The Institution of Engineering and Technology

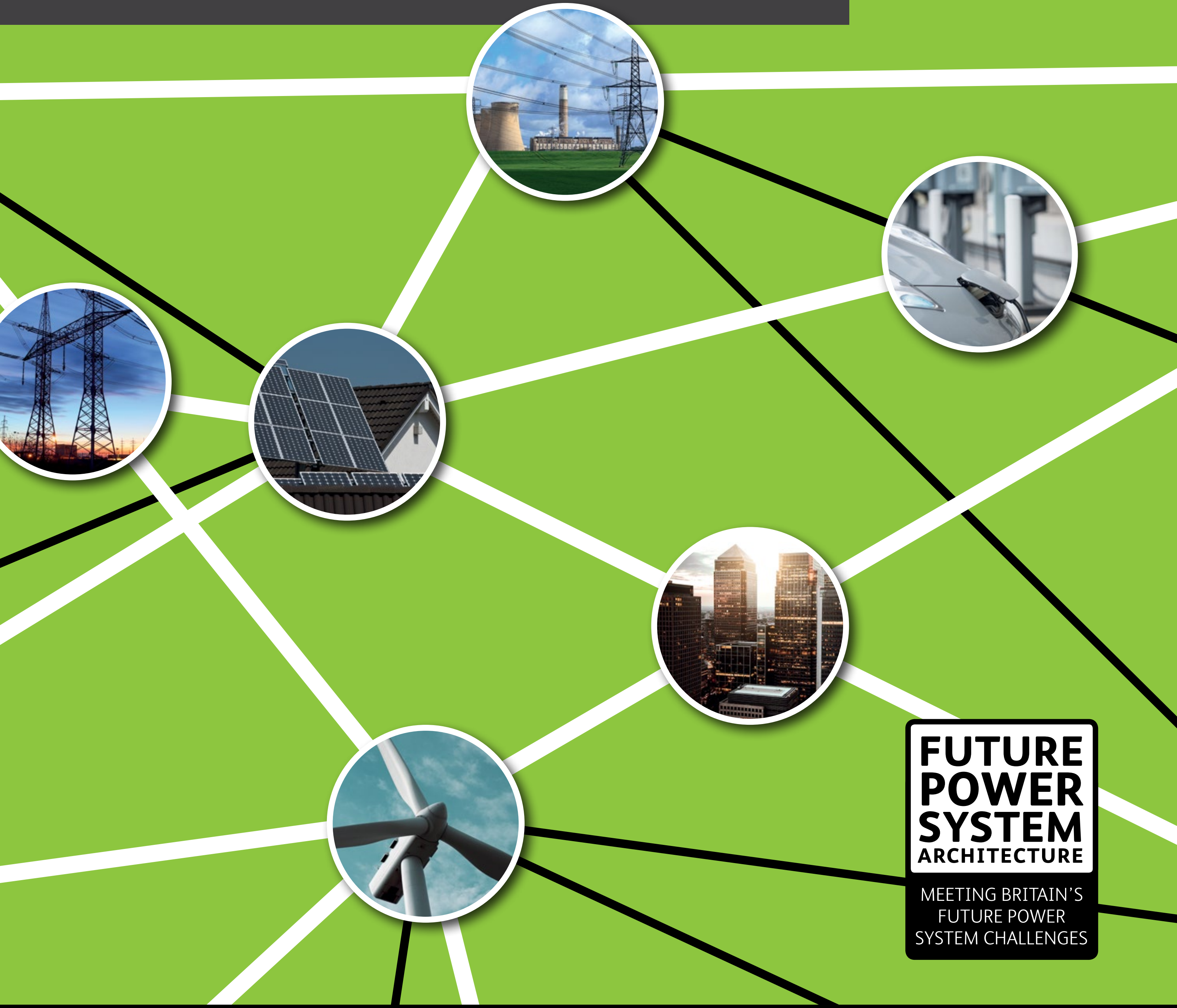
CATAPULT Energy Systems

# Future Power System Architecture

## Project 2

### Policy Briefing Paper

A report commissioned by Innovate UK and delivered through a collaboration between the Institution of Engineering and Technology and the Energy Systems Catapult.



FUTURE POWER SYSTEM ARCHITECTURE

MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

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# Future Power System Architecture Project 2

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## Policy Briefing Paper

**Future Power System Architecture** – A report commissioned by Innovate UK

**The Future Power System Architecture (FPSA) project 2 was commissioned by Innovate UK and delivered through a collaboration between the Institution of Engineering and Technology (IET) and the Energy Systems Catapult.**

The collaboration built upon the shared commitment to responding effectively to the challenges presented by the energy trilemma: decarbonisation, security of supply and affordability. The Energy Systems Catapult and the IET drew upon their respective strengths and engaged with a broad community of stakeholders and other experts to deliver the project.

The collaboration brought extensive expertise and experience to the project, combining technical, commercial and customer perspectives, and included the significant contribution of senior thought leaders from the IET membership. The unique combination of complementary skills enabled innovation in approach, deep analysis and strong evidence building. The collaboration worked closely on project governance, delivery and commercial management and applied best practice in all aspects of its work. The position of the IET and the Energy Systems Catapult in the energy sector assured independence of the outcomes.

## About the Institution of Engineering and Technology

The Institution of Engineering and Technology is one of the world's largest engineering institutions with over 167,000 members in 127 countries. It is also the most multidisciplinary – to reflect the increasingly diverse nature of engineering in the 21st century.

The IET is working to engineer a better world by inspiring, informing and influencing its members, engineers and technicians, and all those who are touched by, or touch, the work of engineers. The Institution of Engineering and Technology is registered as a Charity in England and Wales (No. 211014) and Scotland (No. SCO38698).

## About the Energy Systems Catapult

The Energy Systems Catapult is the UK's technology and innovation centre set up to support companies and Government for the development of new products and services to address the new commercial opportunities created by the transformation of UK and global energy systems (covering electricity, heat and combustible gases).

