Future of Electricity Transmission

Seeking your views

JULY 2018

How to use this interactive document

To help you find the information you need quickly and easily we have published the *Future of Electricity Transmission* as an interactive document.

Home
This will take you to the contents page. You can click on the titles to navigate to a section.

Arrows
Click on the arrows to move backwards or forwards a page.

Hyperlinks
Hyperlinks are highlighted in bold throughout the report. You can click on them to access further information.

Your input is important. Help shape the Future of Electricity Transmission by providing comments, guided by our questions[1].

Please take the time to share your views with us by responding to our survey, which is available **here**.[1]

You can also email your feedback to **ivo.spreeuwenberg@nationalgrid.com** by 21 September 2018.

Contents

[1] https://www.surveymonkey.co.uk/r/foen_tx_ng

The transitioning to a low carbon economy, along with transforming how and where energy is produced and consumed, is happening. This impacts the way we plan, develop and manage the electricity transmission network.

This *Future of Electricity Transmission* discussion document sets out our initial views of the role of the electricity transmission network in facilitating the transition to the energy system of the future for our customers and consumers. Your input is key in helping us set the direction for the next price control period[2] and beyond.

As transmission owner (TO) in England and Wales, we sit at the heart of the nation's energy system and we're tackling some of the most pressing energy challenges. We own and manage the electricity transmission network in England and Wales, which comprises approximately* 7,200 kilometres (4,474 miles) of overhead line, 1,500 kilometres (932 miles) of underground cable and 342 substations. This network connects large scale generation and electricity markets in neighbouring countries, transporting electricity to the local distribution networks and ultimately end consumers.

Electricity generation is not spread evenly around the country relative to electricity demand and its availability is increasingly linked to the level of wind or sun as the system continues to decarbonise. Whilst some areas of the country will have a surplus of electricity production to local consumption at a given moment, others will have a deficit. These surpluses and deficits can exist for short periods, seasons or until longer-term developments take place.

The electricity transmission network interconnects these regional requirements, enabling the transfer of electricity from the generation source to the demand location and allowing consumers to access the lowest cost source of electricity whenever they need it.

In recent years we have seen significant changes in generation and consumption. With the rapid introduction of new technologies and business models, the electricity industry is experiencing fundamental change, with the opportunity to deliver great value for consumers and society overall. In this document we want to talk to you about what this could mean for the role of the electricity transmission network in facilitating the transition to the energy system of the future.

Progressing these changes in a coherent, coordinated way will be key to maximising the benefits for society. Your feedback is very important in directing our future business planning.

Please let us know your thoughts through the linked *survey* or at: *ivo.spreeuwenberg@nationalgrid.com*

Mark Brackley
RIIO-T2 Project Director

[2] Ofgem – Network price controls from 2021 (RIIO-2)
* AR 2016/17 figures

1. The changing electricity landscape

The shift towards a more decarbonised, decentralised and digitised electricity system is accelerating

The energy landscape in which we operate is undergoing a period of significant and rapid change as we move away from a historical reliance on large, centralised thermal power generation and price insensitive consumption towards a greater diversity of supply and flexibility of demand than ever before.

How energy is generated, transported and consumed is changing, driven by three main trends:

Decarbonisation – The transition to a low carbon future is changing the nature of the electricity system rapidly. This transition has been led by the electricity sector with a 60% reduction in greenhouse gas emissions in the last 4 years alone. Since 2011, we have seen around 15GW of fossil fuel powered generators close and disconnect from the system, predominately driven by government decarbonisation policies. Looking to the future, there is likely to be a considerable role for the electricity system in decarbonising both transport and potentially heat. The timing and pace of decarbonisation in these sectors is uncertain.

Decentralisation – Traditionally, electricity flowed from large transmission-connected generation, benefitting from economies of scale, through passive distribution networks to the end consumer. Advances in technology for smaller forms of generation in recent years, particularly solar, have driven significant changes in supply and demand patterns with greater amounts of electricity being produced closer to where it is consumed and distribution networks playing a more active role in managing power supply and demand regionally.

Digitalisation – The world is becoming increasingly connected, empowering consumers and disrupting traditional business models across almost every sector. Energy is no exception and we are only now starting to see changes to what has traditionally been a disengaged, price-insensitive market. New business models exploiting smart meter deployment, increases in the use of sensors, data collection and analytics (sometimes referred to as the ‘internet of things’) have the potential to transform the way we consume electricity. This will lead to both increased flexibility of demand and volatility. The evolution of this trend has not yet reached the point of rapid adoption typical of this type of change.

The changing energy landscape

2. Drivers behind this change

Many current trends are expected to continue, bringing more distributed generation, including fast distributed storage, more variability of supply, more interconnection with Europe, growth in electric vehicles and more flexible demand. These changes are being driven by a range of factors including:

1) Government policy – The Climate Change Act 2008 requires the UK to reduce emissions by at least 80% from 1990 levels by 2050. This, coupled with energy efficiency trends, is reducing overall demand. Financial support for low carbon technology (Contract for Difference, Renewable Obligation certificate, grants for new electric vehicles etc.) continues to support changes in these areas.

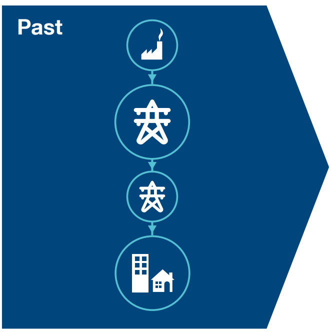
2) Rapid reduction in the cost of distributed generation – Since 2009, the cost of wind and solar PV generation has fallen 66% and 85% respectively. Similarly, energy storage solutions (batteries) have experienced similar, almost exponential, reductions in cost in recent years. Indications are that these trends will continue.[3]

3) Change in end consumer behaviour – The adoption of electric vehicles (EVs), increase in penetration of in-home technologies, smart tariffs and new retail business models are all changing end consumer behaviour.

