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Social acceptability of wind farms and electricity export:

A discrete choice econometric approach

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EXECUTIVE SUMMARY

Due to high wind speeds, particularly along the west coast, its unique position in the Atlantic Ocean, and its large ocean footprint, Ireland has a comparative advantage in wind energy over other European countries and has therefore focussed on this form of energy as the primary vehicle to achieve its renewable energy targets (Irish Wind Energy Association, 2012). For Ireland, increased interconnection and the ability to trade in renewable electricity generation could lessen the potential negative impacts of wind energy intermittency, enable surplus power to be transported elsewhere when not needed (Bahar and Sauvage, 2013, Becker et al., 2014, Abrell and Rausch, 2016), deliver cost reductions (Cleary et al., 2016, Abrell and Rausch, 2016, Pean et al., 2016) and provide diversification and energy security (Tortajada and Saklani, 2018).

Wind energy development in general can face opposition due to concerns related to environmental and physical impacts such as height, setback distance and number of turbines as well as fears over negative health and property price impacts (Onakpoya et al., 2015, Pedersen and Waye, 2007, Gibbons, 2015, Brennan and Van Rensburg, 2016, Dimitropoulos and Kontoleon, 2009). The concept of exporting wind energy can also face public acceptance issues. Exportation projects have faced criticism on the basis that the market benefits of development (e.g. reduced electricity prices) and the positive externalities (provision of decarbonised electricity and enhanced energy security) would be received by the importer (consumed by residents in the importing country), with all of the negative externalities being imposed on the exporting country (Dutton and Lockwood, 2017, Lennon and Scott, 2017) and its local residents (Brennan, 2017). Ireland has experienced difficulties in recent years developing wind energy projects for an export market, primarily due to negative public reaction (McGreevy, 2013, Duffy, 2014, McDonald, 2014); a change in UK government policy (McGreevy, 2014), and the complexity involved in designing an energy trading framework (Department of Communications Energy and National Resources, 2014).

This project addresses these issues of public acceptance and trade in wind energy development by:

1. Identifying the main externalities associated with wind-farms and how exporting the energy produced interacts with the social tolerance for these externalities.
2. Establishing how the required level of community compensation for wind-farms is impacted by the decision to export the energy produced.
3. Investigating which combination of wind-farm attributes minimises community compensation costs in the context of an integrated renewable energy framework for international trade.

To investigate these issues, a series of focus groups and surveys were carried out. Two focus groups were held with members of the public and one with policy-makers. A local-scale face-to-face survey was conducted with 253 individuals across 5 counties in Ireland. A national online survey with 1107 respondents was also carried out. Both surveys contained choice experiments to measure the acceptance of wind energy exportation and trade.

This research finds that the number of turbines and setback distance are crucial determinants of project acceptance in Ireland and, generally, the concept of exporting wind energy has a negative impact on an individuals preferences. If existing wind farms have provided employment, information, financial support and proactive participation respondents are generally more accepting but may also view the introduction of development for export more favourably. Our findings from the choice experiment used in the local surveys indicate that respondents are particularly wary of export projects if they involve shares, if respondents have strong place attachment (Devine-Wright and Howes, 2010) or perceive that the benefits are not reinvested in the area, or to have been exaggerated. If respondents do not trust the developer or if the wind farm ownership does not involve the state then they are also less likely to be in favour of export projects (Brennan, 2017). Some respondents appear to have a preference for renewable energy produced locally to be consumed locally or at least nationally and are also concerned about avoiding fines for not meeting EU targets.

Our findings show that respondents regard distributive aspects of wind farm development as important. Respondents reveal strong preferences in favour of wind farms to supply domestic requirements compared with exports even for cases where 50% of the power is retained for domestic consumption. This is consistent with research in a number of other studies (Liebe et al., 2017, Brennan, 2017, Dutton and Lockwood, 2017). We do not find a NIMBY reaction to wind farms for exports but they may cost more in terms of community benefits than domestic projects. Only 20% of the sample favoured wind farms for export, yet the choice experiment indicates that most respondents are willing to trade-off electricity exports against changes in their electricity bill. Respondents are willing to accept the highest level of wind energy exportation in exchange for electricity discounts of between €400 and €460 per household per annum. Hence, wind farm development for export is generally accepted when certain conditions are met even in counties where such opposition is strongest.

The majority of the national-scale survey respondents find renewable energy intermittency to be an important issue and derive positive utility from solutions to reduce it, particularly electricity trade. In the choice experiment, electricity trade is portrayed as a solution to intermittency, whereby excess wind energy is exported when not required and imported when needed. In the analysis, a significant majority of respondents are willing to forego a discount in their electricity bill to permit electricity trade. Concerns were expressed amongst focus group participants about overreliance on electricity imports, particularly considering uncertainties associated with Brexit. Support for the grid infrastructure required indicates preferences for underground rather than above ground cabling, however, consistent support for the former may be influenced by a lack of information on the drawbacks of undergrounding. Individuals who are highly concerned about electricity infrastructure including above and below ground grid expansion are also less likely to accept wind farm development and corresponding intermittency measures.

This study highlights the importance of the provision of local benefits and engagement in all aspects of renewable electricity infrastructure, even when the public do not reasonably expect to receive these benefits. The Green Fund in particular; which was suggested by participants in a focus group as a compensation method for local residents; results in positive utility for most respondents in the national choice experiment. Benefit provision is widely recognised as a method of increasing the acceptance of renewables and associated infrastructure amongst affected communities (Kermagoret et al., 2016, Walker et al., 2014a, Ferreira et al., 2019, Gebreslassie, 2020) however, this study indicates that it also has the ability to positively impact wider public acceptance outside of these areas. This study carries out a scenario simulation, which finds that the provision of local financial support via a Green Fund results in significant welfare gains for residents in development areas, even at relatively close setback distances and for wind energy developments involving 100% export. The provision of such a fund, which also results in significant positive utility for the public who do not directly benefit from it, could help minimize the social cost of wind energy development incorporating trade at both a local and national level.

HIGHLIGHTS

- Local residents want greater levels of participation and engagement in wind farm planning and design than is currently permitted under statutory legislation.
- Members of the public living close to wind farms which have provided employment, information, financial support and proactive participation are generally more accepting of wind farms and view the introduction of wind farms for exports more favourably.
- Individuals with experience of local community representation in the planning process are more in favour of export projects and less likely to choose a scenario that rejects new development.
- Wind farm externalities are more pronounced if they involve trade and the associated compensation costs to local communities will be greater compared to circumstances in which the power is consumed locally.
- The Irish public are supportive of trade as a solution to intermittency.
- The Irish public value the provision of benefits and engagement opportunities for residents in wind farm development areas.

INTRODUCTION

Responding to the challenge of increased future energy demand and the GHG mitigation targets of COP 21 and COP 26 (UNCCC, 2021) will require a substantial integration of renewable energy into the energy system, widespread electrification to support transport and domestic residential heating (MacDonald et al., 2016) and a corresponding increase in interconnection and trade in renewable energy sources (DECC, 2022). Meeting these goals is challenging even for countries with high potential renewable energy endowments (Taylor, 2021) partially due to the intermittent nature of power generation from renewable sources (Ren et al., 2017, Yekini Suberu et al., 2014, Energy Ireland, 2020).

Fuel combustion from transportation and domestic lighting, heating and cooking using polluting fuels are two of the biggest drivers of outdoor air pollution (WHO, 2017). Ambient air pollution causes an estimated 4.2 million premature deaths worldwide each year, causing illnesses such as heart disease, lung cancer and stroke. Due to this, governments worldwide, including Ireland, have prioritised decarbonising transport and reducing the use of polluting fuels domestically as part of a drive towards increasing electrification of the energy system (Houses of the Oireachtas, 2018). Countries across Europe have employed incentive schemes with variable success to promote the uptake of electric vehicles including financial incentives in the form of grants and indirect consumer incentives in the form of preferential access to low-emission zones, use of car pool lanes etc. Countries with a greater number of charging ports indicate higher uptake rates, helping to eliminate fears associated with limited range (Tietge et al., 2016).

In Europe, heating and hot water account for 79% of final energy use. 75% of heating and cooling is generated from polluting fuels. One of the methods to aid in reducing this is to deploy combined heat and power units which generate heat and electricity (EC, 2019). In Ireland, a range of homeowner grants are available including solar PV grants to produce electricity (SEAI, 2018).

The demand for electric appliances in the home has grown year on year. In developed countries this trend is fuelled by the demand devices like tablets, routers, and more powerful televisions. The rise of ownership of washing machines, televisions and refrigerators in emerging markets is also contributing to the global demand for electricity (Cabeza et al., 2014; IEA, 2019).

Due to this increased demand from industry, transport and heating combined underpinned by sectoral policies designed for increasing electrification countries around the world including Ireland are eager to increase the supply of renewable electricity generation to meet the increased demand for electricity in a way that can reduce overall emissions as part of the low carbon energy transition (EC, 2014; U.S. Energy Information Administration, 2019; Sharma, 2019).

Although Ireland’s potential renewable resource endowment is high, many promising technologies including wave, tidal and biomass and even solar energy are unlikely to make a significant contribution to meeting this demand in the near term. For the foreseeable future, the renewable energy sector in Ireland is likely to be dominated by on onshore and offshore wind energy. In what follows we discuss wind farm development in Ireland.

WIND FARM DEVELOPMENT IN IRELAND

Due to the high wind speeds, particularly along the west coast, its unique position in the Atlantic Ocean and from its large ocean footprint, Ireland has a comparative advantage in wind energy over other European countries and has therefore focussed on this form of energy as the primary vehicle to achieve its renewable energy targets (Irish Wind Energy Association, 2012). Ireland’s marine territory spreads far beyond its coastline, covering approximately 220 million acres meaning its potential capacity for offshore wind energy is extremely large (Marine Institute, 2014).

The first wind farm was connected in the west of Ireland in 1992. Following this, no other wind farms were connected until 1997. Development has steadily picked up pace, with over 300 wind farms currently built in the Republic and just under 400 including Northern Ireland (Wind Energy Ireland, 2022). The Irish government has introduced a target of up to 80% electricity generation from renewable sources by 2030, which is a significant increase from its current level of 36%, most of which will be derived from wind energy (Government of Ireland, 2021a). This will require up to 8 GW of onshore wind capacity; which is almost double the current capacity; and at least 5GW of offshore wind capacity, a significant increase from the current baseline of 25MW.

The electricity generated by almost all wind farms in Ireland is fed into the grid and this electricity is traded in the Integrated Single Electricity Market (I-SEM), a system of multiple auctions which cover different time frames with their own clearing mechanisms. This system is designed to integrate electricity markets and lower costs (EirGrid Group, 2016). If the demand is not available in Ireland at the time the energy is created, then this energy needs to either be stored or exported. Ireland is connected to the UK via the East West interconnector in the Republic and the Moyle interconnector in the North. In 2021 Ireland was a net importer of electricity, importing 1,672 GWh, its highest level since 2014. This shortfall in domestic electricity supply was primarily due to poor wind energy production, with electricity generation from wind down 18% in the first 10 months of 2021 in comparison to 2020. Electricity generation from gas in Ireland was also down 7% in the same period in comparison to 2020 due to technical faults (SEAI, 2022). Intermittent renewable power generation can result in a number of economic concerns including electricity outages (Csereklyei et al., 2021), curtailment (Joos and Staffell, 2018), production externalities (Percebois and Pommeret, 2019), negative electricity pricing (Brijs et al., 2015) and other unintended impacts on consumer welfare amongst countries engaged in renewable energy trade (Horst Keppler et al., 2016). The volatile nature of wind power output is widely acknowledged (Ireland 2050, 2021, Ravestein et al., 2018, Davies et al., 2021). One study which analysed Irish wind energy variability over a three year period found that in any 6 week timeframe there will be at least one 9 hour period where wind energy output is 1-6% of its average output and at least one 9 hour period where it achieves three times the average (Newbery, 2018).

For Ireland, increased interconnection and the ability to trade in renewable electricity generation could lessen potential negative impacts of wind energy intermittency. Enhanced grid connection and interconnection between countries enables surplus power to be transported elsewhere when not needed (Bahar and Sauvage, 2013, Becker et al., 2014, Abrell and Rausch, 2016), deliver cost reductions (Cleary et al., 2016, Abrell and Rausch, 2016, Pean et al., 2016) and provide diversification and energy security (Tortajada and Saklani, 2018). Grid interconnection is particularly beneficial in terms of import and export opportunities for more geographically isolated countries who have invested early in renewable energy technology such as Ireland (Becker et al., 2014). (Newbery, 2021) find that adding the proposed Celtic Link from Ireland to France could reduce curtailment in Ireland from 13.3% to 12.4% and would prevent 235 GWh of spilled wind.

However it is important to assess the understanding of the trade in renewable energy on different stakeholders and to examine its impact on them. This includes local residents, the general public and developers.

WIND ENERGY EXPORTATION AND PUBLIC ACCEPTANCE

Social acceptance of wind energy projects, both onshore and offshore, is recognised as a major concern in reaching our 2030 EU renewable energy targets and net-zero by 2050. Wüstenhagen et al. (2007) illustrate social acceptance of renewable technologies in terms of a three-dimensional framework, comprising (i) community acceptance, (ii) market acceptance and (iii) socio-political acceptance (see Figure 1). Issues arising from each dimension can influence the others. For example opposition to a wind energy development at community level can affect the outcome of local political support for the development. Socio-political acceptance of wind energy is acknowledged by the renewable energy commitments outlined in the Climate Action Plan (Government of Ireland, 2019). On the other hand, market acceptance recognises the economic benefits of wind energy investments. Community acceptance appears also to constitute a critical aspect (Ellis and Ferraro, 2016).

