Grid and Supergrid – a European energy future
“No transition without transmission”

University of Oxford Energy Colloquium
March 10th 2015

Dr Eddie O’Connor

Grid and Supergrid – a European energy future

“No transition without transmission”

Ladies and Gentlemen

Introduction

It is a pleasure and a privilege to be with you today. The University of Oxford is a great institution of learning and innovation, and it is a particular delight to be a guest of the University’s Energy Network.

I am a chemical engineer by education, but a developer of energy by profession. While we will always need chemical engineers, we could do with more energy graduates, and more energy faculties. I commend you for setting up this Network, and I commend the University on its foresight in asking Sir Chris to bring a number of different disciplines together under an Energy umbrella – so much of what I do on a daily basis involves aspects of a range of disciplines from engineering and science to economics and politics.

When you were kind enough to invite me to speak to the University Energy Society in 2013 I noted that in 2010 the Royal Society held an exhibition of the work of one of the Fathers of Modern Chemistry – the Irishman Robert Boyle. You might claim him as an Oxford man, but anyone born in Lismore who learned to speak Gaelic before he could speak English, Latin or Greek, is an Irishman in my book.

Boyle is truly one of the greats of our profession, and the Royal Society published his list of 24 Inventions which he believed not only could be discovered but which would immeasurably benefit mankind.

The extraordinary thing is that most of the items on his List have been invented, including "perpetual light", which we would call electricity, or more accurately, electric light.

Electricity is one of the mainstays of modern civilisation. Although the United Nations estimates that 1.3 Billion people lack access to electricity, we who live in the developed world cannot conceive of modern life without it.[1]

In 2013 I spoke about how we could build a zero carbon energy future. I want to look in more detail at one aspect of that future today. Although I will discuss generation technology – because you cannot describe a

[1] http://www.sustainableenergyforall.org/objectives

future electricity system without mentioning supply – I would like mainly to talk about transmission. Grid – or more accurately – Supergrid, and how with it we will transform Europe's energy landscape.

But, just as you can't describe an electricity system without discussing supply, you can't avoid regulation and markets either. It is fortuitous then, that at the end of February the European Union announced the broad outline of what is being called the Energy Union.

Originally a play by Poland and other members of the Visegrad Group to mobilise the buying power of the Union to negate the malign influence of the Russian government in gas supply, it has become, very quickly, a blueprint for a single European electricity market. This is something I have waited some time to see, and may yet have to wait some more, but we now have a route map to an interconnected and low carbon Europe.

So this afternoon I would like to do three things. Firstly to briefly tell you a bit about my interest in Supergrid, and my credentials for being here.

Secondly to review the policy context which underpins the development of a European Supergrid.

And, thirdly, to look in some detail at the technology that we might see deployed as we build an interconnected society.

Let me return for a moment to Robert Boyle. In 2010 the Royal Society of which he was a founder member observed that:

There is strong evidence that changes in greenhouse gas concentrations due to human activity are the dominant cause of the global warming that has taken place over the last half century. This warming trend is expected to continue … over the long term in many regions.[2]

Another Irishman, John Tyndall made the extraordinary discovery that some gases absorbed infrared radiation, whereas others did not. CO_2, CH_4 and water vapour absorbed it, whereas O_2 and N_2, the principal gases that make up our atmosphere did not.

This discovery was made in the Royal Institution in 1861.

Since 2010 scientific analysis has only further strengthened this position. Greenhouse gases, whose concentration was 270 ppmv in pre industrial times, this year breached the 400ppmv level and are being added to the atmosphere at a rate of 2.5 parts per million by volume with each passing year.

---

[2] *Climate Change: A summary of the Science* The Royal Society 2010

One of the heaviest emitters of greenhouse gases is the power sector. The burning of fossil fuels to generate electricity contributes 10 billion tonnes of CO_2 annually to the world's collective carbon footprint.[3]

Decarbonising the power sector, while at the same time undertaking a once in a lifetime redesign of Europe's power systems, and in turn delivering cheap and secure supplies of electricity across an open and competitive market, strikes me as a good thing to be doing.

Mainstream Renewable Power

Perhaps, first, I should say a bit about myself and my company Mainstream.