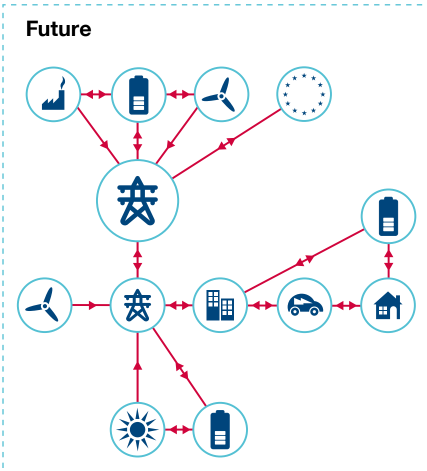
4) Advances in digital technology – Smart meter deployment and introduction of in-home energy management tools (e.g. Nest, Hive etc.) are transforming interactionwith the energy system.

The changing roles of networks – Decarbonisation, decentralisation and digitalisation are transforming the GB electricity system. In the past, electricity flowed from large transmission-connected generation to passive distribution networks. In the future, electricity will flow far more dynamically between transmission and distribution-connected parties including renewables, electric vehicles and battery storage while maintaining security of supply. The role of the networks is changing to facilitate this transition.

Q1: Do you agree that these are the main drivers of transformation and are there any other important drivers that we have not covered?



In the past, electricity flowed from large transmission-connected generation, through passive distribution networks to the end consumer.



The future power system will be a sophisticated and intelligent infrastructure, connecting a range of new technologies and more active consumers, while maintaining overall resilience and reliability.

[3] BEIS_Electricity_Generation_Cost_Report

3. Our approach to assessing long-term uncertainty arising from change

The previous two sections have described the technical, environmental, political and economic factors, coupled with customers' evolving needs and expectations. These factors introduce future uncertainty and affect the entire energy value chain; the way energy is produced, transported and consumed.

Against this backdrop, we are facing three key uncertainties on the future role of the electricity transmission network:
- Uncertainty over **WHAT** will happen
- Uncertainty over **WHEN** it will happen
- Uncertainty over **WHERE** it will happen

In today's complex environment, organisations regularly make difficult strategic decisions against an uncertain future and established frameworks exist for how to think through this uncertainty.[4] The use of scenarios that set out a range of credible futures is a common tool and the Future Energy Scenarios (FES)[5] are integral to existing processes that make decisions in the short to medium term, as well as the starting point for our longer-term thinking covered in this document.

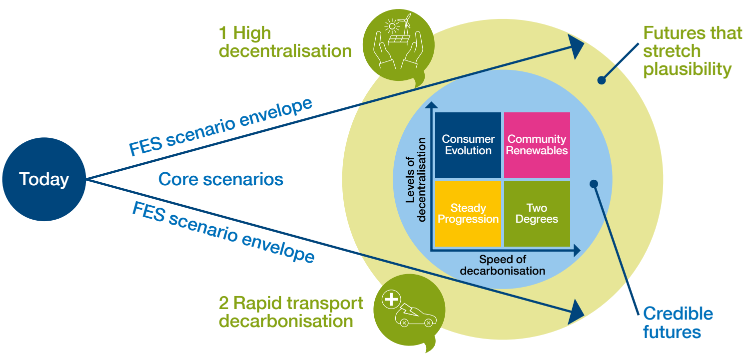
The electricity system operator develops the FES via extensive consultation and analysis of the overall energy system and how it might have to develop out to 2050 to meet the UK's greenhouse gas emissions targets.

The underlying analysis for FES 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.

In the short to medium term, FES is used alongside Least Worst Regret and Cost Benefit Analysis in the Network Options Assessment (NOA) process.[6] The NOA process assesses options to meet capability requirements on the electricity transmission system, recommending which options and when they should go ahead to maximise consumer benefit.

We want to ensure that processes already in place to manage uncertainty in the short to medium term are robust against the role of transmission in the longer term. To do this, we have used two additional sensitivities that stretch plausibility to stress test some of the key industry trends beyond the core FES envelope: (1) High decentralisation and (2) Rapid decarbonisation of transport. Our approach to considering longer-term uncertainty is summarised by the illustrative diagram below.

Q2: Do you have any suggestions for how we might improve our approach to uncertainty? Have we missed anything?



[4] https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/strategy-under-uncertainty
[5] http://fes.nationalgrid.com/
[6] https://www.nationalgrid.com/uk/publications/network-options-assessment-noa

High decentralisation

One sensitivity used to assess the future role of electricity transmission is an extreme case of a highly decentralised future, suggesting rapid growth of distributed renewables, consumer flexibility and a significant reduction in large capacity generation.

