Decarbonising Energy End Use

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Ireland and the Climate Change Challenge: Connecting 'How Much' with 'How To'

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1. Introduction

The coming together of two previously isolated technologies in the 1960s—computers and the communications—had paradigm-shifting consequences for the way economic and social systems operated. Up to the late 1960s the communications system was characterized by centralized switching stations via which communications (telegram and telephone) were routed and users were manually connected. In the new system these hierarchies were flattened, allowing the flow of information to and from each user across various networks. This automated system was governed by a flexible and constantly revised series of protocols that were interpreted by computers at each node (Ryan, 2010).

The internet protocol suite TCP/IP established the rules governing these interactions. It had been developed incrementally and in an open source[1] manner by a community of programmers working in a range of diversified and loosely coordinated research groups. Because the architecture was developed in this manner it was available to all interested developers, and the rulebook was therefore constantly redrafted by its users according to their evolving needs. The platform was therefore responsive to the rapid rate of technological evolution, and adaptable to all suitable devices and networks, allowing for the gradual emergence of the internet as we now understand it. Even though the early developers could never have imagined web 2.0, on-line commerce, you tube, itunes or facebook, it was flexible enough to facilitate these developments. This transformation, and others throughout history, point to the role of networks as levers for catalysing broad change across the economy.

In this Background paper we provide an overview of how a decarbonised energy sector can be a catalyst for the decarbonisation of energy use throughout the economy: in the transport sector, homes, commercial businesses and industry. In doing so, we draw extensively on the findings of the Interim Report, but we also draw together a new element: the deployment of a smart grid in Ireland. We would tend to agree with the characterization of the electricity grid by Zysman & Huberty (2012) as *a* (or perhaps even *the*) key lever in the transition to a low-carbon economy. We argue that valuable lessons from the ICT revolution should be born in

[1] Open source is a philosophy or pragmatic methodology that promotes free redistribution and access to an end product's design and implementation detail. A main principle and practice of open source software development is peer production by bartering and collaboration, with the end-product, source-material, blueprints and documentation available at no cost to the public.

mind to guide its deployment; in particular that as yet unforeseen transformative consequences for the rest of the economy may emerge, as was the case with the ICT revolution.

The importance of the development of transmission system, interconnection and the integration of high quantities of wind and other renewables onto the grid are discussed in the background paper, No5, on Ireland's energy system. We focus here on the development of a smart grid, arguing that its rapid development underpins the key pillars of Ireland's emerging decarbonisation strategy.

The background paper is structured as follows: we first define what we mean by the smart grid and outline the potential benefits it may bring; we then assess progress so far in the deployment of a smart grid in Ireland, identifying the international leadership position that has been developed. In the following section we explore how the rapid deployment of a smart grid in Ireland has the potential to enable the decarbonisation of energy use in homes, commercial businesses and industry. This is followed by a discussion of decarbonisation of the transport sector, and the key role of smart grid deployment in enabling this transformation. Finally looking forward, we examine the market, regulatory, investment requirements necessary to galvanize the transition to a low-carbon economy in 2050.

2. Defining a Smart Grid

A standard electricity grid facilitates the flow of electricity from large centralized thermal generation stations through the transmission and distribution system to end users. A smart grid can, in addition, enable financial, informational, as well as 'electrical' transactions among consumers, grid assets, and other authorized users. At the core of the smart grid concept, therefore, is the integration of information and communications technologies onto the grid. This ensures that greater levels of information are available to producers and consumers, facilitating the automation and more effective management of various electricity system processes.

There are many discrete aspects of the smart grid, each requiring significant investment for deployment. The following benefits could be delivered by full deployment of the smart grid:[2]

First, it will enable active (though probably automated) participation by consumers. The smart grid has the potential to give consumers information, control, and options that enable them to engage in new ways with their power suppliers, or indeed to become suppliers themselves. Willing consumers will be in a position to trade

[2] The analysis in this section draws heavily on an entry: (Miller, 2012).

flexibility in usage for lower prices. For example, a consumer might agree that their electric vehicle, washing machine, refrigerators, heat banks, or heat pumps could be charged or switched on or off at the discretion of their utility within certain pre-agreed limits, or that the grid could draw on their generator of micro-generator or storage resources under certain conditions. Consumers may be encouraged to sign up to a plan with a supply company that allows for a certain amounts of flexibility, somewhat analogous to consumers signing up to a mobile phone 'bundle' to suit their needs.

Second, the smart grid will accommodate all generation and storage options. The traditional grid is manually managed and configured by switching on and off large thermal plant in response to anticipated demand, somewhat similar to the communications networks of the past. Managing a system with everything from micro power generators to large thermal plant to small and perhaps large-scale electricity storage is technically challenging. Using sensors, smart meters, variable pricing, digital controls and analytic tools, two-way energy flows along the grid will be automatically monitored and controlled. This is analogous to the movement from the manual configuration process characteristic of the first computers, to the advent of software and hardware devices that first integrated some level of automation in configuration, to the current fully automated system that now supports a 'plug-and-play' level of convenience. Because many of the new sources which will be connected are renewable, or are storage solutions that can facilitate more renewables on the grid, the smart grid will facilitate the decarbonisation of power generation, as well as offering the potential to decarbonise transport and heat.

Third, and arising from the above, the smart grid will enable supply companies to use willing consumers as an effective new source of energy. Active participation by consumers opens up the possibility for energy supply companies to treat willing consumers as resources in the day-to-day operation of the grid. Consumer demand could be managed to respond to either a supply shortage, of a surplus supply of cheap variable electricity. These aggregated consumers can be conceptualised as 'fifth fuel' (in addition to coal, oil, gas and renewables) that suppliers can use to meet demand. Aggregated consumer response has also been described as a 'virtual power plant', although in this conceptualization micro-renewables, micro storage and automated demand response[3] are aggregated and controlled by one central entity. New and sophisticated business models, with variable tariffing at their core, will be required in order to develop products and packages that are attractive to consumers.

