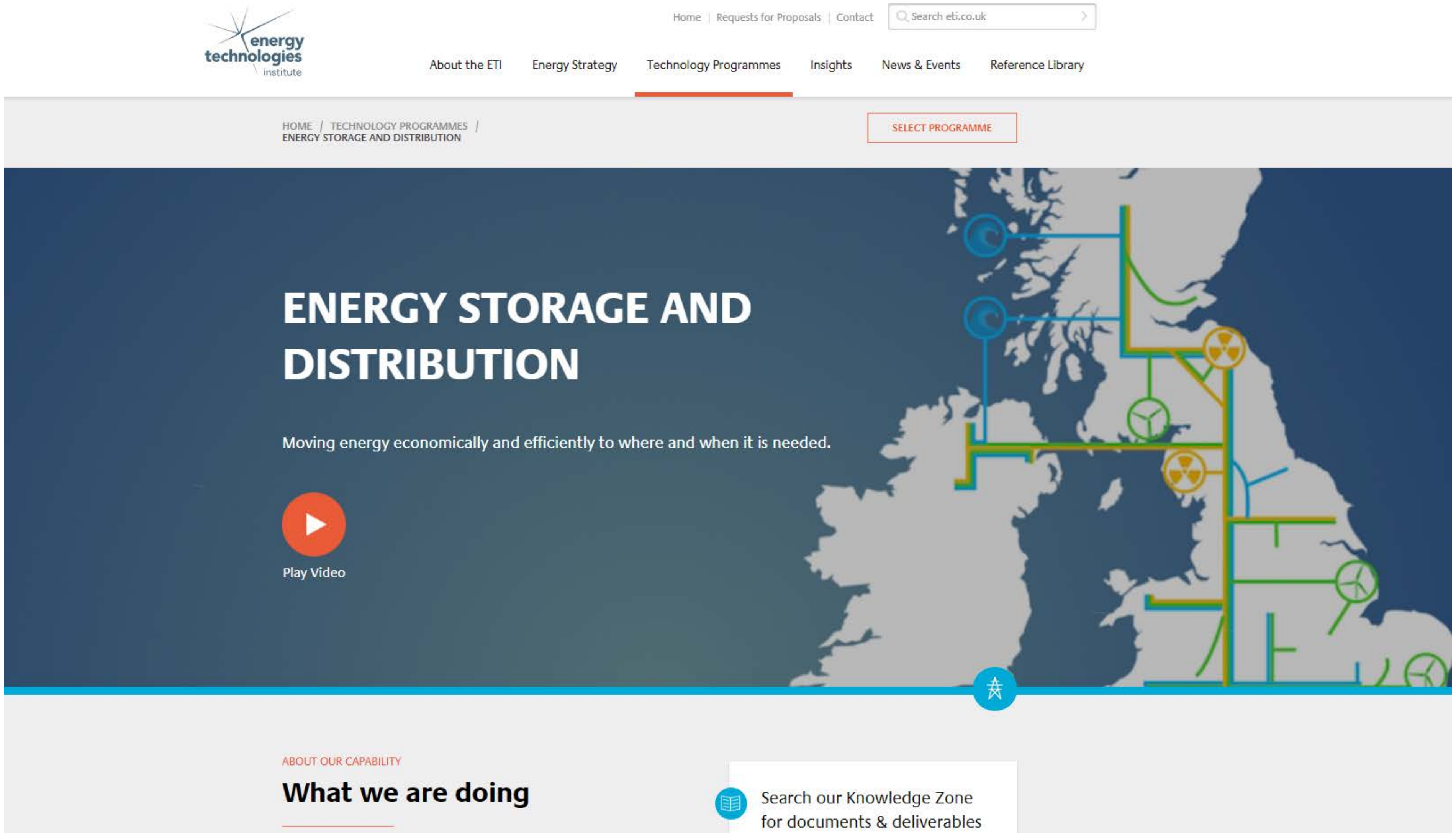
- Assessing the potential for moving to a more integrated networks
  - Cross vector integration
  - Services that could be delivered
  - Opportunities
  - Identification of implications




£300k

elementenergy

# Knowledge Zone



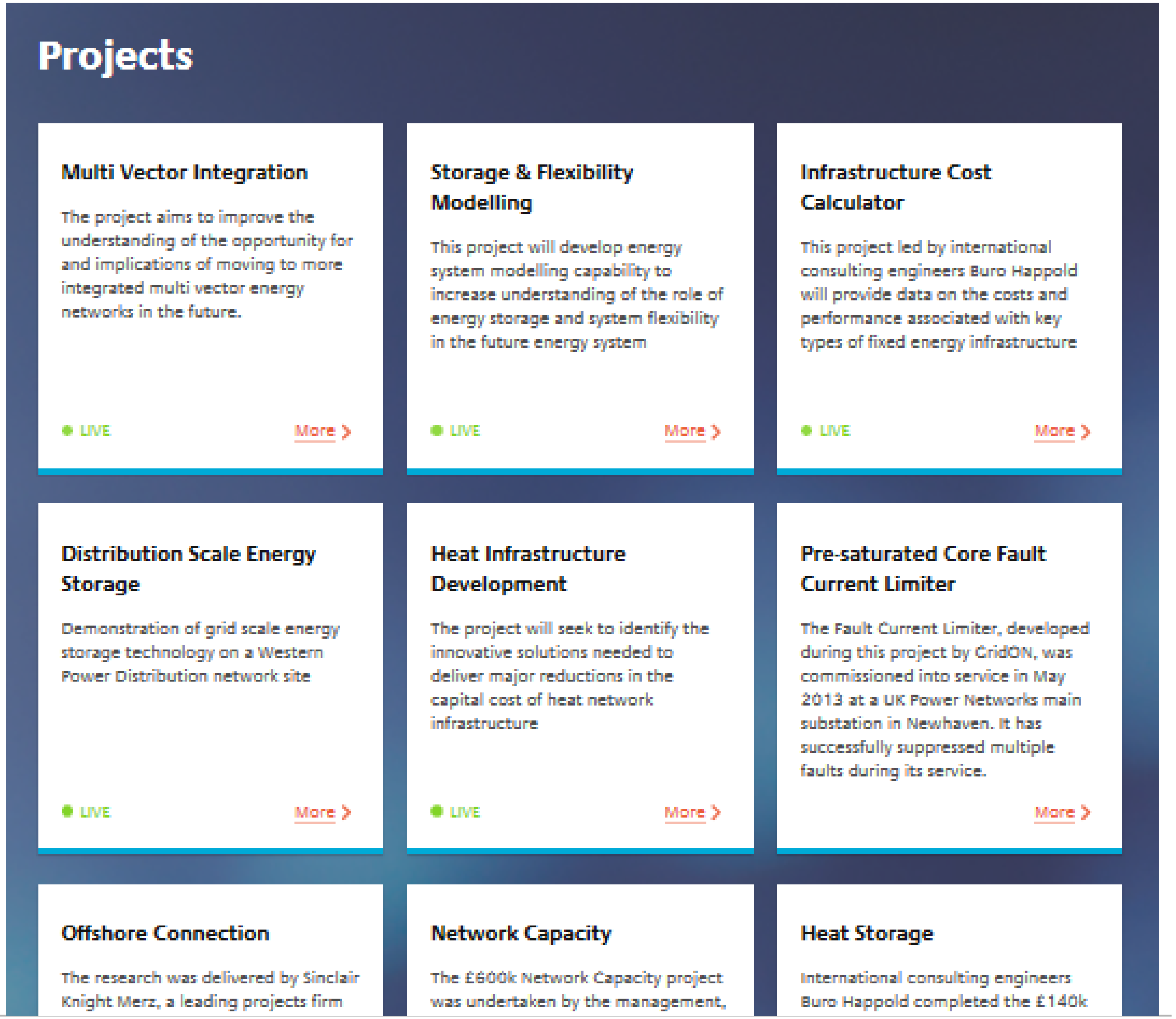

http://www.eti.co.uk/programmes/energy-storage-distribution

# Knowledge Zone

Over the last decade the ETI has invested over **£26.9m** in projects in the *Energy Storage and Distribution* programme