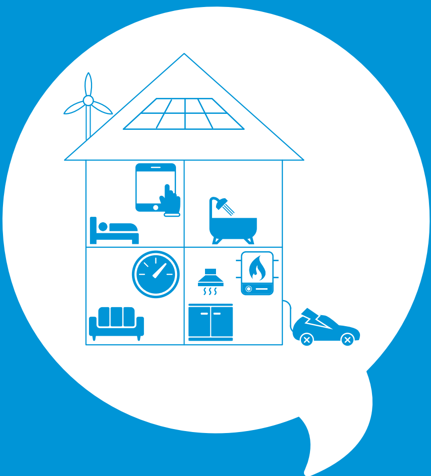
20% reduction in transmission peak demand, from current level

63 GW of solar generation
5-fold increase that is almost exclusively distribution connected

42 GW of energy storage
All distribution connected and co-located with wind and solar or at point of consumption

65 GW of wind generation
4-fold increase in installed wind capacity. Majority distribution connected in England & Wales

What would you need to believe in this future?



Almost all domestic and commercial consumers become prosumers by installing small scale renewable generation

Batteries provide wider consumer benefits in a decentralised future driven by significant reduction in cost

Majority of buildings act as mini power stations

A number of different commercial models have evolved to facilitate more flexible demand

Decarbonisation of transport

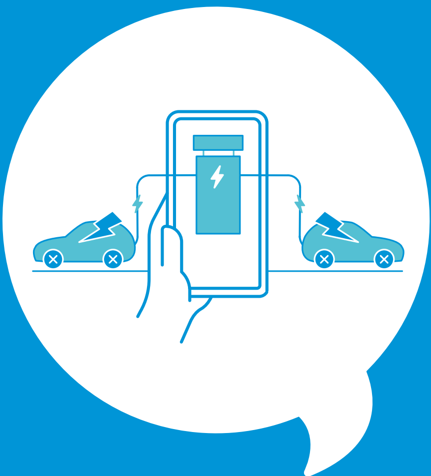
Another sensitivity used to assess the future role of electricity transmission is an extreme case of a decarbonisation of transport, suggesting rapid adoption of electric vehicles coupled with significant volume of distributed generation and consumer flexibility.

Peak demand sees additional 24 GW by 2040

50% of installed generation connected at local distribution network

EV uptake to reach 100% of passenger car sales by 2040 which represents almost 40 times increase from current sales

What would you need to believe in this future?



Private ownership of personal vehicles remains popular. Hybrid car sales reach zero by 2025 and pure electric vehicle sales reach 100% by 2040

Limited use of smart charging and vehicle to grid and automation (2/3s of homes have off-road charging with 1/5 of homes used for peak charging)

There is a greater role for natural gas and hydrogen powered vehicles, particularly in the commercial sector

Consumer transport behaviours remain consistent with today (7,900 average annual mileage)

4. Major trends for transmission

The challenges that networks face in facilitating the energy transition are diverse. From our analysis of the core FES scenarios[7] and additional, stretching sensitivities, **four common, major trends are seen for the electricity transmission network:**

1) Transmission peak demand declines in the 2020s driven by greater energy efficiency and increased distributed generation (generation of electricity close to where it is consumed). Underlying system demand recovers to differing degrees in 2030 as electrification of transport and heat rolls out.

2) Changes in supply connections, including new transmission connected generation, interconnectors and considerable increases in distributed generation. Battery storage offers some ability to match renewable generation output and consumption, but geographic variations in generation/ demand persist.

3) Greater extremes in power flows become the norm and this volatility will need to be managed. Rapid changes in power output from different types of generation and differences in power prices between Great Britain and Europe result in flows on the network changing direction quickly and potentially exceeding capabilities unless controlled.

4) Operability challenges likely across all scenarios driven by the increase in intermittent, non-dispatchable and low inertia generation and its changing location.

Although some impacts are common across the range of future scenarios the rate and magnitude at which they could materialise varies, affecting the extent of investment needed across upcoming decades. The rate and magnitude at which the different impacts could materialise is shown in the illustrative diagram below.

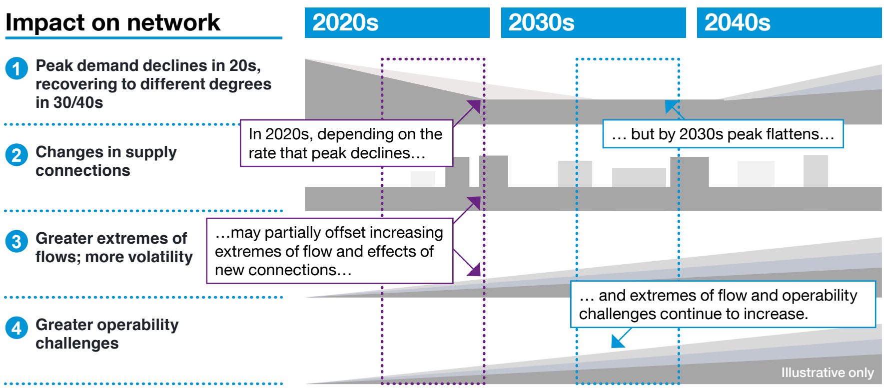
We have set out three overarching questions to explore the future role of the electricity transmission network:

1) Is the electricity transmission network needed in a highly decentralised world?

2) Could the current transmission network be a blocker to rapid growth in electric vehicles?

3) How does the transmission network need to evolve to facilitate the energy transition?

Q3: Do you think the scope of our analysis sufficiently captures the challenges we face? If not, please suggest additional questions you would like us to answer.



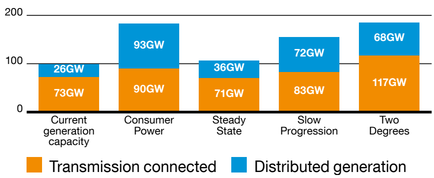
[7] Our analysis in this document is built on FES17 data

5. Assessing the need for the electricity transmission network

Supporting the energy transition is not only about facilitating flexibility, increasing interconnectivity, data and real time operation but it is also about considering the role and requirements of the wider electricity system. The key concerns associated with traditional network operation and design philosophy are related to economic efficiency and balancing the cost of operation and network infrastructure against the security benefits delivered to customers. In this context, we have looked at the future need for the transmission network by analysing a range of different futures, including the extreme case of a highly decentralised future.

