ELEC6049: REPORT 3, How Does Technology Make Money? - Compliance, Government and other factors

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ABSTRACT

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INTRODUCTION TO GOVERNANCE

Government legislation pervades all aspects of modern life from welfare to industry, infrastructure to enterprise. This report is primarily concerned with legislation that governs industry. Finance, healthcare and research are just a few areas that are subject to government legislation. Large national infrastructure such as energy, transport, water and communication are also particularly heavily regulated. In this report, the role of governance in several industries is examined to understand how legislation can promote or diminish the profit potential of technology dependent industries.

The dictionary definition of legislation is “laws, considered collectively” [1] and the two terms are used synonymously in this report. One of the main roles of the elected parliament is the debate and passing of new laws or modification to laws. Figure 1 shows how new legislation comes into being through the parliamentary process.

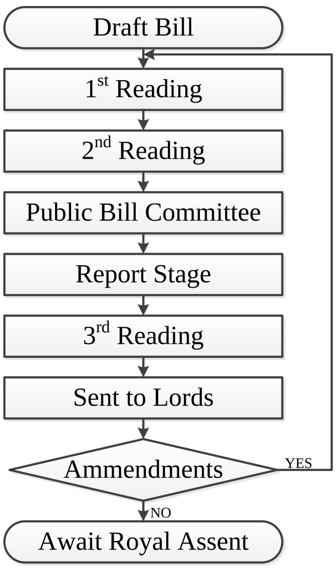

Figure 1: The passage of a Bill or Act to become Law - adapted from [2]

The legislation the government sets influences industry in two ways; directly or indirectly. Direct investment in infrastructure is one method the government uses to establish infrastructure. Historically, this has been the case for many of the then privatised industries such as energy, water and transport. The Central Electricity Generating Board (CEGB), the government-owned electricity utility, had a planned investment programme totalling £600m for the year 1980, equivalent to 9% of gross fixed manufacturing investment at the time [3]. While many of these utilities have now been privatised, the government still directly invests in roads, rail, airports and other large civil projects. During 2014-2015 around 200 government backed construction projects are due to start representing around £36bn investment [4]. Where the government chooses to directly invest, there is considerable profit potential for companies that can position themselves in the supply chain.

Legislation indirectly dictates the profit potential of several large industries. By setting out plans in the form of acts and bills, the government steers the direction of key infrastructure investment and retains some degree of control over important private markets. Energy, transport and communications are examples of heavily regulated yet private industries. Opportunities to profit from technology are widespread in these industries. However, companies must anticipate and align with the direction of governance in order to remain profitable. Achieving this alignment can present a significant opportunity to profit from technology.

The role of governance is explored in further depth in this report. The impact of government policy on the profit potential of several industries are examined through case studies. The findings from the consideration of the case studies will develop a view as to how companies align with emerging Government policy, and the impacts this has on financial performance.

SECTION 1 - INVITED TALKS

Lecture 1 - Fabrice Perrot, Managing Director Alstom Grid Research and Technology Centre

Alstom Grid is one of four technology sectors making up the Alstom group. The grid sector was formed in 2010 when Alstom acquired Areva's transmission and distribution arm [5] for €2.3bn [6]. With a worldwide presence and over 20,000 employees [5], Alstom Grid has a significant presence in the High Voltage grid sector as outlined in Figure 2 Projects undertaken can be very large scale, including a €62m involvement in floating substations in the German north sea [5], building the Gulf's largest High Voltage Direct Current (HVDC) converter station [7], and delivering the converter transformers for the world's longest HVDC transmission scheme at Rio Madeira in Brazil [8].

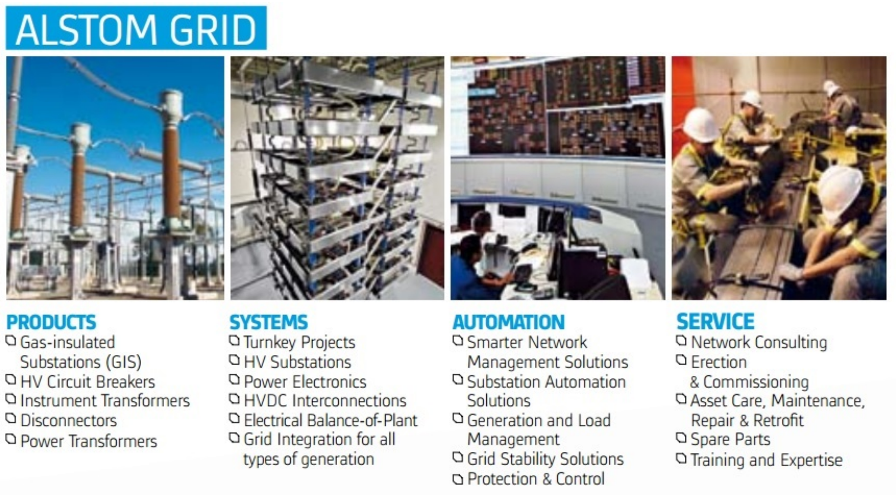

Figure 2: Alstom Grid Services - reprinted from [5]

The electrical transmission infrastructure is an often overlooked service critical to maintaining a western lifestyle. The supergrid infrastructure in the UK was built largely in the 1950s to cater for the connection of the large coal and gas power stations to the large load centres [9]. The nature of the electricity industry is fundamentally changing. An increase in embedded generation and the remoteness of renewable sources leaves the grid network in need of significant investment.