[3] Demand response is managing customer consumption of electricity in response to supply conditions, for example, having electricity customers reduce their consumption at critical times or in response to market prices.

Fourth, the smart grid will optimize asset utilization and operational efficiently. Managing the grid in the manner described above would result in greater efficiencies by improving load factors, minimizing transmission and distribution losses, optimizing asset utilization and dramatically improve outage management performance. The availability of additional grid intelligence will give planners and engineers the knowledge to build what is needed when it is needed, to extend the life of assets, to repair equipment before it fails unexpectedly, and to more effectively manage the work force. Operational, maintenance and capital costs will be reduced thereby keeping downward pressure on prices.

Fifth, the smart grid will anticipate and respond to system disturbances (self-heal) and will be more resilient to disaster or attack. It will monitor, diagnose, and respond to power quality deficiencies resulting in a dramatic reduction in the business losses currently experienced by consumers due to insufficient power quality. Remote monitoring devices will tell when and where faults occur, alert to impending overload condition, and locate inefficiencies. It will also handle problems too large or too fast-moving for human intervention. The Smart Grid will incorporate system-wide solutions that reduces physical and cyber vulnerabilities and enables a rapid recovery from disruptions.

Sixth, it will enable new products, services, and markets in ways that are not fully scoped out at present, but can only be guessed at. The emergence of these new markets, technologies and sellers will be enabled by the great wealth of data that will become available from the sensors on the system. This intelligence has the potential to both link and blur the distinction between buyers and sellers, generators and consumers. It has the potential to support the creation of new electricity markets and technologies, from home energy management systems at a consumer's premise, to technologies that allow consumers and third parties to bid their energy resources into the electricity market.

3. Smart Grid Roll Out In Ireland

Interest in the development of smart grids has increased considerably over the last number of years. In April 2011 the International Energy Agency published a smart grid roadmap that declared that smart grids are 'crucial for a secure, cost effective, clean energy future' (IEA, 2011). This was followed by a *Commissions Communication on Smart Grid Deployment* that put the smart grid at the top of the political agenda in Europe (Eirgrid, 2011).

Worldwide investment in upgrading grids is significant and growing. The global smart grid market has experienced double-digit growth rates over the last five years and is expected to continue with growth rates of approximately 20 per cent per annum to 2020 according to various assessments (PR Newswire, 2012); (Kennedy, 2012). Overall, the worldwide market for smart grid data analytics (meter analytics, grid analytics, asset analytics, and renewables integration for business intelligence, operations, and customer management) is expected to grow steadily through 2020, with cumulative worldwide spending from 2012 through 2020 totalling just over $34 billion (Pike Research, 2012a).

Ireland has achieved an international leadership position in the deployment of a smart grid. These results are borne out by the IBM Smart Grid Maturity Model (SGMM). This is an analytical tool that IBM has developed for use by utilities to help gauge their level of maturity in smart grid deployment compared with other utilities. In 2009, IBM carried out this analysis for ESB and found that of a total of 58 utilities worldwide that had used the tool, ESB was ranked third on a composite basis, and was ahead in five out of eight categories assessed.[4]

Another useful comparative assessment of progress is provided in a report by Electric Power Research Institute (EPRI) of USA (EPRI, 2012). In their assessment, which involved a comparative assessment of progress by fifteen of the leading utilities globally, ESB was found to have one of the most complete levels of coverage of the relevant technologies and applications, and was and one of only three utilities to have progressed projects to the 'analysis' stage (along with EDF and Exelon).

Below we first detail the natural advantages that have led to an international leadership position emerging in smart grid deployment in Ireland. This is followed by sections that explore the role of ESB Networks and Eirgrid respectively in smart grid deployment, and finally a section detailing smart grid pilot programmes that illustrate potential applications and benefits of smart grid deployment.

3.1 Factors Influencing Smart Grid Roll Out in Ireland

Several factors have influenced the relatively rapid rate of smart grid deployment. In the first place, the integration of high levels of wind onto Ireland's small and relatively isolated grid has spurred the deployment of aspects of the smart grid. Second, there is effectively only one electricity grid and one market on the island of Ireland, there is a single owner of the networks on the island of Ireland (ESB) and a single owner of the System Operation companies (Eirgrid). This means a limited number of parties are involved in promoting a particular strategic direction. Third, the regulatory regime currently supports investment in smart grid deployment as well as appropriate R&D activities. Finally the role of active stakeholder communication and engagement has been important. This engagement has been

4 Results provided by Tony Carroll, Smart Grids Ireland.

coordinated effectively by Smart Grid Ireland, which is an industry led network of organisations based in or operating out of Northern Ireland and the Republic of Ireland—seeking to jointly exploit new commercial opportunities in the Smart Grid sector locally, nationally and internationally. Member organisations are drawn from industry, research bodies, universities and government agencies. SEAI has also taken a leading role in coordinating the voice of various stakeholders by convening a group aimed at the development of a roadmap for the deployment of the smart grid to 2050 (SEAI, 2011a).

These combined factors perhaps place Ireland in a unique position to offer networks and systems as a proving ground or test-bed for the deployment of smart grid technologies, and in particular how various applications may function across two jurisdictions with different currencies (the Republic of Ireland and Northern Ireland).

3.2 Distribution Network Investment and R&D

ESB Networks operates the part of the grid known as the distribution system, which carries electricity from the electricity highways across a lower voltage network to end users. This is the part of the grid network in which significant infrastructural investment is required to facilitate the emergence of a smart grid. A supportive regulatory environment has allowed ESB networks to invest significant amounts in distribution system upgrades in Ireland, and in vital R&D activities.

Investment has been focused on renewal of the medium voltage network, ensuring remote visibility of the network, the integration of microwave and polling radio, and on the roll out of a fibre network. Adding remote visibility of the network is key to the smart grid concept, in particular driving 'observability' into the mid-low voltage distribution network that is currently lacking. Distribution automation, where a technology similar to a sim card is installed at each switch is also required to enable machine to machine communications. Devices now being installed are a key stepping stone to a fully smart network.[5]

This investment programme has already greatly increased customer satisfaction, reduced customer minutes lost, and greatly reduced operational costs. In order to sustain this leadership position, ESB have recognised the need to undertake network R&D, and current research activities are focused on the self-healing network automation (see below), closed loop pilots, innovative protection and fault diagnostics, wireless telecom trials, low loss transformers, dynamic sectionalising and voltage conservation reduction.