Reports and outputs from the projects are available on the ETI's website

http://www.eti.co.uk/



# Insights and Modelling Capability

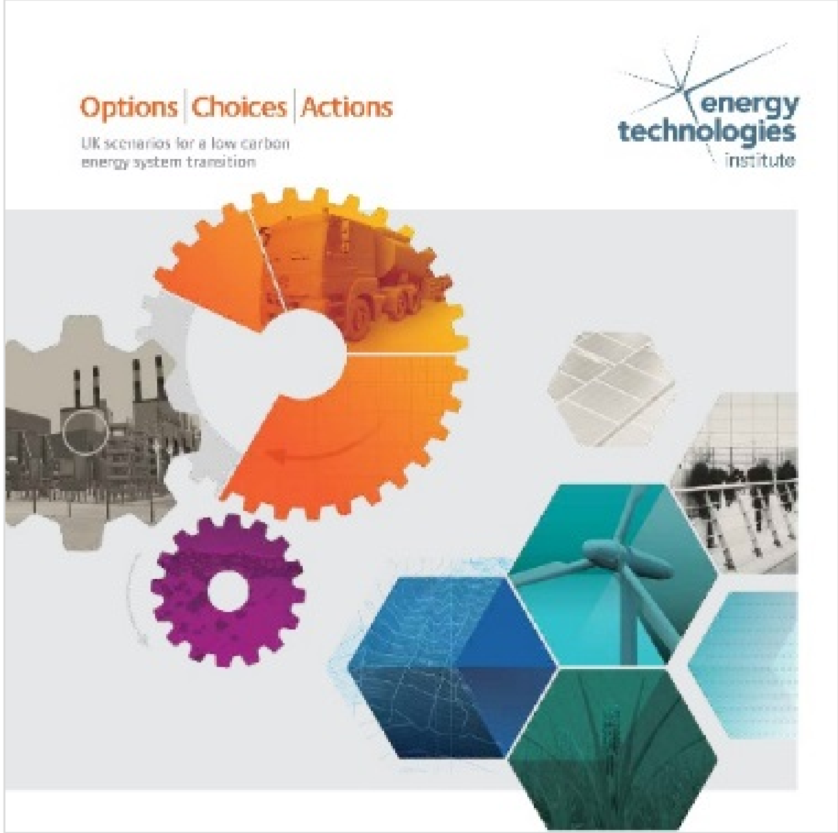
Strategy Manager - Liam Lidstone
Strategy Analyst - Alex Buckman

Liam Lidstone

Strategy Manager

# Network Transition Challenge Insights

# Energy system scenarios




Available at: http://www.eti.co.uk/insights/options-choices-actions-uk-scenarios-for-a-low-carbon-energy-system/

Or search for: ***ETI scenarios***

- **Self-consistent** and **functional** energy systems that, crucially, meet:
  - Projections for future energy service demands and customer expectations
  - GHG emissions targets
- The underlying analysis covers:
  - How technologies might develop
  - Technology compatibility and operational constraints
  - Practical roll-out timeframes
  - Constraints on energy resources

ESME
Energy System Modelling Environment

# Network transition challenges

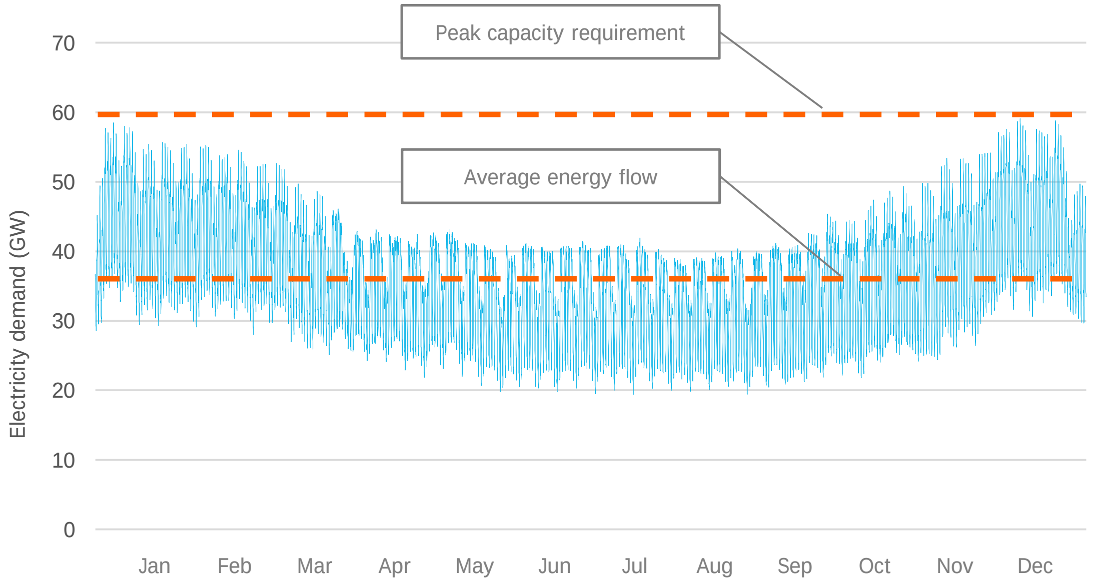
| Adapting and enhancing existing networks | Creating efficient and effective new networks | Integrating networks to optimise performance across energy |
|---|---|---|

| Electricity | Gas | Heat | Hydrogen |
|---|---|---|---|
| Handling increased capacity | Decommissioning (especially within the distribution network) | Cost reduction and technology advancement | Meeting the needs of different sectors |
| Delivering new connections | Operating at much lower utilisation | Supply-chain scale-up | Scale-up |
| Balancing supply and demand | Integrating low carbon fuels at significant levels | Adoption | |

# Transitioning electricity networks

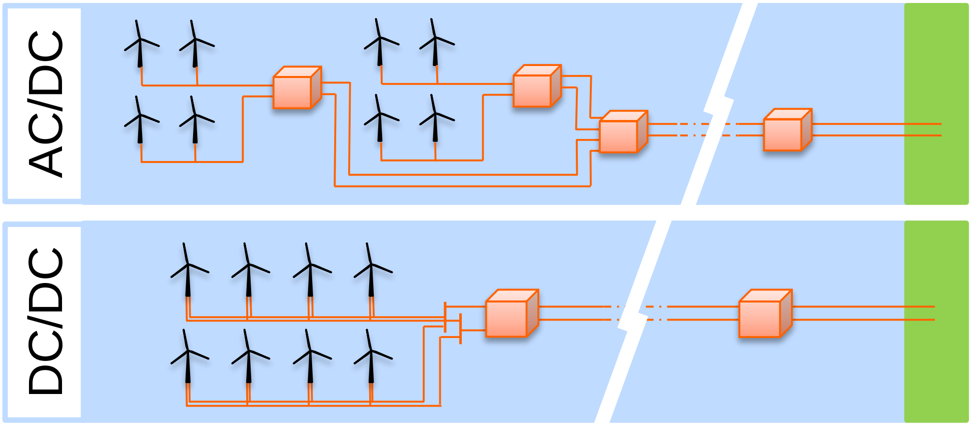
## Increased capacity

- There is a major challenge in knowing, where, when, in which way and to what extent to enhance the network
- This will be particularly acute for the distribution network, where information on the existing state of the network is not as widely available
- Factors include: variation in capacity growth requirements; available physical space; and land value
- Options include: smart grid solutions; fault current limiters; energy storage; and conventional reinforcement




## New connections

- It will be necessary to connect new and a greater number of sites
- Network architecture choices for integrating, e.g., new types of generation, new locations, higher capacity connections
- Trade-offs in network and generation choices, e.g., resource availability vs network length and generation technology vs network technology



# Transitioning gas networks

*For greenhouse gas emissions targets to be met there will need to be significant decarbonisation of heat supply*
*This has implications for the **gas distribution network***

## Decommissioning

- Establishing the costs and practicalities of decommissioning
- Managing the logistics of switching over to the replacement heating system
- Resource requirements

## Operating at much lower utilisation

- Provide back-up to electrified heating
- Efficiency, safety and reliability impacts for use of the gas distribution network at low levels of utilisation need to be properly examined
- Sustainable operation will require the costs of infrastructure operation and maintenance to be recouped somehow
- Integration with the electricity network

## Integrating low carbon fuels at significant levels

- The need for sustainable and cost effective sources and the value of use elsewhere

**Hydrogen**

- Energy content
- Leakage, embrittlement (for some steel grades), compatibility with boilers, etc.