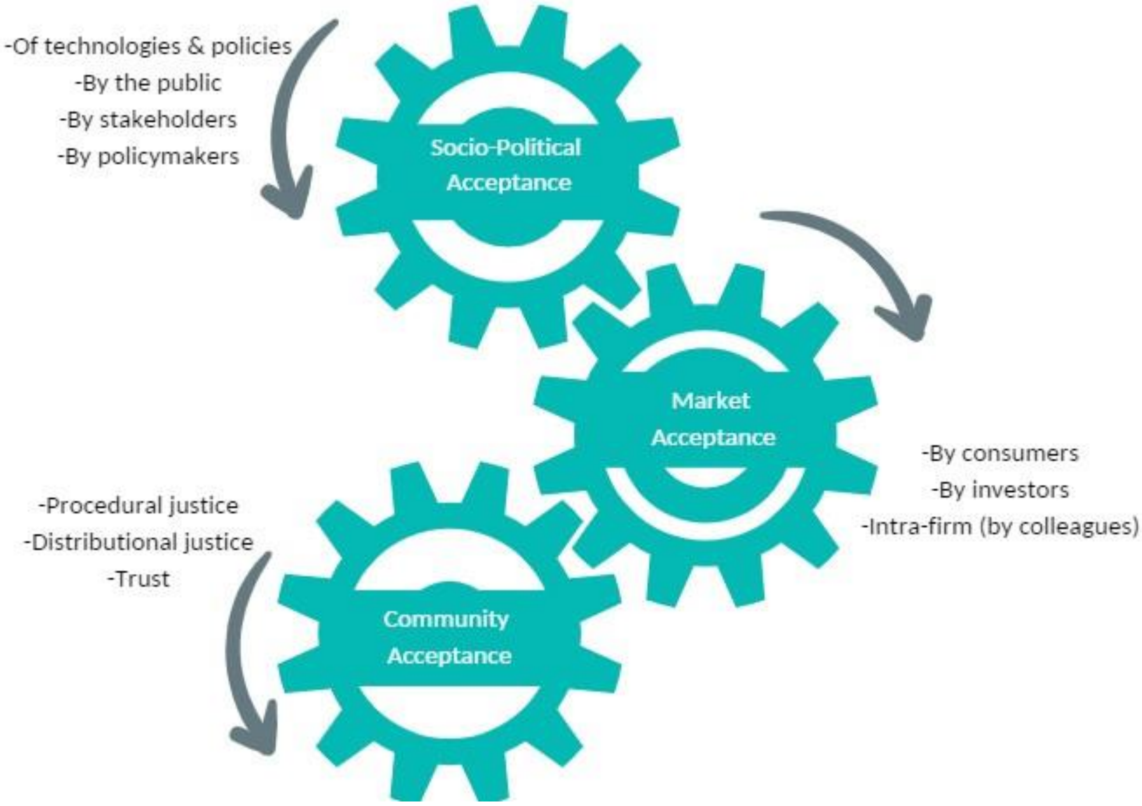

Figure 1: Three dimensions of renewable energy technology social acceptance. (Source: Adapted from Wüstenhagen et al., 2007).

Wind energy development in general can face opposition due to concerns related to environmental and physical impacts such as height, setback distance and number of turbines as well as fears over negative health and property price impacts (Onakpoya et al., 2015, Pedersen and Waye, 2007, Gibbons, 2015, Brennan and Van Rensburg, 2016, Dimitropoulos and Kontoleon, 2009).

Exportation projects have also faced criticism on the basis that the market benefits of development (e.g. reduced electricity prices) and the positive externalities (provision of decarbonised electricity and enhanced energy security) would be received by the importer (consumed by residents in the importing country), with all of the negative externalities being imposed on the exporting country (Dutton and Lockwood, 2017, Lennon and Scott, 2017) and its local residents (Brennan, 2017).

Community acceptance may be increased if a wind farm project provides positive outcomes for the local area, either through financial benefits including community benefit arrangements, share schemes, community development or increased employment (Bidwell, 2013, Chen et al., 2015, Caporale and De Lucia, 2015, Guo et al., 2015, Gamel et al., 2016). An open and transparent planning process can also increase local acceptance (Hall et al., 2013, Gross, 2007, Cohen et al., 2014) as well as early stage local involvement in the project (Hammami and Triki, 2016, Khorsand et al., 2015). Community representation has also been highlighted in the literature as a methodology for ensuring a fair process and increased engagement (Brennan and Van Rensburg, 2016).

RESEARCH OBJECTIVES

Although there may be significant economic and efficiency gains to be derived from increased trade in renewable energy, studies on the public preferences for greater interconnection and exports is limited. Studies on wind farm acceptance indicate that public opposition to renewable energy infrastructure can arise due to the physical infrastructure of development and its corresponding potential for negative local environmental and visual impacts (Leung and Yang, 2012, Bishop and Miller, 2007) noise concerns (Wang and Wang, 2015), health effects (Botterill and Cockfield, 2016), and property price impacts (Jensen et al., 2018, Skenteris et al., 2019) amongst others.

Recent studies have found the public can have negative preferences for the exportation of renewable electricity from their local wind farm and prefer to meet domestic needs first (Brennan et al., 2017, Liebe et al., 2017, Dutton and Lockwood, 2017). However, these studies have not assessed public preferences at a national scale for general wind energy exports, particularly in the context of intermittency management. Therefore, the first objective of this research aims to identify the main externalities associated with wind-farms and how exporting the energy produced interacts with the social tolerance for these externalities.

Secondly, renewable energy acceptance can often be influenced by the local benefits provided and engagement with the local community (Brennan et al., 2017, Brennan and Van Rensburg, 2016, Hall et al., 2013, Bidwell, 2016, Caporale and De Lucia, 2015). However a quantitative assessment into the preferences of near neighbours or the general public (at a national scale) for local engagement and community benefits in an export context has yet to be conducted. Therefore the second objective of this study is to assess, how the required level of community compensation for wind-farms is affected by the decision to export the energy produced.

Finally, for policy makers and the renewable energy industry it is important to identify development scenarios that involve levels of trade that are acceptable to communities but which minimise compensation costs. In order to fully incorporate the impact of increased wind energy development and trade in Ireland, other attributes, which take into account aspects of intermittency, may also be important. Consequently, the final objective of this project is to identify what combination of wind-farm attributes minimises community compensation costs in the context of an integrated renewable energy framework for international trade.

LITERATURE REVIEW

WIND FARM EXTERNALITIES

Opposition to renewable energy infrastructure such as wind turbines can arise due to their potential for negative local environmental and visual impacts (Leung and Yang, 2012, Bishop and Miller, 2007, Vuichard et al., 2022, Swofford and Slattery, 2010, Fergen and B. Jacquet, 2016, Baur et al., 2022), as well as fears over the potential health impacts (Songsore and Buzzelli, 2014, Zaunbrecher et al., 2017, Botterill and Cockfield, 2016). The human health concerns from those living near developments primarily focus on noise from the developments (Ata Teneler and Hassoy, 2021, Jalali et al., 2016, Wang and Wang, 2015, Freiberg et al., 2019). The public may also have concerns about potential negative impacts on property prices in the surrounding area of energy infrastructure development (Vyn and McCullough, 2014, Walker et al., 2014b).

COMMUNITY ENGAGEMENT

Distributive justice in the case of renewable energy is concerned with an equitable distribution of outcomes from a project and often becomes important due to local opposition arising from inequitable distribution of costs and benefits. Procedural justice is concerned with decision-making processes and the extent to which affected residents are involved in these processes (Gross, 2007). Greater engagement with local residents can take the form of local participation in the wind farm development (Ek and Persson, 2014, Brennan and van Rensburg, 2020, Brennan and Van Rensburg, 2016, Dimitropoulos and Kontoleon, 2009, Langer et al., 2017, Lienhoop, 2018); employment opportunities (Ku and Yoo, 2010, Caporale and De Lucia, 2015); local ownership of the development (Lienhoop, 2018); the provision of payments to the local authority (Ek and Persson, 2014, Lamy et al., 2020); the provision of recreational facilities (García et al., 2016); and funds earmarked for local sustainability programs (Ek and Persson, 2014, Kermagoret et al., 2016, Caporale and De Lucia, 2015). Previous work has also indicated that positive beliefs in the economic benefits associated with renewable energy development can influence acceptance (Olson-Hazboun et al., 2016, Fergen and B. Jacquet, 2016, Bergmann et al., 2008).

Figure 2 outline these aspects of fairness in planning and outcomes by indicating a space within which a commercial or community wind farm might operate (Walker and Devine-Wright, 2008).

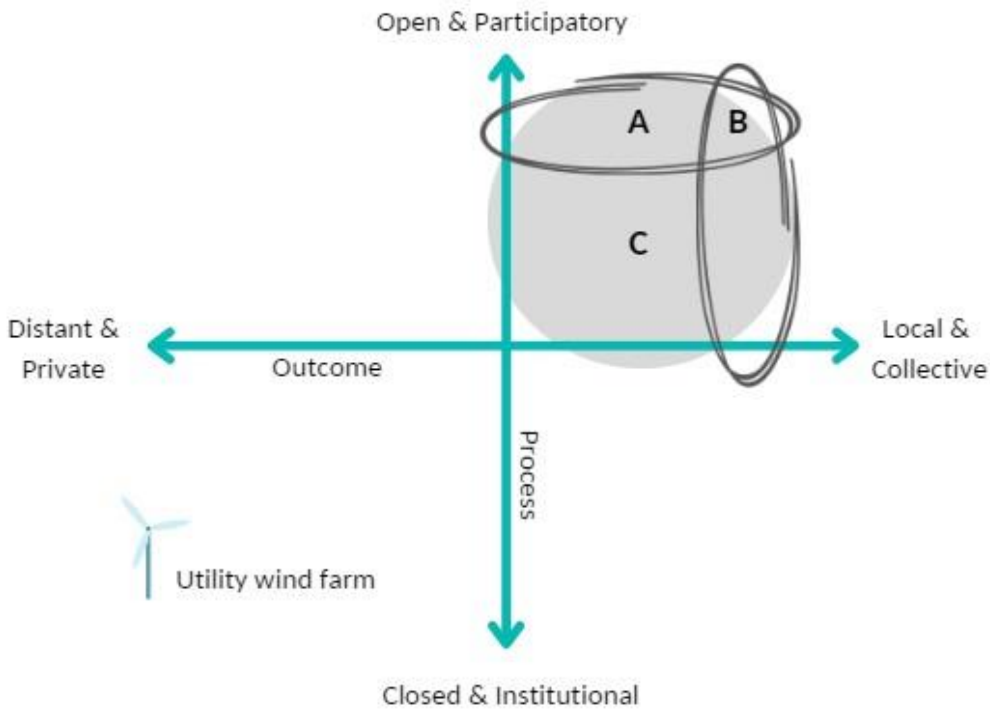

Figure 2: Understanding of community renewable energy in relation to project process and outcome dimensions (Source: Walker and Devine-Wright, 2008).

The vertical *process* aspect focuses on who develops and operates the wind farm and who can make decisions and have influence over the project. The process can range from one that is open and participatory, representing a wind farm that is transparent in its implementation and planning processes, incorporating the opinions and influences of a wide range of stakeholders; to one that is closed and institutional, with only the private operators having influence over the wind farm's operation. The horizontal outcome element relates to the beneficiaries of the project, economically or socially. These benefits can range from those which are *local and collective*, with the majority of the benefits accruing to those in the vicinity of the wind farm to those which are *distant and private* at the other extreme, with most of the benefits being received by operators or owners who do not have any connection to the area within which the wind farm is located. A traditional privately operated wind farm would be located in the bottom left of the space whereas a "community" wind farm would be located on the top right. Community projects could be those which have high levels of involvement from local residents in the establishment and running of the project (A) or those which place the majority of the benefits of the project primarily in the surrounding area of the wind farm (B). A project which leads to some productive outcome for the locality, regardless of the extent of these benefits or the degree of involvement from residents, could also be considered a community project (C).

(Hall et al., 2013) also note the importance of distributive justice, with respondents in their study suggesting methods for a more equitable distribution of project benefits for residents in the wider community. If the method of benefit provision is viewed as unjust then this can lead to social divisions. This study also highlights the importance of procedural justice, with respondents having strong preferences for planning processes that include open, participatory and transparent elements. The Figure below outlines the forms of engagement community respondents requested in this study, from the pre-proposal stage to the finished project.

Figure 3: Recommended Consultation stages (Source: Adapted from Hall et al., 2013)

Community projects have the potential to provide renewable electricity to the grid, generally on a smaller scale to that of private wind farm developments. There are benefits associated with community wind farm development over private ownership, with research suggesting that if the revenue from wind farm development was retained locally, the employment impacts could be up to eight times higher than that of a traditional commercially owned wind farm (Okkonen and Lehtonen, 2016). Local ownership also generally increases the acceptance of wind farm development (Maruyama et al., 2007, Jobert et al., 2007, Musall and Kuik, 2011, Wolsink and Breukers, 2010).

Although the average strike price in the Renewable Energy Support Scheme (RESS) auctions 1 and 2 resulted in higher average support payments per MWh for community projects (Eirgrid, 2020, Eirgrid, 2022), the vast majority of wind farms in Ireland are owned by private developers (van Rensburg et al., 2015) primarily due to a lack of access to finance and specific expertise (Power et al., 2022, Renewable Energy Partnership, 2004). RESS 2 aims to support for community energy projects, and deliver social cohesion and community development and to ensure that local communities benefit from the energy transition. The community elements of RESS 2 initially included: a community category within the RESS 2 auction which gives a route to community led projects; the provision of trusted intermediaries and advisors and the provision of information and financial support; a mandatory community benefit fund set at €2/MWh for all projects to be used to develop local communities and mandatory investment opportunities for citizens and communities in RESS projects (Department of the Environment, 2021). As a contrast with RESS 1, all projects that apply under the community category must be 100% owned by a Renewable Energy Community, rather than 51% as was the case in the previous version. The option for local communities and citizens to invest was removed from the final terms and conditions for RESS 2 (Government of Ireland, 2021b).