[5] Approximately half of wind currently connected to the Irish grid has also been connected through the distribution network, which has also required significant investment.

3.3 Systems Operator Innovation

The power superhighways known as the transmission system, are operated by Eirgrid.[6] Much of Eirgrid's work is aimed at the development of the transmission system as outlined in its Grid 25 strategy, and described in the Background Paper No. 5. We view this work as a necessary complement to the work on developing a smart grid.

Many of the elements of the smart grid associated with the transmission system[7] are already in place arising from the challenge of managing high levels of wind penetration. A key upcoming challenge is developing a grid to securely handle real time penetration levels of 75 per cent wind at one time by 2020. This will required extensive innovation and planning and, according to Eirgrid, this objective effectively makes Ireland a laboratory of smart grid evolution. It will require major changes, not only the need for appropriate infrastructure, but also in the behaviour of the power system over a wide range of operational metrics. EirGrid and the Systems Operator of Northern Ireland (SONI) have established a programme of work entitled *Delivering a Secure Sustainable Electricity System* (DS3) which is crucial to achieving this objective.

As part of this work programme Eirgrid has established a smart grid innovation hub in the National Digital Research Centre (NDRC), it aims to couple Ireland's academic strength in ICT with the presence of major international ICT companies in Ireland. This centre is effectively a forum where concepts and technologies in new grid applications across the smart grid domain can be piloted with the support of Eirgrid. Funding for commercialisation of ideas is, access to necessary data, as well as access to a wider network of experts are all available. There is a particular interest in stimulating projects in the areas of:

- New demand side management concepts;
- System operation including advanced voltage control at transmission level;
- System services e.g. reserve provision; and
- Transmission technology types e.g. dynamic line rating.

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6 EirGrid holds licences as independent electricity Transmission System Operator (TSO) and Market Operator (MO) in the wholesale trading system in Ireland, and is the owner of the System Operator Northern Ireland (SONI Ltd), the licenced TSO and market operator in Northern Ireland.

7 These elements include dynamic line rating, real time stability analysis tools, and synchrophasor measurement devices, see (Eirgrid, 2011).

Eirgrid also cooperates closely with ESB to manage more complex distribution and transmission system interdependence associated with developing the smart grid.

3.4 Smart Grid Pilot Programmes

A number of technologies associated with the smart grid haven been piloted in various trials.

A **smart meter** pilot programme was conducted by the Commission for Energy Regulation (CER) in 2009 and 2010 involving 9000 homes and businesses. The project assessed the performance of available smart metering systems and communication technologies and identified risks, issues, and information relevant to a cost-benefit analysis for a national smart metering rollout. Time-of-use tariffs and demand side information management tools such as in-home displays, detailed billing, and an online customer portals were introduced as part of the trial. The CER concluded that smart meters could yield net benefits of up to €174 million over 15 to 20 years taking into account customer bill reductions, efficiency, and environmental benefits. On this basis a decision was taken in 2012 to roll out a nationwide smart metering programme. The CER is presently in the planning stages of this national rollout of a very sophisticated smart meter[8] in conjunction with ESB Networks. While not the first country to roll out smart meters nationally, this level of sophistication would place Ireland in the vanguard internationally and will allow for the growth of new technologies and business models not possible among earlier adopters (such as Italy) who have deployed a less sophisticated meter.

Electric vehicles are a key technology enabled by the deployment of a smart grid. Building on the deployment of this infrastructure, eCar Ireland is an all-island project that pilots a basic EV charging infrastructure where drivers pay their nominated electricity supplier (not the charging station) for the electricity the EV consumes. This cross-jurisdictional project involves multiple electricity distributors, two currencies, and creates a competitive retail market that is accessible in either country. ESB Networks will use IBM's Intelligent Electric Vehicle Enablement Platform to provide the services needed to operate and manage the charge-points installed throughout Ireland. The project team has developed smart charging algorithms using weather, customer travel plans, wind generation, and real time electricity prices. These will be used through a 'cloud' infrastructure to dynamically control EV charging. This system will provide the analytics and intelligence needed to

[8] Applications envisaged include in home display, smart meter to Home Area Network (HAN) connectivity integration with gas meter, daily profile reading, automatic meter reading, remote meter operation, event monitoring, and remote tariff configuration.

better forecast and balance the load on the power grid as well as help ESB Networks to monitor the health and status of the charge-points to ensure service reliability.

The size and scale of the Ireland's electricity distribution system presents unique challenges in terms of maintaining continuity of supply to customers within a high standard, and ensuring that network losses are minimized. ESB is piloting a **self-healing network** technology (smart green circuits or switches) which act autonomous in the event of a fault so that supply is restored to the effected part of the network autonomously and the faulty circuit is isolated. In this way supply can be restored to the vast majority of customers without delay or intervention by the central control centre. ESB Networks conducted tests of these technologies on four distribution circuits (Kerry, Galway, Dungloe and Sallynoggin).

3.5 Conclusion

Ireland has established a leadership position in the deployment of several aspects of a smart grid. This is possible because of the nature of Ireland's grid, the plans to deploy high levels of variable wind, the small number of players organized into a coherent stakeholder group, and a supportive regulatory environment.

4. Decarbonising Energy Use in Buildings & Industry

The EU Council of Ministers who have agreed that total gross EU emissions should be 80 to 95 per cent below 1990 levels by 2050.[9] The Commission's modelling work suggests that a least cost pathway would involve a significant proportion of this burden falling in the residential and industrial & commercial sectors. Table 1 below illustrates the impact that a 79 to 82 per cent emissions reduction across the EU would have on the residential and commercial & industrial sectors by 2050.