Connecting large capacity users

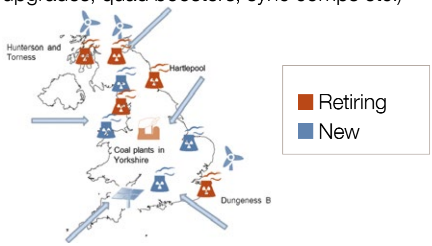
One of the key roles of the transmission network is to enable access to the electricity market and facilitate competition in wholesale and retail markets. A level of decentralisation is evident across all scenarios but even in the most extreme case, with 60% of generation capacity decentralised by 2050, a significant amount (~50 GW) of large plants will still be required to meet electricity demand and further decarbonise the system. This large generation capacity will predominately include low carbon generation, such as offshore wind and nuclear power, as well as gas fired generation that require transmission network access to participate in the market due to their size.



Diversified location of new capacity

Another key role of the transmission network is to maintain system integrity, ensuring the supply of electricity is available when and where it is needed.

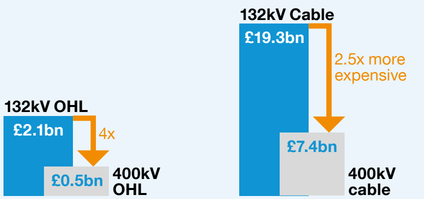
Although peak electricity demand is falling over the coming decade, the diversified geographic location of new large capacity, more variable sources and increasing interconnection will drive the continuing need for the transmission network. Whole system solutions are required to cope with operability challenges e.g. provision of additional or upgraded transmission assets (protection upgrades, quad boosters, sync comps etc.)



Conclusion 1:
The transmission network is required to provide cost effective access for large capacity generation, increased interconnection and the continued decarbonisation of supply.

Why transmission network for new capacity?

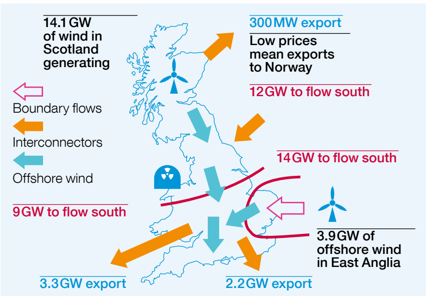
High power output from large capacity generation requires the large conductor sizes of the transmission network to export energy in a cost effective way over long distances. Technically, it is possible to use the distribution network, but for carrying large flows, higher voltage transmission is more efficient, creates less disruption and has lower environmental impact. We have compared total lifetime costs of providing large capacity reinforcements (7 GW over 73km) which shows the transmission network to be four times cheaper for overhead lines and 2.6 times cheaper for underground.



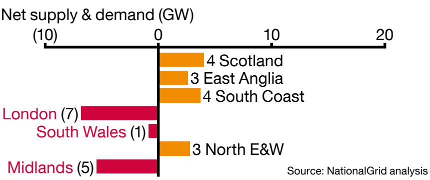
6. Assessing the need for the electricity transmission network – case studies

We have conducted analysis on a range of specific case studies within the highly decentralised sensitivity to assess the role of the transmission network. This sensitivity is used as the one most likely to have the least need for the transmission network in future. The way we have assigned the level of decentralisation by technology type and spread demand and generation across the country has been done to better understand regional impacts and push the boundaries as far as possible in a highly decentralised world:

1) High wind and low solar – December, 1am, 2030 – Under this case study, large volumes of wind power in Scotland and the North of England flow south to meet demand in large urban centres.



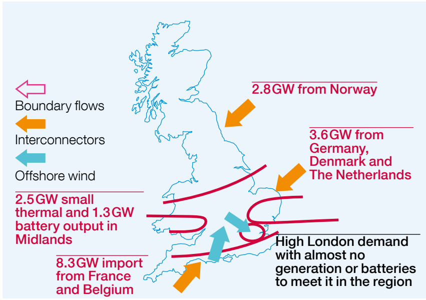
Our analysis shows Britain exporting power to Europe over the interconnectors due to the low relative wholesale prices arising from high wind generation output.



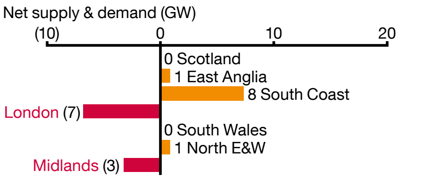
Source: NationalGrid analysis

On a more granular level, even with significant amounts of energy storage included in this scenario, areas of energy surplus and deficit are significant and efficient transfer of bulk power across regions is still needed.

2) Low wind and low solar – summer, 10pm, 2030 – With low wind output, significant import via interconnectors occurs to match supply and demand.



In this study, low demand in non-urban areas (East Anglia and South Wales) is being supplied within region by batteries and small thermal generation. However, some areas (Scotland and North England) still need additional capacity via interconnectors (e.g. 2.8 GW from Norway). On the other side of the spectrum, the Midlands, despite 1.3 GW of battery output, is unable to self-balance[8] and remove the need for imports into the region.



To conclude, greater regional self-sufficiency exists in the highly decentralised sensitivity but big population areas such as London and Birmingham struggle to self-balance, while the South Coast shows a significant surplus (driven by imports from Europe).