For some time I ran an Irish state-owned company called *Bord Na Mona*. It extracted 5 million tonnes of peat per annum and sold it to domestic and international consumers. I became convinced in 1989 of the greenhouse gas effect on climate. I realised that the generation of electricity by burning peat was neither sustainable nor good economics.

I persuaded my Board to let me build a wind farm. They concurred, but after I had built one in 1992, that was enough for them. That wind farm, producing 6.4MW, with equipment which generated 250kw per turbine

[3] http://www.sciencedaily.com/releases/2007/11/071114163448.htm

is still running strongly today. This despite the fact that, by today's standards, it is primitive.

So I left, and with some great colleagues, we built a company called Airtricity. In ten years we had fashioned an organisation which developed, built and operated wind farms in America, Canada, and Europe. We developed Europe's largest onshore and Europe's largest offshore wind farms.

But as we did so, three things struck me.

The first was that in Europe there would always be a practical limit to the amount of wind that could be built on land. This inevitably translates into a political – and social – limit to how much onshore development could be delivered.

Wind output is variable.

Up to a certain point this doesn't matter, as the variability in customer demand, or more precisely the amount of dispatchable plant that has to be held in reserve to meet this variability, is enough to allow wind to penetrate to about 20 to 25% of overall demand.

The second was that the North and Baltic seas were huge, and relatively shallow, platforms for offshore wind development, sitting in the middle of a very large area of demand.

And, thirdly, wind and solar power are continental and not national resources. Country, or island only, approaches to renewable energy development will fail to maximise the benefits of renewable technologies. In most countries, system designers can only plan on a penetration of 25% at most if their nation remains an electricity island.

As Atlantic storm fronts pass across the British Isles we should be capturing the energy in Ireland, then in the UK, then in the North Sea and then in Denmark, and sharing the resource. To meet its true potential wind must be looked on as a continental rather than a national resource.

Those insights persuaded me that the development of big grids to carry these new sources of generation from where they were captured to where they were needed, would be the key to delivering a decarbonised power sector in Europe, the USA and China.

We launched the concept of Supergrid in 2002, making the case for an interconnected Europe powered by wind in the north and solar in the south. Some 13 years later, with the publication of the EU's Energy Union proposals, that concept is beginning to look like reality.

In 2008 we sold Airtricity for USD2bn. We then set up Mainstream Renewable Power with many of the team that had created Airtricity. We chose the name of the company deliberately. While the story at Airtricity was about building a business developing wind power, which was on the margins of generation technology, and proving its commercial viability; the story at Mainstream is about building new generation and transmission systems at the heart of which sit wind and solar power. Wind and solar are capable of delivering 100% of our electricity generation, and this company is set up to prove this concept, practically and commercially.

In 2008 we brought together 20 of Europe's largest industrial concerns, including Siemens, GE, Alstom, ABB and National Grid, to form the *Friends of the Supergrid*, a name first suggested to me by the then German environment Minister who after politely listening to me on the need for Supergrid, said:

"That is all very well, Dr O'Connor, but where are your friends?"

The need for change

Last year Mainstream announced a change to our corporate strategy. This evolution in our approach from creating value by developing renewable energy in regulated markets, to one where we will increasingly partner with customers to build bespoke generation, has come about due to the profound change underway in the wider energy sector.

2014 will be seen as the year in which renewable electricity fully emerged as a conventional generation technology and we passed the point of no return in our creation of the electric society.

Firstly, as I will explore in more detail later, we have had confirmation that new wind and solar plant now has a lower cost of energy than comparable new fossil generation across a number of markets. The continued price degression for both onshore wind and solar PV has seen a number of analysts confirm that we have arrived at an inflection point in the cost of these technologies in relation to traditional fossil generation.

Secondly, with an eye on the likelihood of a global climate deal at COP21 in Paris this year, institutional investors are now closely examining the prospect of stranded fossil assets and have begun to price in the cost of carbon to corporate inventories, in what is termed a “carbon bubble”.

At the same time, growing energy efficiency is shrinking the market for fuels. According to *Bloomberg New Energy Finance*, imports of oil into the USA have dropped nearly twice as much because of improved vehicle efficiency and reductions in miles driven, than they have because of discoveries of unconventional oil.

