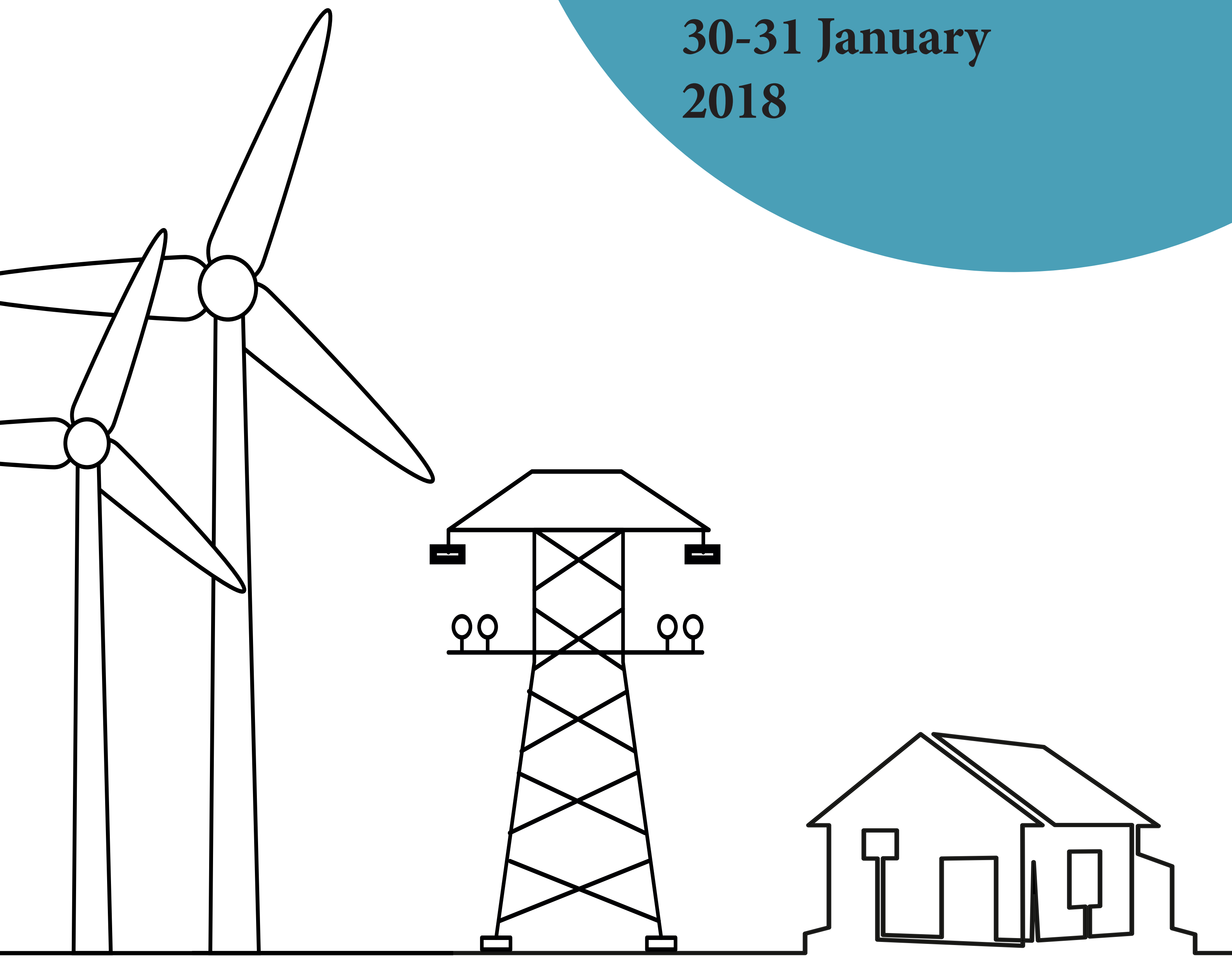
Smart Grids

UK-US smart grid commercialisation summit

University of Cambridge
Maxwell Centre
30-31 January 2018



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Foreign & Commonwealth Office

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DELTA Energy & Environment

UNIVERSITY OF CAMBRIDGE

Energy @Cambridge

Executive summary

Digitalisation, decentralisation and decarbonisation of energy is resulting in a rapid transition in the energy system.

The future system will need to be more flexible, customer centric, and dynamic with a wider range of participants influencing and obtaining value from energy generation, distribution and sales / services. Smart grids will be at the centre of this transition, providing the platform for managing and distributing energy.

