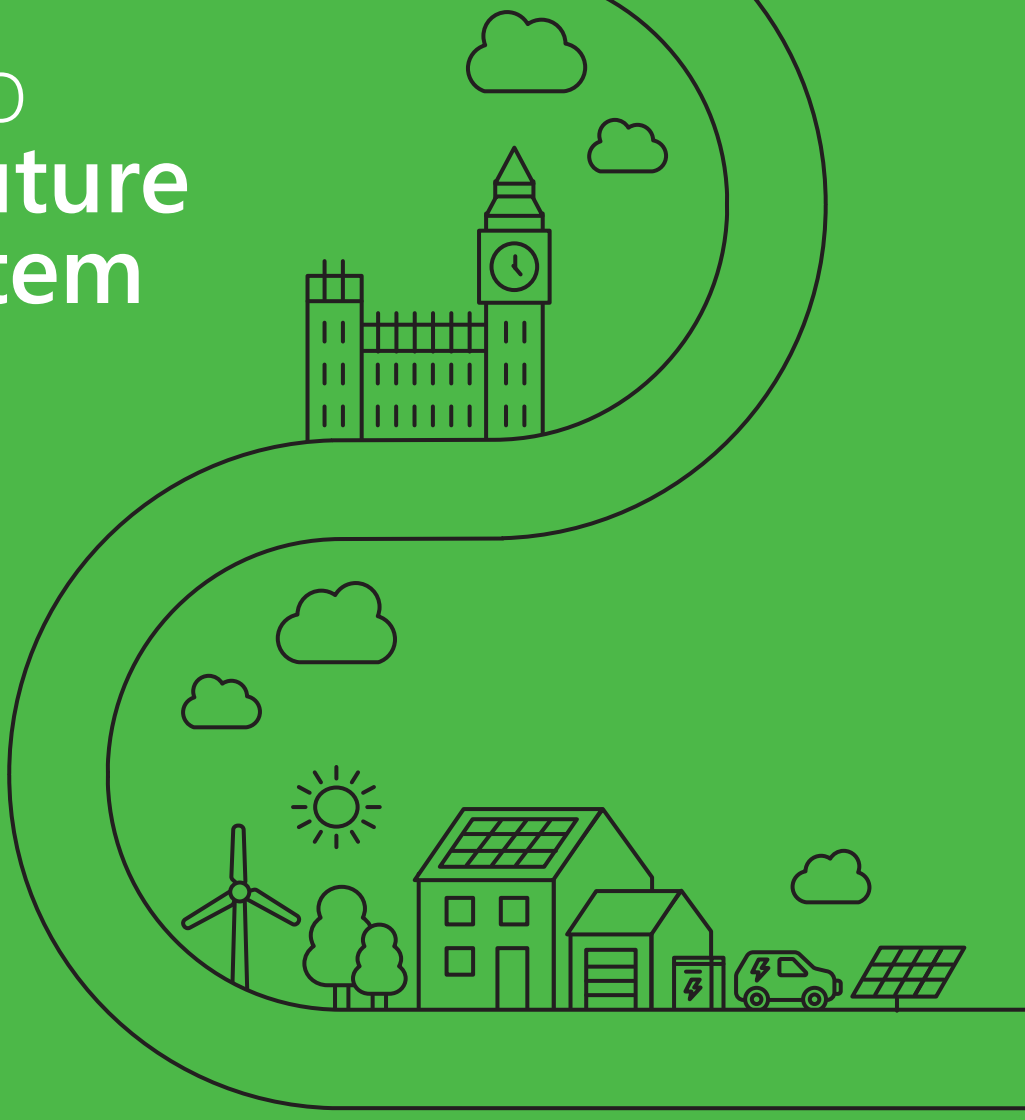
CATAPULT
Energy Systems

Fast Track to **Britain's Future Power System**



The Institution of Engineering and Technology

FUTURE POWER SYSTEM ARCHITECTURE

MEETING BRITAIN'S FUTURE POWER SYSTEM CHALLENGES

Executive Summary

The Future Power System Architecture Programme – redefining Britain's power system, encouraging innovation and accelerating change.

The world of energy is changing before our eyes. The dynamic transformation of electricity is well under way. New assets, new services, new risks and most importantly new demands from customers are all shaping a very different set of opportunities and challenges for the sector.

We need to respond by recognising that a business-as-usual approach will not deliver a power system that meets the future desires of customers or the ambitions of Government.

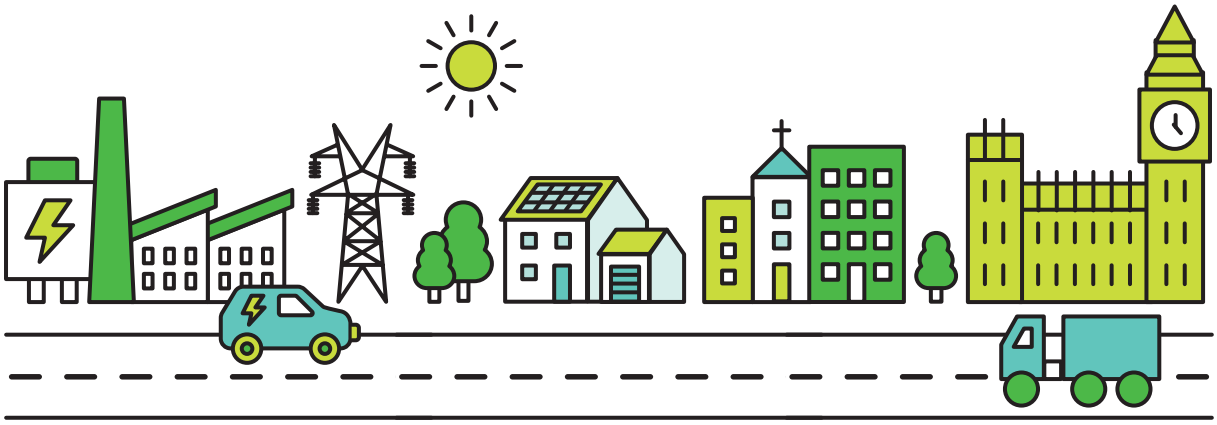
The Future Power System Architecture programme (FPSA) aims to ensure that these exciting new developments are embraced, that momentum is not lost and that the power system, as it is shaped today, does not stand in the way of a better future.