The drive towards renewables is driven by government policy. The Climate Change Act 2008 sets out targets to reduce carbon emissions by 80% of 1990 levels by 2050 [10]. In order to meet this commitment in any meaningful sense, the electricity sector must be decarbonised considerably earlier than 2050, so that space heating and transport sectors can transition to a carbon-neutral energy vector. There is a unified approach in many developed nations, particularly in Europe, promoting renewable energy development. It is this legislation that is driving the change in the design basis for almost all modern transmission and distribution infrastructure.

The opportunities to profit from developing and installing new grid infrastructure is huge. In the UK, the cost of network reinforcements is estimated at £8.8bn [11]. A large majority of the investment will be required for the connection of offshore wind, usually via HVDC links [11]. Similar opportunities to profit from government infrastructure investment exist worldwide. The DeserTec solar project aims to connect the North African grid to the European Super Grid providing access to cheap, carbon-free concentrating solar power plants. The scale of the project can be appreciated in Figure 3. The project is an extremely challenging endeavour considering the political cooperation involved, but should the project proceed, the investment could total $560bn [12]. Alstom grid should be in a position to provide HVDC equipment for this project, which could present significant profits.

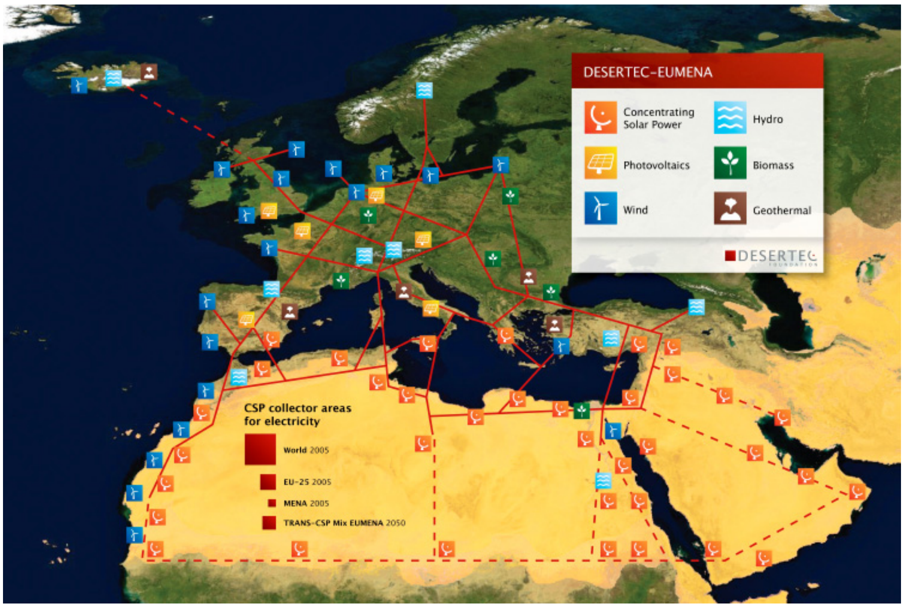

Figure 3: Potential structure of the DeserTec HVDC network extending over the Middle East, North Africa and Europe - reprinted from [12]

Considering these opportunities, Alstom's acquisition of Areva Transmission and Distribution seems a clever strategic investment. The acquisition of a core competence in HVDC at a time when global government policy is promoting renewed investment in the sector is a clever move to align with government policy in order to profit.

Lecture 2 - Mr Tim Whitcher, London Power Associates

Mr Tim Whitcher is a contractor, providing management support. Mr Whitcher's current project involves the upgrade of the Northen and Jubilee Lines on the London Underground.

Transport for London (TfL) is a govenment body who are responsible for public transport in London. Their respnosibilities include the London Underground, bus service and the Boris bikes, amongst other areas [13]. Around 24 million journeys are made every day accross the TfL network. In order to support this capacity of commuter, TfL must supply an efficient service, and their use of technology is key to this.

The Oyster Card was introduced in 2003 and now around 80% of all journeys are paid for using the contactless payment card [14]. The card supports a standard, initially written by NXP. Although there is controversy over the security of the Mifare RFID cards [15], the Oyster card does not use a second generation card which is significantly more secure [16]. By exploiting this standard, and the ease of use of the technology, large queues are avoided on public transport, getting commuters to their destination much quicker. Although the cost of the travel is less to the commuter, the service the Oyster card enables TfL to provide is a clear benefit.

There is also expansion to look into the use of technology on buses to help prevent accidents [17]. Although this is not fully live yet, it looks promising to prevent collisions with bicycles or pedestrians that the bus driver cannot see. If less accidents are caused, the reputation of the bus system will be increased, and a quicker service will be supllied to the commuter. The idea of electric buses is also a potential technology for London's shorter bus routes [18].

Overall, the technology used by TfL does not directly create income for the transport system. However, by exploiting technology, the whole London Transport system can be made seemless, attracting more commuters to use it.

Lecture 3 - Dr Peter Hatto, Chair BSI Nantechnology Standardisation

SECTION 2 - CASE STUDIES

Case 1 - Businesses connected to Crossrail Ltd

Crossrail Ltd (CRL) is a subsidiary of TfL. Originally a joint venture with the Department for Transport (DfT) their goal is to develop transport links throughout the South East and secure London's financial excellence in Europe [19]. In February 2005 CRL proposed the *Crossrail Bill* which became the *Crossrail Act* in July 2008. This supports construction of a "railway transport system running from Maidenhead…and Heathrow Airport…through central London to Shenfield" [20]. As the largest civil engineering project in Europe CRL has awarded contracts worth £5.5bn benefiting over 17, 000 businesses [21]. In this group of small enterprises and large companies which have benefited most and did they adapt their business model because of this governance?