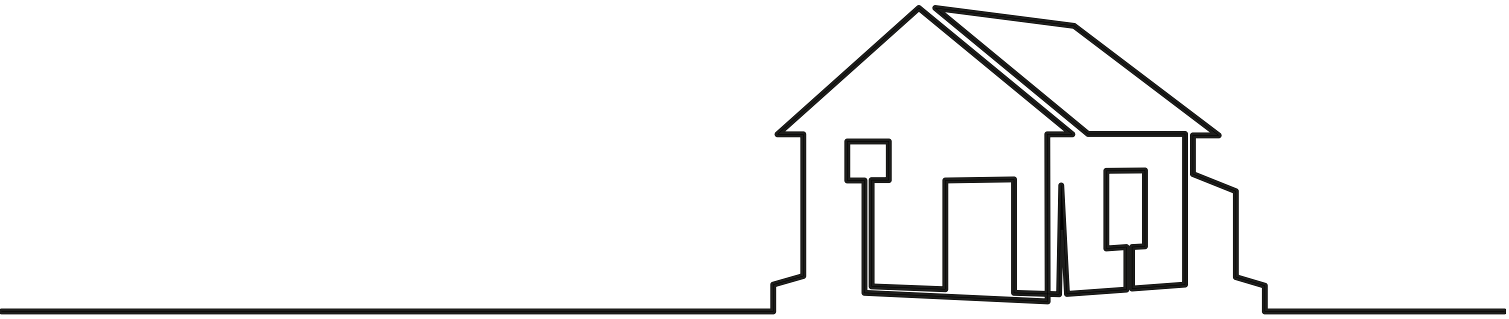
The 2018 UK-US Smart Grid Commercialisation Summit (30th – 31st January) hosted jointly by Cambridge Cleantech and the University of Cambridge in the UK and funded by the UK Foreign and Commonwealth Office aimed to explore some of the common themes behind smart grids in the UK and US by bringing together a number of key actors including policy makers, regulators, network operators, innovators and strategists.

The Summit aimed to develop a common understanding, identifying where the countries can learn from and support each other, and further develop cross-Atlantic relationships to their mutual benefit.

Through the deep discussions and presentations at the Summit, a range of challenges and opportunities were identified which are common to both the UK and US, alongside insight into case studies and trials of smart grid systems.

Areas were identified where each country could learn from the other, in particular with the UK experiencing the energy system transition challenges earlier than the US, and the US providing deep insight into different market and regulatory approaches.

This report aims to highlight the key themes that emerged throughout the two-day Summit and encourage the continued relationship building and knowledge exchange.



1 Introduction

The UK Foreign & Commonwealth Office funded a 2018 UK-US Smart Grid Commercialisation Summit[1] to further the trans-Atlantic sharing of knowledge. This followed on from the success of the 2017 UK – US Grid Modernization Workshop[2], which was held at the request of the UK Science and Innovation Network[3].

Building on the 2017 Workshop, the 2018 Summit brought together experts from internationally recognised UK and US utilities, technology companies, emerging organisations and universities (a list of attendees is provided in the appendix). The Summit was held at the University of Cambridge Maxwell Centre, UK.

Energy systems are currently undergoing a radical transition from the existing passive top-down systems with predictable loads and supplies. The rapid increase in intermittent low carbon distributed generation, phasing out of more conventional fossil supplies, and more dynamic customer loads (including electric vehicles) and increased electrification is presenting both opportunities alongside challenges to the

1 Referred to simply as 'the 2018 Summit' or 'the Summit' for the rest of this report
2 https://www.nrel.gov/docs/fy17osti/68733.pdf
3 https://www.gov.uk/world/organisations/uk-science-and-innovation-network

systems. Smart grids aim to capture these new opportunities and values alongside helping overcome the challenges by enabling increased automation and flexibility in the energy system through dynamic operation enabled by digitisation and communications, and integration of customers into the system operation and optimisation.

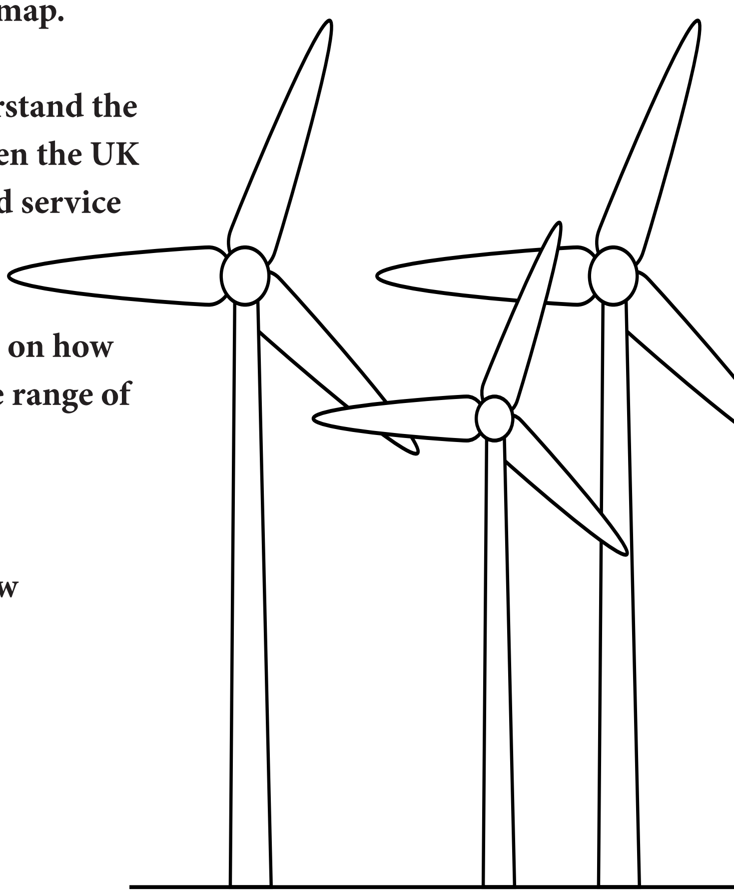
The Summit's goals and objectives were to:

> **Hold conversations that cross the Atlantic divide and spur new ideas and opportunities for the smart energy transition, and contribute to the UK / US development roadmap.**

> **Facilitate discussions among key players to understand the differing policy incentives and regulations between the UK and US energy systems, and how new product and service technologies will impact the energy system.**

> **Discuss and brainstorm with network companies on how their world is changing and will impact on a wide range of stakeholders.**

> **Conduct collaborative development workshops with flexible energy market players to explore how they will create value in the future and how other energy sector players will need to respond.**



Similarly to the 2017 Workshop, the 2018 Summit was designed to focus not only on the passive sharing of information but also to provide a platform for active discussions and engagement to take place. Some of the most interesting ideas and insights emerged as a result of the post-presentation questions and panel discussions.