Thirdly, alternatives to renewables have fallen away. The two other major low carbon technologies expected to make an impact, CCS and new nuclear, simply haven't.

CCS remains a large laboratory experiment, and the nuclear renaissance has collapsed due to the cost and risk associated with the construction of new plant. Not only is the levelised cost of new wind and new solar PV now less than that of new nuclear, but the average time from planning consent to operation of a 1GW solar or onshore wind plant is one year, compared to at least twelve for new nuclear.

Only last year, the developers of the Olkiluoto plant in Finland pushed out the commissioning date to 2018, some nine years later than the original plan. This plant, it should be remembered, is essentially the same as that planned at Hinkley C.

So, this clear direction of travel means that we have adapted our approach. We remain committed to the development of wind and solar energy. We believe they remain the keys to unlocking a sustainable future. But, we want to be able to capture value in developments across this new electric market. That will include investment in new grid, but it will be coupled with rapid deployment of energy storage. This combination with variable generation will allow for the expansion of smart technology, putting power into the hands of consumers – whether corporate or household – and further undermining the utility business model, which is already broken.

You don't have to keep up to date on a daily basis with trends in the sector to recognise that Google's acquisition of Nest, or California's mandate for energy storage, or Tesla's soon to be opened Giga-factory for batteries, or technology breakthroughs like that of Oxford PV with perovskite thin-film solar cells, is all part of a relentless march to a very different future.

In smart technology terms we are moving to an anticipatory future, where technology predicts your future needs rather than just reacting to place-in-time commands. That mirrors the profound change across the electricity sector, where traditional models of utility provision are now being replaced by customer-led, smart supply and demand management. Or as UBS put it in a briefing note from August last year:

Our view is that the "we have done it like this for a century" value chain in developed electricity markets will be turned upside down within the next 10-20 years…[4]

[4] *Will solar, batteries and electric cars re-shape the electricity system?* UBS Q-Series 20 August 2014

Only this month, in a Report written, I have to say, by Cambridge University for the National Bank of Abu Dhabi, concluded:

While the economies of this region have been built on oil and gas production…the energy system of the past will not be the same as the energy system for the future. It is clear that renewables will be an established and significant part of the future energy mix.

We live in an age of unprecedented concern about the security and sustainability of energy production. The threats presented by a changing climate have compounded the existing challenges presented by diminishing carbon resources – often located in unstable regions. Set against this reality, Europe must refashion its relationship with energy, replacing the polluting technologies of the last century with a clean and sustainable platform for meeting the energy needs of the future.

Realizing that goal will see the establishment of a new European energy framework; from clean technologies that harness the continent's wind, solar, tidal and geothermal potential delivered through a transmission network that connects to where people and businesses need it. Just as the challenges we face transcend national boundaries, they require a shared solution based on mutual self-interest and an appreciation of our common future.

Never was the unifying principle of mutual interdependency, on a European scale, more exemplified than in the energy area.

A transcontinental Supergrid will allow Europe to confront the threats posed by climate change, secure an independent energy future for the continent and provide ongoing access to affordable and stable supplies of energy that meet all our needs. However, it can do more than that; by simultaneously taking advantage of 'Smart Grid' technologies we can develop a transmission system that acts as an 'electricity internet'.

Replacing the constrained, hierarchical one-to-many model of the past, such a grid would become a many-to-many intelligent network that is largely automated and able to operate, monitor and, to some extent, heal itself. As well as providing a safer and cleaner supply of electricity, such a grid will also deliver considerable savings in terms of transmission costs and reductions in lost supply; in short, it will be more flexible, more reliable and better able to meet our needs.

To meet these goals, Europe needs a Supergrid based on smart technology. To meet these goals in time, it needs to begin that transition today.

Generation and Grid Parity

I mentioned that in this new electric society, generation, transmission at both the high and low voltage levels, metering, pricing, billing, and appliances are all part of the one systemic whole.

Generation is the most expensive part.

Much uninformed comment attends this debate.

One hears talk of grid parity; that newly built wind is more expensive than old coal, oil or gas.