Fresh thinking is required to address the changing technical, commercial and market dimensions that all need to be considered together. The FPSA programme has initially considered the power system and its touch points with other vectors as part of its Whole System approach. The definition and the boundaries of the power system need to be reimagined. They must encompass homes and businesses and ensure that the traditional electricity industry boundaries are not barriers to innovation.

In addition to promoting Whole System thinking, the FPSA programme has identified a new approach to facilitating change and its governance. This will enable faster, more flexible change, delivering a more customer-focused electricity sector. We recognise that today's change and governance arrangements present serious barriers to exploiting new opportunities. They no longer align with the character, dynamism and nature of the challenges ahead.

The FPSA's proposals will break down unhelpful boundaries, reduce bottlenecks and speed up change. They will make governance more open and encourage new entrants with new skills to engage. Without fundamentally reshaping the governance of the system, we will struggle to deliver necessary changes in a timely way. New services will be stifled, costs increased, and current practices allowed to delay the dynamic transformation now emerging.

The FPSA programme has already made a material impact within the electricity sector, which now has a range of initiatives and projects underway that are broadly aligned with its thinking and which can be used to progress, test and demonstrate it. Going forward, the FPSA will seek to work with the Department for Business, Energy & Industrial Strategy (BEIS), Ofgem and a broad community of stakeholders to achieve its Whole System vision.



Introduction

The Future Power System Architecture programme – delivered by an independent, expert body working with stakeholders to facilitate energy system transformation.

Fundamental goals of the transformation:

- **Technically** fit for purpose
- **Unlocking** innovation at scale
- **Enabling best value** for customers
- **Adaptable** to ongoing change

The Future Power System Architecture programme (FPSA) is a collaboration between The Energy Systems Catapult (ESC) and The Institution of Engineering and Technology (IET). It was established in 2015 to take forward the IET's Power Network Joint Vision (PNJV) thinking. The work has been sponsored by Government and Innovate UK. The FPSA programme has brought together extensive expertise and experience, combining technical, commercial, regulatory, digital and customer perspectives. The position of the IET and ESC in the sector assures impartiality of approach and recommendations.

The FPSA programme's initial task was to identify the functionality that Britain's power system will need to support the wider energy transformation. This published work[1] highlighted that much of the new functionality will not be confined within traditional ownership boundaries; it will be truly Whole System in nature and will require technical/commercial coordination across ownership and licence boundaries. As this coordination is key to reliable and secure operation, it must be accompanied by clear accountabilities and ongoing oversight.

Subsequently, the programme investigated the barriers to implementation[2] and developed an innovative option for a new change and governance approach, capable of delivering the new functionalities in an agile, holistic and inclusive way.

The PNJV and FPSA programmes have already made a material impact within the electricity sector. Many of the Whole System issues identified in the FPSA programme's first reports are also the concerns of National Grid expressed through its System Operability Framework. The FPSA's Whole System thinking and its insight into the nature and scale of change required by 2030 takes its place with other initiatives with shared goals and objectives. The Open Networks project at the ENA is a notable example as is the work now actively underway in Ofgem addressing future price controls.

A key aspect of the FPSA programme's approach is that it does not dictate technical or market solutions. Rather, it assists stakeholders to engage and develop their own solutions in ways that meet their needs and are robust for the future, using principles that ensure Whole System integration.

Positive Outcomes Ahead

The transformation of our energy systems to meet our environmental goals presents many opportunities. It is a priority to ensure that change happens in a timely and seamless way and delivers real value to customers.

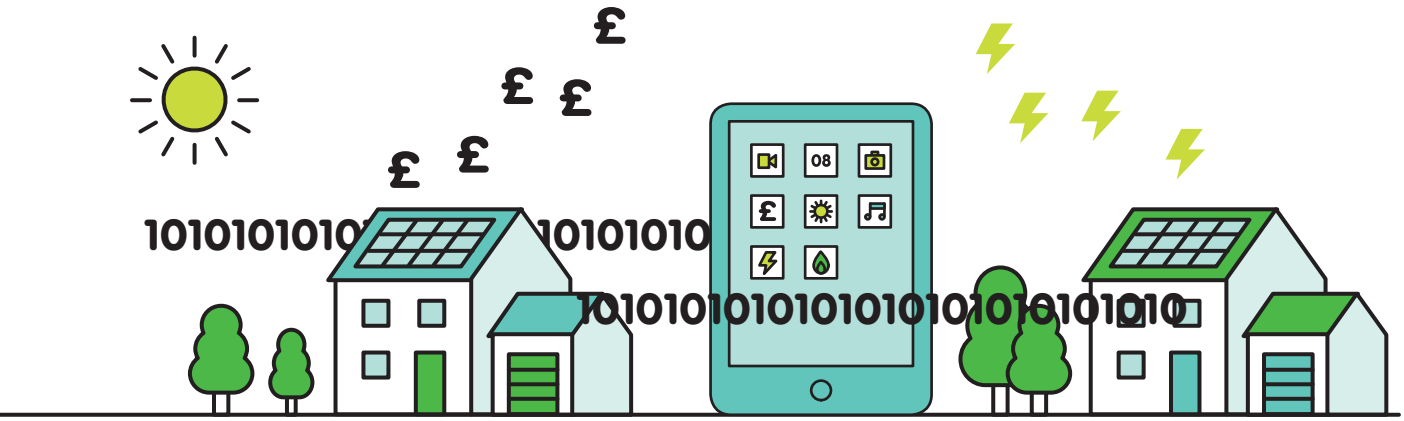
For decades, customers have had a very simple relationship with their energy suppliers, usually large utility companies. They have used energy as it was needed with most paying for it under a simple pricing model that disregards the time of use. However, the future will be very different.