Arnstein's 1969 work on social programs in the US highlights a broad spectrum of community participation, and provides a framework by which true meaningful engagement can be classified.

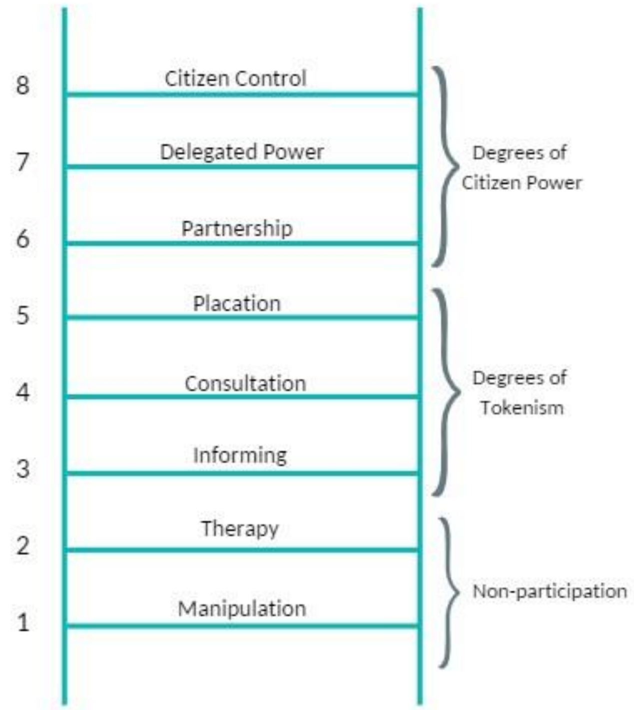

Figure 4: Arnstein's ladder of citizen participation (Source: Arnstein, 1969)

She identifies citizen participation as the redistribution of power from the "haves" (the wealthy, those in power) to the "have nots" (the poor, minorities, those lacking power). Participation allows the "have nots" to make decisions about how planning decisions are undertaken, the information provided and the distribution of benefits. In this work, she provides 8 stages or "rungs" on a ladder of citizen participation (Arnstein, 1969).

This framework can be used to classify the type of community engagement carried out by wind farm developers. The bottom rungs of the ladder are manipulation and therapy. These types of engagement are regarded as “non-participation” as their goal is not to provide the public with control over the process but rather to “educate” or “cure” them of their beliefs. This could occur in wind farm developments where members of the public in the surrounding area are not informed about the full scale of the project or where advisory meetings are really exercises in support gathering. The next three rungs are considered “tokenism”. They allow members of the public to have their say but the “haves” retain the final decision-making power. Informing residents is regarded as the first true stage towards citizen participation. This stage does not allow for resident feedback. In wind farm developments, this stage may involve the provision of newspaper articles, flyers and posters about the project and basic responses to inquiries. Public meetings may be one-way if they provide basic information and discourage questions. The next rung, consultation still does not guarantee that the public’s opinion will be taken into account. This stage in a wind farm development may involve attitudinal surveys, local meetings and public forums. Residents who engage in consultation achieve nothing more than “participation in participation” and developers have performed a box-ticking exercise. The first stage that allows citizens some influence is placation, though this is still regarded as tokenism. At this stage, a select resident may be chosen to act on a public board or in a decision making position, though he/she can easily be outvoted or bullied into submission by the power holders. Rungs 6-8 signify levels of citizen power. At the partnership stage, power is redistributed through negotiation. This can occur in wind farm developments where the developer and community actively engage and negotiate over the planned project. This occurs best when the community is organised and has the financial capabilities and time to organise its own experts and leaders. Rung 7 represents the stage at which the residents have more decision making power than the traditional “haves”. When this occurs, the “haves” must bargain with the citizens rather than only engaging once under pressure from residents. In this situation, a wind farm developer may approach a community with a proposed development prior to the planning stage and open to negotiation, rather than announce a project post-planning as a fait accompli. The final rung on the ladder of citizen participation is citizen control. At this stage, residents have the power to govern a program or development, are in charge of policy and managerial characteristics and can negotiate fully with any “haves” involved. In wind farm development, this level of participation may take the form of a community wind farm. This may still involve development and construction by private wind farm developers but residents can engage meaningfully with the private developers throughout the planning, construction and operational phases of the project. Residents have the final say over the scale and location of the project, how it is run and to whom the benefits are distributed.

Many studies have analysed public preferences for renewable energy policies and developments (Lee et al., 2020, Mariel et al., 2015, Boeri and Longo, 2017, Yoo and Ready, 2014) but few have considered the impact of the exportation of wind energy on local acceptance (Liebe et al., 2017). (Liebe et al., 2017) find that respondents prefer if they can participate in the decision making process, if the turbines are locally owned and if the electricity is consumed within the country rather than exported. Most studies also do not consider public preferences for renewable projects that provide local benefits or involvement. (Ek and Persson, 2014) find that local ownership and involvement in the development process was important to the general public, even if they did not personally benefit from such wind farm designs. It may be important to know this since it is possible that affected residents are not willing to take on the preferred type of wind energy developments identified by the public or, alternatively, the public are not willing in principle to compensate affected residents to accept them. This could be challenging for statutory authorities and the wind industry.

WIND ENERGY TRADE

Market coupling refers to the joining of two or more electricity markets to allow for the joint selling of electricity and interconnection capacity. It is designed to maximise welfare for all participants and allow for the free movement of electricity between the connected markets. In order to align with European integration, Ireland created the Integrated Single Electricity Market (I-SEM), a wholesale electricity market between the Republic of Ireland and Northern Ireland. At the end of September 2018, Ireland successfully coupled with the Great British market (Nord Pool, 2018). The integrated market is designed to break monopolies and allow for the reduced cost renewable electricity to reach the markets that require it. The market also provides incentives for using electricity when efficient (Cornélusse, 2017).

Electricity trade in Europe is carried out via a system of markets and auctions. The system consists of two ex-ante markets- the Day Ahead Market (DAM) and the Intraday Market (IDM). In the DAM, customers can buy or sell electricity for use in the next 24 hours. Orders are placed taking into account social welfare and network constraints (Nord Pool, 2019). Orders are accepted at the calculated market-clearing price, and any price difference between trading countries is due to congestion of transmission lines (Cornélusse, 2017).

In the Intraday Market, participants can make adjustments to their positions made in the DAM, typically taking the form of continuous trading during specified opening and closing times. With the addition of more renewable energy to the system, the IDM is crucial to make short term adjustments to allow for any related intermittency. Typically prices in the IDM follow those of the DAM (Glowacki, 2021).

Though the market systems outlined above are designed to smooth prices and reduce volatility, the intermittent nature of renewables can have a significant impact on the trading price of electricity in Europe. For example, there are two peak price times in Germany for electricity daily, one early in the day and one in the evening time. Prior to 2011, the early peak was at approximately midday, and was higher than the evening price peak. Since then, this trend has reversed, with the midday peak occurring earlier in the day and having a lower price than the evening peak. This is due to the high supply of renewables, solar in particular, becoming available to meet demand at midday (Khoshrou et al., 2019).

This effect of solar energy on the grid in Germany impacts on the price of electricity elsewhere in Europe. France and Germany, prior to 2012, experienced price convergence as they imported and exported electricity at different times of the day from each other. However, since 2012 the countries have experienced price divergence due to the clustered nature of solar at specific times of the day. When RES production is high, German exports flood interconnections and create price divergence between the two countries. Price convergence maximises consumer surplus, and one study suggests that while German customers may lose €265 million in consumer surplus, the gains to French consumers may be as high as €2.29 billion (Horst Keppler et al., 2016).

The trade in electricity may also hide the exchange of CO_2 emissions. It is possible for a country with “clean” electricity to be exporting renewables and to be importing dirty electricity. Storage may provide a solution to balance the burden of renewable production forcing other countries to increase their own production (Zafirakis et al., 2015). Increases in trade of electricity can also lead to increases in consumption, and therefore CO_2 emissions if the electricity consumed is not renewable (Billette de Villemeur and Pineau, 2010).

The rise in renewable electricity as a result of support schemes, the prioritisation of electricity from RES, the inaccuracy of renewable energy generation estimates and the inability of traditional energy plants (e.g. coal and oil) to quickly shut down output can lead to production that exceeds demand. This “incompressibility of power systems” has occurred in many European countries in both the DAM, IDM and real-time balancing markets (the market for power that has not been traded in advance) (Brijs et al., 2015). Between the SEM-I launch in Ireland at the end of September in 2018 and April 2019, there have been 556 half hour periods of negative pricing in the balancing market, where conventional power producers offered electricity at a negative price in order to avoid the difficult and expensive process of shutting down while wind production was high and re-starting when low (Brennan, 2019). This negative pricing can be considered as a market signal indicating the lack of low cost downward flexibility in electricity production (Brijs et al., 2015).

Ireland has experienced difficulties in developing wind energy projects specifically for energy export. In January 2013, a memorandum of understanding (MoU) was signed between Ireland and the UK initiating plans for three large wind farm developments in the midlands of Ireland which aimed to export all electricity produced to the UK by private operators Element Power, Mainstream and the semi-state body Bord na Mona. Trade in renewable energy from a project like this could be beneficial to both member states (Cleary et al., 2016), however the project did not go ahead due to a number of factors including high construction costs (O'Doherty, 2014), developers public dismissal of the concerns of the Irish public on live television debate shows (McGreevy, 2013); organised Irish protests against the development (McDonald, 2014); bilateral UK and Irish Governmental disagreements (Duffy, 2014); the UK Government's inability to make key decisions (Department of Communications Energy and National Resources, 2014); a change in the UK Conservative Governments energy policy away from wind energy in favour of fracking, oil and nuclear power instead (McGreevy, 2014) and the economic, political and regulatory complexities of designing an energy trading framework by 2020 (Department of Communications Energy and National Resources, 2014).

There are a number of solutions for the issues raised by trading RES, the aims of which are primarily to increase flexibility. These solutions include encouraging conventional energy generators to invest in more flexible technologies to allow for quick downward movements in output, the application of more energy storage, interconnection and improved forecasting (Strbac et al., 2015).

INTERMITTENCY MANAGEMENT

A variety of solutions have been proposed to address the problem of intermittency for wind energy including energy trade, storage solutions and electricity demand management. These are discussed in detail below.

GRID INFRASTRUCTURE DEVELOPMENT

European 2030 targets require investment in grid infrastructure to ensure renewable energy can be exported from countries with a comparative advantage to those without. In many areas of the world, including the EU, the expansion of renewable energy development and trade is restricted by aging and inadequate grid infrastructure (ENTSOE, 2018, Schlachtberger et al., 2017, Gulagi et al., 2017, Antweiler, 2016) and so improvements and developments are required.

The Ten Year Network Development Plan (TYNDP) is a Europe-wide infrastructure development project which aims to improve electricity interconnections throughout Europe. The main aims of this project are to keep the costs of decarbonisation as low as possible and to ensure security of supply (ENTSOE, 2018). This improved interconnection could reduce emissions throughout Europe and result in large welfare gains, up to 3.31 billion dollars by 2050. Enhanced transmission networks which allow for imports and exports of renewable energy will be crucial to capture the full benefits of renewable energy generation in Europe (Abrell and Rausch, 2016).

The benefits associated with increased interconnection and trade include cost reductions (Cleary et al., 2016, Abrell and Rausch, 2016, Pean et al., 2016, Antweiler, 2016, Timilsina and Toman, 2016, Bogdanov and Breyer, 2016), the potential to include more variable renewable energy (Becker et al., 2014, Abrell and Rausch, 2016) and diversification and energy security (Tortajada and Saklani, 2018). Grid interconnection is particularly beneficial in terms of import and export opportunities for more geographically isolated countries who have invested early in renewables, such as Ireland (Becker et al., 2014).

From an Irish perspective, the development of greater interconnection with the UK may not lead to a large export benefit and increased wind energy penetration. In fact, interconnection may result in greater imports from the UK if the wholesale price is greater in Ireland. This will continue until the price equals that of the UK or up to the maximum capacity of the interconnector. In one simulation of increased interconnection, Ireland experienced reduced prices, an 80% increase in imports and 23% increase in exports. However this increased interconnection did not increase wind generation significantly in Ireland. Rather than an increase in wind energy production, baseload non-renewable energy reduced due to the imported energy supplied. While this scenario would result in reduced emissions in Ireland, this would be counteracted by increased emissions in the UK (Denny et al., 2010).

Grid infrastructure development can also face opposition by local authorities who disagree with the locations and local residents who have environmental and health concerns. A report by the EU in 2006 highlights the serious opposition faced by project planners. One project connecting Italy and Switzerland took 12 years to complete due to delays related to local opposition. These issues were only resolved once compensation mechanisms were provided and environmental impact mitigation measures were carried out. Other projects were seriously delayed due to local authorities disagreement over the location, local fears over environmental and tourism impacts and the health impacts from electromagnetic fields. Project planners note that in order to get projects through local actors must be involved, the project must be negotiated in a fair and transparent manner and incorporate local facilitators (European Commission, 2007b). These local acceptance issues often arise from a lack of concrete regulations (Battaglini et al., 2012), the visual impacts (Lienert et al., 2015, Bertsch et al., 2016) potential health impacts of grid infrastructure (Jay, 2007, Zaunbrecher et al., 2017), the environmental impacts (Sumper et al., 2010), a lack of transparency and community involvement in the planning procedures (Ciupuliga and Cuppen, 2013, Hyland and Bertsch, 2018, Steinbach, 2013) and a lack of information in general on the project, potential impacts and benefits (Komendantova and Battaglini, 2016).