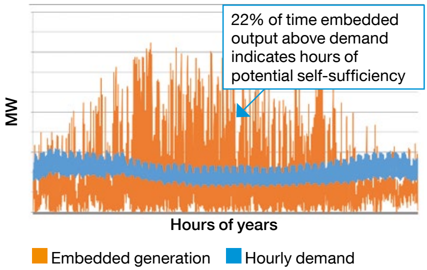
Conclusion 2:
The bulk power transfer capability of transmission will still be needed to ensure consumers can access the cheapest sources of electricity at all times.

[8] Ability of the region to maintain the balance between generation and demand

6. Assessing the need for the electricity transmission network – case studies

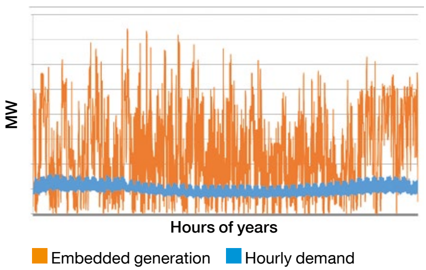
In previous case studies we looked at specific points in time. In the following study we consider each hour across a year.

South West England, 2037 – Under this case study we have analysed the ability of a region with considerable solar potential to self-balance across the year using only local, embedded supply sources (10GW of solar and 1GW of embedded wind).



The graph above shows that the wind and solar output (embedded generation) alone is insufficient to meet hourly demand 78% of the time (i.e. when the orange trace is below the blue trace), with the worst shortfall reaching 3GW.

To further stretch this study, we repeated the same analysis with an additional 9GW of embedded wind capacity. As expected, the regional ability to self-balance increases, however 26% of the time embedded generation output was still insufficient to meet demand, with the worst shortfall unchanged at 3GW.



Finally, we investigated if installing batteries, like those used in South Australia, could be an option to allow a region to become self-sufficient. To meet the observed maximum shortfall of 3GW would require the installation of 24 130MWh batteries.

Based on their current design and capacity, the batteries would be able to cover the energy shortfall for an hour. However, the study showed that the largest concurrent period of local energy shortfall could be over four days long. Even with a projected 70% fall in battery costs over the next 20 years, it would be more economical to maintain existing transmission assets rather than seek to make local areas totally self-sufficient. This would afford the added benefit of being able to sell excess renewable generation output to other regions/ countries at times of surplus.

Q4: Are the case studies we have considered sufficiently challenging? If not, please suggest additional case studies.

Conclusion 3:
Areas of regional energy surplus and deficit are likely to remain. The transmission network will be needed to ensure electricity is there when consumers want it.

Despite future uncertainty, National Grid's analysis of a sensitivity that pushes the boundaries of trends that reduce reliance on the electricity transmission network indicates that it will continue to play a role in enabling cost efficient transfer of power and maintaining energy system resilience and robustness into the future.

Q5: Do you agree with our key conclusions on the need for the network? Why?

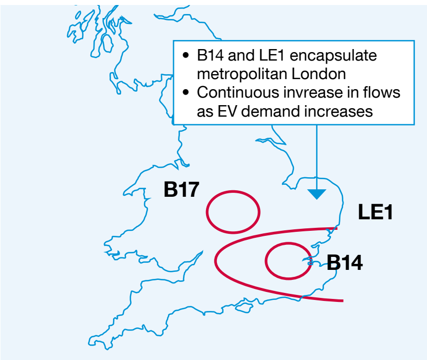
7. Could the transmission network be a blocker for a rapid EV roll-out?

The momentum behind the shift towards decarbonisation of transport, realised largely through Electric Vehicles (EVs) is considerable, especially with the UK Government's commitment to stop all sales of petrol and diesel cars by 2040. It is likely that this will result in some increased demand for electricity. Our analysis explores whether the electricity transmission network could act as a blocker to this shift.

Decarbonisation of transport, 2040 – We have conducted our analysis using a rapid decarbonisation of transport sensitivity built from the FES17 Consumer Power scenario. With EV sales reaching 100% by 2040, and limited use of smart charging (as a worst case), our analysis shows that additional system peak demand could grow 1.3GW a year. In order to better understand the impact on the network and to allow for a more nuanced localised view, we have:

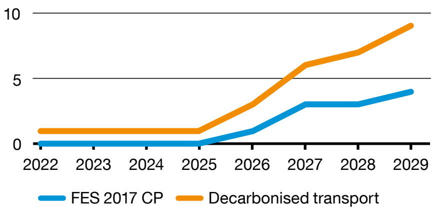
- allocated additional EV demand using the distribution of current vehicle ownership by UK post code, and
- assumed EV ownership demographics remain consistent with internal combustion engine car ownership today.

Output from our work suggests that, despite significant demand growth, the impact on the transmission network is relatively small in the short term and is mainly concentrated on southern areas (boundaries B14, B17 and LE1) of the network, with flows slightly above the core FES scenario.

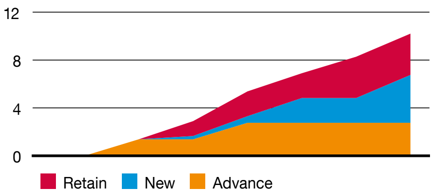


On a more granular level, our analysis also indicates a relatively small increase in the need for demand and generation connections when compared with the core FES scenario.

Transformer growth



Additional capacity (GW)



Even in a world with rapid EV uptake, and only limited smart charging, initial results suggest a modest impact on the electricity transmission network in the near term which can be managed through existing processes and mechanisms.

