



UK NETWORKS TRANSITION CHALLENGES

Electricity

An insights report from the
Energy Technologies Institute



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INTRODUCTION

Any move to a low carbon UK energy system that uses new and more varied sources of energy generation will require investment and an upgrade of the current energy network infrastructure.

At ETI we see there are three key challenges to transitioning UK networks for a wider adoption of low carbon sources. These are:

1. A need to adapt and enhance the existing network infrastructure to absorb new forms of energy generation
2. The creation of efficient and effective new network infrastructure to deliver new forms of energy generation
3. The integration of energy networks so the UK can optimise the use and performance of energy generated across a number of different energy vectors, effectively and efficiently

Our analysis in this area has pointed to the fact that we see there is real value in the UK employing a multi-vector approach to its energy supply, both from the perspective of transitioning to a low carbon energy system, but also in a manner that is convenient and affordable to the end consumer.

To make this a reality, whole energy system thinking is critical. Analysing the interactions between networks (as well as with the wider energy system) and how today's network infrastructure will influence the infrastructure you are going to need in the future is central to this. Because the challenge is one of knowing where, when and to what extent to enhance the network.

Today, current governance and regulatory frameworks are simply not designed to enable and incentivise the radical transformation that will be needed to move to a low carbon solution.

Against this backdrop, the ETI recommends the following actions should be taken to effectively transition to a low carbon energy system with a network infrastructure that delivers for future generations.

1. The UK should incentivise and target investment to allow it to adapt and enhance existing networks
2. Alongside this the UK needs to make clear decisions upon what and where they want new networks to operate and invest in them accordingly
3. The UK should design network infrastructures to ensure that they work together efficiently across multiple vectors in real time – providing an economic and consumer solution to the delivery of low carbon energy

Whilst we advocate the systems-wide approach, this insight report looks in more detail at the challenges that are facing the UK's electricity network and how that network can adapt and be enhanced in the future to provide a low carbon solution and form a strong component of a multi-vector approach to UK energy infrastructure.

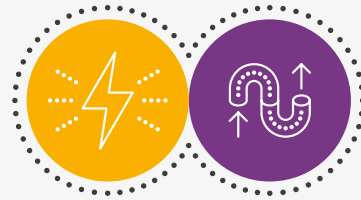
INTRODUCTION

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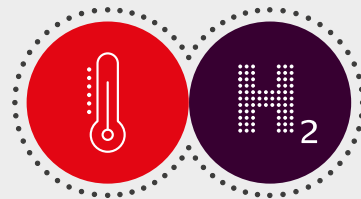
Challenge one

Adapting and enhancing existing network infrastructures



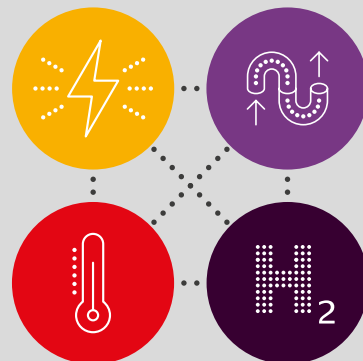
Challenge two

Enabling creation of efficient and effective new network infrastructures



Challenge three

Integrating new and existing networks to enable optimisation across vectors



ELECTRICITY NETWORKS, WHERE ARE WE NOW?

In the UK, the electricity network is the most widespread energy network, reaching nearly every home and public, commercial and industrial building. It is also the one that serves the greatest number of end-uses, from lighting and heat to appliances, electronics and industrial loads. The possible means of generation are also broad, though currently large-scale thermal power generation (notably gas and nuclear) dominate and are linked by the transmission system. Recently there has been a growth in renewable generation (including on- and off-shore wind, solar PV and biomass) that has been connected at both transmission and distribution level, some of which has required additions or upgrades to the network.

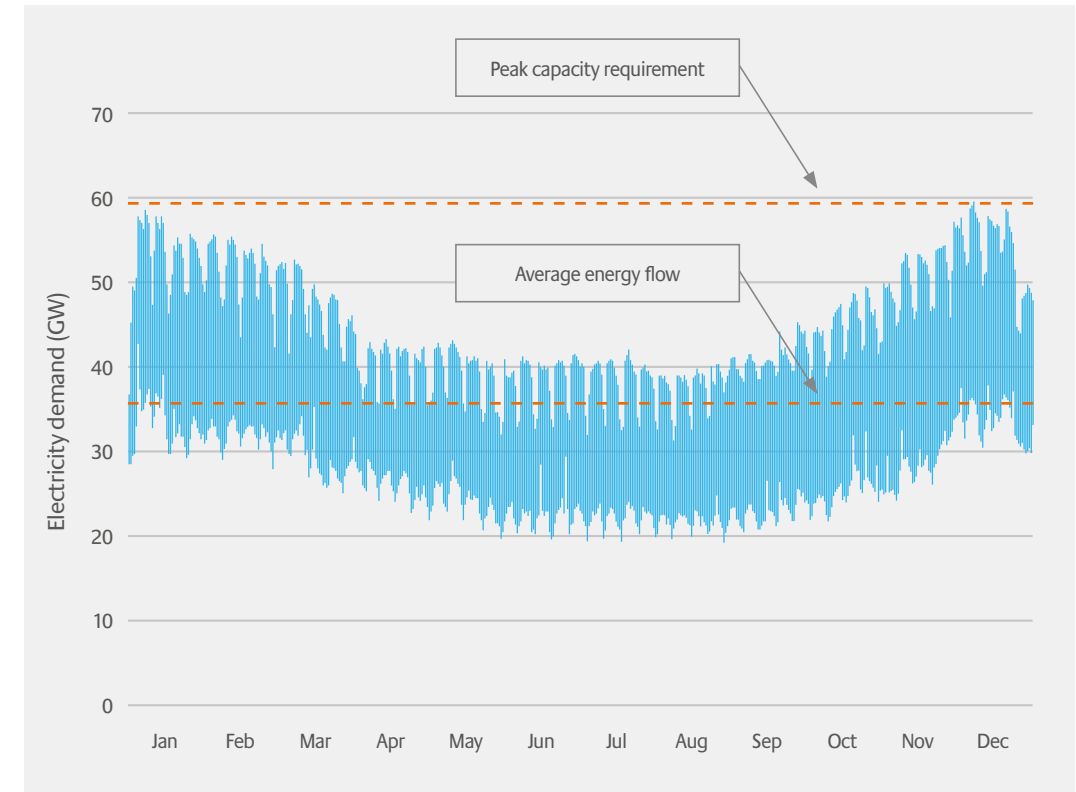
Electricity usage is variable throughout the day and to a lesser extent between seasons. As illustrated in Figure 1, this is important as the network has to be designed to carry the maximum amount of energy that would flow through it rather than just the average. In the interests of economy, though, it isn't sensible to oversize them as, along with the length of a network, capacity has a significant influence over its cost.