Residents tend to show strong support for underground cabling rather than standard above ground pylons (Devine-Wright and Batel, 2013). However, this support may be due in part to a lack of information on the drawbacks of undergrounding. Placing grid cabling underground is difficult and much more expensive than the over-ground alternative. It also does not resolve health fears that residents may have, particularly related to magnetic fields, which are stronger just above an underground line the than just below an over-ground line. Underground lines also necessitate the removal of trees and other vegetation resulting in land-use restrictions. Providing the public with more information on these negatives reduces the perceived benefits of underground versus over-ground lines (Lienert et al., 2018). Acceptance of grid development may not indicate support; while residents understand and accept the need for infrastructure in terms of meeting energy needs this does not necessarily mean that they are in favour of such developments (Aas et al., 2014). While those living in areas with underground cabling may perceive themselves to be less impacted by grid expansion this does not necessarily translate into support for grid expansion or reduced proclivity to protest further development (Mueller et al., 2019).

BATTERY STORAGE

Another approach to the intermittency problem is wind energy storage. When production outpaces demand, wind energy can be stored and used when demand is at its highest. This helps to smooth out any potential peaks and troughs associated with intermittent renewable energy. The Electricity Supply Board (ESB) in Ireland provides battery solutions to major electricity consumers so they may charge at low tariff hours to avoid peak prices (ESB, 2019). Ireland is a relatively new adopter of energy storage, but the country has seen rapid growth, with one of Europe’s largest battery storage facilities to date, based in the Irish midlands, coming online in December 2020 and plans recently announced for a further 1GW of storage across the island of Ireland (Grundy, 2021).

There are potential disadvantages to wind energy storage. Firstly, selection of the correct form of storage is difficult as each technological solution offers its own potential shortcomings. Flywheel storage technology (a mechanical storage option) can have fewer environmental impacts than other types but has a lower energy density and higher associated cost. On the other hand, high energy density options such as Ni-Cd batteries can have negative environmental impacts. Other potential issues with storage solutions include risk of explosion (hydrogen), high land requirement (pumped hydroelectric storage), safety concerns (NaS battery) and health issues (Super conducting magnetic energy storage) amongst others (Ayodele and Ogunjuyigbe, 2015).

Storing off-peak renewables for use in peak times also has the potential to increase emissions. In situations where renewables are not the primary source of electricity, storing off-peak wind energy means increased use of non-renewable energy at this time. If the emission rates of those producing energy during peak times are not significantly below the emission rates of those producing at non-peak times then this can lead to increases in short-term emissions (Carson and Novan, 2013).

Another potential issue centres on the ownership of the storage facilities. The introduction of storage can smooth distortions by lowering electricity prices for consumers and producer profit, which reduces the arbitrage value for storage. One study suggests that by shifting off-peak energy to peak times the loss in arbitrage value can be up to 20% for 1 GW of energy (Sioshansi et al., 2009). Therefore, despite the potential net welfare gains from the introduction of storage, storage owners may not behave in a way that maximises external welfare and may instead choose to act in a self-interested manner. Independent storage owners will under-use storage given that they do not reap the external benefits and are overly sensitive to the possibility of reducing the price differences between peak and off peak times. Similarly, if the electricity generators were to own the storage units, they too will tend to under-use the facility given the reduction in producer profits in shifting off peak electricity to peak times. Consumers, if they own the storage facilities will tend to over-use, given the fact that they do not internalise the loss in producer welfare. These effects are lessened in a perfectly competitive situation, where storage is owned by an independent competitive storage facilitator, no electricity generator has market power and consumers do not have monopsony power (Sioshansi, 2010).

Despite these possible issues, there are few studies that examine attitudes toward electricity storage using stated preference techniques, and those that do tend to concentrate on domestic scale or storage for business. Although (Kalkbrenner, 2019) finds that respondents would prefer to choose no storage system, (Gallassi and Madlener, 2014) reports that PV owners prefer external control and maintenance of the storage system to reduce any technical knowledge burden and studies that analyze the attitudes of solar PV purchasers find preferences for direct ownership of storage facilities over use rights (Kalkbrenner, 2019, Gährs et al., 2015). According to (Harajli and Gordon, 2015), company owners strongly prefer an electricity system driven by renewable energy that includes battery storage to lessen their reliance on diesel backup generators. Thomas et al. (2019) carried out a qualitative investigation.

Thomas et al. (2019) used deliberative workshops to carry out a qualitative study on public acceptance of storage in the UK. They discover that individuals underestimate the difficulty presented by rising levels of renewable energy production and have expressed worries about safety, dangers, equity, and the effects on disadvantaged groups. The public's preferences for battery storage facilities to lessen the intermittent nature of renewable energy sources have not been examined in any research on stated preferences.

DEMAND SIDE MANAGEMENT

Intermittency can also be handled through demand response techniques such as demand smoothing with smart grid technologies and consumer price alerts, in which consumer behaviour is modified to lower peak load. It has been suggested that a large number of users is not necessary to have an impact on the grid (Tchuisseu et al., 2019).

One such option for demand side management is the installation of smart meters. According to a thorough assessment by Sovacool et al. (2021), the number of smart meters placed worldwide increased by 3013% between 2010 and 2019 and to date, more than 800,000 of these meters have been installed in Ireland. According to industry trials, adjustments in electricity use can result in peak demand reductions of 8% and average consumption reductions of up to 3%. (ESB, 2021). An analysis of smart meters across the EU revealed small energy reductions of 2% to 10%, as well as financial savings of €230 for gas and €270 for electricity, spread out over 15-20 years (European Commission, 2019a). The use of the smart grid may be impacted by temporal considerations. In New York, Bugden and Stedman (2021) evaluate the use and acceptance of smart meters before and after their rollout. They discover that potential cost savings on bills and perceptions of how utilities treat consumers can cause social acceptance and adoption of smart meter technologies to decline over time.

Although demand side management of the energy system is still a relatively new technology in Europe, there is a sizable body of literature on the subject that discusses stated preferences (Gobiowska, 2020). According to a number of studies on readiness to accept demand side management, the general population values autarky highly and is averse to giving up any control over their energy consumption (Broberg and Persson, 2016, Daniel et al., 2018). According to research by Huh et al. (2015), Gobiowska et al. (2021), and Ruokamo et al. (2019), respondents do demonstrate a readiness to engage in demand-side measures if they feel doing so will enhance the energy system or if they receive a sizable reward for their efforts. The perception of usability and awareness of environmental issues may influence someone's willingness to utilize a smart grid or price alert system (Buryk et al., 2015, Ruokamo et al., 2019). In most stated preference studies demand side management is typically discussed independently, rather than in conjunction with other supply side intermittency management tactics like storage or trading.

METHODOLOGY

The following sections outline the methodology used in this research, including focus groups, local and national surveys, choice experiments, multinomial logit models, random parameters models, latent class models and principal components analysis.

FOCUS GROUPS

Focus groups are frequently conducted as part of the survey creation process at the beginning of non-market valuation research (Brennan and van Rensburg, 2020, Brennan and Van Rensburg, 2016, Ek and Persson, 2014). Focus groups allow for interactions, which can be particularly helpful when discussing new renewable energy projects, which are frequently associated with conflict, uncertainty, and top-down decision-making, and can provide "depth" in responses and insights into the sources of complex behavior and motivations (Cass et al., 2010, Spiess et al., 2015).

Three focus groups were held between January and March 2020 in order to identify relevant features and potential motivations underpinning preferences. Two public focus groups were held with seven members of the public in each. Two members of local councils, a representative of the Department of Housing, Planning, and Local Government, an employee from the Renewable Energy Support Scheme, and a representative of the Sustainable Energy Authority of Ireland participated in a policy makers' focus group.

Public focus group attendees discussed renewable energy targets, wind energy intermittency and export, grid infrastructure issues, onshore wind vs offshore wind and their preferences for engagement with wind energy developments. The policy maker focus group attendees discussed issues related to the provision of information and consultation, renewable energy targets, accountability and wind energy intermittency and export. Each focus group lasted approximately 90 minutes. Public focus group attendees also took part in an exercise to identify the most important attributes and levels of each for wind energy development.

The public focus group participants generally had positive opinions on electricity trade, but some expressed worries about security of supply, cost increases brought on by Brexit, and the likelihood that local residents would gain. Although it was acknowledged that there was an absence of knowledge regarding the effects of developing grid infrastructure, it was noted that underground cabling was generally preferred to above ground cabling.

One participant proposed a "green fund" for community members, which was positively received by the group as a prospective benefit that developers might offer. It was suggested that this fund may be used to support local homeowners' upgrades to their homes' energy efficiency, such as solar panels and insulation. The public participants saw battery storage as the key means of addressing intermittency, although members of both groups also emphasized the lack of knowledge on potential adverse effects of battery infrastructure and the requirement for impartial, unbiased information.

Relevant outputs from both the public and policy maker focus groups are outlined in the results section.

CHOICE EXPERIMENT SURVEY: NATIONAL AND LOCAL

Following the focus groups a national-scale public survey was designed with sections exploring attitudes to environmental issues and intermittency as well as a choice experiment to explore trade-offs between several intermittency solutions and local benefit options. The choice set alternatives within each attribute were established based on the literature on common intermittency solutions (Jones et al., 2018, Albani et al., 2016, Broberg and Persson, 2016, Kalkbrenner, 2019, Brennan and van Rensburg, 2020) and local community benefits (Brennan and Van Rensburg, 2016, Krueger et al., 2011) and through the focus group discussions. A willingness to accept structure offering reduced electricity bills for wind farm development that incorporates better intermittency management was chosen following previous studies which have analysed public preferences for wind energy and intermittency solutions (Brennan and van Rensburg, 2020, Kim et al., 2021, Broberg and Persson, 2016, Gołębiowska et al., 2021, Ruokamo et al., 2019).

A professional survey company conducted 1107 online surveys in Ireland between August and November 2020. Each respondent had to complete six choice sets in the survey. In each choice set, respondents were given three options for controlling future wind energy in Ireland; options A and B offered combinations of the final attributes and levels within these attributes, while option C offered the status quo, or "No new wind farm development," as an option. The following are the final attributes and levels:

Table 1: Final national survey choice set attributes and levels

Attributes	Information Provided	Levels
Intermittency Management	Wind electricity can be intermittent - the wind may be blowing at times of low electricity demand and may not be blowing at times of high electricity demand. This can be managed through:	**Battery Storage**: Excess wind electricity is stored in batteries around the country for later use. **Exporting & Importing**: Excess wind electricity is exported when not needed and electricity is imported when needed. **Price Alerts:** Electricity suppliers will provide alerts to consumers (by text/email/app notification) the previous day on the cheapest times to use electricity and rates (based on excess wind electricity availability). **None:** No intermittency management.
Local benefits	Benefits provided to local area	**Local Authority Benefit:** One-off monetary benefit donation to local authority. **Green Fund:** Fund to finance environmental improvements for residents within 5KM of the development (e.g. grants for home heating, insulation, solar panels etc.) **None:** No specific benefit to local area
Community representative	This refers to the presence or not of a community rep to provide information and updates about the development to locals and meet with the developer to present concerns and negotiate on behalf of the community	**Yes:** There is a Community Rep **No**: There is no Community Rep
Electricity discount	This refers to the discount in euro **in your annual electricity bills** due to the increased use and management of renewable electricity.	€110 €280 €450 €620

The intermittency solutions offered here are not alternatives and a combination of these is likely to be required in the future (Ren et al., 2017, Abrell and Rausch, 2016). However, the choice experiment structure enables respondents to trade-off each attribute in order to provide more detail on general preferences for each option. Additionally, respondents received a practice choice card that elaborated further that the respondent was the recipient of the hypothetical electricity discount and that locals in wind farm development areas would receive the benefit funds.

The results in this report also incorporates data gathered from a smaller face-to-face survey (253 respondents) which also involved a choice experiment. The aim of this survey was to establish local preferences for wind farm development, the key determinants of acceptance from communities in development areas, and how the exportation of wind energy interacts with these preferences.

The attributes and levels are indicated in Table 2 and were evaluated and tested in a pilot survey. The design of the choice sets was updated once after the pilot results were tested. Five final attributes including a payment attribute were determined. The survey provided respondents with 12 choice tasks to complete, offering them two options for local wind farm development and the status quo option of “no new wind farm development”.

Table 2: Final local survey choice set attributes and levels

Attributes	Information Provided	Levels
No. of wind turbines	This indicates the maximum amount of turbines in this wind farm for the project lifetime (20 years).	8 20 40
Export level	This indicates where the energy produced from this wind farm will be used. The wind energy could be 100% domestic (used totally in Ireland); 100% Export (used totally outside Ireland); or 50% domestic 50% export (used both in Ireland and outside Ireland).	No export 50% domestic & 50% export 100% export
Setback	This refers to the minimum distance that these new turbines will be required to be spaced from your home	500m 1000m 1500m
Community control	This refers to the level of control and information your local community will have over the planning and development of the wind farm. The levels of control could be Low (your community are informed about the development but cannot make changes); Medium (your community are informed and consulted and their opinions may be considered) or High (the developer and your community actively negotiate the planned wind farm together and inform one another throughout the development/at all times).	Low Medium High
Electricity discount	This refers to compensation paid to you for this wind farm development, in the form of a discount in your electricity bills each year over the project lifetime (20 years).	110 280 450 620

MULTINOMIAL LOGIT MODEL

Three planning choices for wind farms are presented to respondents in this analysis, including a status quo option that denotes no more wind energy development. Respondents choose the option from these three that gives them the most personal utility. This choice may be analyzed using a logit structure because it can be seen as the likelihood of choosing one of these three possibilities. Due to the large number of option sets that would arise from a full factorial design containing all conceivable combinations of attributes and levels, a sequential experimental Bayesian framework is used, with a Multinomial Logit Model (MNL) providing the base outputs.