In February 2014 a Canadian company Bombardier Inc. won a £1bn contract, over Hitachi and CAF, to deliver and maintain 65 new trains and a depot for the line [22, 23]. Bombardier has been providing mass transit solutions since 1974 and growing steadily since so this opportunity is part of their core competence [24]. The company owns a passenger rolling stock plant in Derby and in 2011 cut over a third of staff there as they failed to win a contract for the Thameslink service over Siemens [**?**]. At this pint the entire future of the plant and subsequently a remaining 1, 500 jobs in Derby lay on securing the contract for the Crossrail project.

Citation needed

Case 2 - Opportunities Presented by UK Government Policy on Nuclear New Build

The UK has a rich nuclear heritage and has been generating commercial quantities of power from nuclear power plants since Calder Hall opened in 1957 [25]. The nuclear industry is one of the most heavily regulated industries in which to operate and opportunities to profit from technology are strongly coupled to the position of the government and their subsequent policy decisions. New nuclear build marks a recent turn-around in government policy, and private companies are now positioning themselves to profit from the infrastructure investment that is sorely needed.

UK Government policy has been largely anti-new-build since the last nuclear plant was commissioned at Sizewell B in 1992. This plant was envisioned to be the first of a fleet of new pressurised water reactors, but only Sizewell B was ever built [26]. The new build supply chain has since diminished, with construction expertise and nuclear specific skills depleting. However, opportunities to profit from nuclear technology did not diminish entirely in this period. The UK's ageing fleet of nuclear reactors contributed 19% of UK electricity supply in 2012 [26]. The French utility EDF made £880m profit in 2012 from their UK nuclear operation including eight plants totalling 8.7GW capacity [27]. Evidently there were sparse but significant opportunities in the industry prior to 2008.

Government nuclear policy has gradually evolved since privatisation of the energy industry in 1995. Labours 1997 manifesto was strongly against new nuclear [28]. The 2003 Energy White Paper set targets for the reduction of carbon emissions by 60% by 2050. While new nuclear build was not ruled out, it was not supported for economic reasons [29]. Against a backdrop of rapidly increasing fossil fuel prices and increasing concerns over energy security, the 2007 Energy White Paper started the public consultation on new nuclear build [30] resulting in the plans to promote new nuclear build in the 2008 White Paper on nuclear [31]. This turnaround in Government policy opens a new era of opportunity for private companies to profit from investments in new nuclear. The new policy is expected to attract £40bn investment by 2025 [28]. Currently there are five UK sites under active development, as shown in figure 4, by three companies each intending to deploy a different reactor technology.

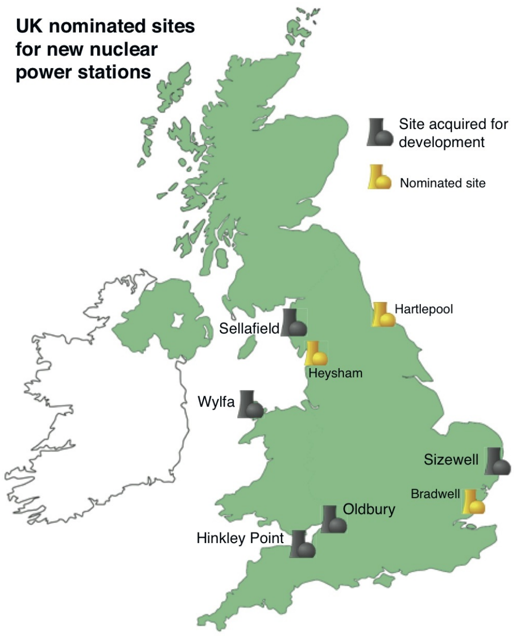

Figure 4: Nominated Sites for New Nuclear Build in the UK - reprinted from [32]

Investment in nuclear new build in the private market is difficult to secure. A very rough estimation of daily turnover for Hinkley Point C can generate is shown in equation 1, assuming a capacity of 3.2GW and a strike price of £92.50 per megawatt hour.

$$\begin{aligned} Turnover &= capacity \times power\ price\ per\ hour \times hours\ per\ day \\ &= 3,200MW \times 92.50\ \pounds/MWh \times 24 = \pounds 7.1m \end{aligned} \tag{1}$$

The profit margins appear attractive, however securing investment remains difficult due to very large capital costs. The EDF commitment to Hinkley Point C is of the order of £16bn [33]. In order to stimulate investment, the 2013 Energy Act set out the final phase of the Electricity Market Reform (EMR) [34]. One of the major components of the reform is the introduction of contracts for difference (CfDs), which guarantee an agreed power price for renewable projects to reduce cost risk [35]. CfDs are available for new nuclear projects and will help give investors in new nuclear certainty on their returns [35]. The operation of CfDs is explained in figure 5.

