Development of Electricity Networks: Essays on Incentive Regulation and the New Role of Consumers

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Abstract

The electricity sector is undergoing a remarkable change, supporting the overall transition required to meet policy objectives of lower carbon emissions as well as a safe and secure supply of electricity in a cost-effective manner for consumers. Electricity networks are part of the infrastructure vital to a functioning modern economy. This thesis considers specific elements of ongoing developments related to electricity networks, namely the changes in the economic regulation of networks and the new role for consumer. Achieving environmental and climate change policy targets is reliant on electricity networks adapting to changes and embracing an increased role in the electricity supply chain. The need for sensitivity to social justice and the preferences of electricity end-consumers is relatively new to network owners but is becoming increasingly important. Four main chapters, employing both theoretical and empirical economic methods, quantitative and qualitative, explore and advance aspects of incentive regulation and, particularly, the role of consumers.

List of publications

1. Tobiasson, W. and Jamasb, T. (2016), The solution that might have been: Resolving social conflict in deliberations about future electricity grid development. *Energy Research & Social Science*, *17*, pp.94-101.

2. Tobiasson, W., Beestermöller, C. and Jamasb, T. (2016), Public engagement in electricity network development: the case of the Beauly–Denny project in Scotland. *Economia e Politica Industriale*, *43*(2), pp.105-126.

3. Poudineh, R., Tobiasson, W. and Jamasb, T. (2015), Electricity distribution utilities and the future. *The Routledge companion to network industries*, pp.297 - 311.

4. Tobiasson, W. and Jamasb, T. (2015), Sustainable Electricity Grid Development: Whose Power?, DEI Briefing Note, June 2015, available at: https://www.dur.ac.uk/resources/dei/briefs/WhosepowerbriefFinal.pdf

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Declaration

I hereby confirm that the thesis submitted is based on my own work. I have previously submitted no part of the material offered for a degree in this or any other University. Where the thesis includes the results of joint publications, I confirm that the primary contributions were my own. Appropriate credit has been given within the thesis where reference has been made to the work of others.

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Chapter 1

Introduction

1.1 Introduction

2017 was the year that energy firmly re-established itself as one of the top priorities on the British policy agenda. Whilst Brexit remained the main concern, it could be argued that overexposure saturated the media and the public's appetite towards the end of the year, leaving room for other areas of focus. In terms of energy specific topics, the Labour Party launched its renationalisation plans, the high cost of energy generated a back-and-forth between the Department for Business, Energy and Industrial Strategy (BEIS) and Ofgem (the government regulator for gas and electricity markets in Great Britain (GB)) on whose responsibility it was to implement a retail price cap – Ofgem stubbornly resisted and the government folded [1] – meanwhile electricity networks were making headlines for "above acceptable" returns (Citizens Advice, 2017; and The Labour Party, 2017). Nevertheless, most citizens day-to-day do not give much thought to efforts required to make modern life possible through the power of electricity.

Safe and secure supply of electricity is assumed in developed countries and as long as that is delivered, what tend to drive change in the industry are wider government policy goals. The GB energy sector is made up of many private companies operating in different segments that together make up the system required to deliver energy across the county. The plans for privatising the GB energy sector was first mentioned in 1981, with an initial focus on oil and gas. It was argued that the government should let a competitive market produce and consume energy efficiently. British Gas was subsequently privatised in the 1986, still as a vertically integrated utility, and the early 1990s saw the start of electricity industry privatisation (Pearson and Watson, 2012). The 12 regional

[1] The cap, now legislated, is due to be implemented in December 2018.

electricity boards in England and Wales were the first to be privatised followed by the Central Electricity Board, which had been divided into a monopoly transmission business (National Grid Company) and two competitive generators (National Power and PowerGen). Nuclear generation remained under public ownership under the name Nuclear Electric. The Scottish regions were also privatised although remained as vertically integrated utilities, that is, they retained ownership and control of their transmission networks. Various initiatives were introduced during the 1990s to increase competition in electricity and in 2000 the competitive segment of retail supply was split from the regional distribution networks. Divestment by National Power and PowerGen as well as the 'dash for gas' saw an increase in competition in electricity generation (Pearson and Watson, 2012).

Whilst the Labour Party is pledging to renationalise the energy sector, much of the policy focus has moved on and decarbonisation of the industry, as well as the economy in more general, is driving the debate. The UK Climate Change Act 2008 introduced the world's first long term legally binding framework to tackle climate change. Through the act the UK government set a legally binding target to reduce greenhouse gas emissions by 80% of 1990 levels by 2050 and sets out a framework of how to get there. Being much of the driver behind current energy policy and subsequent market changes, it is within the context of decarbonisation that this thesis is set.

The introductory chapter is outlined as follows; section 1.2 outlines the thesis motivation, including the main challenges facing the electricity network utilities. Technological developments, which will ultimately change network owner's operating environments, are summarised. Networks connecting end-users, distribution network operators (DNOs), are likely to face greater challenges, which will require a fundamental change in the relationship between utilities and their customers. It is this part of the changing relationship and the new role for energy consumers and customers that is explored throughout this thesis – an outline of the changing nature of demand is provided in section 1.2.2. Section 1.3 outlines a brief summary of economic regulation of electricity networks and section 1.4 provides an overview of the theoretical framework, which is applied throughout the thesis. Section 1.5 describes the outline of the remaining chapters of the thesis.

1.2 Thesis motivation

Electricity is relied upon daily to provide a vast range of amenities. From switching a light switch to light our homes or boiling the kettle for a cup of tea to running major machinery and construction. Electricity is an integral part of modern lives and as such, a safe and reliable supply of electricity is a prerequisite for a well-functioning society and benefits the economy in similar ways to other infrastructures, such as transportation. In most developed countries electricity is reliable with limited interruptions (Joskow, 1998). Few people reflect over the efforts that lie behind seemingly simple tasks that are required to make many aspects of their lives possible. However, the route from electricity generation to safe use in homes and offices is highly complex.

Electricity networks are a crucial part of the power system as they transport electricity from generators to end-users. The power grid consists of transmission and distribution networks that differ in terms of voltage level, size, operation, and objectives. The transmission grid comprises high-voltage circuits designed to transfer bulk power from power plants to load centres. Following generation, step-up transformers are generally used to raise the voltage to a level allowing for efficient long-distance transportation. Distribution networks meanwhile deliver electric energy to end-users after receiving bulk power from the transmission grid. Substations, where voltage levels are reduced, connect circuits between transmission and distribution networks. Electricity is delivered to homes and businesses through underground cables or overhead lines.

In providing such essential services, the electricity industry is often the subject of public debate and highly influenced by government policy and strategic objectives. Currently, reducing the human impact on climate change is an area of particular importance. The UK government's green policy agenda include a number of measures with direct impact on the energy sector, such as subsidies for renewable generation, ending all generation from unabated coal by 2025, and a target of ending the sale of new conventional petrol and diesel cars and vans by 2040 (UK government, 2018a). As a result, the government's measures and policies drive changes that impact the whole electricity supply chain along technological, social, and economic dimensions, from increased intermittent generation, increased demand for charging stations for Electric Vehicles (EVs), to smart meters in homes, which enable more active electricity consumers. Electricity networks, and particularly distribution networks by being the point that physically connects consumers to the system, face a number of challenges going forward. A smarter electricity system will cause distribution networks, which were originally designed as passive transporters of electric energy, to face a shift in their operational model in terms of bi-directional power flows and use of Information and Communication Technologies (ICTs). Moreover, penetration of Distributed Generation (DG) sources, EVs, and storage facilities create techno-economic challenges that require grid upgrade, reinforcement, technological improvement, and, possibly, the development of new business models (Poudineh and Jamasb, 2014; ENA, 2017). Furthermore, with increased focus on consumer involvement, both in terms of active participation in the market and revenue recovery, as illustrated by, for example, the ENAs Open Networks Project (ENA, 2017), the DNOs will be required to develop methods to allow for demand response, smart metering, and consumer involvement in planning and operation of the networks.

1.2.1 New technologies – Game changers

Distributed energy resources

Distributed Energy Resources (DERs) are facilities that can generate electricity (and heat) using several small- and medium-scale technologies. These include different types of DG such as small turbines, fuel cells, Combined Heat and Power (CHP), and photovoltaic systems (IEA, 2002). These facilities either connect to the distribution network or serve customers directly on-site. This differs from the traditional system, which produces electricity in a few large facilities that is then transported over long distances through transmission and distribution networks to reach consumers.

DERs have several possible benefits. A greater number of local generation facilities can potentially reduce congestion in the network and defer upgrades to transmission and distribution systems. Additionally, quality of supply can increase as energy is generated closer to demand, and system losses may also decrease (IEA, 2002). DG currently accounts for a small proportion of total capacity, but this share is set to increase as these technologies improve. Furthermore, growing concerns over climate change, constraints in upgrading the transmission grid, and supply security are increasing the number of generators connected to distribution networks (IEA, 2002).

However, large volumes of DG can affect the quality of supply, voltage levels, and phase imbalance (Putrus *et al.,* 2009), whilst large increases in renewable sources can create new bottlenecks in distribution networks. In passive networks, the DG capacity that can be connected is limited as network stability is essential for a safe and secure supply, and large volumes of DG may cause system volatility (Lopes *et al.,* 2007). The GB Electricity System Operator (SO), National Grid, is working to alleviate operational challenges caused by, for the SO, essentially hidden ("behind the meter") generation capacity as well as the increase in non-synchronous renewable generation. Due to the rise of DG, GB grid minimum demand is falling, as is overall demand (although this may be reversed following increased uptake in EVs (National Grid, 2018b)). 7 out of the 10 lowest demand periods ever recorded in GB were in 2017. The other 3 were in 2016. Moreover, due to the large proportion of installed solar capacity, the grid minimum demand now sometimes occurs during daytime, a new phenomenon that represents an operational challenge for the SO (National Grid, 2018a). The cost of balancing the system is therefore increasing and becoming more volatile (Ofgem, 2017).

Alongside the increased focus on DG is the prospect of development of storage technologies. Depending on the duration of storage, benefits include voltage and frequency control (short storage), peak load topping, renewable power smoothing (medium storage), smoothing of weather effects, and annual smoothing of loads (long storage). Thus, energy storage can increase the penetration of DG by ensuring a smoother supply and offering greater demand predictability (Barton and Infield, 2004).

The smart information and communication technology era:
Smart grids and meters

Conventional distribution networks are passive and operate based on predefined values and are thus unable to respond to short-term customer behaviour. They are also unable to accommodate the wide range of renewable and DERs. Therefore, large increases in DG and EV necessitate the development of active networks with the ability to respond to changes in demand and supply. A smart grid uses ICTs to collect and respond to information about customer and supplier behaviour. With two-way communication technologies and smart meters, the networks can better respond to changes in demand, aggregate consumption, and grid condition, enabling informed participation by their customers (Byun *et al.,* 2011).

However, the implementation of smart technology does not automatically lead to smart network operation. The transition must be comprehensive and requires retraining of staff as well as development and implementation of new protocols that are compatible with the new operating environment (Arends and Hendriks, 2014). Moreover, the costs associated with active smart networks are substantial, and their benefits need to justify and outweigh their costs. In the conventional business model, DNOs do not normally have an incentive to implement a responsive grid as these would only be able to offer limited immediate benefits to the network operators (Lopes *et al.,* 2007). By 2020, the UK government wants every home in England, Wales, and Scotland to be offered a smart meter. The national rollout has to date installed about nine million smart meters in homes and businesses (BEIS, 2017). Although a smarter electricity system can benefit network operators, with access to real-time data, end-users have the potential to control their consumption, which, without sufficient operational and technological advancement, may increase volatility on the system.

Electric vehicles

The UK government has implemented a number of measures to incentivise the public to switch from traditional vehicles, which run on petrol or diesel, to EVs. These measures include grants, road tax waivers, and exemption from London congestion charges (TRL, 2013). Most recently, the UK government committed to ending the sale of new conventional petrol and diesel cars and vans by 2040 (UK government, 2018a). In 2014, only 5% of consumers were considering buying an electric car or van in the near future (Department for Transport, 2014) and although new registrations of EVs have been increasing since then, they still only account for 1.7% of all new vehicle registrations (UK government, 2018b). On the other hand, strong incentives in countries such as Norway have resulted in a greater demand for electric cars. A recent study by Regen (2018) finds that high up-front costs as well as range and charging anxiety are current barriers to high consumer updates. It is therefore possible that financial incentives and technological progress can increase the uptake of EVs in the UK (Putrus *et al.,* 2009).

Electric vehicles have yet to make a substantial impact on the distribution network; however, since the vehicles use batteries with large storage capacity, allowing them to travel longer distances, an upsurge in uptake may place strain on the network. One potential problem relates to a mismatch of supply and demand due to uncertainties regarding when and how owners charge their vehicles. The distribution grids can only safely carry up to a certain load, and if owners charge their vehicles at peak demand hours, a congested network may overload. Therefore, substantial local infrastructural reinforcements are required to accommodate the integration of EVs (Lopes *et al.,* 2011). Alternatively, a portfolio of charging options, for example workplace of destination charging, may help spread the demand load both geographically and over time (Regen, 2018). DNOs are currently consulting on a proposal to let network operators control EV charging to manage potential overload events. This is argued to be an interim solution to protect local electricity network assets in the absence of market-led solutions (SSEN, 2018).

As the number of vehicles increases, the DNOs will need to upgrade the network to supply the charging points and other required infrastructure (Pieltain Fernández *et al.,* 2011). However, provided that the necessary infrastructure is in place, the vehicles may be able to deliver electricity back to the grid. This opens the possibility for electric cars to provide peak-demand relief, which would reduce the need for grid capacity enhancement. Additionally, the potential mismatch between demand and supply can be eliminated through improved communication and provision of price incentives to consumers to encourage off-peak, or smart, charging arrangements (Putrus *et al.,* 2009). These changes in the operating environment of distribution networks will necessitate a shift in the operating philosophy of these companies from being Distribution Network Operators (DNOs) to Distribution System Operators (DSOs). This shift is the current subject of an industry wide project led by the ENA; the Open Network Project (ENA, 2017).

1.2.2 The consumer and society: The changing nature of demand

Governments across Europe have set ambitious green energy targets to curb emissions. The policies, including increased generation of renewable energy and EV expansion, largely depend on public and local support for their success. The role of the individual and the community in energy policy issues is thus on the rise (Akcura *et al.,* 2011). This trend is also noticeable in the transportation of electricity. The technical challenges of electricity networks, particularly DNOs, to ensure a sustainable energy future include extensive expansion and modernisation of the networks to allow for smaller but more numerous generation facilities, uptake of EVs, and active grid management. However, whilst the technical and economic aspects receive more attention from the sector and academics alike, they are only part of the challenge. As the nature of electricity demand and supply is changing, so is the role of the society and consumer engagement in the sector.

Societal and consumer acceptance of green energy innovations play an important part in addressing and curbing climate change. Whilst it is generally thought that public attitudes towards renewable energy are positive, local opposition to large facilities remains significant. The importance of public acceptance has been discussed with regards to large infrastructural projects, such as transmission lines (Ciupuliga and Cuppen, 2013), renewable-energy-generation technologies (Devine-Wright, 2011), and hazardous facilities (Johnson and Scicchitano, 2012). However, where large infrastructure, put simply, only needs "passive" consent (see Ciupuliga and Cuppen, 2013), DG, EVs, and smart networks depend on "active" acceptance from consumers. This includes the willingness to invest, install, and change behaviour to adapt to these new technologies (Sauter and Watson, 2007). The slow progress from simple acceptance to participation and changing behaviour shows how priorities expressed by citizens, e.g. supporting green economy agenda, sometimes fail to translate into actions by customers, e.g. purchasing an EV (Cotton and Devine-Wright, 2012).

The shift to a decentralised generation mix creates a flow of electricity that is less predictable and, at least initially, less controllable. Shifts in both demand and supply will have an effect on the operation of DNOs. Through increased uptake of demand–response, smart grids, and DG, customers are more involved and can actively contribute to increased energy efficiency, energy saving, and peak load shifts. Not only are customers able to influence the demand side through altering their electricity consumption patterns, but also on the supply side, where consumers can take on the role of producer through distributed generation, the so-called prosumers (Mah *et al.,* 2012).

Moreover, customer action is the main driver behind reaching the policy goals to curb climate change, and consumer engagement should therefore be a priority (Honebein *et al.,* 2011). Smart grids and DG require communication between utility companies and its customers. The relationship is likely to change from a one-way information flow to a two-way interactive discussion. However, not only will network owners be required to engage actively with customers once new technologies are implemented, through dialogue at an early stage, but they can also learn about their customers' priorities and concerns and adapt these technologies accordingly. Early communication and customer participation are important for building trust and confidence among consumers, which in turn is important for achieving customer acceptance of new technologies (Gangale *et al*., 2013).

Ultimately, increasing communication and participation with customers will bring to light the heterogeneity of customer behaviour, as the same technology may be perceived differently among different groups in the same or different communities (Batel and Devine-Wright, 2014). The role of the consumer in the sector is shifting. As distribution networks change from passive to active utilities, the public is changing from being a passive to an active stakeholder. Similarly, on a bigger scale, with energy policy driving a need for an expansion of the electricity network, society is becoming more active in the development process. This changing nature of demand, increased customer and public engagement, acts as a common thread throughout the thesis.

1.3 Economic regulation of networks

Electricity networks are capital intensive, creating high economies of scale and therefore high barriers to new entry. As a result, the network segment of the electricity system is considered as natural monopolies. Due to the non-competitive nature, electricity networks are subject to regulation to prevent monopoly pricing, discriminatory access to network services and ensure sufficient maintenance for an efficient level of supply (Jamasb and Pollitt, 2001; Newbery, 2002).

Performance of networks is important since the transportation of electricity represent a significant cost of end-consumers final energy costs. It is also the platform for competitive segments of the electricity system, wholesale and retail markets, and therefore affects the performance of the whole sector.

There are many different models applied in the regulation of natural monopolies. The individual regulators' knowledge about operations, ability to monitor, and administrative burden of governance will all influence the choice of model. However, due to information asymmetries between the regulator and the regulated companies, traditional command and control models, which are heavy-handed with detailed instructions on specific technologies, assets, or procedures, have given way for incentive-based frameworks that are less prescriptive.

1.3.1 A new regulatory environment– drivers behind change

Investment and innovation

The post-liberalisation policies of achieving a low-carbon economy have changed the dynamics of the electricity sector. This is reflected in the need for smart technologies, DERs, EVs, network security, and integration of electricity markets. Achieving these objectives calls for substantial innovation and investments. Ensuring sufficient and efficient investments in the networks is among the most challenging tasks facing regulators (Poudineh and Jamasb, 2015).

The current regulatory models of investment treatment are either *ex ante* (e.g. Ofgem), *ex post*, or a combination of the two (e.g. the Norwegian regulator, NVE). Under the *ex ante* model, network companies need to submit business plans that contain details of their investment needs over the subsequent regulatory period. The regulator uses auditing, cost–benefit analysis, benchmarking, and consultants to verify the prudence of investments plans. At the end of the regulatory period, if there is a deviation from the agreed level of capital expenditures in the business plan, the regulator might partially or totally disallow the excess investment (Ofgem, 2010a; Ofgem, 2010b).

The *ex ante* approach has been criticised on the grounds that it provides incentive for strategic behaviour. For example, network companies will have incentive to inflate their capital costs by reporting high volumes of work or by capitalising their operational expenditures. Averch and Johnson (1967) demonstrated that under this model firms will, for a given level of output, employ more capital compared to non-regulated companies.

In *ex post* regulation, the regulator adds the controllable costs incurred to the company, including the operating and capital expenditures, in order to construct a single variable reflecting the total cost. The total cost is then benchmarked against the similar companies in the sector to obtain the cost efficiency. The firms' revenue is set based on their deviation from the frontier of best performance. The threat of financial loss from the benchmarking process can lead to an inefficient level of operating and capital expenditure. Poudineh and Jamasb (2015) showed that this model is vulnerable to harmonised behaviours, such as over- and under-investment by utilities. Harmonised behaviour changes the costs for companies uniformly, and within-group comparisons cannot detect the incidence of overcapitalisation. Additionally, the minimum productivity level to pass a benchmarking exercise (that is, no-impact efficiency) is also vulnerable to harmonised behaviour.

Regulatory treatment of investment presents a trade-off between intervention in firms' operation and distribution of risk between the firms and their consumers. The *ex ante* model is more interventionist, but the firm bears little risk compared to the consumers. This is because consumers are more likely to be exposed to the actual costs of the firm rather than the efficient costs. The *ex post* model, on the other hand, is less interventionist, but firms bear more risk compared to consumers. The choice between the two approaches depends on the regulator's view of intervention and risk.

As noted by Müller *et al*. (2010), under incentive regimes (both *ex ante* and *ex post*), efficiency gain has mainly been achieved in operating costs, but regulatory models do not incentivise dynamic, efficient behaviour among firms. In the case of *ex post* regulatory treatment of investment, Poudineh *et al*. (2014) show that persistent inefficiency due to the presence of quasi-fixed inputs, such as capital, can affect companies' short-run cost efficiency and regulated revenue. This can create disincentives for long-term investment and innovation. In the case of *ex ante* regulation, although capital costs are excluded from benchmarking, the model does not provide explicit incentives for dynamically efficient behaviour.

Incentives and alignment of benefits

In order to unlock the system-wide benefits of dynamic networks that will be able to respond to demand and supply signals, the incentives that guide the behaviour of players need to be realigned. Additionally, policies need to serve the diverse interests of distributed resource developers and consumers. The public, as well as community engagement with the sector as consumers and as citizens, can affect the development of the network and energy infrastructures. Some projects have stood still because local communities perceive them as failing to meet their objectives (Tobiasson *et al.*, 2016). The need for involvement of customers in the planning of new projects or through demand-side participation requires a new consumer–network utility framework and relationship.