Well of course it is.

The old plant was built on the balance sheet of nations, with low and nationally guaranteed interest rates, at labour costs appropriate to the mid-seventies and eighties.

These power stations were fully depreciated and amortised by 2005. They now operate at marginal cost. When planning the power systems of the future the full capital, operating, and maintenance costs of the competing technologies have to be compared to arrive at the lowest delivered cost of energy.

It is very useful to take a practical example.

South Africa is an electricity market that shares many of the characteristics of European and North American countries. There is a dominant utility – Eskom – which operates a fleet of old coal plant. Big customers, like mines, pay in the order of R0.5/KWhr for their power. The power stations supplying them were built in the seventies and eighties. New coal fired power stations, being built by Eskom at Medupi and Kusile, need a price of R1.1 for their power.

We can now directly compare the cost of this new plant with renewables. In 2010 South Africa launched a competitive tender for wind and solar plant. My company has won over 500MW of capacity in the first three rounds of this tender process.

In the latest round, wind was competitively bid at R0.65.

It should be noted that the R1.1 price for new coal does not include any charge for CO_2 pollution. If a pollution price is charged at say $25 per tonne then an additional cost of coal fired electricity would be R0.27. So new wind versus new coal would compare in price as R0.65 vs. R1.37, or 0.47 the cost of coal.

These economics are not unique to South Africa, but can be seen wherever new onshore wind, and increasingly solar PV, runs head to head with <u>new</u> fossil plant.

The background – what is Supergrid

Let us return to transmission.

'Supergrid' is the term for the future electricity system that will enable Europe to undertake a one-off transition to sustainability. This transmission network will make possible the delivery of decarbonised electricity across the continent, enhancing existing AC networks. It will become the backbone of Europe's future power system.

Europe's current renewable energy targets necessitate the development of renewable generation remote from existing population centres, with much of it based offshore. Mixed with solar from the south, tidal, wave, biomass, existing onshore wind and hydro resources and storage - and connected to many small-scale inputs - this will form the sustainable energy supply system for the continent. Supergrid will allow future generation to be built where resources are optimal and transported to existing grids for delivery to existing and future load centres.

I should point out that the 2020 European climate and energy package has been hugely instrumental in delivering renewable energy at scale across the continent, and has led to the rapid price degression in both wind and solar technologies. Wind power has dropped by 45% and solar PV by 80% over the period since the 2020 package was adopted.

However, it has one deficiency. The centrality of member state targets has meant that countries are not incentivised to trade. There has been some very limited cross-border collaboration, but large schemes which would have seen generation in optimal areas and transmission to load centres in another country, like my company's proposal to build onshore wind in Ireland and connect it directly to the GB grid, failed to garner sufficient support from national governments.

All that is about to change. The 2030 Energy and Climate package has no national targets. Instead there are EU targets for emissions reduction, renewables deployment and interconnection. Some governments, including the UK, may have been tempted to conclude that this would keep European intervention in national energy markets to a minimum. On the contrary, the opposite will almost certainly be the case.

The proposals for Energy Union – released on 25 February, set out an impressive vision for a "*fundamental transformation of Europe's energy system*", in which "*we have to move away from an economy driven by fossil fuels … and outdated business models*". The Energy Union promises to be "*climate friendly*", with Europe becoming "*the world leader in renewable energy*". This is, as one commentator stated, strong stuff for a normally conservative and understated Institution.

As Jonathan Gaventa, of European energy analysts, E3G put it, "The Energy Union communication hints at the biggest shake-up to EU energy markets since the Third Energy Package was proposed in 2007. Since that point, there have been major changes to energy technologies such as smart demand and cheaper renewables, and to business models with the EOn demerger and radical changes to other European utilities. There has also been increasing conflict between the EU's single market aspirations and national market interventions. We should expect a clampdown on national capacity mechanisms, new rules for renewable energy support, and efforts to beef up EU energy regulators."

To which I would add "Amen".

National capacity markets, in the context of a single European market, are anathema, and in an economic context, deeply sub-optimal. Why UK consumers should subsidise coal and gas generation here, when we could buy cheaper power from our neighbours, I simply cannot comprehend, beyond a certain insularity within institutions of government in the UK that are better explored by this University's PPE department, rather than by a simple chemical engineer like me.