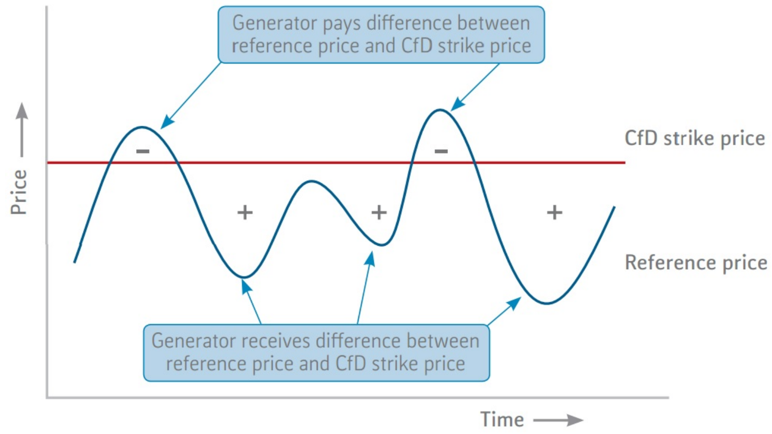

Figure 5: The operation of a CfD scheme - reprinted from [35]

The first nuclear strike price was agreed for EDF's Hinkley Point project in October 2013 at £92.50 per MWh, more than double the current unit price of electricity [36]. The spectator estimates that the Hinkley Point plant will generate pre-tax profits of between £2bn - £5bn per year for the duration of the 35 year contract [33]. This is a substantial return on investment given the operating profits of the big six energy companies combined was £2.1bn in 2012 [33]. Cash dividends in addition to paying off the construction debt should be of the order of £65bn-£80bn [33]. EDF have positioned themselves in a very favourable position to profit from the opportunities in nuclear new build. It is expected that NuGen and Horizon Nuclear Power will follow suit in the pursuance of a CfD deal.

The nuclear new build case study has shown two different impacts of governance. It was seen how the industry was stifled prior to 2008. Then the turn-around in policy shows how governance can stimulate massive investment in an otherwise dying industry. It is clear that the new build companies and their large parent organisations stand to profit significantly from the infrastructure investment the Government requires to keep the lights on, provided adequate capital investment can be found.

Case 3 - 4G Mobile Broadband

The radio spectrum is considered a state's national renewable resource. Since the first wireless broadcast in 1897, wireless communications has grown hugely [**?**]. The rise of the semiconductor unlocked higher radio frequencies, enabling the use of more of the spectrum. The current radio spectrum spans from $3kHz$ to $300GHz$. A simplified diagram of the radio spectrum in the United Kingdom can be seen in Figure 6, but in reality, it is much more complex [37].

Citation needed

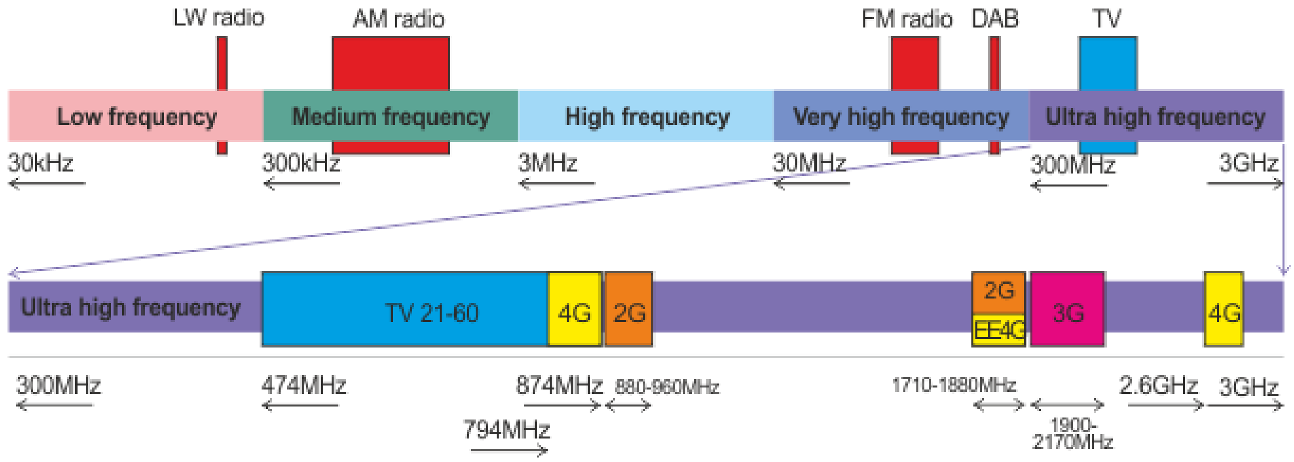

Figure 6: A simplified diagram of the UK Radio Spectrum from [38]

The allocation of radio spectrum must be managed to avoid interference. A large number of devices rely on wireless communications, from GPS, mobile phones and even car keys. Signal interference between devices is considered an issue with wireless communications [39]. Therefore the allocation of radio frequencies is now done by a governing board, Ofcom [40]. By correctly managing the spectrum, money can be made an innovation can be encouraged.

The switch off of analogue TV in the UK freed up a large amount of the spectrum [41]. This has since been reallocated to be used for 4G Mobile Broadband. The allocations can be seen in Figure 6.

The allocation is done by a spectrum auction. Companies each put bids in for use of the spectrum. If a company wins the auction, this allows them to transmit using the allocated frequencies. The auction for the 4G spectrums raised £2,340 million.