**Bio-SNG**

- Assessment of the overall lifecycle emissions

The gas grid as a whole also serves the power and industry sectors

- Gas consumption in non-heat sectors could grow in the 2020s and 2030s (depending on the availability of CCS)
- How to maintain investment in the gas network as a whole when there is declining overall usage

# Transitioning heat networks

Heat networks possess several features that make them a compelling proposition for helping to decarbonise heat:

- Able to deliver **large amounts of heat** cheaply
- **Long asset life**
- **Flexible** to a multitude of heat sources – *can adopt new heat sources as they become available / cost effective*
- Most cost effective when serving large numbers of buildings in **close proximity**

A major opportunity for heat networks lies in connecting **existing (less efficient) properties** – *a shift from the current focus on new developments* – in **denser areas**

To achieve this key challenges need to be addressed…

*Advances made in these areas will need to be compatible with the beneficial qualities of heat networks*

**Cost reduction and technology advancement**

- Installation advances
- New technology and processes
- Minimise disruption

**Supply-chain scale-up**

- Increase deployment to reach as much as 20x current levels
- In a shorter time than current levels were reached
- To a new market category

**Adoption**

- Put in place the mechanisms, processes, technologies and supply chain
- Showcase successful implementations to create industry and consumer demand

# Transitioning hydrogen networks

## Scale-up

- Significant quantities from the 2030s – *back-to-base fleets for the transport sector prior to this*
- Decisions need to be made and initial steps taken to demonstrate and prove these options by the mid-2020s
- Infrastructure options include: road tanker transportation, new pipelines, repurposed natural gas pipelines, hydrogen storage and electrolysis
- Practical and economic factors influence the suitability of each
- A sufficient scale-up of an industry supply chain would be needed to deliver the required roll-out

## Meeting the demands of different sectors

- Large scale salt cavern storage (and limited pipeline infrastructure) will be needed
- The NW and NE of England provide a good opportunity for hydrogen storage and CCS connected production

- Repurposed natural gas pipelines may be an option
- The long term certainty of industry demand will affect the investibility of new network infrastructure

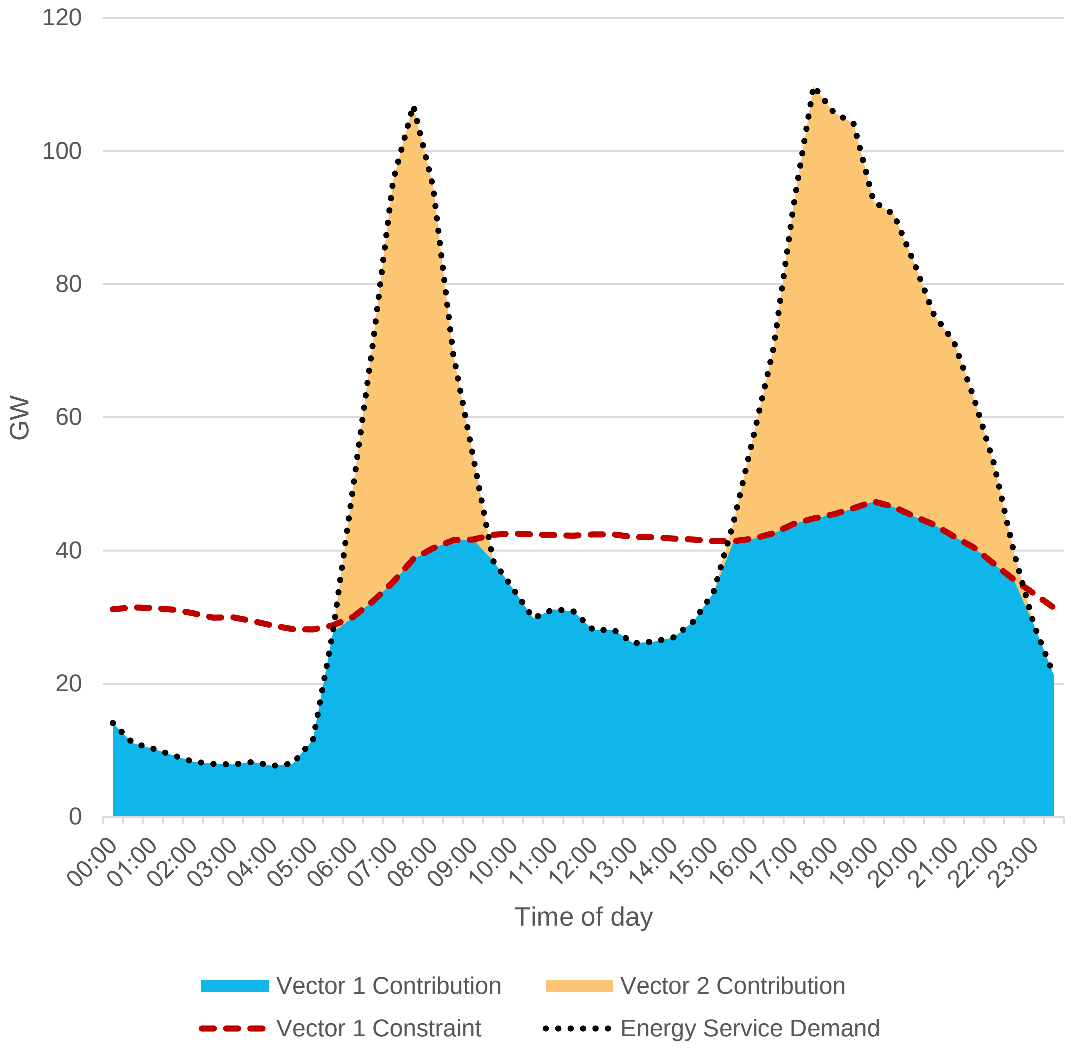
- Nationwide refuelling infrastructure will be necessary for mainstream use
- Very high purity hydrogen will be required
- Integration of a mixture of hydrogen sources and modes of delivery – both in any transition to mainstream hydrogen vehicles and to provide nationwide coverage

- Making use of existing gas distribution network infrastructure
- Managing leakage and network component compatibility
- Regional conversions – managing possible appliance replacement and ensuring hydrogen resource availability

# Integrating networks to optimise across energy vectors

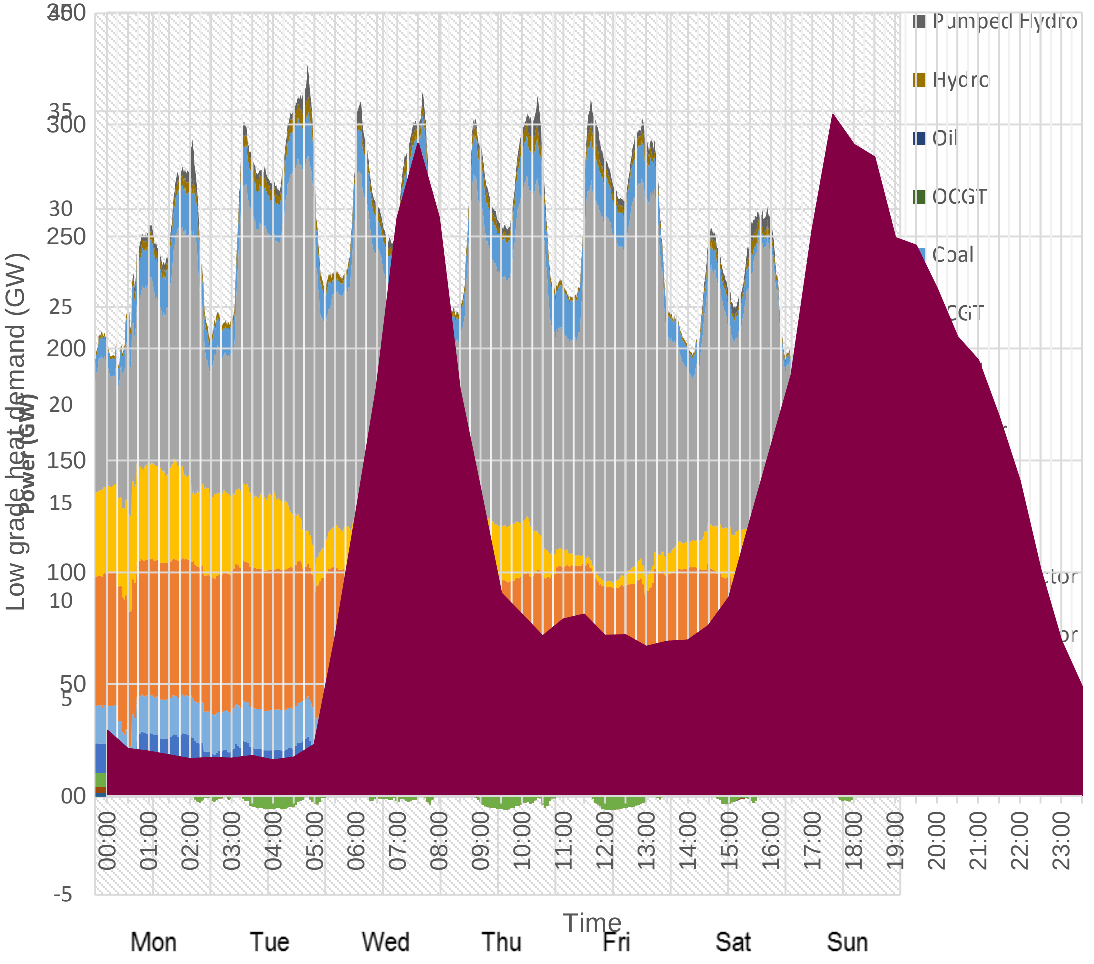
There are multiple ways where, in future, increased integration between networks could yield benefits

- **Peak avoidance** – demand on one network is substituted for another vector at peak times. This is mainly related to the electricity network.
- **Flexibility** – the system provides ability to flex between vectors due to a range of price signals or constraints on particular networks.
- **Generation capacity constraint** – switch from electricity to a different vector due to constrained generation capacity.
- **Generation curtailment** – curtailment of a generating technology due to a surplus of supply
- **Back-up** – use of an alternative energy vector to back-up a primary source.