Table 1. Implications of EU-Wide Emissions Reduction (2050 per cent)

EU	79	82
Residential	81	91
Industrial and Commercial	83	87

Source: (European Commission, 2011)

Similarly in the Irish case, a significant proportion of the decarbonisation challenge may fall in these sectors in the period to 2050. Irish TIMES modelling work undertaken by UCC suggests that a 95 per cent decarbonisation of all energy use

9 This target includes the possibility of the purchase of international credits.

would result in an 98 per cent reduction in residential emissions and a 99 per cent reduction in services sector emissions. An 80 per cent emissions reduction, however, results in only a 50 percent reduction in the residential sector and a 62 per cent reduction in services sector emissions. Industrial sector emissions are reduced by 94 per cent in both scenarios modelled by UCC (Ó Gallachóir *et al.*, 2012). It should be noted, however, that this model does not consider energy-efficiency technologies available in the residential and services sector against other options for generating energy, and probably therefore underestimates the potential decarbonisation available in these sectors.

The SEAI Residential Energy Roadmap, by contrast, suggests that the residential sector could be 90 per cent decarbonised by 2050 with high levels of retrofit, deployment of renewable technologies, and high levels of electrification (assuming a highly decarbonised power generation sector).

4.1 New Buildings

Approximately half of the 2050 building stock is not yet built. Under existing building regulations a 'reasonable proportion' of the energy consumption in residential houses to must be provided by renewable energy sources.[10] New and anticipated building regulations for the residential and non-residential sector mean that all new buildings must be built to nearly zero energy standard. The development of these regulations needs to happen in line with the Nearly Zero Energy Buildings plan which is a requirement of the Recast Energy Performance of Buildings Directive. A pathway for all new buildings to be net zero energy has been set out by Department of Environment, Heritage and Local Government.

A nearly zero-energy building is a building with nearly zero net energy consumption and carbon emissions annually. To achieve this objective a building must be insulated to an extremely high standard to reduce the heating load requirement, but it must also cover the majority of its electricity use through energy harvested on-site. It is important to note that this is only possible through the integration of micro renewable technologies such as solar photovoltaic systems, biomass systems, systems using bio-fuels, aero-generators and other small scale renewable systems. These buildings must be 'net' zero energy, opening up the potential to use the electrical grid in times of need, and export electricity when generating a surplus.

Which micro-generation solutions will become part of Ireland's energy future to meet these demanding requirements is as yet unclear. While no distributed

[10] These are listed as 'solar thermal systems, solar photovoltaic systems, biomass systems, systems using bio-fuels, heat pumps, aero-generators and other small scale renewable systems'.

generation system is currently economically attractive in the residential sector, the rapid cost reductions for solar photovoltaic technology over the past three years have taken analysts by surprise, and suggest that it could yet be an important technology in Ireland. The Department of Energy and Climate Change in the UK anticipate that solar PV will achieve grid parity in the UK before 2020 for domestic, commercial and industrial PV systems (Department of Energy and Climate Change, 2010).

The electrification of heating may be a particularly attractive option in well-insulated residential buildings. This could take the form of heat pumps or smart storage solutions solutions, powered from renewable sources. Heat pumps in particular are projected to reach a penetration rate of 25 per cent in the residential sector in the UK by 2030 (UK Committee on Climate Change, 2010), and may therefore also play a prominent part in Ireland also. Smart storage heating technologies may also become an attractive solution because of the grid services they could provide, as discussed in the Interim Report. The alternative of some form of renewable heating system seems less attractive given the low heat load requirement of future buildings, and there may well therefore be a case for a more proactive exploration of options for electrification of heating systems in new buildings.

In the commercial sector, Heating, Ventilation and Cooling (HVAC) and lighting generally accounts for at least 60 per cent of energy costs. Advances in software for building energy management systems as well as for building design (through building information modelling) mean that new buildings can use Direct Digital Control Energy Management Systems to 'listen' to the price signal sent through a smart grid, and remotely control and optimize air-conditioning/heating set points and lighting levels accordingly during peak periods. The business premises of the future should therefore know when electricity is expensive (i.e. during peak usage times), and be able to make automatic decisions such as changing thermostat setpoints and reducing unnecessary lighting. This is known as Auto-Demand Response. If a building is not smart, it will end up paying much more in electricity costs.

As with the residential sector, a key option for supply-side decarbonisation, particularly in the post 2020 period, may be electrical heat pumps. Heat pumps are more cost-effective in sectors with higher heat demand, such as health-care facilities. According to a report prepared for the UK Climate Change Commission, the use of air source heat pumps in commercial buildings is a mature option. Developers of modern commercial buildings often install combined air conditioning and heating systems whereby the air conditioning functions in reverse to perform as a heating system as well (NERA Economic Consulting *et al.*, 2009), these systems are projected to reach a penetration of 60 per cent in the non-residential sector of the UK by 2030

(UK Committee on Climate Change, 2010). We therefore see electrification as a key aspect of the story in the industrial and services sector also.

Whatever the technology, distributed renewable generation, and renewable and electric heating systems are expected to supply and increasing proportion of the electricity and heat requirement in new buildings in Ireland in the post-2020 period. New buildings will be insulated to an exceptionally high standard meaning that the heat requirement itself will be significantly diminished. In fact the possibility of Net Positive Energy (NPE) homes—which supply energy to the grid—emerging in the post 2020 period should not be discounted. New homes will therefore be in a position to generate and store (see transport section below) energy at times of abundance, and to export energy to the grid, while drawing from the grid when required.

These new buildings will therefore transform the energy landscape. The smart grid will allow new storage, heating and power generating technologies in nearly zero energy homes of the future to be optimized and used as a resource by the grid. Storage solutions should be able to avail of lower off-peak tariffs to charge, while power generating technologies should be able to sell back to the grid when generating excessive supply, thereby repaying some of the upfront cost of the investment. The combination of smart meters with smart heating, lighting and appliance controls in new homes will optimise return on these investments. The deployment of a smart grid therefore dovetails with Ireland's objectives for new net zero energy buildings of the post 2020 period.