The variability in electricity usage is also important from the point of view of the lifetime of the network. Components can be sensitive to being cycled too much or too often, particularly near to their limits, which may lead to them needing to be replaced more often, ultimately adding to the

cost of the network. Electricity networks are also very limited in terms of the amount of inherent storage they have (a feature of, for example, gas networks), so the balance of supply and demand needs to be much tighter than with other networks. Including dedicated storage can help but this is costly and much of the opportunity for what has historically been the most cost-effective means for providing this, pumped hydro storage, has already been developed. Generally, if it is not possible to utilise storage, action needs to be taken either at the supply or demand ends of the network to maintain system balance.



Figure 1
UK annual electricity demand profile for 2010¹



¹ Based on data from Robert Sansom, Imperial College, (2011)



HOW MIGHT THINGS CHANGE?

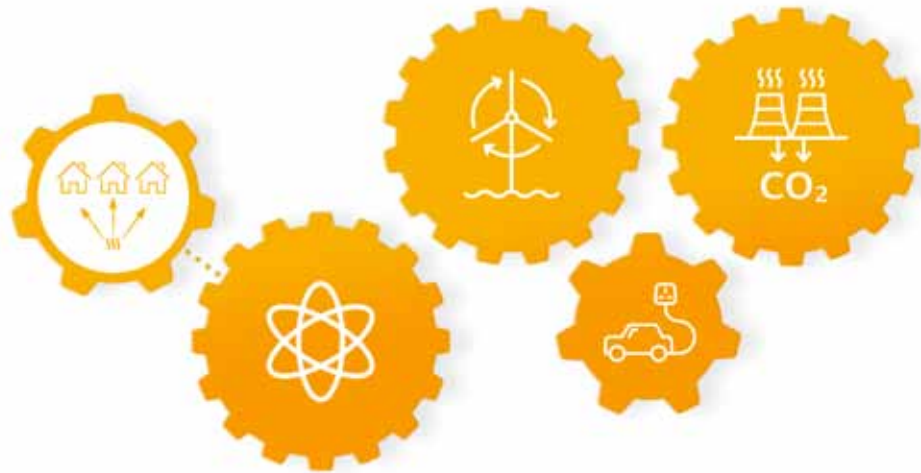
In this report we have used the ETI's published scenarios, which illustrate how the wider energy system might evolve, as a basis for exploring how we might need to adapt and invest in the electricity network. The scenarios themselves have been developed from extensive analysis of the overall energy system and how it might have to develop out to 2050 in order to meet the UK's greenhouse gas emissions targets. The underlying analysis covers, amongst other things: how technologies might develop; how they would need to interact with each other as part of an overall energy system; practical roll-out timeframes for those technologies; potential constraints on energy resources; operational constraints and, not least, changes in energy demands and customer expectations.

Two scenarios are depicted which offer contrasting pictures of the UK energy system evolution to 2050. These are referred to as **clockwork** and **patchwork** and are plausible and self-consistent examples of how the energy system might evolve to meet the UK's 2050 greenhouse gas emissions targets. They are not forecasts but portray distinct (yet not exhaustive) ways in which the gas network could need to evolve, offering a means to explore a range of challenges that it might face.



HOW MIGHT THINGS CHANGE?

Continued >



CLOCKWORK

In the clockwork scenario, the electricity transmission system will be faced with increased overall loads and higher peaks. There will be a need to connect new thermal power generation, whilst catering to increasingly (though still partially) electrified heat and transport sectors. The increased loads will also affect the distribution network with the effects of new demands being more prominent in some locations than others. Growing distributed generation, again in some areas more than others, further adds complexity, whilst also having the potential to affect the transmission system. Longer term there is an increase in build out of larger-scale renewable generation, including offshore, and the electricity infrastructure needed to connect that.



PATCHWORK

For patchwork, the electricity transmission network must expand to connect a steady but significant growth in renewables, especially offshore wind. Over the same period, thermal power generation declines, markedly in early decades, with the transmission system needing to evolve to accommodate this. Overall loads on the system grow to meet a considerable increase in heat electrification and some electrification of transport. This has pronounced effects on the distribution system which needs to be reinforced in some locations as the ad-hoc growth of these loads emerges. These effects are exacerbated by similarly ad-hoc growth in distributed generation, particularly solar PV and CHP systems.

HOW MIGHT THINGS CHANGE?

Continued >



Clockwork

The electricity network increases in capacity to connect a steady but significant build-up of large-scale thermal power generation and renewables at a mixture of established and new locations.

Nuclear forms the bulk of this with coal plants nearly all shut down by the 2020s and unabated gas usage declining.

Whilst the regional concentration of electricity generation into a small number of large-scale plants looks similar to today, some old sites are decommissioned in favour of new sites elsewhere, requiring both network expansion and decommissioning.