This report aims to highlight some of the similarities and differences between the UK and US smart grid landscape as well as challenges facing the smart grid revolution. It also examines how the varied technical and regulatory challenges are likely to evolve in the short-, medium- and long-term. It concludes by highlighting the key themes covered, as well as recommendations for future UK-US smart grid summits.

The Summit organisers encourage Summit participants and readers of this report to be leaders in taking the next steps, seizing opportunities identified and neutralising challenges. Summit participants should use the discussions that took place at the Summit as a platform to initiate collaborations and engage with one another.

The Summit organisers encourage Summit participants and readers of this report to be leaders in taking the next steps.

Chapter 2

UK versus US smart grid landscape

There are many similarities between the UK and US grids and energy systems but also, of course, some key differences. These provide strong opportunities for cross border learning to take place to promote innovation and knowledge sharing.

2.1
Similar challenges and opportunities facing both the UK and the US

The rapid pace of change facing the energy sector and associated challenges is driving the development of smart grids in the UK and US. According to some industry veterans at the Summit, the "last five years have been the most exciting of our lives." Common challenges identified during the Summit included:

> Widespread and rapid electrification, in particular adoption of electric vehicles and their associated increased loads on distribution networks.
> Smart meter rollout across the UK and across many US states.
> Distributed generation growth, in particular intermittent renewables deployment. Increasing numbers of small domestic customers are generating, consuming as well as exporting their own electricity (primarily rooftop solar PV).
> Energy storage is reducing in cost and more widely deployed, especially at the distribution level.
> Distribution network operators are trantisioning into system operators due to the increasing need to manage and balance

demand and generation resources on the distribution networks, whilst supporting the transmission systems.

- Both the UK and the US have large amounts of aging primary grid infrastructure that requires replacing in the near term.
- US infrastructure and markets are not fully interconnected or integrated, and parts of the US system are islanded in a similar manner to the UK.

2.2
Differences between the UK and US

Many differences between the UK and US also exist arising from both the physical environment and systems, and also varying regulatory systems and policy landscape. The differences can make it more difficult to draw parallels, but also provide opportunities for knowledge sharing. Key factors include:

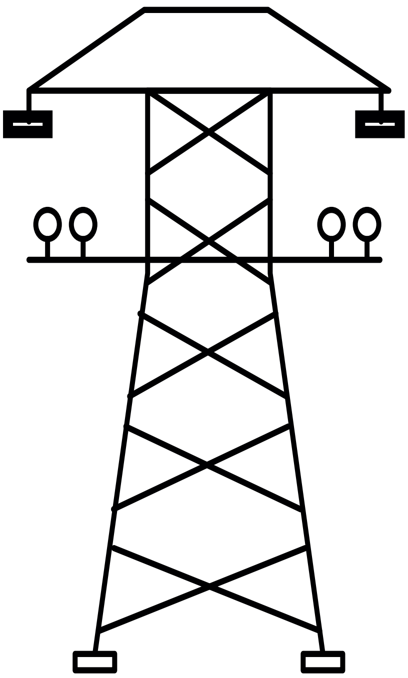
- The varying regulatory landscape in the US, resulting in many different outcomes in terms of approach to the energy transition.
- A perception that the US has a more direct implementation approach for smart grid deployment, whereas the UK takes an incremental approach based around smaller scale trials, and feasibility studies.
- The UK electricity system is more advanced in decarbonisation than the US system. For example, on 21 April 2017 the UK had its first 24-hour coal-free period since 1882.
- In the UK, the government and central regulator is the primary innovation driver, whereas in the US there is less dependence on government input.
- The challenges facing the UK are generally nearer term than in the US due to more ambitious decarbonisation targets as well as a higher focus on social equality.
- The uptake and level of expertise in each country varies in terms of advancement in different technical areas.

On 21 April 2017 the UK had its first 24-hour coal-free period since 1882.

Chapter 3

Challenges facing the smart grid landscape

This section identifies the major challenges facing the UK and the US in the smart grid space drawing on the presentations and discussions that took place during the course of the two-day Summit.



3.1
Managing uncertainty in a period of rapid change

A common theme identified throughout the two day Summit was how smart grid stakeholders are to manage uncertainty in a period of rapid and often uncertain change. The key drivers identified were:

> **A lack of consumer trust in smart grid technology.** Most customers do not see the direct value or benefit of smart grids. While the industry sees the necessity of developing smart grids from a reliability, environmental and cost savings perspective many end-use customers currently do not experience any of the 'pains' associated with the current legacy grid systems. The lack of consumer trust might be aggravated by the predicted rapid deployment of electric vehicles (EVs), which are to reach the millions in the UK and California by the mid-2020s. As the future operation of the energy system will require greater engagement with customers and access to customer data, the value of providing data and engaging will need to be clear to customers for their participation.