There will be new opportunities for customers to benefit from playing an active part in the electricity system. Businesses, communities and households will increasingly be producing their own electricity. Also, the storage of electricity will become practical at business and domestic scale, either in dedicated storage devices or using the batteries of electric vehicles. Customers will be able to choose to become energy self-sufficient and reduce their energy costs by offering to provide services to others, including the owners of the electricity networks.

A good example of such a service is for customers to be flexible about when they buy electricity from the grid or sell it back, because the time at which electricity is consumed is becoming much more important. As electric vehicles and heating increase the demand for electricity, customers should be able to schedule their consumption and in some cases their export of electricity. This will offer a valuable way of reducing the amount of new infrastructure required in our electricity system, ensuring supply security and enabling customers to access the best prices.

Services like this can be easily automated. Technologies that we have become so familiar with to seamlessly access apps through our mobile phones and tablets can be applied to managing this safely, simply and securely. In the future, artificial intelligence will further enhance these experiences.

New services like this need to be reliable, simple and attractive to use. This requires significant changes to be made to the rules and standards that govern the way the electricity system is planned and operated, both technically and commercially. These changes should be invisible to the customer, but they must happen in a timely and coherent way. The FPSA's Whole System thinking supports stakeholders in achieving the desired outcomes with the proposed approach to governance and change providing the structure that can help ensure successful implementation.



The Power System is Changing Fundamentally

The power system was one of the most complex achievements of the twentieth century. But it is now becoming even more complex. In the near future, it will have millions of active components, producing, consuming and storing electricity. Whole System coordination is fundamental to managing this complexity safely, securely and unobtrusively to customers.

The transformation of Britain's power system is well under way, driven by decarbonisation, decentralisation and more opportunities for customer engagement, all underpinned by digital technologies. The decentralisation trend is set to continue. One of National Grid's Future Energy Scenarios[3] shows the percentage of peak demand supplied from the transmission system falling from 85% in 2017 to 61% in 2030.

An important consequence of this is the new challenge it brings for controlling the power system. In the past, National Grid, as the System Operator, could balance supply and demand for the entire GB power system using a relatively small number of large generators. In the future, there will be millions of small electricity generators and smart devices that are 'invisible' to National Grid. Customers will increasingly take more control of their electricity supply. This is a fundamental change that brings many new Whole System challenges, with risks to security of supply that must be managed in a different way.

The term Whole System is now widely used but with many subtly different meanings, an issue that Ofgem has raised in its recent RIIO2 consultations. The term, and its implications, must be clearly defined and understood. The FPSA programme's definition of the term Whole System has a strong customer perspective; it addresses the coordination of devices and systems on both sides of the customer's meter, fully recognising the interaction between the power system and its users.

The Whole System's architecture must evolve to recognise the new interfaces created by the demand for multi-party interactions. To facilitate this, the sector's change and governance arrangements will need to reach across the customer's meter. They will need to be much more flexible and adaptive and ensure there is clear accountability in regard to on-going resilience of the system and its security of service for all users. It will need to be responsive to the changes to physical energy flows, data flows and commercial value flows. To date, changes to functionality have been governed by codes and regulations set in strictly defined silos of responsibility; an approach that is widely recognised as no longer being appropriate and which is becoming increasingly unhelpful.

