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MAKING DEEP DECARBONISATION OF THE ENERGY SYSTEM A REALITY:
THE CHALLENGE FOR THE NEW COMMISSION AND PARLIAMENT

SIMON SKILLINGS

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EXECUTIVE SUMMARY

The Juncker Commission's landmark clean energy and electricity market reform package, agreed in the last moments of 2018, represents a step forward in decarbonising the European energy system. However, current and future political challenges stand in the way of achieving the change that will be necessary to deliver deep decarbonisation of the EU's energy sector. Helping member states overcome these challenges should be a priority for the new Commission and Parliament.

This paper sets out a framework to help understand the political challenges that are likely to arise on the road to a decarbonised energy system. Whilst there are many differences across the EU, there is a common underlying set of themes that can be addressed effectively at EU-level.

The period from 2019 to 2024 will be critical if we are to achieve our decarbonisation objectives and EU policy makers must not 'tread water' and wait while member state governments implement recently adopted EU energy legislation as part of the 'Clean Energy for All Europeans' package. Instead, they must pursue three critical new initiatives:

> Support member states in developing credible plans for growth and jobs in a low carbon future and link this to the important energy system choices that must be made.

> Adapt the regulatory framework to ensure that it drives the energy system transition through improving the lives of all citizens.

> Implement a new security of supply assurance framework to allow resource sharing between member states alongside the decentralisation of the energy system.

It is too early to specify what the solutions to these policy challenges might entail. Instead, this paper identifies the key questions that EU policy makers must seek to answer.

1. POLITICS OF DEEP ENERGY SYSTEM DECARBONISATION

All EU member states are committed to decarbonise their economies in line with the Paris Climate Agreement. However, they also have other important objectives, and these can create conflicts and obstacles that prevent the decisions being taken that will drive forward the process of decarbonisation. It is important to understand these political challenges, not only those that are already in play, but those that are likely to emerge going forward. EU policy makers need to ask what they can do to help member state governments overcome these obstacles to achieve a secure and prosperous future for European citizens.

EU member states face different challenges and opportunities arising from the energy system transition as a result of their different individual circumstances. Moreover, the issues involved are very complex, and it is necessary to find a simple way to discuss them that is relevant across the EU.

Notwithstanding these complexities, the underlying drivers for change are common to all EU member states (and beyond) and this gives rise to a generic set of political issues. By adopting a simplified model for the energy system transformation[1] (see Box 1), it is possible to identify these generic issues, work out how much progress has been made and how much is still to do, and highlight the current and future political 'bear traps' that need to be addressed.

Box 1: Simple model for the energy system transformation

The following simplifying assumptions about the energy system transformation have been made to help identify the generic set of political issues:

> Power will need to be produced largely from renewable energy sources, much of this being variable in nature.

> Transport will be decarbonised largely using electric vehicles.

1 Our focus is the energy system and, therefore, we have not considered other sectors such as industry and agriculture.

> Heating and cooling will be decarbonised largely using electric heat pumps (although other solutions such as district heating will be widely deployed in urban areas).

> 'Green gas', biofuels, nuclear power and CCS may all have a role to play but will generally need to augment rather than replace a renewables and electrification approach.

Whilst these assumptions are not universally applicable, they are representative of most energy system contexts and provide a good basis for discussing specific national issues and the associated political challenges.

This simplified model for the energy system transition implies that each sector (power, transport and heating and cooling) will experience several critical phases of change, where these phases are driven by the significant interaction between the sectors. These phases are described in Annexes 1-3 and summarised in Table 1.