The Independence of Irrelevant Alternatives (IIA), which presupposes that the chance of choosing option A over option A' is independent of the range of other alternatives in the choice set, is one of the limits of the MNL model, which can provide information on some observed heterogeneity.

This study also uses alternate models that do not assume this restriction, such as a Random Parameters Logit (RPL) model and a Latent Class Model (LCM).

RANDOM PARAMETERS MODEL

In a random utility function with random parameters, a respondent i's utility from selecting alternative j in choice situation t can be defined as follows:

$$U_{jti} = V_{jti} + \varepsilon_{jti} \equiv \beta'_{ik} X_{jtik} + \sigma'_k z_i X_{jtik} \varepsilon_{jti} \quad (1)$$

where respondent i $(i = 1, \ldots . i)$ obtains utility U from choosing alternative j (Option A, B or C) in each of the choice sets t $(t = 1, \ldots 12)$.

The utility has stochastic term (ε) and a non-random component (V). The assumption is that the non-random component is a function of the vector of k choice specific attributes: X_{jtik}, with corresponding parameters β_{ik} that may vary randomly between respondents due to preference heterogeneity with a mean β_k and standard deviation σ_k. The six attributes in this vector are: TURBINES, HEIGHT, SETBACK, CITIZEN CONTROL, EXPORT, COMPENSATION, and the alternative specific constant (ASC) reflecting the status quo option (this takes a value of 1 when the respondent chooses the option of no new wind farm). The ASC also captures all the attributes erringly excluded from $\mathrm{X_{jtik}}$ and the utility associated with not choosing the status quo. It is assumed that the individual chooses the option i that provides them with the highest utility.

In the RPL framework preferences are allowed to vary across individuals and coefficients are characterised by a distribution which depends on certain parameters e.g. the mean and covariance of the distribution. By introducing individual specific characteristics, z_i, sources of preference heterogeneity can be identified. These variables are interacted with the choice-varying attributes $\mathrm{X}_{\mathrm{jtik}}$. The RPL model described above will therefore identify two types of variation in preferences, the variation associated with individual specific characteristics (e.g. income) and a random, unobservable and unconditional preference heterogeneity captured by the standard deviation σ_k of the distribution of each random parameter β_{ik}. If this standard deviation is statistically significant, than the coefficient does actually vary across individuals, as opposed to the MNL model where homogenous preferences are assumed for all respondents. Given a specific distribution these parameters can be estimated by a simulated maximum likelihood estimator using Halton draws. Halton draws are "pseudo-random" sequences that simulate independent draws from a uniform distribution and are more efficient than standard random draws. It is recommended that a range of Halton draws of between 100-2000 draws are carried out (Hensher et al., 2005).

LATENT CLASS MODEL

The LCM assigns different marginal utility levels to each class and divides individuals into groups according to how likely it is that they belong to that class. For instance, an LCM can show that high income respondents are more likely to belong to one class while allowing for the possibility that they may belong to a different class with a lower likelihood. A LCM structure allows us to evaluate the marginal utility parameters that come from various classes and identify the set of external factors that influence a person's preferences.

As outlined in (Dillingham, 2016), the LCM assumes that the likelihood of an individual i selecting option j in choice set t is a function of that individuals class membership c. The choice probability density function for individual i can be denoted as:

$$P\,(y_i|z_i) = \sum_{c=1}^{c} P(c\colon z_i)\ \prod_{j=1}^{J} P\,(y_i\colon x_i|c\,) \qquad (2)$$

where y_i refers to the full set of choice responses which lead to maximum utility for individual i, with y_i=0 if individual i selects option j in choice set t and 0 if they do not. z_i denotes certain characteristics associated with individual i and x_i is the combination of attribute alternatives and levels within each individuals choice set.

$P(c: z_i)$ refers to the probability of respondent i being in class c which is unconditional on y but varies with z_i. z_i is comprised of individual covariates, which in this paper refer to renewable energy and climate change beliefs and demographic factors.

Through the inclusion of an electricity discount as a payment vehicle, the willingness to accept for each class c can be determined as:

$$WTA_{(k|c)} = \frac{\beta_{(k|c)}}{\beta_{(e|c)}} \tag{3}$$

where β_k is the utility coefficient for a non-monetary attribute k and β_e refers to the utility coefficient for the electricity discount.

PRINCIPAL COMPONENT ANALYSIS

Principal component analysis is a method of decreasing the dimensions in a dataset by reducing the number of fields into those that help explain the majority of the variance. Data gathered from Likert-scale questions is frequently used for this. Incorporating a technique like PCA with choice experiments can aid in identifying the social elements that may have an impact on the heterogeneity of preferences for a renewable energy project and enable the evaluation, in monetary terms, of the trade-off between attributes (Strazzera et al., 2012). This method in combination with choice experiment data can reveal greater information on the probability of an individual $i's$ membership of class c.

If X is a vector of n data fields with population variance-covariance matrix Σ, then Σ can be determined as:

$$\Sigma = \sum_{i=1}^{n} \lambda_{ie_ie_i'} \tag{4}$$

where λ_i represents the eigenvalues and e_i the eigenvectors. The principal components can be are classified as:

$$\begin{aligned} Y_1 &= e_{11}x_1 + e_{12} + \cdots + e_{1n}x_n \\ Y_2 &= e_{21}x_1 + e_{22} + \cdots + e_{2n}x_n \\ &\cdots \\ Y_n &= e_{n1}x_1 + e_{n2} + \cdots + e_{nn}x_n \end{aligned} \tag{5}$$

While incorporating all possible n covariates would explain all variance, this would not lead to a reduction in the amount of data. However, if the X variables are correlated then a significant proportion of the variance can be explained while at the same time reducing the data size.

RESULTS:

In the results section we first present the demographic information for the sample. Next, we outline the results that pertain to the first objective: assessing the externalities of wind energy in Ireland and impact of export on preferences. Following this, the results are outlined for the second objective: examining the impact of community compensation on preferences for exporting wind energy. Then finally we present the results for the third objective: minimising community costs in an integrated energy network including trade.

DEMOGRAPHICS

Descriptive statistics for the national survey population and corresponding national statistics are outlined in Table 3.

Table 3: National survey demographics

Variable	Survey results	National statistics
No of respondents	1107	
Gender (percentage share of females)	56%	50%
Highest education: Primary school[a]	2%	4%
Highest education: Secondary school	43%	30%
Highest education: Third level	55%	51%
Age: 18-24[b]	10%	7%
Age: 25-34	20%	18%
Age: 35-44	20%	20%
Age: 45-54	20%	17%
Age: Over 55	30%	31%
Live less than 4Km from a wind farm	11%	
Do not live near a wind farm	43%	
Selected status quo for each choice set	2%	

[a] Central Statistics Office (2020).

[b] Central Statistics Office (2016).

These findings suggest that the national survey sample had a higher proportion of females, younger respondents, and respondents with higher levels of education. The national sample differs slightly from the CSO numbers in terms of education because respondents aged 18 to 55+ are included, but the CSO study only looks at those between the ages of 25 and 64. Similarly, our survey sample includes those aged 18–24, while the CSO age profiles only cover people who are between the ages of 20 and 24. These variations are not uncommon in choice experiment studies (Ek and Persson, 2014, Strazzera et al., 2012, Brennan and van Rensburg, 2020).

Additionally, 253 in-person surveys were conducted throughout 6 Irish counties. Table 4 provides demographic information for the local survey. The gender distribution for the counties surveyed is similar to the regional gender distribution, albeit the local sample had somewhat more male respondents than female ones. Previous research has shown that gender can influence environmental issues (Susaeta et al., 2011, Ek and Matti, 2014, Ek and Persson, 2014). So, to test for any gender impacts, interaction terms were made using the attributes TURBINES, EXPORT, and SETBACK.

Table 4: Local survey demographics

Variable	Sample respondents	Population statistics from survey counties
No of respondents	253	
Gender (percentage share of males)	52%	50%
Average age	55	38[a]
Over 65	34%	12%[a]
Retired	20%	13%[a*]
In paid employment (full or part-time)	53%	59%[a*]
Proportion with higher education	22%	24%[a*]
Income less than national median of €32,000	37%	50%[b*]
Turbines 500m or less from home	4%	
Turbines 1000m or less from home	15%	
Turbines 1500m or less from home	32%	

The sample values for age and retirement are greater than the mean results for these counties because of the rural areas surveyed. Approximately 42% of the 65 and over population in Ireland reside in rural areas (Connolly et al., 2012). Although fewer respondents earn less than the national median income, employment and education figures are similar to the average for the studied counties. According to economic theory, individuals with lower income levels should receive more utility from higher compensation levels than their more financially secure counterparts. To test for this, three dummy variables were created to represent incomes below €24,000 per annum (p.a), income ranging from €24,000-€63,000 p.a and income over €63,000 p.a. These were then interacted with the compensation attribute: LOW INCOME*COMP, MID INCOME*COMP, HIGH INCOME*COMP.

OBJECTIVE 1: EXTERNALITIES OF WIND ENERGY IN IRELAND AND IMPACT OF EXPORT ON PREFERENCES

The following section provides the focus group, survey and choice experiment results for Objective 1. The survey results are outlined for both the national survey provided online to 1107 individuals across Ireland and the local sample of 253 respondents. The choice experiment results are based on the choice sets provided to the local sample.

FOCUS GROUP RESULTS

The focus groups (two public and one developer) were semi-structured in format and the public focus group attendants discussed renewable energy targets, intermittency, grid infrastructure development and community engagement.

When asked if they had a preference for where their electricity comes from the majority preferred electricity from renewables because of its capacity to protect the environment and reduce emissions. One respondent indicated that nuclear was a possibility because living close to the UK Ireland already faces risks from nuclear energy but does not receive the benefits. It was also seen as cheap, clean energy. Wave energy, hydro and solar energy was also discussed.

Respondents would prefer not pay more for green electricity indicating that if it was taxed correctly it shouldn't be more expensive. Some indicated that they would possibly pay a minimal increase of 5%.

In terms of where the energy comes from cost was the major factor. It was indicated that Ireland can produce plenty of its own energy and it shouldn't have to depend on imports. The Celtic interconnector between Ireland and France was mentioned and respondents indicated that it would be best if energy was generated locally because of the possibility of local employment and investment, that it would be easy to maintain by local engineers and locals would have more control over the price.

In terms of exporting energy, it was preferred that only the excess was exported and that locals needs should be met first. The group indicated that people don't know where their energy comes from and that nobody cares. It is not possible to filter to ensure you receive "good" vs "bad" electricity and that green electricity should be advertised better.

Respondents in both of the public groups took part in a group task in which they chose their "best case scenario", "2nd best case scenario" and "worst case scenario" for a new hypothetical wind farm which would be built near them from a list of attributes, outlined in Table 5 (see appendix for full list and levels). All participants were asked to consider the merits of each attribute independently and after choosing their best case starting position, were then asked to agree attributes that they were willing to negotiate on. For both groups, it was important that wind farms were placed at the greatest setback distance, that all grid infrastructure was underground and that they received the highest amount of information and interaction from the developer.

For Group 1 the largest battery storage facility was seen as a benefit to the local area, particularly if the project was 100% community owned and if the majority of the energy was to be retained in the local area. The highest number of turbines was selected as best as it was preferred to have fewer farms of larger numbers than smaller but more scattered wind farms. The tallest wind turbines were selected with the logic that fewer wind farms would then be required to create more energy. This Group also preferred the largest electricity discount.

Table 5: Focus group task results

Attribute	Group 1: Best Start Position	Group 1: Best End Position	Group 2: Best Start Position	Group 2: Best End Position
Setback	1500m	No change	1500m	No change
Information	All information & ongoing interaction	No change	All information & ongoing interaction	No change
Export level	10% Export	50% Export	-	-
CO_2 Reduction	Highest level	2nd highest level	Highest level	No change
No of Turbines	40 turbines	20 turbines	-	-
Grid development	All cabling underground	No change	All cabling underground	No change
Turbine height	200m	No change	-	-
Community ownership	100%	50%	100%	No change
Battery farm	2 acres (largest)	No change	-	-
Elec Discount	50% (largest)	25% (2nd largest)	-	-

When asked on their willingness to compromise, participants did not believe that developers would provide a 50% electricity discount and so moved this attribute to 25%. They debated but finally would not compromise on grid development. Residents agreed to allow for 50% energy export as due to a community ownership share, this could lead to local benefits. They were willing to reduce the number of wind turbines to the second highest level due to the fact that they were using the tallest turbines, and so greater numbers of turbines may not be required. It was also suggested that if they own 50% they would like to maximise their investment and so would like to keep the taller turbines. This reduction in numbers led them to reduce the end CO_2 reduction to the second highest level believing the greater number to be unrealistic. They would not move on the largest battery storage option viewing it as a compensation from the developer for the compromises they made on the other attributes, particularly export. Participants refused to reduce the highest information level.