Consumers with micro-generation, EV, and storage capability are no longer passive users, but can actively benefit or harm the system. The load from EV varies with respect to time and location. In the absence of incentives, the EV owner indifferently charges and discharges at any time and place. However, the power system would benefit from charging during off-peak periods and in uncongested areas and discharging at peak times and in congested zones. Thus, there is a need for incentive signals that coordinate the actions of players to the advantage of power system reliability and efficiency. However, current regulatory models do not provide such incentives and thus are contrary to the paradigm of a sustainable power sector (ENA, 2017; Aurora Energy Research, 2018).

The current incentives for the integration of DERs are not directly relevant in terms of impact on network infrastructure and generation supply. For example, siting a DG close to demand centres or areas served by frequently congested lines will be beneficial for a DNO as it can reduce network energy losses and have an impact on demand-driven investments. DG can have various effects on the grid, depending on factors such as location, technological specification, and timing of investments (Vogel, 2009). The lack of a mechanism that aligns these benefits between the DG developer and the DNO might reverse the expected advantages of DG integration.

An example of this is network energy losses. Networks are incentivised to reduce such losses and are rewarded or penalised for outperforming or underperforming on the loss targets. Although DG can reduce these losses, it is generally bound by time and location and, in the case that capacity exceeds the demand, it can increase overall energy losses (Harrison *et al*., 2007). Therefore, DNOs might be exposed to DG-induced losses, with consequences for their revenue. On the other hand, generators are not incentivised for their positive or negative effect on network energy losses. Hence, there is a conflict between the interest of developers wishing to increase DG penetration and the DNO that wants to avoid potential DG-induced losses.

One solution is to use efficient and effective connection and "Use of System" (UoS) charges—a mechanism that not only includes the real cost of connection but also rewards the developer when DG installation is in line with the optimal operation of the network (Jamasb *et al*., 2005). The distribution UoS charges can play a role, as DGs' connection charges could be based on their capacity and the sole-use network asset used. On the other hand, rewards can be offered based on generator-exported power at system peak, proximity to frequently congested zones, and network assets utilised (Nelson *et al.,* 2014; Poudineh and Jamasb, 2014). This ensures that rewards will reflect the benefits from integration of the resource. Taking into account the cost drivers when devising the charges and rewards will help to guarantee that they are aligned with the costs imposed by DGs on the network.

Managing uncertainties

There are several sources of uncertainty in the operating environment of distribution network companies, which call for uncertainty to be incorporated into regulatory models. These include future strengthening of environmental policies, change in price of fossil fuels and its effect on the rate of growth of renewable resources, cost and performance of networks, carbon prices, uncertain demand and economic growth, availability of capital, and finally, change in the behaviour and expectations of consumers.

Electricity networks face significant uncertainty from unexpected changes in the aforementioned factors. These factors can impact the existing infrastructures in terms of planning and operation, as well as development of new assets. The network infrastructures are long-lived assets and irreversible investments. Hence, insufficient consideration of uncertainty in the regulatory and decision-making process can lead to negative consequences for the firm and consumers. The regulatory framework should also recognise the increasing importance of local communities as part of the low-carbon solution, and provide incentives for these communities to become part of the solution for future networks.

Thus, given the prominence of uncertainty, there is a need for regulatory models that reduce the exposure of firms and society to the adverse effects of changes in the operating environments of network companies (MIT, 2016). Furthermore, investors, who are interested in a stable return on their investments, do not welcome uncertainty. Uncertainty means risk, which is likely to erode creditworthiness of the utilities and manifest in the form of higher capital costs and thus higher bills for consumers. This will lead to reduction of capital availability, which affects network companies' future investment plans.

1.4 Theoretical Framework

1.4.1 New Institutional Economics

Traditional neoclassical economic theories rely heavily on assumptions of perfect information, costless transactions and rationality. In the assessment of the energy sector, and electricity networks in particular, which include many practical issues, these are therefore of limited relevance (Wawer, 2007; Coase, 2000; Kumkar, 1998). Classic economic theories consider commodities, labour and consumers as the smallest units in the analysis of the relation between the individual and forces of nature. This allows the economists to study how supply and demand determine prices but not the factors that determine what goods and services are traded on markets and therefore are priced. New Institutional Economics (NIE) considers the activity between actors and the norms governing them (i.e. transactions) as the smallest unit because these must be negotiated before any level of production, exchange and consumption can occur (Commons, 1931).

As such, NIE offers an alternative method of enquiry compared to the more orthodox theories. NIE accepts the assumptions of profit maximisation and efficiency but rejects those of zero transaction costs, rationality and perfect information. Institutions refer to the rules of an economy such as formal rules (e.g., written rules of contractual agreements, constitutions and laws) and informal constraints (e.g., unwritten codes of conduct, social norms of behaviour and beliefs). Organisations (i.e. a group of actors bound together by a common purpose to achieve common objectives) on the other hand are considered as the players in the economy. Actors form institutions to reduce transaction costs and uncertainty as they facilitate transactions and cooperative behaviour (North, 1990).

Williamson (1979) argues that transaction costs depend on asset specificity, uncertainty, opportunism, bounded rationality and frequency of transactions. Specificity is highlighted as the most important aspect among these and may appear in the form of site, physical asset or human asset specificity (Williamson, 1981).

Electricity networks have characteristics of site specificity, physical asset specificity and human asset specificity, making interactions and cooperation prone to high transaction costs. For example, as will be illustrated in Chapter 4 and 5, reaching unanimous decisions in large transmission developments is difficult due to two main characteristics. First, the size of projects, including physical, financial, and number of stakeholders, makes negotiation and bargaining difficult as the involved parties have different objectives and stakes in the project. Second, many decisions involve public goods which are difficult to quantify and therefore risks being exploited. These characteristics lead to uncertainty, undefined and therefore unsuccessful principal-agent relationships, as well as information asymmetries. In turn, this generates increased transaction costs, externalities, and subsequent market failure.

The central concepts of NIE, namely transaction cost theory, property rights theory, and agency theory, are applied throughout the thesis, with particular focus on the new consumer role.

1.5 Thesis outline

Consisting of four main chapters, the thesis uses theoretical and applied economic methods, both qualitative and quantitative, to explore and advance aspects of economic regulation, focusing on incentive regulation, and the new role of consumers in the ongoing development of electricity networks.

Chapter 2 considers current policy-driven changes and the impact on the consumer role within incentive regulation. It is a qualitative assessment with particular focus on electricity distribution networks. Forming a critical part of the electricity supply chain, electricity networks are facing challenges across technological, social, and economic dimensions, requiring a change in how networks are operated. In response to this, Ofgem, the GB regulator, is adapting its regulatory framework by introducing greater reliance on customer engagement and targeted incentive schemes providing outputs beyond those focusing on efficiency improvements. We present a critical comparison of the treatment of consumers in traditional input-based approaches and the new output-based incentive framework, using the GB framework as an example.

Chapter 3 is a quantitative empirical assessment of incentive regulation using data from Norwegian distribution owners. If applied correctly, productivity analysis and benchmarking can be an effective way of reducing informational asymmetry between regulated utilities and the regulator. We apply a stochastic frontier analysis approach to study the impact of ownership structure and vertical integration between network levels on utilities' cost efficiency. These are two previously overlooked aspects when assessing electricity distribution companies' efficiency. Policy drivers behind initiatives to encourage certain ownership structures or unbundling within the energy sector are often based on assumptions of efficiency improvements, yet not always validated. We will therefore assess the impact of ownership structure and vertical integration between different network levels (i.e. the same company owns both transmission and distribution assets) on companies' *social total cost* efficiency using data from Norwegian DNOs.

Chapter 4 applies the theoretical framework outlined in section 1.4 and the challenges outlined in section 1.3 for a critical qualitative assessment of large-scale network developments and the resolution of social conflict. Increasingly, local opposition to new electricity grid projects cause lengthy delays and places financial and practical strain on the projects. Whilst the structure of the electricity industry is in transition due to the emergence of smaller but more numerous generation facilities and wider society and local communities increasingly engage with energy and environmental issues, the traditional decision-making frameworks and processes remain the same. The chapter proposes an economic approach to resolve conflicts that may arise. We discuss how compensation, benefit sharing, and property rights can have a role in reducing community opposition to grid development. However, we argue that these methods need to be part of an overarching policy towards conflict resolution in grid development. We then propose that such impacts can be addressed within a 'weak' versus 'strong' sustainability framework. We suggest that the concepts of 'collective negotiation' and 'menu of options' in regulatory economics can be adapted to operationalise the suggested sustainability-based approach to arrive at more efficient and socially desirable outcomes. The proposed framework can lead to the identification of socially acceptable outcomes that could otherwise have gone undetected.

In Chapter 5 we look at the practical impact of ambitious renewable energy targets and an aging infrastructure, which necessitate a substantial upgrading and expansion of the electricity networks, in a case study. Although vital for the functioning of the economy and a green energy future, grid development projects are often met by public opposition, which increase costs and lead to lengthy planning processes. Therefore, understanding the social aspects of a green energy economy is becoming increasingly important. We analyse these issues from a New Institutional Economic perspective, outlining the economic characteristics of transmission developments and public engagement. We identify previously overlooked features of the planning process that contribute to the rise in conflicts, public opposition and prolonged project realisation. The Scottish Beauly–Denny high voltage transmission development is discussed in detail and our findings indicate a need for better engagement with local communities at an earlier stage of planning. Trust between communities, developers and government is important for the negotiations and can be achieved through transparency, specific education and set guidelines for stakeholder engagement in the planning process.

Finally, chapter 6 concludes and proposes avenues for further research.

Chapter 2

Incentive Regulation and the New Role for Consumers

2.1 Introduction

Maintaining a well-functioning liberalised sector requires supervision and regulation of the wholesale and retail markets as well as the networks services. At grid level, this becomes more important as there is currently limited competition and the GB network owners are subject to incentive-based regulation. The incentive regulation regimes aim to stimulate market outcomes in this segment of the sector and the expectation is that incentive regulation better realises the objectives of regulators compared to rate-of-return models. Commonly regulatory models focus on incentivising firms to minimise its inputs, namely its costs, whilst delivering a required set of outputs.

Traditional network outputs are determined by demand for energy and network connections, which is exogenous for firms (meaning that they have little control over these, at least in the short run) and firms are therefore only able to adjust their inputs to deliver its services efficiently. The input-focused approach has generally been successful in improving technical and economic efficiency; however, the post-liberalisation experience has shown that incentive regimes give rise to new challenges, including those related to investments and innovation. Additionally, promotion of low-carbon technologies and objectives, as well as a more active customer base, has resulted in new challenges that require regulatory innovation and solutions. The changing energy landscape is driving a change in regulatory efforts, including the introduction of additional incentives and a move to output-based methods, where regulated firms' revenue is not only determined by its efficient use of inputs but also how well it is delivering set targets, outputs and outcomes. The new network outputs go beyond the exogenous outputs of energy delivered or connections and focus on quality of supply, environmental targets, and customer satisfaction. One prominent example is the GB regulator, Ofgem, which has adapted its regulatory framework in an attempt to better facilitate the current energy and environmental transition by introducing greater reliance on customer engagement and targeted incentive schemes beyond those focusing on efficiency improvements. The broad nature of the challenges, across the energy sector, shows a need for whole system consideration at each step. Specific issues and solutions cannot be viewed in isolation and whilst the energy system is becoming more decentralised, thinking must be joined up at all levels.

In this chapter, using qualitative analysis, we provide a critical comparison of input and output-based incentive regulation, using the GB electricity networks as an example, with particular focus on the treatment of consumers and consumer engagement. Policy objectives are driving intensified public interest in environmental issues and the electricity sector is currently undergoing changes that are making energy companies' actions more visible and consumers more active. Consumer engagement is a relatively new concept to electricity networks but it is becoming increasingly important in order to keep up with the rapid changes. Regulatory changes are notoriously slow and can, given the high degree of regulation of networks, which includes revenue control, act as a barrier for networks to follow progress in the sector. This risks delaying the realisation of policy targets.

The chapter is outlined as follows: Section 2.2 provides an overview of incentive regulation, focusing on the more traditional input-based approach, including theoretical underpinnings, practical examples and the treatment of consumers. Section 2.3 outlines the new output-based framework, using the GB frameworks as an example. Section 2.4 compares and contrast the role of consumers in the two approaches and section 2.5 concludes.

2.2 Incentive regulation

Electricity networks are regulated to ensure sufficient supply at fair prices for consumers, however charges must also be set to assure that the regulated firms secure sufficient revenue from their investments to maintain the grid. A traditional form of regulation is rate-of-return regulation, which lets firms cover its operating and capital costs plus a return on capital. This method is however criticised due to its lack of incentive for firms to increase efficiency and reduce costs. Sectorial reforms and regulators across Europe have therefore focused on an alternative form of regulation, namely incentive regulation. It is used to provide firms with incentives to become more efficient and increase investments, and to make sure that the costumers benefit from the cost reductions.

Using rewards and penalties to incentivise network utilities to achieve certain goals or motivate certain performance can partly overcome one of the main issues of regulation, namely information asymmetry between the regulator and the regulated firms. The approach of the firms to achieve the set goals of performance measures is up to the firms themselves, providing the opportunity to utilise internal information to improve performance.

Two issues arise from asymmetric information, *adverse selection* and *moral hazard* (Joskow, 2008)*.* Adverse selection arises when a firm is perceived to have higher costs than it actually does in order for the regulator set higher prices. Moral hazard arises because the regulator is unable to know the managerial efforts of the firm. By increasing information availability and quality, the regulator can reduce its informational disadvantage.

The most commonly applied incentive regulatory models are price cap, revenue cap, and yardstick regulation (Jamasb and Pollitt, 2007).

Price and revenue caps are based on the same underlying theory where the cap is adjusted to an index that reflects the rate of inflation in the economy. This is to provide an incentive similar to firms in competitive markets, which are subject to input prices increasing with inflation. It provides the opportunity to regulated businesses to increase efficiency relative to average firms by reducing its costs or improving performance thus outperforming inflation.

Yardstick regulation encourages firms to cut cost and become more efficient by comparing performance to a reference point or frontier, set by either comparing performance among firms (also called benchmarking) or using an optimal reference firm. Identifying the appropriate yardstick depends on data and technical availability of the regulator and may therefore not be appropriate in some situations.

It is common practice that regulators utilise a hybrid of different regulatory methods. A widely used method based on the price or revenue cap model is RPI – X, where the price adjusts for the retail price index in the previous year and an expected efficiency improvement – the X-factor. The method was first implemented by Ofgem in GB but has since been replicated in many countries. However, one of the issues facing regulators is how to appoint the appropriate requirements for efficiency, i.e., the X-factor. It is therefore common to apply benchmarking as a method to distinguishing a firm's actual performance to enable a comparison of its relative efficiency against a reference point or benchmark performance. Poorly performing firms will be assigned greater X – factors to give them the incentive to reduce the gap between themselves and the most efficient firms (Jamasb and Pollitt, 2003). Benchmarking is argued to be cost effective and advantageous when regulating individual or numerous utilities, domestically or across borders. Generating the X-factors using external measures increases the firms' incentive to become more efficient and improve information transparency since the reliance on the firms' own cost information is decreased (Jamasb and Pollitt, 2001; Joskow, 2007).

The Norwegian energy regulator, NVE, utilises an incentive-based revenue-cap regulatory framework to encourage network companies to reduce costs and improve efficiency. The allowed revenue is set using total cost benchmarking of comparable firms and the revenue cap is determined using a share of firms' actual cost and the benchmarked norm cost. The incentive power of regulation and stimulated competition among utilities to improve cost efficiency is achieved by placing a higher weight on the norm cost. That is, by putting a higher weight on the norm cost, the regulator is incentivising firms to move closer to the frontier of best-performance.

2.2.1 Incentive regulation and the treatment of consumers

Regulators objectives with regards to network regulation have traditionally focused on protecting customers from monopoly pricing by monopoly network owners. Ofgem state its principal objective as "*protecting the interests of existing and future electricity and gas consumers*". Without extensive detailed knowledge of the customer base and its priorities assumptions must be made of what this actually entails. Based on basic economic theory of rationality of agents it is fair to assume that cost minimisation for a given level of service is a priority. This is also the approach of most regulators incentivising firms to optimise their inputs (i.e. costs) to achieve a certain level of outputs exogenously set by demand.

The driving forces behind privatisation of the energy sector in the UK was the prevailing market conditions, which in included spiralling inflation rates and unemployment. There was also a political shift regarding state involvement in economic activity and ownership of industry. Prioritising efficiency improvements was therefore necessary and the main aim of the regulator, acting in line with general government policy of the time. Direct engagement between customers and network owners or regulators in the post-liberalised era has therefore been limited. 20-30 years on we have seen efficiency improvements in the operation of electricity networks, however, regulation will have to change to meet the challenges, such as technological development and demands from electricity consumers and producers (Jamasb and Pollitt, 2007).

Following concerns that cost-minimisation incentives was having an adverse effect on quality of service of networks, many regulators have opted to include a measure of service quality in their regulatory models (Giannakis *et al.,* 2005). This can be considered as a first step towards a more output-based framework, aimed at increasing customer focus although, as we will see, not necessary customer participation, in the regulatory process.

Economic theory suggests that the level of quality should represent customers' valuation and the marginal cost of quality improvements. Ideally, customers should be given a choice of quality and charged according to the cost of providing it. However, offering different levels of quality depending on willingness to pay for it may be politically sensitive given the equality aspects of the possibility that those with more money can enjoy a more reliable electricity supply (Waddams Price *et al.* 2002).

In 2001 NVE introduced a quality variable in its calculation of network companies' revenue caps. The variable uses interruptions to supply, estimates of energy not supplied and an average interruption cost for different customer groups. The estimated cost of interruptions for customer groups is calculated by the regulator based on responses to customer surveys. Similarly, the Finnish regulator uses cost estimation surveys as a basis for its quality of supply incentive, with regular updates to ensure that the values applied in the regulatory model are still valid (CEER, 2016a).

Many countries across Europe have implemented reward and penalty schemes or incentives to optimise quality of supply levels in its electricity networks. However, the estimation of the price of quality is not always achieved through identifying customer willingness-to-pay or willingness-to-accept, as in Norway and Finland, discussed above. For example, when Sweden introduced a quality indicator in its regulatory framework in 2012, the regulator Ei opted to employ customer group specific cost norms, identified through a general assessment of available cost of interruptions information, rather than a customer specific survey (Ei, 2010). Moreover, in 2009, Ofgem extended its

RPI-X model to include a quality indicator without conducting cost or optimal quality level surveys with GB customers (CEER, 2016a).

Generally, electricity customers have had a limited role in the regulation of electricity networks. However, the concept of customer engagement is on the rise and play a central role in a number of regulatory jurisdictions in North America where negotiated settlements has emerged over time. Negotiated settlements between companies and their customers have been found to reduce costs and uncertainty, whilst limiting regulatory burden (Littlechild, 2016).

2.3 A new approach to incentive regulation: an output-based framework

Following liberalisation, the main concern of network regulation was ensuring security and reliability, which was provided by engineering, health and safety requirements. Incentive regulation has generally been successful in improving technical and economic efficiency and traditionally, regulators have used an input-based approach where firms are rewarded for cost-minimisation. However, network long-term sustainability and innovation concerns are often overseen in the input-based framework, thus the innovations in incentive regulation of quality of service have lagged that of cost efficiency schemes (Growitsch et al., 2005; Giannakis et al., 2005). The intention of increasing customer focus in the regulatory framework is not always associated with increased direct customer or consumer engagement, meaning that the customer role remains much the same. However, 30 or so years later, the energy sector is undergoing a remarkable change, particularly noticeable in distribution networks. As the go-between connecting transmission and customers, distribution networks are expected to play an important role in reaching a sustainable energy future. The services that DNOs are required to deliver are increasing; DNOs are expected to engage with customers, through demand response and stakeholder engagement, allow for an increased uptake of EVs and DG, whilst ensuring a safe and reliable service at fair prices for customers. A combination of challenges, including increased reliance on renewable energy, DG, aging infrastructure, and increased concern of utilities' social and environmental impact, is expected to render the traditional DNO business model out-dated (Lehr, 2013). In other words, the days of passive transporters of electricity are over.

As a result of the changing nature of DNOs, GB regulator Ofgem have adapted a new regulatory framework, which puts an emphasis on long-term sustainability through increased focus on expected deliverables. The new regulatory scheme, RIIO (Revenue = Incentives + Innovation + Outputs), is an example where a wider set of incentives focus on output measures of companies' performance, rather than merely cost-minimisation. RIIO aims to promote greater benefits for customers and stronger incentives for utilities to deliver a sustainable energy sector for current and future generations (Ofgem, 2010a).

The move to output-based regulation signals an increase in the demands and expectations of network owners. It reflects the shift in the industry from one which is concerned mainly with technical matters to one which increasingly involves social, political, and environmental aspects. In order to meet the future challenges, network owners must take on a more active role, engage in stakeholder discussion, respond to instant changes in demand and supply, increase customer service, as well as focus on environmental concerns and equality. In order to meet these challenges, extensive investments are needed (Ofgem, 2010b).

As the only proclaimed output-based incentive regulation framework applied to electricity networks, we will focus on RIIO in our discussion, below. Additionally, we will highlight key takeaways from Ofwat's new output-based (although referred to as outcomes-based) price control for England and Wales' water and sewage sectors due to the similarities between the two approaches. Both Ofgem and Ofwat envisages a greater role for consumers compared to previous frameworks, seeking 'to put the customers at the heart of business plans (Littlechild, 2016).

RIIO

The RIIO framework builds on the RPI-X model, a form of price cap regulation which allows utilities to recover efficient costs linked to inflation with the expected efficiency saving subtracted, with added incentives for a wider range of outputs.

At the start of the price control period, a set of, supposedly, clearly defined and measurable outputs are identified and used to incentivise a desired outcome. Allowed revenue is linked to the performance in each of the outlined output categories. In the case of RIIO, the outputs are set through stakeholder consultations (Ofgem, utilities and customers) and aim to encourage DNOs to "*play a full role in the delivery of a sustainable energy sector"* and to *"deliver value for money network services for existing and future customers*" (Ofgem, 2010a, p.1).