Conclusion 4:
The electricity transmission network will not be a barrier for a rapid decarbonisation of transport.

However, if a sudden tipping point in EV growth were to occur, there is a residual risk of bottlenecks and consequential high system management costs. To prevent this from happening, the energy industry needs to evolve to give customers clear messages and to better anticipate load growth.

Q6: Do you agree with our key conclusions on decarbonisation of transport? Why?

8. How do networks need to evolve?

Continued efforts to decarbonise our society will lead to the electrification of transport and, to some extent, heat, as well as changes in consumer behaviour which in turn will drive the need for the energy system to evolve. In this context, we have looked at how the electricity transmission network needs to evolve to satisfy the needs of end consumers.

Broadening of network power flows

To understand the impact of these trends on the electricity transmission network we have analysed power flows across key circuits making up the main network boundaries.[9] The outputs of our analysis, presented on the graphs below, show how often the flow of power across these boundaries is at a particular level. Flows outside the red dotted lines represent those exceeding the capacity of the boundary considered (known as ‘constraints’). Constraint management is performed by the electricity system operator and involves market instruction to increase and decrease the amount of electricity at different locations on the network with the cost passed to the consumer.

Key observations:

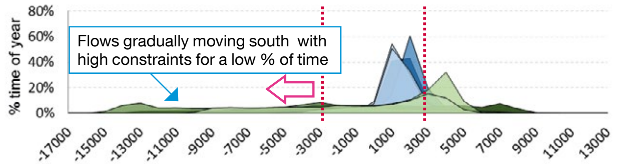
- Today, power flows across the electricity transmission network are relatively consistent, with greater predictability and limited variation (they spend a greater % of the year at a given level – the blue shaded areas of the graph).
- By the mid-2020s, we are seeing a much wider range of possible flows across all boundaries and significantly higher import flows from neighbouring markets as interconnection capacity grows.
- By the mid-2030s, flows become more volatile (less % of year at a given level – the green shaded areas of the graph), extreme (greater variance in levels) and with a significantly greater incidence of flows from south to north.

Conclusion 5:
The diverse geographic location and variability of supply sources and new points of connection are creating new operability challenges when managing the network.

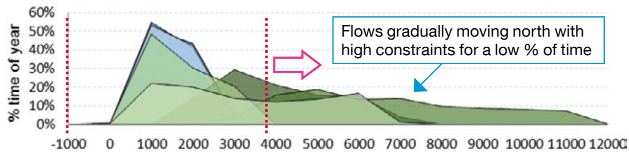
Boundary	Boundary flow impact

2018 CP 2018 GG 2018 NP 2018 SP 2018 CP 2018 GG 2018 NP 2018 SP ··· Boundary capability

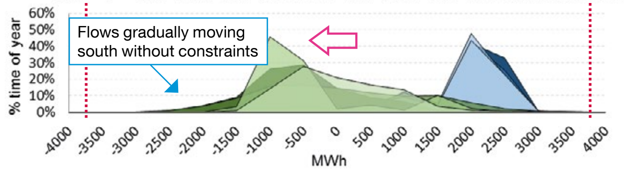
2700 MW boundary capability



3840 MW boundary capability



3940 MW boundary capability

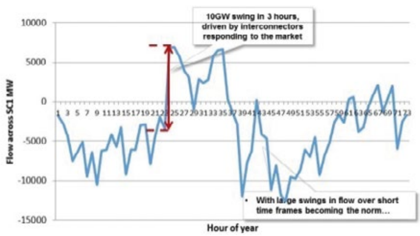


[9] A boundary splits the system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered.

9. Greater operability challenges

As the owner of the electricity transmission network in England and Wales, we are obligated to design the network so that it remains operable across a range of possible system conditions. We are seeing the measures needed to meet this requirement become more onerous over time as the growth of new technologies and a changing energy landscape creates a much more dynamic and complex whole energy system.

In addition to the broadening of power flows explored in the previous section, swings in flows can occur from one direction to the other in a matter of hours, due to changes in market price between GB and Europe[10], creating significant operability challenges for the electricity system operator to manage.



Overall, operability challenges are observed across all scenarios. These include volatile power flows, voltage management, security of supply, provision of Black Start, system inertia etc.

Whilst the challenges around operability can only be efficiently solved with contributions from each part of the energy system, we looked at the ability for the transmission network to help with the different challenges. These are set out in the figure at the bottom of this page.

It's clear that meeting the needs of the future energy system will require extensive collaboration across industry. We are actively taking part in The Electricity Networks Association (ENA) Open Networks Project, which is a major energy industry initiative that will transform the way our energy networks work, underpinning the delivery of the smart grid. This project provides the platform for industry participants to share experience and coordinate the transformation of our networks and markets to operate efficiently in a more decarbonised, decentralised and digitised world.

Conclusion 6:
The electricity transmission network is an important tool, in a range of solutions, to manage operability challenges in the most cost effective way for consumers.

Q7: What is your view on the role of the electricity transmission network in offering solutions to operability challenges?