Group 2 had difficulties in deciding on levels for many of the attributes, deeming them too site specific and would not negotiate on any of the levels they selected, however they recognised that wind farms would not be built with this structure. 1500m was selected as the best case scenario due to the reduced likelihood of negative outcomes such as shadow flicker, noise, TV and mobile reception interruption and property price impacts. Participants highlighted that they preferred the highest CO_2 level as a concession for "living with" the wind turbines, but needed more information on the actual positive CO_2 benefits. Underground cabling was preferred due to the reductions in visual, health and property price impacts. It was felt that greater community ownership would engender trust in the development and lead to the highest local benefit. Although the highest electricity discount was generally preferred, participants would not agree on this unanimously due to its potential to cause divisions in the local community. Although participants initially indicated no concern with 100% export so long as benefits came locally, they ultimately couldn't decide on the best level. This group in general indicated greater concerns about the environmental impacts of renewable energy, grid infrastructure and battery storage and placed a lot of importance on the need for increased information and local community benefits.

In the policy maker focus groups, participants discussed issues related to the provision of public information and engagement, target accountability and energy exports and variability. Participants noted the need for greater public engagement, community involvement and local benefits to increase acceptance of increased renewable energy and grid infrastructure development. Although participants acknowledged the visual disamenity associated with wind energy development, it was generally agreed that strong wind energy opposition comes from a vocal minority and not is representative of the general public. Electricity trade with other jurisdictions through interconnection was seen as an integral part of intermittency management, though it was acknowledged that the increased infrastructure required for this may face public acceptability issues. It was also highlighted that the public would likely become active participants in intermittency management and electricity policy in the near future through demand side management strategies which incorporate smart meters and grids and domestic micro generation. In order to assist with information provision it was suggest that public meetings should be held at community level to deliver the message that by 2040 Ireland will be zero carbon. Participants noted the need to change focus from specific development and to discuss challenges with communities as part of an overall picture rather than at a micro level.

NATIONAL SURVEY RESULTS

In the national survey respondents were asked to indicate their level of agreement from 1 (no agreement) to 5 (full agreement) with the following statements;

- I am in favour of onshore wind farm development
- I am in favour of offshore wind farm development
- I am in favour of building wind farms in Ireland specifically to export wind energy to other countries.

"Don't know" responses are classified as 0.

40% of respondents are fully in favour of onshore wind farm development, 55% are fully in favour of offshore wind farm development and 28% are fully in favour of wind farms for exporting energy only. These results suggest that export only wind farms attract the most disagreement with 16% disagreeing entirely with this type of development in comparison to the onshore (5%) and offshore (2%) results.

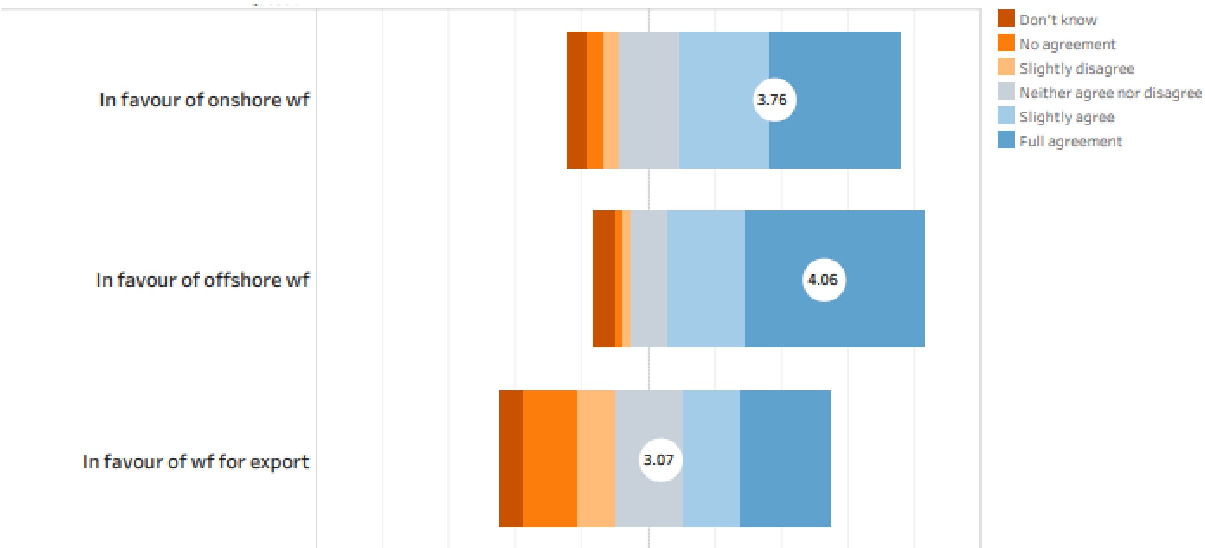

Figure 5: Attitudes towards onshore, offshore and export only wind farms

In order to assess reasons underlying this hesitancy towards export-only wind farms, respondents were asked how reliable they believed wind energy was in terms of its ability to meet Ireland's electricity needs. The majority of respondents believe that wind energy is reliable enough to meet over 50% but under 100% of Ireland's electricity needs (62%) and few respondents believe that wind energy is reliable enough to meet less than 20% of Ireland's energy needs.

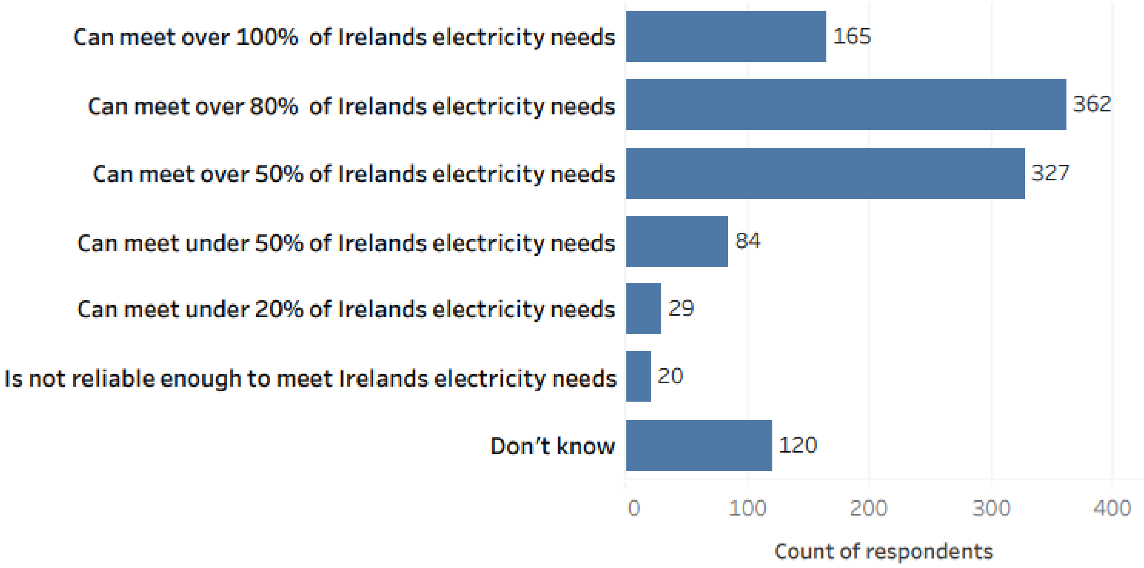

Figure 6: How do you feel about the reliability of wind energy in Ireland?

Although this indicates that respondents are generally positive about the reliability of wind energy in Ireland, this suggests that relatively few believe that wind energy is reliable enough to generate power over and above the needs of the Irish consumer (15%). To elaborate further on this, respondents were asked if they believed that there was enough wind energy currently generated in Ireland to possibly export the surplus. 51% of respondents believe there is not enough wind energy generate to meet Irish consumer needs and just 5% believe that there is enough surplus wind energy currently generated to export.

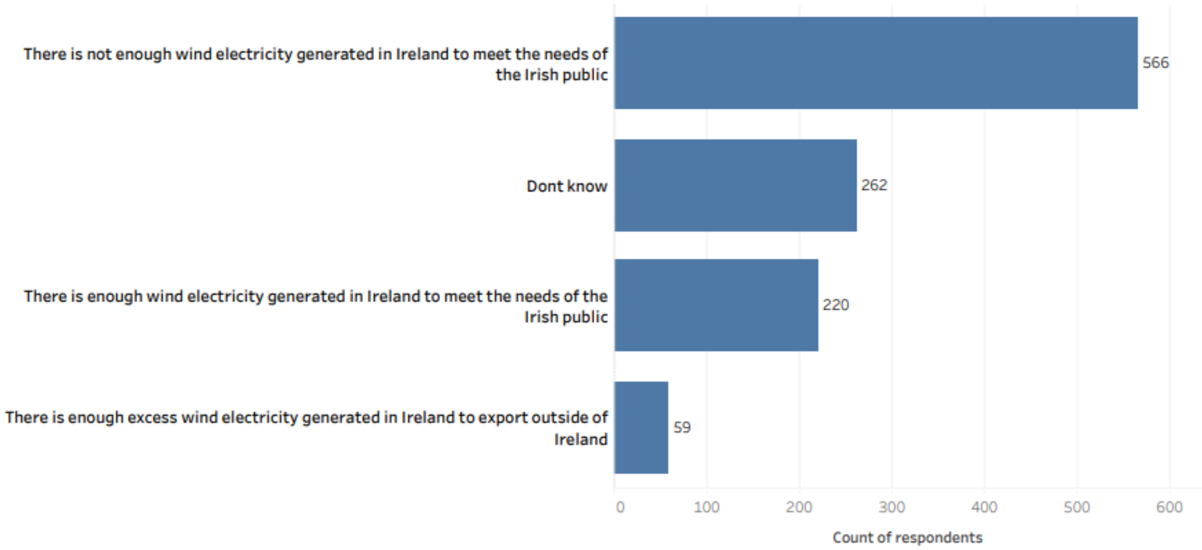

Figure 7 : How do you feel about the current level of wind electricity generation in Ireland?

To further assess attitudes towards wind energy exportation, respondents were asked their level of agreement from 1 (no agreement) to 5 (full agreement) with statements related to wind energy exportation. "Don't know" responses were categorised as 0. Most respondents either agree or fully agree (69%) that each country should develop renewable energy to meet their own needs. Many respondents also agree or fully agree (46%) that limiting wind energy exports will increase the amount of energy available to Irish consumers. Although 46% of respondents agree or fully agree that exporting will lead to significant monetary benefits to the state, many respondents answered "don't know" to this statement (21%). 42% of the sample agree or fully agree that exporting energy could generate many jobs. Although 42% of the sample also agree or fully agree that limiting exports could mean fewer wind farms developed, about 21% responded "don't know". Finally, 32% of the sample believe that exporting will lead to cheaper electricity prices in other countries, although 28% of the sample responded "don't know" to this statement. These results suggest that most of our respondents generally agree that there are high benefits associated with exporting wind energy but that each country should be developing renewable energy to meet their own needs. There does appear, however, to be some lack of knowledge related to monetary benefits and what greater or fewer exports could mean for the level of wind energy construction in Ireland.

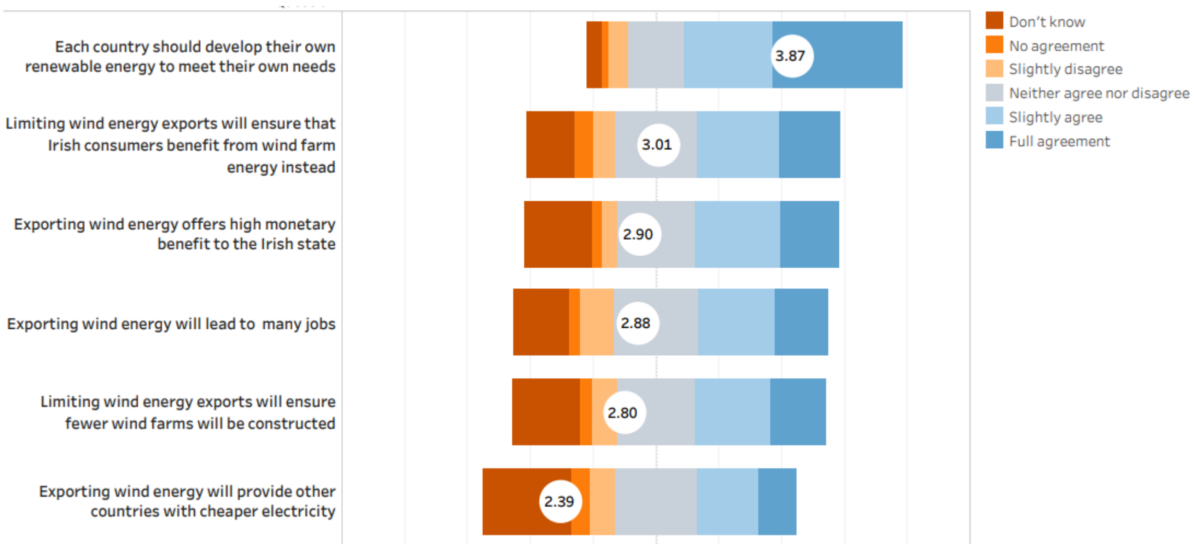

Figure 8: Export agreement statements

In order to test if the source of information about wind energy exports is important to respondents, the survey sample was split into four groups. Each of the groups received the same statement:

[SOURCE] say that wind energy exports and imports will be required to manage the supply of electricity in Ireland and that exporting wind energy can offer benefits to the Irish state.

The source provided to the respondents was one of the four following: University researchers (278 respondents); the Irish government (280 respondents); the ESB (273 respondents) or wind farm developers (276 respondents). Each respondent indicated whether they agreed, disagreed or didn't know their level of agreement with the statement.

Table 6: Export agreement by information source

Agreement	Uni Researchers	Irish Govt	ESB	Wind farm dev
Agree	58.3%	57.9%	61.2%	50.4%
Disagree	8.6%	16.4%	9.2%	12.7%
Don't know	33.1%	25.7%	29.7%	37.0%

Respondents were most likely to agree with the statement when the source was the ESB and least likely when the source was wind farm developers. Respondents were most likely to disagree with the statement when the source was the Irish government and least likely when the source was university researchers.