A well-designed auction is key. Competition must be allowed, as a monopoly over a spectrum, and therefore a technology, causing a lack of innovation and high prices. However, the companies must be well equipped to be able to fulfil the In the 4G auction, there were two main frequency bands for grabs - the low frequency $800MHz$ band and a high frequency $2.6GHz$ band. The compromise made here is between coverage and speed: the higher frequency can support a higher density of traffic with a higher speed, but the lower frequency is more suitable to rural areas and provides better signal to the users.

The results of the auction saw Vodafone, Three and O2 have a portion of the low frequency. Vodafone and EE were awarded a part of the high frequency. EE already owned the middle 4G frequency which is leased to Three. This should generate healthy competition in not only the high speed market.

However, spectral auctions can cause issues. The 3G spectrum was originally auctioned in 2000. The money raised fell short of the £3,500 million by £1,000 million [42]. In Europe, companies overpaid for the 3G licenses and ran up huge debts. This, combined with home broadband expectations, was a huge overestimation of the data demand and caused the Telecoms Crash in 2001 [43]. It is thought that the 3G spectral auctions contributed to this crash.

In conclusion, governance is needed in the mobile and wireless communication markets for two main reasons. Firstly, the spectrum must be managed to ensure that the technologies are not subject to accidental interference, causing the technology to fail. Secondly, the competition must be managed to keep costs down and encourage innovation between the rivalling companies.

CONCLUSIONS

REFERENCES

[1] A. Stevenson and M. Waite. *Concise Oxford English Dictionary*. Concise Oxford English Dictionary. OUP Oxford, 2011.

[2] House of Commons Information Office. Parliamentary Stages of a Government Bill. Factsheet L1 Legislation Series, 2010.

[3] The Monopolies and Mergers Commission. Central Electricity Generating Board: A Report on the operation by the Board of its system for the generation and supply of electricity in bulk. Her Majesty's Stationery Office, London, 1980.

[4] Prime Minister's Office. PM and Chancellor welcome £36 billion infrastructure projects. https://www.gov.uk/government/news/pm-and-chancellor-welcome-36-billion-infrastructure-projects, 2014. (Visited on 29/04/2014).

[5] Alstom. Introducing Alstom Grid. http://www.alstom.com/Global/Grid/Resources/Documents/Alstom%20Grid%20Brochure%20ENG.pdf, 2011. (Visited on 03/05/2014).

[6] Alstom Press Centre. Alstom creates a third Sector, Alstom Grid, with the acquisition of the transmission business of Areval. http://www.alstom.com/press-centre/2010/6/Grid-acquisition/, 2012. (Visited on 03/05/2014).

[7] Majed Almajed. Alstom in Saudi Arabia. http://www.alstom.com/Global/Group/Resources/Documents/Factsheets/Saudi%20Arabia%20factsheet.pdf, 2013. (Visited on 03/05/2014).

[8] Alstom Press Centre. Alstom Grids 600 kV Ultra High Voltage Direct Current converter transformer en route from Stafford to Brazil. http://www.alstom.com/press-centre/2012/3/83403/, 2012. (Visited on 03/05/2014).

[9] National Grid. National Grid at 75: Celebrating 75 years of electricity transmission. http://www.nationalgrid75.com/wp-content/uploads/75-years_FINAL.pdf, 2010. (Visited on 03/05/2014).

[10] UK Government. Climate Change Act. Her Majesty's Stationery Office, London, 2008.

[11] Electricity Networks Strategy Group. Our electricity transmission network: A vision for 2020. http://namrc.co.uk/intelligence/uk-new-build-plans/, 2012.

[12] Joel Stonington. Quagmire in the sahara: Desertec's promise of solar power for europe fades. http://www.spiegel.de/international/europe/the-desertec-solar-energy-project-has-run-into-trouble-a-867077.html, 2012. (Visited on 03/05/2014).

[13] Transport for London. What we do. https://www.tfl.gov.uk/corporate/about-tfl/what-we-do?intcmp=2582. (Visited on 13/05/2014).

[14] Wikipedia. Oyster card. http://en.wikipedia.org/wiki/Oyster_card. (Visited on 13/05/2014).

[15] David Molnar and David Wagner. Privacy and security in library rfid: issues, practices, and architectures. In *Proceedings of the 11th ACM conference on Computer and communications security*, pages 210–219. ACM, 2004.

[16] Thing Magic. Rfid security issues - generation2 security. `http://www.thingmagic.com/rfid-security-issues`. (Visited on 13/05/2014).

[17] Transport for London. Technology trials on london buses. `http://www.tfl.gov.uk/info-for/media/news-articles/technology-trials-on-london-buses`. (Visited on 13/05/2014).

[18] The Guardian. Electric buses hit london roads. `http://www.theguardian.com/environment/2013/dec/19/electric-buses-hit-london-roads-routes`. (Visited on 13/05/2014).

[19] Crossrail Ltd. About us. `http://www.crossrail.co.uk/about-us/`. (Visited on 13/05/2014).

[20] UK Government. Crossrail act. Her Majesty's Stationery Office, London, 2008.

[21] Crossrail Ltd. Suppliers. `http://www.crossrail.co.uk/suppliers/`. (Visited on 15/05/2014).

[22] BBC News. Bombardier wins 1bn crossrail deal. `http://www.bbc.co.uk/news/business-26063121`. (Visited on 15/05/2014).

[23] Department for Transport. Crossrail rolling stock and depot contract to be awarded to bombardier. `https://www.gov.uk/government/news/crossrail-rolling-stock-and-depot-contract-to-be-awarded-to-bombardier`. (Visited on 15/05/2014).