2.3.1 Output categories

The output-oriented approach combines the efficiency mechanisms in a revenue cap framework with output-based incentives. In RIIO the outputs are set through stakeholder consultations including Ofgem, network utilities and customers. Through the consultations, six output categories have been identified; Safety, Reliability and Availability, Conditions for Connections, Environmental Impact, Social Obligation, and Customer Satisfaction.

2.3.2 Revenue constraint

The revenue constraint is determined in three parts. First, base revenue is set *ex ante* using the expected efficient costs. When determining the base revenue, both quantitative and qualitative measures are used. The price control will be based on forecasts of: output requirements; demand for network services; cost of deliver and financing costs. This is different from RPI-X where revenue was constrained at an allowed rate, the X-factor. However, company data will remain the primary source of information for setting the price control and the *ex ante* 'building block' approach, i.e. assessing expected efficient cost of delivery, depreciation allowances and an allowed return on the regulatory asset value, is still implemented. The final expected efficient cost is set using 75% of Ofgem benchmarked costs and 25% DNO estimated costs. Second, two *ad hoc* measures – rewards and penalties based on the performance in delivering the outputs, and adjustments for uncertainty – are carried out throughout the price control period. As such, the revenue of the utilities will vary depending on how well the companies perform in terms of outputs delivered (Ofgem, 2014; Ofgem, 2013b; Jenkins, 2011).

2.3.3 Output-based incentive regimes and consumer engagement

Consumer engagement can take different shapes in regulatory regimes. During the development of RIIO, Ofgem followed a traditional regulator-led price control review, however, with increased involvement by customers and other stakeholders. Customer and stakeholders acted as consultees to both the regulator and companies, providing input into the regulatory framework as a whole, including development of the outputs to be included, as well as on individual companies' business plans. The shape of the customer engagement was not stipulated nor was there a requirement that companies and customers agree to certain points ahead of Ofgem's final decision (Bush and Earwaker, 2015). In the development of RIIO-2, Ofgem is introducing further stakeholder engagement models, including a framework-central Challenge Group, open public hearings, and a requirement for individual company Customer Engagement Groups. Input from all stakeholder and customer engagement will inform the regulators final decision (Ofgem, 2018c).

Moreover, Ofwat applies a similar approach to its price control review of water and sewage sectors in England and Wales, aiming 'to put the customers at the heart of business plans' (Littlechild, 2016). Ofwat requires companies engage with customers and stakeholders to propose outcomes and delivery incentives. Customer Challenge Groups are then responsible for scrutinising companies' proposals and report to Ofwat on the quality of customer engagement and how their views are represented in the plans (Ofwat, 2016).

It is also possible for stakeholder and customer engagement to play an even greater role in defining the overall regulatory framework and details determining regulated utilities revenue or price caps. It could be dictated by the regulator that companies and their customers agree to certain aspects of the regulatory model and the regulator simply act as an arbitrator - only stepping in if no agreement is reached. This could take the form as negotiated settlements or 'constructive engagement'[2], which is utilised by the aviation regulator in the UK (Bush and Earwaker, 2015).

2.4 Discussion

Regulation of natural monopolies generally aims to mimic a competitive market where competition itself is not possible. By including a greater focus on outputs and customer views, output-based regulation provides another dimension to traditional incentive regulation as firms now must respond to customer quality demands and priorities rather than outcomes purely set by the regulator. The set outputs, which the network utilities are expected to deliver in a given price control period, acts as a contract between the utility and the customers. Increased customer engagement in network services and regulation is argued to reduce regulatory burden, reduce social conflicts, and increase efficiency in planning and development (Tobiasson *et al.,* 2016; Doucet ad Littlechild, 2006).

A relevant problem in regulation is information asymmetry between utilities and regulator. Incentive regulation reduces information asymmetry and increases efficiency by allowing regulated utilities to decide on the use of its resources. However, the heavy emphasis on cost-minimisation of input-lead incentive regulation has been criticised to reduce service quality in order to cut costs and therefore increase profit. For example, in a study on GB DNOs, Giannakis *et al.* (2005) find evidence supporting a possible trade-off between costs and quality of service and Ter-Martirosyan and Kwoka (2010) find that incentive regulation is associated with longer, yet not necessarily more

[2] Note that this does not necessitate an output-based framework.

frequent, outages. This is offset when where the regulator incorporates service quality standards in the regulatory framework. An output-based method has the potential to reduce information asymmetry whilst ensuring quality of supply as a result of increased focus on what customers want from network services rather than the regulator acting on their behalf (Jenkins, 2011).

Prior to the introduction of RIIO, network companies in GB were used to responding to and engaging with Ofgem, acting on behalf of customers. In a survey by Utility Week ahead of the implementation of RIIO, DNOs reported to be confident that their networks would meet the reliability and security demands set by the outputs. However, customer service was highlighted as the most difficult area by all responders to the survey (Utility Week, 2013). This result is hardly surprising given the priorities to date in the sector. Reliability and security have always been a main importance whilst customer engagement is a relatively new concept, albeit one proving to be increasingly important (Tobiasson *et al.,* 2016; Cotton and Devine-Wright, 2012). It could also be an indication of a poorly defined remit of how customers are to be engaged and how it will feed into the regulatory model or business model. Clearly defined guidelines are important given that the sector is new to this way of working (Bush and Earwaker, 2015). The more deterministic procedures for customer engagement in RIIO-2 is likely a result of this.

Furthermore, with companies heavily involved in developing and setting their own outputs, the regulator faces a challenge in ensuring sufficient objectivity in the process and independence of consumer groups. Whilst Ofgem declared that the plans received ahead of RIIO-1 showed a marked improvement over previous price control submissions (Ofgem, 2013c), this could increase regulatory burden and higher costs, particularly if a wide range of outputs are included. RIIO has been criticised for allowing excessive profits for the network utilities (Citizens Advice, 2017). The nature of an ex ante approach means that a level of uncertainty is to be expected regarding the accuracy of forecasts (Ofgem, 2010a). Still, the increased deliverables in the output-based framework puts greater pressure on network utilities as well as a greater burden on the regulator monitoring the sector.

Moreover, increased reliance on customer and stakeholder engagements lead to stakeholder fatigue where customers are asked to contribute over a long period of time (price control reviews traditionally last for several years and in some frameworks customer engagement continue throughout the entire period) and comment on multiple companies' business plans. This issue will be exacerbated if more sectors implement a similar approach to regulation, demanding the same skill set within the customer base.

Traditionally, input-based regulatory frameworks have had limited customer involvement. However, there could be an increased role if the regulator stipulates it, without the need to move to a fully output-based method. One example is negotiated settlements. However, the narrow focus on inputs limits the opportunities of customer engagement to the specific rates used within the regulatory framework, for example cost of capital. Additionally, the added value of this kind of customer engagement is unclear given inability of customers to voice priorities beyond cost-minimisation and the limited representation of the customer base due to the need for expert knowledge.

Continued development of RIIO

In July 2018 Ofgem published its decision on the RIIO-2 framework (Ofgem, 2018c). RIIO-1 was ground-breaking in many ways and perhaps ahead of its time. Change is not happening as quickly as perhaps was envisaged and the regulator appears to be taking a step back in RIIO-2. The price control period is reverted back to five years, reflecting uncertainty in how the networks will be utilised in the future, and there is a renewed focus on efficiency and the objectives are simplified and reduced. The key areas from RIIO-1 that are maintained and include further stakeholder engagement and opportunity to influence and innovate. Ofgem is also set to extend the role of competition in energy networks (Ofgem, 2018c).

Given the uncertainty going forward, in terms of network utilisation, system requirements, technological developments, and customer needs, any framework developed and implemented by the regulator must allow for a degree of flexibility. This is however not popular with network companies as they would prefer certainty of revenue longer term. Flexibility in the framework can also lead to increased regulatory burden if many decisions are made throughout the price control period rather than set rules agreed and determined at the start.

2.6 Conclusions

The energy sector is undergoing a significant change and as the crucial physical link between electricity generation and consumers, electricity networks is playing a key role. Reaching climate change reduction targets cost effectively whilst ensuring security of supply relies on getting the future framework for owning, maintaining, upgrading and regulating the networks right. The green energy agenda is driving technological change, including renewable energy sources, DG, and EVs, which the networks must accommodate. Moreover, electricity consumers are becoming increasingly aware and active in the market. Technological developments are allowing consumers to take more control over their own electricity consumption and even the opportunity to become their own producers. Together with larger scale DGs, this is providing a significant challenge for transporters of electricity as it is becoming increasingly common that electricity may flow both ways, rather than following a traditional centralised process: generation > transmission network > distribution network > costumer.

In this chapter we look at the ongoing developments within incentive regulation, from an input-based framework focusing on cost-minimisation and efficiency improvements to an output-based approach where a wide range of outputs determine regulated companies' revenues. We focus particularly on the role of customer and stakeholder engagement within the regulatory framework.

Traditional regulatory regimes are generally focused on cost minimisation and efficiency improvements, leaving other objectives largely overlooked. With the new regulatory framework RIIO, GB regulator Ofgem introduced a wider set of objectives and outputs for network owners to deliver, including more targets for delivering timely connections, environmental impact, and customer engagement. Customers and stakeholders acted as consultants in the development process, a common feature in output-based frameworks.

We find that there are greater opportunities for constructive customer engagement within an output-based framework, given the wider range of deliverables affecting companies' revenues. It can be argued that output-based regulation provides another dimension to traditional incentive regulation and may reduce the impact of information asymmetries between the regulator and the regulated companies given the increased reliance on customer engagement. However, with companies heavily involved in developing and setting their own outputs, the regulator faces a challenge in ensuring sufficient objectivity in the process and independence of consumer groups.

Finally, whilst traditionally limited in input-based frameworks, it is possible to increase the level of customer engagement regardless of the regulatory framework. This can be achieved through negotiated settlements or customer determined cost of interruptions in quality of supply incentives.

Chapter 3

Vertical Integration, Ownership, and Performance of the Norwegian Electricity Distribution Sector

3.1 Introduction

Since the 1980s, many countries have liberalised their electricity sector, changing its institutional structure. The potentially competitive segments of the sector, such as generation and supply, have been vertically separated from the naturally monopolistic transmission and distribution networks. Privatisation was considered to be the answer to stop spiralling costs and improving efficiency in a currently volatile economy. However, due to the lack of competition, the transmission and distribution of electricity are subject to economic regulation in order to ensure access, security of supply, and fair prices for customers. By late 1990s, incentive regulation was common practise in many countries aiming to promote improvements in investment and operating efficiency (Jamasb and Pollitt, 2001).

Information asymmetries commonly arise in regulated industries. Firms have an informational advantage over the regulator in terms of its actual costs, production, technology, and managerial effort, and this is the main barrier to successful regulation of natural monopolies (Joskow, 2007; 2008). Much of the research and application of regulation attempts to address the issues caused by information asymmetry and to reduce its negative impact on social welfare. In order to aid the assessment of firms, many regulators rely heavily on productivity and efficiency benchmarking. The analysis makes use of information from the regulated firms to determine their performance relative to a predetermined benchmark. The results are then applied to determine the allowed revenue of the utilities (Jamasb and Pollitt, 2001). Because of the weight put on the outcome, i.e. determining firms' revenue, ensuring accurate estimation and measurement of productivity and efficiency is crucial.

Regulators have an important task deciding on the regulatory framework. The choice of benchmarks and techniques used to measure efficiency is a key factor and must accurately reflect the environment in which the firms are working. Overall efficiency is a combination of *technical efficiency* and *allocative efficiency*. That is, to be overall efficient firms should aim to move as closely to the best-performance frontier by maximising output given available inputs, and firms should choose the mix of inputs which produce a given output at minimum cost (Coelli *et al.,* 2005). Regulators tend to focus on technical efficiency in their analysis as capital-intensive monopolistic industries are seldom able to reach allocative efficiency due to firms' inability to individually control their input and output mixes (Coelli *et al.*, 2003).

In this chapter we consider two previously overlooked aspects when assessing electricity distribution companies' efficiency; vertical integration between transmission and distribution utilities (i.e. the same company owns both transmission and distribution assets) and ownership structure (private or public ownership).

Allowing the same company to own two different segments of an otherwise unbundled sector is justified through assumed benefits of coordination and economies of scale. For example, when the GB electricity sector was liberalised in the 1990s, the two Scottish organisations, Scottish Power Transmission (SP Transmission) and Scottish Hydro Electric Transmission (SHE Transmission), remained vertically integrated with control of all four major segments of the sector (namely, generation, transmission, distribution and retailing), north of the border. The two companies remain vertically integrated still today, albeit with strict business separation requirements to ensure no unjust competitive advantage gained from its organisational structure. However, this excludes the distribution and transmission network businesses since there are recognised potential efficiency gains from economies of scale which outweigh the potential disbenefits of allowing the same company own electricity networks of different voltages. Furthermore, the EU Third Energy Package was introduced in 2009 to further liberalise the energy sector across Europe, including unbundling of vertically integrated businesses. The Scottish TOs are certified under a derogation stipulating that special circumstances ensure sufficient independence of its transmission business to allow for continued integration.

Moreover, believed efficiency gains were one of the major drivers behind electricity sector privatisation in the UK during the 1980s and 1990s. This has been generally accepted as true, although recently challenged by the UK Labour Party, who went to election in 2017 pledging to renationalise big utilities due to the profits enjoyed by private companies (The Labour party, 2017). This has brought the subject of ownership structure and its impact on companies' productivity into focus.

In this chapter we use an unbalanced data set of 100 Norwegian Distribution Network Operators (DNOs) from 2007 to 2014 to estimate the impact of the ownership structure and electricity network vertical integration on companies' technical inefficiency. We use the econometric statistical estimation technique Stochastic Frontier Analysis (SFA) to model the effect of vertical integration between network levels and ownership structure on efficiency. The perceived benefits of vertical integration and private ownership in regulated networks has not been assessed in this form before.

The chapter is outlined as follows. Section 3.2 provides a background on the theoretical context of regulation and benchmarking as well as review of existing empirical literature. Section 3.3 outlines the methodology, describes the data, and presents the empirical model. Section 3.4 provides a discussion of the results and Section 3.5 concludes.

3.2 Theoretical and practical context

3.2.1 Information asymmetry

Naturally monopolistic industries are commonly regulated to evade market failures caused by poor economic performance. When a regulator implements a framework, the goals are generally increased efficiency (of costs and production) and an aim to improve social welfare. Government intervention of any sort comes at a cost and it is therefore important to consider the costs of intervention compared to the economic gain.

Regulators have imperfect information regarding the technology, costs, and behaviour of the firms that they regulate. Firms on the other hand generally have more information about these attributes and can use this to gain a strategic advantage. The choice of regulatory framework thus depends on its potential to limit or mitigate asymmetric information problems.

Two issues arise from asymmetric information, *adverse selection* and *moral hazard* (Joskow, 2008). Adverse selection arises when a firm is perceived to have higher costs than it actually does in order for the regulator set higher prices. Moral hazard arises because the regulator is unable to know the managerial efforts of the firm. By increasing information availability and quality, the regulator can reduce its informational disadvantage.

3.2.2 Regulatory frameworks

Traditionally two types of regulatory frameworks have been considered when regulating privately-owned utilities: price cap and cost of service regulation. By setting a price cap or fixed price, firms and its managers are incentivised to exert maximum capabilities as any cost reductions remain sole with the firm. The problem of moral hazard is thus removed. However, the costs associated with adverse selection are fully realised as firms have an incentive to exuberate their costs to maximise potential gain.

Additionally, in order for the firms to cover all their costs, the regulator, with limited information, would have to set a relatively high price. This would increase the rent available to the firm and increase social cost. Cost of service on the other hand is able to address adverse selection. Provided that the regulator is capable of accurately audit cost, the firm is guaranteed to be reimbursed for all its production costs. It has no incentive to exuberate its costs as this will be checked. Meanwhile, the managers of the firm have no incentive to increase their efforts to reduce costs either, as the full true cost will be recovered. The cost of moral hazard is thus fully realised.

Throughout the years, variations of the two traditional regulatory methods have been used, for example sliding scale and yardstick regulation, which introduces performance comparison between utilities, to better incentivise desired behaviour and improve performance. Today, regulatory frameworks tend to be a combination of methods with a relatively large reliance on some form of benchmarking (Jamasb and Pollitt, 2001).

3.2.3 Incentive regulation and benchmarking

Incentive regulation makes it possible for the regulator to encourage both improvements in efficiency and desirable behaviour by rewarding good performance and penalising poor performance. Actual performance is measured against a predefined benchmark, which will, at least partly, determine firms' rewards (or penalties in case of two-sided incentives). The regulator has a challenging task to determine what the benchmarks should be and how performance should be measured (Jamasb and Pollitt, 2001). The application of efficiency and productivity analysis in network regulation is a response to the information asymmetries that exists between the regulator and the firms. Benchmarking of firms make use of available information beyond what is revealed by the firm itself.

Jamasb and Pollitt (2001) provide a good assessment of benchmarking and regulation of electricity networks and differentiates between 'frontier benchmarking', which identifies the efficient performance frontier from the best practice in an industry or sample, and 'average benchmarking', which measures average performance. In recent years, frontier benchmarking is more common and includes nonparametric methods such as Data Envelopment Analysis (DEA), parametric methods such as Corrected Ordinary Least Square (COLS) and Stochastic Frontier Analysis (SFA) or even models with both components, the so-called semiparametric methods. In SFA and

COLS, relative efficiency scores are estimated, with SFA recognising the possibility of stochastic errors in the measurement of firms' performance. In DEA, on the other hand, the efficiency of firms is computed as the distance to the piecewise linear frontier made up of the most efficient firms. That means that a number of firms will always be considered fully efficient. An advantage of the non-parametric DEA method is that a functional from must not be specified and only an assumption about convexity, in terms of the nature of production technology, must be made. However, this comes with a major disadvantage in that the method is deterministic and is unable to distinguish between random noise and inefficiency. The statistical analysis technique of SFA on the other hand allows for separation of random noise from inefficiency but estimations need a functional specified, which increases the risks of estimation issues (Hjalmarsson *et al.,* 1996).

Norway introduced incentive regulation and efficiency benchmarking in 1997 and has since used DEA in setting the revenue caps for low (distribution) and mid-voltage (regional transmission) networks.

3.2.4 Ownership structure

When considering ownership structure, privately owned, when compared to state owned, companies are often assumed to be more efficient and perform better. This has been one of the key drivers behind privatisation in the electricity market. However, empirical analysis on the matter of ownership structure on large utilities can be argued to be inconclusive. For example, when assessing factors that influence the technical efficiency of thermal power plants, See and Coelli (2012) find that privately-owned power plants achieve on average higher technical efficiencies compared to publicly owned power plants. Similar results are found when assessing the impact of the ownership form on European and Australian airports, where public airports operate less cost efficiently than fully private airports (see Adler and Liebert, 2014). Meanwhile, in a study on the US electricity utilities, Atkinson and Halvordsen (1988) show that on average publicly owned and privately-owned firms have the same level of cost inefficiency. This is, however, disputed when examining the efficiency of the Swedish distribution networks, where privately owned companies are relatively more efficient (Kumbhakar and Hjalmarsson, 1996).

Whilst the studies on electricity networks ownership structure and impact on efficiency are limited and show no conclusive results, continued assessment and greater understanding may aid the regulator in reducing the informational disadvantage. Additionally, with a major political party pledging to renationalise the energy sector, as the UK Labour Party did in 2017, assessing the impact of ownership structure on efficiency is as timely as ever (The Labour party, 2017).

3.2.5 Vertical integration

Due to its physical nature, the generation, transmission and distribution of electricity are highly interdependent. Whilst the technology of storing electricity is progressing, it is still not available on a large scale meaning that the electricity produced and consumed must always be balanced. Both the production and delivery of electricity requires assets that are highly specialised and once the assets are in place in one area, they cannot easily be redeployed somewhere else. These characteristics indicate that vertical integration is an efficient organisational structure (Williamson, 1971). There are three main attributes that explain this; i, market distortions are eliminated by eliminating markets; ii, coordination of investment in a complex system; and iii, risk reduction and risk management (Michaels, 2005).

The Third Energy Package is one of the most important legislations from the EU concerning the European gas and electricity markets. It came into force on 3 September 2009 and is mainly aimed at further liberalising the European energy markets. Under the package, energy networks are subject to unbundling requirements, which oblige Member States to ensure the separation of vertically integrated energy companies. As a result, the various segments of the electricity sector (generation, distribution, transmission, and supply) should be separate. The introduction of stricter unbundling rules is a response to concerns that a vertically integrated company can obstruct competitors' access to infrastructure, which would prevent competition and lead to higher prices for consumers (CEER, 2016b). Despite the EU-wide unbundling rules, the two Scottish TOs remain part of vertically integrated businesses. The circumstances in the GB energy market are slightly different from other European markets with three TOs and one SO. It is common that other markets have one, often combined, TO and SO. As such, and with the guarantee of effective independence of their transmission businesses, SP Transmission and SHE Transmission remain part of vertically integrated undertakings (CEER, 2016b). To ensure no unjust competitive advantage, Ofgem have stipulated business separation requirements on the companies, including rules around accounting, office space, personnel, information sharing, and IT systems. The exception, however, regards the distribution and transmission network businesses, where a provision in the Electricity Directive allows for cooperation to foster the consistency of legal, regulatory and technical frameworks in the EU single market. Vertically integrated companies are however required to implement a compliance programme to ensure that discriminatory and anticompetitive behaviour is prevented (European Parliament, 2009). Additionally, all the accounting must remain separate and whilst regulated by the same framework, the transmission and distribution businesses' revenues are determined separately, as is the assessment of revenue-determining incentives.