As a follow on exercise, those who indicated "disagree" or "don't know" to the previous statement were asked the reason behind their disagreement from 4 possible options.

Table 7: Reason for disagreement by information source

Reason	Uni Researchers	Irish Govt	ESB	Wind farm dev
I do not agree with the statement	29.2%	8.7%	32%	25.7%%
I do not trust the source of information	16.7%	47.8%	28%	34.3%
I do not agree with the statement and I do not trust the source of information	37.5%	39.1%	40%	34.3%
Other reason	16.7%	4.3%	0%	5.7%

Respondents were most likely to indicate that they disagreed because they didn't trust the source of information when it came from the Irish government and least likely to indicate this reason when it came from university researchers.

LOCAL SURVEY RESULTS

Local residents were also asked their level of agreement with onshore, offshore and wind farms specifically for export. As with the national sample, local respondents appear to be less favourable towards wind energy development specifically for the exportation of wind energy, in comparison to onshore and offshore wind energy. 39% of respondents were fully in favour of onshore development, 56% of respondents were fully in favour of offshore development and 20% of respondents were fully in favour of wind development for export. These attitudes differ according to location (see Appendix).

The majority of respondents agree that it is important to achieve renewable energy targets and that renewable energy should remain in the area where it is generated. 29% of respondents fully agree that limiting exports will ensure fewer turbines are constructed and 35% believe that fewer exports mean Irish consumers will benefit from renewable energy. This corresponds with Brennan et. al. (2017) and Westskog and Winther (2014) who find that respondents believe that increased exports means less cheaper electricity available for residents in the generating country.

Although 30% of respondents fully agree that exporting energy offers high monetary benefits to the Irish state only 16% fully agree that jobs will be created. This reflects the results of Brennan et. al. (2017) which found that many respondents believed that the employment opportunities promised from the proposed Midlands exportation development were either exaggerated or entirely false.

The majority of respondents (74%-76%) fully agree with the three place attachment statements. These responses vary considerably by location, with Donegal respondents in particular indicating the importance of green and fairness issues and disagreeing with the benefits of export projects (see Appendix).

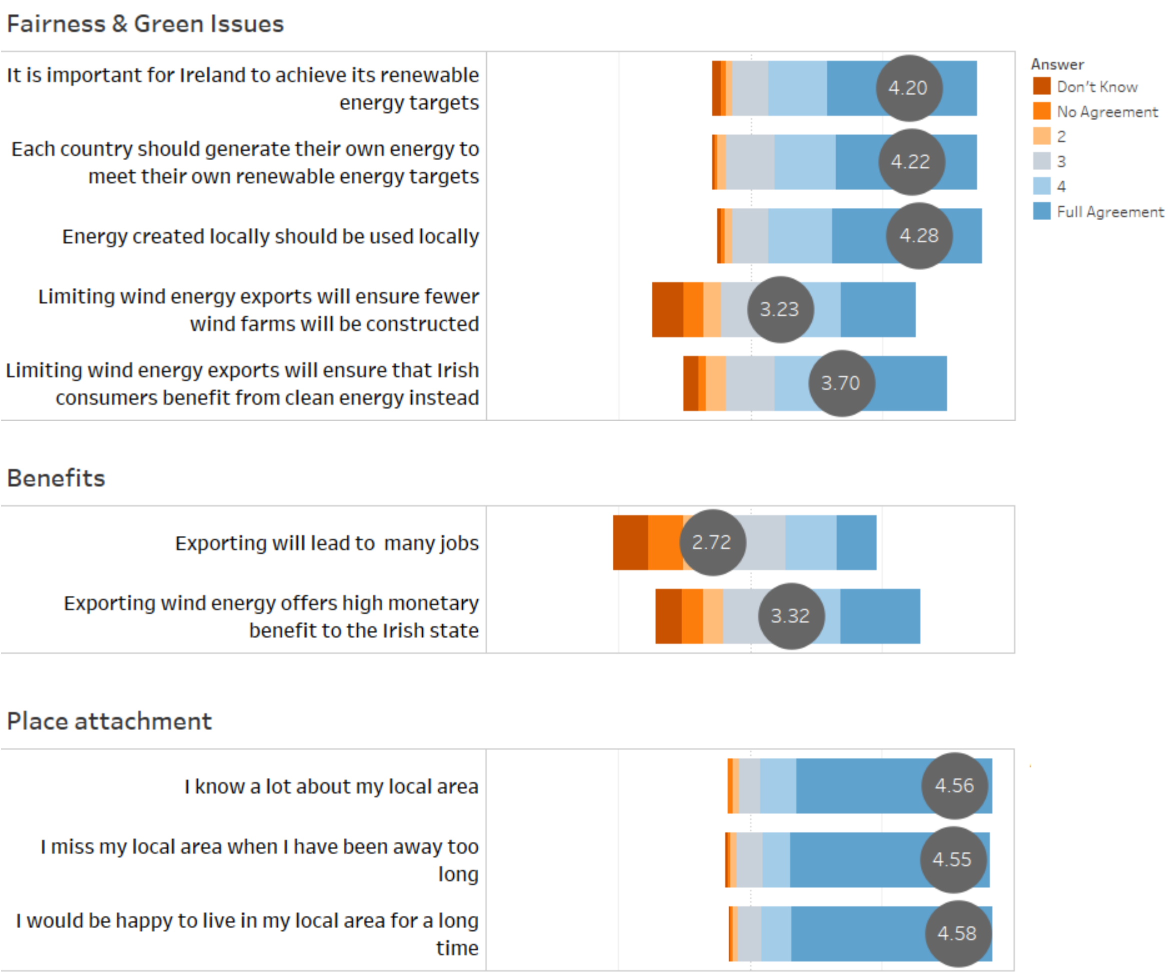

Figure 9: Fairness & green issues, export benefits & place attachment

Local respondents were also asked if their nearest wind farm developer cooperated/ cooperates with the community; provided/ provides financial support to the local community and provided/ provides information to the local community.

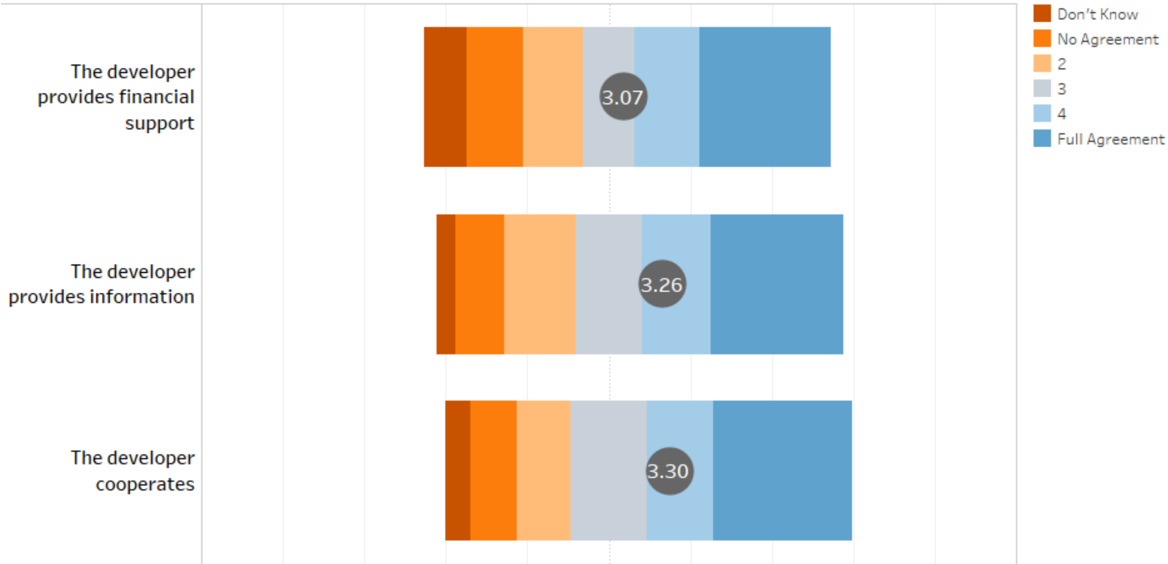

Figure 10: Developer cooperates, provides financial support & information

Although the results suggest that most respondents generally agree that developers cooperate, provide financial support and information, these results vary significantly based on region (see Appendix).

According to research, offering financial incentives can boost public support for the construction of wind farms (Bidwell, 2013, Caporale and De Lucia, 2015, Guo et al., 2015). In order to assess if experience with financial benefits influences respondents willingness to engage with the wind farm process, interaction terms were created between a score of 4 or above for agreement with the financial support statement and the citizen control attributes: FINANCIAL*CIT LOW, FINANCIAL*CIT MED, FINANCIAL*CIT HIGH.

The local survey respondents were asked to list the ways that the closest wind farm benefits their community. Non-cash benefit was the most frequently mentioned benefit, while "other" was the least frequent. Window blinds that reduce shadow flicker, a facility for cycling and walking, road improvements, water system improvements, and donations to the church are some of the benefits listed under the "other" category. Respondents who indicate that employment is generated as a result of the wind farm are the most positive about exporting wind energy. People who claim that a local representative was made available also have positive perceptions regarding exports.

Respondents who claim that shares were offered are more critical of export development and rate exports lower than people who claim there is no benefit available. In contrast, people who reside in locations where share schemes were provided are strongly in favour of development of on and offshore projects for domestic consumption (see Appendix).

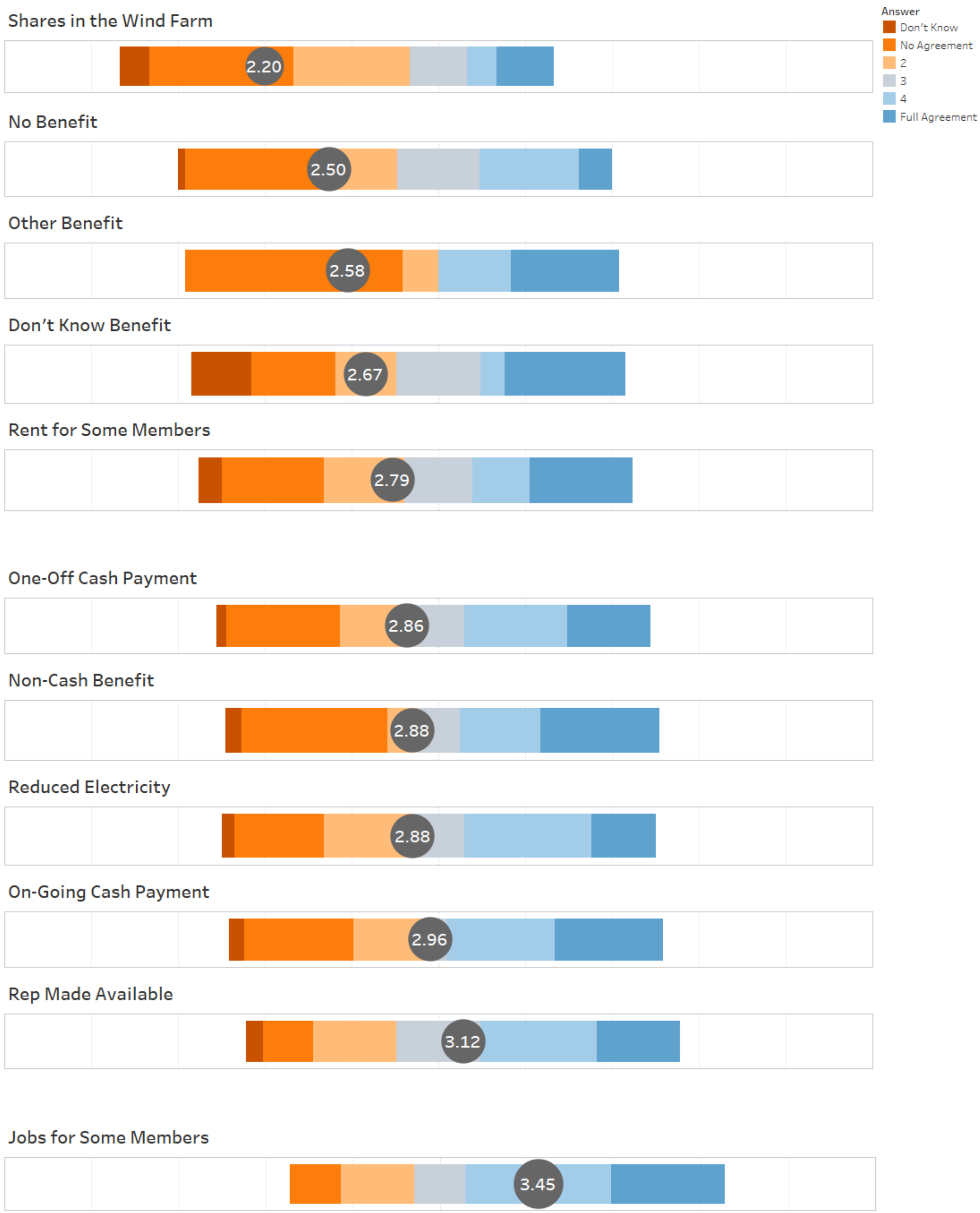

Figure 11: Impact of benefits on attitudes to exports

Previous research indicates that the provision of a community representative could increase the acceptance of a wind farm project (Brennan and van Rensburg, 2016). In order to test if those with experience of representation are less likely to reject new development, the variable Rep (1 if rep was present, 0 otherwise) was interacted with the STATUS QUO option of no new wind farm: REP*SQ.