The Catapult's mission is to bring the worlds of industry, academia and Government together to encourage and support the development of new technology-based products and services in the energy sector. It is a non-profit, non-partisan company limited by guarantee.

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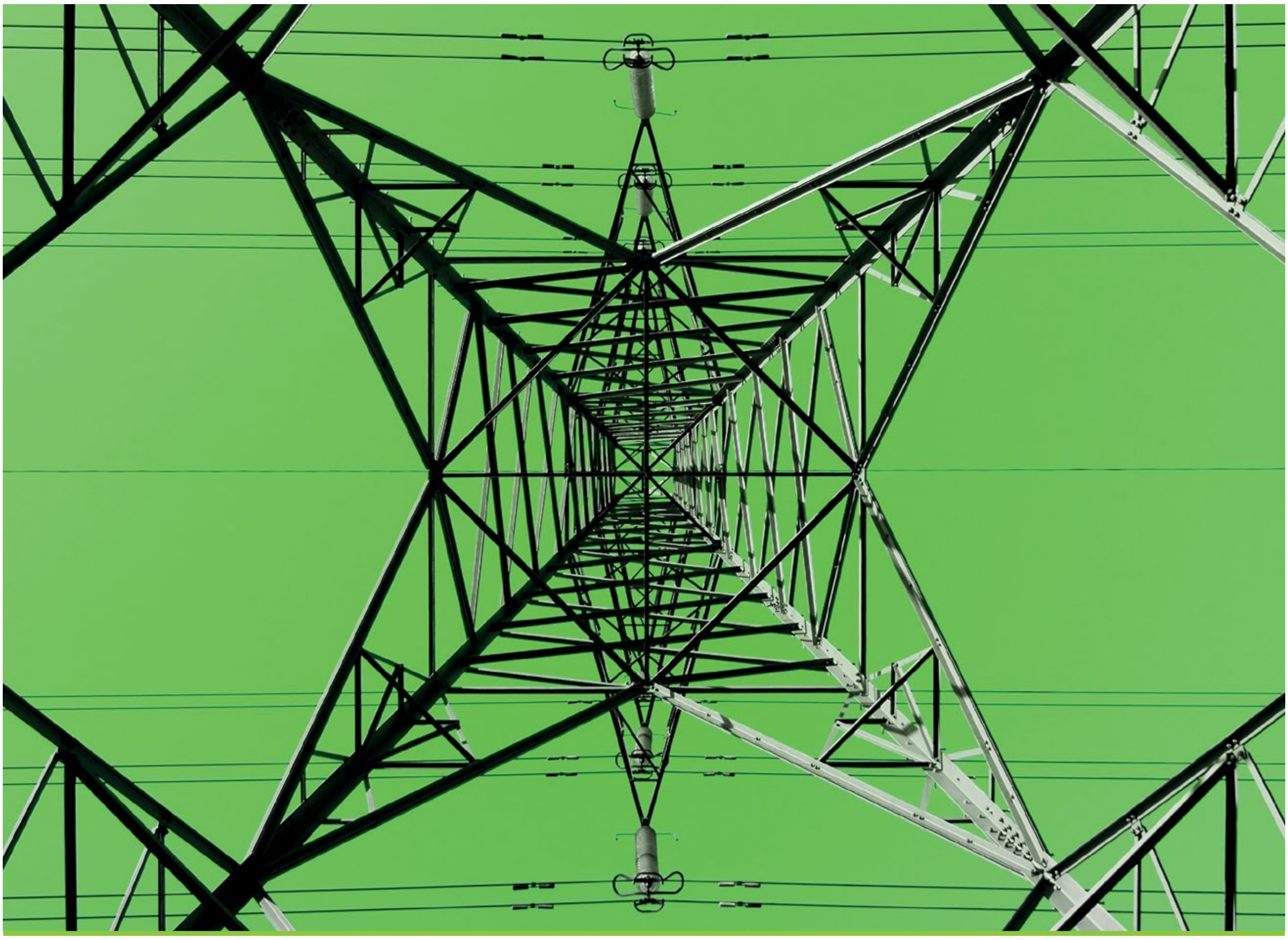

# 1. Introduction – The Future Power System Architecture Programme

The ‘power system architecture’ is the underlying design and structure of the electricity system – how its components and its participants are organised and interact. A major transformation in the electricity system is underway and its pace will accelerate over the period to 2030.

The Future Power System Architecture (FPSA) programme has involved an extensive stakeholder base and has been led collaboratively by the Institution of Engineering and Technology (IET) and the Energy Systems Catapult. It has examined the drivers of change, the new power system functionalities required, the barriers to be overcome and the appropriate approach to timely, cost-effective and agile delivery. The Future Power System Architecture (FPSA) programme seeks to **create a dynamic environment in which the GB power system architecture can develop**, taking a holistic and whole-system perspective.

The first phase or FPSA (FPSA1) completed in April 2016 and was commissioned and sponsored by the then UK Department of Energy and Climate Change (DECC) and Energy Systems Catapult. The current phase, FPSA2, is sponsored by Innovate UK. This report is a summary of a more comprehensive synthesis and six specialised reports on the component Work Packages within the project. The full package of evidence, findings and recommendations is available online at www.theiet.org.uk/FPSA and https://es.catapult.org.uk/fpsa

# 2. Drivers of Power System Transformation

Power system transformation is driven by national and international policy commitments, by evolving customer requirements, by emerging new business models and by advances in technologies. These drivers include:

**Sustainability commitments**. The Climate Change Act 2008 sets demanding decarbonisation targets in law and a fifth carbon budget for the period 2028-2032 that will represent a deep cut in carbon emissions. The Industrial Emissions Directive, which addresses air quality impacts of large combustion plants, will drive the closure of coal-fired power stations by 2025. The Government and European Union have introduced multiple incentives and mechanisms to drive decarbonisation through uptake of low-carbon technologies and energy efficiency.