From 2030 onwards, network expansion must also enable connection of other generation, including small modular reactors and hydrogen-fuelled generation, and by 2040 more renewable generation, including substantially more offshore wind.

In addition to connecting new sites there is an overall growth in capacity requirements from 2030 onwards (with over 120GW of installed generation capacity by 2050) to allow the power sector to serve growing electrification of heat and transport.

Electrification of heat occurs primarily in rural and some suburban areas, yet heat still becomes the largest consumer of electricity by 2050, with electricity networks having to carry 3 times as much electricity for home heating as today.

Electrification of transport is spread more evenly geographically and by 2050 the growth in plug-in cars and vans requires electricity networks to carry 8 times as much electricity as is currently used by the rail sector.

These increases in energy demand require solutions for managing peak power demand in distribution networks.

Upgrades to the distribution network are undertaken on a planned basis, including through the implementation of network operator instigated smart technologies and systems, with capacities increased to accommodate electrification of heat and transport.

Patchwork

The electricity network must expand over relatively short periods to connect renewable generation (especially offshore wind) at a far greater number of sites than today.

Close to 200GW of generation capacity is connected by 2050 (more than double today's capacity).

The growth in renewable generation (including rooftop and ground mounted solar PV and tidal) coincides with the closure of coal plants and some gas plants and decommissioning of network connections to them.

Wind is the dominant generation source by installed capacity; by 2050 75GW of wind capacity is connected, two-thirds of which is offshore, requiring significant grid reinforcement to allow transmission of power to centres of demand.

The network expands to connect up to 2GW/yr of offshore wind alone by 2030 and up to 3GW/yr by 2050.

In the 2040s renewables capacity expands at its greatest rate to meet increased electrification of heat and transport, placing greater onus on means of providing flexibility, including hydrogen peaking capacity (requiring further network expansion); interconnection; and integration with storage and smart energy systems.

A mixture of measures to mitigate distribution network capacity constraints are adopted, from conventional reinforcement to smart energy solutions.

The emergence of viable smart energy solutions and changes to network regulations in the 2020s and 2030s enables increased uptake of plug-in vehicles and alternative forms of heat supply, alongside greater integration between electricity, gas and heat networks.

From the 2030s local electricity network capacity requirements are further affected by the deployment of large-scale heat pumps to supply heat networks. These both replace retiring gas CHP systems and allow further growth of heat networks.

By 2050 the electricity network is carrying 4 times as much electricity for home heating as today.

It is also supporting plug-in vehicles drawing on 10 times as much electricity as the rail sector does today, on top of that needed to supply electrolyzers in support of hydrogen vehicles.

WHAT DOES THIS MEAN FOR THE ELECTRICITY NETWORK?

Whilst the electricity network is well established, it is expected to grow in prominence. Greater electrification, particularly of heat and transport, is set to increase the load on the network substantially. As a result peak loads could almost double. The network will need to serve new sectors and connect new and additional generation. This places a lot of emphasis on adapting and enhancing the network to be able to do so.

At the distribution end of the spectrum, there are challenges not only in terms of knowing how much to reinforce the network but also in terms of where and when. Uncertainties about both uptake of technologies, such as heat pumps and electric vehicles, and also the capacity of the existing network itself all contribute to this.

At the transmission level there are barriers to reinforcement in terms of cost and planning. The scale at this level of the network makes even individual power lines and cables very expensive. Planning timeframes can be long and add to what is an already time-consuming construction, which again increases the cost. Acceptable routes need to be found that satisfy local concerns, are affordable and crucially connect the relevant parts of the system.

Three principal challenges present themselves when considering how the electricity network will need to be adapted and enhanced to meet its future requirements:

- › Handling increased capacity
- › Delivering new connections
- › Balancing supply and demand in the energy system



ETI Project: Pre-saturated Core Fault Current Limiter

Development and demonstration of a pre-saturated core fault current limiter.

The fault current limiter, developed during this project by GridON, was commissioned into service in May 2013 at a UK Power Networks main substation in Newhaven. It has successfully suppressed multiple faults during its service.

Product design offers advantages of a non-superconducting pre-saturated core fault current limiter with instant response and recovery, a small footprint and can utilise established transformer design and build processes.

Increased capacity

Whilst there are multiple options for enhancing the network to carry greater loads – from smart grid solutions, to fault current limiters, to energy storage and conventional reinforcement – not all will be suitable for all parts of the network. Some parts of the network are closer to their existing capacity limits than others, whilst growth in loads will not be equally spread across the network. In addition, factors such as available physical space or land value, are specific to local areas and will differentially affect the viability of the enhancement options in those locations.

There are different considerations for transmission and in distribution and in the case of the former marked differences between onshore and offshore.

The transmission network

Onshore, there is the opportunity to locate at least some new thermal power generation on or near to existing sites, given the suitability of those sites to hosting this type of plant (e.g. having sufficient space, environmental factors and access to sufficient cooling water) and the limited availability of these types of sites in the UK. Reusing sites alleviates the burden on installing new connections but connecting this plant at sufficient capacity remains an important consideration. Indeed, as power plants are built, if there is a view that further power plants will need to be built at some point in the future and the possibility that they will be built on the same site, there is a question as to whether sufficient network capacity should be built straight away for the long term or whether additional lines should be built or upgrades undertaken as it becomes certain that greater capacity is required.

Figure 2

A pre-saturated core fault current limiter



Transmission lines offshore have higher absolute costs and the relative increases in cost are also higher. This makes it more challenging to oversize offshore transmission lines than those onshore and could create a barrier to subsequent expansion of offshore renewables. There may also be the added complexity of integrating with any supra-national Europe-wide transmission system that might emerge. In the design of the networks, attention will need to be paid to the variation in output of the intermittent generation, including any diversity across the dispersed supply and how this will affect network capacity requirements. There are also likely to be opportunities for storage and other means of balancing the system, to avoid network capacity limiting supply from a certain location and resulting in renewables capacity being constrained.