Increasing operability challenges for the SO	Differing ability for the TO to help control
Ensuring security of supply • Network reliability • Facilitating system access	• **Strong role for TO:** coordinating network development and operation to ensure security of supply
Managing voltage • More Distributed Energy Resources (DER), lower transmission (Tx) flows • Higher volts • Demand more capacitive	• **Role for TO:** provision of reactors and availability of circuits for switching
Providing Black Start • Fewer conventional gas turbines • Geographic divergence	• **Role for TO:** provide set-point voltage control and stable demand as part of restoration strategy
Maintaining frequency • Less synchronous plant • More DER: fewer incentives and routes-to-market for services	• **Some role for TO:** in extreme situations can support e.g. switching out circuits to lower demand
Managing inertia • Less synchronous plant	• **Potential role for TO**

[10] Behaviour of interconnectors dependent on European markets – more detailed 'sensitivity' modelling may be required to test impact further

10. Transmission network reinforcement

Historically, transmission network reinforcement was driven by increases in peak demand. With projected declines in demand in the 2020s, some would expect the need for network reinforcement to also disappear.

Nevertheless, retirement of existing generation, the dispersed location of new generation and the resultant change in power flows on the network are likely to drive some need for reinforcement to minimise costs to consumers.

We have analysed the impact on network constraint costs across a range of possible futures if we were to stop reinforcing the transmission network from the start of the next price control (2021) and only continue necessary maintenance of existing assets.

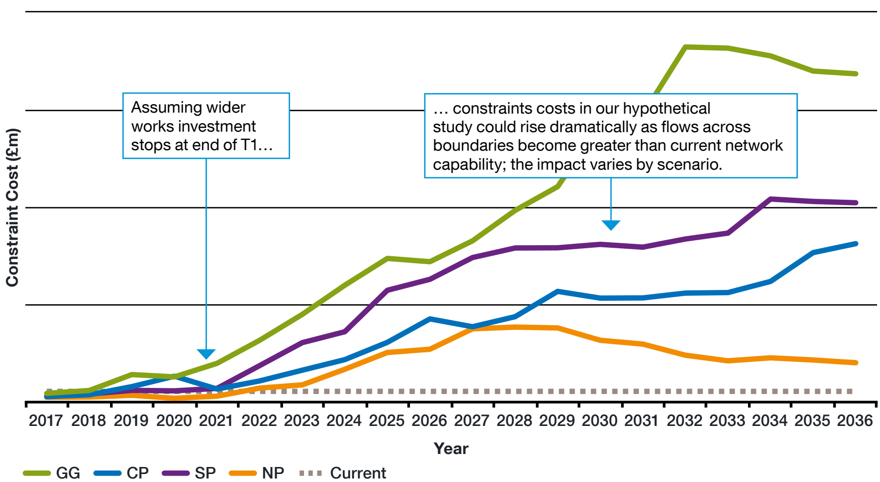
The chart below shows that constraint costs could rise dramatically in this hypothetical situation as flows across boundaries become greater than current network capability (and more expensive generation needs to be dispatched by the electricity system operator). This indicates managing constraints simply through operational measures is not optimal or efficient for consumers over time and that transmission network reinforcement could be beneficial by avoiding persistent future constraint costs.

Exact timings and need for reinforcement or alternative, non-network solutions vary depending on scenario (as illustrated below). It is the electricity system operator's role to assess the network each year and signal whether reinforcement or operational measures are best value to the consumer through the Network Options Assessment.

Meeting the needs of the future system at the lowest cost to the consumer will require the use of all options available for managing transmission system issues and greater collaboration across the industry. Whole system thinking and cross vector operability are essential to ensure a least cost transition to a low carbon world and maximise the benefits delivered to consumers through this transition.

Conclusion 7:
Whole system thinking and cross vector operability are essential to ensure a least cost transition to a low carbon world; doing nothing is unlikely to be in consumers' interests.

Q8: Do you agree with our conclusions that whole system thinking is essential?



11. Value of retaining optionality

In previous sections we have seen that radical changes to the supply and demand characteristics of the electricity system are creating different power flows on the network.

Considering the forecast fall in peak demand in the medium term, utilisation of the network will drop in certain areas, perhaps even to below existing network capability across an entire year of operation. This opens the question of whether we could decommission some elements of the transmission network?

As a prudent Transmission Owner, we consider the decommissioning of assets when cost effective to do so for current and future consumers. Both practical and security of supply considerations are needed before making a final decision.

In certain circumstances, when a sole-use customer disconnects from the network and the connection is no longer needed, we will proceed with removal and reconfiguration after considering the overall cost benefit of doing so.

On the other hand, maintaining existing assets represents a fraction of the cost of rebuilding those same assets. For example, maintaining single sections of overhead line typically costs approx. £1m/km p.a., whilst decommissioning can cost in excess of £5m, and re-building can cost more than £100m (provided planning consent can be achieved).

With expected recovery of underlying system demand in the 2030s and considerable uncertainty around future network flows, decommissioning before end of life could create large regret cost.

The delay of decommissioning investment until we have greater certainty over whether it will be truly beneficial in the medium to long term may mean it is avoided altogether, if new customers or new load arrives.

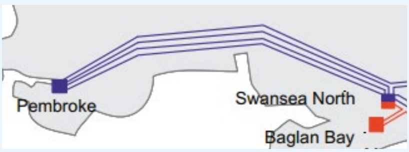
Meanwhile, assets provide additional value for management of the system, reducing constraint costs and outage payments.

Conclusion 8:
Given the level of uncertainty around future pathways and relative low cost of maintenance, it is in consumers' interests to leave the option of existing infrastructure open.

Q9: Do you believe that the option for future use of existing infrastructure should remain open?

Is maintaining or decommissioning the lowest cost solution?
The overhead line circuit between Pembroke and Swansea North consist of 4 circuits and it is possible to remove one circuit and still maintain required security standards. We have looked at a theoretical cost benefit across four scenarios, including decommissioning with no re-build and rebuild required after 10 or 20 years versus the cost of maintaining the circuit.