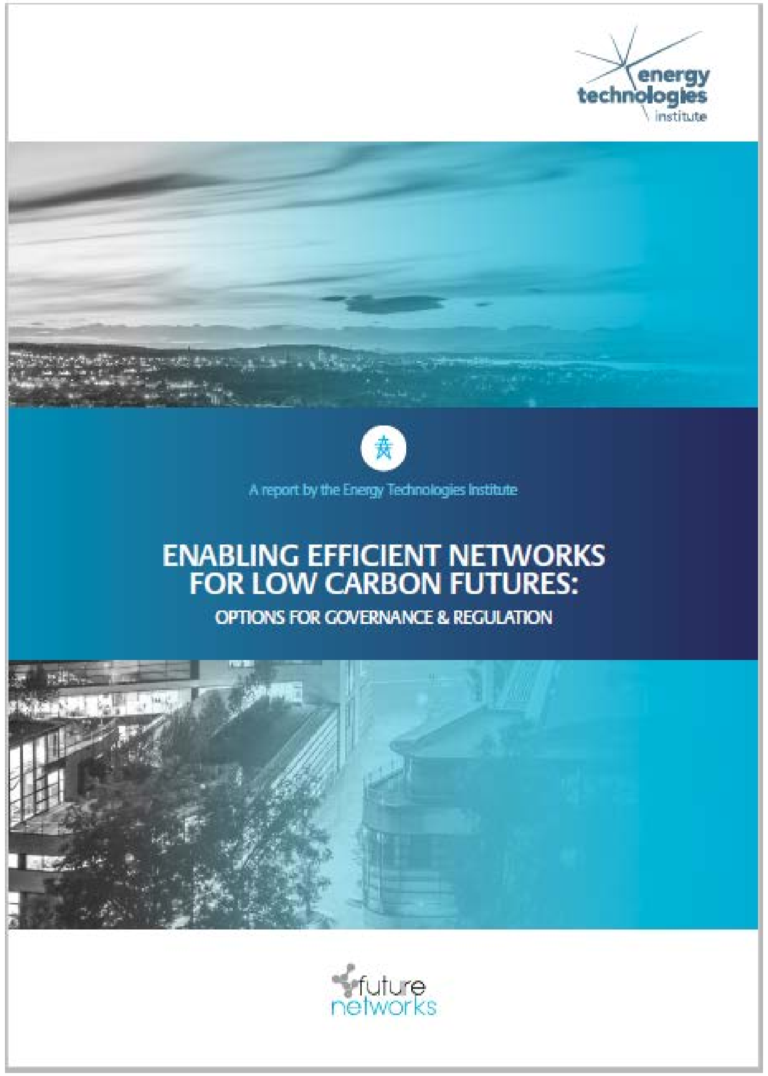


# Balancing supply and demand

- Flexibility (keeping supply and demand in balance) is a key feature of a functional system.
- Energy storage is one means of providing system flexibility
- The ability to provide storage varies amongst the network types:
  - Gas, hydrogen and heat networks all have a level of inherent storage (e.g. line-packing in gaseous pipeline networks); whilst dedicated storage is relatively low cost
  - Electricity supply needs to be in real-time balance; and electricity storage is generally expensive
- Future flexibility options extend beyond just grid-connected electricity storage, for example:
  - Gas and hydrogen fuelled peaking plant to help balance electricity supply
  - Heat storage in homes allowing the load on electricity networks to be reduced at peak times
  - Gas as peak support for heat pumps
  - Managed charging of plug-in vehicles
- How applicable and successful these are also affects the extent to which storage is needed

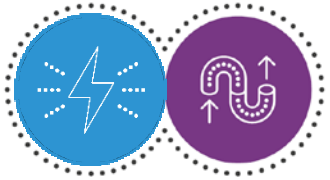


# Market, policy and regulatory implications

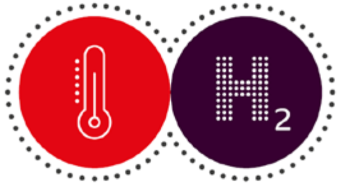



Governance, market and regulatory arrangements are needed to:

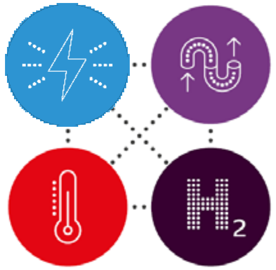
- Incentivise and target investment in substantially adapting and enhancing existing network infrastructures – *e.g. efficient configuration of electricity networks to meet needs of low carbon generation*



- Enable clear decision making and incentivise investment in creating efficiently configured new network infrastructures – *e.g. new heat networks and/or heat-based energy storage*



- Ensure that network infrastructures are designed and work together efficiently across vectors in real time – *e.g. enabling efficient interplay of power, heat and gaseous energy vectors*



# Conclusions

- Energy networks are a vital part of the energy system
- Over the next decade, decisions will be needed about:
  - which existing networks to enhance or adapt,
  - which new networks to create and
  - how new and existing networks can be integrated to optimise across the whole energy system.
- Factors that will need to be considered, include:
  - Changes in how energy can and will be generated and consumed
  - The ability for different networks to meet needs individually and in unison
  - Transition pathways for generation, demand and the networks that link them
  - Network lifecycle and investment opportunities
- Making robust choices is important as networks can take years or even decades to build; and once they're built cannot easily be moved or changed.
- **Systems thinking is critical** which means across vectors and up and down the energy supply chain.
- Decisions should also be based on well evidenced data and analysis.
- The next decade is critical to develop the evidence, through ongoing research and demonstrations at increasing scale

Alex Buckman
Strategy Analyst

# Modelling Capability

# Analysis tools

- Analysis tools have been developed within the Energy Storage and Distribution programme to complement the analysis tools across the ETI's programmes

- The tools cover:
  - Vehicle decarbonisation
  - System storage and flexibility
  - Multi-network cost analysis
  - Heat network cost analysis

Consumers, Vehicles and Energy Integration model

Storage and Flexibility model

Infrastructure Cost Calculator

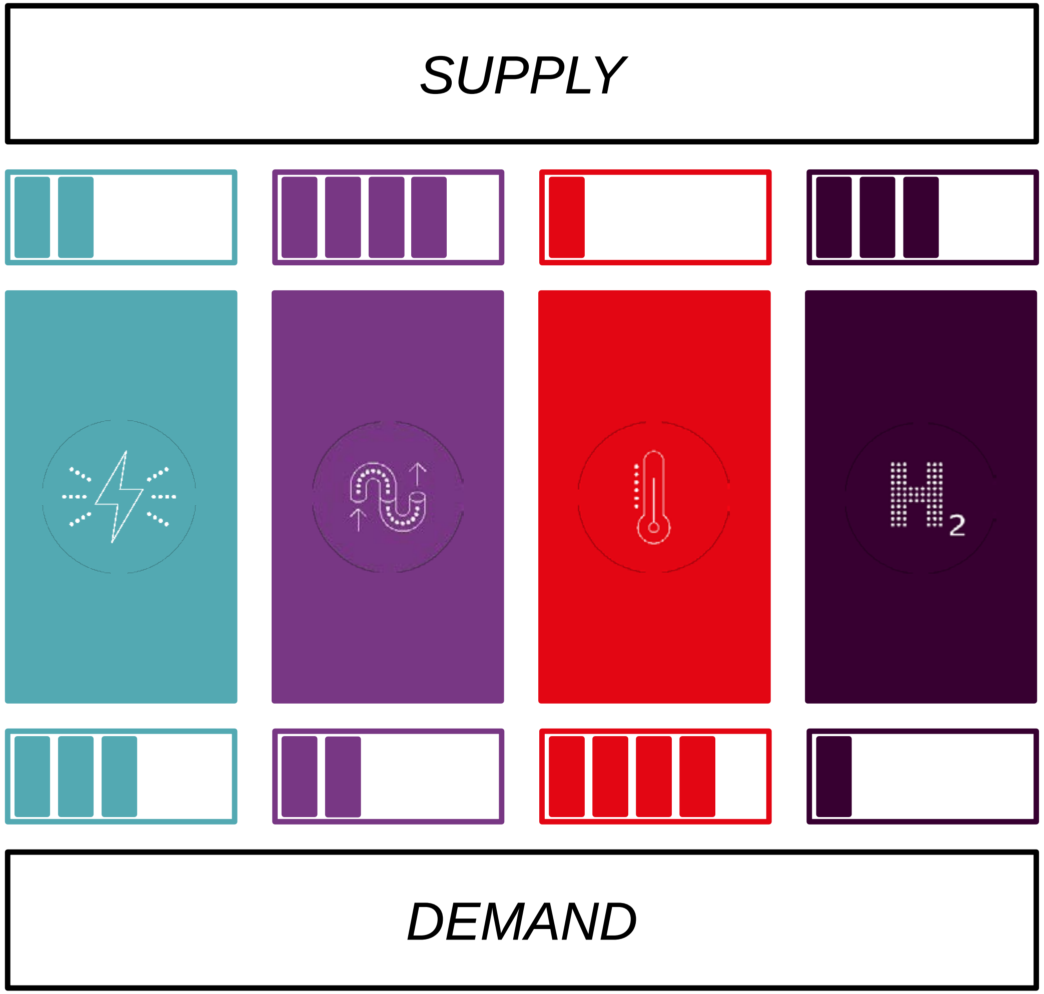
Heat Network Cost Model

# Storage and Flexibility Modelling

- Energy system modelling capability to increase understanding of the role of energy storage and system flexibility in the future energy system