Moreover, Norway has about 150 DNOs and about half of them are also involved in the operation of regional transmission networks. The accounting, revenue regulation, and reporting is kept separate although business can benefit from economies of coordination. The Norwegian electricity networks, particularly the DNOs, receive significant attention from academics and researchers (for example Poudineh and Jamasb (2015); Kumbhakar *et al.* (2015); Growitsch *et al.* (2012); and Førsund and Kittelsen (1998)). The vast and high-quality data that span many years is suitable for applying in a range of studies on, for example, different models of productivity and efficiency analysis through benchmarking. This work is important since there are many different models that can be applied in regulated industries and the outcome often directly influence network companies' revenues and therefore the price that consumers pay. An important aspect is how different variables influence network companies' efficiency. There is however one aspect that has previously been overlooked, namely that of vertical integration between distribution and transmission assets.

Theoretically, allowing cooperation between networks businesses operating in the same region could lead to operating and efficiency advantages, for example, by sharing of staff and physical locations and certain assets such as depots and maintenance facilities. As such, regional cooperation can benefit from economies of coordination. This is recognised in the Third Energy Package, which otherwise mainly aimed at increasing electricity sector unbundling (European Parliament, 2009). However, the empirical literature assessing the alleged economies of coordination and benefits of regional coordination between electricity networks are limited.

Pollitt (2008) explores the arguments for and against ownership unbundling of energy transmission networks. However, the study experiences difficulty in distinguishing and assessing the impact of ownership unbundling from the general impact of electricity reform and liberalisation. Availability of appropriate data will be an issue because many countries either have a limited number to network owners (for example GB with only two vertically integrated network businesses) or adopted strict rules of network unbundling at the time of the reform, making it difficult for comparative studies.

Instead, it is more common with the analysis of unbundling of competitive and monopolistic elements of the electricity supply chain, for example Filippini and Wetzel (2014) showing that ownership separation of electricity generation and retail operations from the distribution network appear to have a positive effect on the cost efficiency of distribution companies in New Zealand, and Gugler *et al.* (2017) indicating potential scope economies between the stages of upstream generation and downstream transmission in Europe.

3.2.6 The Norwegian setting

Norway was one of the first countries, following Chile and the UK, to liberalise and reform the power sector. However, unlike the market-based approach and privatisation of UK state-owned utilities, the Norwegian power industry remained mainly under state and local municipalities' control. Following the implementation of the Norwegian Energy Act in 1991, The Norwegian Water Resources and Energy Directorate (NVE) was appointed the sector regulator. The authority was, prior to the deregulation, in charge of the oversight of the power sector as well as water resources and flood control.

The Norwegian electricity grid is divided into three levels: central network, regional network, and distribution network. State-owned Statnett owns most of the central grid (about 90%), which constitutes the bulk of the high voltage transmission grid. Statnett is also Norway's Transmission System Operator (SO), thus in charge of balancing the production and consumption of electricity. Norway has over 150 distribution network owners, responsible for the lower voltage section of the grid. In 1997, NVE introduced an incentive-based regulatory framework to encourage utilities to reduce costs and improve their efficiency. The allowed revenue is set using total cost benchmarking according to the formula in (1):

$$RC_t = 0.4C_t + 0.6(C_t^*) \tag{1}$$

where RC_t is the revenue cap in year t, C_t is the cost base (actual) for each network company and C_t^* is the cost norm (efficient) for the company. C_t and C_t^* are both calculated using data from t-2 and C_t^* is obtained through DEA programmed to benchmark the companies costs. Ordinary Least Squares (OLS) is then used to correct the DEA results for environmental factors (NVE, 2012). The revenue cap is thus determined using a share of actual cost and the norm cost. The incentive power of regulation and stimulated competition among utilities to improve cost efficiency is achieved by placing a higher weight on the norm cost. That is, by putting a higher weight on the norm cost, the regulator is incentivising firms to move closer to the frontier of best-performance.

The cost base is calculated as follows:

$$C_t = (OM_{t-2} + CENS_{t-2}) \times \frac{CPI_t}{CPI_{t-2}} + PL_{t-2} \times P_t$$
$$+DEP_{t-2} + RAB_{t-2} \times WACC_t \qquad (2)$$

where OM is the operation and maintenance costs, CEN is the company's costs of energy not supplied. Multiplying actual power loss (PL) with the reference price of power (P, given by a volume-weighted monthly area spot price from Nord Pool Spot) gives the cost of power losses, whilst DEP is depreciation and RAB is the regulatory asset base (book value plus 1% working capital). WACC (Weighted Average Cost of Capital) is defined by NVE to calculate the capital cost of each company.

3.3 Methodology

The application of SFA allows for the modelling of a frontier within a regression framework so that inefficiency can be estimated. This is important in the present analysis as we are interested in measuring the effect of vertical integration between electricity networks and ownership structure on efficiency. This has previously not been done before with regards to electricity distribution networks, although, as outlined in the sections above, are applied in the real world based on theoretical assumptions. Testing these assumptions should therefore be of interest to regulators, policymakers and consumers alike.

Whilst the effect of vertical integration and ownership structure may be a novel approach, the method, SFA, has been used by several authors to evaluate electricity network efficiency. Llorca *et al.* (2016) use SFA to analyse US network firms' performance including environmental factors in the modelling to find that efficiency has declined and diverged over time. Growitsch *et al.*

(2012) use Norwegian distribution network data to examine the efficiency effects of observed and unobserved heterogeneity. The results indicate that the observed environmental factors have a limited impact on firms' average efficiency – a significant finding given the Norwegian regulator's reliance on environmental factors in the regulatory model. Meanwhile, Poudineh and Jamasb (2015), estimate an SFA model to estimate the relationship between cost efficiency and investment among DNOs in Norway with results found to depend on the size of the network.

3.3.1 Model specification

Following Aigner et al. (1977) and Meeusen and van den Broeck (1977) we specify a stochastic cost frontier model with a convoluted error composed on two random terms. This is in order to capture both uncontrollable or unobservable aspects as well as deviations with respect to the frontier of best-performance that can be attributed to managerial inefficiency. The general SFA model for a cost function to be estimated is presented in (3) as follows:

$$\ln C_{it} = \alpha + X'_{it}\beta + v_{it} + u_{it} \qquad (3)$$

where i stands for utilities, t for time, C_{it} represents utilities' total cost, X_{it} is a vector of explanatory variables that includes outputs, input prices and other control variables, whilst α and β are parameters to be estimated. Deviations with respect to the cost function are illustrated by v and u, where v_{it} is the traditional noise term and u_{it} captures utilities' inefficiency. The model assumes symmetric random noise, $v_{it} \sim N(0\ \sigma_v^2)$, whilst the inefficiency is a positive one-sided error term that can follow distributions such as the half-normal, truncated normal or exponential. If we assume in equation (3) that the inefficiency term is homoscedastic, we are unable to examine the drivers behind utilities' performance, which might produce biased estimates of the inefficiency scores and frontier coefficients (Caudill and Ford, 1993). In order to get around this issue and to allow us to examine the impact of ownership structure and vertical integration on utilities' technical inefficiency, we will instead estimate a heteroscedastic stochastic frontier model including a set of contextual variables in the inefficiency term. These contextual variables (frequently called environmental or z-variables) can be introduced in the model through the pre-truncation mean, the pre-truncation variance or simultaneously in both parts of the inefficiency term (see for instance, Llorca *et al*., 2016).

In this chapter we estimate a model in which the environmental variables enter through the pre-truncation variance of the inefficiency term as proposed by Reifschneider and Stevenson (1991), Caudill and Ford (1993) or Caudill et al. (1995). This type of model has an appealing economic interpretation. There is a base efficiency level of the utilities that captures things like managers' natural skills, while how well these natural skills are exploited depends on the set of contextual variables introduced in the inefficiency term (Alvarez et al, 2006).

3.3.2 Data

In this chapter we use an unbalanced panel data set of 100 Norwegian DNOs. The data comprise economic, technical, and environmental information collected by NVE between 2007 and 2014. Several observations were dropped from the data set due to missing values in key variables, lack of information on contextual variables, extreme outliers in terms of size, or unexplained values, such as negative or zero cost information.

We specify a cost function with total cost (totex) as the dependent variable. Following NVE's approach, we specify totex as the social cost, that is, including external (customer) quality costs. Totex is made up of capital expenditure (capex), including Cost of Energy Not Supplied (cens), operational expenditure (opex), and losses. The cost of losses is calculated by multiplying physical network energy losses with annual average system price. cens is calculated by multiplying the energy not served/interrupted (which includes details on length of interruptions, time and day of the interruption and if the interruption was planned or not planned) with consumer willingness to pay to avoid interruptions. The current framework includes willingness to pay for six different consumer groups. NVE introduced quality adjusted revenue caps in 2001 with the cens-arrangement to ensure that efficiency improvements the operation of networks came at a cost of reduced service quality. Including consumers in determining the cost ensures that the service quality is not improved beyond a level and cost that consumers are willing to pay for, thus providing consumers the opportunity to influence the regulatory process. Since 2001, NVE has extended the framework on a number of occasions, for example in 2009 to include interruptions longer than three minutes and the classification of different customer groups (NVE, 2016). All monetary variables are measured in 1000 NOK and in 2014 real terms. We have used consumer price index to deflate the monetary variables.

The choice of variables is an important consideration and the subject of much debate. Jamasb and Pollitt (2001) show this in a review of international benchmarking methodologies, indicating no clear consensus of the variables to be used to assess networks' performance. The Norwegian regulator assesses its model regularly and calibrates to ensure best fit. We consider the utilities able to control its inputs and therefore, by using the social cost, put greater weight on quality of supply as a direct consequence of utilities' choices. Generally, network outputs are considered more difficult for utilities to influence.

The outputs in our model are number of *network stations* (substations) and *number of customers*, used to illustrate network size. We included the variable length of network in early testing, which can also be considered a proxy of network size but decided to drop this due to correlation with the other variables. We also use two input prices; cost of capital, which is NVE's determined rent for cost of capital, and labour price, which is the average salary in the sector. We use the cost of capital to impose homogeneity of degree one in input prices.

The main focus of this chapter is to study the impact on efficiency of *vertical integration* between different network levels and *ownership structure*. In this sample we introduce a dummy variable to capture the impact of integration between the distribution network and the regional transmission network, that is, the same utility owns both distribution and regional transmission assets. Networks of different voltage owned by the same utility is separate from an accounting perspective however would in theory be able to benefit from knowledge sharing and resource optimisation (see section 3.2.5 for further discussion). 54% of DNOs in our sample are also involved in operating or own regional transmission assets. Ownership structure is presented in three different categories, each variable representing the share of ownership within a certain category: State owned, municipal/council owned, and private company owned. The network companies in the sample are either fully within one ownership category (100%) or split between two ownership categories (e.g. 75%-25%). Traditionally the lower voltage networks were owned by the council or municipality but may also have been developed by private companies to support an energy intensive industry. These variables are expected to affect utilities' performance and are therefore, together with a variable measuring the number of islands at least 1km from the coast within the network, included as inefficiency determinants.

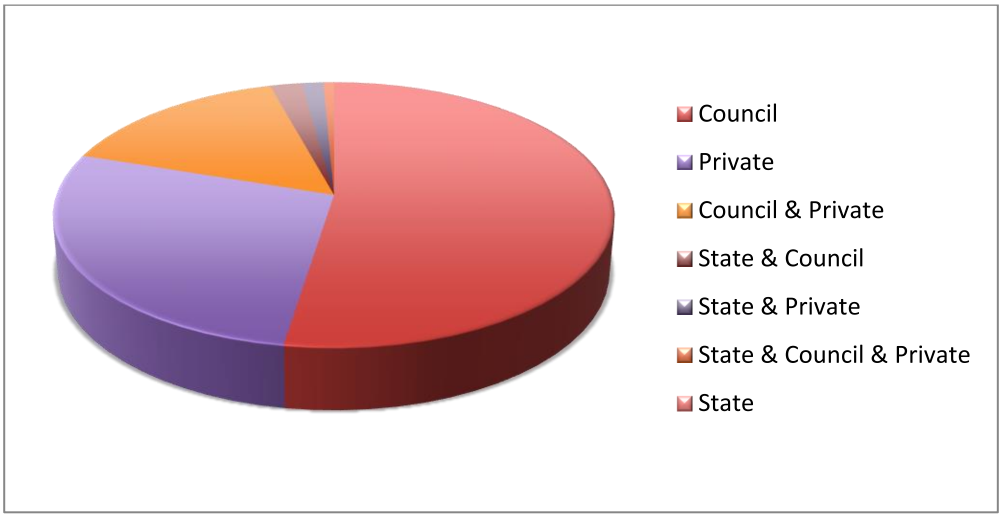
Whist the number of islands within the networks service areas is likely to have an impact on DNOs costs, it is also helpful in reducing the impact on the analysis of uncontrollable characteristics of individual networks. We include a time trend to account for technical change and can capture issues such as, for example, changes in the regulatory environment. Table 3.1 and Figure 3.1 presents the descriptive statistics and details of the variables included in our analysis.

Table 3.1 Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Totex	972	109076	246590	840	2390549
Number of customers	972	22750	67265	18	682253
Number of network stations	972	800	1473	9	11474
Number of islands 1km from coast	972	2.50	5.43	0	30

Vertical integration	972 observations	Dummy variable where 1 = ownership of both distribution and regional transmission assets, 54% in the sample.

Figure 3.1 Distribution of ownership structure



3.4 Results and discussion

Our main model is a translog cost function, including a full set of interaction terms between outputs and input prices. The variables are in logarithms except the time trend. Homogeneity of degree one in prices is imposed by normalising cost and labour price with capital price. The estimated equation can be written as follows:

$$\ln\left(\frac{totex_{it}}{kp_{it}}\right) = \alpha + \Sigma_{j=1}^{2} \beta_j \ln y_{jit} + \frac{1}{2}\Sigma_{j=1}^{2} \Sigma_{k=1}^{2} \beta_{jk}\, y_{jit} y_{kit} + \beta_m \ln\left(\frac{lp_{it}}{kp_{it}}\right)$$
$$+ \frac{1}{2}\beta_{mm}\left[ln\left(\frac{lp_{it}}{kp_{it}}\right)\right]^2 + \Sigma_{j=1}^{2} \beta_{jm} \ln y_{jit}\, ln\left(\frac{lp_{it}}{kp_{it}}\right) + \beta_t t \quad (4)$$
$$+ \frac{1}{2}\beta_{tt} t^2 + \Sigma_{j=1}^{2} \beta_{jt} t \ln y_{jit} + \beta_{mt} t \ln\left(\frac{lp_{it}}{kp_{it}}\right) + v_{it} + u_{it}$$

where *kp* is capital price, *lp* is labour price, *i* and *t* stand for the utility and time, respectively. *y* stands for the vector of outputs and α and β are parameters to be estimated. In addition, we have also estimated a cost function using a Cobb-Douglas specification and a translog specification without including inefficiency determinants. The output from these can be found in table 3.2 whilst the result of the estimation of our translog model with inefficiency determinants is illustrated in table 3.3.

The results display the expected signs for the coefficients of outputs and input prices, with labour price as major cost driver followed by number of network stations.

The aggregation of the three ownership variables is 100%, meaning that one variable will be dropped from the estimation due to collinearity. In this case, the *State owned* variable is dropped and therefore the remaining variables, *Council owned* and *Privately owned* should be interpreted with respect to that variable. Our results indicate that an increase in *Private ownership*, with respect to *State ownership*, does not have a significant effect on cost inefficiency. However, an increase in *Council ownership*, with respect to *State ownership,* indicates a reduction in cost inefficiency.

The frontier parameters show the expected signs and in general, and all models perform well. The magnitude of the coefficients remains stable across the models, as is the significance of the results. The two variables used to illustrate network size both show positive signs, of similar magnitude, and an increase in the price of labour is, as expected, also found to increase totex.

Table 3.2 Parameter estimates – Cobb-Douglas and translog without inefficiency determinants

		Translog			Cobb-Douglas		
	ln totex	Coefficient		SE	Coefficient		SE
Frontier							
	intercept	13.477	***	0. 056	13. 316	***	0.009
	ln customers	0.436	***	0.024	0. 405	***	0.022
	ln network stations	0.461	***	0.024	0.500	***	0.026
	ln labour price	0. 630	***	0.103	0.857	***	0.037
	ln customers^2	0.495	***	0. 026			
	ln network stations^2	0.639	***	0.063			
	ln labour price^2	- 2.525	*	1.474			
	*ln customers*ln network stations*	-0. 559	***	0. 041			
	*ln customers*ln labour price*	-0. 001		0. 084			
	*ln networks stations *ln labour price*	0. 043		0. 102			
	time	0. 015		0. 016	-0.036	***	0.005
	time^2	-0. 072	**	0. 025			
	*ln customers * time*	0. 006		0. 010			
	*ln network stations*time*	-0. 003		0. 013			
	*ln labour price*time*	0. 405	**	0. 203			
Inefficiency							
	intercept	-5.977	***	1.997	-3.474	***	0.112
Noise							
	intercept	-3.321	***	0. 146	-3.773	***	0. 077
Significance code: * p<0.1, ** p<0.05, *** p<0.01							

Table 3.3 Parameter estimates – translog with inefficiency determinants

	ln totex	Coefficients		SE
Frontier				
	Intercept	13.46	***	0.025
	ln customers	0.429	***	0.020
	ln network stations	0.454	***	0.023
	ln labour price	0.607	***	0.099
	ln customers^2	0.501	***	0.026
	ln network stations^2	0.680	***	0.061
	ln labour price^2	-2.016		1.408
	*ln customers*network stations*	-0.583	***	0.040
	*ln customers*labour price*	-0.011		0.086
	*ln networks stations*labour price*	-0.029		0.103
	time	0.014		0.016
	time^2	-0.067	***	0.025
	*ln customers*time*	0.010		0.011
	*ln network stations*time*	-0.007	**	0.013
	*ln labour cost*time*	0.341	*	0.194
Inefficiency				
	Intercept	-6.501	***	0. 520
	Vertical integration	1.451	***	0. 417
	Council owned	-0. 023	**	0.011
	Privately owned	-0. 008		0.011
	State owned			(omitted)
	Islands	0.130	***	0. 021
Noise				
	Intercept	-3.557	*	0.058

Significance code: * p<0.1, ** p<0.05, *** p<0.01

The Norwegian electricity industry was largely developed on a regional level around small-scale hydro plants and when the sector was unbundled much of the network ownership remained under council ownership. It is also clear from the sample that many large industries privately own the networks supplying their businesses. This is most likely still in place from when the country was industrialised and small-scale generation was developed to provide power to factories allowing greater economic opportunities for rural areas. Only later was the large high-voltage system developed connecting the regional grids. The local experience and knowhow of many years may now therefore serve to benefit efficient operation of the distribution networks. It is also possible that the state-owned lower-voltage networks are overlooked as the state's main interest in networks generally lies in the high-voltage central network.

Moreover, with a positive sign, the results indicated that *vertical integration* between the different network levels increase cost inefficiency. Although previous studies are limited in this area, following theoretical thinking on the potential of economies of scale and opportunity of efficient resource allocation, the results may appear somewhat surprising. For example, the Third Energy Package allows for regional cooperation between electricity networks to take advantage of perceived economies of coordination and the theoretical work on the subject by Williamson (1971) indicate that vertical integration in energy system is an efficient organisational structure. This is however based on the assumptions that the network businesses are located in the same region. This information is unavailable in our data, although one might assume that where utilities own assets across both distribution and regional transmission levels that these are located in the same area. However, yhis may not always the case. For example, in GB, the Scottish network owners own both distribution and transmission assets in Scotland in addition to distribution networks in England - these are not physically connected to the Scottish assets. As such, with assets covering different areas, the opportunity for efficient sharing of labour and other inputs are limited and as a result, the potential efficiency gains of the same firm owning networks of different voltages are reduced Furthermore, both in GB and Norway, revenue for electricity networks of different voltage levels are determined using separate price controls. Although similar in nature in terms of the framework, incentives and objectives, differences, differences exist.

In Norway, part of the regulatory differences lie in the variables used in the benchmarking model, where the distribution assessment utilise inputs such as number of customers, kilometres of overhead line and number of network stations, whilst the regional transmission assessment include weighted values of different underground and overhead lines. With heavy reliance on the benchmarking exercise to determine utilities' revenue, it may therefore be possible that network owners allocate costs to where overall revenue is maximised. Although the regulator will do everything in its powers to prevent this kind of behaviour, its informational disadvantage will possibly act to limit its success. Information asymmetry between the regulator and the regulated firm is one the key issues in the regulation of natural monopolies. Benchmarking is often used as a tool to reduce the firms' informational advantage. Nevertheless, strategic behaviour or regulator gambling is still possible. For example, Jamasb *et al.* (2003) find in a survey study of energy regulators that firms are gaming the regulator's benchmarking model in a number of ways that are contrary to the intentions of the regulatory framework. Regulators appear to be aware of this and although not usually illegal, it leads to forgone efficiency improvements, reduced social welfare and a welfare transfer between customers and the firms. Similarly, De Witte and Marques (2012) identify gaming by firms in the water sector in regulatory frameworks applying benchmarking.

Moreover, as the number of islands at least 1km away from the cost increase, so does utility inefficiency. This is expected given the impact on cost of subsea cables, maintenance and possibly reduced reliability. This is good example of a variable that firms are unable to change to impact performance. However, with the variable being significant, it is an indication of the operational difficulties of certain regions and one that should be considered by regulators to account for performance determining uncontrollable factors.

Figure 3.2 depicts a histogram of efficiency scores for the firms using the translog model with inefficiency determinants. The average efficiency in the sample is 93.6%, which is in line with previous studies of Norwegian networks, see for example Senyonga and Bergland (2018).

Figure 3.3 graphs the average efficiency score for each year. It appears as though the average level of efficiency is fairly steady year on year although possibly a slight indication of decreasing towards the end of the sample. It also appears as though firms' performance increasingly diverge over time. This should be of interest to the regulator and indicate that there are possible efficiency improvements possible among DNOs.