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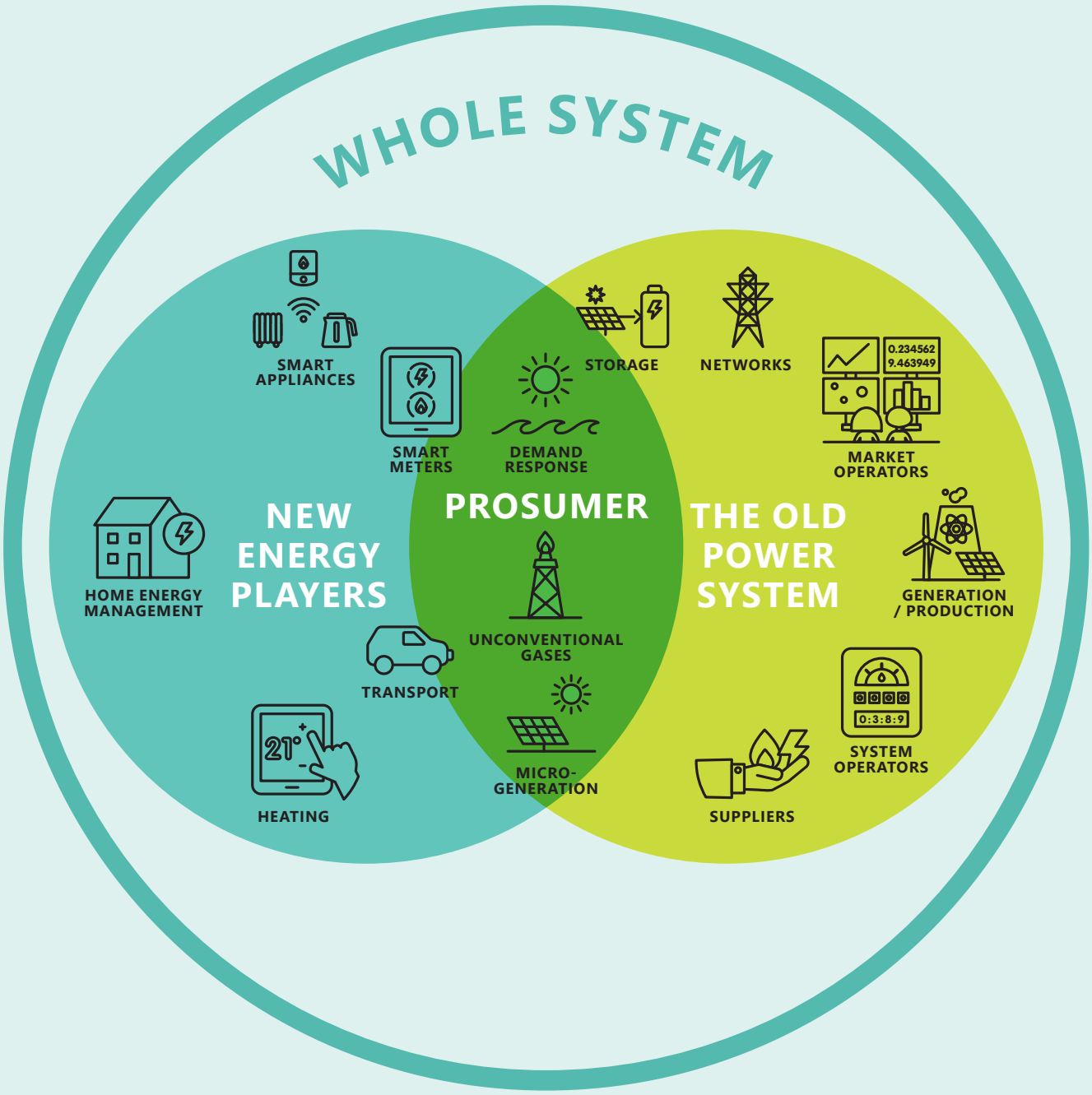

Definition

Whole System includes:

- The physical power system equipment;
- Consumers and the equipment they control;
- The touch points with other energy vectors e.g. gas, heat and transport;
- Associated communications, data and digital platforms;
- Power system regulations and market rules;
- Commercial transactions, business models and contracts.

New Architecture

The Whole System architecture will have to recognise the new interfaces and procedures necessary to allow multi-party interactions. Its governance of change will need to be much more flexible and adaptive while ensuring clear accountabilities for cross-boundary coordination and the resilience of the system and security of service for all users.

New Considerations

The power sector is being influenced by an increasing range of external social, technological, economic and political factors. It will need to encompass changes to physical energy flows, data flows and commercial value flows that to date have been governed by codes and regulations set in strictly defined silos.

Coherent Whole System change is required to deliver value to customers

Innovation on the customers' side of the meter will be a driving force for enhanced services and better value – but we need to unlock it.

The future that the FPSA programme has investigated will present many new opportunities to customers.

Imagine that you have bought your first electric vehicle. The equipment to charge it has been installed but, just like choosing a provider for your mobile phone, you will need to decide how you will purchase electricity for your electric vehicle.

You should have different options and much greater flexibility than we see today. You could decide to simply minimise the cost of recharging the vehicle. Alternatively, you might agree to allow the vehicle's battery to be used to provide services to a company that owns your local network, the national grid or an energy services provider in exchange for a lower tariff, or even a lower lease cost for the vehicle. Or, your priority might be to have the vehicle fully charged and ready for use in the shortest possible time, regardless of the cost.

The FPSA programme has explored how these services could be delivered from a technical perspective. It has also highlighted that, depending on your preferences, you will need access to new markets for energy and services that aren't available today. Innovative new companies with new business models are already entering the market to provide these kinds of services. They will also be able to help integrate electric heating and cooling into your home energy network or work with community energy schemes to allow peer-to-peer trading and other new services.

This all requires change in the way the power system operates. The FPSA programme identified no fewer than thirty-five new or significantly enhanced functions that need to be implemented to transform the electricity system. These changes require Whole System solutions driven by the needs of those that use the power system, either as producers, consumers or both. Without these, there is a real risk of very high additional costs, or that the security of supply that we have taken for granted for decades could be at risk.

The FPSA programme identified no fewer than thirty-five new or significantly enhanced functions that need to be implemented to transform the electricity system.


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The FPSA programme has identified barriers to these new services reaching customers

Today's change and governance arrangements are uncoordinated and cause bottlenecks. They present barriers to new entrants and cannot deliver the changes needed in a timely way.