Table 1: Four phases of energy decarbonisation (a simplified model)

	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Power	Initiate deployment of large-scale renewables	Renewable output becomes significant and affects current and future output from fossil fuel generators	Renewable output begins to dominate the power system at certain times of day/year	Primarily renewable generation creates major imbalances with potential demand
Transport	Initiate the adoption of electric vehicles	Growth in the sales of electric vehicles begins to affect incumbent interests (oil companies, car manufacturers)	A large proportion of vehicles on roads are electrically powered	Electric vehicles provide the primary means of personal transportation on roads
Heating and Cooling	Explore low carbon heating and cooling solutions that have the potential for mass deployment	Develop deployment strategy based on results of early trials and testing with larger trials	Initiate mass deployment programmes which will create regions with large electric heating or cooling loads	Large proportion of consumers have electric heating or cooling creating large seasonal swings in power demand

Source: E3G analysis

Each phase has significant political challenges which need to be avoided or overcome. Delivering an orderly transition will only be possible if early strategic choices are made and if there is the political will to fundamentally reform institutions and markets. Failing to do so will create high costs, risk security of supply and undermine social acceptability. The timing of each phase will vary between countries and the phases are not sequential – a country may still be grappling with phase 1 challenges at the same time as those in phase 4 are beginning to emerge.

This analysis highlights that the path to deep decarbonisation is littered with potential political pitfalls. These political issues can be grouped under three headings:

> *Plan for jobs and growth:* Without a credible plan for jobs and growth in a low carbon future, it will be difficult for member state governments to make the choices that allow the decarbonisation process to maintain momentum and enable efficient infrastructure (and fiscal) planning. Examples of key choices required include phase-out dates for coal and the internal combustion engine or how to manage the future for gas as we move towards deep decarbonisation including its role in industrial heat and freight transport.

> *Consumer focus:* Energy system decarbonisation requires consumers to act and they will not do so unless it improves their lives. This will require a constant policy focus on ensuring the best possible experience alongside attractive financial outcomes when, for example, upgrading premises and adopting new transportation options.

> *Secure energy supplies:* National governments are acutely aware of their responsibility to ensure secure energy supplies. Whilst focus has traditionally been on securing access to, and transporting, fossil fuel resources, the deployment of renewable energy will bring about a new era of resource abundance in which the key challenges will relate to energy storage and balancing supply and demand. This will involve sharing resources with neighbouring countries and delegating responsibilities to local authorities and system operators. The current governance framework will not provide politicians at national level with the assurances they need regarding the security of energy supplies in the new situation.

2. CLEAN ENERGY FOR ALL EUROPEANS?

A huge amount of effort has been devoted to establishing a new legislative basis for European energy markets. The most recent package of measures promised to set us on the path to delivering 'clean energy for all Europeans'. Whilst it undoubtedly represents progress, few people believe that it is the end of the policy journey.

Global drivers shaping energy markets

Global energy markets are changing through a combination of policy, social and technological factors and these changes are already significant. Indeed, the changing energy landscape is pre-occupying much of the strategic 'bandwidth' of industry, regulators and governments as they try to assess the implications of what is happening and how it might unfold.

There are four key drivers for change (often referred to as the four D's): decarbonisation, digitalisation, decentralisation and democratisation. These are seismic shifts in the energy industry and present big opportunities for the decarbonisation agenda. The Juncker Commission launched a major policy initiative – the 'Clean Energy for All Europeans', or clean energy package for short – that sought to take advantage of these opportunities.

Results from the 'Clean Energy for All Europeans' legislative package

The package included several legislative proposals related to the design of Europe's electricity markets which built on previous work to create an internal energy market that would allow member states to share resources and, thereby, significantly reduce the costs of delivering a secure and decarbonised energy system. It also introduced a series of measures that aimed to align the desire to improve citizens lives with the policy objective to decarbonise the energy systems through allowing consumers to participate directly in energy markets.

The policy measures that have now been agreed have taken several positive steps towards this goal, as described in Box 2 below.

Box 2: Assessment of reforms related to energy markets contained in the clean energy package

Changes to short-term wholesale markets including removal of wholesale price caps, removal of priority dispatch for renewable energy sources and encouraging greater participation of demand response.

Assessment: More cost-reflective short-term prices and allowing demand response to participate in these markets are necessary but insufficient steps to help build the new framework to provide assurance of security of supply.

Improved use of the grid network through greater regional co-ordination of TSOs and reducing bottlenecks at borders.