The 2030 energy and climate package also commits the EU to reduce its greenhouse gas emissions by 40% from 1990 levels, as part of a longer term objective of reducing these emissions by 80-95% by 2050.

Considering Europe's current fuel mix, delivering these levels of emissions reduction will require a significant change to Europe's generation portfolio, most significantly a reduction in coal, oil and gas.

Energy Security

In setting out options for what became the agreed 2030 Energy and Climate package, the European Commission and others commissioned a number of studies to determine the future shape of Europe's energy system.

These included work by consultants including Booz & Co on the benefits of an integrated European energy market, by the European Climate Foundation on the preferred routemaps to a 2050 low carbon Europe, and by operators such as ENTSO-E and Eurolectric on the generation and transmission choices that would have to be made.

While the conclusions of these studies may differ in specifics, a definite consensus emerges among them. For example, most conclude that the electricity system will have large penetrations of renewable energy and that delivering this will require significant investment in the infrastructure of the transmission grid. Many of the studies considered various scenarios to be examined in the analysis of future grid design in the context of large scale renewable penetration in Europe by 2050.

Common to all scenarios and reports is the need for increased transmission interconnection across Europe. According to the working paper 'Infrastructure networks and the 2030 climate and energy framework' undertaken by E3G:

"2050 Roadmaps and scenario studies point to the critical role of network infrastructure for cost-effective decarbonisation pathways, in both integrating variable generation and in enabling more efficient market operation. While investment in transmission and distribution infrastructure will need to increase in nearly all scenarios, the cost is more than offset by the savings made in capital and operational expenditure for power generation.

"Delivering this network infrastructure at sufficient scale and speed to meet with Europe's climate and energy objectives will be a significant challenge. European Commission Roadmaps suggest that rates of overall grid investment would need to double by 2025, and triple by 2045. Electricity TSOs are currently planning to increase their rate of investment by 70% out to 2020.

"Achieving this will require mobilisation of large amounts of capital investment. For power transmission this is in the range of €114-184 billion by 2030 and €273-420 billion out to 2050.

One of the benefits of Regional Interconnection is in reducing the variation in demand. According to the European Climate Foundation's 2050 Roadmap:

"By 2050, Europe could achieve an economy wide reduction of GHG emissions of at least 80% compared to 1990 levels. Realizing this radical transformation requires fundamental changes to the energy system. This level of reduction is only possible with a nearly zero-carbon power supply. Such a power supply could be realised (if we expand) the trans-European transmission grid".

Enabling Technologies

An enabling technology for the new grid is HVDC, driven by modern power electronics. AC power links become uneconomic over long distances. With buried cable, AC links longer than 70kms are impractical.

DC networks, however, become economic for shifting large amounts of power over long distances; such as the 800 mile Yunnan to Guangdong 5000MW, 800kv transmission project in China.

The advent of modern HVDC links based on Voltage Source Converter (VSC) – using Insulated Gate Bipolar Transistors (IGBT) rather than thyristors, technology has one particular advantage in Europe. It will facilitate the interconnection of offshore wind clusters with existing onshore grids and with each other.

These new links - connected at SuperNodes - can form a European Supergrid and will be developed and built using this next generation of HVDC technology and marine generating plant. It will further enable clean energy generation and deliver firm renewable power across the EU.

[Show a diagram of a supernode]

Design concepts

There are a number of design concepts for the new European Supergrid developed by various organisations. These concepts share the characteristics of a master plan based on differing selections of fuel mix, generation and load location and technology choices.

An example is the European Climate Foundation Roadmap for 2050 which identifies net interregional transfer capacities to deliver renewable energy from abundant sources to centres of load for various renewable energy levels of penetration and is an example of the output of these design concept studies.