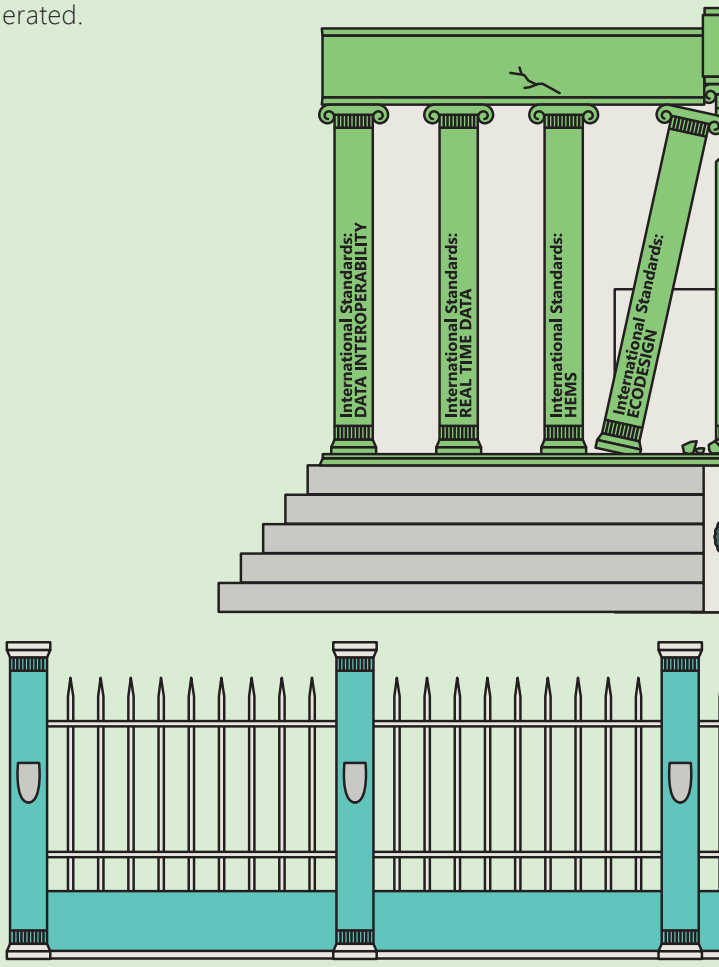
Today's arrangements were designed to mirror the structure of the industry that emerged from privatisation. They have served us well but are becoming increasingly out of step with the type and extent of the changes that are now becoming necessary and urgent.

The changes and innovation necessary to deliver the functionality needed in the future are significant. Incremental changes to the existing arrangements will not suffice.The record shows that the existing change governance arrangements are unable to deliver in a timely manner and so are unfit for purpose in today's much faster, more uncertain and increasingly digital world.

For example, change in the electricity sector is currently governed by licence modifications, allied with eight codes[4] and five code administrators[5]. Each code has a specific remit, whether it be the way the electricity distribution networks operate, or the processes established between electricity suppliers and distribution companies to enable customers to switch suppliers. There are no overarching formal coordination mechanisms between these bodies and so Whole System solutions to complex challenges are impracticable. This has been recognised by many and was also raised in the Competition and Markets Authority's review of sector governance published in June 2016[6]. However, little progress has been or is being made to address this.

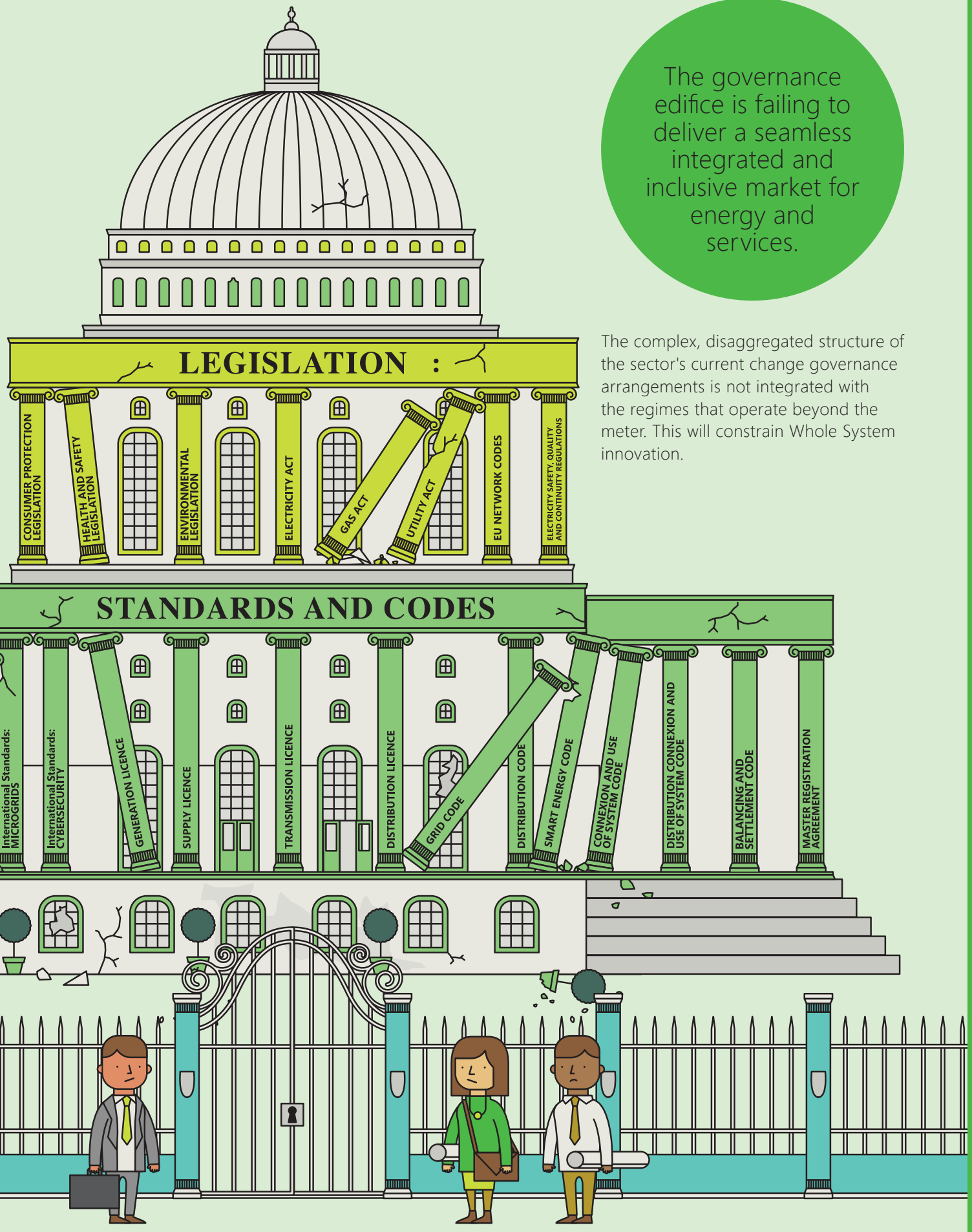
The process of delivering market-wide half-hourly settlement using smart meters offers a good example of how long current change processes take. This work started in April 2014. Ofgem's decision as to how this will be implemented is not expected until the second half of 2019[7].