- Providing holistic, techno-economic analysis of storage and competing sources of flex. across multiple:
  - **Energy vectors**: electricity, heat, gas, hydrogen
  - **Points in the energy system**: transmission level, distribution level, behind-the-meter (industry, commercial, domestic)
  - **Geographical positions**: across 11 onshore ESME regions
  - **Services**: e.g. frequency containment and replacement along with wider system benefits such as peak shaving

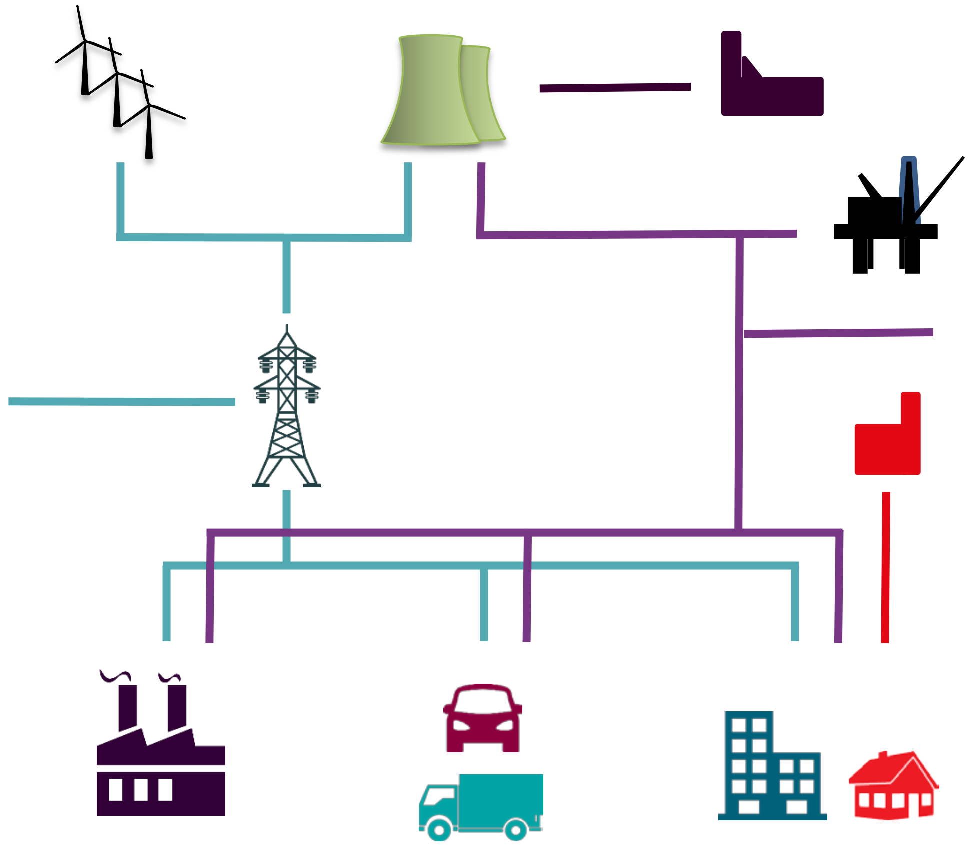
- Accounting for different types of future energy systems