The following quote from the roadmap report is worth noting in full: *"The most noticeable case for this is Iberia, where favourable onshore wind and solar conditions could result in significant export potential for RES capacity. The resulting need for transmission capacity to France (32GW in the 60% pathway) is therefore also large. However, the composite cost for the grid assumes a significant amount of underground/submarine HVDC for the grid expansion, which could be used to minimize the challenge by, for instance, running cable undersea through the Bay of Biscay. It is also clear that more wind and solar could be built outside Iberia lessening the need for transmission capacity from Spain to France. Finally, while adding capacity in this region has historically been limited, it should be seen in the light of the overall context of this work: a European energy system that will be fundamentally different from that of today in which overcoming this challenge will be only one of the large obstacles for decarbonisation".*

Without a Supergrid, Spain has had to stop renewable energy generation at around 25% penetration. There was not a single MW installed in 2013/14.

Simply put, without transmission we cannot meet our future energy and climate goals. There can be no transition without transmission.

Integration of Supergrid

The challenge of matching an increasingly variable and geographically diverse energy mix will require a power system designed specifically with the new generation portfolio and power market in mind.

According to the global power technology company, ABB:

"There is a convergence occurring between the business realities of the utility industry, the energy demands of modern society, and the sustainability requirements of the environment in which we live. The combination of these factors is driving the development and implementation of a new power delivery system. This network will utilise the same basic infrastructure we know today, but will also draw on advanced monitoring, control and communications technology that is currently only beginning to be applied.

"The result will be a grid that is largely automated, applying greater intelligence to operate, monitor and even heal itself. This 'smart grid' will be more flexible, more reliable and better able to serve the needs of a digital economy."

This future grid will see trading of large scale renewable resources connected to the Supergrid, medium scale storage and backup connected to the existing high voltage AC grids and distributed generation connected to medium voltage distribution networks. With variable resources, storage and Demand Side Management or Smart Grids and with price as proxy, new data management and real-time communication systems will be required to operate this “intelligent” market: the result will be sustainable, reliable and fair – an “electricity internet”.

“Just as the internet has driven media from a one-to-many paradigm to a many-to-many arrangement, so too will the smart grid enable a similar shift in the flow of electricity.”

Information and Communications Technology (ICT) has been a ’game changer’ in today’s world. It is ubiquitous and although power systems have had some level of ’smartness’ built in for many years, modern ICT innovations will allow new models and efficiencies.

According to Alstom:

“These intelligent networks evolve regularly with the technological innovation, both at transmission and distribution level, with embedded controls, IT and telecommunications capabilities. Smart grids provide a real-time, bi-directional flow of energy and information, connecting all the stakeholders in the electricity chain – allowing better communication

between the power plant and the transmission grid operator, better coordination between the distribution electrical utility and the end-consumer."

Imagine your home in a few years' time. You have an electric vehicle parked outside. You have solar PV panels on your roof and a small stationary battery in the garage, or you share one in a district scheme with your neighbours. The EV charges at night, and smoothes the demand curve. The battery stores excess solar electricity generated in the middle of the day and passes it back to the grid in the evening. In the morning, or at other periods of low generation, a combination of other renewables – mainly wind and biomass – drawn from remoter areas over an HVDC grid, fill in the gaps.

You may even have an App – and why not – that gives you access not only to your own heating and lighting systems as you can today, but to pricing data and supply information. In fact – to go back to what I said about anticipatory technology, your SmartPhone will already be powering down or up appliances in your home, or your business, based on the pricing and demand criteria that you have already supplied.

No more need for base-load, or large centralised power plant. No more paying out large sums to your utility by direct debit only to have your money earn them interest. No more market dominance. You the consumer, are in charge.

This is why the more far-sighted electric utilities are scrambling to find a new business model. Their transition has to be to become energy service providers. Or, as Peter Terium, the relatively new CEO of RWE put it:

In the future RWE's competitive edge will be determined by our ability to be a service company applying energy supply capabilities and information technologies intelligently.[5]

It is not just enlightened utilities and technology companies that see the need for a new integrated approach. The report 'Foresight Study into Future Market Opportunities in Sustainable Energy Technologies**',** prepared by the MATRIX Sustainable Energy Horizon Panel for the Northern Ireland Government states:

"Going forward, the instantaneous matching of energy supply and demand will become much more complex and will require networks that are flexible and reactive, with new tools that enable the participation of new actors (primarily end users)."