Figure 3.2 Histogram of efficiency scores

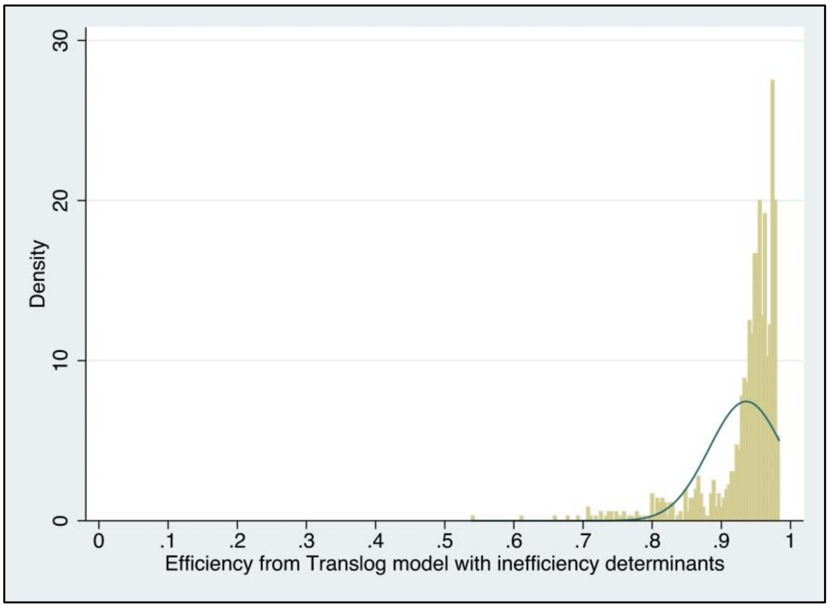
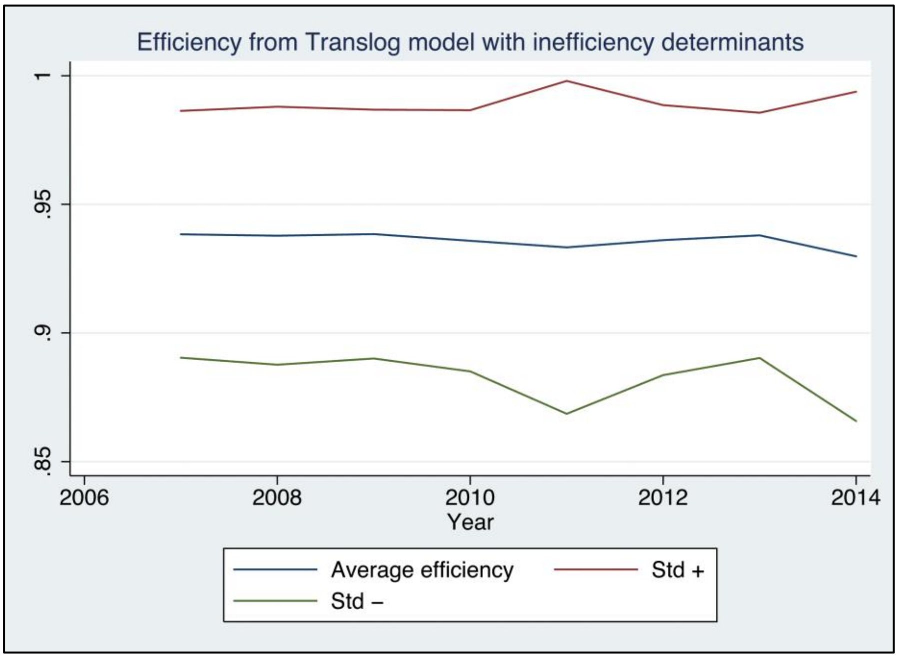


Figure 3.3 Annual evolution of efficiency



3.5 Conclusions

Effective economic regulation of electricity networks has been a goal of most developed countries following energy industry liberalisation in the 1980s and 1990s. Incentivising network owners to behave in a way to mimic competition is seen as the second best option after actual competition, which is normally not possible in natural monopolies.

Information asymmetries, where firms have an informational advantage over the regulator in terms of its actual costs, production, technology, and managerial effort, commonly arise in regulated industries. The regulator is therefore at a disadvantage when determining revenue allowances. As a result, many regulators rely heavily on productivity and efficiency benchmarking to assess firms performance. The choice of benchmarks and techniques used to measure efficiency is a key factor and must accurately reflect the environment in which the firms are working. If applied correctly, the sector regulator can reduce the informational disadvantage and encourage efficiency improvement among the network utilities.

In this chapter we have analysed the performance of Norwegian DNOs using a data sample from 2007 to 2014 applied to stochastic frontier models. We contribute to the literature by looking at the impact of two, previously largely overlooked, areas in this sector; vertical integration between network levels and ownership structure.

The results are interesting from mainly a policy perspective. Generally, we find no real improvements in efficiency over time. Rather, we possibly see a slight downward trend and greater firm divergence. This suggests that improvements are possible.

Moreover, we find that vertical integration between the DNO and regional transmission levels increase technical inefficiency, that its, network owners with an interest across network levels are likely to be less efficient in its operation of the lower level network. Assumptions of economies of scale and resource sharing does therefore not hold true in this instance. It may also be that the DNOs are able to shift costs between the network levels depending on the more favourable regulatory framework, i.e. gaming of the regulator. Vertical integration between network levels is therefore an area that would benefit from further consideration.

The result on ownership structure indicates that an increase in *Private ownership*, with respect to *State ownership*, does not have a significant effect on cost inefficiency. However, an increase in *Council ownership*, with respect to *State ownership,* indicates a reduction in cost inefficiency. This is possibly explained by the state generally having a main interest in high voltage electricity networks, rather than low voltage, and the decentralised model which the now centralised system once was developed from.

Chapter 4

The Solution that Might Have Been: Resolving Social Conflict in Deliberations about Future Electricity Grid Developments

4.1 Introduction

A timely development of national infrastructures is a prerequisite for economic growth and is generally associated with significant economic and social returns (Easterly and Servén, 2003). Such undertakings include electricity transmission networks,[3] which following ambitious environmental targets need to connect a growing number of renewable energy facilities. Government policy is thus driving a rapid expansion of the transmission network, unseen in modern time for similarly sized infrastructure networks, such as the railways. Albeit their economic benefits, grid development projects often involve adverse environmental impacts and give rise to community opposition.[4] Failing to reach agreement on deployment and siting of projects causes lengthy and costly delays and may even jeopardise the project altogether (Furby *et al.* 1988; Kunreuther and Easterling 1996; RGI, 2012).

Although community opposition to major national infrastructure projects is not new, the implications of local resistance for the future development of the sector are on the rise. The context of decision-making in the electricity sector has gradually shifted from one of being a primarily technical matter to an increasingly social, environmental, and thus political one. However, due to the technical nature of the electricity grid and importance to the functioning of any modern economy (there are currently no viable alternatives) this shift has

[3] Grid developments can also include the lower voltage network, distribution, however, this chapter focuses on transmission developments only.
[4] Apart from transmission grid development, other developments that cause local opposition include airports, prisons, power plants and linear structures such as pipelines, and railways.

been slow. The current process, which can be described as a Decide-Announce-Defend approach, is perceived to be unfair and to lack transparency (Tobiasson *et al.*, 2016). The roles of different stakeholders are also unclear as is the process of how decisions are made, therefore eradicating potential local and public participation due to a lack of knowledge and information (Cotton and Devine-Wright, 2013). Consequently, the established decision-making framework and processes seem increasingly ineffective to engage with more active local communities.

There are three main reasons behind the increased involvement of the public and local communities in grid developments. First, the nature of the energy industry has been changing due to the emergence of smaller but more numerous generation facilities, thus increasing their visibility and potential local impact. Second, the public and community awareness and engagement in relation to the energy sector and environmental issues has increased. Third, as the nature of the sector and public engagement with the grid has changed, the institutional arrangements within which policy decisions are made have not changed. Thus, an innovative approach is required to adapt the decision-making framework to better suit the evolving and future needs and features of the sector.

From an economic point of view, local opposition can be considered as the result of externalities caused by grid developments and imposed on neighbouring communities. Given the standard assumptions of economic rationality, perfect information and zero transaction costs, a solution that internalises the local externalities can, in theory, be derived. With regards to single location facilities (e.g. generation facility), the potential for providing financial compensation to affected communities is explored in an extensive body of literature, initiated first by O'Hare (1977).

However, the practical applications of a financial compensation are not trivial, including the difficulty in estimating the exact costs and benefits of projects and the public perception of compensation as a bribe (Frey *et al.*, 1996). Other measures to foster acceptance and to increase the local retention of profits include the provision of community benefit schemes. These measures are particularly common in wind power developments and have been successfully implemented in countries such as the UK, Denmark and Germany (CSE, 2009; Cass *et al.,* 2010).

Relative to renewable energy developments and other single location infrastructure facilities, transmission network developments have received comparatively limited attention from academic researchers (notable exceptions include Tobiasson *et al., 2016;* Ciupuliga and Cuppen, 2013; Cotton and Devine-Wright, 2013; Soini *et al.,* 2011). This is particularly the case with regards to compensation or community benefit schemes. Arguably, there are some shared characteristics between single location facilities and grid developments, such as large sunk costs, negative externalities, public goods, information asymmetries and similarities in resistance from local communities. However, the technical characteristics and economic regulation of transmission grids necessitate design of innovative approaches to organise local community impact and involvement in grid development. Therefore, there is a need for alternative modes of conceptualising community opposition and engagement with grid development projects (Batel *et al*., 2013).

Drawing from established economic theories and concepts found in New Institutional Economics, this chapter outlines a qualitative assessment and suggests a new approach based on the environmental sustainability perspective to facilitate a sustainable and more efficient planning and implementation of transmission projects. The conceptual framework presented here aims to look beyond the simple use of financial compensation to resolve social conflict in grid and other similar infrastructure development projects. Instead, we propose an economic theory-informed and sustainability-oriented methodology which also requires a multidisciplinary approach to the problem.

The chapter is structured as follows: Section 4.2 outlines the economic properties of electricity networks and developments. Section 4.3 discusses the economics characteristics of community engagement in developments and reviews relevant literature. Section 4.4 outlines and applies an analytical framework to develop a conceptual model. Section 4.5 concludes.

4.2 Economics of Electricity Networks and Grid Development

4.2.1 Economic characteristics of electricity transmission networks

Electricity networks are regarded as natural monopolies. This implies that they are highly capital intensive and their cost structure is such that their fixed costs are very large in relation to the total costs. This feature results in declining average costs as their scale increases. As a result, the provision of a given quantity of output by a single network is more cost efficient than by several competing networks. Consequently, such networks are subject to public ownership or some form of economic regulation. This is true for both high voltage networks (transmission) and lower voltage networks (distribution). Although this chapter considers transmission developments only, it is worth noting that the distribution networks across Europe are undergoing a considerable change.

The introduction of smart technology, electric vehicles, and distributed generation are exerting pressure on the distribution grid to become more active in terms of managing and matching the supply and demand. The transmission grid is less affected by the new technologies and is, compared to the distribution grid, already actively managing supply and demand since electricity generators are traditionally connected to the transmission grid. Moreover, transmission networks are considered to be transportation networks – transporting large volumes of high voltage electricity over long distances with no or few outlets along the way. This gives rise to particular issues as a number of communities along large transmission lines benefit little from the developments despite living next to it.

Network utilities generally operate under licence agreements that oblige them to connect the generators and end-users in a timely and effective manner. The utilities are also expected to operate the network in a cost-efficient manner. In return, the utility can charge the users for the use of network services and earn a regulated return or revenue (Joskow, 2007). The network charges are, in the first instance, accrued to generators and retail suppliers but are ultimately passed to end users through their bills. Many networks in Europe operate under incentive regulation models that reward firms for cost efficiency and penalises high costs (Joskow, 2013).

The costs incurred by network utilities can be classified into allowable controllable and non-controllable costs. Non-controllable costs are regarded as being beyond the control of the management and are generally treated as pass-through and thus do not affect the profits of the utility. On the other hand, controllable costs are subject to reward and penalty incentives. A cost type or item that is disallowed by the regulator will directly and negatively affect the revenue and profit of the utility. Allowed operating costs can be recovered and allowed investments will earn a specified return (Jamasb and Pollitt, 2001).

A key objective of the sector regulator is to maximise the socio-economic welfare of the consumers. The regulator in effect acts as the guardian of public interest who cannot individually protect their interest. Costs that are over and above the efficient level will reduce the net system benefits. Although major grid projects may have net system benefits, uneven distribution of the costs and benefits can cause distributional implications between local and national interests. It appears that while regulators are tasked with protecting public interest they are less able to balance the distributional inequity that arise between the local public and wider public. Compensations to local communities are also a financial transfer to ease the distributional implications between the communities and the consumers of the grid services as a whole. Prior to addressing the specific methods and mechanisms for compensation or community benefits, it is important to conceptualise the nature of community level environmental impact and entitlement to compensation in economic terms.

4.2.2 Economic characteristics of transmission projects

Transmission lines cross long stretches of land and each new project has a number of stakeholders, including the government, local authority, local businesses, landowners, local communities, and interest organisations. Each stakeholder perceives the grid projects differently and has their own view and experience of the decision process. These heterogeneous views and objectives of stakeholders often cause conflict of interest and opposition. Moreover, information asymmetries among the actors can intensify the frictions between stakeholders further as it can induce rent-seeking behaviour and reduce trust between them. Consequently, the economics of grid development can be characterised as having high transaction costs. Achieving agreements that internalise the externalities caused by transmission projects can be costly to negotiate, especially when the number of stakeholders and the range of interests involved is large (Tobiasson *et al*., 2016).

A grid project can be thought of as having two types of costs – i.e., private costs in the form of construction and maintenance costs as well as external costs accrued to third parties. The latter type of costs can include direct economic costs, for example, loss of revenue to owners of agricultural land, and as in the form of negative environmental externalities. The direct economic costs are generally observable and measurable through market prices or compensation methods. For instance, there are established norms and formulas for compensating owners of farmlands for loss of use value of land in terms of lost output and revenue[5].

The main difficulty arises, however, when taking the external costs in the form of intrinsic value of environmental amenities accrued to third parties, i.e.,

[5] Example from Canada:
http://www.albertapowerline.com/resources/Documents/3012_APL_ROW_Compensation_Program_info_sheet_Final.pdf, and GB:
http://www.northernpowergrid.com/asset/0/document/1949.pdf

affected communities, into account. Grid development projects can be viewed as having an effect on public goods characterised by non-excludability and non-rivalry in consumption. The communities along the new lines enjoy limited or no direct benefits from the project, similar to a railway passing the community without stopping at the local station. The effects of these externalities such as negative visual, health, and environmental effects as well as financial loss through reduced property values, translate into reduced utility and economic welfare (Cohen *et al*., 2014).[6]

4.3 Community Engagement and Conflict in Grid Development

4.3.1 The causes of conflicts

A growing body of literature considers the motives behind and discusses possible measures to reduce community opposition to locally unwanted facilities. The pejorative label of NIMBY (Not In My Backyard) opposition is considered as outdated (Burningham *et al.,* 2006) and recent work has revealed a complex heterogeneous composition of opposition (Batel and Devine-Wright, 2014; Cotton and Devine-Wright, 2013; Johnson and Scicchitano, 2012; Wolsink, 2000).[7] Research to date is predominantly focused on single location facilities, such as renewable energy generation technologies (Jobert *et al.,* 2007; Wolsink, 2000; Devine-Wright, 2011), as well as waste and hazardous facilities (Johnson and Scicchitano, 2012; Kunreuther and Easterling*.,* 1996; Kunreuther *et al*., 1994).

Opposition to transmission projects, characterised as linear infrastructure, are similar to those of single location infrastructure. The main triggers of public

[6] In the absence of explicit valuation, public goods can implicitly be assigned a monetary value of zero. Some scholars disagree with monetising environmental resources on ethical grounds. However, when the value of a resource is unknown or is valued at zero, it may be over-exploited. This often holds for resources that lack clearly defined property rights giving rise to conflicts of interest. Some view monetisation as a second best option, while accepting that the valuation can be flawed but that any value over zero is better than no value.
[7] Rather than the homogeneous assumptions defining NIMBY opposition.

resistance include strong place attachments to the local area; the type, level and quality of communication; lack of trust for the developer and governmental agencies; harmful effects on health and the environment; and unconvincing arguments for the need case of the new line and for any beneficial impacts arising from it (Ciupuliga and Cuppen, 2013; Cotton and Devine-Wright, 2013; Devine-Wright, 2013).[8]

Unlike local communities, landowners tend to be consulted at the initial stages of planning when the optimal route is being identified, mainly because they possess a legal right to their land and others cannot normally use the land without their consent. In theory, financial compensation offered at the market rate of the land should be accepted. However, in practice, this is not always the case, as seen in the development of an Irish gas pipeline where five landowners were imprisoned following their refusal to allow the developer access to their land (Gilmartin, 2009).[9]

Public and local opposition to new transmission lines is a common cause of costly delays and can emerge as a barrier to the realisation of future low-carbon systems. Recent cases of conflicts include the Scottish Beauly-Denny line, which was the subject of the longest ever public inquiry in Scotland, studied in Chapter 5 (Tobiasson *et al.,* 2016); the France-Spain interconnection project, first proposed in 1980 and met by considerable opposition bringing round a second proposal in 2003 (Ciupuliga and Cuppen, 2013); and the Norwegian Hardanger transmission line, which was one of the 2010's most reported news stories in Norway (Ruud *et al.*, 2011).

Devine-Wright *et al.* (2010) find that public beliefs of energy networks are rather detached from reality. Generally, electricity networks are seen to be represented by technological structures, such as cables and pylons, rather

[8] Criticism of the need case often refer to alternative technological solutions, e.g., distributed generation and enforcing existing lines.
[9] However, compensation to landowners is not considered here as each sector has established norms and methods of addressing direct losses. In this chapter we focus on the environmental impacts of grid development projects on local communities, which are often ignored.

than organisations and systematic networks. Moreover, in the planning of new lines, the study found great disbelief in the process, especially regarding stakeholder engagement and who can actually influence project developments. The invisibility of network firms and disbelief in the planning process is thought to increase public opposition and delays to new network developments. The invisibility and lack of already established consumer-firm relationships is one of the distinguishing features of transmission developments when considered alongside other linear infrastructure networks, such as railways.

Public opposition is argued to have played a large role in the delayed France-Spain interconnection project (Ciupuliga and Cuppen, 2013). The project lacked transparency and the public requests of undergrounding the line were ignored without explanation. As a result, citizens felt overlooked and cooperation between stakeholders ceased. Similarly, the Scottish Beauly-Denny project was criticised by local communities for disregarding their points of view and lack of communication. Trust and perceived procedural justice is arguably important for public acceptance (Bronfman *et al.,* 2012; Wüstenhagen *et al.,* 2007).

Moreover, in a study on electricity generation sources Bronfman *et al.* (2012) find that perceived benefit of a new installation had the greatest effect on acceptability. This is one of the reasons to why opposition to transmission projects is particularly difficult to address and why the experience from single location facilities is of limited usefulness. Part of the difficulty in addressing the stakeholder conflicts in grid developments lie in the challenge to define, measure and compensate communities for their environmental impacts. The benefits of most infrastructure facilities are spread across the economy, whilst much of their adverse impacts tend to be local. This is also the case with energy generation plants.

However, for energy generation plants the capacities and outputs, and therefore the benefits, are more easily measurable in both physical and monetary terms. Meanwhile, the large geographic span of linear infrastructures often affects multiple communities rather than a single host community. Also, due to the complex design and technical nature of the grid, the system benefits associated with an incremental network expansion or enhancement project can be difficult to estimate. As such, local communities perceive the benefits of a transmission line as limited, thus intensifying conflicts.

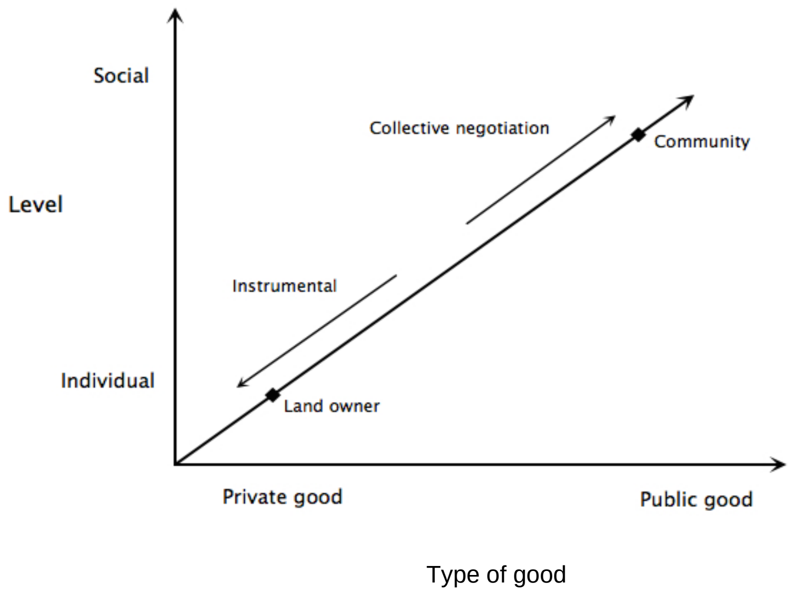
4.3.2 The need for a new approach to grid conflicts

Although there are some shared characteristics with other energy facilities, the technical and economic features of transmission grid projects are different in several respects and thus require specific solutions. For instance, measuring the relevant output of an incremental new line for compensation and benefit sharing is considerably more complicated. Also, electricity transmission networks are natural monopolies and require economic regulation.

New grid projects are ultimately financed by electricity consumers through transmission fees collected on electricity bills. Thus, increasing the project costs through either undergrounding lines or paying compensation is borne by all electricity users across the country. In terms of land-use, transmission lines are linear infrastructures, covering great stretches of land, thus affecting many stakeholders, types of land, land uses, and sensitive areas. Additionally, the physical features of networks complicate matters further as a change in one part of the network will also have an effect on the rest of the system. Consequently, specific benefits of grid upgrades are difficult to identify, quantify, and allocate. Rather than confined benefits of a single line, any upgrade benefits the reliability and security of the network as a whole.

