DEPARTMENT OF ENERGY & CLIMATE CHANGE

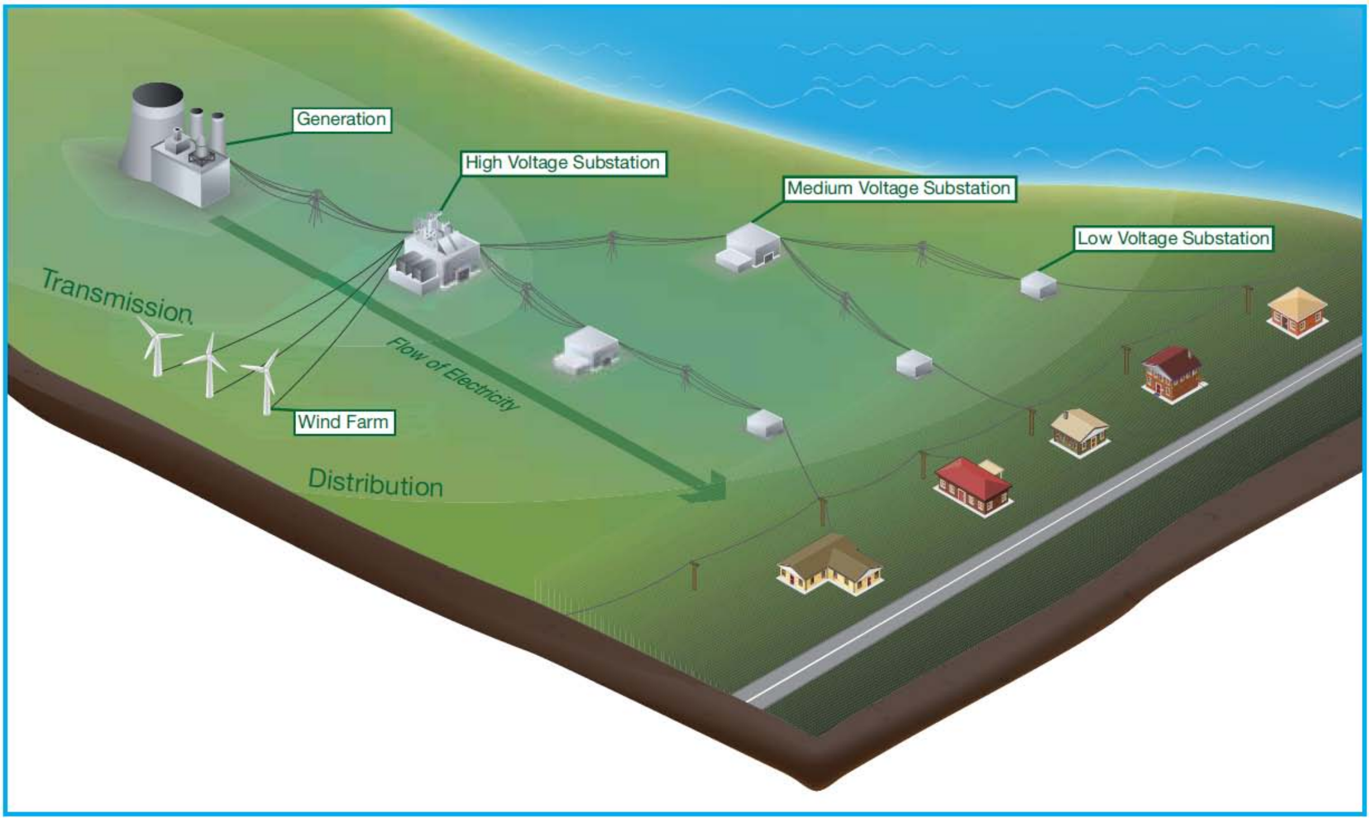
Electricity System: Assessment of Future Challenges - Summary

9 August 2012

The GB Electricity System

1. The primary aim of the electricity system is to generate and transmit electricity according to where and when it is demanded. Ensuring that supply and demand are always in balance, and therefore the integrity of the system is protected, currently relies primarily on the availability of sufficient generation that is predictable, controllable and can be operated flexibly in order to react to fluctuations in demand and supply shocks. It also requires a fit for purpose network to ensure that electricity can be moved around the system efficiently and securely.