4.2 Retrofit

A major retrofit programme is envisaged under the *Better Energy* programme in the coming decade. This policy intention is underpinned by the Energy Efficiency Directive (2012) and will require dramatic improvements in end use efficiency in Ireland in the period to 2020, as detailed in the Interim Report. The Recast Energy Performance of Building Directive (EPBD) also requires member states to calculate cost-optimal levels of minimum energy performance requirements for buildings and building elements and DECLG, and SEAI are undertaking Cost Optimal calculations for existing buildings as per the requirements of the Recast EPBD.

Current retrofit activity is shallow, and focuses on building fabric and efficient oil and gas heating systems. We argue in the Interim Report that the focus of retrofit activity needs to be on deeper retrofit solutions than is currently the case, and we also identify significant barriers to be overcome if the wide scale refurbishment of buildings is to be achieved. Indeed the government is actively developing a PAYS concept that should facilitate deeper retrofit activity, and on this basis we see a move to deeper retrofit activity over the coming years. Bringing the majority of the building stock up to a minimum C2 level on the BER is a realistic objective within the next decade.

The SEAI Residential Energy Roadmap (SEAI, 2011b) envisages additional schemes to promote further retrofitting and installation of low and zero-carbon technologies in the post-2020 period. The smarter, more efficient and flexible use of energy in homes can be facilitated through integration of smart meters, energy management solutions, the possibility of widespread electrification of heating, micro-renewable and renewable heating solutions, and these new technologies become increasingly cost-competitive. These technologies are—and will increasingly become—part of a standard retrofitting packages, enabling higher levels of decarbonisation potential in the residential sector is to harvested.

In the post-2020 period, there are two broad pathways that might be chosen, with different implications for the electricity system. Decarbonisation can be achieved on the one hand through focusing on improving the building fabric to a very high standard of efficiency. Highly insulated buildings require very little heat load which reduces the attractiveness of an expensive heating solution (such as, for example, a biomass boiler). We there see something of a trade off between investing in efficiency on the one hand and renewable heating on the other. Efficiency solutions are perhaps the most cost-effective and it seems wise to focus on improving building fabric in the medium term.

SEAI's Smart Grid Roadmap foresees an increasing role for electrification of space and water heating in the period to 2050, though a less significant role for both in the period to 2020 (SEAI, 2011c). While we find in the Interim Report that simple electrification is not viable in the period to 2020, it seems likely that electric heat pumps (and perhaps smart electrical storage systems) could play some role in meeting Ireland's mitigation challenge in the period to 2020, subject to changes in the policy environment. These are solution that work well in highly insulated buildings and therefore have the potential to be cost effective and combined with a focus in policy on building fabric. As with new buildings, solar PV technologies could also come to play a part in standard retrofit packages, although this depends on cost reductions for associated technologies continuing their recent downward trajectory into the early years of the next decade.

The economic opportunity available for retrofitting commercial and industrial buildings is perhaps even more convincing, as detailed in the Interim Report. In this sector the growth of ESCo activity and the delivery of a Green Fund to finance these investments should ensure that options are readily available to those in the public and private sectors who wish to undertake a retrofit. These buildings generally use pneumatic thermostats which are not programmable and non-communicating and traditional lighting without sensors or automatic controls, and are not capable of Auto-Demand Response. Retrofit will focus therefore on smart HVAC and lighting systems, as well as other types of hardware like controls and submeters, as well as solutions focused on building fabric. http://www.automatedbuildings.com/cgi-bin/redirect/sinclair/hotspotclicks.log?http://www.reliablecontrols.com/products/wireless

These trends are apparent worldwide. In North America, revenues for a wide range of smart building technologies and services including building automation systems (BAS), energy service companies (ESCos), and demand response (DR) are steadily growing. In Europe, growing adoption of the ISO 50001 energy management standard is driving investment in building energy management systems (BEMS) and submeter technologies that help facility owners comply with the standard. In the Asia Pacific region, where the building stock is expected to grow at an average of over 2 billion square meters per year for the foreseeable future, the potential for smart building technology deployments is all but untapped (Pike Research, 2012b).

In addition, many commercial buildings, factories and processing plants have their own generators, in some cases used only as backup. The deployment of a smart grid should enable the electricity systems manager to call on these resources to ensure grid stability, thereby optimising all investments in generation, be they by traditional power suppliers or other actors in the economy. Power generating technologies may be able to sell back to the grid when generating excessive supply, thereby creating a revenue stream that can be used to *amortize* some of the upfront investment cost. This could be a particularly attractive proposition for industry considering investing in large new on—site generating technology.

4.3 Conclusion

With the combination of investment in deep retrofit, renewable technologies and electrification, and increasingly demanding buildings codes in both the residential and non-residential sector, it should be possible to approach decarbonise energy use in buildings and industry by 2050. The deployment of a smart grid allows for investments by businesses and homeowners in energy efficiency, storage, and on-site renewables to be optimized. As with the IT revolution, the introduction has the potential to flatten the hierarchies of the power generation system. The combination of smart meters with smart heating, lighting and appliance controls will optimise return on these investments also.

The deployment of a smart grid dovetails with Ireland's strategic objectives for new and existing buildings. It would enhance the strong business case set out in the

Interim Report for a focus on retrofit in the commercial and residential buildings, along with the introduction of progressively enhanced standards regulating the carbon efficiency of buildings.

The implications for the electricity system are somewhat unclear. Should the deployment of efficiency technologies and distributed generation proliferate, demand from the grid for electricity may decrease. SEAI estimate that total energy demand in the residential sector could be reduced by 50 per cent by 2050 under these circumstances (SEAI, 2011b). If efficiency is combined with more electrification of heating, demand from the grid may actually increase—in general modelling work tends to suggest that a deeper decarbonisation trajectory lends a greater impetus for electrification across end use sectors.[11] We would therefore tend to view the emergence of an increasingly electrified economy as perhaps the most likely and desirable outcome, although undoubtedly all of these technologies will play a part in Ireland's decarbonisation story.