Our analysis shows that maintaining assets is the lowest cost solution for consumers across all four scenarios. When re-build is required, the case is clear cut. Even in a world where future customers or demand do not materialise and re-build is not required the costs of maintenance are less than that of decommissioning in this example.



Potential futures	Present Value constraints	Present Value costs	Present Value total
Maintain 4 cts	£0m	£38m	£38m
Decommission 1ct and rebuild in 20yrs.	£9m	£115m	£124m
Decommission 1 ct and rebuild in 10yrs.	£4m	£145m	£149m
Decommission and no rebuild (maintain 3 cts)	£17m	£46m	£63m

Summary of our conclusions

The UK energy sector is changing at an unprecedented pace and we are facing a major challenge in identifying where, when, and to what extent to evolve the network as a result. To think through uncertainty we have adopted a robust approach which is being influenced and developed together with our stakeholders. Building on our analysis, we set out a number of conclusions to help us answer the overarching questions we set up front. We believe that the future role of the electricity transmission network can be defined in 3 key conclusions set out in the diagram below.

	1	2	3
Overarching questions	**Is an electricity transmission network needed in a highly decentralised world?**	**Could the current transmission network be a blocker to rapid growth in electric vehicles?**	**How does the electricity transmission network need to evolve to facilitate the energy transition?**
Key conclusions	**Despite uncertainty, the continuing need for a transmission network is evident.**	**The transmission network will not be a barrier for rapid growth in electric vehicles.**	**Whole system thinking and cross vector operability are essential to ensure a least cost transition to a low carbon world.**
Conclusions	**1 –** The transmission network is required to provide cost effective access for large capacity generation, increased interconnection and the continued decarbonisation of supply.	**4 –** The electricity transmission network will not be a barrier for a rapid decarbonisation of transport.	**5 –** The diverse geographic location and variability of supply sources and new points of connection are creating new operability challenges when managing the network.
	2 – The bulk power transfer capability of transmission will still be needed to ensure consumers can access the cheapest sources of electricity at all times.		**6 –** The electricity transmission network is an important tool, in a range of solutions, to manage operability challenges in the most cost effective way for consumers.
	3 – Areas of regional energy surplus and deficit are likely to remain. The transmission network will be needed to ensure electricity is there when consumers want it.		**7 –** Whole system thinking and cross vector operability are essential to ensure a least cost transition to a low carbon world; doing nothing is unlikely to be in consumers' interests.
			8 – Given the level of uncertainty around future pathways and relative low cost of maintenance, it is in consumers' interests to leave the option of existing infrastructure open.

Getting involved

We hope that you have found our analysis on the future of electricity transmission interesting, informative and thought provoking. Your views are important to us.

Your feedback is an important part in setting the direction of travel and moving the debate forward. We welcome your views on all aspects of our approach to thinking through uncertainty and the future role of electricity transmission. We have listed some specific questions on the next page to provide structure but we would be interested to hear any feedback on the issues and proposals raised in this document either through the linked survey or to the following email address
Ivo.Spreeuwenberg@nationalgrid.com

We are also happy to meet you directly or at other events, such as trade association meetings. Please get in contact if you would like to discuss your thoughts with us.

We will also be continuing the conversation on this topic through a webinar on Wednesday 15 August. If you are interested in attending, please sign up **here**[11].

We will collate your responses to this document and give an update on our proposals by the end of September 2018.

Q10: How have you found this document? How can we help you engage in this topic more effectively?

[11] https://www.eventbrite.co.uk/e/future-of-electricity-transmission-webinar-tickets-48408558301

Getting involved

Future of Electricity Transmission consultation questions[12]

Please take the time to share your views with us by responding to our survey, which is available **here**.[1]

You can also email your feedback to **ivo.spreeuwenberg@nationalgrid.com** by 21 September 2018.

Q1: Do you agree that these are the main drivers of transformation and are there any other important drivers that we have not covered?

Q2: Do you have any suggestions for how we might improve our approach to uncertainty? Have we missed anything?

Q3: Do you think the scope of our analysis sufficiently captures the challenges we face? If not, please suggest additional questions you would like us to answer.

Q4: Are the case studies we have considered sufficiently challenging? If not, please suggest additional case studies.

Q5: Do you agree with our key conclusions on the need for the network? Why?

Q6: Do you agree with our key conclusions on decarbonisation of transport? Why?

Q7: What is your view on the role of the electricity transmission network in offering solutions to operability challenges?

Q8: Do you agree with our conclusions that whole system thinking is essential?

Q9: Do you believe that the option for future use of existing infrastructure should remain open?

Q10: How have you found this document? How can we help you engage in this topic more effectively?

[12] https://www.surveymonkey.co.uk/r/foen_tx_ng

Continuing the conversation

Join our mailing list to receive email updates for *Future of Electricity Transmission* and other *RIIO2* related updates.

Share your views by responding to our survey **or sending us an** email**.**

Keep up to date on key issues relating to National Grid via our Connecting website: http://yourenergyfuture.nationalgrid.com/

You can write to us at:
RIIO2 team, Block D3
National Grid House
Warwick Technology Park
Gallows Hill
Warwick CV34 6DA

YouTube National Grid UK

Twitter @nationalgriduk

LinkedIn National Grid

Facebook NationalGridUK

nationalgrid

National Grid plc
National Grid House,
Warwick Technology Park,
Gallows Hill, Warwick.
CV34 6DA United Kingdom
Registered in England and Wales
No. 4031152

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