WHAT DOES THIS MEAN FOR THE ELECTRICITY NETWORK?

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Distributed generation

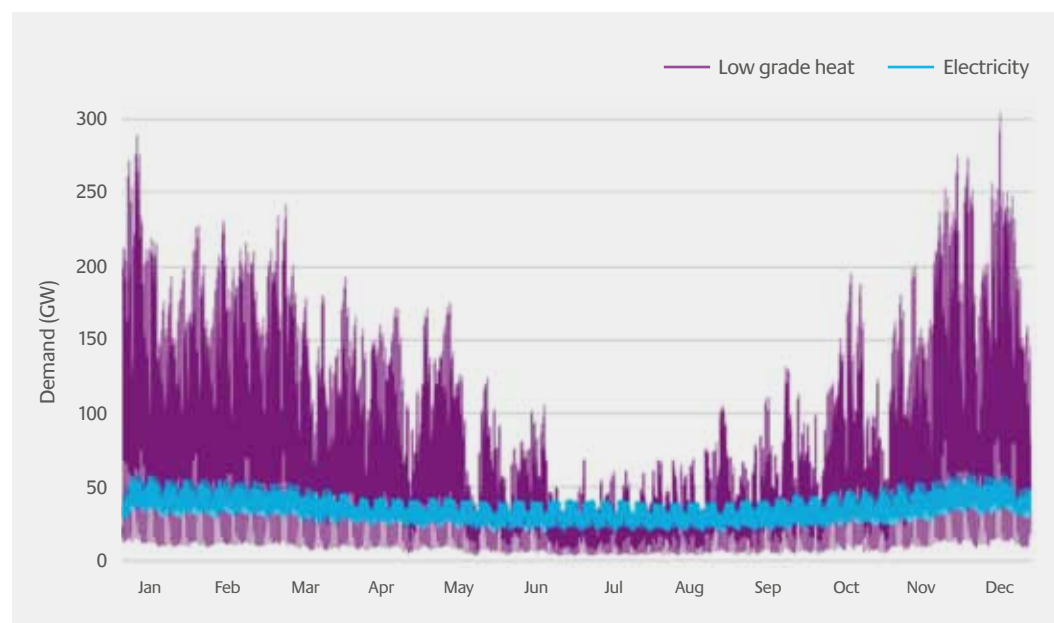
Distributed generation tends to have a shorter lifespan than large-scale thermal power generation, so there will be questions as to whether any growth in capacity to support this is needed for the longer term. There is no guarantee, for example, that solar PV panels will be replaced once they reach the end of their lives. In the situation where CHP systems supply heat networks in the near to medium term before being supplanted by other forms of low carbon heat generation, the longer term need for the electricity network capacity to enable excess electricity from the CHP systems (which would be significant) to be exported to other concurrent loads (e.g. heat pumps in rural areas) is not guaranteed. Depending on local factors, the CHP systems could be replaced by advanced geothermal systems or large-scale heat pumps. Geothermal systems would have little use for the additional network capacity that would

have previously been used to export electricity from the CHP systems. However, if large-scale heat pumps replace the CHP systems the extra capacity would be required and there might even be a need for greater peak capacities (albeit with the electricity flowing in the opposite direction). So, when considering to what extent to reinforce the network these future changes need to be borne in mind.

To integrate either PV or CHP systems the network will need to be able to handle variations in electricity output as solar output varies throughout the day and with the seasons as heat demand changes. These are both electricity supply factors (even if the latter is driven by a demand for heat). Also affecting the distribution network will be factors relating to electricity demand. Prominent amongst these is greater electrification of heat and transport. This would lead to very significant increases in electricity consumption. However, from a network

Figure 3

A comparison of annual heat and electricity demand in the UK²



2. Based on data from Robert Sansom, Imperial College, (2011)

perspective, it is how these demands would vary over the day and year and what the maximum demand would be that is most important. These usage profiles and peak demands determine the network that is required. In both cases this is influenced by people's requirements – further information on this can be found in ETI analysis on light vehicles³ and consumer insights⁴ – and the technology choices that are made.

Electrification of heat

For heat, the use of heat pumps and to a lesser extent resistive heating is most relevant for electricity networks, with deployment in rural areas and some suburban areas. Much of this demand is currently met by gas. Data on current gas consumption (shown in purple in Figure 3) illustrates the extent to which heat demand varies over the year. When compared to current electricity consumption (shown in blue in Figure 3, the same data shown in Figure 1) this highlights that the electricity network would have to cope with a much greater variation between seasons than it does now. Figure 3 also gives a sense of the scale of heat demand. The peak amount of energy handled by the gas network far exceeds that of the electricity network at present. For the electricity network to carry all of that heat demand in addition to the other demands it already carries would be extremely challenging.

However, neither of the scenarios present a wholesale switchover to electric heating and further mitigation is offered by the heating profiles of heat pumps, which are likely to be steadier than those of boilers. So whilst gas boilers can output a large amount of heat in a short period of time, heat pumps would provide their heat over a longer period, lessening their peak demand on the network. It is often assumed that with heat pumps being more efficient than boilers (in the sense that they need less electricity than boilers need gas to deliver the same amount of heat) that this also lessens the peak demand

3 Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>

4 Lipson, M. (2015). Consumer challenges for low carbon heat. [online]. Available at: <http://www.eti.co.uk/insights/smart-systems-and-heat-consumer-challenges-for-low-carbon-heat>



ETI Programme: Smart Systems and Heat

WHAT WE ARE DOING

- > Connecting together – the understanding of consumer needs and behaviour with the development and integration of technologies and new business models into;
- > Delivering enhanced knowledge amongst industry and public sector;
- > Resulting in industry and investor confidence to implement from 2020 which enables a UK heat transition.

they place on the network. However, this is only partially true since the highest heat demand occurs at the coldest times and this is when heat pumps are at their least efficient, which means the peak demand is closer to boilers than is often assumed.