- **The government can and should only do so much.**
  Governments often lag behind in terms of keeping up with rapid technological advancements and industry needs. However, when governments do act there is also the risk of over-regulation stifling innovation. A careful balance is required where regulatory support can help de-risk and promote innovation without stifling and limiting options.

- **Gas and electricity grid funding, and innovation cycles are often out of sync.**
  A smarter energy system means greater interaction between energy vectors so that optimisation takes into account the synergies between different energy vectors. There needs to be coordination of innovation and funding activities across the different sectors to get out of the silo approach. The UK's network regulatory periods and associated innovation funding are different for gas and electricity which makes true cross vector thinking challenging.

- **Large-scale decentralisation of power generation.**
  The rapid decentralisation of power generation has led to many smaller generators being connected to the distribution network. This has led to reverse power flows (end-user to grid). Both the UK and US are moving from having fewer, larger generation assets to having many smaller distributed generation assets with no central visibility or control over how and when they generate. As more distributed generation assets are deployed, the uncertainty associated with their effects on power demand, and distribution and transmission grid, will increase.

> **Rapid deployment of microgrids.**
> In the wake of Hurricane Sandy, microgrids emerged as a more interesting and viable option to improve the resilience of the power system. The increased deployment of microgrids can be viewed as both an opportunity and a threat to traditional utilities. Microgrids may allow certain utilities to delay expensive network upgrades, but at the same time potentially reduce utility revenues and create other reverse-power flow issues.

3.2
Structure of energy system going from tree shaped system to a cellular system

Energy systems have historically been managed centrally, in a top-down manner, with small numbers of large central generators and system operators balancing supply and demand. With a significant rise in the number of smaller distributed generation sources, intermittent generation requiring storage and demand response, distribution networks increasingly need to be more actively managed, balancing supply and demand at a local level and using flexibility services with customers' loads. This results in a more cellular approach with a mix of both local control and optimisation combined with the more traditional central management.

The rising prominence of smaller distributed sources means some form of aggregation will be required to effectively control and obtain value from the energy system. The point was raised during the summit that large scale aggregation could ultimately result in a more centralised approach where commercial and operational decisions are made across a large portfolio, and some of the local and customer orientated values are lost. Some consolidation of distributed sources is inevitable and desirable to allow access to the energy system's values, but there may need to be controls on how aggregators operate and activate their portfolios so all stakeholders retain value in the system. This raises a broader question of how different stakeholders act and are allowed to act in a smart system where commercial interests could over-ride system and customer benefits. Safeguards or structures may be required so that monopolies don't form and innovators and customers can still obtain value.

The rising prominence of smaller distributed sources means some form of aggregation will be required.

3.3
Hardware and software challenges

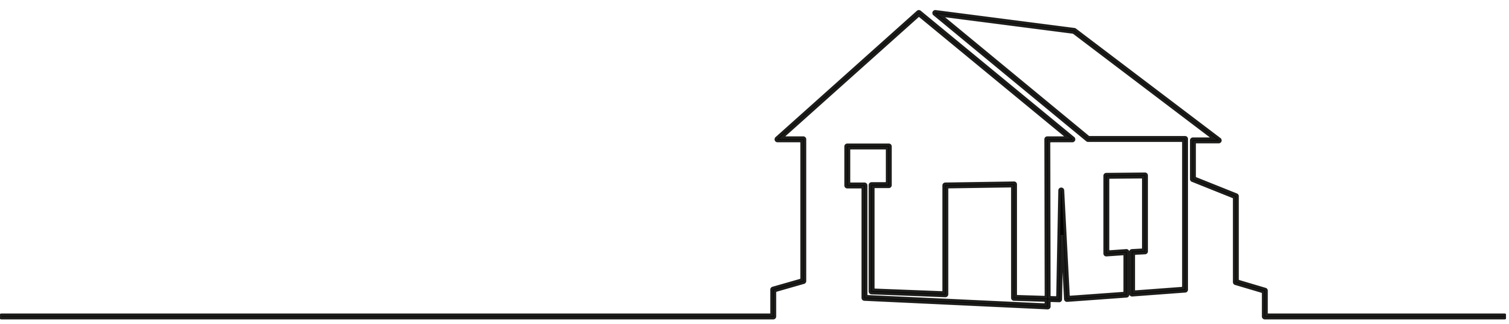
There are unique hardware and software challenges facing development of the smart grid. The underlying communications infrastructure of the smart grid needs be an order of magnitude more reliable than existing public communications infrastructure to ensure fast and reliable real time operability. This is a constraint that many governments and utilities are yet to fully acknowledge.

There are many established companies as well as incumbents producing technology and software in the smart grid space but no commonly accepted hardware or software communication protocols and standards. Given the large number of proprietary

technology vendors there is significant risk of technological lock-in for those purchasing smart grid related infrastructure that is currently delaying investment. Standards are required to unlock the investment for utilities and municipalities, support infrastructure innovation of new devices and operation regimes, and provide longer-term certainty.

Due to the complex multi-stakeholder nature of energy systems and smart grids, companies facilitating and promoting smart grid technologies are often uncertain where to focus their sales efforts in different markets. With many of the smart grid technologies and skills potentially emerging outside the energy sector (communications, etc.), there needs to be a clear set of pathways provided for innovators to use.

Companies facilitating and promoting smart grid technologies are often uncertain where to focus their sales.



Chapter 4

Factors influencing the smart grid outlook

There are a number of factors which may provide both challenges and opportunities.