[24] Bombardier. About us. `http://www.bombardier.com/en/about-us.html`. (Visited on 15/05/2014).

[25] D Whan, J Jackson, and N Thornton. Calder Hall Nuclear Power Station Feasibility Study. Nuclear Decommissioning Authority, 2007.

[26] World Nuclear Association. Nuclear power in the united kingdom. `http://www.world-nuclear.org/info/Country-Profiles/Countries-T-Z/United-Kingdom/`, 2014. (Visited on 28/04/2014).

[27] EDF Energy Holdings Limited. Annual Report and Financial Statements, 2012.

[28] Birmingham Policy Commission. The Future of Nuclear Energy in the UK. University of Birmingham, 2012.

[29] Department of Trade and Industry. Energy White Paper: Our energy future - creating a low carbon economy. Her Majesty's Stationery Office, London, 2003.

[30] Department of Trade and Industry. Meeting the Energy Challenge: A White Paper on Energy. Her Majesty's Stationery Office, London, 2007.

[31] Department for Business Enterprise and Regulatory Reform. Meeting the Energy Challenge: A White Paper on Nuclear Power. Her Majesty's Stationery Office, London, 2008.

[32] Nuclear Advanced Manufacturing Research Centre. Uk new build plans. `https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48275/4264-ensg-summary.pdf`, 2014. (Visited on 12/05/2014).

[33] Peter Atherton. Why has Britain signed up for the worlds most expensive power station? http://www.spectator.co.uk/features/9141142/why-has-britain-signed-up-for-the-worlds-most-expensive-power-station/, 2014. (Visited on 04/05/2014).

[34] UK Government. Energy Act. Her Majesty's Stationery Office, London, 2013.

[35] Baringa Partners. UK Contracts for Difference: Risks and Opportunities. http://www.baringa.com/sites/default/files/Viewpoint%20UK%20Contracts%20for%20Difference_FINAL.pdf. (Visited on 04/05/2014).

[36] BBC News. Ineos boss says Hinkley nuclear power too expensive. http://www.bbc.co.uk/news/business-25390456, 2013. (Visited on 04/05/2014).

[37] Roke Manor Research. The uk frequency allocations. http://www.onlineconversion.com/downloads/uk_frequency_allocations_chart.pdf. (Visited on 12/05/2014).

[38] UK Free TV. How do i know if the 4g broadband will overload my freeview? http://www.ukfree.tv/fullstory.php?storyid=1107052059. (Visited on 12/05/2014).

[39] GPS.gov. Gps spectrum and interference issues. http://www.gps.gov/spectrum/. (Visited on 12/05/2014).

[40] Ofcom. What is ofcom? http://www.ofcom.org.uk/about/what-is-ofcom/. (Visited on 12/05/2014).

[41] Ofcom. End of an analogue era paves way for 4g mobile. http://consumers.ofcom.org.uk/2012/10/end-of-an-analogue-era-paves-way-for-4g-mobile/. (Visited on 12/05/2014).

[42] The Register. Telecom bigwigs: 'we're all friends really'. http://www.theregister.co.uk/2013/02/25/mwc_keynote_one/. (Visited on 12/05/2014).

[43] The Economist. The telecoms crisis: Too many debts; too few calls. http://www.economist.com/node/1234711. (Visited on 12/05/2014).

APPENDIX

1. TEAM CONTRIBUTIONS

Note that for each report there will be a different chair person. The chair person is expected to lead the report writing process, including ultimate decision on topic, the allocation of research and the collation of content provided by others. Hence it is expected that one team member contribute more per report, thus averaging out over all three reports for the module. The contribution to the module as a whole will be approximately even from each team member.

Team Member	**Contribution**
Thomas J. Smith 23914254	Introduction, Lecture 1, Case 2 and Notes from Invited Presentations.
Henry S. Lovett 23900091	
Ashley J. Robinson 24008349	Chairperson for this report.

2. MEETING MINUTES - KICK-OFF MEETING

5. NOTES FROM INVITED PRESENTATIONS

These notes are raw and not altered in any way from when they were taken from the invited presentation. These notes have been distilled and focussed through the lens of our report title and hypothesis to the content shown in section 1.

Lecture 1 - Fabrice Perrot - Managing Director Alstom Grid Research and Technology Centre

Alstom 130 years old. Emerged from General Electric Company in the UK. Alstom made up of four sectors; thermal power, transport, renewable power and grid. All four sectors are present in the UK. Alstom Grid section based in Stafford. Power transformers are built at a large factory in Stafford. They also make HVDC transformers there. Instrument transformers, circuit breakers and disconnectors and gas insulated substations (GIS) are also manufactured and design within Alstom Grid but not necessarily at Stafford. In Stafford the R&D for HVDC power electronics and offshore substations are investigated. They also design substation automation solutions or relays and controls as it used to be called.

5 research and development centres with 4% of Alstom sales being reinvested in Alstom Grid R&D. 1200 skilled engineers working on R&D challenges including HVDC, UHVDC and Smart Grid techniques. Experts in final element modelling and have developed their own unique software for FEM calculations. The core competency of Alstom Grid is in High Voltage and Dielectric Materials. They are experts in developing materials that are largely non-porous to prevent voids. Glass fibre materials are an example of this. This helps to avoid partial discharge in the material which can eventually lead to breakdown. Some of these materials are employed in different industries and settings, such as the Eurostar, T45 Destroyers and the Astute Submarines. The applications of this research are quite wide ranging.