Assessment: Important steps towards increased sharing of resources, but push-back from member states means that there is still a long way to go to create the trust necessary for the levels of trading that will be needed in the future.

Active operation of distribution grids through encouraging DSOs to use flexibility services and energy efficiency and the creation of a new 'DSO body' to develop a new framework for DSO operation.

Assessment: This will support the early steps in changing the nature of DSO operation but there is a long way to go before there is an integrated sub- and supra-national framework for delivering security of supply.

Tighter rules governing capacity mechanisms including the design and operation of the mechanisms used by member states to procure capacity resources with focus on recognising the contribution of resources in neighbouring countries.

Assessment: Significant time has been spent on this issue, but it is unclear that capacity mechanisms in their current form have any role to play in a longer-term framework to deliver security of supply. However, the introduction of an emissions performance standard for capacity mechanism payments is one of the only places where the package recognises that active management of technology choices is required.

Making it easier for consumers to switch supplier through ensuring better information on bills, access to comparison tools and streamlining the switching process.

Assessment: It is important to move beyond the 'switch and save' narrative and focus on building the conditions to ensure that all consumers benefit from participating in the energy system transition.

Create the conditions for both individual consumers and communities to actively participate in electricity markets through access to smart metering, enabling consumers to generate their own electricity and sell it back to markets and ensuring all consumers can offer demand response, either directly or through an aggregator.

Assessment: The dynamic consumption of electricity will be increasingly important, and these are vital early steps in establishing this capability.

Increased focus on vulnerable consumers by allowing the use of regulated retail tariffs as an interim measure, obliging member states to monitor and report on energy poverty and helping consumers in arrears to avoid disconnection, whilst recognising that energy efficiency provides the most effective solution to the causes of energy poverty.

Assessment: Managing equity issues associated with the energy transition will be critical to ensure all consumer share the benefits and this topic will need to become more central to the market and regulatory discussion.

Remaining challenges

The fundamental philosophy that underpins this legislative package is that consumer engagement in the energy market will be driven by the appeal of new technology and the opportunity to save energy costs. Whilst this approach would be appropriate in most market contexts, **the decarbonisation imperative requires significant changes in the way energy is produced and consumed within a limited timeframe. Importantly, this will require most energy consumers to make changes, not only to their behaviour[2], but to the premises in which they live and work**. It will also require significant changes to the way the energy system is designed and operated.

It is extremely risky to rely purely on the appeal of new technology and the opportunity to save energy costs to drive the necessary consumer engagement. The uncertainties involved mean that we cannot be confident that the required changes will happen sufficiently quickly or that system planners will be able to efficiently identify future infrastructure needs. Moreover, where consumer engagement does arise, it is least likely from those most vulnerable in society and this will inevitably create concerns about the social equity of the energy system transition.

These issues suggest that **a process will be needed to manage the energy system transition, leverage the forces for change and ensure all consumers benefit from the opportunities available**. Such a process is absent from the clean energy package. This fundamental gap provides just one important reason why we should not expect this package to represent the end of the market design journey and further refinements to the regulatory and market framework that governs the energy system are inevitable.

2 'Change in behaviour' is likely to be largely managed remotely by an energy service provider and, therefore, not apparent to the consumer. Changes to premises will be far more intrusive and represent a much more significant challenge.

The analysis described above suggests that there is still a long way to go to establish a regulatory and market design that will support the efficient deep decarbonisation of the EU energy system and the Clean Energy package is an early step on this journey. It notably shows that:

> There is little to directly help member states develop a plan for jobs and growth in a low carbon future and link this to the energy system choices that will maintain momentum in the journey towards decarbonisation.

> There have been important steps taken in enabling the flexible consumption of electricity. However, this has not been associated with a new approach that drives deployment of the relevant technology and encourages all consumers to share the benefits of the energy transition.

> Whilst it is recognised that security of supply issues will increasingly be dominated by the need to balance supply and demand of electricity and this, in turn, will require more sharing of resources across borders and active operation of distribution networks, there have been no significant shifts in the framework that governs security of supply.