The FPSA programme believes that unless the current change and governance arrangements are radically reformed and extended to include businesses, communities and households, many of these opportunities will be wasted and value lost. More specifically, the thirty-five power system functions that have been identified by the FPSA programme's work will not be implemented in a timely manner. Ofgem has commenced a programme of governance reform and the work of the FPSA programme suggests this should be accelerated.



The governance edifice is failing to deliver a seamless integrated and inclusive market for energy and services.

The complex, disaggregated structure of the sector's current change governance arrangements is not integrated with the regimes that operate beyond the meter. This will constrain Whole System innovation.



This graphic is of course a caricature but it represents the perceptions of many in the sector, especially those 'outside the gates'.

The FPSA programme has proposals to respond to the challenge

The FPSA programme has developed proposals for a new, agile approach to change. It adopts Whole System principles and is designed to be driven by the needs of those that use the power system.

The FPSA programme has developed proposals to deliver the required future functionality in an agile, flexible and inclusive way, using a new change and governance approach to address identified barriers. These proposals are founded on a clear set of principles:

- To facilitate decarbonisation, support competition and champion customer interest;
- To do this in ways that involve all stakeholders, enhance coordination and recognise synergies in the needs of customers;
- To operate transparently, encourage engagement, promote innovation and harmonise technical and commercial requirements;
- To remove barriers to entry and encourage innovation and opportunity;
- Perhaps most importantly, to be consistent with the imperative of ensuring Whole System technical/commercial coordination and for change to be driven by the needs of those who use the power system.

At the heart of these proposals is a concept termed Enabling Frameworks. An Enabling Framework is a process of facilitated stakeholder engagement that allows the capabilities of the power system to be enhanced or extended to meet specific user or system needs. This could be a technical capability, a market mechanism or or regulatory change. Very often, it is a combination of all three. Enabling Frameworks are aligned with specific Whole System functionality. For example, an Enabling Framework might address the FPSA programme's functions that are necessary to allow electric vehicles and smart appliances to react to

real time prices. Several Enabling Frameworks, each addressing a specific functional requirement, may co-exist at any one time. Some may operate on a continual basis to address on-going change. The Enabling Frameworks are 'joined up' and coordinated by an Enablement Organisation. This organisation has a clear view of the technical and commercial architecture of the Whole System and is responsible for facilitating coordinated change by all those involved. It assures the operation of the Enabling Frameworks and addresses issues that might be common amongst them.

Working together, the Enabling Frameworks and the Enablement Organisation empower any stakeholder (whether existing or a new entrant) to understand, propose and pursue changes to the way the Whole System works. The FPSA programme believes that this approach should, in time, also be extended to other energy vectors.

The new governance delivers a seamless integrated market for energy and energy services for and between all customers and stakeholders.

The FPSA programme offers an alternative for consideration: a Whole System approach to change governance that is in tune with today's open, agile and stakeholder driven ways of working. It will encourage fresh thinking, innovation and positive outcomes for customers.

The FPSA programme's proposals have great potential to improve today's unsatisfactory situation

The FPSA programme's option for a new approach to change and governance is more coherent, transparent and inclusive and has the potential to deliver Whole System change and accountability faster than today's arrangements.

The FPSA programme has produced an evidence base to demonstrate the need for change and its proposals offer significant benefits compared with today's change and governance arrangements. The proposals are summarised here:

- Adopt a Whole System approach, extending into businesses, communities and households;
- Provide coordination in place of the current arrangements' siloed code bodies;
- Seek engagement with all stakeholders to ensure change is driven by the users of the power system and is less dominated by today's incumbents;
- Apply agile techniques facilitated by digital collaboration tools to allow more stakeholder engagement and deliver change more quickly;
- Overcome the barriers that current practices create between those pursuing technical change and those dealing with commercial or market issues;
- Connect power sector standards with wider industrial and digital standards bodies.

Returning to the example of electric vehicles, allowing their energy storage capability to provide services to the power system in a non-coordinated manner has potential for disruptive technical impacts on the local distribution network and the national power system. In addition, market mechanisms will be required to trade the services securely. Electric vehicles will present many challenges of this kind, which is why the Government has set up a task force to address user needs and the limitations of the power system. Enabling Frameworks would have the capability to take on challenges arising from the deployment of electric vehicles and other new technologies. This could avoid ad hoc solutions being put in place in a reactive way, which would be slow and would tend to increase costs. Instead, stakeholders will be engaged in a continuous process of learning and change supported by the Enablement Organisation. Accountabilities can be clearly allocated to the most appropriate parties.