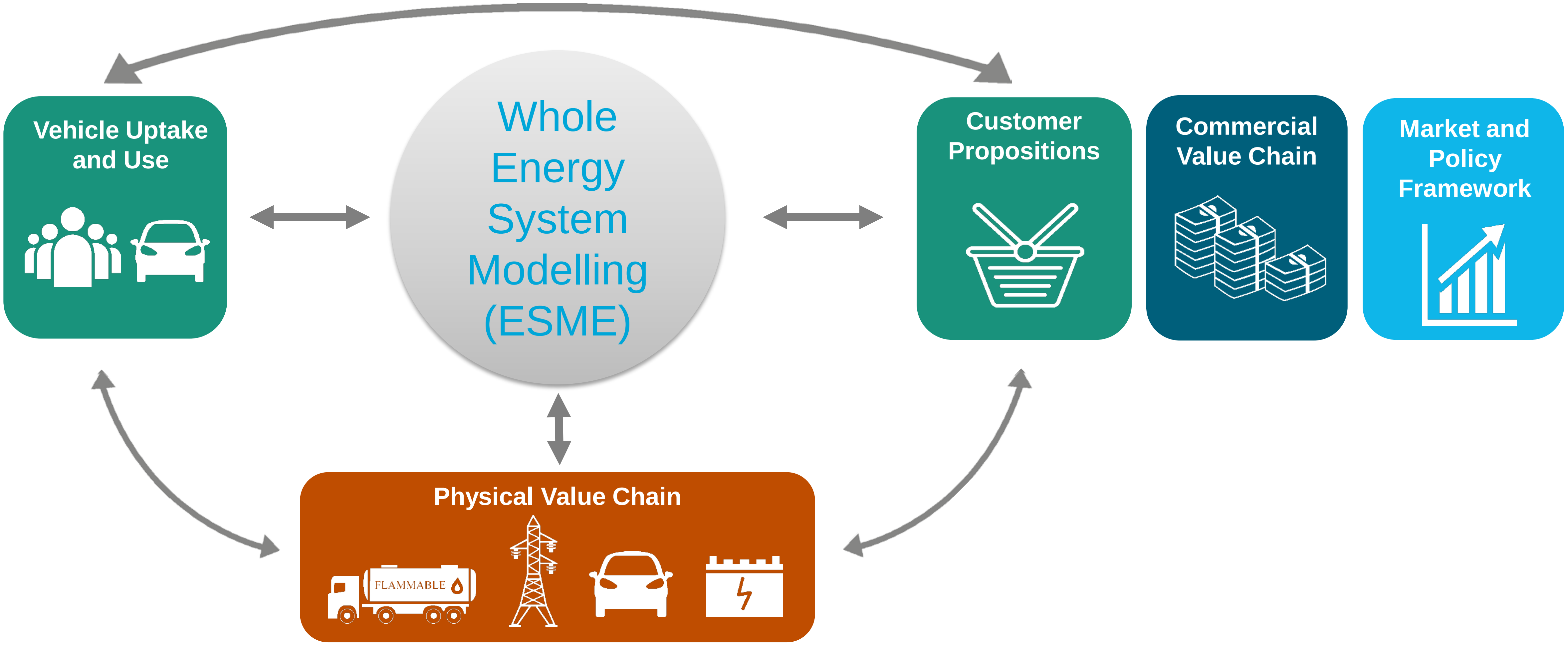
# Modelling approach

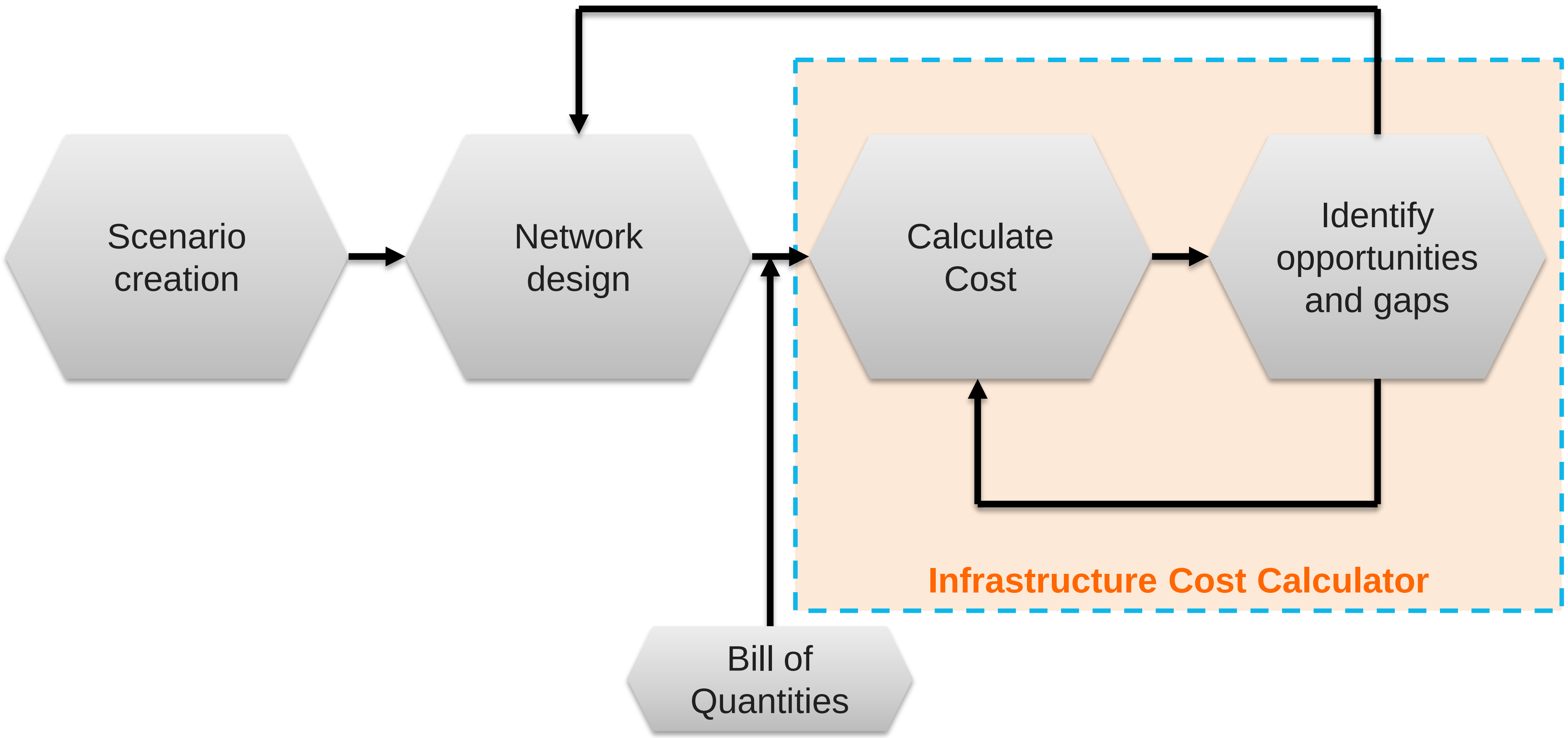
The modelling capability accounts for:

- Underlying **demand** which the overall energy system needs to meet – *across industry, transport, housing, power generation*
- Different **generation mixes** – *e.g. different levels of intermittent renewables, nuclear and CCS*
- **Available flexibility options** – *including: storage, interconnectors, managed charging plant and gaseous storage*
- **Operating characteristics** of different generation assets and flexibility options
- Existing **network capacities**
- System **operational factors** – *technical requirements and system benefits*
- Long term **constraints** – *e.g. decarbonisation*

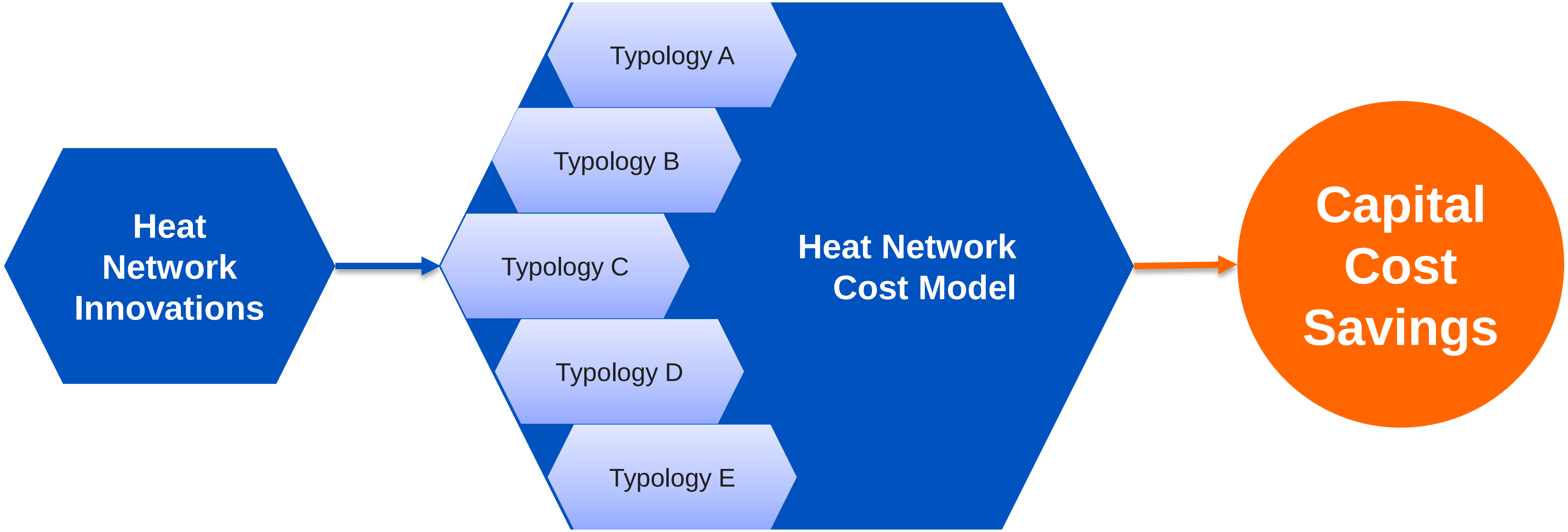


# Consumers, Vehicle and Energy Integration Model




Scenario creation
Network design
Calculate Cost
Identify opportunities and gaps
Infrastructure Cost Calculator
Bill of Quantities

# Heat Network Cost Model



# Thank You

Speak to our analysts and developers in the modelling zone to get more details

ETI10 TEN YEARS OF INNOVATION 2007—2017

IET The Institution of Engineering and Technology

CATAPULT Energy Systems

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

# Future Power System Architecture

Energy Technologies Institute

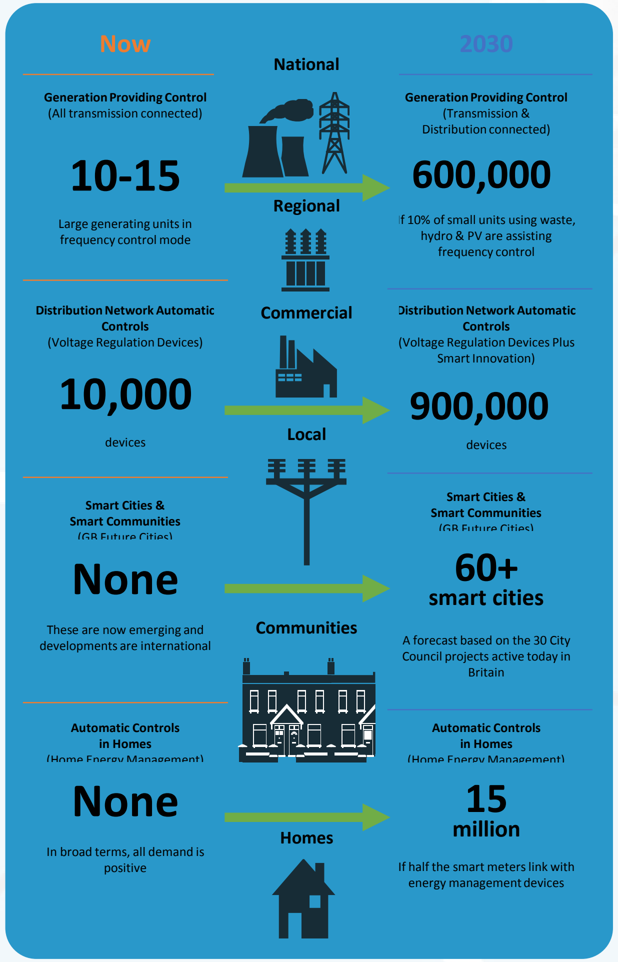
Energy Storage & Distribution: The Networks Jigsaw

London, 5th September 2017

# Future Power System Architecture

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

- Provide analysis, insight and advice to assist ministers, officials, industry professional and innovators on how the architecture of the GB power system should evolve to meet the challenges of:
  - delivering the policy and legal commitment to deep decarbonisation
  - the Industrial Strategy commitment to efficiency and value for money as new technologies and techniques are integrated at scale
  - the operational imperative of maintaining secure, reliable, and affordable electricity supply.
- Funded by Government
- Built on collaboration and broad stakeholder engagement across industry, Government, academia and business of all sizes
- Managed by the Catapult and the IET working in collaboration with specialists with diverse expertise spanning technical, market and social issues



# What FPSA1 told us

- Transformational change requires **35 new or significantly enhanced** power system functions to be developed and implemented
- Most of these functions have **whole-system** implications
- Many of the functions involve solution sets facilitated by activity on the **customer side of the meter**
- Although the time horizon of the work was 2030, **work needs to start urgently** to embed the necessary functionality for when it is needed