4.1
Further development of policy and framework space

The UK government has directly or indirectly funded numerous studies looking into the future trajectory of the UK energy system, and the frameworks and structures that can support this. A presentation in the Summit on the UK's Future Power Systems Architecture (FPSA)[4] programme showed how a strategic assessment can help understand the changes required in the electricity system and identified 35 fundamental new functions that are required in the future network. There appear to be fewer strategic assessments of this nature looking into development of the US energy systems. However, there are analyses that show how the different grid management regions in the US are performing relative to one another and the variation across the US provides insight not available in the UK's single regulatory and market system. Differences in policies can be analysed to determine the primary drivers behind the success of some states versus others. This provides many lessons to be learnt both by the UK and US states and grid operators on what policies work in practice.

It was agreed by most participants of the Summit that the development of smart grids should be driven by more of a framework approach rather than by rigid legislation. Over-

4 https://es.catapult.org.uk/projects/future-power-system-architecture-fpsa/?EKXSHOW=SHOW

regulation can stifle innovation and make the market less attractive for investment and ultimately slow down the grid transition. The challenge for government is to strike a balance and ensure that all parties are encouraged to work across sectors (and across energy vectors) to develop smart grids and make sure that all new infrastructure is working toward the same goal, to the benefit of all stakeholders including end use customers. The recommended approach from participants at the Summit was for regulators to focus on developing a framework to create common standards and protocols that help support innovation and modernisation, rather than regulating the approaches.

A key feature of future frameworks and market structures is the move away from commodity sales to customers (selling / buying kWh), and a move towards delivering services with outcomes. Time of use (ToU) tariffs and associated demand response services will be one mechanism to help encourage customers to take account of the direct costs associated with intermittent renewables and peak network loading. However, variable costs and values (such as ToU tariffs) also bring with them unique challenges and require careful regulatory attention. One major issue identified with ToU tariffs is the issue of socio-economic equality. It will be unacceptable to allow a situation where wealthy households can afford to pay price premiums and not offer any demand response during peak periods, whilst low-income households are forced to turn off – or pay exorbitant premiums to run - essential services. Furthermore, the ability to accommodate and engage with technology (such as smart controls or storage) creates winners

Grid operators and utilities may have to ensure that EV owners are educated regarding EV charging issues, although increased automation and service models may help alleviate this.

and losers, which may not be equitable across customers. It will be important that technology is accessible for most customers and safeguards are in place for non-accessible customers so everyone obtains the system benefit values.

A further regulatory issue raised during the course of the Summit was related to data access. With the increasing digitisation of the grid, specifically with increased number of smart meters being deployed, there will be increasing amounts of data collected. It is important that regulators develop guidelines on how this data is collected, used and stored and that the data is made accessible to all relevant stakeholders in a manner that protects the privacy of individual users whilst being open to innovators. In other sectors (such as telecommunications or social media) customers are willing to open up their data in return for value from the service, and a challenge of the energy sector will be to demonstrate value to customers.

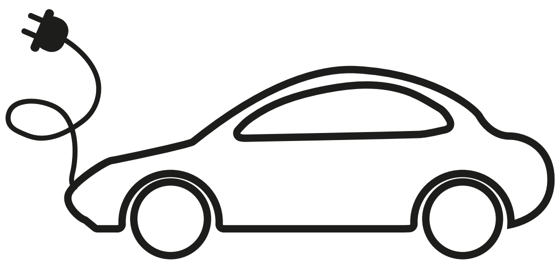
4.2
Electric vehicles

Electric vehicles have the potential to make or break the grid. Given the large-scale projected increase in EV use over the coming decades, the charging of plugin EVs is going to represent a substantial additional load. There will be a growing need to implement the smart charging of EVs so that the loads are diversified where possible (i.e. owners don't all try and charge EVs during the evening peak when returning from work), and automated smart charging systems combined with price incentives and service propositions could help increase off-peak charging. Emerging results from WPD's Electric Nation project indicate that there is significant flexibility available in charging times, which will enable loads to be spread to reduce the impact on networks and generation.

Delegates at the Summit also warned that consideration is needed on customer protection to prevent situations where electricity becomes prohibitively expensive during peak times for lower income homes' basic energy needs (e.g. lighting, cooking and heating) due to the charging of EVs.

It was suggested that EV charging may need to be controlled by system players with distribution grid operators having the ability to temporarily suspend charging at residential and commercial charge points when demand is too high. Grid operators and utilities may have to engage closely with customers to ensure that EV owners are educated regarding EV charging issues, although increased automation and service models may help alleviate this.

EVs also provide the opportunity for providing services to the grid. Plugged in EVs have the technical capability to feed electricity back into the grid to help mitigate peak demand / supply constraints in return for income, and research from Imperial College discussed at the Summit has shown that in optimum conditions, this could result in net negative electricity costs for an EV operator through off-peak charging and on-peak supply. However, there are many issues still to be addressed regarding the further development of vehicle-to-grid



or vehicle-to-home capabilities including factors such as lifecycle impacts though the provision of grid services.

4.3
New business models for the customer

Smart grids are intertwined with new business model opportunities, both facilitating and benefiting from. The value shift from commodity sales to services means that networks and utilities will increasingly see customers as part of the system operation rather than treating them as meter points. New innovative business models will increasingly be focused on motivating customers to act in the best interest of the smart grid. This includes incentivising customers to use more electricity when there is excess generation (e.g. during the night to wash their clothes and dishes) and possibly provide ancillary grid services during the day when demand is high (e.g. households give the ability to utilities to turn off their fridges for short periods in return for rebates). Summit participants noted that from their collective experience, customers would much rather receive cash back for their efforts than discounts or other incentives. While educating customers is important, customers will also ultimately react to the right kind of price signals if the process is suitably automated.