5. Electrification of Transport

The transport sector is considered one of the more intractable from a decarbonisation perspective. According to the *EU Roadmap for Moving to a Low Carbon Economy by 2050* the transport sector is deemed to have a lower level of low cost abatement potential than the average across sectors, and therefore decarbonise slower than other sectors in the period to 2050. Conversely, the results of the Irish TIMES modelling work suggest that under an 80 per cent emissions reduction and the 95 per cent emissions reduction scenario (for CO_2 emissions), transport emissions would be reduced by nearly 98 per cent by 2050 (Ó Gallachóir *et al.*, 2012). These results suggest that the Irish transport sector would decarbonise more rapidly than the rest of the economy.

EVs are potentially the most important technology for decarbonising the transport sector. The International Energy Agency suggest that the majority of vehicle will be fully electric or plug in hybrids by 2050 (IEA, 2012). Car manufacturers envision a mostly electrified European market by 2030 (Euractiv.com, 2012), and at that stage the IEA predict a mass market for EVs will have emerged. According to SEAI Electric Vehicle Roadmap, EVs could account for between 48 to 70 per cent of the transport fleet by 2050 (SEAI, 2011d). The Irish TIMES modelling work, electrification of private

[11] As explained in the Interim Report, wwitching to electricity for heating has the effect of moving demand from the heat sector into the electricity sector—i.e. from the non-ETS to the ETS. This results in an absolute drop in non-ETS emissions for Ireland and no increase of emissions in the ETS sector on an EU basis.

transport also comes through strongly, although however a significant role for biogas and biodiesel in freight is also evident (Ó Gallachóir *et al.*, 2012).

It should be acknowledged that the market penetration of EVs has been behind expectations. We argue in the Interim Report, however, that with disruptive technologies such as EVs, short term levels of sales are not a reliable barometer of future potential. We would tend to the SEAI view, that EVs could play the central role in the decarbonisation of Ireland's transport sector.

This is first because of the synergies created between the transport and energy sector through the mass penetration of EVs. Every electric vehicle has a powerful battery and nine out of ten cars are parked at any one time. The smart grid has the potential to integrate these parked vehicles and to use them as a grid resource through dynamic smart charging. This opens up the opportunity for electric vehicles to be facilitated on the grid without significant investment in generation, transmission, or distribution infrastructure. Car owners would therefore become 'prosumers'—consumers and suppliers of energy from the grid.

The prosumer would be enabled through the development of sophisticated Vehicle to Grid (V2G) systems that enable the provision of ancillary grid services by parked vehicles, such as fine-tuning the grid to its intended frequency and voltage. They could also potentially be used to level out peaks and could be called on as a resource instantaneously, thereby fitting well with the move to renewable energy. Instead of disconnecting turbines when they risk overloading the grid, V2G systems could store that power in parked electric cars and retrieve it when the wind dies down. The Danish island of Bornholm, with a population of 28,000, and 50 per cent of energy from renewables, is already trialling such a system (EcoGrid EU, 2012). Researchers hope that the system can increase the island's share of renewable power without installing any additional wind turbines. The EV could therefore plays a pillar strategic function in the management of Ireland's energy system.

Second, the absence of a charging network, widely considered the most significant barrier to EV deployment, is being addressed. In the Republic of Ireland, ESB Networks has already installed approximately one thousand public charging points, and are on track to deliver one of the largest integrated and operational electric vehicle infrastructures in Europe. When the first stage of deployment is completed 500 public chargers will be installed in Dublin and at least one in every town with a population of 1500 people of more in the first stage of deployment. Fast Chargers will be installed every 60km on the inter-urban routes, mostly at motorway service stations, with similar efforts being made in Northern Ireland.

Third, the policy and regulatory direction supports EV deployment. In Ireland there is a great weight of policy support behind electric plans are well developed to facilitate the roll out of EVs in Ireland. An ambitious national target has been set for the roll out of electric vehicles. A number of measures are in place to assist in moving towards the 200,000 target, both on the supply and demand side, as detailed in the Interim Report. A two year grant support is available to incentivise the purchase of Battery Electric Vehicles and Plug-in Hybrid Electric Vehicles. There are also accelerated capital allowances available to businesses purchasing EVs. EVs furthermore enjoy the lowest road tax band of all vehicles and benefit from some relief from vehicle registration tax.

Fourth, based on projected cost reductions, EVs may offer cheaper ten year cost of ownership than traditional vehicles by 2019 (SEAI, 2011d). Battery technologies are evolving rapidly allowing for greater range to be achieved from one charge. Ireland's limited geographical size also means that range is somewhat less of an issue than in larger countries and non-island states.

Fifth, there could be significant green economy spin offs available to Ireland from the rapid deployment of EVs. The focus of this work is principally on the surrounding technology: issues such as supporting ICT and data analytics; financial and payment services; charging infrastructure and engineering; working with companies and local authorities to create public charging infrastructure; and trials with drivers. IDA Ireland is focusing on securing inward investment from multinational corporations in the electric vehicle sector by leveraging the trialling, test-bedding and demonstration of relevant technologies and services.).

On this basis we view EVs as likely to play the predominant role in the decarbonisation of the Irish transport sector. This is not, however, to diminish the role that other technologies might play (such as, for example, biogas).