# Eight groupings of functions

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

- Design a competitive framework to deliver the energy trilemma
- Manage the interface with connected energy systems
- Form and share best view of state of system in each time scale
- Use smart grid and other technologies to accommodate new demand, generation and energy resources
- Enable and execute necessary operator interventions
- Monitor trends and scan for emerging risks/ opportunities on the power system and implement appropriate responses
- Provide capabilities for use in emergencies
- Develop market to support customer aspirations and new functionality

# Examples of Functions

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

## Three Examples of New or Extended Functions

**1.**

**Enabling the cost-effective connection and integration** of new types of demand (such as EV charging), generation (such as solar PV arrays) and energy storage devices (such as batteries)

*Enabling techniques include smart active management and communications systems which can relieve capacity constraints on electricity networks and maintain the security and stability of the wider power system.*

**2.**

**Enabling secure and open data exchange for all sector parties** – including traditional parties (such as Suppliers, DSOs and the GBSO) and new parties (such as aggregators and providers of intelligent home devices)

*These parties have systems and services that require the secure sharing of information and a common requirement for access to open data protocols and coordinated data management structures.*

**3.**

**Identifying and designing-out emerging new threats to the power system** arising from the expansion of highly distributed communications, control and data management systems

*These new threats give rise to increased opportunities for unauthorised access to data, cyber attacks, and potential shocks to the system from uncoordinated control actions leading to demand step-changes.*

# What FPSA2 told us

- The 35 new power system functions are validated
- There are barriers to implementation of these functions – but these are now better understood
- Failure to implement the functions will have adverse consequences
- The concept of Enabling Frameworks is proposed as an improved approach to implementation
- There are Innovation/R&D opportunities we can progress now
- There is strong stakeholder interest in sector transformation

# Risks to delivering functionality

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

**Barriers to delivering functionality**

| | |
|---|---|
| Technical | System functional limitation<br>Technical challenges to implementation<br>Changes to infrastructure<br>Industry standards<br>Technical Codes |
| Commercial | Commercial framework<br>Market structures<br>Strength of business case |
| Governance | Legislation and policy<br>Regulatory framework<br>Code governance |
| Societal | Accommodation of customers' needs<br>Accommodation of new parties |

**Consequences of late or non-delivery of functionality**

| | |
|---|---|
| Sustainability | Insufficient low carbon generation<br>Insufficient low carbon demand |
| Security | System instability<br>Network unreliability<br>Inadequate energy security |
| Affordability | High operational cost<br>High investment need<br>Impediments to new business models |

It is axiomatic that the government's Industrial Strategy, and export and job opportunities would also be affected.

# Identified priority areas for innovation

FUTURE POWER SYSTEM ARCHITECTURE

MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

### RD&D actions based on Evolutionary Pathways

- Mechanisms to encourage participation in change processes
- Market designs and policy mechanisms for promoting policy objectives
- Monitoring impact of customer behaviour on networks
- Exploring new options for Black Start and Cold Start including distributed energy resources
- Forecasting modelling and scenarios with increased complexity to account for the whole power system including distributed energy resources
- Maximising power system capacity through implementing technical and commercial smart grid solutions
- Mechanism for automated and secure management of demand and generation
- Mechanisms to enable new market options that reflect customers' needs

### RD&D actions based on primary research

- Customer protection including consideration of engagement materials and channels, including a focus on vulnerable customers
- Consumer response to price and the role of social norms in consumer engagement

### RD&D based on future functionality and common FPSA themes

- Power systems and market modelling capability, including whole systems modelling accounting for increased complexity
- Capabilities for monitoring/metering across the whole power system, and use of data for system operation and settlement for services
- Future IT, communications and control, and cyber security requirements of the system and develop solutions where needed
- Data collection, transport, analytics and use, including 'big data'
- New business models being proposed, or those that may be required in the future, including enabling local energy markets
- Multi-vector interactions, including technologies and techniques, and their benefits to the whole power system and a wider multi-vector energy system

# Stakeholder responses

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

**FPSA2 was tasked with establishing closer stakeholder engagement**, especially the new, beyond-the-meter parties. Two influential strands of work are:

1. The dedicated Work Packages, contracted to separate consultants, to address **(i) today's stakeholders** The work of the Communications team that includes an analysis of **stakeholder segmentation**, and an examination of how issues look through their different perspectives. The five perspectives used are:

- **SO, DNO/DSO, TNO**, Large Generators, established networks vendors, key consultancies, technical media
- **Domestic / micro-SME customers**, Suppliers, the smart metering community, smart home and energy services
- **Large I&C Customers, Aggregators,** Energy Communities, Smart Cities, DG Operators, Storage Operators
- **Policy Makers, Academia,** Research Councils, and non-technical media
- **Vendors new to the Supply Chain** including grid edge products, data systems, and white goods manufacturers

2. Stakeholders share the same vision for a highly integrated web of new energy services, although the extent and timing of significant customer "pull" for new services etc remains uncertain

# An inescapable conclusion ….

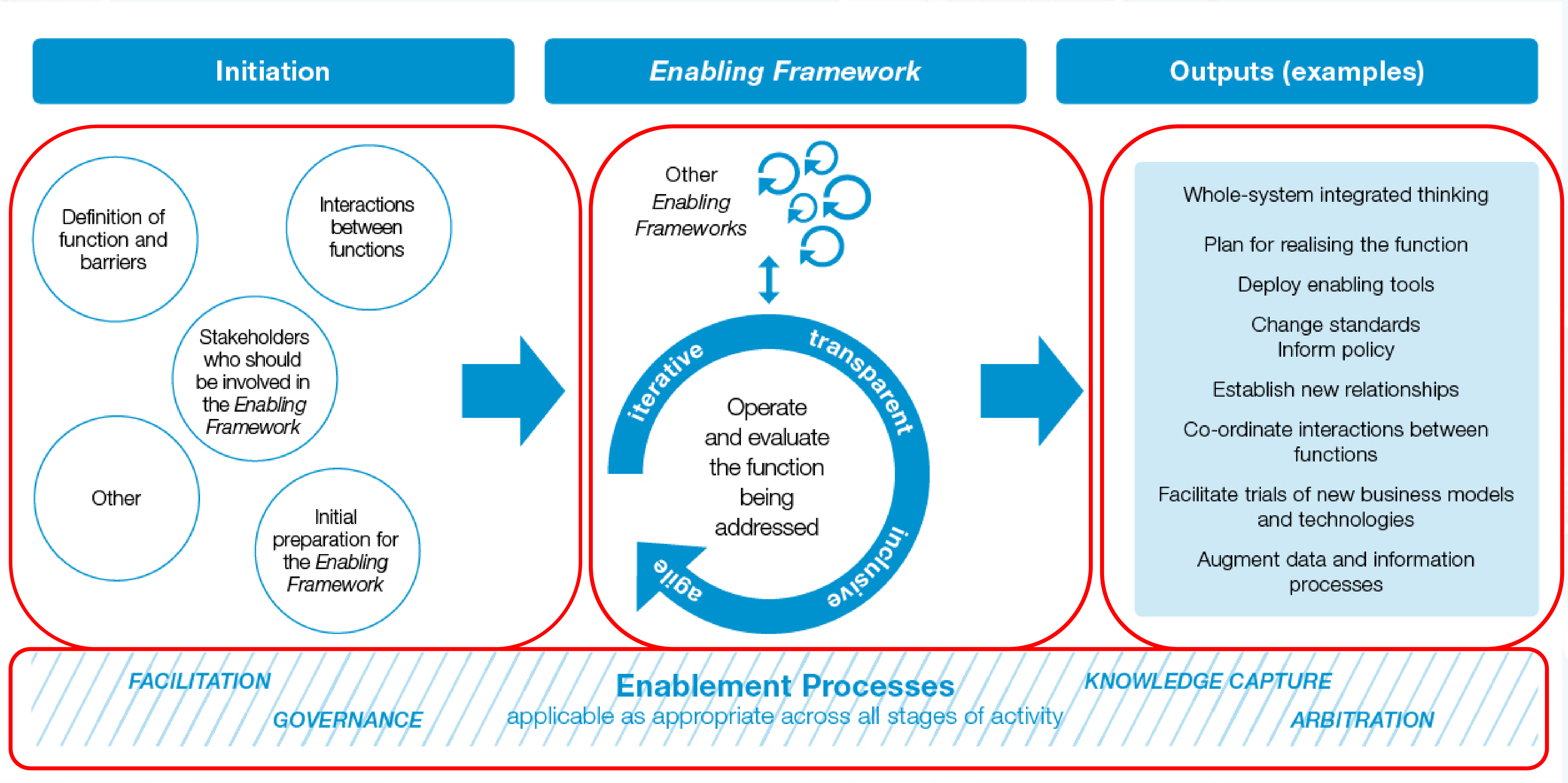
FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

When risk is assessed across all 35 functions it becomes clear that ….

today's change governance mechanisms have neither the scope nor the agility to ensure the timely delivery of required new functionality