2. In Britain, power stations are built by private companies under a liberal market and the electricity they produce is traded in bilateral trades or through power exchanges to energy suppliers, which are also private companies. Consumers buy their electricity from the suppliers and can also sell electricity to the suppliers in the case of surplus they may generate themselves from distributed generation (such as solar panels).



3. The network we currently have has two distinct parts: the transmission network and a number of regional distribution networks. The transmission network carries power at high voltages (between 275kV[1] and 400 kV) over long distances. There are also 14 regional distribution networks in Great Britain. In these distribution networks the voltage of electricity from the transmission network is reduced down through a series of transformers to the 230 volt supply that reaches most homes and businesses.

[1] In Scotland and offshore, voltages of 132kV and over are defined as transmission.

4. The GB electricity system is facing significant challenges over the coming years and decades as we seek to transform the UK into a low carbon economy and meet our 15% renewable energy target by 2020 and our 80% carbon reduction target by 2050. The generation mix will evolve from a mix dominated by large power stations providing predictable and mostly flexible electricity to a mix with a significantly greater proportion of variable and less flexible generation.

5. Demand profiles will also change. The level of electricity consumption will increase due to the expected electrification of heat and transport. Daily peaks and troughs are likely to become more extreme. The locational profile of demand will also change as residential demand increases to power cars and heat homes.

Figure: An example of the current demand profile (red line) and generation mix, on an average winter day.