3. STATUS CHECK

EU member states have diverse political, social and economic contexts. It is, therefore, unsurprising that issues relating to decarbonisation vary from country to country. However, most member states find themselves struggling to maintain momentum in the face of various political obstacles.

The model of deep energy system decarbonisation described in Section 1 sets out a 4 phase transition process for each sector and this can be used to assess the progress that has been made across the EU, and what remains to be done. This assessment is described below and summarised in Table 2:

Table 2: Status check on the 4 phases of energy decarbonisation

	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Power	Initiate deployment of large-scale renewables	Renewable output becomes significant and affects current and future output from fossil fuel generators	Renewable output begins to dominate the power system at certain times of day/year	Primarily renewable generation creates major imbalances with potential demand
Transport	Initiate the adoption of electric vehicles	Growth in the sales of electric vehicles begins to affect incumbent interests (oil companies, car manufacturers)	A large proportion of vehicles on roads are electrically powered	Electric vehicles provide the primary means of personal transportation on roads
Heating and Cooling	Explore low carbon heating and cooling solutions that have the potential for mass deployment	Develop deployment strategy based on results of early trials and testing with larger trials	Initiate mass deployment programmes which will create regions with large electric heating or cooling loads	Large proportion of consumers have electric heating or cooling creating large seasonal swings in power demand

Source: E3G analysis

Power sector

Most EU countries have initiated the deployment of renewable energy sources and supportive legislation is in place at EU-level. Moreover, the need for significant subsidies is reducing as the costs of renewables reduce. Nevertheless, pressure on short term prices remains, particularly where those paying to support the energy transition do not feel they benefit directly from the changes that have happened.

Most member states are stuck in phase 2 of the transition, struggling to maintain momentum in the face of various political obstacles. Whilst there are challenges associated with objections from local communities to the construction of new infrastructure, the primary problem relates to the lack of a credible plan for jobs and growth in a low carbon future. Importantly, these political problems (and solutions) are largely challenges for member state-level governments and few have been able to make the choices necessary to drive forward the transformation.

Whilst there is no technical limit to the proportion of the power system that can be provided by renewable energy sources, the costs of system integration will begin to escalate as penetrations increase. There is limited transparency on progress with the technical capability of grid networks across the EU to integrate large proportions of renewables and 'smart grid' initiatives remain largely at the pilot stage. There is a need to ensure that system operators – both at transmission and distribution levels – along with regulators are preparing appropriately for high levels of renewables penetration. There must be a clear understanding of where innovation will be required to reduce integration costs and a policy focus on delivering this innovation.

Security of supply remains an important responsibility for member state governments. Whilst some progress has been made in implementing mechanisms to allow resource sharing across the EU through more regional co-ordination of system operation, there is still much more that needs to be done. Developing a more regional approach to optimising the use of resources in operational and planning timescales received significant push-back during recent discussions related to the clean energy package[3] and this illustrates the discomfort that many member state governments feel about this issue, despite the obvious cost benefits. The introduction of a 'DSO body' has recognised the increasing importance of distribution system operators, but no progress has been made in implementing governance structures that will create a new

3 The original proposals by the Commission for Regional Operational Centres with the ability to overrule national transmission system operators (TSOs) were diluted to Regional Coordination Centres who can only act in response to a request from national TSOs.

assurance framework with high levels of decentralised electricity production. There remains much to do to create a governance framework that will provide member states governments with the necessary assurances about security of supply such that the system transformation can proceed.

Transport sector

Most EU countries have initiated the deployment of electric vehicles, although overall penetration of zero emissions vehicles remains low with around 0.6% of new car registrations in 2017 being for pure electric models[4]. These early deployments are supported by a variety of grants or subsidies and the EU has recently agreed a 'Mobility Package'[5] of measures to further drive deployment. Importantly, the need to improve air quality in many urban centres provides a powerful political narrative to support these emerging initiatives.