In aggregate this would still represent a significant increase in the peak electricity demands that the network would need to handle. Whether heat pumps will practically be able to meet peak heating requirements on the coldest days depends on building sufficient network and generation capacity and the extent to which we are able to implement building retrofits to improve efficiency. It is plausible they will need to be supplemented by other heating systems (such as peaking boilers) or in-home heat storage. In terms of the variation in the loads on the network, the steadier heating profile alleviates some of the concerns around day variations but the variation between seasons would remain. As a result not only does capacity of the network need to increase, it also increases the ratio of the network capacity to the amount of energy carried, placing pressure on the ability to derive a return on investment.

WHAT DOES THIS MEAN FOR THE ELECTRICITY NETWORK?

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Electrification of transport

With over 30 million vehicles on the road today electrifying transport has the potential to have significant impacts on network capacity. How much of an impact will depend on a variety of factors, not least:

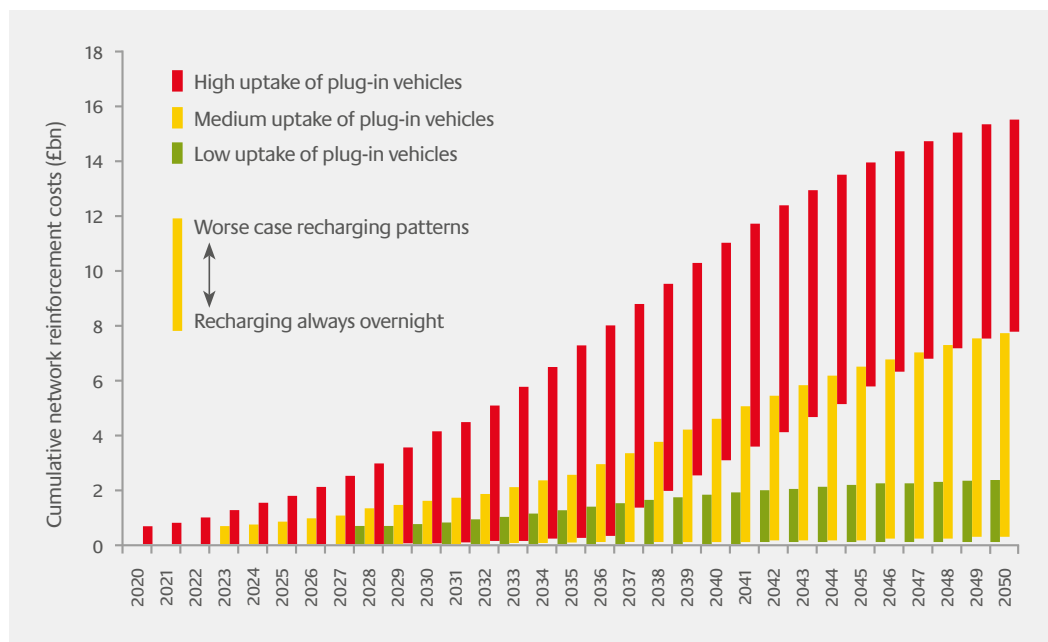
- > The number of plug-in vehicles⁵ there are at any one time
- > When the vehicles are charged and at what rate
- > The existing network capacity in the locations where the vehicles are being charged

As the level of uptake of plug-in vehicles increases, the potential for the local network capacity limits to be reached increases.

The likelihood increases further if the vehicles are charged at peak times, which ETI analysis⁶ indicates would unfortunately coincide with when the majority of vehicles would be plugged in. Figure 4 shows the cumulative network reinforcement costs that could arise for different levels of uptake of plug-in vehicles in conjunction with different charging patterns.

Some locations are closer to their existing network capacity limits than others, so even lower levels of uptake could trigger the need to reinforce the network there. Equally, if plug-in vehicle uptake is concentrated in certain locations (even if wider uptake was more moderate), this could lead to network reinforcement being necessary in those locations.

Figure 4
Potential costs for electricity distribution system reinforcement for plug-in vehicles



⁵ Plug-in hybrid electric vehicles and battery electric vehicles

⁶ Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>

The ETI has previously undertaken detailed analysis of the most affordable route to transitioning the UK's light vehicle fleet to low carbon alternatives⁷. Key aspects of how managing vehicle charging can mitigate the impact on electricity networks are included in the Balancing supply and demand section.

Any electrification of transport raises the prospect that longer term demand for rapid (high power) charging of those vehicles will increase. Accommodating this is also likely to pose a number of challenges for electricity networks. Given journey patterns and the exigency behind rapid charging, it is most likely to occur at or close to peak electricity times and, unlike overnight charging, will not be moveable. There is no guarantee that this will be available to all who would need it. To meet driver needs this type of charging is most likely to be needed along major tributaries. The network will thus need to be developed to connect both the generation and these recharging sites at sufficient capacities to meet demand.

New connections

Increased electrification requires the network to be adapted. New sites will need to be connected to add more power generation capacity and to replace retiring power stations, the sites of which will not all be suitable for the generation that replaces them.

The needs for connecting large thermal-based power generation will differ to those for connecting renewable generation. This is mainly to do with the routes and the capacities that will be required, though different network architectures and network component technologies may also be required.

Where new sites are needed, additional high voltage lines will be needed and decisions about which sites to use for new plant will impact when and how much to upgrade connections.

Although renewables generally require new connections with lower capacity than those for thermal plants, they tend to be more geographically dispersed. This will require new connections and overall network length would be greater. This is most significant with offshore renewables where the distances are far greater. In fact, these distances can exceed the distances where standard high voltage lines (HVAC) are the most cost-effective option.