**The Industrial Strategy and the efficiency agenda**. The Industrial Strategy green paper (Building our Industrial Strategy, January 2017) has two distinct approaches to energy. First, using technology to keep improving cost-effectiveness, keeping power costs down to reduce burdens on the rest of the economy. Second, supporting the development of innovative energy technologies, such as electric vehicles (EVs), storage and smart grid techniques. The green paper outlines the potential synergies:

> *EVs are less polluting and cheaper to run and have the potential to provide electricity storage and demand flexibility that could provide benefits to consumers and our electricity system. Drawing together these battery, energy storage and grid technologies is sensible because step changes in innovation will likely involve all of them. For example, smart grids that respond to the demands of consumers could potentially use new battery technologies, particularly storage in EVs, to deliver power efficiently and at lower cost. (The Government Green Paper, page 32)*

The new functionalities required in the power system to achieve objectives of this nature, and the means to deliver them, are a key focus of the FPSA programme.

**Critical National Infrastructure**. The power system as a whole and the networks in particular are classified as critical national infrastructure, implying major economic, social and human consequences arising from their loss or compromise. This has created a long-standing energy policy objective to maintain security, stability and reliability of the power system in the very short to very long-term. This is not a new requirement, but it is far more challenging to achieve in a period of major transformation e.g. during a significant increase in embedded and weather dependent supply from wind and solar and as new forms of demand from EVs and heat pumps increase from being incidental to being large-scale features of the power system. As information technologies begin to play a greater role in the power system, so the diversity and scope of cyber risks will increase.

**Changing customer and stakeholder requirements and behaviour**. The interactions between the customer, the supplier and the power system are rapidly evolving. Customers are becoming more assertive and have expectations of high quality service, better deals and new capabilities. At the same time, customers are responding to policy-led incentives designed to meet environmental objectives. This is increasing the uptake of technologies such as EVs, heat pumps, energy information and management devices; and building-scale renewable generation. As these technologies and ideas become more widespread, establishing new social norms, it is likely that we will reach tipping points and see rapid acceleration, with both great opportunities, but also some risks.

**New participants and business models in the sector**. New participants and aggregated services providers are emerging, such as smart connected technology providers and community energy groups which can represent groups of customers and their interactions with the rest of the power system. The system benefits by being able to co-ordinate with a single point of contact, with access to many different potential services. Customers will benefit from innovative new tariffs and/or contracts and smart control systems which reduce costs while helping them tailor their energy usage to their lifestyle.

# 3. The Power System is Undergoing Radical Change

FPSA2 has conducted a broad stakeholder consultation on attitudes to energy innovations. For example, an online panel comprising 495 domestic customers was surveyed and the following observations were made:

- High interest in the visions for future home energy systems that included solar photovoltaic (solar PV) systems and especially combined with energy storage. In general, there was an appetite for the **transition to smarter energy systems in homes**.
- **Awareness was high** for many examples of new energy technologies, including smart meters, solar PV and smart heating systems. In contrast, the idea of switching to a green electricity tariff had low levels of awareness.
- The highest level of interest was in **using a smart meter**. The next highest interest was for a green electricity tariff, for which there was more interest than prior awareness. There were lower levels of interest in EVs and smart heating systems.
- Interest in options for electricity energy supply showed **high interest in the lowest cost option** and in supply from a local authority acting as a not-for-profit supplier.

Note, the panel responses may not be representative of the whole customer base.

In its role as System Operator, National Grid produces Future Energy Scenarios - four visions of the future with differing assumptions about prosperity and 'green ambition'. In the 2016 edition, the scenario most consistent with the Government policy: *Gone Green* – high prosperity and high environmental ambition[1]. The table below illustrates some of the radical change built into *Gone Green*. This scenario is the one of four that most closely aligns with the Government's economic and environmental ambition. **The table below indicates the scale of change** implied in these goals.

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[1] In the 2017 edition, to be published on 17 July, National Grid is to replace *Gone Green* with a new *Two Degrees* scenario.

| National Grid Future Energy Scenario | 2015 Actual | 2030 Gone Green |
|---|---|---|
| **Demand side** | | |
| Electric vehicles: units | 0.05 million | 5.8 million |
| Electric vehicles: proportion of vehicle fleet | 0.16% | 17% |
| Smart meters | 1 million | 29 million |
| Heat pumps (air source & ground source) | 0.06 million | 3.7 million |
| Hybrid heat pump gas boiler | 0.0 | 2.3 million |
| Peak demand (GB average cold spell) GW | 61 | 67 |
| Electrical energy demand TWh/year | 334 | 346 |
| **Supply side** | | |
| Total capacity GW | 97 | 165 |
| Renewables capacity GW | 30 | 91 |
| Solar PV GW | 10 | 31 |
| Wind GW | 13 | 47 |
| Interconnector capacity GW | 4 | 23 |
| Storage GW | 3 | 8 |
| Distribution system or locally connected GW | 23 | 53 |
| Distribution or system locally connected % | 23% | 32% |
| Implied overall capacity factor | 39% | 24% |

Source: National Grid Plc, Future Energy Scenarios 2016. http://fes.nationalgrid.com/

The *Gone Green* scenario is similar to the scale of change envisaged in the Central Scenario presented by the Committee on Climate Change in its supporting advice on the fifth carbon budget (2028-32). This scenario also estimates a carbon price of £78/t$CO_2$. By way of comparison, the current carbon price floor is capped at a maximum of £18/t$CO_2$ through to 2020. If the UK is to remain on track to meet the fifth carbon budget we should anticipate significant changes in the economic signals in the energy sector.

However, such scenarios are provided to *illustrate* possible futures and to give more concrete form to the implications of government targets and aspirations, not as forecasts of a future technology mix. The more subtle requirement is to **develop the flexibility and agility to accommodate a range of futures** that involve significant change but considerable uncertainty about its nature. The direction of such changes was probed in FPSA2 through a horizon scanning exercise. These were the primary findings:

1. **The boundaries** traditionally considered for the power system are now having to be redefined to encompass the customer side of the meter - the 'grid edge' - incorporating electric heating and cooling, EVs,

batteries and generation.