Most large vehicle manufacturers have refocused their development activities towards electric vehicles and this has made it easier for member state governments to introduce measures to support deployment. Nevertheless, challenges remain in countries with a manufacturing base and significant employment associated with the internal combustion engine, particularly where it is not clear how this will be replaced in a world dominated by electric vehicles. However, **even where governments have committed to support electric vehicles, this has not provided enough certainty over deployment to allow long term integrated infrastructure planning** to commence and, in any case, the regulatory structures are not in place to drive this 'whole systems' approach. It is also important to note that little progress has been made with making choices relevant to those parts of the transport sector that are more difficult to electrify, such as freight, shipping and air travel.

Whilst there has been some charging infrastructure deployment, it is not yet at a stage to provide the capacity that will allow convenient charging for a very large number of electric vehicles. This is because **no clear decisions have been taken about the required deployment of electric vehicles and the processes do not exist to drive integrated infrastructure planning**. Moreover, whilst the creation of alternative transport choices has been pursued at local/city level, this has yet to be part of longer-term plans to deliver national decarbonisation targets.

The new electricity market design legislation as part of the clean energy package will enable all willing end consumers to access real-time power prices, through improvements to the operation of wholesale markets and the

4 **European Environment Agency: Electric vehicles as a proportion of the total fleet**

5 **Europe on the Move: Commission completes its agenda for safe, clean and connected mobility**

deployment of smart meters. However, these changes are a long way short of delivering enough granularity to optimise local charging and minimise overall system costs. Whilst the smart systems and artificial intelligence is not yet in place to support complex driver charging choices, it is likely that these would be adopted quickly by car manufacturers once local power system pricing is in place.

Heating and cooling sector

The heating and cooling sector challenges are much more difficult for some member states than others. Cooling is generally delivered electrically, and the challenge is to accommodate new sources of demand growth. The heating challenge is more complex, particularly where it involves the replacement of legacy fossil-based systems. **For both heating and cooling, establishing efficient buildings is a prerequisite. Decarbonisation of this sector will require significant changes to the built infrastructure and there are no programmes underway to deliver mass retrofitting** or, in many instances, any clear view on the low carbon heating systems to install. This is further complicated by the fact that heating solutions must be delivered locally, and the preferred approach may differ from location to location.

The absence of mass deployment programmes means that member states have not made the choices that enable efficiency measures and deployment of low carbon heating electrification to be integrated into the infrastructure planning processes. Where legacy gas networks exist, the 'green gas' option remains politically attractive since it requires less change in consumer behaviour. However, it is unclear how this can be aligned with a deep energy system decarbonisation, other than on a marginal basis[6].

The granularity in local power system prices that will be required to integrate electric vehicles will also be required to support large-scale electrification of heating (or significant expansion of cooling). Moreover, it is likely that significant new sources of long-cycle storage will be required to cater for changes in demand between seasons.

6 See: E3G (2018) **Renewable and decarbonised gas: Options for a zero emissions society**

4. CHALLENGE FOR NEW COMMISSION AND PARLIAMENT

The period from 2019 to 2024 will be critical if the EU is to achieve its decarbonisation objectives. EU policy makers must not 'tread water' and simply wait while national governments focus on implementing the clean energy package. Instead, they must pursue three critical new initiatives:

> Support member states in developing a credible plan for growth and jobs in a low carbon future and link this to the important energy system choices that must be made

> Adapt the regulatory framework to ensure that it drives the energy system transition through improving the lives of all citizens

> Implement a new security of supply assurance framework to allow resource sharing between member states alongside the decentralisation of the energy system.

Designing and implementing changes to energy market design and regulation takes time[7] and time is not on our side. The Commission recently published a 'strategic vision' document that sets out a clear preference for achieving climate neutrality (or net zero greenhouse gas emissions) by 2050[8]. It is now necessary to explicitly recognise what this means in terms of the deployment of low carbon energy technologies and how quickly progress will need to be made.