⁷ Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>



ETI Project: Electricity Distribution and Intelligent Infrastructure

This project looked at the potential impact of electric vehicles on the UK electricity distribution grid. It also assessed the recharging infrastructure required to support mass market adoption of plug-in vehicles in the UK.

In collaboration with a number of stakeholders it defined a system architecture to integrate vehicles, electricity networks, charging points and payment systems.



ETI Project: Offshore Connection

This project examined the specific challenges and opportunities arising from the connection of offshore energy to the UK grid system and considered the impact of large-scale offshore development.

It also looked into the novel electrical system designs and control strategies that could be developed to collect, manage and transmit energy back to shore and identified and assessed innovative technology solutions to these issues and quantified their benefits.

WHAT DOES THIS MEAN FOR THE ELECTRICITY NETWORK?

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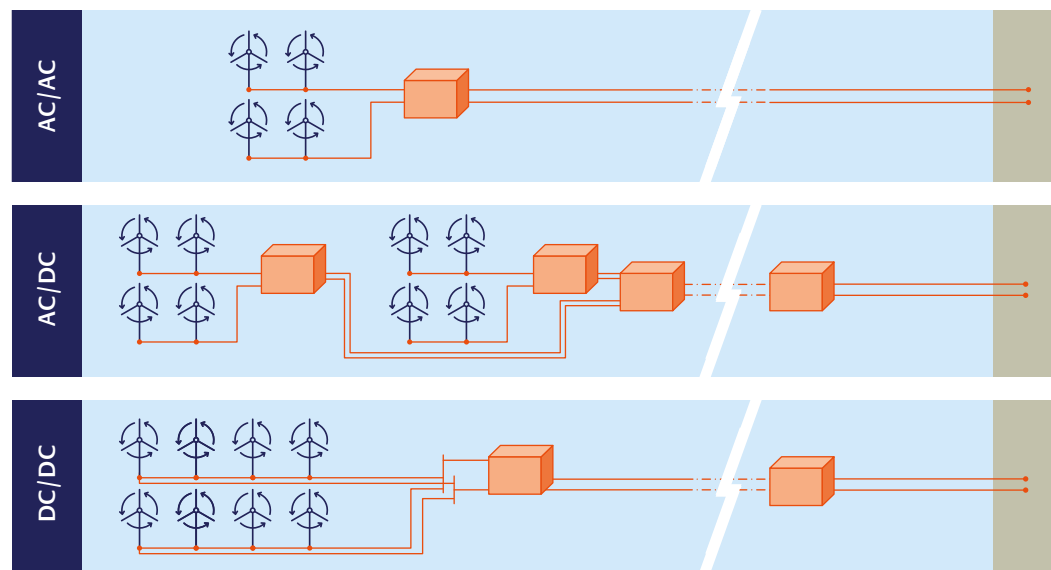
Over longer distances a switch to an alternative technology, high voltage direct current (HVDC), becomes more affordable. At high levels of deployment of offshore renewables it is particularly important to consider how best to connect the large amount of dispersed generation to shore. The most appropriate network architecture to use – whether that is, for example, a “spoke and hub” approach or the use of more individual connections – will depend on factors such as the distance to shore, the grouping of generation sites and the level of confidence there is about the need for future connections. Figure 5 shows some example network architectures that might be used to connect offshore renewable generation.

The network architecture needs to be considered alongside the generation, e.g. wind turbine, technology. There are cost trade-offs between network and generation technologies, so

removing cost from one can result in cost increases for the other. Similarly, there are trade-offs when considering the location of the renewables, between distance from demand (and thus network length) and the levelised cost of energy production that is possible from the site (given, for example, the wind resource there). So whilst the cost of production might be lowest off certain parts of the coast of Scotland, given the distribution of demand, it might be better to spread the offshore wind sites around the UK to reduce network costs⁸.

Growth in distributed generation presents a further set of challenges, though it can also aid network management. Traditionally generation tends to be connected at transmission level, with electricity flowing down to demand that is predominantly at the distribution level. A growth in generation connected at the distribution level would represent a change in network design

Figure 5
Example network architectures for offshore connections



⁸ Bradley, S. (2015). Offshore Wind: Floating Wind Technology. [online]. Available at: <http://www.eti.co.uk/insights/floating-wind-technology>

philosophy. To understand what the network will need to handle, it will be necessary to ascertain, for example, what proportion of energy is likely to be used locally and what will need to be exported to other areas and where. This affects how the network will need to be adapted at both distribution and transmission levels.

Balancing supply and demand

A functional energy system requires supply and demand to be in balance at any point in time. The conventional means for achieving this has predominantly involved varying supply to meet changes in demand, which requires supply to be at least partially flexible. An increasing amount of electricity generation could be inflexible⁹, so to maintain a functional electricity system some flexibility needs to be provided. Unlike other networks such as gas, there is no inherent storage in the network itself.

Whilst there are a wide variety of technologies able to provide storage for electricity networks; most currently available options are either expensive (e.g. batteries) when compared to other means of providing system flexibility or constrained in terms of where they can be deployed (e.g. pumped hydro). Alternative means of providing flexibility include:

- > low carbon peaking plant, such as hydrogen-fuelled power generation¹⁰
- > managed charging of plug-in vehicles¹¹
- > heat storage in electrically heated homes¹²

⁹ Such as intermittent renewables and less flexible thermal power plants

¹⁰ Gammer, D. (2015). The role of hydrogen storage in a clean responsive power system. [online]. Available at: <http://www.eti.co.uk/insights/carbon-capture-and-storage-the-role-of-hydrogen-storage-in-a-clean-responsive-power-system>

¹¹ Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>

¹² Douglas, J. (2015). Decarbonising Heat for UK Homes. [online]. Available at: <http://www.eti.co.uk/insights/heat-insight-decarbonising-heat-for-uk-homes>



ETI Project EnergyPath Operations

EnergyPath Operations will:

- > Enable an expert user to dynamically simulate the operation of energy system assets within the context of various business models / value propositions and specify potential control architecture
- > Be capable of representing a wide range of potential policy, regulatory and business models
- > Provide additional confidence in the delivery of value propositions to support business models which may enable a Smart Systems and Heat type market roll-out



ETI Project Storage and Flexibility Modelling

This project will assess the role of energy storage and other key means of providing energy system flexibility in the context of the overall energy system

WHAT DOES THIS MEAN FOR THE ELECTRICITY NETWORK?