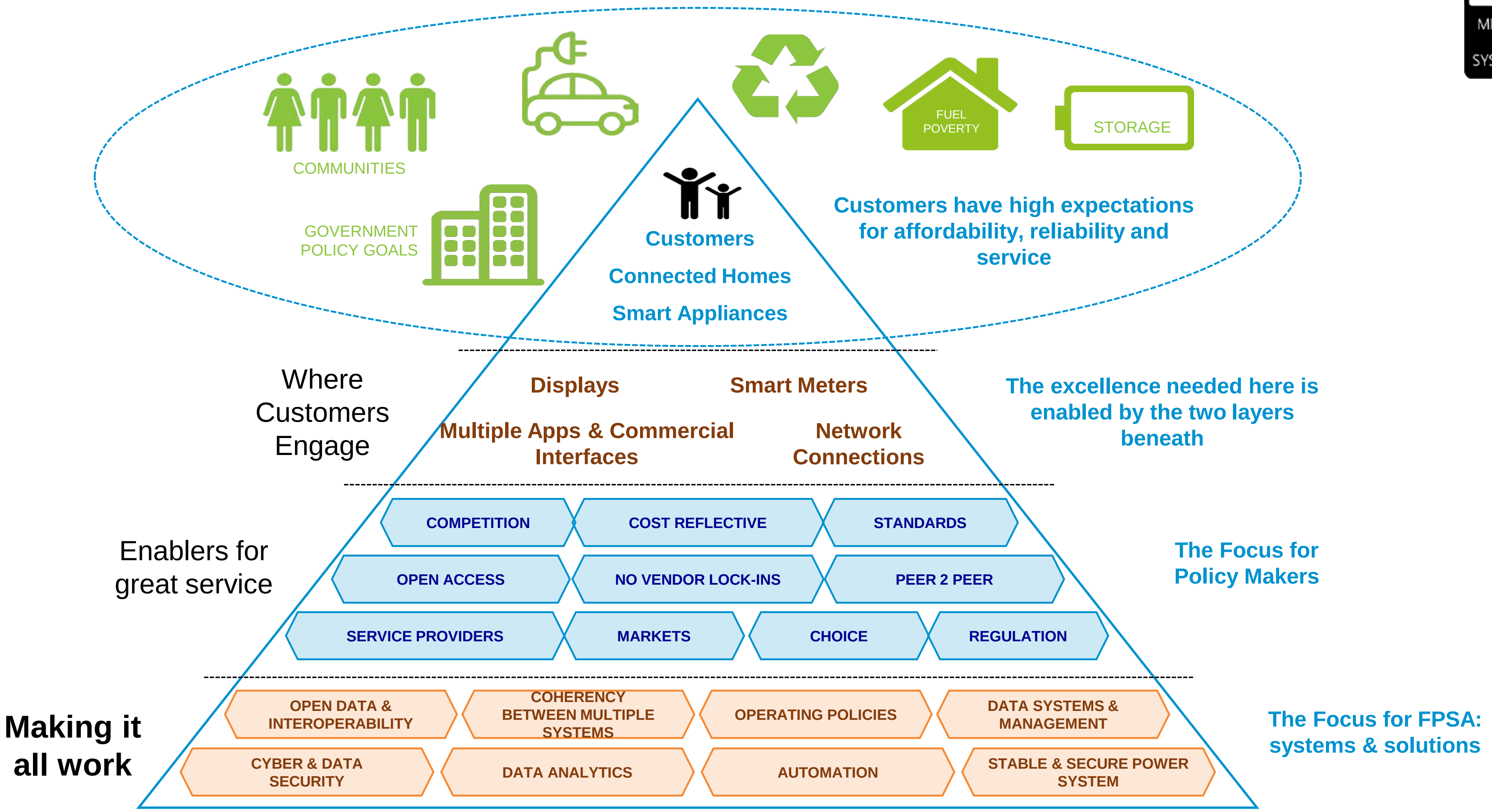
Instead, a new more inclusive and agile form of change governance is required ….

# Enabling Frameworks: Summary of key concepts

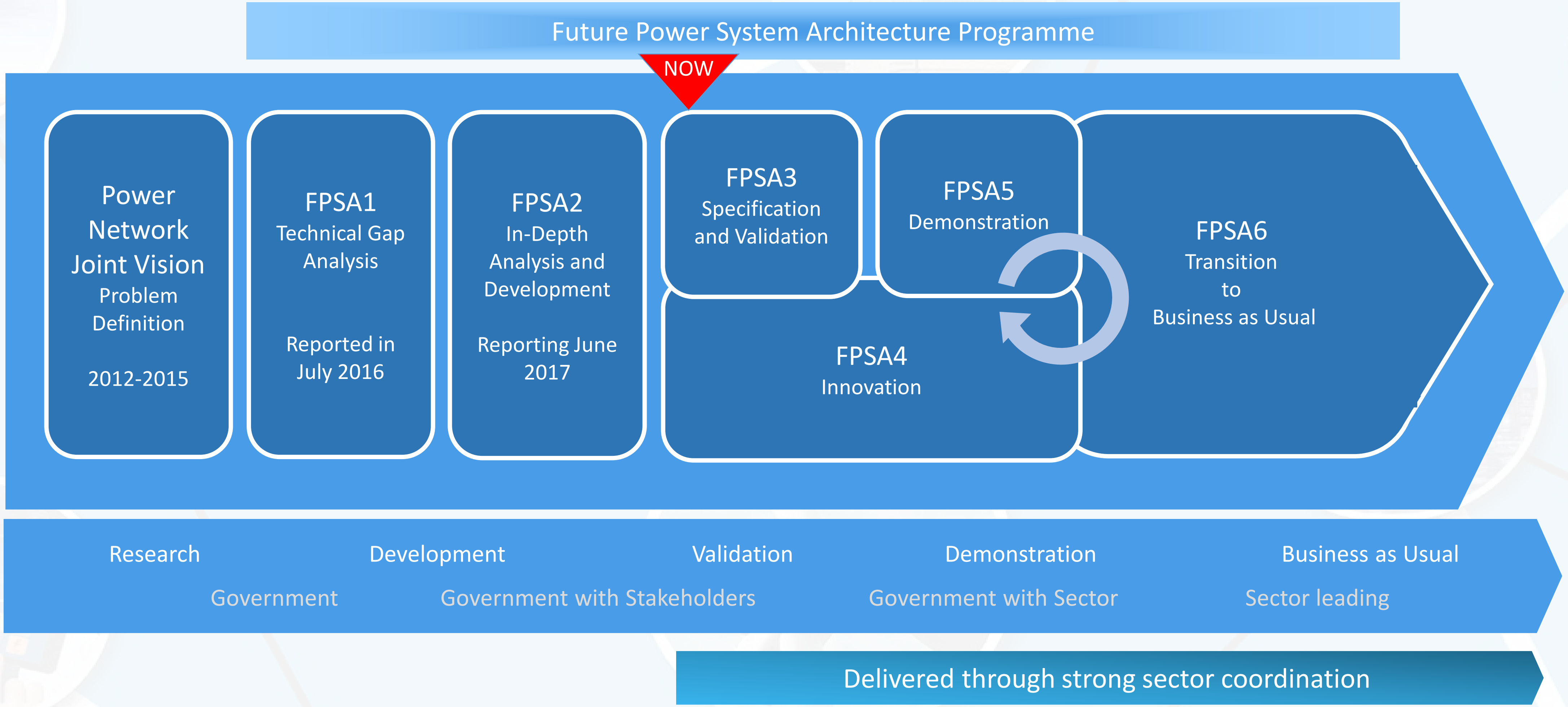


# The Elements of the Smart Energy Future

FUTURE POWER SYSTEM ARCHITECTURE
MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES



# Beyond FPSA2

# Potential use cases (for consideration)

- **Leveraging Flexibility in EV Charging** - for system optimisation - managing network constraints, maximising low marginal cost generation, minimising system balancing costs
- **Enabling the Smart Home** - smart appliances, smart meters, HEMS, home energy storage, hardware and software standards, innovative tariffs, comfort, safety and security
- **Black & Cold Start Capability** - technical capabilities, black start service options, market mechanisms, network constraint management options, innovation in service provision
- **Enabling Real and Virtual Communities** - generation and storage, inter and intra community trading, cost-reflective network charging, ancillary services, licensing implications
- **Maximising the Potential for Energy Storage - ownership and operation, managing synergies and conflicts, strategic and locational planning, principles of network charging

# Summary

- The drivers for change remain strong with the customer playing an increasingly prominent role
- Whole-system thinking and approaches are essential
- Whole-system includes ‘beyond the meter’
- We sense an inflection point – things are moving quickly and there is a growing body of work
- Other transformations can inform our thinking
- The project methodology used in FPSA2 demonstrated the value of applying agile techniques, learned from other sectors

# Coffee Break

20 minutes

# Panel Debate

## ‘Challenges facing UK Energy Networks in a Low Carbon Future’

# Drinks Reception

Now open in the exhibition area