These type of business models will be supported by the continued roll out of smart meters and other technology and software developments such as the rise of blockchain. New entrants are also a threat to the space. Some Summit participants shared the concern that if current utilities and network operators do not step up to the plate the likes of Amazon and Google could potentially enter the space and rapidly take market share. This is a threat to utilities, but also to networks in that the core motivations and drivers of these new entrants may not be aligned with the energy system's needs.

4.4
New business models for network companies

Networks have traditionally (and currently) been valued based on their physical assets. In the future, value will be based on their operations and revenue potential. There are many new companies entering the smart grid sector, offering new products and services, and some with unique value propositions and alternative business models. However, some are struggling to find their feet in an industry where protracted traditional investment cycles and drawn-out approval processes are the norm. There has been increasing awareness of these barriers to entry and specialist funds are being set up to assist companies to successfully launch products and services in this space.

Alongside new companies struggling with market entry, existing companies also find trans-Atlantic trade challenging, particularly UK companies trying to enter the US market. Moving forward there needs to be greater transparency regarding the projects that the UK and US are carrying out so that potential opportunities for collaborations can be identified. A platform that promotes visibility of activities across the UK and US would be beneficial for companies to export products and services.

Big data is another key theme in the energy space. Big data was not explicitly discussed in detail at the Summit but was a theme identified as being important in the future of smart grids and inherent in many of the future operations. In particular, network companies will rely on increasing amounts of data from customers to inform their operations, including non-energy related data which can be used as a proxy. As discussed in Section 5.1, data access needs to be free and fair to allow all stakeholders equal access.

4.5
Whole systems approach in realising a smart grid future

In order to accelerate the development of smart grids and harness their true power, a multi-vector whole systems approach needs to be employed. Collaboration of a wide range of stakeholders across the heat, power, telecommunications and transport industries will be essential.

Gas networks

As heat becomes increasingly electrified, the synergies between the gas networks and electricity networks presents valuable opportunities for storage and demand response. Technologies such as hybrid heating systems can support this interplay. Longer-term, the development of a hydrogen based gas network could use electrolysis to produce hydrogen, could be a potential solution and link between absorbing excess electricity supply and meeting demand when renewable power output is low.

Heat networks

Heat provides the lowest cost form of storage, and exploiting the thermal capacity of buildings and heat networks could be a strong feature in future smart grids. Heat networks in particular could provide great flexibility for working alongside gas and electricity networks providing a form of storage for both energy vectors.

Telecommunication companies / networks

Telecommunication infrastructure will be at the heart of the smart grid. Rapid digital communication networks will facilitate the necessary two-way communication and rapid feedback and monitoring that enable smart grids. Therefore, there is the requirement for smart grid and telecommunication networks to grow in tandem to take advantage of all available opportunities. When power infrastructure is being developed, e.g. laying of underground cables, the potential for telecommunications equipment to be laid at the same time should be considered. Likewise, for other new infrastructure such as rail and roads, co-installation of telecommunications networks should be considered.

Smart cities

Smart grids are an important sub-set and facilitator of smart cities and one cannot exist without the other. Smart cities are the ultimate local incarnation of a multi-vector approach. Local authorities and municipalities will have an important role in enabling the development and integration of smart grids as part of smart cities and network companies will need to start taking a more local / regional viewpoint on their activities.

As heat becomes increasingly electrified, the synergies between the gas networks and electricity networks presents valuable opportunities for storage and demand response.

Chapter 5

Summary and conclusions – next steps

The Summit demonstrated that smart grids offer an exciting future for the energy system and customers.

There are many challenges in developing and delivering the smart grid future, but it provides unlimited opportunities for changing the way in which the energy system operates, and engages with its end users – energy customers. An overarching theme identified during the course of the Summit is that customers, more specifically domestic customers, have a very central role to play in the future of the smart grid. Whilst smart grids comprise of new technology, communications systems, and modes of operation, the real "smart" part is how energy is managed and consumed by significantly changing the relationship with customers and how they use energy.

5.1
Recommendations from the Summit for promoting interaction

The following are recommendations identified from the Summit:

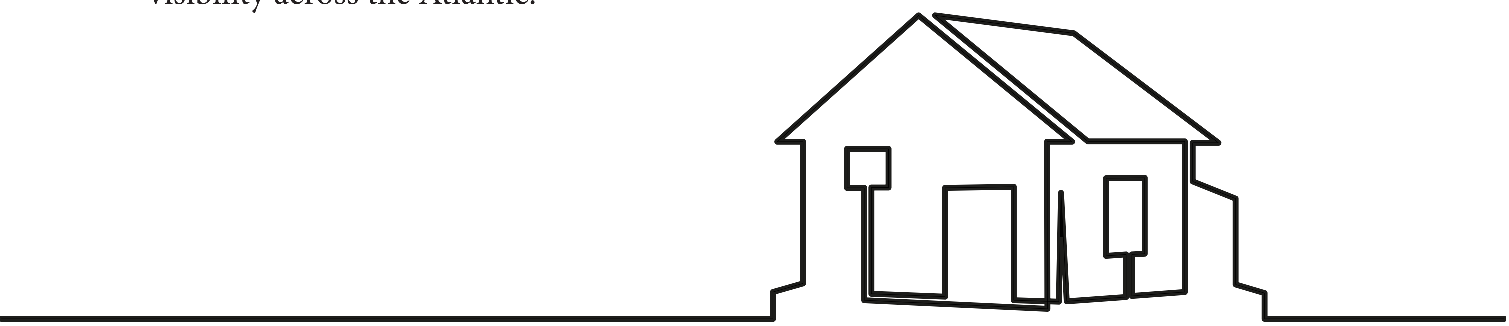
1. The Summit was a useful forum to share trans-Atlantic success stories and challenges relating to the future development of the smart gird. The UK Department for Business Energy and Industrial Strategy (BEIS) also affirmed the value of holding such Summits and identified the importance of future events.