Figure 4.1 illustrates the main insights from recent research and the economic characteristics of grid developments. The figure shows the key dimensions and features of community engagement when implementing a new grid project. On the one hand, issues related to private goods with few stakeholders are considered. In these cases, decisions tend to be based on *individual* preferences, choice and rationale. On the other hand, decisions regarding the issues related to public goods tend to consider *social level* interests and rationale.

Figure 4.1. Dimensions of community engagement



Source: Adapted from Vatn (2005, 419)

The figure identifies two different approaches to community engagement with grid projects. Goods, which have private ownership and entitlement, can be considered on an individual level as they involve few stakeholders. Issues on an individual level may therefore be managed through an instrumental approach. The term instrumental refers to a set framework that can be applied in a similar way in different situations without much modification. This is the current approach for offering compensation to landowners for structures such as pylons that are placed on their land, for example, through offering a fixed amount per pylon or a wind turbine, dependent on its size or alternatively on its energy produced or transmitted.

Conversely, goods which are public in nature and entitlement, and thus must be considered on a social level, i.e., involve many stakeholders, require a collective negotiation approach. When the number of stakeholders is high, and a decision will affect large groups, the importance of communication increases, especially two-way negotiations. As illustrated by the figure, communication on a collective level is the approach that could be adopted in engagement with communities. This is however seldom the case, giving rise to conflicts (RGI, 2012).

In order to increase public trust, reduce stakeholder conflicts, and encourage acceptance of new grid developments, recent research suggests better information provision and more emphasis on communication and community involvement at an earlier stage and in a more deliberative planning process (RGI, 2012; Newig and Kvarda, 2012; Cotton and Devine-Wright, 2012; CSE, 2009). Additionally, Ciupuliga and Cuppen (2013) highlight the role of dialogue in the planning process, which is argued to not only improve the potential to reach agreement but also benefit the project through the access to local knowledge and insights.

The lessons emerging from the above-mentioned cases and similar projects suggest that they share some key features. Such conflicts are often treated on an *ad hoc* basis whilst trust and perceived procedural justice of the process is generally low. The conflicts are often treated as planning and financial compensation matters while sustainability and citizenship aspects are often the root cause of the conflicts. For example, financial arrangements such as compensations and benefit sharing schemes have been suggested as practical measures to redistribute the costs and benefits of large projects in order to make the outcome of decision-making more socially acceptable and economically efficient.

An important issue with a purely monetary approach is that it fails to take into account the broader range of reasons behind community opposition. Therefore, a broader theory-informed approach and conceptualisation of community engagement with grid projects is needed to devise structure and more effective solutions to resolve them (Been, 1993).

4.4 Towards a Sustainable Grid Development Approach

4.4.1 Financial compensation and benefit provision

A common measure to assist the siting of locally unwanted facilities, which has long been the focus of particularly economic researchers, is that of monetary compensation to prospective host communities. This notion was first introduced by O'Hare (1977), declaring it to be necessary for an efficient siting process. More recently, Lesbirel (1998) find compensation to positively facilitate the siting of energy plants in Japan while McAdam *et al.* (2010) argues that failing to compensate the host country of a pipeline is linked to mobilised opposition.

Community compensation through financial arrangements can in principal be in the form of (i) one-off lump sum payments, (ii) a stream of payments; or (iii) some form of part-ownership. Alternatively, the developers can offer direct investments in the community such as infrastructural upgrades (e.g., new and better roads, increased connectivity such as fibre optic broadband) or other benefits such as tax reductions or reduced energy prices.

Lump sum payments involve one-off payments to a community fund when the project starts operating. Assuming good management and careful investment the fund could generate continued income. Alternatively, a developer may offer annual payments. In wind power developments in the UK this is normally per megawatt (e.g., £5,000 per MW), linked to the generation capacity, energy output of the project, or a fraction of the revenues generated (CSE, 2009). As mentioned, given the nature of transmission development projects, the output and added benefits of a new line are difficult to determine rendering such measures difficult to implement. Instead a less direct option could be to link the size of compensation to total investments, number of pylons, or perhaps per km of grid length.

A share in the project can either be provided as a form of compensation from the developer or acquired as an investment (CSE, 2009). In a study conducted in Scotland, Warren and McFadyen (2010) find that local ownership may have a positive effect on public attitudes towards wind farms. Allan *et al.* (2011) suggests that local community ownership and thus local retention of profits increase the economic impact of wind farms. However, direct application of the instruments used in wind power developments for transmission lines is difficult. For a regulated industry, where profits are generally earned through return on assets rather than through market operation, the nature of the risks is different. Additionally, the deposition of the electricity grid and dependency with other parts of the network make it difficult to integrate community ownership of one or part of a transmission line.

However, offering financial compensation is not a one size fits all solution. Frey *et al.* (1996) argues that offering compensation to prospective host communities will have a negative effect on acceptance and Kunreuther and Easterling (1990) and Oberholzer-Gee *et al.* (1995), find no link between financial compensation and efficient siting and local approval of nuclear-waste repositories. Instead, the perception of compensation as a bribe and the crowding out of the feeling of civic duty can increase the opposition to the project. This was shown to be the case in a Swiss study where the rate of community acceptance of a nuclear-waste repository was found to decline, from 50.8 to 24.6%, when compensation was offered compared to when no compensation was offered (Frey and Oberholzer-Gee, 1997). Similarly, in a study on new overhead line construction, Simora (2017) find financial compensation to diminish willingness to accept proposed projects.

As a result, rather than using direct financial compensation, Frey *et al.* (1996) suggests that in-kind compensation, intended to benefit the community as a whole, weakens the bribe effect and thus supports the siting process of locally unwanted projects. An example of local benefit sharing is the provision of 'Community Benefit Schemes'. Such sharing schemes, which may contain "good-will" gestures, such as upgrading a road or a new playground, to financial arrangements, such as payments to a community fund or community ownership, have proven effective in increasing local support for wind power developments. This is particularly the case in countries such as Denmark and Spain, where local ownership, and thus greater local retention of profits, are more common (CSE, 2009; Warren and McFadyen, 2010; Allan *et al.,* 2011). However, UK communities remain unconvinced of the intentions behind the benefit provision with many still considering it as a method to silent opposition with bribes (Cass *et al.,* 2010). Even well-intentioned developers seldom receive the trust of local communities, which may be partially due to the timing of the offered compensation (Aitken, 2010).

4.4.2 A property rights view of grid development

While the communities affected by grid development may oppose the projects, the nature of the community claim on the local environment needs some consideration. The affected communities (apart from landowners) do not normally have a private ownership right to the landscape in question. Nevertheless, they have the right to the use of their immediate natural environment along with the general public.

However, if a community have enjoyed the benefits of a public good, such as a landscape or scenery, over time, a right to use may come to be perceived as actual ownership entitlement or right to these (Silberstein and Maser, 2000).[10] Formation of entitlement or rights is common and also occurs in the case of subsidies, licences, or quotas that are awarded and renewed over long periods of time. A community can assume or behave as having a property right or private entitlement to local aspects of public goods adversely affected by grid projects and thus the perception of entitlement to property or user rights becomes a central, though subtle, aspect of the opposition to the project.

Using a property rights view, we can consider a simple community compensation payment or benefit receipt to reach a resolution. In order to construct a new transmission line, there are two technical options: An overground line at cost (A) or, a more costly partially undergrounded cable at

[10] Note that this view of entitlement and benefit is purely from an economic perspective, opinions of other fields of research, such as environmental phycology, would no doubt differ.

cost (B). The cost difference between the two options is thus (B-A) and undergrounding is assumed to achieve project acceptance.[11] If the general public holds the property rights to the affected landscape, the local communities can be thought as having a willingness to pay (WTP) to avoid the project. This WTP will be equal to (B-A) and to the willingness to accept (WTA) of the general public (or network utility). Both actors will be indifferent between the two options given that the project costs will remain the same.

Alternatively, the property rights to the landscape can be allocated to the affected local communities.[12] In this case, the community can accept the project through a WTA mechanism. In this case, the society or the developer will have a maximum WTP that is equal to the cost difference between the underground and overground options (B-A), which is also equal to the maximum WTA the communities can achieve. If the communities demand more than (B-A) they will receive nothing as the developer will choose to underground the line.

Following Coase (1960), the outcomes of the above two cases are equal in terms of economic efficiency as the WTA and WTP will be equal to (B-A). However, depending on the initial allocation of property rights, the distributional effects and the actual or perceived equity implications are significant and crucial from a political economy point of view. For example, the former case may be perceived as being unfair that the communities should be expected to pay off the wider society in order to avoid the negative impact of the project or have the line placed underground.

Theoretically, WTA and WTP are assumed to be equal. However, experimental evidence suggests that WTA is usually greater than WTP (Horowitz and McConnell, 2002). Following the example above, we have two potential outcomes. Independent of if the property right lies with the community or the

[11] Although this may not be a realistic assumption in real world situations we use this simplified view to illustrate our example.
[12] Note that transmission lines may affect other than local residents although not captured by this approach.

developer, if WTP is higher or equal to the cost of undergrounding, the project will go ahead and placed underground. If, however, the cost of undergrounding the line is greater than the WTP, the project will not be realised. Again, the implications in terms of social and distributional point of view are significantly different and will affect the manner in which the project will be perceived.

4.4.3 An environmental sustainability approach to grid development

The economic approaches to community engagement in grid development based on individual or collective compensation, benefit sharing, and property rights allocation can help reduce community opposition to grid development projects. However, these approaches have, on their own, methodological and practical shortcomings. The main limitation is related to that of identification as well as the lack of clear property rights and assignment of such rights in the absence of clear entitlement to these. In addition, although such approaches could help reduce the level of conflict, they may not necessarily be desirable from an environmental sustainability point of view as they are generally short-term approaches without a sustainability and intertemporal rationale. Therefore, the above economic instruments can be more effective when used within a high-level environmental strategy that links the individual and community interests to an overarching social policy and public decision rule and process (see Cain and Nelson, 2013). Given the above reasoning, we propose an economics informed environmental sustainability approach as the basis for a coherent and comprehensive decision framework.

This alternative economic approach can be explored based around the concept of environmental sustainability and the related notion of intergenerational equity. Sustainability in this context can be considered as the ability to meet the needs of the present without compromising the needs of future generations. It is the continued capacity to engage in certain activities. Within this perspective, the adverse environmental effects of grid projects can be viewed in terms of transformation of natural assets from one form to another. As first suggested by Hartwick (1977) and Solow (1986), the total value of a non-renewable environmental resource can be preserved over time by investing or transforming the benefits or rents from the use of a natural resource into other assets. This transformation can be in the form of strong or weak sustainability.

In a strong sustainability viewpoint, the total value of a resource or natural asset is to be maintained for current and future generations if an equivalent value of environmental asset can be created from the rents. This can, for example, be part of an ecological strategy which attempts to preserve ecosystem services. On the other hand, within a weak sustainability view, some form of financial or social capital (in this case perhaps community capital) of the same value can be created from the benefits of the project. Other possibilities such as transforming the natural asset into physical or human capital can also exist in the spectrum of sustainability options (Ayres *et al.,* 1998; Dietz and Neumayer, 2007). Weak sustainability draws on the notion that environmental problems are caused by inefficient use of natural resources. By monetising externalities (caused by inefficiencies) the costs can be internalised and a solution devised. The economic rent from a project would be redistributed and social costs would equal to private costs. Practical examples of weak sustainability policy include the sovereign funds in resource rich countries, such as Norway who uses the Norwegian Petroleum Fund to invest part of their proceeds from oil extraction in the North Sea in financial assets.

The environmental impact of a grid development can be viewed in terms of weak and strong sustainability. If a grid development project is deemed to produce a net socio-economic surplus this implies the project can compensate for the environmental damage of the project. This compensation can be in the form of creating an equivalent benefit or value elsewhere. Within this framework, the wider society as a whole must decide on the acceptable form of the transformation and conversion of the value of the natural assets affected by grid development while preserving their total value – i.e., whether the natural asset affected should be transformed into another natural asset or into physical, financial, social, or human capital. This decision should be part of a high level and long-term sustainability strategy that informs the decision-making framework, rules, and processes.

From compensation and benefit sharing to community investment
Compensation of a public nature can be perceived to be fairer and more honest compared to individual monetary compensation and is thus more likely to be successful (Terwel *et al.,* 2014: Frey *et al.,* 1996). However, grid projects have lasting inter-temporal environmental impacts. A weakness of *ad hoc* and narrow approaches based on compensation and benefit sharing is that they may result in one-off short-term solutions and settlements that do not ensure dynamic and inter-generational equity. Therefore, preserving the value of an environmental asset will often require investment in other assets that produce sustainable long-term benefits.

It is, in principal, possible for the society to adhere to a strong or weak sustainability criterion and create 'community capital' through 'community investments' in another form of capital. For example, the Beauly-Denny transmission line project had an element of both strong and weak sustainability; the developers were required to improve the environment along certain sections beyond the effect of the new line and in two cases they were also required to provide financial compensation to affected communities.[13]

Assigning compensation to individual members of a community is impractical as the transaction costs would increase significantly with allocating individual compensation rights. Also, the task of identifying *who* is entitled to compensation is difficult as there are often no defined criteria. Proximity to the new line may seem an obvious measure – for example, Sims and Dent (2005) find that proximity to a transmission line lowers property prices, and Gibbons (2015) suggests similar results with regards to wind power developments. However, where the dividing lines for compensation should be

[13] This additional cost was approved by Ofgem, the GB energy regulator, as it was a condition of the consent from the Scottish ministers.

drawn is difficult. A more suitable approach is therefore to aggregate compensations and the method agreed on through collective negotiations on a society-wide level.

Community investment through collective negotiation

Offering investments in community infrastructure or services is common in wind power developments, often labelled as 'community benefits'. Upgrading roads or recreational spaces gives a developer the opportunity to work directly with the community. Transmission developments involve several communities (rather than one host community as in the case of energy generation facilities) and each community has specific needs that can be identified through participation in the planning process and addressed when developing the compensatory approach. Furthermore, by encouraging the stakeholders to reveal private information about their preferences, negotiations between the developer and the community about the level and type of compensation can increase social welfare. Here, the concepts of weak and strong sustainability can act as a starting point and guide the negotiations on how the environmental costs of a development are to be allocated and how the rents from it may be redistributed.

Oberholzer-Gee *et al.* (1995) find that granting authority to affected communities and two-way negotiations, thus customer and public participation in the planning process, increases local approval of the facilities. Such negotiation will open for innovative solutions that would not have been envisaged by policy makers and developers as local knowledge and needs is utilised, thus increasing the efficiency and welfare effect of the outcome (Doucet and Littlechild, 2006; Ciupuliga and Cuppen, 2013). This is further emphasized by Kunreuther and Easterling (1996), arguing the case for a voluntary siting process and negotiated compensation, rather than using predetermined compensation measures without community influence.

As a complement to traditional regulatory approaches, some regulators in North America have used negotiated settlements between grid utilities and their customers to determine cost, price and operating projections. Negotiated settlements have proved to limit the regulatory workload, decreasing delays and increase efficiency (Doucet and Littlechild, 2006). Nevertheless, consumer engagement is a new concept to electricity grid owners, particularly the transmission grid given its role within the electricity system. Challenges related to low levels of knowledge of the public related to what transmission developments entail and their need will be an issue and risks network companies benefitting from informational and bargaining advantage.

Voluntary agreements (VAs) between environmental regulators and polluting firms have become an increasingly popular policy instrument to ensure the protection of environmental quality. VAs are seen as an alternative to mandatory approaches based on regulation or legislation with a wide range of applications including water pollution, air pollution, and waste management (Segerson and Miceli, 1998). The European Commission (1996) identify three main potential advantages of VAs: i, the encouragement of a pro-active cooperative approach from industry, which can reduce conflicts with regulators, ii, greater flexibility and freedom to find cost-effective solutions that are tailored to specific solutions, and iii, the ability to reach solutions more quickly due to reduced negotiation and implementation lags. This implies possible reduced compliance, administrative and other transaction costs. However, Segerson and Miceli (1998) find that VAs could reduce environmental quality compared to stricter legislation and Lyon and Maxwell (2003) find that VAs are more likely in situations where industry display strong resistance to stricter regulatory and legislative measures, risking less socially optimal outcomes. Furthermore, VAs are argued to be more efficient and effective in the existence of a strong regulatory threat, that is, in situations where the regulator display strong bargaining power (Alberini and Segerson, 2002). As a result, whilst collective negotiation can increase cooperation, reduce transaction costs and lead to efficient results, the regulator or other governing body must be in a position of strong bargaining power with the ability to impose decisions in case of negotiation breakdowns. This is particularly important if the number of stakeholders is high, as is in transmission developments. Compensating and negotiating with the communities rather than individual members of the public reduces the transaction costs as the number of participants in negotiations is reduced. Nevertheless, negotiations risk the possibility of a breakdown if the parties fail to reach an agreement. In order to reduce the probability of unsuccessful negotiations, an independent authority such as the sector regulator could step in as mediator, which will intervene in case that no agreement is reached. It is, however, in the interest of both parties to reach an agreement as, in case of failure to agree, the regulator can impose a socio-economically less favourable outcome (Doucet and Littlechild, 2006). Appointing an ultimate decision maker and arbitrator also limits the appeal of hold up as it is less likely that one party to negotiations can delay the process through rent seeking behaviour.

Menu of options method for collective negotiations

At the presence of uncertainty and information asymmetry it is difficult to form and maintain robust principal-agent relationships. The transaction costs are higher in negotiations, leading to inefficient outcomes. In regulatory economics, the use of a menu of options or contracts is expected to reduce the effect of uncertainty and information asymmetry (Laffont and Tirole, 1986; Laffont, 1993). Keeping consumer welfare constant, the regulator can offer the firm a choice of different regulatory contracts, which essentially consist of different combinations of cost sharing provisions (a fixed component and a component dependent on the responsiveness of the firm's revenues to costs). The firm will choose the optimising contract depending on its cost opportunities (Joskow, 2007). Pareto improvements are possible since consumer welfare is kept constant and firms can increase their welfare due to the flexibility to choose an optimising contract based on private firm information which was previously unknown by the regulator (Crew and Kleindorfer, 1992).

A menu of contracts can thus be used in order to elicit information and increase efficiency. Drawing on the theory of economic regulation, a similar approach may be developed to optimize the provision of sustainability-based compensations for transmission grid projects. In this, the developer offers the affected community a set of compensatory measures. The cost of different alternatives can be held constant at a reference cost, for example in the above case at the difference between the cost of an overhead line and an underground cable. Given the knowledge in terms of different compensatory options, a menu of options may, for example, consist of choices between community fund payments, infrastructure developments, community ownership, and environmental investments.

By providing a menu of options, the communities can choose among a set of sustainable solutions that maximizes their welfare depending on their attributes and value to the community. This self-selecting process is preferable since choosing one contract or option is the equivalent of revealing internal information, which would otherwise remain unknown. Thus, the process is more efficient than if the developer or the government were to design and implement a policy without consulting the community through collective negotiation within a sustainability framework.

4.5. Conclusions

The electricity networks need to upgrade and expand in order to meet the future demands of the sector, including connecting smaller but numerous conventional and renewable generation facilities. However, many new transmission lines are facing opposition from the affected local communities on the grounds of their environmental, social and possible economic impacts. The conflicts cause delays and prolong planning thus adding to the project costs and foregone system benefits. The conventional decision approaches seem unable to resolve many of the conflicts. There is therefore a need for a new approach to address the community opposition to grid development projects.

In this chapter we discussed direct compensation and benefit sharing methods, as well as property rights approaches and how these measures can play a role in reducing community opposition to grid development. However, these methods currently lack an overarching theoretical and methodological framework to structure and guide the process, which is important for gaining the trust and acceptance of communities and society as a whole. Additionally, methods based on purely compensatory measures are not devised to allow for public and local participation in the planning process and therefore fail to address the underlying causes of opposition.

We suggest a socio-economic approach to grid development that is based on the concepts of weak and strong sustainability and that the environment affected by grid developments, rather than the community *per se*, can be compensated within a sustainability approach. It is however ultimately for the larger society to decide, through public and social policy decision framework, on the nature of the compensation along the spectrum of weak to strong sustainability options – e.g., in the form of lasting investments in environmental, physical, financial, social, or human capital. This compensation can, to an agreed upon extent, accrue to the affected communities; although it is up to the society decide on how and on the level. While financial compensations appeal to the consumer dimension of communities and members as economic agents, compensation in the form of environmental assets appeals to the citizenship dimension of these.

The suggested mechanism can be in the form of collective negotiations between the communities and developer with the consent of the regulator and policy makers. Collective negotiations ensure that stakeholders are better able to participate in the decision-making framework. The efficiency and acceptance of the outcome of collective negotiations can then be further improved through the use of a menu of options, an established concept in regulatory economics.

Chapter 5

Public Engagement in Electricity Network Development: The Case of the Beauly–Denny Project in Scotland

5.1 Introduction

The future of energy networks holds important technical, economic, and social challenges. Across Europe, the electricity grids are in need of modernisation to support the on-going development of low carbon energy systems. In order to connect the large number of emerging renewable energy plants and integration of energy markets the networks need to expand. This is true regarding both distribution and transmission networks.[14] Meanwhile, larger development projects such as expansion of transmission networks tend to dominate the public debate, much due to their greater impact in terms of national importance, economic costs, environmental impacts, as well as their potentially negative effect on neighbouring communities.

Network developers, traditionally this would be monopolistic transmission owners (TOs), face a number of constraints which may extend planning processes and delay projects – considering alternative project designs, negotiations with the regulator to justify the need case and cost efficiency, environmental constraints which will have to be considered, or a change in government policy – are a few of the potential issues. The focus of this chapter is on public and community opposition and, although not a new issue, it is proving to be an increasingly important aspect in planning and development of grid projects. It is an indication that the role of electricity consumers is changing and that energy companies are slow to react.

[14] The development of distributed generation sources and demand for electric vehicles, among others, is exerting pressure on the distribution networks to take on a new role as active networks compared to a previously passive role (Poudineh *et al.,* 2015).