Funding is also taken on collaborative projects from the public purse. The EU HORIZON 2020 policy is one such source of funding for HV research. The technology strategy board funds “catapults” to try and deploy innovation as a product. National Grid, Scottish Power and Scottish and Southern Electric are transmition system operators that can gain access to funding through Ofgem and a new funding system called RIIO - Revenue = Incentives + Innovation + Output. The RIIO is comprised of the Network Innovation Allowance, Network Innovation Competitions and the Low Carbon Network Fund. These are just some of the levers available.

Energy Policy 80% reduction of 1990 CO2 levels by 2050 and 34% by 2022. Renewables to supply 15% of UK energy by 2020. UK achieves about 3% currently. This is not a very long time in the power industry. Road transport and energy efficiency is important. The energy trilemma is key - security, economics and emissions. The Climate Change Act 2008 and the Energy Act 2008 are key with chapters 27 and 32 respectively being the chapters with the figures in them.

In order for this to take place, the complexity of the distribution network must increase. Energy world consumption is likely to increase by 50% between 2007 to 2035. A huge increase in renewables is required while a huge reduction in the very large fossil fuel powered stations.

One of the European wide strategies is increased interconnection. There are vast renewable resources, including huge amounts of wind in the North Sea, Hydro in Norway and a massive amount of thermal solar in the North of Africa. The distances involved are very large, with thousands of kilometres from the renewable concentrates to the load centres. One of the ways of distributing this power is through HVDC rather than the AC networks currently prevalent throughout distribution. Clearly there are large technical challenges and massive political challenges in dealing with instability in North Africa for the Solar.

The wind however is a different story. The distances can be up to 3000km, which AC transmission would simply not be cost effective. There are numerous plans to start harnessing North Sea power and there are a few already in deployment. These projects are very capital intensive - 100 millions of euros and can cost Alstom dearly if the small weather window is missed to deploy the technology.

Why Do We Need HVDC?

Thomas Edison proposed DC and George Westinghouse proposed AC. Westinghouse won due to the difficulties with DC. Transformers for DC do not exist and made it very difficult to step up the voltage for long distance transmission. For HVDC, you start with an AC power source and put it through a big rectifier bridge. Then you transmit the HVDC power over the cables, then you change it back to AC at the other end.

Several types of link exist. Back to back links allow asynchronous connection, allowing 50Hz and 60Hz networks to be connected. Point to Point is the same but has an Over Head Line (OHL) for bulk transmission over distance. Point to Point schemes also exist in submarine versions, where the cable is subsea and this is used for the connection of wind farms in the North Sea. AC power is continuously charging and discharging the capacitive impedance in the cable, resulting in large reactive power consumption. The DC version only charges the impedance once (like a resistance) so the consumption is much less over long distances. The HVDC scheme between France and the UK was extremely successful, it paid for itself in just 3 years and achieves over 97% availability.

Another aspect of AC is space. AC for a double circuit would require six large cables - requiring a big tunnel for heat dissipation. DC requires only one for a monopolar link or two for a bipolar link, thus saving space. DC cables also produce less heat. AC systems require reactive compensation in the form of FACTS (Flexible AC Transmission System) over long distances. Even though DC converter stations cost alot of money, they do not require periodic compensation. Thus over a very long distances, there is a distance break-even point where HVDC becomes cheaper than AC. This is around 30 miles for underground or submarine systems and around 500 miles for OHLs.

The power rectifier is usually a 12 pulse connection. This is a six pulse grid connection utilising 6 thyristors to produce a DC voltage. You can put two six pulse bridges together to produce a twelve pulse bridge to allow more power to be put in the system. You can then add two of these twelve pulse bridges together, to allow one for V+ and one for V-. In China these run at +800kV and allow 5000-6000 MW to be transmitted down just two wires. This is a huge amount of power.

The key technology is thyristor technology that enables this HVDC connection. A huge amount of technology is invested in these systems. There are also VSCs (Voltage Source Converters) which are a series of capacitors in series with the AC, and a set of insulated gate transistors (IGCT) which switch the capacitors in and out. These are called multi-level converters. This technology is very useful for renewable energy connection.

Thyristor valves are usually arranged in quadrivalves. The Alstom H400 valve modules provide two stacks of thyristors in series. These are watercooled. Thyristor technology is interesting because they fail short circuit. So they build in redundancy. Every two years, the HVDC system undergoes maintenance. Each H400 module is arranged in fours to make a quadrivalve and then there are six of these in a twelve pulse bridge. These are suspended from the ceiling for seismic reasons.

In early 2000s, HVDC was largely a curiosity. In China and other large countries, there was a huge renaissance in HVDC technology. 800kV is the standard voltage for HVDC in China. India is building it's first 800kV

HVDC scheme, although it is only 2.5GW capacity compared to the huge ones in China. In the late 80s, the Brazillian Itaupu Hydro dam was the highest voltage introduced by ABB at 600kV. In China they are starting to think about +1.1MV. Although Fabrice thinks this is probably uneconomic.

One of the highest power schemes was in China. The Ningdong-Shandong +660kV scgene was built. It is the world's largest single power electronic converter at 2GW. 4 converters in total, 2 at each end. It was built in pairs of valves not in quadrivalves.