2. Future events could take more of a whole systems approach based on the importance identified during this Summit. Future summits should include a wider range of stakeholders and perhaps include more customer insights. End-use customers have traditionally been under represented in industry discussions and are due to play a larger role in the future of the grid.

3. The smart grid arena is vast and there needs to be a strong focus during discussions on the types of outcomes desired.

4. Relationships were developed during this and the previous summit but maintaining the interaction and visibility of activities in the UK and US is challenging. One solution could be the development of a simple information exchange platform or portal.

5. Greater visibility of actors in the smart grid sector will facilitate innovation and development. A database of companies active in the smart grid space should be formulated and circulated to help create more awareness of companies active in the space. The UK Energy Systems Catapult is in the process of developing such a database of UK companies and this could be used to help further visibility across the Atlantic.

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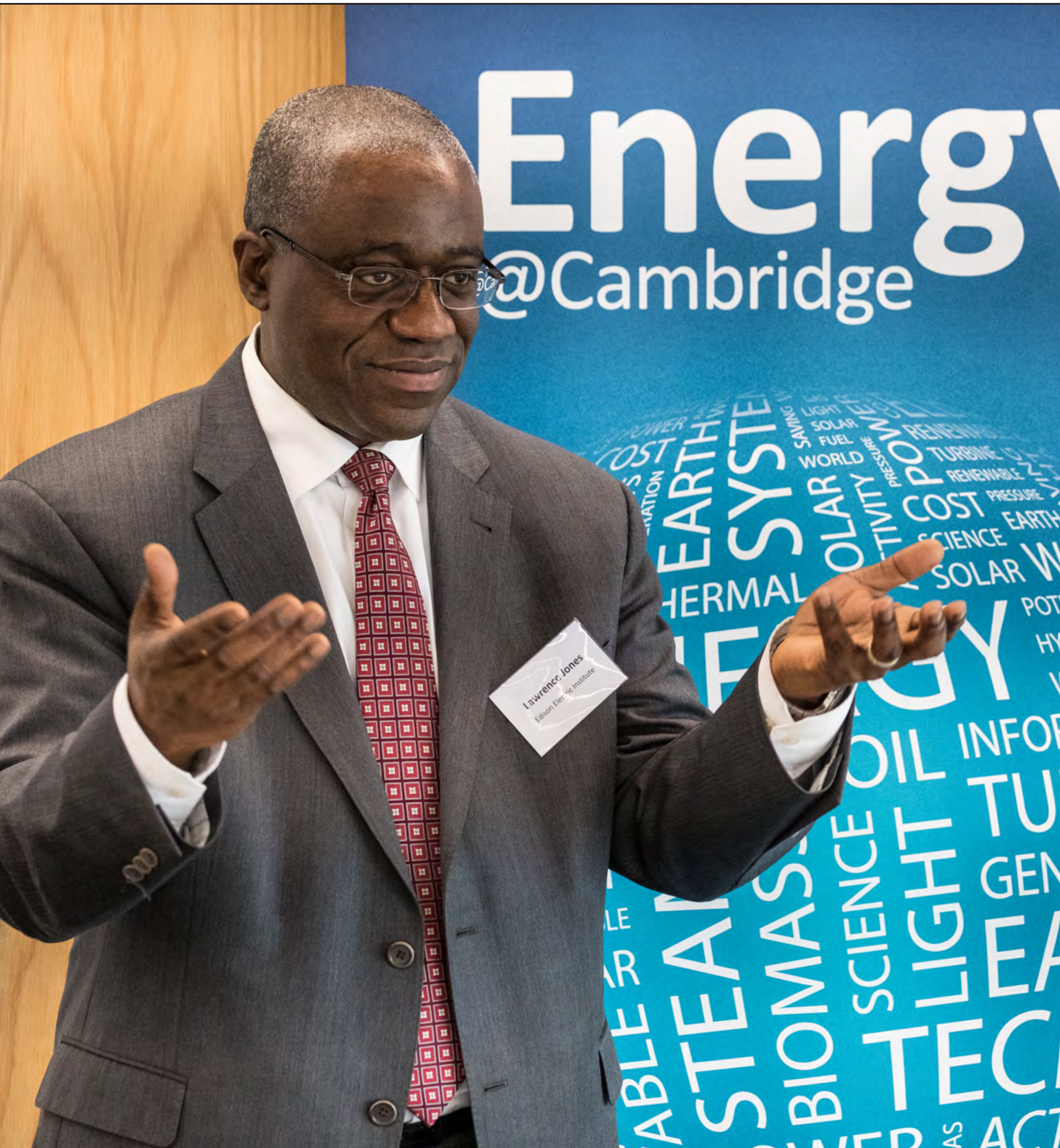