2. **The deployment rates** of the above technologies are uncertain, as they are subject to a wide variety of factors, including policy, technology development and pricing and customer appetite and awareness.
3. **The move towards service provision**, rather than product provision, e.g. mobility-as-a-service (e.g. combining transportation services from public and private providers through a unified platform), heat-as-a-service (e.g. providing agreed levels of comfort) and energy service business models.
4. **Business models that incorporate 'flexibility'** through optimising, influencing and/or controlling the timing of demand, storage and generation will be an important part of the future. This optimisation will take place at different scales in the power system (from buildings to smart cities), across various classes of assets (from vehicle charging at multiple sites to optimising asset utilisation within a commercial building).
5. **Connectivity and data analytics**, artificial intelligence and machine learning will be important enablers of optimisation and service-based business models.
6. **An ecosystem of service providers** with stakes in the power system will make a broad and diverse contribution. They will include companies from outside the energy sector (such as vehicle manufacturers), companies that are product-focused today but service-orientated in the future (such as heating equipment manufacturers) and start-ups and new entrants, some of which do not exist today.
7. **Customers and communities**, both geographical communities and communities of common interest, will exert increasing market power in the future, providing services to, as well as buying services from, the wider energy system.

**Enabling flexibility is seen to bring significant savings**. For example, if the use of heat pumps and EV charging is not smoothed out by means of customers engaging with new smart technologies, these new forms of demand are likely to create high peak loads requiring large-scale investment in network strengthening.  High peak loads may also create high-cost calls on the capacity mechanism and cause price spikes, which may in turn limit customer acceptability of cost-reflective pricing. There is significant scope for avoiding wasteful investment in physical infrastructure that has low utilisation.  The cost-efficiency of smart grid technologies that enable greater flexibility are an important consideration in forthcoming distribution and transmission price control reviews.

# 4. New Power System Architecture Functionality is Required

The first phase of FPSA identified ***thirty-five*** new or enhanced functions that are necessary to deliver the capabilities expected of the power system by 2030. FPSA2 has validated and deepened the original analysis and categorised these functions into eight groups, A to H.

### Group A

**Design a competitive framework to address the energy trilemma**. This category consists of a single function that is responsible for the provision of means to model the increased complexity of various energy system portfolios and assist with the design of competitive frameworks that best achieve the policy objectives of sustainability, security and cost-effectiveness of supply ('the trilemma'). These portfolios could include centralised and distributed generation, energy storage and demand response.

### Group B

**Manage the interface with connected energy systems**. This group consists of five functions that are concerned with interactions between stakeholders and activities within the energy sector (power, gas and heat networks and international interconnectors). The functions include co-ordination, engagement and collaboration with these parties to optimise power system operation and planning, to manage incidents and to facilitate efficient market behaviours.

### Group C

**Form and share best view of state of system in each time scale**. Seven functions manage information flows about the state of the power system. This includes functionality for forecasting and observing, and for the sharing of information on availability and performance of power resources. Information on real-time availability of assets is required for balancing and for assessment of actual performance, which informs settlements.

### Group D

**Use smart grid and other technologies to accommodate new demand, generation and energy resources**. This group consists of a single function that is responsible for accommodation of new connections and organic load growth across the power system by any appropriate means, including the use of smart grid technology and other innovative arrangements, to make efficient use of capacity.

### Group E

**Enable and execute necessary operator interventions**. The eight functions in this group are concerned with enabling system operator and network operator interventions that can be executed reliably when necessary. Primary enablers for operator interventions include adequate monitoring and control capability, understanding credible events/faults and planning contingency actions.

### Group F

**Monitor trends and scan for the emerging risks/opportunities on the power system and implement appropriate responses**. Four functions make up this group that involves ongoing monitoring and periodic horizon scanning activities. This ensures new developments, such as customer behavioural changes, threats to operability and cyber security, are managed effectively. Function F1 is an overarching function that manages these changes and identifies and implements solutions as necessary.

### Group G

**Provide capabilities for use in emergencies**. Three functions take account of power system operation in emergency situations and planning the actions and capabilities that will be required during these periods. This takes account of the more challenging circumstances that will arise from new forms of electrical demand and more widely distributed generation. It includes planning the restoration of supplies following a partial or total shutdown, and the provision of emergency procedures either to avoid loss of supplies or to facilitate restoration.

### Group H

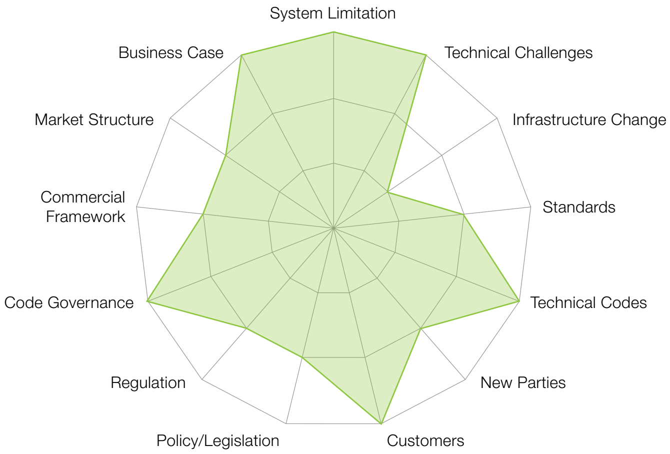
**Develop markets to support customer aspirations and new functionality**. This group covers six functions that focus on the provision of a market structure, market mechanisms and aligned financial incentives to offer a range of choices to customers on how they interact with the power system, while balancing competition with social objectives, such as protection of vulnerable groups or low-income households.