This report describes how the new power system will use "*technology that can measure, analyse and communicate the status of power*

[5] *RWE sheds old business model* ReNewEconomy 22 Oct 2013 http://reneweconomy.com.au/2013/rwe-sheds-old-business-model-embraces-new-energy-reality-52967

transfer at and between all levels of the system to optimise performance."

Next Steps

However, technology companies and governments are not enough to realise this future. The Global Smart Grid Federation in its 2012 report states that the "*most difficult challenge to a successful smart grid lies in winning consumer support…* and that this will *require a radical change in thinking by utilities about their customers and by consumers about electricity…"*

It continues:

"… Utilities risk taking their customers for granted, being overly technocratic in their relationship with them, and possibly alienating them. They would be well-advised to engage with consumers on a new level, perhaps borrowing from the best practices of more competitive, consumer-centric industries. Likewise, in many developed countries, consumers risk taking electricity for granted as a low-cost commodity, which is always available, rather than a commodity subject to market swings in a manner similar to gasoline. Active consumer engagement in the power system will depend on a change in this perspective…"

In addition to the transition to sustainability and energy security, there are other economic benefits. A recent *Fraunhofer Institute* Report on the potential benefits of an ’intelligent‘ power system estimates that Smart Grids in Germany will result in a societal net benefit of €55.7 billion per year. This benefit is composed of expected efficiency gains of €39.0 billion and additional growth stimuli of €16.7 billion.

The Supergrid cannot operate in isolation. The power system of the future will require integration of Supergrid and Smart Grid principles with ICT combining the two. Technological innovation in power electronics and telecommunications have allowed us to imagine the immediate future of the world’s energy system. However, this is not the end of the story. The new vision will require technological leadership not just in the areas such as interoperability between manufacturers, fast acting protection and DC-DC converters, but also in ICT, SCADA, modelling and simulation, and data management.

Ending where we began

In drawing my remarks to a close, I can’t help but note in passing that the very distinguished previous occupant of this lectern presented last week on the subject “Can storage save renewables”. While I wouldn’t dare challenge the credentials of the Wolfson Professor, might I be permitted to suggest that renewables don't need saving.

Storage clearly has an important role as I set out earlier, but my contention is simply that the development of Supergrid will resolve the problems of regularity of supply and difficulties of storage by moving away from a reliance on local generation. Further, large-scale renewable generation can be directed to areas with high demand when there is excess production in any one location, removing the need for that energy to be stored locally.

And, finally, the scale of the Supergrid compensates for the fundamental limitation of electricity:

Use it or lose it

Conclusion

In conclusion, I would simply restate some fundamental truths.

The development of the Supergrid can begin today. The required technologies are mostly available in an operational form while the remainder are largely at the point of operational testing or patent application.

No insurmountable hurdles to the creation of a pan-European transmission network have been identified. Existing large-scale HVDC technology – already in place in Europe – can be complemented by AC in 'Supernodes' that can contribute to achieving the required security of supply in larger HVDC networks. The remaining difficulties relate principally to interoperability between regulatory regimes and manufacturers' equipment.

That leads us neatly back to the creation of the European Energy Union. One of the proposals under review by the Commission is the development of a regional market across the North Sea with a single transmission operator to co-ordinate market coupling and interconnection. With a sense of humour not previously identified in the Berlyamont, this putative grid operator is being called "NOTSO".

I look forward to the day – soon to come – when NOTSO becomes JUST-SO, and the North Sea is an energy platform supplying power to homes and businesses across the continent in an open, and competitive electricity market.

I very much welcome Oxford's interest in Supergrid. A short train ride from here will take you to Siemens and Alstom's global centres of excellence for HVDC transmission. It will be collaboration between universities such as this, and companies such as those, and mine, which will deliver this transformative future, and I look forward very much indeed to building it with you.

The electric society is being built around us. Global electricity systems are opening to new players. Customers are demanding control of their supply. That is why Mainstream's business model is evolving. We have seen the future, and so have our partners and customers. Most people in business only get one opportunity to make a change – I think we achieved that with Airtricity. To get a second – with Mainstream – is a bonus, but it is one I am determined to deliver.

Thank you.