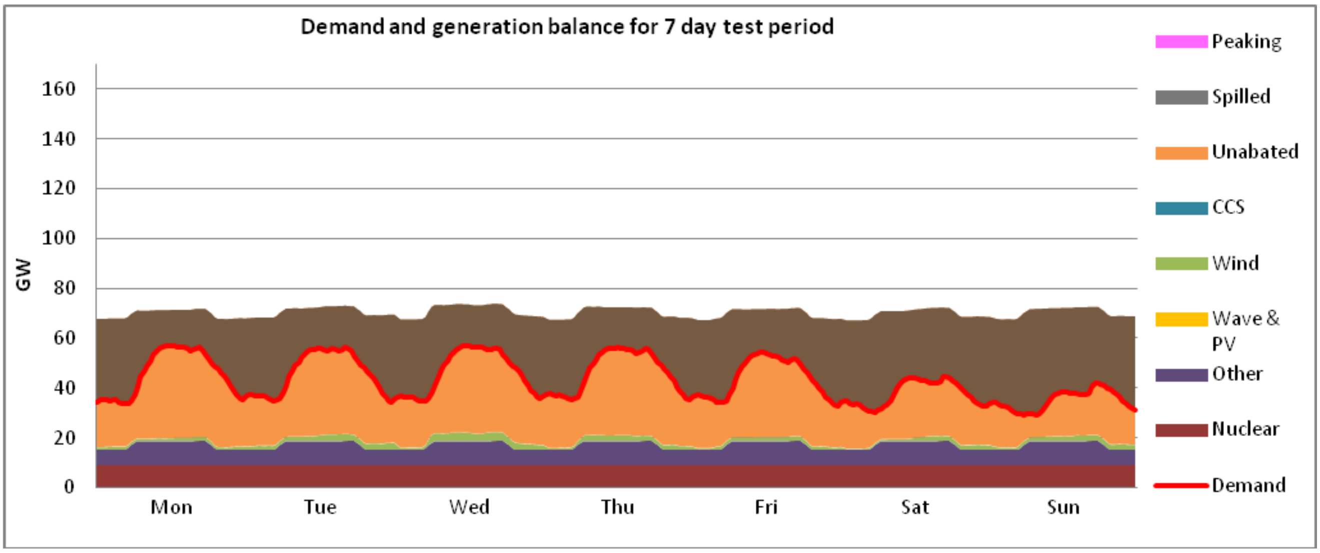
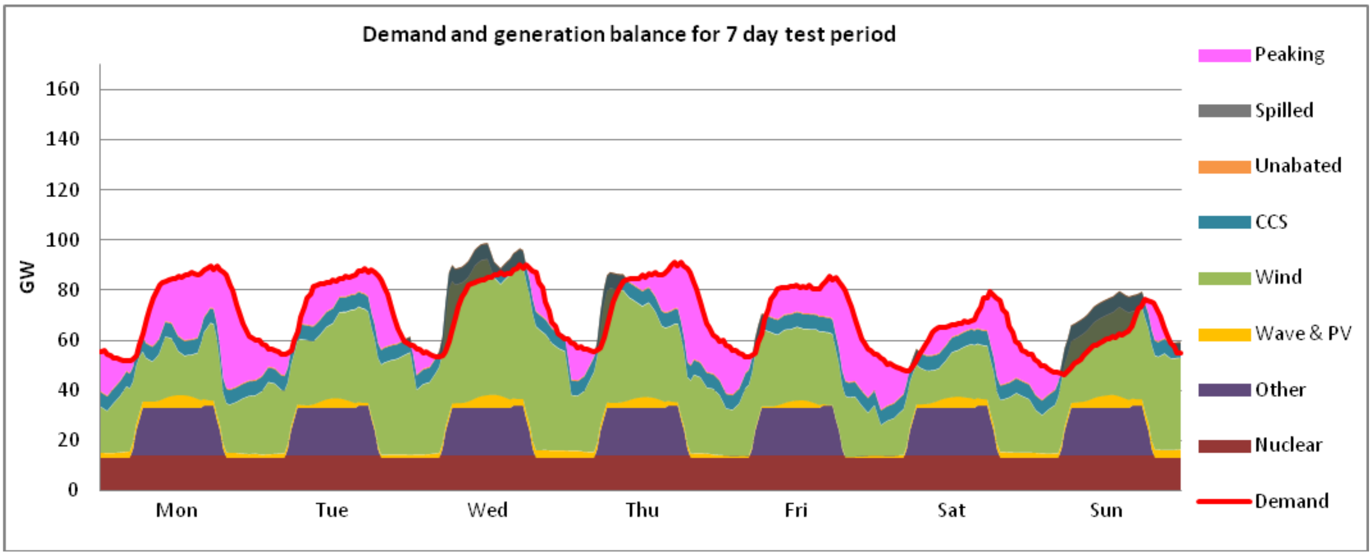


Figure: *illustrative example of a potential 2050 demand profile (the red line) and generation mix, taken from the Higher Renewables Carbon Plan 2050 future on an average winter day.*



Balancing Technologies

6. Increasingly, technologies that can be used to help balance the supply and demand of electricity (demand side response (DSR), electricity storage and interconnection) and smarter networks are likely to be required to help match the supply and demand of electricity efficiently and cost-effectively under the changing generation and demand profiles highlighted above.

Demand Side Response (DSR)

7. DSR is an active, short-term reduction or shifting in consumption of electricity at a particular time.

8. In a world where there is going to be more intermittent and inflexible generation, DSR can be used to help balance supply and demand of electricity by providing system flexibility, especially at times when customer demand and availability of variable renewable generation pull in opposite directions (i.e. demand is increasing while availability of variable renewable generation is falling to a minimum and vice versa). This could be achieved by self-supplying using local backup generation, or by not using the electricity at that time, reducing the need for peaking plant and network reinforcement. In this way, DSR can reduce the total capacity needed on the system, and reduce the need for generation capacity to meet peaks in demand.