This new roadmap should establish new energy system targets for 2030 and beyond. This process of updating and setting new targets is at the core of the five-year cycle of the 'ambition mechanism' of the Paris Agreement, which is meant to align national commitments to the long-term goal of delivering well below 2˚C with efforts to pursue 1.5˚C. However, it is also necessary to align the regulatory and market arrangements for the energy system with the 2050 pathway. The analysis set out in this paper provides a framework to identify the issues that will arise and the changes that must be put in place to prevent the transition being driven off-track.

7 The European Commission consulted on a new market design in 2015 following several years of research and analysis. These proposals formed an important part of the Clean Energy for All Europeans package that has just been agreed. However, it is unlikely that the new rules will be incorporated into member state legislation until 2020.

8 **The Commission calls for a climate neutral Europe by 2050**

The EU should begin to develop the rules for a deeply decarbonised energy system and should aim to have these in place by 2030. **'Vision 2030' should not only cover revised energy system targets, including national binding efficiency and renewable targets, but include the delivery framework to support and sustain the future energy system**.

This work should be an early priority for the incoming Commission in 2019. It must rise to this challenge by initiating programmes of work to answer the following key questions:

> How to help member states develop credible plans for growth and jobs in a low carbon future:
    - It will be too costly to keep all options open – when do key choices need to be made?
    - How can a whole systems approach to energy infrastructure planning and ensuring efficiency is an infrastructure priority minimise the costs of the system transition[9]?
    - Where is innovation critical to support the transition and is this consistent with innovation funding priorities?
    - Where and how might EU funds be deployed to support regions undergoing industrial transition?
> How to create a regulatory framework to drive the energy system transition through improving the lives of all citizens:
    - What is the new narrative that moves beyond 'switch and save'?
    - How to encourage companies to invest in consumer premises whilst preserving/enhancing consumer protections?
    - How to maintain fairness and ensure everyone benefits from the energy system transition?
    - How will efficiency and demand response become reliable system resources that can offset traditional infrastructure expenditure?
    - What governance structures will allow mass deployment programmes that take advantage of local differences and allow diversity of approaches?
> What is the new security of supply assurance framework that allows member states to embrace resource sharing alongside the decentralisation

9 See E3G 2016: **Energy as infrastructure: leaping the investment gap**

of the energy system and the need for active management of the power distribution network:

- What local power markets will allow efficient electric vehicle charging and smart heating and cooling of buildings?
- How to efficiently plan and build new infrastructure requirements?
- Where will resource sharing between member states deliver the largest cost benefits?
- What are the institutions that will deliver the assurance needed by member states to confidently share resources? Who provides information? Who makes decisions? What is their incentive framework?
- How will international institutions need to be integrated with local balancing entities to create a robust overall assurance framework?

5. CONCLUSION

Whilst the clean energy package represents progress, analysis shows that there is still much to do if we are to have European energy markets and regulation that support the transition to deep decarbonisation. This represents a challenge and an opportunity for the new Commission and Parliament and they must focus on driving this agenda forward.

We are not on-track to deliver the reductions in carbon emissions that are required by the Paris Climate Agreement or consistent with the recently published vision for the 2050 energy system. Member states are struggling to overcome political challenges associated with energy system decarbonisation and this is making it difficult to maintain the necessary momentum. Moreover, as the decarbonisation process proceeds, further political obstacles will be encountered. There is an opportunity for the new Commission and Parliament to refocus on helping member states overcome current obstacles and prepare for those that lie ahead.

This paper contains analysis that suggests three key areas of work should be prioritised by the new administration:

> Support member states in developing a credible plan for growth and jobs in a low carbon future and link this to the important energy system choices that must be made.

> Adapt the regulatory framework to ensure that it drives the energy system transition through improving the lives of all citizens.

> Implement a new security of supply assurance framework to allow resource sharing between member states alongside the decentralisation of the energy system.

ANNEX 1: POWER SECTOR ANALYSIS

Transition analysis for the power sector

Transition phases

1. Initiate deployment of large-scale renewables.
2. Renewable output becomes significant and affects current and future output from fossil fuel generators.
3. Renewable output begins to dominate the power system at certain times of day/year.
4. Primarily renewable generation creates major imbalances with potential demand (from within day to between seasons).