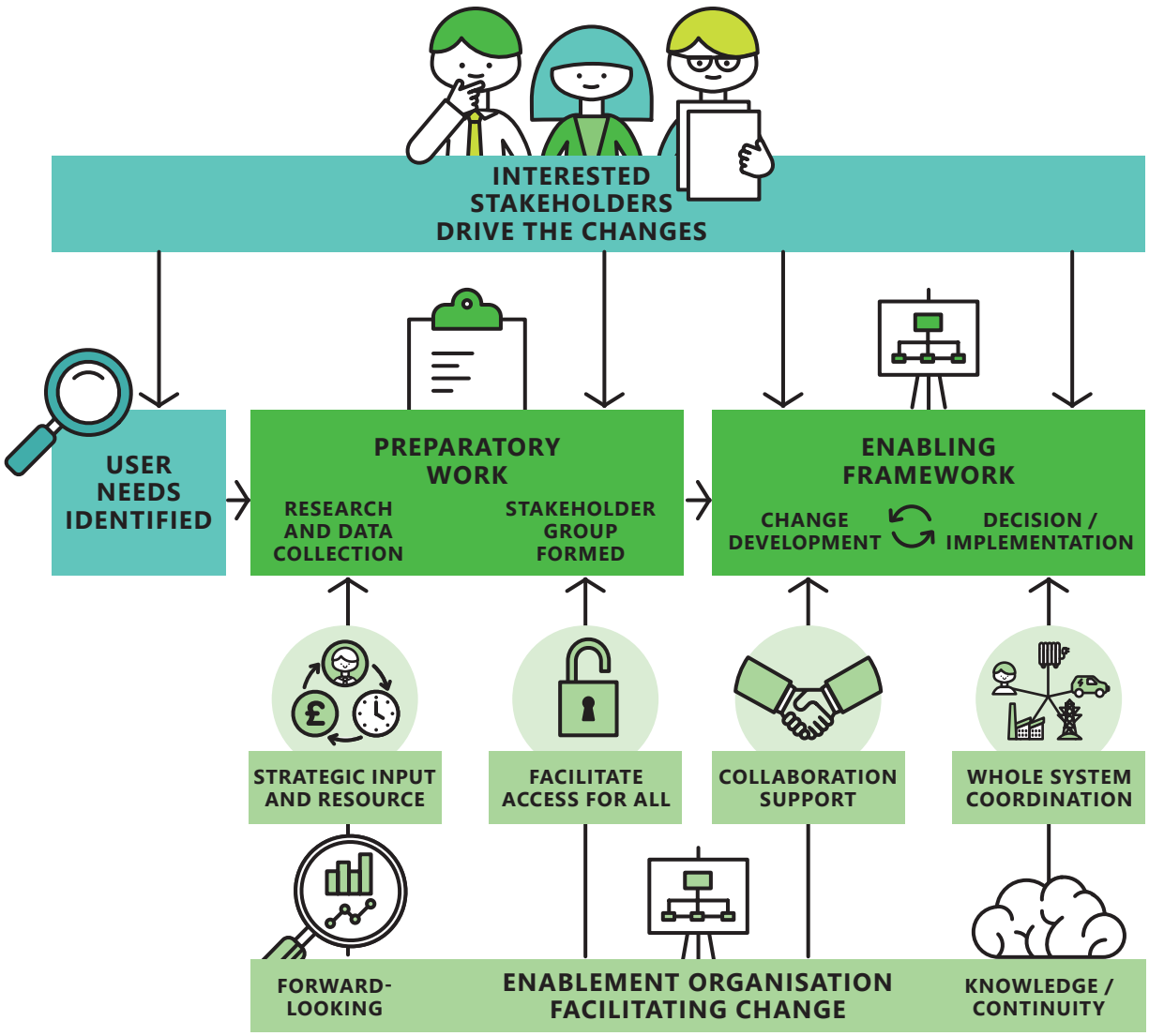
Without a new approach of this kind, the risk of unintended and unwelcome outcomes will be significantly increased. Customers may well find that the new services they require are not available, costs increase unnecessarily as emergent problems are resolved using traditional means and, even more importantly, the security and resilience of the power system they rely on is compromised.

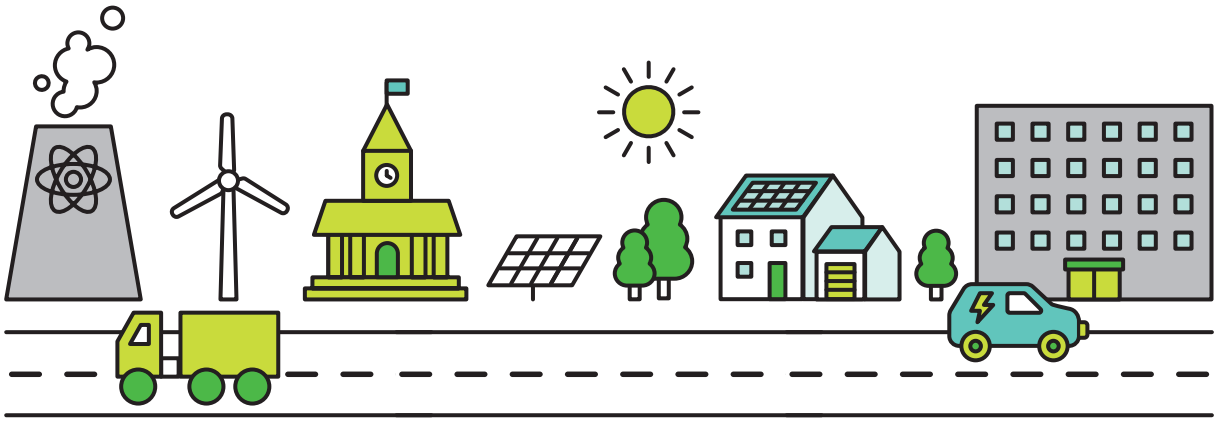
Enabling Frameworks would have the capability to take on challenges arising from the deployment of electric vehicles and other new technologies.