Storage

9. Storage has the technical ability to provide a number of benefits to the electricity system – for example, by smoothing supply profiles from variable generation and potentially reducing constraint costs by allowing generation to run during periods of low demand. It can also potentially save or defer network upgrade costs that may be required in the future to meet peak demand.

10. There are two main ways to deploy storage. Bulk storage connected at transmission level (e.g. Dinorwig pumped storage) offering significant balancing services for example to respond to the variable output from some renewables and to capture the benefit of extreme variations in prices. Distributed storage is built onto the distribution network, and, in addition to the balancing services provided by bulk storage, may avoid the need for upgrades to the distribution network.

11. A number of storage technologies can provide very fast response rates to support the electricity system. For example battery storage and pumped hydro storage are able to respond almost instantaneously.

Interconnection

12. Network cables connecting neighbouring countries have the potential to reduce the total cost of the GB's electricity system and increase the security of supply to GB consumers. It would do this in a future scenario of significantly expanded inflexible or variable generation by increasing the utilisation of GB generation stations (for example, by allowing us to export wind on a windy day when the GB grid has capacity in excess of demand, instead of curtailing it) and by providing GB with access to European/international generation, allowing GB to export to countries that have a higher electricity price and import electricity from countries with a cheaper price.

13. Although interconnection may mean that GB consumers pay higher prices at certain points of the year, and lower prices at others, the overall reductions in system costs described above should more than offset these occasional higher prices. Price increases might occur if there were a supply shortage (or demand spike) coinciding in both connected markets meaning that the GB had to compete for available generation. Like DSR and storage, interconnection can generate revenue from price arbitrage - forward selling capacity to energy traders who take advantage of the price differences between the two connected markets.

Smarter networks

14. The higher voltage transmission part of the GB electricity network is already relatively "smart". National Grid, in its role as System Operator, can in real-time ensure electricity demand is met (but not exceeded) by managing what electricity is put onto the networks by generators and by monitoring the system in real time.

15. This contrasts with the distribution networks. Their operation is mostly passive as they only manage power flows in one direction. This has worked as demand has been predictable and there has been relatively little distributed generation on the local networks. The significant new demand expected from the electrification of transport and heat together with the increased penetration of distributed generation will pose new challenges for distribution networks. Smarter networks and smart meters will offer important opportunities to enable homes and communities to contribute to demand side management and energy storage as well as smart community energy schemes to optimise local energy.

16. Building a 'smarter' distribution network involves network companies applying new technologies and a communications platform to give them better information about, and more control over, the flow of power on their networks. This will allow network companies to use existing assets more efficiently by actively managing power flows, improving their ability to assess what reinforcement is needed (and therefore reduce or defer investment), fix outages more quickly, and drive up safety standards. It also has the potential to reduce the amount of generation and transmission investment required, particularly as more distributed generation comes online. Some of these smart technologies, such as automatic voltage control devices, are relatively simple and well understood whereas others, such as those to facilitate community level energy systems, are more sophisticated.

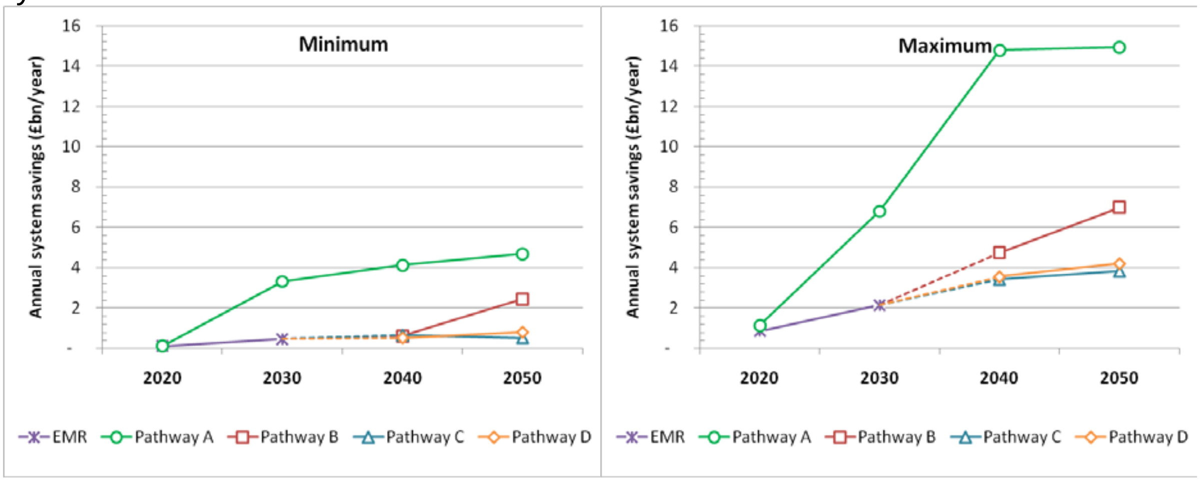
Potential for the use of balancing technologies