These were all tested in the lab at full scale before deployment. These are very big pieces of kit. The HVDC centre of excellence in Stafford produced a very large power transformer suitable for these huge amounts of power.

A Line Commutated Current HVDC station at Chandrapur 2x500MW back to back station in India has a small building to house the thyristors, but 440mx530m is required to filter the high frequency harmonics from the system.

Nanotechnology Advantages available for both AC and DC technologies. Cigre D1-40 WG Functional Nanomaterials for Electric Power Industry was a technical brochure published at the end of 2013. Nanotechnology could improve the performance of dielectrics massively, increasing safety and economics.

There is an issue understanding how the dispersion of micro and nano fillers act within epoxy matrices. We need to understand how to make reproducible materials and try to understand how this works and what benefits can be offered. An important research area is the improvement of thermal conductivity while maintaining electrical resistivity.

If thermal conductivity can be increased by a factor, then the size of equipment can be vastly reduced. Diamond is the example of this is nature. It has very good thermal conductivity while remaining electrically insulative. Boron Nitride is another interesting material that could be a candidate to improve dielectric strength while improving thermal conductivity.

Epoxy-Alumina nanocomposites show promise in resisting surface discharge. Often pollution and impurities and imperfections in the insulating material can cause partial discharge in the form of surface discharge. The 3% nano filler material can resist surface discharge for extreme periods.

The Technology Strategy Board funds the Alstom project, NanocompEIM. Around 20 engineers working together. It costs around a million euro for 30 months, and about half of it is covered by the TSB. They are tackling the increased dielectric strength while increasing thermal conductivity problem. Today they can make small quantities of nano-materials, but they are trying to develop ways to mass manufacture when proven. The upscale is the objective of the project. The TSB require reporting and a focus on the deployment and demonstration of the technology.

The BIG Multi Disciplinary Challenge A huge amount of innovation is required to meet the energy challenge in all engineering disciplines. Mechnicals, electronics, controls…there is loads of opportunities. A huge amount of investment is required. The Government is setting out more provision for these types of challenges to be met. Will we see the planned expansion in HVDC multi-terminals systems in Europe in our lifetime?

Questions What currents do you transmit at? The issue with DC is that the current never goes through zero, so the magnitude is not the problem, it is the fact it is not cyclic. Multi- terminal systems require very quick acting circuit breakers. The DC current for the Chinese projects was around 4000-5000 amps. This pushes all the connections as far as possible (6250A is around the maximum). DC is perhaps more dangerous as DC burns you while AC stops your heart - which is worse?!?

Are the 20:20:20 goals realistic? What are the financial motives in a private market? We need to achieve it - the consequences of climate change could be catastrophic. The finance is a huge issue. The economic climate is a big issue. Huge investment is required. We need investment banks to be more positive.If you removed the subsidies from EU and government policies, would Alstom or any other power equipment manufacturer be profitable? The financing of the R&D is an issue for governments. These require the finding mechanisms from government. The large HVDC schemes are commercial entities, and alot of money can be made in the private market for new transmission systems. You need to spend money as a company in innovation to continue profitability. These funding schemes are important to providing that lifeline. These could be viewed more as a stimulus, the Horizon 2020 schemes is of the order 70 billion euro. It is quite important therefore that these continue, but perhaps this is since electricity is vital, if intel's chip R&D halted, we would probably be OK for a short while.

What about integrating micro generation in the grid and how invested is Alstom in meeting government targets? Innovation is required throughout the industry. Even in AC, work is undertaken to leakproof SF6 systems and ultimately to find a non-greenhouse effect insulating Gas. Also mineral oil coolant for transformers contaminates the ground in the event of a leak, and burns in an accident. Research into vegetable oil coolants could be useful if regulations change to disallow or penalise mineral oils (or SF6 mentioned prior). There is a huge amount of innovation required and Alstom is constantly trying to stay one step ahead of the crowd.

Lecture 2 - Tim Whitcher - Capbrown Management Consultancy

Taking a big picture view of an engineering project. There are technologists with a primarily technical focus and requires detailed in-depth knowledge. The delivery tasks focus on project management. The systems roles take a broader high level views. Often the backbone of major projects and the interface between engineers and managers. Finally Management as in the conventional manager. These are parallel tasks. Often modern organizations are matrix organizations - you can move between the four tasks freely to some extent. Some people naturally fall at one end of the parallel tasks.

Consider the exploitation of technology. An R&D project requires a huge amount of consideration. Who is the target market? Stakeholders? Technical Limitations? Market Conditions? Future Proof? Shipping? Sustainability? Export and Import Fees? Local Distribution? Is the product sufficiently viable to let all these things happen? Do you know your markets well enough and think out of the box with applications of your technology?

From R&D you go to delivering the product in an industrial setting. The exploitation of technology takes much more than just the technology. Project skills are really important to deliver that technology to market in order to profit.

Think about Gooch and the railways. He had to build the locomotive sheds to build trains for great western. He built the sheds at swindon as they are equidistant. As the bird flies its not - Bristol is 50 miles and London is 70 miles. However due to the different trans used, Swindon is exactly band in the middle of the number of wheel rotations required. Think out of the box - solve some big problems.

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Capbrown are a consultancy and they are mostly ex rail professionals. Most of their work is with rail companies. They are an international company, working in Melbourne at some points. Jubilee and Northern line upgrade. TFl traffic management system. Vic upline and district line and reading with Siemens.

Lecture 3 -