Objections to large projects often relate to environmental, visual and health aspects (Soini *et al.*, 2011), particularly from communities in close proximity to a planned development. Failure to agree between stakeholders leads to costly delays or even causes projects to be abandoned altogether. As a result, the potential for reaching the targets set for reducing carbon emissions and climate change, thus a green energy future, is in jeopardy (European Commission, 2008).

Grid development projects tend to affect a number of stakeholders – from state and local communities to NGOs, landowners and corporations – each with different objectives and perceptions of the project and surrounding matters. The existing decision-making processes and institutions have proven ineffective at resettling conflicts that appear between stakeholders, causing uncertainty and delays. Increased information provision and public engagement in transmission grid planning can increase public trust in network companies, public acceptance and therefore accelerate the realisation of new grid developments (RGI, 2012; Newig and Kvarda, 2012; Cotton and Devine-Wright, 2010). The Aarhus Convention (European Community signed and implemented in 1998 and 2003 respectively) advocates early and effective public participation to increase the transparency of the planning and decision-making process.

Public engagement implies the involvement of members of the public in policy-forming and policy development. The concept is not new but is becoming increasingly important in infrastructural developments. For example, in 2010 a United Nations legal tribunal found that the UK government had failed to provide sufficient information and decision-making powers to the public regarding two major wind developments (UN, 2010).

However, despite the pressure through the Aarhus Convention and elsewhere there are no established guidelines, rules or frameworks defining how public participation ought to be formalised. Recent high-profile projects, such as the

Norwegian Hardanger line and the Scottish Beauly-Denny line[15], show that transmission projects increasingly involve vested social, economic and political interests. Noticeably, there is a need for new approaches for defining and organising the role and tasks of the actors, including the public and affected communities.

Exploring project characteristics and stakeholder relations using an economic approach is previously untested in transmission developments but it can potentially generate several efficiency improvements. Based on the seminal works by Coase (1937) and Williamson (1979) on the role of institutions, rules, and norms, this chapter analyses economic characteristics of transmission projects following a New Institutional Economics approach. Additionally, using the contentious Beauly-Denny High Voltage transmission line project and input from previous literature, this chapter outlines how public engagement may be approached to allow for a more efficient planning process. Personal interviews with representatives from TOs, government and affected communities inform the assessment and provide a novel perspective.

The Beauly-Denny project is a representative example for current issues and developments within the energy sector; its need is driven by government policy to meet climate change targets, a more active public and stakeholder base with over 20,000 objections indicates the changing role for consumers, and sluggish response from the governing frameworks, including regulatory, legislative, planning and decision-making.

This chapter is outlined as follows: Section 5.2 applies the economic theory to the practical issues, including the economic characteristics of transmission developments and public engagement. Section 5.3 presents and assesses the Beauly-Denny transmission line development with a critical discussion on the treatment of consumers and public engagement. Section 5.4 concludes.

[15] The Hardanger transmission line crossing the Hardanger fjord on the Norwegian west coast, was one of the most reported news stories in Norway in 2010. The Beauly-Denny transmission line received over 20,000 objections and was covered extensively by UK media.

5.2 Theoretical application

5.2.1 Economic characteristics of transmission developments

The integration of high levels of renewable energy sources in electricity systems and having effective market competition in wholesale electricity generation both require substantial investments in new and upgraded transmission networks. At the same time, transmission grid is a natural monopoly function and is, as a result, subject to economic regulation and oversight by the sector regulator (Biggar and Hesamzadeh, 2014). In practice, this means that over-spending or disallowed investments on new grid projects will reduce the revenues and profits of the network utilities (Joskow, 2008). The technical nature of the transmission networks means that determining the operational and economic benefits of the grid projects can often be complex (see, e.g., Volk, 2013; Brattle Group, 2013).

Transmission lines are essentially electricity highways with the purpose to transport electricity, for example, from an area rich in resources to another where demand outweighs supply. Areas at either end of a transmission line can enjoy benefits from new installations, including revenues from energy production, reduced electricity prices and a more reliable service. However, the benefits to the areas along the lines are less obvious. Connecting renewable energy sources and reliable networks benefit the country as a whole, yet potential costs of reduced property prices, visual amenity, tourism and damages to wildlife are mainly borne by communities along the line. These costs are not easily quantified as they can either be labelled as public goods or they are not directly observable. Thus, the construction of new transmission lines produce externalities as the local social costs are greater than the private costs.

The planning process of grid developments is highly specific and depends on the knowledge and experience of developers, consumers, and authorities. Reaching unanimous decisions in transmission developments is difficult as the physical and financial size of projects, as well as the number of stakeholders, tend to make cooperation difficult. Public knowledge regarding electricity networks relate largely to technical aspects, such as pylons and wires, rather than their organisations (Devine-Wright *et al.*, 2010). The low level of public knowledge regarding transmission line development and administration is not only a cause of increased public opposition to new grid projects, it also restricts increased public participation and a more active role for communities within the development process.

Another aspect is the large number of affected communities and citizens along the transmission lines. Although all stakeholders should have the chance to express their views and perspectives towards a project, it would be impossible to consider all statements and objections. The Beauly-Denny project alone received over 20,000 objections. The developer and planning authority must balance the public's views to be taken into account and the wider benefits of acceleration of developments.

5.2.2 Economic characteristics of public engagement

Public engagement is defined as the practice of involving members of the public in policy-forming and decision-making activities of organisations responsible for policy development. Depending on the flow of information between the participating public and the responsible organisation, public engagement is divided into (i) public communication; (ii) public consultation; and (iii) public participation. Public communication relates to a one-way information flow from the organisation to the public whilst public consultation considers a flow of information from the public to the organisation. In public participation, a formal dialogue takes place and information is exchanged between members of the public and the organisation (Rowe and Frewer, 2005). Public engagement is therefore considered in policy and decision-making frameworks only if initiated by the responsible organisation. However, the extent to which public engagement is allowed to influence the process is often unclear.

Newig (2007) notes that the rationale for public participation in sustainable environmental planning includes access to local knowledge, attitudes and acceptance, increased awareness, transparency and, thus, trust between stakeholders. If properly framed, some of the lessons from environmental planning could be used to address the opposition to and conflicts in grid development projects. Given the similarities between sustainable environmental planning and the characteristics of the energy sector, e.g. multiple stakeholders, public goods and market failure, instruments of environmental governance and policy analysis such as cost-effectiveness and social and environmental cost-benefit analysis are also applicable to transmission developments (Think, 2013; LIFE Elia, 2015).

Public and community engagement in power line projects shares some features with that of other major infrastructure developments. Such engagements have often been discussed in the literature in the context of specific types of projects: for example, nuclear power plants (Otway *et al*., 1978), in the context of carbon capture and storage (Kraeusel and Möst, 2012), wind power (e.g., Swofford and Slattery, 2010) or airports (e.g., Jue *et al.,* 1984). Recent large-scale grid projects like the Beauly-Denny transmission line however show that the public takes an increasing role in the realisation and success of these projects.

5.3 The Beauly-Denny Transmission Project

5.3.1 Background

There are two main TOs in Scotland: Scottish Hydro Electric Transmission Ltd (SHETL), a subsidiary of Scottish and Southern Energy plc (SSE), and Scottish Power Transmission Ltd (SPT), a subsidiary of SP Energy Networks. Scotland's energy policy is devolved from the UK government, and therefore independently decides on consents for developments of energy infrastructures. However, the GB wide energy regulator Ofgem regulates the TOs in Scotland and National Grid operates the whole GB system whilst owning the transmission network in England and Wales.

The Scottish and UK government targets of tackling climate change have prompted an increase of renewable energy generation. The existing transmission capacity is insufficient to allow the intended renewable energy facilities to connect to the network. As part of their transmission licences, SHETL and SPL maintain that they have a duty under the Electricity Act 1989 to develop and maintain an efficient, co-ordinated and economical system of electricity transmission. This is to facilitate competition in supply and generation of electricity. The Beauly-Denny line was argued to be a key infrastructural development towards maintaining competition and enable development of renewable energy.

5.3.2 Beauly-Denny project facts

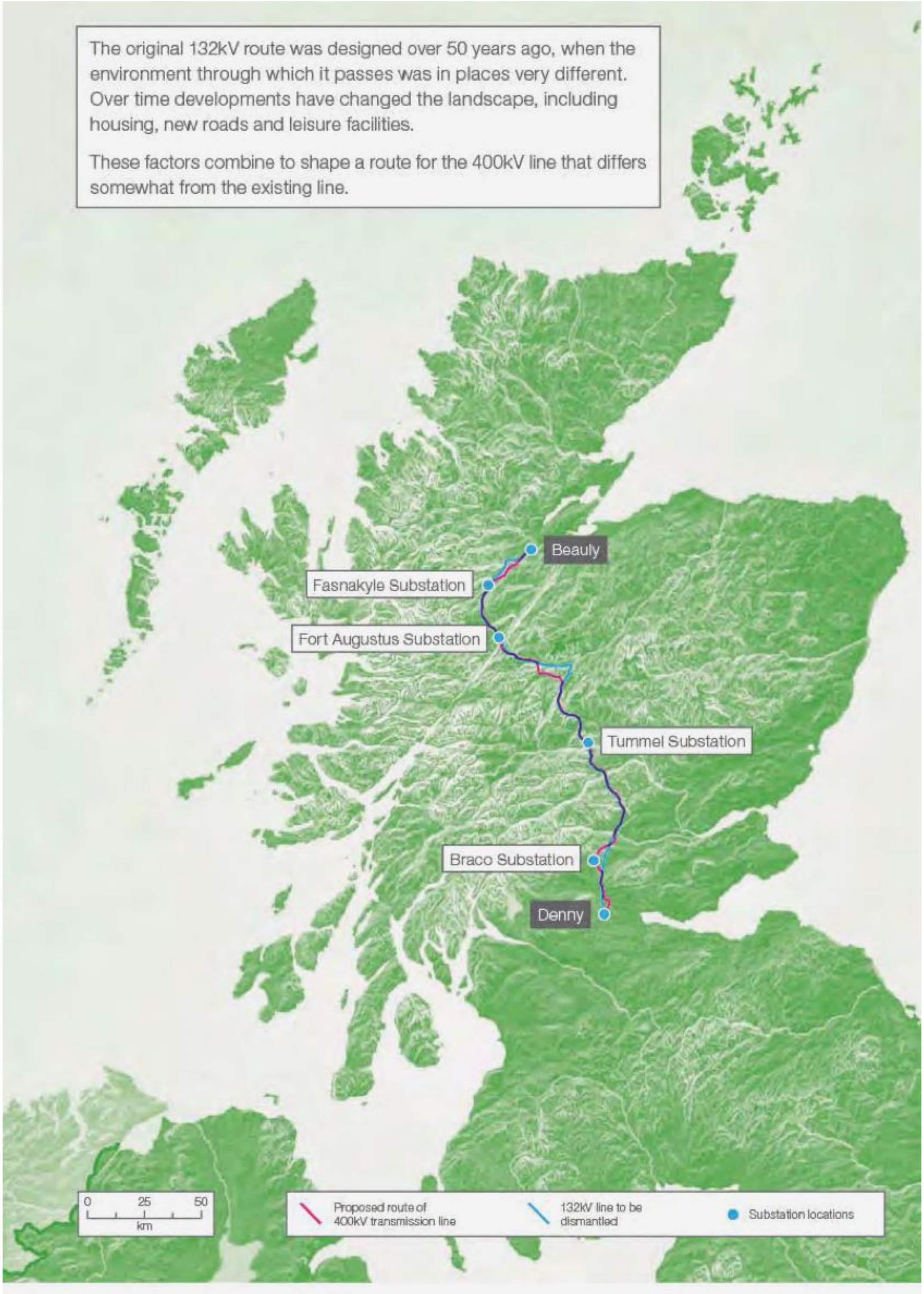
The Beauly-Denny High Voltage Transmission Line (HVTL) is a high profile development, subject to the longest ever public inquiry in Scotland. It has been followed closely in media and has generated close to 20,000 objections from all over the world. The planning process has taken ten years from the initial identification of the need for the project to the start of construction. Applying the theoretical concepts outlined in Section 5.2, i.e. transaction costs, information asymmetry, and principal-agent relationships, this case study will focus on how consumer engagement was managed in the Beauly-Denny planning process. The project is an example of how conflicting interests of the stakeholders delay the execution of projects and reveals a lack of suitable a decision-making framework for such developments. The study is based on first-hand information collected through interviews with key stakeholders and an extensive research and collection of information published by all the relevant stakeholders.

In September 2005, SHETL and SPT applied for planning consent under Section 37 of the Electricity Act 1989 to construct a new high voltage power-line between Beauly, near Inverness, and Denny, near Stirling. The project involves the construction of a 220 kilometres[16] long 400kV double circuit overhead transmission line set to replace the current single circuit 132kV transmission line, which will be dismantled as part of the development. One circuit will operate at a voltage of 400kV and the other at 275kV. Further expansion and construction of substations will also take place. Approximately 600 steel pylons between 43 and 65m tall will support the line, although the majority of towers are between 50 and 56 meters tall. The spacing of towers are dependent on topography, altitude and the exposure of weather effects, such as high winds, but will normally vary in a range of 275 to 450m and they will be fixed in the ground using concrete tower foundations (SSE, 2012a; SSE, 2012b). The Beauly-Denny project was completed and the line went live in November 2015.

The new power-line mainly follows the same route as the old 132kV line, however changes in the use of land in the course of time required slight deviations (Figure 5.1 illustrates the new route in relation to the old route). The 220km long stretch is divided into four sections, separated by the new substations. The landscape along the line is characterised by varying land uses including remote moorland, forests, river valleys, roads (A9) and some more populated areas[17]. The routing around the Stirling area was particularly contentious as the power-line passes close to residential areas and near Stirling's most famous tourist attractions: Stirling Castle and the Wallace monument. Following the longest public inquiry in Scotland, Scottish Ministers gave consent to the construction in 2010, provided that certain mitigation measures were adapted. SPT worked with Stirling council to reach agreement on an appropriate mitigation scheme and the final consent was given in December 2011 and construction commenced in February 2012[18].

[16] SHETL is responsible for 200km and SPT is responsible for 20km.
[17] See Appendix 5.1 for a more detailed outline.
[18] See Appendix 5.2 for a project timeline.

Figure 5.1: Overview of the Beauly-Denny power-line routing.



Source: Used with the permission of SSE

Strategic options

Several strategic options for routing of the corridors and alternatives for achieving the required transmission capacity were considered at the initial stage of planning. The identification of a number of plausible routes was followed by a more detailed analysis of technical, economic and environmental aspects. The environmental evaluation followed the guidelines of the Holford Rules [19] and aimed to achieve the best fit within the landscape, balancing minimal effects on sensitive landscapes with the requirement of keeping alignments more than 100m from residential buildings.

A public consultation was exercised once an 'optimal' route was identified. Undergrounding of the line was considered at early stages of the project. Although undergrounding the line or sections of it would reduce potential visual or health effects, it will still have a significant environmental impact. SHETL states that a 25m wide corridor of land would be cleared in order to position the power-line. Such a corridor would be needed to remain clear after construction to allow for future access for maintenance and upgrading of the line (SSE, 2012b). National Grid (2009) estimates that, using modern cable technics, undergrounding a typical 400kV double circuit power-line will cost 12 to 17 times as much as installing the same line overhead. This is mainly due to the differences in the cables themselves, the insulation of underground cables and the construction method itself.

5.3.3 Stakeholders and their objectives

The difficulty in any major infrastructural development is to strike a balance between the long-term objectives of the various stakeholders and the overall benefits of the development. The complex nature of the planning process is largely due to conflicting interests, information asymmetry and the various principal-agent relationships amongst the vast range of stakeholders. Such conflicts occasion transaction costs, further increasing the externalities of

[19] Guidelines for the construction of new high voltage overhead transmission lines. These include the notions of avoiding major areas of high amenity value, areas of scientific interests, choosing the most direct route and a preference for tree and hill backgrounds rather than sky (National Grid, 2012).

projects. This section outlines the participants' differing practical roles in the planning process and discusses the theoretical underpinnings, characteristics and incentives relative to the varied range of stakeholders. The focus is on the process in Scotland; however the theoretical aspects, characteristics and incentives are not country specific.

The Scottish Government

The Scottish government belongs to the public sector. The public sector is characterised by a multiplicity of dimensions regarding tasks, stakeholders and conflicting interests. A multitude of principal-agent relationships arise from dealings related to both distributive and allocative issues. Governments generally set out to maximise welfare rather than profits and therefore often fail to minimise costs and maximise economic value (Libecap, 1989). In particular, compared to the private sector, incentives for efficiency in the public sector are rather weak due to the absence of competitive situations.

The Scottish government is responsible for setting long-term targets through its Energy Policy. It provides a framework for the authorities and is an important factor in guiding private sector interests. In The Climate Change Act 2009, the Scottish government set an ambitious target for greenhouse gas emissions at reductions of 42% by 2020 and 80% by 2050. Scotland aims to drive technological development and place itself at the global forefront of providing a sustainable low carbon economy.

The main sources of renewables in Scotland are hydropower and onshore wind farms, however, the Scottish government is implementing support schemes for the development of offshore wind farms, wave power, tidal stream and biomass, of which a growing level is situated in the north of Scotland. An important aspect of the challenge lies in connecting these generation facilities to the transmission network. The construction of the Beauly-Denny HVTL will increase the transmission capacity between the Highlands and central Scotland and was therefore deemed important for a successful Scottish Energy Policy (Scottish government, 2010). The Beauly-

Denny line will enable the construction of an interconnection between Scotland and England – Scotland's port to export green energy.

In Scotland, applications to construct new or modify existing grids are made to the Scottish Ministers. The Energy Consents Unit (ECU) considers all projects relating to electricity generation facilities and overhead power-lines. Both cases for and against an application are considered before giving consent, although particularly sensitive projects are subject to public inquiry. The ECU received the applications from SHETL and SPT to construct the Beauly-Denny line in September 2005. One year later, the unit announced that the proposed upgrade would be subject to a public inquiry. Public consultations, environmental and technical statements, and evidence from nearly 200 witnesses collected during the inquiry were considered when making their recommendation of consent.

The Sector Regulator

The GB regulator of the gas and electricity markets is Ofgem. The main priority of the regulator is to protect customers by promoting competition and regulating (natural) monopolies where competition is not an alternative. The focus lies in providing Britain with a secure energy supply and to contribute to limit the energy sector's adverse environmental effects. Ofgem regulates the TOs through eight-year price control periods, which aim to incentivise innovation, efficiency and curb expenditure. The price controls set the maximum revenue TOs are allowed to generate through transmission levies[20].

Major network updates require significant investment from the TOs who seek approval from Ofgem to raise the capital through increased transmission charges. The TOs are pressured to minimise the expenditure of any project as Ofgem will only approve the costs that are clearly justifiable. However, despite claiming that the interests of the UK consumers are the main priority, Ofgem does not operate within a framework that allows for consumer participation

[20] Transmission levies form part of the end-users' energy bill.

(Littlechild, 2012). Moreover, the formal rules within this framework may not have been created to be socially efficient (North, 1995). North suggests that institutional rules are designed to benefit those with the bargaining power to effect change. In the context of grid developments, the TOs, relative to communities, are the players with the bargaining power; they are rich in capital and resources and have all the experience in the planning and execution of grid development.

Although the Beauly-Denny line is argued to be an important infrastructure development project to maintain competition and enable development of renewable energy, it is not officially considered a national necessity for promoting competition and protection of consumers and is thus outside the price control allowance. In 2004, Ofgem presented a mechanism designed to fund transmission projects specific to connecting renewable generation. The Transmission Investment for Renewable Generation mechanism (TIRG) is comprised by four projects, one of them is Beauly-Denny. The mechanism allows for an accelerated process to fund these projects and thus fast-tracking the connection of renewable energy sources to the national grid (Ofgem, 2011).

Scottish Hydro Electric Transmission Ltd (SHETL) and Scottish Power Transmission Ltd (SPT)

Through their transmission licences, the TOs are responsible for providing a secure and reliable service to their customers. Part of this service is identifying, planning and designing new power-lines, which also require them to produce an environment report to show Ofgem and the ECU that their proposal is justified and that all possible alternatives have been considered.

The incentives for efficiency in the private sector are more powerful relative to the public sector because of external competition. Private companies typically follow the objective of minimising short-term costs and maximising long-term profits. However, the TOs are natural monopolies and despite Ofgem's regulation, following Dixit (2002), it seems realistic to suggest that where there is a lack of competition, little attention is paid to consumer preferences. Therefore, on the surface it seems as though the TOs incentives for substantial public engagement are weak.

SHETL maintains that the construction of the Beauly-Denny line is vital to the future of the Scottish transmission network. Further developments, including generation facilities and additional transmission lines, depend on successful and timely construction. As licence holders, SHETL are responsible for ensuring a secure and reliable supply of electricity at reasonable prices and they argue that their license could be in jeopardy if they do not deliver (Personal interview 1, 2012). Although the Beauly-Denny line is mainly covered by SHETL's area of responsibility, SPT realises the importance of the project for future connections, many of which will occur in SPT's area (Personal interview 2, 2012). Consequently, Ofgem has granted SHETL and SPT the right to recover the cost of the project from their customers through transmission levies. The nature of the industry makes investments in transmission lines relatively safe although there is a certain regulatory risk. These major investments, where the value is in the actual asset rather than its usage, will be at risk if the regulator decides to change the rules of the sector.

Local communities

Community involvement in the planning process is relatively limited. Although invited to comment on draft proposals, communications with local stakeholders are more educational than a two-way information exchange. The communities are characterised by a heterogeneous pattern and also belong to the public sector. They consist of many and diverse individuals and local firms with different preferences that can also change over time. Their targets and objections are therefore difficult to contract and customers may not be willing or able to adequately reflect the interests of present and future customers (Littlechild, 2012).