Based on analysis of the *thirty-five* functions a series of **potential areas for research, development or innovation have also been identified**. The *thirty-five* functions and the research, development and innovation topics are set out in full detail in the Synthesis Report and more detailed technical reports available at www.theiet.org.uk/FPSA

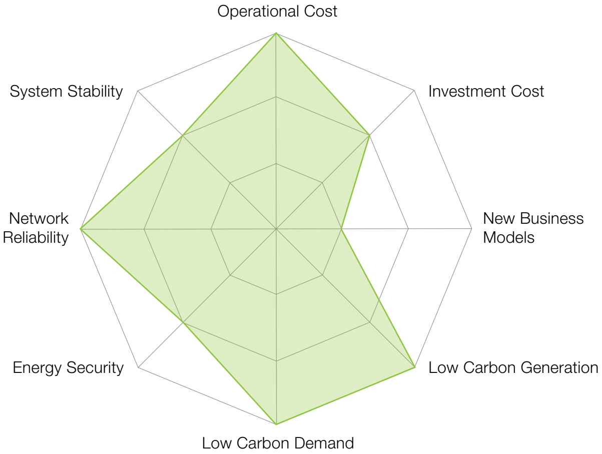
# 5. Barriers to Realising New Functionality

FPSA2 has examined in detail the technical, governance, commercial and societal barriers to delivering the new functionality and whether such functionality would be delivered successfully in the normal course of business. The project has concluded there are significant barriers to the timely implementation of each of the *thirty-five* new functions. Each function was assessed against a range of barriers and the consequences of non-delivery. An example of the analysis is provided below for function G3: Plan for the timely restoration of supplies following a total or partial shutdown (Black Start). The radar plots below show where the degree of Difficulty and Consequence is 'low' close to the centre of the of the plot, and 'high' at the edge of the plot.

## Barriers to delivery



## Consequences of non-delivery



The analysis in FPSA2 has shown the following barrier categories have the greatest impact:

1. **Existing industry governance processes.** Implementation of new functions will require significant interaction with technical and market codes and potentially require complex and rapid changes, involving a larger number and wider range of stakeholders.
   - Industry code governance today is not sufficiently agile or flexible to respond to the degree and pace of future change envisaged. Relatively minor changes can take several months or even years to implement in today's processes, especially where multiple codes are affected, as commonly arises with whole-system impacts.
   - The scope of today's industry codes and the consequent representation of parties is too narrow to address emerging requirements. Today's arrangements are segmented across the supply chain and have no remit for addressing whole-system issues. Also, engaging a larger group of stakeholders, including parties such as aggregators, energy communities, energy managers and large-scale integrators is problematic under existing arrangements.

2. **Extent of technical change required.** It will be necessary to specify or enhance a large volume of technical standards some of which may be novel or contentious.
   - Forecasting and decision support capabilities need enhancement, especially taking account of the whole-system and other vectors.  These will be important in making significant economic decisions such as transmission and distribution price control reviews.
   - There are limitations in monitoring, control, data management, and communication in the existing power system, especially within distribution networks. There are also interoperability challenges with existing beyond the meter systems that have to be resolved if they are to support local system balancing.
   - Existing standards are inadequate for some essential future functionality e.g. cyber security, data access, control interfaces and other aspects of interoperability.

3. **Regulatory frameworks.** The current regulatory frameworks do not embrace a whole system view or reflect the changing marketplace.
   - Existing licensing and regulatory arrangements do not fully account for new parties and new business models.
   - The whole power system, including its interaction with other energy vectors and technology beyond the customer meter, is not considered holistically.
   - The regulatory framework needs to balance flexibility and agility with long-term certainty. This requires early attention given the rapid transformation ahead and the forthcoming price control reviews RIIO ET2 and ED2, which may have an eight-year outlook.
   - Lack of data access for new parties. The boundaries between public and private data will create commercial and security sensitivities and distort or enhance competition.

4. **Commercial frameworks.** These barriers mostly relate to new commercial requirements that cannot be adopted under the current market structure.
   - Existing commercial arrangements can sometimes act counter to core policy objectives. For example, the current structure of network and system balancing charges, coupled with double charging of renewable energy levies, can have an adverse effect on the business case for energy storage.
   - Commercial frameworks may fail to realise potential synergies through insufficient transparency, liquidity and co-ordination of existing markets. For example, energy markets, capacity mechanisms and balancing services can be a barrier to full commercial exploitation of distributed generation, storage and other distributed energy resources.
   - New commercial models are required to deliver some of the new functionality, including, e.g. half-hourly settlement, local trading, and Black Start services.
   - Current commercial frameworks are not geared towards offering accessibility to markets for new entrants, in particular, new entrants without deep prior experience, market knowledge and administrative and commercial strength.

**Societal barriers** such as a distrust of energy sector parties, risk-aversion, behavioural inertia or simply lack of awareness or interest might also inhibit the take-up of new service offerings or greater engagement.  Addressing this is likely to involve several elements, including the use of automation to shield customers from underlying complexity; incentives for participation; behaviour change or 'nudge' techniques; building awareness and developing social norms and new forms of collective action.

There is work underway to address some of these challenges in the Department of Business, Energy and Industrial Strategy (BEIS) and Ofgem, which provides a valuable basis for further development.

FPSA recommends taking a systematic approach to assessment and implementation of the *thirty-five* FPSA functions and to consider whole-system implications via the new concept of *Enabling Frameworks (EFs)* (see section 6).