6. Looking to 2050

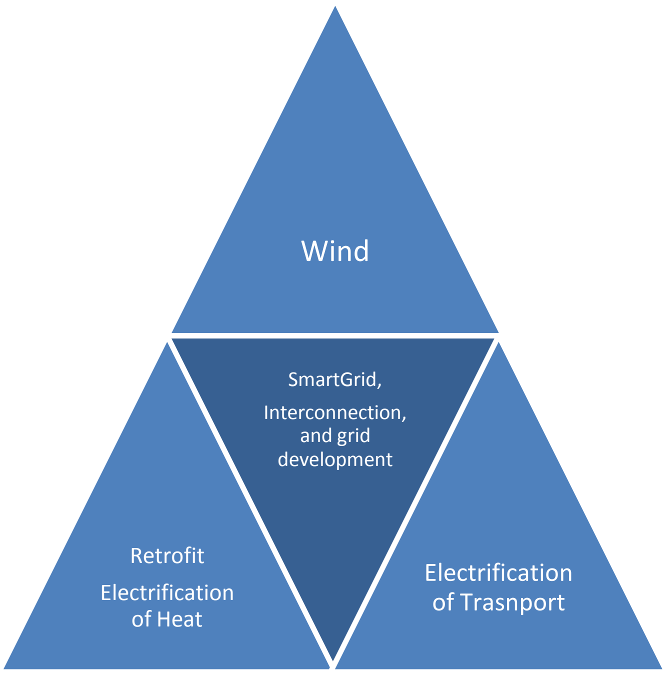
In this section we look forward, in an attempt to assess how the long term decarbonisation of end use energy can be progressed. In the Interim Report we looked at steps necessary to decarbonise energy end use in the transport and buildings sectors in the period to 2020. In the analysis presented in this chapter, we combine a longer term analysis of decarbonising energy use in transport, industry and residential and commercial buildings, with the deployment of a smart grid.

On this basis, and on the basis of the findings of the previous chapter, we propose that the narrative around decarbonisation needs to be built upon:

- The deployment of a smart grid;
- Retrofit (including electrification of heating) in buildings;
- Electrification of transport;
- Increasing the penetration of wind into the energy system; and
- Developing the grid to facilitate the connection and connecting Ireland's grid more fully with the North European Grid.

We realize that this is necessarily a simplification of what will be a highly complex transformation, requiring the deployment of a proliferation of energy-efficient and low-carbon technologies. Nonetheless, we believe that there is an element of consensus around these key pillars, and we offer this view as a contribution to the development of a societal narrative around decarbonisation which can be widely understood and accepted.

Figure 1: The Irish Energy System 2050



In order for these agendas to be brought forward in tandem, we explore in detail some policy options below. We focus here on the energy end use discussed in this Background paper, and in particular on the deployment of a smart grid, which has not been addressed in the Interim Report or in other working papers.

6.1 Regulatory Environment

Efficient regulation at national level is perhaps to the key tool for driving the European development of a highly modernised grid, and incentivising the transition to a low-carbon economy. The regulatory environment has generally been supportive of investment in smart grids and in wind energy, investment in smart grid R&D, deployment of aspects of the smart grid and grid upgrades and interconnection more widely. Once a business case can be proven, as was the case with smart meters, the regulatory authorities have shown a willingness to approve very substantial investments that are in the best interests of consumers. Nevertheless, it is the regulators primary objective in Ireland as elsewhere to protect the short term interests of the consumer and prevent any unnecessary price increases. Regulators may therefore have a tendency to take a narrow or short term view when evaluating cost efficiency, penalising extra expenditure on R&D or smart grid pilot projects and encouraging business-as-usual expenditure instead (Eurelectric, 2011).

To ensure investments in smart grids and other low-carbon technologies necessary to underpin the transition to a low-carbon economy, the regulatory authorities might be required to focus more strongly on long-term requirements of decarbonisation, and on providing a fair rate of return on the necessary investment. There perhaps needs to be greater focus within the regulatory process on protecting customers by ensuring that there is sufficient network investment to protect against potential risks. Several assessments have found that as one deploys smarter solutions, the total investment needed to achieve objectives decreases. For instance, in UK it has been estimated that the total investment on the grid up to 2050 will be £19 billion lower with smart technology rather than conventional technology (Ernst & Young, 2012). It is important to consider cost and risks of moving ahead with rapid deployment as well as costs and risks of status quo. This could come from both the regulator and companies being expected to publish a risk review, and also a requirement to identify and evaluate what might be termed 'no or at least low regrets' investments.

There may therefore be a requirement to revise the rules and directives that govern the decision making of the Commission for Energy Regulation. The functions and duties of the CER have been altered and expanded significantly by legislation transposing EU directives into Irish law in recent times, and there is therefore perhaps a case for clarifying these rules in any case. A further challenge will be integration into a European Target Market model, and the rules governing remuneration of network operators therein.

In a future with increased proliferation of smart meters, distributed generation, and energy storage, and the potential emergence of virtual power plants, it is important not to take the current industry model as a given. In the post 2020 period, there are some complex challenges to work through there it is therefore necessary to actively explore alternative models. For example, utilities may play a more expansive role in managing and, potentially, investing in distributed resources (for example in households or businesses) as a tool for reducing costs. Alternatively, the utility could provide highly differentiated price signals to incentivise customers to provide the highest value energy supply, load management, or ancillary services to the utility system (Rocky Mountain Institute, 2011).

6.2 Agree a Shared Societal Vision and Strategy for the transition to a -carbon-neutral economy

Agreeing in government and communicating a shared vision for the transition to a -carbon-neutral economy would be of significant benefit in galvanizing wider support across society for this transition. Governments have a central role to mobilise capital to low-carbon infrastructure by delivering what the OECD describes as 'investment grade' policies. This starts with goal setting and aligning policies across and within levels of government, including the articulation of a long-term vision and targets for infrastructure and climate change. We have sketched above what we believe the key elements of this transition might be in the introduction to this section.

If the smart grid in particular is going to become a reality, its purpose and benefits need to be understood by society and policy makers. Agreeing and communicating a shared vision for the deployment of a smart grid in Ireland, as official government policy, could be a key enabler of a predictable deployment of different elements of the smart grid. A vision can also underpin the development of a strategy which can be useful for evaluating smart grid business and investment objectives, to benchmark technological, regulatory, and organizational readiness and progress, and to prioritize current smart grid opportunities and projects. SEAI's Smart Grid Roadmap (2011a) already provides a useful starting point for the development and articulation of a vision, and could form the basis upon which a robust vision and strategy could be developed.