17. We asked Imperial College and NERA Economic Consulting to look at the value of these balancing technologies under different future generation mixes and demand profiles to understand when the electricity system might start to experience significant cost savings from widespread deployment of these alternative technologies. In order to do this they used the scenarios from the 2050 Carbon Plan:

    - Pathway A – high levels of renewable generation and energy efficiency, full electrification of heat and transport
    - Pathway B – high levels of nuclear generation, high electrification of heat and transport, lower energy efficiency
    - Pathway C – significant levels of generation plant fitted with carbon capture and storage, low electrification of heat and transport with medium energy efficiency
    - Pathway D – balanced generation mix with low levels electrification of heat and transport but high levels of energy efficiency

18. The analysis suggests that balancing technologies start to deliver significant savings in the 2020s and increasing into the 2030s and beyond.

Figure: Minimum and maximum system savings with combinations of flexible options across Pathways and time



19. The same analysis also shows that under the majority of likely generation and demand scenarios there is likely to be an important role for all balancing technologies.

Demand side response (DSR)

20. In the Imperial College analysis, DSR tends to have the highest value compared to the other balancing technologies. The analysis does, however, assume there are no costs associated with DSR. Although smart meters have already been mandated (and could be considered the main technology cost) in reality there are likely to be further technology and non-technology costs associated with the deployment of DSR. These might include equipment so appliances can communicate to the smart meter, data and communications costs, system upgrades for suppliers, product changes or the need to compensate consumers or reward certain behaviours. This means that the analysis may overestimate the value of DSR, particularly in comparison with storage. Nevertheless, even at low penetration (10%) there are considerable benefits across all Pathways.

21. Infrastructure being developed and invested in now can support the greater use of DSR in the future. The Government is currently considering the business case for functionality required to enable DSR and smart networks through smart meters. The development of technology and infrastructure associated with electrified heating and transport could also present important opportunities for DSR and should similarly take account of how it can facilitate DSR further.

22. Consumer engagement will be key to the take-up of DSR in households and equally it will be important that households benefit from taking actions to amend their demand to help the system.

Storage

23. The Imperial College analysis considered both bulk storage on the transmission network and distributed storage on the distribution network. The analysis chooses distributed over bulk storage in the majority of circumstances because distributed storage was assumed to have the additional potential to avoid distribution network investment required by the electrification of heat and transport. The efficiency of storage and the availability of DSR also had an impact on the value and level of storage installations.

24. The analysis indicates that given the value to the system, additional storage could be installed in the range of 1GW - 29GW under certain future scenarios by 2050, of which distribution storage is estimated to dominate bulk storage, due to the savings from avoided distribution network costs. If bulk storage costs come down more rapidly than distributed storage costs, or the savings from avoided distribution network costs are less, then different results would be seen given the overall sensitivity of the results to costs[2]. In such circumstances, Imperial estimate that additional bulk storage could be installed in the range of 1GW – 18GW. Where all other technologies are assumed to be high cost/low penetration, between 11GW - 29GW of storage is installed.