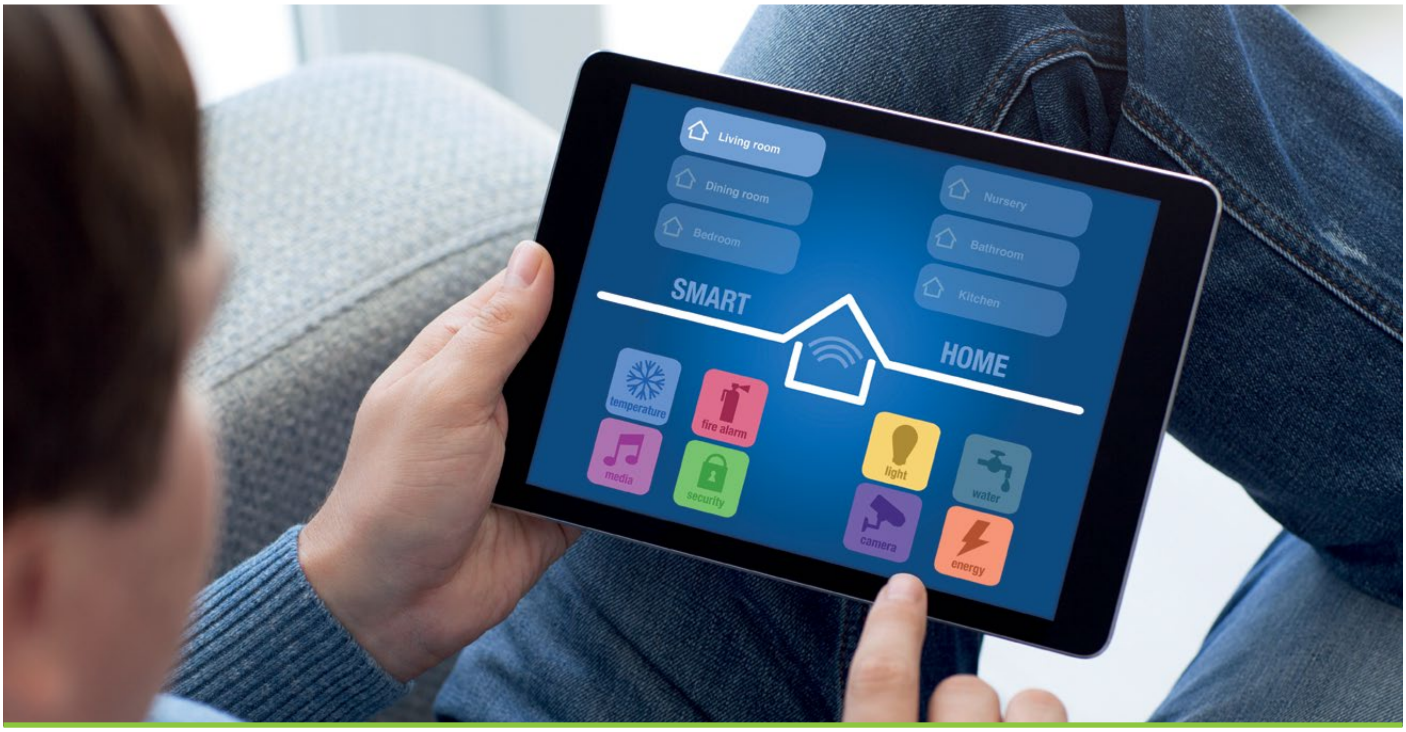
### 5.1 Consequences of not delivering enhanced functionality

FPSA2 has undertaken a counterfactual analysis to provide insights into the consequences of late or non-delivery of the new functionality. Three forms of impact were defined:

1. **Sustainability of power supply** – the possible risk to meeting climate change targets arising from constraints to the deployment of low carbon generation options, low carbon demand technologies, and related enabling techniques and procedures.
2. **Cost-effectiveness of power supply** – this includes having unnecessarily high operational and investment costs and impeding the introduction of new business models that may otherwise serve to provide customers with more choice and with services which better suit their needs and goals. This has implications for forthcoming distribution and transmission price control reviews.
3. **Security of power supply** – this includes minimising interruption to supply, maintaining that supply to within the quality required by customers and efficient recovery from weather extremes or other incidents.

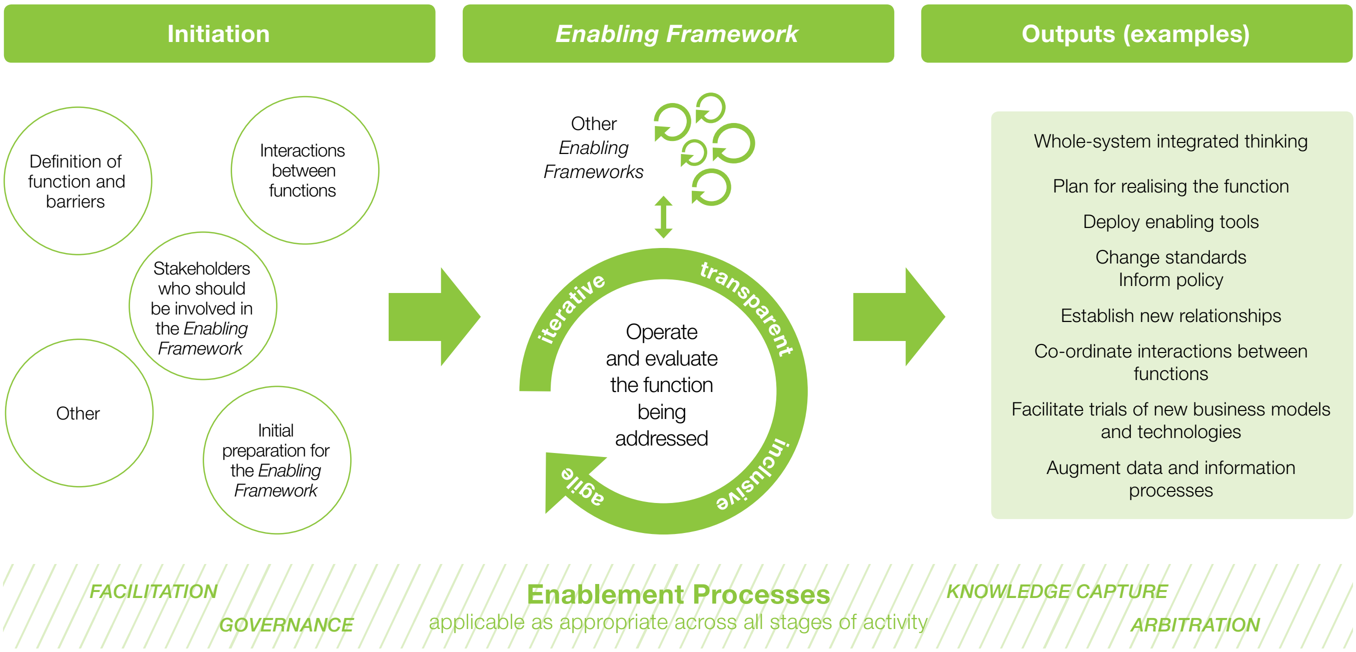
The impact analysis found that delay or non-delivery of the FPSA functions results in material consequences to system security, decarbonisation and affordability, ultimately risking delivery of GB energy policy and system reliability and resilience.