Phase 1 – Initiate deployment

The key political challenge during the first phase is to provide the necessary fiscal support for early renewable projects and governments must be prepared justify this investment from energy consumers or the wider public. There are now many established regulatory approaches to minimise these costs such as the efficient application of feed-in-tariffs and priority access to the grid. However, ensuring that those paying to support subsidised sources of generation feel that they benefit from these additional costs remains a challenge.

Phase 2 – Drive growth in renewables

As generation from renewables begins to make a significant impact on the power system, there is likely to be resistance from incumbent fossil generators to policies that are supporting the change. These objections will cover a variety of factors including concerns about security of supply, loss of employment and increases in energy prices. There may also be increasing local opposition to infrastructure such as grid reinforcement or onshore windfarms.

During phase 2, governments need to make strategic choices about future energy mix to ensure the transition maintains momentum, including coal phase-out dates, a long-term strategy for gas and an associated network infrastructure plan. This requires actions to address the concerns of incumbents and local communities. Such actions include a credible plan for growth and jobs that takes advantage of a renewables-based economy, a fiscal strategy to replace lost tax income and 'just transition' measures to manage the social impacts of the change. Other important measures include helping communities to share the benefits of infrastructure developments and tough

competition regulation and focus on efficiency to minimise impacts on energy prices.

Phase 3 – Renewables periodically dominates the power system

Inadequate grid operational practises can make it expensive to accommodate variable renewables and, in extreme situations, create the risk of blackout (e.g. South Australia). This political fallout from these security of supply problems would be significant and would inevitably halt the progress of renewables deployment.

Transmission system operators and regulators must plan to be able to securely operate the power system when it is dominated by variable renewable generation. This involves the adoption of improved operational procedures such as fault ride through and mandatory reserves. It is also important to avoid the escalation of the costs of integrating renewables, and therefore innovative approaches, such as adopting smart grid operation and the deployment of new battery technologies, will be required.

Phase 4 – Renewables dominates power system all year

The operation of a largely renewable power system will be very different from one based on fossil fuels. Balancing supply and demand will require significant flows of power across large geographical areas and the dynamic operation of the power grid at local level. Ensuring that national governments receive adequate assurance of security of supply will require a radically difference governance framework combining international collaboration and the devolution of responsibility to local grid operators along with the interaction between these supra- and sub-national activities. High levels of penetration of renewable electricity will not be possible politically unless the new governance framework provides the necessary assurances about security of supply to member state governments.

Significant innovation will be required to enable supply and demand to continue to be balanced efficiently. Demand will need to be highly controllable, storage facilities will need to operate over a range of timescales and larger (international) balancing areas will be required. These capabilities will need to be efficiently deployed through the extensive use of artificial intelligence with appropriate data privacy and other consumer protection measures.

ANNEX 2. TRANSPORT SECTOR ANALYSIS

Transition analysis for transport sector

Transition phases

1. Initiate the adoption of electric vehicles.
2. Growth in the sales of electric vehicles begins to affect incumbent interests (oil companies, car manufacturers).
3. A large proportion of vehicles on roads are electrically powered.
4. Electric vehicles provide the primary means of personal transportation on roads

Phase 1 – Initiate adoption

The key political challenge during Phase 1 is that governments must provide enough fiscal support and justify the expenditure. There are now many established approaches to providing the necessary incentives such as cash-backs and grants.

Phase 2 – Drive growth in electric vehicles

As the popularity of electric vehicles begins to increase, there is likely to be resistance to on-going government support from incumbent interests such as oil companies and car manufacturers. These objections will primarily be based on the loss of employment in manufacturing industries associated with the internal combustion engine.

Governments need to make strategic choices about the future transport system during this phase to maintain momentum in the shift towards electric vehicles. These choices might include infrastructure needs, an end date for internal combustion engine sales and a roadmap for freight transport which may, in turn, define a future role for biofuels or hydrogen. The ability to make these choices will require a credible plan for growth and the creation of new jobs both within and outside the transport sector, a fiscal strategy to replace lost tax income and 'just transition' measures to manage the social impacts of the change.