Continued >

Even with these options the need for grid-connected electricity storage is likely to increase. To what extent depends on the make-up of the wider energy system in which it operates. There are also questions as to where on the network, both geographically and at what level of the network, it should be deployed. How energy storage is used will affect which investment models are most appropriate.

For managed charging of plug-in vehicles ETI's analysis¹³ highlights that the greatest opportunity for vehicle charging is overnight at owners' homes. During this time vehicles are sat for a more than sufficient period of time to fully recharge, even using relatively low power charging. In addition, other electrical demands are at their lowest, meaning there will be spare capacity both on the network and in generation capacity (see Figure 6). Conversely, the period

with highest demand, and thus least spare capacity, is in the early evening. This, however, coincides with when the majority of those vehicles arrive at properties (see Figure 6). So, if vehicles were plugged in and began charging immediately, this would add to what is already the peak demand on the network. Delaying charging by just a few hours to the overnight period moves the recharging to a more favourable time. Implementing this successfully will require intelligent charging systems that can adequately manage the interaction between the vehicle, people, the network and the wider energy supply. This places an onus on the development of suitable technologies, systems and market and policy frameworks and the effective implementation of those. The knowledge gained from this will aid decisions about when, where and to what extent to upgrade networks.



ETI Project: Consumers, Vehicles and Energy Integration

This project aims to understand the required changes to existing infrastructure, as well as consumer response to a wider introduction of plug-in hybrid and electric vehicles in the UK.

The project is being carried out in two stages. The first stage will focus on detailed analysis and design of market, policy and regulatory frameworks, business models and customer offerings, electricity and liquid fuel infrastructure and technologies throughout the

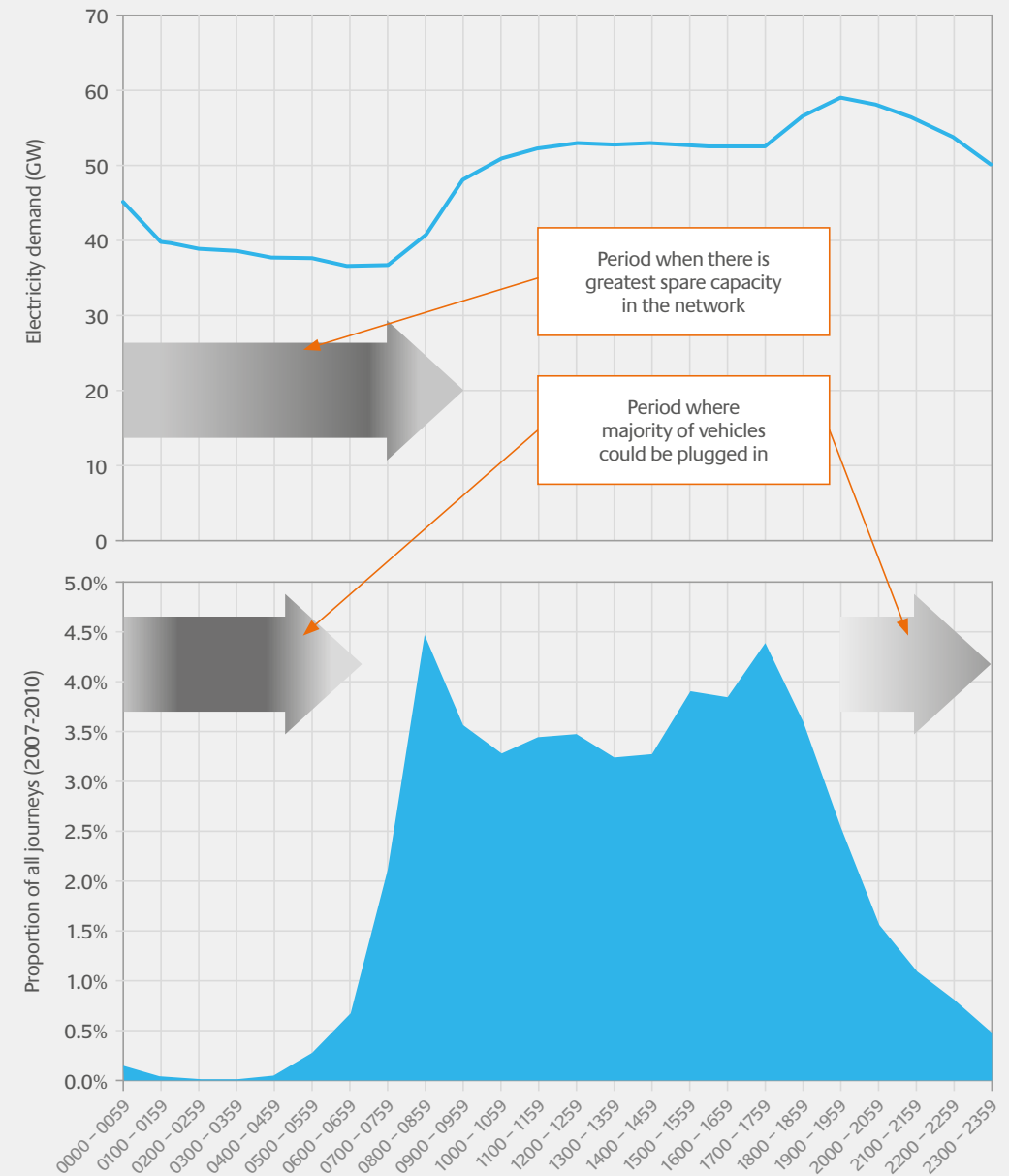
energy system as well as at charging and refuelling points and on-vehicle. This will be supported by insights from consumers and fleets into use of plug-in vehicles.