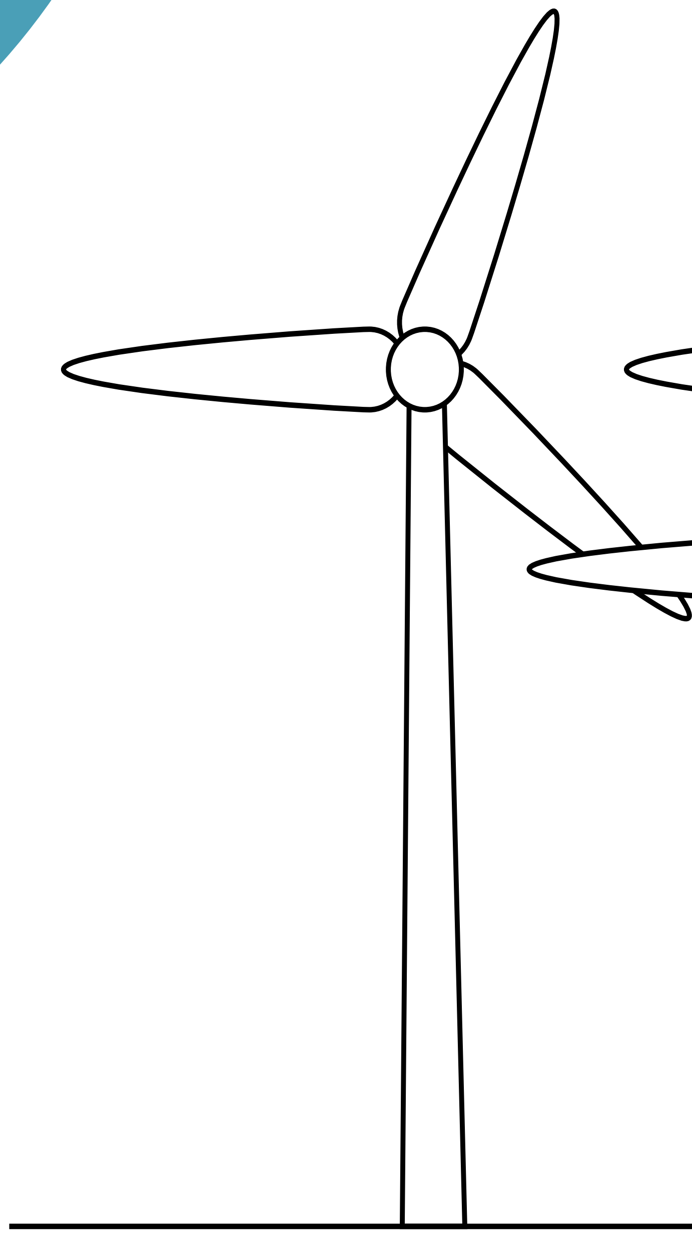
The Foreign & Commonwealth Office would like to thank Cambridge Cleantech and Energy@Cambridge for their support in designing and facilitating this programme. Special thanks to the University of Cambridge's Maxwell Centre for hosting both days of the event.

Appendix

List of attendees

Name	Company/affiliation
Curt Kirkeby	Avista
John Goodin	CAISO
Martin Garratt	Cambridge Cleantech
Sam Goodall	Cambridge Cleantech
Sophie Meuwissen	Cambridge Cleantech
Tim Collins	Centrica
Andrew Turton	Delta Energy & Environment
Matthew Myers	Delta Energy & Environment
William van der Byl	Delta Energy & Environment
Freda Zhao	Delta Energy & Environment
Alice Fourrier	Department for Business, Energy and Industrial Strategy
Ian Llewellyn	Department for Business, Energy and Industrial Strategy
Lawrence Jones	Edison Electric Institute
Neil Hughes	Electric Power Research Institute
Phil Lawton	Energy Systems Catapult
Grant Bourhill	Energy Systems Catapult
Lauren George	Foreign and Commonwealth Office
Justin Normand	Foreign and Commonwealth Office
Ben Springer	Foreign and Commonwealth Office
Shaun Duff	Freedom Group
Steve Pedder	GE Energy Consulting
Ben Kellison	GTM Research
Cholly Smith	Illinois Commerce Commission
Goran Strbac	Imperial College London
Tim Green	Imperial College London - Energy Futures Laboratory
Laura Brown	Newcastle University - Centre for Energy Systems Integration
Phil Taylor	Newcastle University - Centre for Energy Systems Integration

Name	Company/affiliation
Martin Crouch	Ofgem
Dale Geach	Siemens
Paul Monroe	SMAP Energy
Edward Black	SSE Enterprises
Stephen Stead	SSE Enterprises
Chris Hole	TTP
Sotiris Georgiopoulos	UK Power Networks
Stathis Mokkas	UK Power Networks
Teng Long	University of Cambridge
Michael Pollitt	University of Cambridge
Shafiq Ahmed	University of Cambridge - Energy@Cambridge
Isabelle de Wouters	University of Cambridge - Energy@Cambridge
Barry Smitherman	UT School of Law / NRG Energy
Roger Hey	Western Power Distribution
Raj Sivalingam	WHP Telecoms
Julian Stafford	WHP Telecoms



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