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[2] More detail on the relationship between bulk and distributed storage can be found in the Imperial storage project undertaken for the Carbon trust.
http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/administration/energyfutureslab/newssummary/news_5-7-2012-14-8-41

25. The development of storage technology is encouraging and costs of storage should fall over time making it a more attractive proposition. Innovation funding will continue to support this. Given the complex impacts of storage on the system and the variety of ways it can be used, it is important that innovation also focuses on the development of commercial arrangements that allow owners and operators to capture an appropriate return for the benefits that storage can provide to different parts of the system.

Interconnection

26. The analysis by Imperial College suggests that something in the region of 23 – 37GW (at least 10GW with mainland Europe and 11GW with Ireland) might be beneficial for the European system as a whole by 2050 (on the basis of the input assumptions used for this analysis). The optimal level of interconnection as per the modelling results changes considerably if different assumptions are made and is highly sensitive to Europe's future generation mix[3], the levels of flexibility that are developed by neighbouring countries.

27. All scenarios assume that interconnection is not used to help with security of supply. Relaxing this assumption produces a large increase in interconnector build up to 43GW-66GW. This is because electricity generated connected markets is used by GB to meet the short periods of peak demand, and replaces some additional GB-based generating - but as a consequence interconnectors are not operated at full capacity over the year.

28. Interconnection theoretically brings a positive overall benefit to the area over which it operates but we need to understand better where this benefit falls under different circumstances to ensure that UK consumers receive these. In particular we need to understand the impact for GB if we are a net exporter, both on the security of our system and on what consumers pay for their electricity. Further work also needs to be carried out in conjunction with European partners to understand the most efficient and effective way to develop interconnection in conjunction with network infrastructure. This understanding will be key to ensuring that interconnection is built to the right levels and in the right way.

Smarter Networks

29. Making the most efficient use of these balancing technologies will require the deployment of smarter distribution networks which allow the network companies to have more active control over power flows and act as enablers of tools like storage and DSR.

30. Smarter networks will be critical as a tool to enable real time information flows, as an enabler of other technologies and to connect increasing levels of distributed generation. The effective development of smarter networks will require network operators to work differently particularly in the way they interact with suppliers, customers and National Grid (as operator of the electricity system); how they anticipate and respond to developments which affect their networks; and how they develop and deploy innovative solutions. Work has already been undertaken to understand and overcome the barriers to delivering a smarter grid including with the Smart Grid Forum.

[3] The input data on the generation mixes of other European countries used for this modelling exercise was derived from the European Climate Foundation 2050 Roadmap, which involved a high level of intermittent renewables and very diverse generation mixes across countries. This generation mix diversity and renewables content tends to be higher than European governments' actual forecasts which, if used, would tend to result in less interconnection to

Conclusions

31. The need for a more flexible electricity system with more widespread deployment of balancing technologies and a smarter network appears to crystallise in the 2020s, nevertheless it is important that we ensure we are facilitating its development today. This means ensuring market arrangements are fit for purpose, supporting the development of key balancing technologies and promoting investment in smarter network infrastructure.

32. The market framework is changing as a result of the Electricity Market Reform (EMR) programme and other initiatives to improve the overall efficiency of the electricity market and it is difficult to predict accurately the strength of signals for flexibility under the new arrangements (although there is no evidence to suggest that the necessary signals will be not provided). The importance of promoting flexibility in the electricity system is explicitly recognised in the opportunity for both electricity storage and DSR to play a fair and equivalent role alongside generation in the Capacity Market proposed as part of EMR.

33. Technology development is central to the successful evolution of a flexible electricity system - in terms of delivering key balancing activities (electricity storage and DSR in particular) and also in terms of helping new electricity infrastructure developments (such as electric vehicles) be sufficiently flexible to support DSR. There are a number of different dimensions where Government could help tackle barriers hindering technology development and deployment, ranging from standard technology development support, through understanding consumer engagement with new technologies to looking at how effective commercial arrangements could be developed.