6.3 Establish Smart Grid Test Bed Facility

Ireland in a unique position to offer our networks and systems as a proving ground (test-bed) for the deployment of smart grid technologies. The central role of Eirgrid and ESB Networks North and South of the border provides a unique environment where cross-jurisdiction concepts, applications and business models can be tested. This was the case with the EV pilot described above

In order to further build on this reputation in this areas a test bed facility could be established where new technologies, business models and applications could be tested. This might involve the establishment of a zone where all smart grid technologies are rapidly deployed on the grid (such a concept is currently being proposed in the Donegal-Derry region, in a so-called North Atlantic Green Zone initiative that has been proposed to the European Commission).

Another component of a smart grid test bed facility might involve a Green IFSC-type initiative, where Ireland is actively promoted internationally to businesses and investors who wish to test leading technologies, business models or concepts. In some ways this agenda can be seen as similar to the Green IFSC concept, and would require similar levels of resourcing and government support at the highest levels.

In establishing such a test bed facility, it is important that the grid be as open a platform for experimentation as is possible, and that proprietary solutions are avoided. Regulatory authorities and distribution and transition system operators need to be as open to potential collaboration as possible. The importance of having open access to data, and the open development of protocols, and even open access to the network itself to plug and trial various applications is key.

6.4 National Rollout of Smart Meter and Variable Tariffing

The roll out of smart meters is key to facilitating the further deployment of the smart grid, as well as driving decarbonisation from the power generation system into homes, business, industry and the transport sector as detailed above. A range of technical, customer engagement and education, regulatory and financial hurdles need to be address to ensure the successful roll out of smart meters nationally. It is planned to commence the roll out in 2014, and it should be competed between 2017–2019. The success of this roll out is vital to the deployment of a smart grid in Ireland.

Many of the issues are around consumer acceptance. Consumer acceptability may be impacted by concerns over privacy, e.g. use of usage data by law enforcement or social concerns over Enron style abuses of information leverage, or concern that complex rate systems (e.g. variable rates) remove clarity and accountability, allowing the supplier to take advantage of the customer. There may also be concerns over a remotely-controllable 'kill switch' incorporated into most smart meters, this could lead to social concerns over the 'fair' availability of electricity. Some concerns have also been expressed over the RF emissions from smart meters. With the advent of cybercrime there is also concern on the security of the infrastructure, primarily that involving communications technologies. Concerns chiefly centre around the communications technology at the heart of the smart grid. Designed to allow real-time contact between utilities and meters in customers' homes and businesses, there is a very risk that these capabilities could be exploited for criminal or even terrorist actions. The key to understanding and managing these concerns is consumer engagement well in advance of roll out.

There may also be some intractable issues around the introduction of variable tariffing. The variability of tariffs, the degree of flexibility given to suppliers and the sequencing of smart meter roll out the introduction of variable tariffing are all issues that require careful consideration.

6.5 Encourage Electrification in Buildings

As discussed in the Interim Report, there are several obstacles to the electrification of heating that need to be addressed to facilitate the greater electrification of heating and the public awareness and acceptance of the technologies required. Public acceptance is a particular challenge when it comes to electric heating solutions as there is a general perception that traditional electric heating systems are expensive, inefficient, or difficult to control and optimize. In new buildings regulations require the use of renewable heating (though heat pumps, which are classified as renewable). Building regulations could in time be modified to allow for consideration of smart electric heating systems, which enable and use increasing proportions of renewable electricity on the grid.

Furthermore *Better Energy: Homes* scheme provides an incentive for the replacement of oil boilers with more efficient oil boilers and heating controls. This provides a disincentive for considering electrification. As argued in the Interim Report, without subsidy, heat pumps are an attractive option in the new off-gas grid in residential and non-residential sector buildings, yet oil boilers can still be chosen in these situations. Regulation should prohibit the choice of oil boilers in these situations.

6.6 Electrification of Transport

Applying virtual power plant-class models to the management of electric vehicles is a key challenge currently being researched. It is likely that only large scale pilots can resolve the system management issues arising with testing this concept. There are also technological limitations associated with battery range, V2G systems, fast-charging procedures and handling heavy battery packs to swap within minutes.

Nonetheless, on this basis it would seem that the continued emphasis in policy on the promotion of early deployment of EVs in Ireland is justified. While the future is inherently uncertain, it would seem that EVs have the potential to play a pillar roll in the decarbonisation of the transport sector, as well as playing a key strategic function in the management of an increasingly decarbonised energy system.

6.7 Planning for the unexpected

New business, operational, environmental, and societal opportunities will present themselves along Ireland's transition to a low-carbon economy. For example, the proliferation of new data available arising from the smart grid will allow for the emergence of new business models and concepts. It also opens up the potential for entirely new services or improvements on existing ones.

Within home a single platform may finally emerge, with convergence of telecommunications, entertainment, internet and energy. We could see energy supply bundling with other services such as security, fire monitoring or alarms. Companies such as Google and Opower are already making use of the data that is becoming available to develop new offerings to utilities and bill payers. The combination of mobility and electricity will open up new avenues that at this time can only be guessed at, and the same applies to heat and electricity. Business models associated with the circular economy may also emerge: energy suppliers may become leasers of distributed generation technologies as opposed to just the supply of power.

In order to plan for this uncertainty, a spirit of open collaboration across the actors in society is required. Eirgrid's open call for projects, issues in 2012, is exactly the type of public-private sector collaboration that is required, and a model that could be further developed by ESB networks and others in the future.

7. Conclusions

The smart grid therefore joins together three of the most important pillars of Ireland's transition to: integration of wind, retrofitting of buildings, and electrification of transport. It should be noted, however, that transmission system investment and interconnection with the North European Energy grid is another vital component, as is transmission system development.

There is a synergistic relationship between these pillars of the transition to a low-carbon economy, and the opportunities and benefits that may arise as a consequence, cannot yet to be fully understood, realized or captured. There is therefore a need for developments to be guided in as open and explorative manner as they are progressed along various tracks, to ensure that the fully green economy potentials are exploited as they arise.

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