The second stage will deliver a trial involving over 300 mass market users to validate the impact of solutions identified in stage one and understand consumer and fleet responses to the vehicles and to managed charging schemes.

¹³ Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>



Figure 6
UK electricity demand over the course of a single day in 2010¹⁴ and arrival times of cars in the UK¹⁵



¹⁴ Based on data from Robert Sansom, Imperial College, (2011)

¹⁵ Batterbee, J. (2013). An affordable transition to sustainable and secure energy from light vehicles in the UK. [online]. Available at: <http://ow.ly/v0p7302IUMZ>

INTEGRATING WITH OTHER NETWORKS

Interactions with heat networks

Heat networks fed from combined heat and power (CHP) sources will produce electricity. In meeting variable heating needs, the amount of electricity produced, however, would at times far exceed local electricity demand. For the electricity to be cost-effectively utilised a concurrent electrical demand elsewhere would be required. With sufficient electrified heating (e.g. through heat pumps) there is the likelihood that such an electrical demand would occur over the same periods¹⁶. Viewing the need to meet electrified heating demands from an electricity-only perspective would place significant emphasis on investing in and building sufficient seasonal and peaking generation capacity. Taking a broader system perspective, however, highlights the opportunity for surplus and timely electricity from CHP systems, to offset the need for additional generation capacity.

With sufficiently decarbonised electricity there is the potential, in some locations, for technologies such as large-scale marine heat pumps to produce the heat for heat networks. The viability of this will depend on both the cost-effectiveness of the heat pumps by that point and there being sufficient electricity generation capacity. It will also require there to be sufficient capacity in the local electricity network to supply the heat pumps at the coldest times of the year.

ETI Project: EnergyPath Networks

A software tool to design cost-effective local energy systems for the UK.

Designed in partnership with local authorities.

Demonstrating the capability to create future-proof and economic local heating solutions for the UK.



Interactions with the gas network

Gas networks already interact with the electricity network with gas being a major source of electricity production and the gas transmission network, in particular, having to be able to respond to changes in electricity demand. Developments could lead to greater interaction at a more local level.

As highlighted in the **Increased capacity** section, the ability of heat pumps to practically meet peak heating requirements on the coldest days depends on the extent of building retrofits and constructing sufficient network and generation capacity. One solution that could emerge is gas being used as a backup to electric heating systems to help meet peak heat demands. This would involve the heat pump providing the bulk of heating needs and the gas boiler supplementing the heat supply when the electricity network was constrained. To sufficiently decarbonise there would be a limit to how much gas could be used in this way but this approach could reduce the need to reinforce the electricity network.

Greater integration between gas and electricity networks, particularly where this is driven by electricity network capacity constraints, will ensure this is as effective as possible. Smart energy solutions enabling greater cross-network control have the potential to play a major role here.

ETI Project: Multi-Vector Integration

This project aims to understand the opportunity for, and implications of moving to, more integrated multi-vector networks. This will include:

- > Identifying the ways in which different networks could interact, e.g. one network providing peak capacity support for another;
- > Determining how prominent these interdependencies could be;
- > Examining what the effects on each of the networks would be; and
- > Identifying any technology and/or operational opportunities that would facilitate any increased integration between vectors that may emerge



¹⁶ The size and climate of the UK mean that heat demands across the country broadly occur at the same time of day and year.

SUMMARY

The electricity network is set to have an increasingly important role in energy supply. As a result it is expected to face greater loads and will need to be able to serve rapidly growing demands in certain sectors. To do so it will need to be adapted and enhanced and, in particular, be able to handle increased capacity and deliver new connections. These changes will arise across the network but there remains a major challenge in identifying, where, when, in which way and to what extent to enhance the network. This will be particularly acute for the distribution network, where information on the existing state of the network is not as widely available.

Factors that will influence the need for adaptation and enhancement include:

- › variation in capacity growth requirements;
- › available physical space; and
- › land value

Options for adapting and enhancing the network include:

- › smart grid solutions;
- › fault current limiters;
- › energy storage; and
- › conventional reinforcement

To meet growing electrified demands, in particular for heat and transport, it will be

necessary to connect new and a greater number of sites. There will be network architecture choices for integrating, e.g., new types of generation, in new locations, and with higher capacity connections. There will be system level choices to be made accounting for trade-offs between resource availability and network cost impacts or between generation technology and network technology.

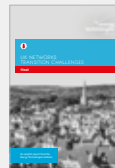
Electricity network operation will also become more important, with the potential both for more involvement in balancing supply and demand and for increased integration between networks to alleviate constraints elsewhere. Many of the policy issues relating to this are covered in the ETI's Enabling Efficient Networks insights¹⁷.

FURTHER READING



UK Networks Transition Challenges – A systems view

<http://www.eti.co.uk/insights/network-transitions>



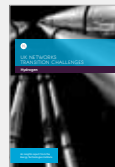
UK Networks Transition Challenges – Heat

<http://www.eti.co.uk/insights/network-heat>



UK Networks Transition Challenges – Gas

<http://www.eti.co.uk/insights/network-gas>



UK Networks Transition Challenges – Hydrogen

<http://www.eti.co.uk/insights/network-hydrogen>

¹⁷ Day, G. (2016). Enabling Efficient Networks. [online]. Available at: <http://www.eti.co.uk/library/enabling-efficient-networks-for-low-carbon-futures>

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