A New Operating Approach
How It Works

Each EF covers all aspects of the change:
technical, commercial, digital etc.

Each EF operates on an on-going basis
where changes are fed back into future thinking.





The next steps for making progress?

The FPSA programme proposes to continue to provide independent, expert analysis and recommendations and will seek to work with BEIS, Ofgem and a broad community of stakeholders to help formulate the improvements to change governance and cross-boundary accountabilities that will enable the delivery of a national Whole System energy vision.

Nationally, we have a clear goal to decarbonise our energy supplies and make them secure and affordable. This requires the transformation of Britain's energy systems and the power system is leading the way. Considerable progress is being made.

Many parties are already working to deliver the future power system that can provide new services and benefits to customers through initiatives such as: the ENA's Open Networks programme, the Smart Systems Forum, Ofgem's innovation incentives, and the Industrial Strategy (Prospering from the Energy Revolution challenge) amongst others. More significantly, innovators and new businesses are taking a fresh look at the energy sector and are bringing innovative ideas that disrupt the status quo. Many are calling for governance change.

It is vital that the approach to change and change governance can efficiently facilitate the transformation that is required. Accountabilities across boundaries must be clarified. Whole System thinking is essential if we are to exploit new opportunities to deliver better services and added value to customers.

The FPSA programme recommends:

- Working to establish an industry-wide consensus on essential Whole System coordination and the mechanisms to achieve it;
- Continuing to promote the need for the FPSA programme's thirty-five functions and act as a catalyst for their urgent development and delivery;
- Working with BEIS, Ofgem and other stakeholders, and through energy sector initiatives, to help realise a more agile change and governance approach for the future power system;
- Adhering to the principle that a new governance approach must be accessible, flexible and fit for purpose so that increasingly dynamic change can be coordinated effectively;
- Considering Enabling Frameworks as a basis to be explored for this approach; actively seeking opportunities to work with others to evaluate their merits and clarify how they could be integrated within overall sector governance.

The FPSA programme is encouraged that issues it has championed are appearing in sector initiatives, but essential elements remain to be resolved.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Supporting Information

The FPSA programme – the story so far – innovation, influence and impact.

The FPSA programme was born out of the work carried out by the IET's Power Network Joint Vision (PNJV) project. The PNJV published "Handling a Shock to the System" in December 2013[8]. This report highlighted the technical challenges that the power system faced and proposed a more coordinated way to address them[9]. This work raised important issues for many in Government and the power sector.

In 2015, BEIS (at that time the Department for Energy and Climate Change) provided funding to establish the FPSA programme as a collaboration between the IET and the Energy Systems Catapult and build on the PNJV's work. Its initial task was to explore the new and enhanced functionality that would be needed in the power system in the near future. This led to the publication of the FPSA programme's Phase 1 reports[1] in July 2016. This work identified thirty-five new or enhanced whole power system functions.

Following the Phase 1 work, the FPSA programme moved on to explore the ways in which the proposed new functionality could be implemented including identification and analysis of the barriers to implementation. This led to the publication in June 2017 of its Phase 2 reports. A conclusion from these reports[2] was that the current change and governance arrangements were not fit for purpose. The FPSA programme outlined a new approach as a model for reform in Phase 2. This approach has been explored further in Phase 3 of the programme and this work will be published towards the end of 2018.

Many of the Whole System issues identified in the FPSA programme's first reports are also the concerns of National Grid, expressed through its System Operability Framework. The FPSA programme's Whole System thinking and its insight into the nature and scale of change required by 2030 takes its place with other initiatives with shared goals and objectives. The Open Networks project at the ENA is a notable example as is the work now actively underway in Ofgem addressing RIIO2.

Also, in 2018 BEIS launched its Industrial Strategy Challenge Fund. The work of the FPSA programme was referenced directly in the competition guidance for "Smart local energy systems; demonstrators and designs". There is potential for the FPSA programme to work with the winning projects to demonstrate its Whole System vision and approach to change governance.

Since the original PNJV work the sector conversation has changed substantially. Many of the requirements called out in PNJV have happened, for example, through advances in electric vehicle range and penetration. Much of the thinking that was controversial then is now mainstream and there is considerable activity in the UK and more widely to deepen understanding of the issues involved and to demonstrate potential solutions.

The role of the FPSA programme is now changing, from progressively initiating more near-to-market programmes of activity, to helping shape, influence and support the work of others.

However, some vital changes are not yet embedded in mainstream thinking. The most significant of these are:

- Considering the system as a whole, with those parts in the hands of customers being as significant in the analysis as those in the hands of utility companies and large generators;
- Embedding a forward looking capability for change into the organisational infrastructure for change and its management;
- The broad concept of an enablement organisation, an entity or organisation charged with ensuring coordination and cross-boundary accountabilities for an ever more complex system. The FPSA programme, in the professional view of its lead members, believes these are essentials for the future British energy system and will continue to make the case for them and wishes to work (along with its partner organisations The Energy Systems Catapult and The IET) with all parts of the industry to ensure their progress.

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2. The Future Power System Architecture Project – Phase 2
   - https://www.theiet.org/sectors/energy/resources/fpsa/fpsa-future-system-challenges.cfm
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5. The five Code administrators are: Electralink, Elexon, Energy Networks Association, Gemserv and National Grid.
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Energy Systems Catapult supports innovators in unleashing opportunities for the transition to a clean, intelligent energy system.

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