Phase 3 – Large proportion of electric vehicles

It is necessary to have an adequate charging infrastructure in place to support large numbers of electric vehicles on the roads and the power system must be able to efficiently accommodate charging demand. This requires that a charging infrastructure deployment strategy is in place which is integrated

with the power network planning process and this deployment strategy will probably require regulated solutions where business response is inadequate (e.g. remote areas).

During this stage of the energy transition, governments should have in place a longer-term transport strategy that is looking to create attractive transportation options beyond individual vehicle ownership such as autonomous vehicles and growth of mobility platforms.

Phase 4 – Primarily electric vehicles on roads

Uncoordinated charging of large numbers of electric vehicles would create high costs for the power system and could cause security of supply problems. A charging infrastructure of 2-way charge points is required with cost/value distinguished by time and place with enough granularity to allow efficient investment in, and operation of, the power network. This will require intelligent in-vehicle charging software which is integrated into the overall network optimisation process.

By this stage in the transition, there should be the wide availability of attractive transportation choices including sophisticated flexible options for short-term vehicle hire.

ANNEX 3. HEATING AND COOLING SECTOR ANALYSIS

Transition analysis for heating and cooling sector

Transition phases

1. Explore low carbon heating and cooling solutions that have the potential for mass deployment.
2. Develop deployment strategy based on results of early trials and testing with larger trials.
3. Initiate mass deployment programmes which will create regions with large electric heating or cooling loads.
4. Large proportion of consumers have electric heating or cooling creating large seasonal swings in power demand.

Phase 1 – Test delivery solutions

There are a range of technical options to decarbonise heating and cooling systems and testing the options will require some Government funding during this discovery stage. The deployment challenges of retrofitting premises and changing legacy heating systems means that it is also necessary to test the governance of delivery rather than simply technical options. Moreover, the preferred solutions are likely to differ at a local level and it is necessary to understand these local differences.

This initial phase requires pilots and demonstrator programmes supported by learning governance and with a focus on approaches to deliver the consumer engagement that will support mass deployment.

Phase 2 – Develop delivery strategy for mass deployment

Governments will need to make strategic choices about the decarbonisation of heating and cooling although there are likely to be a variety of technical solutions involved. For example, it is likely that electric heat pumps and direct renewables will represent the best solution for single family homes, especially in rural and semi-urban areas, whilst district heating with heat pumps, waste heat and direct renewables may predominate in urban areas and wherever it is justified by population density. The key challenge will, therefore, involve creating local delivery governance structures and ensuring the regulatory and market framework will support mass deployment.

There may be push back from incumbents (e.g. gas) based on cost and the risk that consumers will not willingly change behaviour. It is, therefore, important that the delivery strategy is supported by evidence from large-scale trials which must be initiated and funded.

Phase 3 – Initiate mass deployment programmes

The initiation of mass deployment programmes will create regions with large electric heating and cooling loads and it is necessary that energy efficiency is prioritised, and the deployment strategy is integrated into the power network planning process. It will also be necessary to incorporate heat network infrastructure into this planning process. Importantly, it will be necessary to treat investment in consumer premises on an equal basis to other infrastructure.

It may be necessary to introduce significant changes to the regulatory framework that supports mass deployment through restricting the ability of consumers to 'opt out' of the process. It is, therefore, critical that deployment is focused on delivering consumer benefits to ensure continued political support. Moreover, regulatory changes may need to vary from region to region to reflect differences in local delivery approaches.

Phase 4 – Large proportion of consumers have electric heating and cooling

Heating and cooling demands vary significantly between seasons and large inter-seasonal power storage requirements could create excessive power systems costs and possibly security of supply problems. It will be necessary to develop a highly flexible power system with extensive storage capacity. For example, intelligent building control systems must be integrated into overall network optimisation process which will involve power pricing that varies according to location and time of day. Establishing a power system that can cope with this challenging situation will require a strong mission-based innovation focus over the preceding decades.