The general consent among the communities was that not enough effort was directed towards identifying alternative solutions to the routing, such as subsea cables or not enough measures to mitigate adverse effects. It should be noted that community opposition to a grid project may be motivated by the type of proposed technical solution for example in the use of overhead lines instead of underground cables. Community groups, including Stirling before pylons (2010) and Pylon pressure (2010), argued for undergrounding as the only reasonable level to mitigate the impact on wildlife, environment, and limit the visual landscape. However, undergrounding is not the panacea to limit all objections. For example, a section of the Beauly-Denny line crosses over an old battlefield, restricting any construction at the site.

Also, some communities felt unfairly treated as the new developments only inferred costs for them and the benefits are enjoyed somewhere else. They consider the transmission line as substantially reducing the quality of the environment they live in and thus a reduction in their quality of life. The long-term objectives of the government to export electricity through a Scotland-England connection intensify the resistance. Further concerns relate to a loss of tourism and therefore a loss of business.

The potential direct benefits of transmission lines for the communities include local job creation and the increased demand of local goods and services throughout the construction phase. However, the construction of transmission lines is a highly specific task that requires skilled labour and therefore much of the construction was carried out by international teams specialised in lining and on site pylon construction. It is thus unclear to what extent local jobs were actually created.

Third party interests

At a general level, there is strong support for green technology but at local levels there has been frequent controversy and opposition in relation to the actual developments. This has become a phenomenon known as NIMBYism ('Not In My Back Yard'). However, it is wrong to assume that proximity to the developments is the only factor determining opposition. Often there are objections in relation to developments being too costly; having potentially damaging effects on wildlife and ecosystems; and having a visual burden on the landscape. Such third-party objections lead to stalling at the planning stage and reduce the speed of development. For example, non-governmental organisations often develop blanket policies in relation to infrastructural development. Therefore, even when they are not directly affected, their experience and resources can provide robust opposition to controversial developments.

A number of NGOs and environmental preservation groups became involved in the Beauly-Denny project. Based on the economic case for the project and the possibilities for green energy, organisations such as Friends of the Earth Scotland (FoES) and World Wide Fund for Nature (WWF) were supportive of the new development. However, NGOs with interests in preserving wildlife, biodiversity and a scenic landscape were generally opposed to the construction of the new power-line. These NGOs were also more vocal and involved in the public inquiry.

The NGOs challenge the necessity of the project to a greater extent relative to the communities. The John Muir Trust argued that the need for the new line was poorly justified and that the strategic case for the chosen route lacked backing. Rather than a new line, they wanted to see an update of current lines, such as the east coast line. The John Muir Trust maintains a general renewable energy developments policy, which is in favour of a greater focus on small-scale, sensitively sited renewable energy schemes close to existing settlements rather than large scale wind and hydro plants which connect to the transmission network (JMT, 2011). Moreover, the Beauly-Denny Landscape Group[21] took part in the public inquiry and produced a parliamentary briefing, arguing against the case. Part of their concern was related to the future effects of the transmission line, such as the upsurge of applications to develop wind farms along its path.

[21] The John Muir Trust joined the Association for the Protection of Rural Scotland, Mountaineering Council of Scotland, National Trust for Scotland, Ramblers Association Scotland and the Scottish Wild Land Group to form the Beauly-Denny Landscape group.

5.3.4 Public engagement in the planning of the Beauly-Denny project

Statutory requirements oblige SHETL and SPT to advertise their applications in the local press and planning authorities must be notified: Along the Beauly-Denny line these include Stirling Council, Perth and Kinross Council, the Highland Council and the Cairngorms National Park Authority. Further notifications were sent to Scottish Natural Heritage (SNH) and the Scottish Environment Protection Agency (SEPA). Objections were received from Stirling Council, Perth and Kinross Council, the Highland Council and the Cairngorms National Park Authority and 17,250 others. A further 2,994 objections were received after the Inquiry closed (Scottish government, 2011).

Heterogeneous understanding among communities

Communication with communities at an initial stage of the planning process is a way to introduce planned extensions and increase communities understanding and knowledge of projects. Public understanding of transmission networks and transmission owners are generally low, as identified by Devine-Wright *et al.* (2010), and as experienced by both SHETL and SPT in the Beauly-Denny project.

The members of the SSE Community Liaison Team[22] noticed great differences among the affected communities. The communities that were more familiar with electricity transmission and generation facilities, such as hydroelectric generation, were generally more understanding and sympathetic to the idea of the new powerline. These communities were more open as well as able to actively contribute to the planning process. This supports the findings of Soini *et al.* (2011) and Atkinson *et al.* (2006), which suggests that the negative attitudes towards overhead powerlines dissipates over time. It also highlights the importance of provision of information to increase public understanding of the projects.

[22] Following the identification of the need for a close working relationship between the TOs and the communities, SSE implemented the SSE Community Liaison Team in 2009.

Uneven playing field among stakeholders

Apart from the advertisement in the local press, SHETL and SPT are only required to notify planning authorities of the affected communities in the public consultations. As such, the communities are communicated to rather than consulted. Without a formal forum to make their voices heard, communities organise themselves in local groups, hold community meetings, run blogs, sign petitions and write letters to decision-makers. Communities along the Beauly-Denny line invested a great amount of time and money in their attempt to affect the planning process. During the public inquiry, communities had the opportunity to present their statements.

However, many community representatives found the process intimidating and extremely stressful. They were under the impression that the inquiry was simply something for show rather than a chance to reach agreement. The Beauly-Denny Landscape Group engaged both engineers and economists to prepare objections against the technical and economic cases; however, it was felt that these were not adequately taken into account (Personal interview 3, 2012). The process is thus not allowing for public participation where the public and members of the planning unit can effectively consult and negotiate on a level playing field. This view is shared by a member of the ECU, who reports of the public inquiry as an inefficient practice where the bargaining power mainly sit with the project developers (Personal interview 4, 2012). Although local stakeholders are invited to give their views, there is uncertainty regarding how much the government and developers listen. This confirms the theoretical work by Coase (1960) and the findings of North (1994) outlines earlier that it is the party with the better bargaining power that will benefit most from such institutional rule like a public inquiry.

Financial compensation to achieve increased acceptance

The use of compensation methods in connection with major infrastructure projects are relatively common and are often related to loss revenue and land to those directly affected. These methods can take a number of different forms.[23] In this context, some developers have presented innovative instruments such as offering corporate bonds by the Dutch grid company TenneT in Germany to those affected by the projects (GRID ICT, 2016). The pervious chapter explored the limitations of and the more delicate issues that tend to arise when, as in the case of grid development, compensation is also considered for those indirectly affected[24].

In the case of the Beauly-Denny project, communities with experience of generation facilities often expected some level of financial compensation (Personal interview 1, 2012). The question of compensation was also raised during the public inquiry and on community blogs where communities pointed towards successful cases of community benefits provided to host communities of wind farms in Denmark (Pylon pressure, 2010). Expressed disappointment over the fact that compensatory measures were not even considered for the Beauly-Denny project, and transmission lines more generally, was also noted.

However, representatives from SPT argued that there was no revenue margin to absorb increased expenditures from community compensations. Since it is essentially the UK consumers that finance the project, making them pay for something that is not economically justifiable will not be approved in the Ofgem framework (Personal interview 1, 2012). As part of the consent, SHETL were ordered to pay compensation on two occasions to affected communities. These measures were mandatory and thus Ofgem approved the costs of the compensations to be raised through transmission levies.

5.3.5 Discussion and policy implications

In this chapter we have shown that an economic method based on New Institutional Economic Theory can contribute towards framing and resolving conflicts arising from large infrastructure projects such transmission grid

[23] See World Bank (2012) and RGI (2015) for a generic overview of the topic and compensation methods in infrastructure projects.
[24] Also published in Tobiasson and Jamasb (2016).

developments. Settlement of such multi-party conflicts with divergent interests requires more than a simple transactional approach - for example, the use of financial compensations or similar payments. Instead, we adopted elements of a new institutional economics view of such conflicts. We were therefore able to place a better focus on the importance of the rules and norms of the wider planning and regulatory framework within which the stakeholders, including the local communities, interact and settle their disputes.

Public participation in the Beauly-Denny project

The study of the Beauly-Denny project supports the findings of previous studies where the public contribution is at a stage downstream in the decision-making process and thus of little influence (see Littlechild, 2012; Cotton and Devine-Wright, 2010). The communities did not consider the public inquiry as a sufficient forum to argue their case and saw it as just a façade, simply an attempt to calm local opposition (Personal interview 3, 2012 and Personal interview 4, 2012). In order for public engagement to be effective, it has to enter the early stages of a project, at a stage upstream the decision-making process. SHETL realised the need for increased community engagement and created the Community Liaison Team. However, not until after the public inquiry had taken place and thus long after the main bulk of oppositions had been received.

Engagement at the later stages of planning provides little scope for the potential to influence the outcome and leaves communities feeling ignored. Meanwhile, if introduced at the early stages, the integration of public engagement can improve the possibility of a successful and excelled implementation of projects (Cotton and Devine-Wright, 2010). Local involvement in the design and implementation of a project increases local understanding and support and may assist in accelerating planning and development (Herbertson *et al.*, 2009).

Furthermore Arrow (1974) notes that decision making, particularly for issues where no markets exist to determine a price, requires collective action. A number of cases are discussed in Littlechild (2012) where negotiated settlements have proven highly successful in the U.S. and Canadian regulated markets; agreements are reached faster more efficiently and at a greater social outcome. In the Beauly-Denny project, local communities reported feeling blindsided by the developers (Personal interview 3, 2012), however, communities with an established relationship to the developer or other energy infrastructure were less likely to feel this way (Personal interview 1, 2012). This confirms the theoretical work and findings of previous literature that an important aspect of relationships between communities, government and developers is the level of trust. If communities are taken seriously and listened to at the start of a project and throughout, the level of trust for developers increases. In turn, this increases the likelihood of successful communications and lowers the rise of conflicts. A higher level of trust between the stakeholders can redistribute bargaining power, facilitate negotiations and reduce transaction costs. This in turn is more likely to generate successful principal-agent relationships.

The experience from the Beauly-Denny project has significantly changed the way SHETL view and approach new grid developments. A new transmission line linking Caithness and Moray will feature over 160km of underground and subsea cable. For this project the communities and stakeholders were involved from the starting stage. In the process, the subsea/undergrounding solution was identified and ultimately favoured over an overhead line.

Specific knowledge as precondition for effective contribution

Allowing communities to take a more active role in the planning process should be done if the benefits, for example, accelerated development, outweigh the costs such as potential financial increases from the negotiation process. Communities along the Beauly-Denny line felt as if their opinions were not taken seriously and felt left out, partly because they simply did not have the relevant information and knowledge about the planning process

(Personal interview 3, 2012). It has been recognised that consumers at a general level lack knowledge of the grid, which can limit their contribution in the planning process (Devine-Wright *et al.*, 2010; Soini *et al.* 2011; Littlechild, 2012).

Knowledge and experience are two important aspects of grid development and planning, yet the consumers do not require more know-how than the responsible planning unit. It may therefore be a case for educating, perhaps not the whole communities, but their representatives as a community consultation group. More importantly though is that the future framework and process is transparent and that information is easily available to all stakeholders. The roles and tasks of stakeholders should be clearly stated before commencing new projects, an undertaking which may involve policy changes on a governmental level. This minimises information asymmetries and thus transaction costs.

5.4 Conclusions

Increased electricity generation from renewable sources is expected to play a key role in achieving climate change policy objectives. However, the current network infrastructure is not well suited for the purpose, requiring both expansion and modernisation to allow a connection of the new facilities to networks. Public opposition to transmission network developments arise due to conflicts of interests between stakeholders. The lack of information provision, transparency and communication cause uncertainty in local communities, which lead to financial, political and social strains and some projects ultimately being aborted (see Best Grid, 2015). This is an issue in the UK and across the EU. The conventional decision-making and planning procedures seem to have failed to incorporate the relevant stakeholders effectively, thus generating stakeholder conflicts and opposition from affected parties, including local communities. Providing a secure and reliable network, including connecting renewable sources to the grid, is important to ensure a sustainable green energy future.

This chapter has outlined the main issues faced by transmission developments and by applying economic thinking we have identified the potential and shortcomings of the planning process and stakeholder interactions. The case study of the Scottish Beauly-Denny project, conducted through both, first hand interviews and secondary information confirms the findings of the previous studies and showcase a representative modern transmission development. The communities along the transmission line felt ignored, excluded and disappointed of lacking communication from developers and government alike. Communities and involved NGOs' wishes to have been informed of the planned project and consulted at an earlier stage, allowing them more time to process the available information, prepare their own statements and put forward own evidence.

These testimonies illustrate the importance of increased community involvement at an early stage of the planning process. Public contribution is found to be at a stage downstream in the decision-making process and thus of little influence. However, if introduced at the early stages, the integration of public engagement can improve the possibility of a successful and excelled realisation of projects as local involvement in the design and implementation can increase local understanding and support. Moreover, trust between communities, developers and government is important for future negotiations and can be achieved through transparency and set guidelines for stakeholder engagement in the planning process. If communities are taken seriously and listened to at the start of a project and throughout, the level of trust for developers increases. In turn, this increases the likelihood of successful communications and lowers the rise of conflicts.

Furthermore, we detected that the planning process of grid developments is highly specific and requires certain knowledge and experience. For communities to understand and effectively contribute, as a consequence, it could be reasonable to specifically educate representatives from the community forming a community consultation group. Transparency in the process is likely to increase trust between stakeholders, which would increase the potential success of future consultations. In policy developments, governments must recognise the link between strong public engagement and public support and allow communities the possibility to influence planning and development.

However, it is yet to be observed and explored how similar projects proceed and whether or not the same problems and difficulties occur. It is to be expected that from a larger number of case studies more general conclusions can be drawn. Moreover, the potential for financial compensation in transmission projects provides the basis for further research. Opposition groups vented their disappointment of the lack of compensation, comparing their situation to communities hosting wind farms, which are regularly compensated through benefit schemes. In principle and in theory, the redistribution of costs and benefits to reach socially desirable outcomes is a viable and seeming solution, yet its application in practice provides numerous obstacles. This has been discussed at length in Chapter 4.

Chapter 6

Conclusions

The electricity sector is undergoing a remarkable change, supporting the overall transition required to meet policy objectives of lower carbon emissions as well as a safe and secure supply of electricity in a cost-effective manner for consumers. Electricity networks are part of the infrastructure vital to a functioning modern economy. This thesis considers specific elements of ongoing developments related to electricity networks, namely the impact on the economic regulation of networks and the new role for consumer. Achieving environmental and climate change policy targets is reliant on electricity networks adapting to changes and embracing an increased role in the electricity supply chain. The need for sensitivity to social justice and the preferences of electricity end-consumers is relatively new to network owners but is becoming increasingly important.

Chapter 2 uses qualitative analysis to present a critical comparison of input and output-based incentive regulation, using the GB electricity networks as an example, with particular focus on the treatment of consumers and consumer engagement. Consumer engagement is a relatively new concept to electricity networks but it is becoming increasingly important in order to keep up with the rapid changes. Regulatory changes are notoriously slow and can, given the high degree of regulation of networks, which includes revenue control, act as a barrier for networks to follow progress in the sector. This risks delaying the realisation of policy targets. Traditional regulatory regimes are generally focused on cost minimisation and efficiency improvements, leaving other objectives largely overlooked. With the new regulatory framework RIIO, GB regulator Ofgem introduced a wider set of objectives and outputs for network owners to deliver, including more targets for delivering timely connections, environmental impact, and customer engagement. Customers and stakeholders acted as consultants in the development process, a common feature in output-based frameworks.

We find that there are greater opportunities for constructive customer engagement within an output-based framework, given the wider range of deliverables affecting companies' revenues. It can be argued that output-based regulation provides another dimension to traditional incentive regulation and may reduce the impact of information asymmetries between the regulator and the regulated companies given the increased reliance on customer engagement.

With DNOs becoming active, rather than passive transporters of electricity, future work could consider to further investigate the blurring of the lines between distribution and transmission networks in terms of objectives.

Chapter 3 applies an empirical analysis of economic regulation of electricity networks, highlighting the issue of information asymmetries between regulated firms and the regulator and how productivity and efficiency benchmarking can aid in determining efficient costs of network owners.

Using Norwegian data on DNOs from 2007 to 2014 we estimate the impact of the type of ownership as well as electricity network-level vertical integration on technical inefficiency. We find that, relative to state owned networks in our sample, council owned networks appear to have a negative impact on cost inefficiency while privately owned do not show a significant effect. Conversely, network-level vertical integration appears to positively impact inefficiency. From a theoretical point of view this may come as a surprise given efficiency opportunities in sharing of resources and economies of scale. The result may therefore indicate, regulatory gaming by the companies, inefficient resource allocation and a need for the regulator to consider the measures in place to separate different level networks within the one owner. The regulator exposing and correcting unproductive practices will support the goal of protecting consumers from unjust energy costs and plays an important role in a well-functioning energy market.

Moreover, chapter 4 puts social justice, energy stakeholders and the high voltage transmission network in focus. The challenges discussed in chapter 1, particularly extensive build out of renewable generation, and aging assets, necessitate excessive upgrades and expansion of the network. However, many new transmission lines are facing opposition from the affected local communities on the grounds of their environmental, social and possible economic impacts. The conflicts cause delays and prolong planning, thus adding to the project costs and frustration among involved stakeholders.

The chapter reviews previous approaches applied to resolve similar conflicts, drawing on learning from other major infrastructure developments and energy projects such as onshore wind. We discussed direct compensation and benefit sharing methods, as well as property rights approaches and how these measures can play a role in reducing community opposition to grid development. However, ultimately, we suggest a socio-economic approach to grid development that is based on the concepts of weak and strong sustainability and that the environment affected by grid developments, rather than the community *per se*, can be compensated within a sustainability approach. This can be in the form of collective negotiations between the communities and the developer with the consent of the regulator and policy makers. Providing a menu of options has the potential to reduce information asymmetry, by forcing actors to reveal information about their preferences, therefore improve efficiency. The chapter provides a conceptual framework that unlocks an area of potential empirical research. Future studies should examine the practical application and the process of operationalizing the sustainability approach

Finally, chapter 5 provides an assessment of the challenges present in network development projects in a practical setting. The Beauly-Denny 400kV transmission project in Scotland is the subject of a case study. Electricity consumer and customer engagement is relatively new for electricity networks; in the energy industry, it is traditionally the retail segment of the sector that is concerned with consumer engagement. However, the need for network expansions, increased awareness of the general public, and innovation in networks basic functions necessitates greater awareness of social aspects and impact.

The Beauly-Denny project was a contentious transmission line project in Scotland that received over 20,000 objections. We find that the lack of information provision, transparency and communication cause uncertainty in local communities, which lead to financial, political and social strains. Particularly the communities along the transmission line felt ignored, excluded and disappointed of lacking communication from developers and government alike. The importance of increased community involvement at an early stage of the planning process is illustrated and public contribution is found to be at a stage downstream in the decision-making process, therefore of little influence. If introduced at the early stages, the integration of public engagement can improve the possibility of a successful and excelled realisation of projects as local involvement in the design and implementation can increase local understanding and support. Moreover, trust between communities, developers and government is important for future negotiations and can be achieved through transparency and set guidelines for stakeholder engagement in the planning process.

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Interviews

Personal interview 1. (2012, July). SSE representative.

Personal interview 2. (2012, July). SPT representative.

Personal interview 3. (2012, July). NGO representative.

Personal interview 4. (2012, October). ECU representative.

Appendices

Appendix 1

The landscape along the Beauly-Denny route

Beauly to Fort Augustus

This 50km section is predominantly routed in unpopulated moorland and forests. Several rivers and valleys are crossed the current substations at Beauly, Fasnakyle and Fort August will all be redeveloped.

Fort August to Tummel Bridge

This 77km section crosses the Grampian Mountains, areas of remote moorland, coniferous forests and river valleys. The route will follow the A9 a new substation near Tummel Bridge will be constructed.

Tummel Bridge to Braco

This 63km section crosses moorland, rivers, valleys and the low-lying landscape near Crieff and Muthill. A new substation will be constructed near Braco, surrounded by forest and moorland.

Braco to Denny

This 30km section crosses the Allan Water and the A9 before crossing moorland and the Ochil Hills. The route will cross a flat valley of the River Fourth but will avoid the main settlements as this is the most populated section of the route. A new substation will be constructed to the north-east of Denny.

Appendix 2

Timeline of the Beauly-Denny Project

2002/2003:

- Identification of the need for the power-line, planning design

2004:

January and June

- SPT and SHETL publish documents and draft routs for public consultations and initial conversations with landowners.

December

- The community group Stirling Before Pylons is constituted

2005:

July

- SPT and SHETL publish proposed route of the line

September

- SPT and SHETL submitted application to the Scottish Ministers under Section 37 or the Electricity Act 1989, to construct the line in their respective licensed areas.

2006:

April

- Formal process of consolation concluded
- Cairngorms National Park objects the proposed line
- Falkirk Council objects the proposed line
- The Highland Council raises the possibilities of health concerns and asks for further evidence.
- Perth and Kinross council object the proposal
- Stirling Council object the proposal
- SEPA support the application provided that certain matters are satisfactorily addressed.
- SNH supports the application yet requires further information of environmental impacts of certain sections of the route.

August

- Scottish ministers announce that the proposed upgrade will be referred to a public inquiry.

September

- Public Local Inquiry ordered

2007:

February

- The Beauly-Denny Landscape Group is formed opposing the project
- Public Inquiry commenced – Five local discussion sessions

December

- Public Inquiry ended

2010:

January

- Scottish Ministers grants consent to the project

- SPT consult with and meet stakeholders and community to inform the preparation of the Stirling Visual Impact Mitigation Scheme (SVIMS) Consultation Report.

September

- SPT publish the SVIMS Consultation Report and SVIMS Consultation Leaflet

November

- Pre-construction work begins
- SPT undertake voluntary consultation with stakeholders and community on the SVIMS Consultation Report

2011:

February

- SPT submit SVIMS

August

- SPT submit updated SVIMS and Stirling Council given 45 days to comment on SVIMS

December

- Final consents given by Scottish Ministers
- Woodlands and access track constructed

2012:

February

- First tower completed

2015

November

- Delivery and first energy