34. There is already a considerable amount of work underway to promote the development of, and remove barriers to, smarter networks, notably by DECC in partnership with Ofgem and the Smart Grid Forum (an industry group). As well as the technical evolution of smarter networks there could be changes in the roles of, and interactions between, key players in the networks industry and it will be important to remove any barriers to the development of these new interactions and associated commercial frameworks.

35. It is clear that balancing technologies, in conjunction with smarter networks, will have a key role to play in ensuring the supply of and demand for electricity match in a cost-effective way. There are multiple factors that will influence the actual trajectory of generation and demand so a full range of solutions will likely be deployed. There will continue to be a key role for Government in helping to ensure market frameworks and networks develop in a way that is fit for purpose, and in removing barriers to widespread deployment of balancing technologies. The list of actions set out on the next pages show how the Government intends to take this agenda forward.

the UK being efficient from a European perspective, even assuming a perfect EU market and low levels of DSR and storage uptake.

Next Steps

Market arrangements

Action: DECC will work to ensure that DSR and electricity storage can play a fair and equivalent role in the Capacity Market. More generally DECC will seek to ensure that Electricity Market Reform is implemented in a way that allows the development of flexible solutions to generation challenges.

Action: Publish a Gas Generation Strategy in autumn 2012 to ensure that the UK continues to attract investment in gas generation and infrastructure.

Action: Revise our in-house system model to incorporate transmission and distribution constraints, refined modelling of balancing technologies and real-time balancing activities.

Technology development

Action: DECC will undertake an assessment as to whether there is a need for Government to do more to support the development of key balancing technologies, areas to be considered may include:

- ***work with key organisations to support the development of the technologies likely to impact significantly and cost-effectively on the demand for electricity, and the infrastructure required for their deployment, to ensure they incorporate the functionality to support demand side response initiatives.***

- ***studies to investigate further, how consumers can be best engaged to respond to demand side response initiatives, by using opportunities from other engagement initiatives, like the smart meters engagement strategy.***

- ***work, consulting with the electricity storage industry, to understand how effective commercial arrangements could be developed, and to understand the barriers to cost-effective storage options and whether there is a role for Government to remove unnecessary regulatory barriers. In parallel, we will need to consider what incentives may be required, and are appropriate, across the supply chain in order to encourage more DSR.***

- ***explore further how the recovery and distribution of excess and wasted heat through the use of heat networks might minimise the impact of decarbonising heating on the electricity sector. The potential role of heat networks is considered in the Government's strategic framework for low carbon heat, published on 29 March. Using the evidence gathered from the responses to the strategy we aim to develop policy proposals by end March 2013.***

Networks development

Action: work with Ofgem and the Smart Grid Forum to investigate in further detail what could be done to encourage, and remove any barriers to, the development of these interactions and associated development in commercial frameworks.

Action: work with stakeholders in the industry to develop a model that can be used during the RIIO-ED1 process to inform the nature and timing of distribution network investments.

Action: undertake further work to understand the impact of increasing levels of DG on the electricity system including the roles and responsibilities of the SO and DNO.

Action: work with stakeholders to analyse potential transmission network impacts of longer term developments in the electricity system and the potential network solutions.

Action: further development of an evidence base and analysis on the impact on GB under different interconnection scenarios including further exploration of the most appropriate way of developing our interconnection capacity.

Sustainability and Climate Resilience

Action: Government will work with industry and other stakeholders to commission analysis and research to fill evidence gaps on the impact of the new technologies and supporting infrastructure in order to identify a sustainable mix of technologies for future UK power needs. We will also continue to work with industry and civil society manage the risks around access to resources (several of which are critical to low carbon technologies) as set out in the Government's Resource Security Action Plan.

Action: DECC will work with Defra, the Environment Agency and energy companies under the National Adaptation Plan to ensure energy infrastructure is adapted to a changing climate.

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