**A further risk is lost economic opportunity** – the reform of power systems will be a global phenomenon in the coming decades, and by being a leading nation in power sector transformation, the UK can position itself to lead in this emerging advanced technology and knowledge-based marketplace, creating high value jobs, attracting investment and expanding exports.



# 6. *Enabling Frameworks* – Flexible and Agile Implementation

An *Enabling Framework (EF)* is a new form of change mechanism designed to overcome barriers and meet the needs of the required transformation. It provides a way to implement power system functionality as part of an iterative and self-improving change pathway. In the context of the GB electricity system, an *EF* would be aligned to one or more of the functions that have been identified. The work of an *EF* is outlined in the figure below:



**Initiation**

Definition of function and barriers

Interactions between functions

Stakeholders who should be involved in the *Enabling Framework*

Other

Initial preparation for the *Enabling Framework*

***Enabling Framework***

Other *Enabling Frameworks*

Operate and evaluate the function being addressed

**Outputs (examples)**

Whole-system integrated thinking

Plan for realising the function

Deploy enabling tools

Change standards
Inform policy

Establish new relationships

Co-ordinate interactions between functions

Facilitate trials of new business models and technologies

Augment data and information processes

*FACILITATION*

*GOVERNANCE*

**Enablement Processes**
applicable as appropriate across all stages of activity

*KNOWLEDGE CAPTURE*

*ARBITRATION*

The *Enabling Framework* Architecture describes the structure for the creation and operation of *EFs* and it has several key elements:

- A set of *Guiding Principles* stressing stakeholder inclusion, conflict resolution, transparency and an iterative and adaptive approach that responds to new knowledge and innovation.
- A *Stakeholder Network* that plays a significant role in decision-making and creation of new functionality. All relevant stakeholders would be represented, including new players such as energy communities, those who are currently at the periphery such as providers of connected consumer technologies and representatives of customers and other system users.
- An *Enablement Organisation* would provide a facilitation role and in its broadest sense be responsible for the smooth operation of the *Enabling Framework* Architecture, including where necessary arbitration of the stakeholder network's decision-making. Its role is to facilitate, providing tools for the *EFs* to be able to carry out their activities.
- *Common Frameworks* are mechanisms for delivering functionality that cover the system as a whole and/or multiple functions, including cyber security, safety and the treatment of vulnerable or low-income groups.
- *Prestructuring* is the concept of developing the initial, highly flexible and customisable state of a particular *EF* as a starting point for further development in collaboration with the stakeholder network.
- *Transition*. It will be important that migration to *EFs* is managed incrementally and carefully. *EFs* would be adopted gradually to enable migration from the existing processes to future processes through sequential demonstration and implementation to develop the framework itself.

Further work is required to allocate roles and responsibilities, accountabilities, the authority to make investments and the relationships between this organisation and other bodies with relevant roles in the GB power system architecture, e.g. with Ofgem and the existing code panels, including a period of transition.

# 7. Conclusions

The main conclusions from FPSA2 are as follows:

1. **Transformational change in the power system is in progress and will accelerate** over the period to 2030. It is driven by the triple challenges of sustainability objectives, cost-effectiveness and security and stability of supply. New customer demands and novel business models are adding to the pace of change.

2. **The power system is becoming more complex and localised**, with many new developments on the customer side of the meter, new service-based business models, and new real and virtual customer communities. The developments, which are increasingly whole-system in their impact, create both opportunities and risks.

3. The conclusion of FPSA1 that ***thirty-five* new or enhanced functions** are required in the GB power system architecture has been tested and is robust. Development and implementation of a systematic programme to deliver these functions efficiently and in a timely way is a **significant challenge of considerable complexity and some urgency**.

4. **A range of topics for research, development or innovation** have been identified from the analysis of these functions and these would be useful to pursue in the short-term.

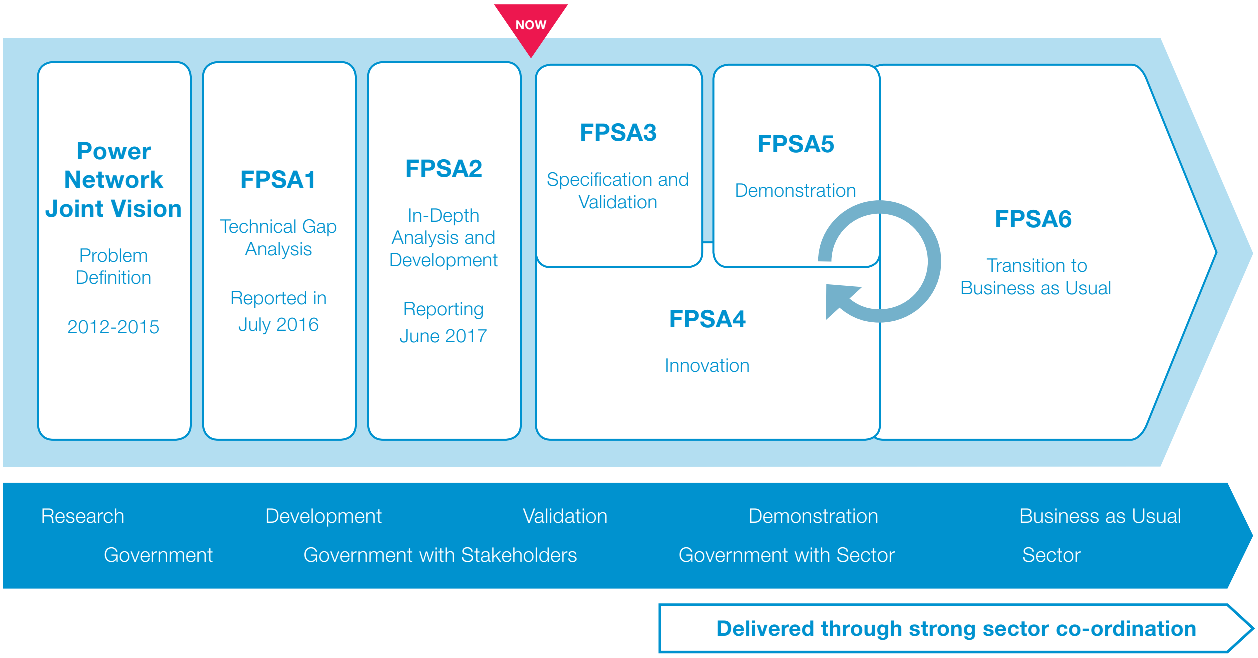
5. **There are numerous barriers to delivering new functionality**, including substantive governance, technical, regulatory and commercial issues. The consequences of late or non-delivery will be to compromise decarbonisation objectives, frustrate customer expectations, increase costs and/or adversely affect reliability and security of supply.

6. ***EFs* could provide a new approach**. Developing the concept and implementing *EFs* in a systematic way could create a flexible, agile and inclusive approach to the development of the GB power system architecture and its functionality. The key features are agility in programme development, a high degree of inclusive stakeholder participation, timely decision-making and an iterative learning approach that embraces uncertainty, innovation and whole-system integration concepts.

# 8. Recommendations and Next Steps

The principal recommendation from the FPSA2 project is to maintain momentum and continue the FPSA journey. The journey is illustrated in the figure below.

### Future Power System Architecture Programme



### 8.1 Government should assume high-level ownership of the transformation

The work of the FPSA programme to date highlights the importance of acting now to ensure that the power system can adapt to address the complex and uncertain demands that will be placed on it in the period to 2030 and beyond.

The programme needs to continue its work to further build its understanding of functional needs, potential future structures, innovation gaps and approaches for managing change as the system undergoes transformation.

FPSA2 provides a technical analysis but **it is also a call to action**. The transformation of the power system built in to government policy and the energy sector trends in innovation represents a profound re-engineering of the power system. The FPSA programme has identified significant new functionality necessary to meet major policy objectives by 2030. A systematic programme is required to deliver these functions as needed and without disruption.

**The Government, with its lead agencies, should now take high-level ownership** of the challenge of defining and delivering a system architecture that is fit for 2030 and beyond. It should put in place appropriate capacity and commission further work, including the next stages of the Future Power System Architecture programme, FPSA3 and FPSA4 as described below:

### 8.2 FPSA3: Develop and test FPSA concepts

FPSA3 would focus on development and initial implementation of *EFs*:

- Validation of the *EFs* structure and further operational design including accountabilities, decision-making and authority.
- Identification of the tools and capabilities needed to support implementation; these are expected to include advanced digital collaboration platforms suited to the complexity and size of required stakeholder engagement.
- Determination of how a prioritised sample of the *thirty-five* functions will be addressed through *EFs* using practical case studies and modelling of use cases/scenarios.
- Explore how the transition from current arrangements can be managed.

**Providing proof of concept**. FPSA3 will deliver proof of concept validation via a study of sufficient depth and strength to be able to drive initial deployment activities in further phases (a possible use case could be the functions needed to enable large-scale EV deployment). Any use case will require consideration of potential wider interactions, such as provision of system flexibility.

**Preparation for initial deployment**. FPSA3 would prepare for initial deployment in which demonstrations of increasing scale and complexity will be undertaken. Preparation will include defining, planning and building the convincing business case for progressing and attracting participants to demonstrators.

### 8.3 FPSA4: Implement an innovation programme

FPSA4 would be undertaken in parallel with FPSA3 and would comprise a portfolio of innovation projects that add value to the *EF* FPSA3 work. The projects will address requirements and opportunities in areas that are very likely to be needed to enable the future power system. The portfolio will be constructed to enable funding to be pursued through innovation competitions and other approaches. The nature of what fits into this portfolio will be drawn from analysis undertaken in FPSA2 and will focus on the Research, Development & Demonstration (RD&D) and Innovation topics required to enable the *thirty-five* FPSA functions. An initial list of innovation opportunities has been developed and is included in the Synthesis report.

### 8.4 FPSA programme: Build a sector leadership role

The lead organisations and stakeholder base also play a role in developing sector awareness and commitment. The next stages of the FPSA programme are designed to:

- Continue to build whole-industry consensus and shared vision for the transformation.
- Achieve a gradual transfer of ownership of the FPSA programme towards more industry finance and direct leadership, including building a clear picture of the roles of government and industry participants.
- Explore key transition pathways of different stakeholders and highlight the business change outcomes needed.
- Continue to deepen the collaboration between industry stakeholders, noting the important interactions with emerging government and regulatory policy decisions.

The Institution of Engineering and Technology

CATAPULT Energy Systems

# Future Power System Architecture Project 2

## Policy Briefing Paper

The full set of FPSA2 documentation including the Main Synthesis Report, Policy Briefing paper, individual Work Package Reports and project data files are available online via the Institution of Engineering and Technology and the Energy Systems Catapult.

www.**theiet**.org/fpsa

**es.catapult**.org.uk/fpsa

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