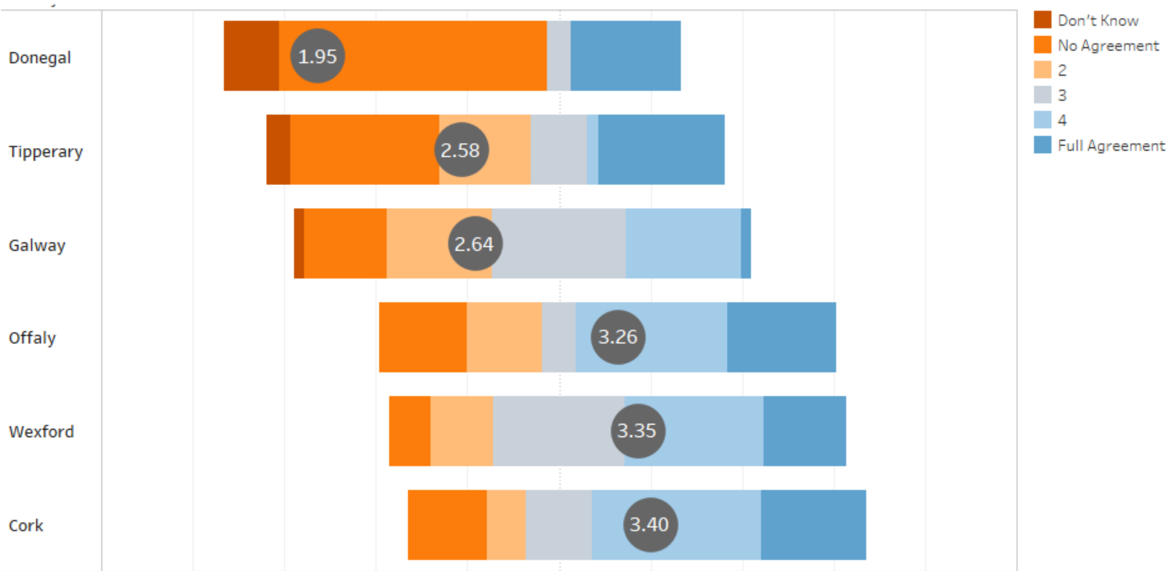

Figure 12: Exports and location

According to an analysis of respondents' opinions toward exports by county (Fig. 13), respondents in Cork and Wexford are the most supportive, while Donegal respondents are the most averse to this kind of development. Compared to just 17% of responses in Cork, 59% of respondents in Donegal express complete opposition to exportation initiatives. Donegal has the most wind farms, the greatest number of turbines, and the greatest number of turbines per resident of any of the six counties studied. Despite having the second-highest number of wind farms and turbines among the sample counties, Cork has the fewest turbines per capita. According to this data, respondents from Donegal seem to be less in favour of export development than respondents from other regions (see Appendix).

Table 8: Number of turbines by location

Counties	No. of turbines	No. of Wind Farms	County Population [a]	No. of Surveys
Donegal	280	34	159,192	58
Cork	187	23	542,868	35
Galway	170	8	258,058	44
Tipperary	101	16	159,553	40
Wexford	79	12	149,722	34
Offaly	28	1	77,961	42
Grand Total	845	94	1,347,354	253

[a] Central Statistics Office (CSO), Ireland, Population at Census 2016 by County.

The number of surveys that were conducted in each site is also shown in Table 8. The county analysis in the Appendix cannot be generalized to represent the preferences of every resident of these counties due to the small total sample size, but it may provide an indication as to the experiences of those living near certain types of wind farms. In order to test if this effect for Donegal reflects in the model, interaction terms were created with the export attributes: DONEGAL*NO EXPORT, DONEGAL*EXPORT 50:50 and DONEGAL*EXPORT 100%.

LOCAL CHOICE SET MODEL RESULTS

This section presents the modelling results from the choice sets provided to 253 respondents in the face-to-face survey. The modelling was conducted using NLogit 5. Twenty eight percent of respondents chose the status quo option, irrespective of the combination of attributes presented. All respondents are included in the analysis.

The results from the three models—a multinomial logit model (MNL), a random parameters logit model (RPL), and an RPL model with interactions—are presented in Table 9. These interaction terms give insight on preferences that may be influenced by a number of different factors and are not just related to the attributes. The analysis examines how factors including income, gender, location (particularly Donegal), and the experience of local financial benefits and community representation affect preferences for the attributes.

The Multinomial Logit (MNL) model assumes the Independence of Irrelevant Alternatives (IIA). This assumption was tested using the Hausman test in Nlogit [1]

The results from these tests (estimating 3 restricted models, one for each choice set option) resulted in *p*-values of 0.00 in each scenario, therefore we reject the IIA assumption for the model. This implies that the MNL model may not be the most appropriate for this analysis and that a less restrictive model, such as the RPL should be considered (Hensher et al., 2005).

[1] . This is a two-stage test; the first stage estimates an unrestricted model with all alternatives, following this a model with restricted alternatives is estimated (Hensher et al. 2005).

Table 9: Parameter estimates (standard errors in parentheses)

Attributes and interactions	MNL Coeff (s.e)	RPL Coeff (s.e)	Std dev	RPL with interactions Coeff (s.e)	Std dev
TURBINES	-.00072	-.00969**	.05351***	-.01829***	.05510***
	(.00194)	(.00490)	(.00544)	(.00706)	(.00584)
EXPORT 50:50	-.15403**	-.34164***	.17544	-.26755*	.27335
	(.06624)	(.09696)	(.19030)	(.15141)	(.21261)
EXPORT 100%	-.30225***	-.45656***	.71167***	-.52647***	.58858***
	(.06644)	(.10695)	(.12391)	(.15762)	(.11803)
SETBACK1000M	.25113***	.65662***	.62435***	.47255***	.62758***
	(.07149)	(.11504)	(.14183)	(.16323)	(.14183)
SETBACK1500M	.40194***	.87357***	1.01812***	.61249***	.88444***
	(.06137)	(.11533)	(.12844)	(.15649)	(.12367)
CITIZEN MED	-.12837**	.03698	.49119***	.25414**	.53147***
	(.06060)	(.09084)	(.13961)	(.12819)	(.13759)
CITIZEN HIGH	-.25129***	-.22681**	.72541***	-.34381**	.82973***
	(.06181)	(.10137)	(.12113)	(.14702)	(.12442)
COMP	.00021*	.00100***		.00133***	
	(.00013)	(.00019)		(.00023)	
ASC	.20421***	.27521	6.55677***	.89849**	6.25115***
	(.07624)	(.31706)	(.67552)	(.37430)	(.60866)
MID INCOME*COMP				-.00081**	
				(.00059)	
HIGH INCOME*COMP				-.97326D-04	
				(.00059)	
REP*SQ				-3.45636***	
				(.83599)	
MALE*EXPORT50:50				.09730	
				(.18959)	
MALE*EXPORT100%				.37612*	
				(.18959)	
MALE*TURBINES				.01485*	
				(.00875)	
MALE*SETBACK1000M				.34666*	
				(.20966)	
MALE*SETBACK1500M				.45190**	
				(.20817)	
DONEGAL*EXPORT50:50				-.59603***	
				(.22823)	
DONEGAL*EXPORT100%				-.63083***	
				(.23651)	
DONEGAL*CITIZEN MED				-.23320	
				(.23483)	
DONEGAL*CITIZEN HIGH				-.35490	
				(.18330)	
FINANCIAL*CITIZEN MED				-24957	
				(.18330)	
FINANCIAL*CITIZEN HIGH				.37283*	
				(.21365)	
Log- Likelihood	-3292.6824	-2204.7028		-2183.5438	
McFadden Pseudo R^2	0.33	0.34		0.35	
A.I.C	2.175	1.464		1.459	
No. of respondents	253	253		253	
No. of observations	3036	3036		3036	
No. of Halton draws		500		500	

Standard deviations are calculated for the RPL models, provided in the fourth and sixth columns in the table. The parameters for each attribute with the exception of the payment vehicle (COMP) are designated as random parameters with normal distributions. The compensation attribute is fixed, as is fairly usual in the literature, to better enable willingness to accept (WTA) evaluation and prevent extremely high marginal WTA estimates (Doherty et al., 2013). This is a strong assumption and it must be noted that it implies that the marginal disutility of income is constant between respondents (Thiene and Scarpa, 2009). Although log-likelihood estimators for other distributions (triangular, uniform, etc.) were tested, the outcomes were not statistically different from those of the normally distributed models.

The RPL models have improved goodness of fit indicators over the MNL in terms of a lower Akaike information criterion[2] (AIC), improved log-likelihood function[3] and improved pseudo R-squared[4] values, with the interacted model resulting in the best fit. This indicates that some of the heterogeneity in preferences can be accounted for through the interactions.

Due to significant standard deviations for most attributes in the RPL models, we can assume the presence of unobserved heterogeneity in preferences and that the parameters for these attributes differ depending on the respondents and choice decisions. Given this, the RPL models over the MNL are more appropriate. However, the standard deviations for the EXPORT 50:50 attribute are insignificant in both RPL models which may suggest that preferences for export may not differ across respondents.

For each model, the TURBINES coefficient, which reflects increases in the number of wind turbines, is negative. This indicates that respondents experience decreased utility for additional turbines. The final

[2] The AIC measures the quality of models for the data provided, generally the lower the number the better the model fit.

[3] The log-likelihood can be used along with other measures to indicate goodness of fit. Log-likelihood is maximised therefore a higher result indicates a better result.

[4] With the McFadden pseudo R^2, the log likelihood of the intercept model is interpreted as a total sum of squares and the log likelihood of the entire model as the error sum of squares. The pseudo R^2 in a logit model cannot be directly compared to that of a linear model, though the two are related (Domencich and McFadden, 1975). Generally pseudo R^2 between 0.30 and 0.40 can be compared to results between 0.60 and 0.80 in a linear model (Hensher et al, 2005).

RPL model with interactions contains a highly statistically significant coefficient for TURBINES. Additionally, prior studies have revealed that respondents derive less utility from larger wind farms (Dimitropoulos and Kontoleon, 2009, Brennan and Van Rensburg, 2016). The MALE*TURBINES interaction coefficient is statistically significant at 10% and is positive. The negative attitude towards new turbines may be partially accounted for by the preferences of female respondents, which is consistent with other research (Brennan and Van Rensburg, 2016).

EXPORT is classified as a dummy variable in all model iterations, indicating a change from a base export level of 0% to 50% export and 100% export, respectively. When moving from a no export condition to one with increasing levels of export, there is a loss in utility, as indicated by the fact that both EXPORT dummy variables are negative. This is in line with the findings of Liebe et al. (2017), who discovered that respondents benefited by retaining the electricity generated domestically. MALE*EXPORT50:50 is positive but not significant in the interacted model, but MALE*EXPORT100% is positive and significant at 10%. DONEGAL*EXPORT 50:50 and DONEGAL*EXPORT 100% are both statistically significant negative coefficients. This suggests that male respondents may derive positive utility from higher levels of export, but Donegal residents in particular derive strong negative utility from increases in exportation. As male respondents are slightly overrepresented in the sample (52%) this could mean that the results for the EXPORT attribute could be marginally understated, particularly for the EXPORT 100% level.

The welfare gains to the respondent from greater distances between turbines and dwellings are shown by the coefficient SETBACK, which is also presented as a dummy variable. The baseline measurement is the distance of 500 meters between respondents' dwellings and the proposed wind farm. The additional settings, SETBACK 1000M and SETBACK 1500M, denote an increase in setback distance from the base level of 500m and 1000m, respectively. According to very significant and positive coefficients for each model, greater distances improve respondents' welfare, which is consistent with earlier studies (Ladenburg and Dubgaard, 2007, Westerberg et al., 2013).The interactions MALE*SETBACK1000M and MALE*SETBACK1500M are positive and significant at 10% and 5%, respectively, indicating that male respondents in particular find larger setback distances beneficial. The fact that there are slightly fewer female respondents in the sample and males appear to have positive utility for increased setback distances suggests that the results for setback are moderately greater than results for a balanced gender sample.

The dummy variable CITIZEN also represents the transition from low levels of community interaction to medium levels that include consultation or high levels that include active participation and negotiation. The highest level of engagement produces negative utility across all three models, indicating that respondents do not favour an option that calls for greater community involvement and effort. In the MNL model, a moderate level of engagement also has a negative impact on residents' utility. This level is positive but insignificant in the RPL model without interactions. This attribute is positive and significant at 5% in the best fit RPL model with interactions, indicating that residents indeed value engagement that goes above tokenistic levels. The interactions DONEGAL*CITIZEN MED and DONEGAL*CITIZEN HIGH are both negative but insignificant. The interaction FINANCIAL*CITIZEN MED (the local developer provided financial support interacted with the medium level of engagement) is negative and insignificant however FINANCAL*CITIZEN HIGH is positive and significant at 10% suggesting that those who have experienced the financial benefits of wind farm production in their community are more likely to view active participation in development as an advantage.

Respondents gain positive utility from increased electricity discounts, represented by the compensation variable, which is standard in a WTA framework. In the RPL model with interactions MID INCOME*COMP and HIGH INCOME*COMP are negative (though HIGH INCOME*COMP is insignificant) indicating that value for compensation may be due partially to the preferences of respondents on lower incomes. This is consistent with previous research (Brennan and Van Rensburg, 2016).

The alternative specific constant (ASC) which represents the status quo is positive and highly significant in each iteration, which indicates the overall preference in forgoing compensation and the negative attributes associated with wind farm development. The variable REP*ASC analyses the attitudes of residents who have experience of a local representative interacted with the Status Quo option. This variable is negative and highly statistically significant suggesting that those with experience of community representation are less likely to select “No new wind farm”. This corresponds with prior research which indicated the importance of community representation in wind farm acceptance (Brennan and Van Rensburg, 2016).

OBJECTIVE 1 RESULTS SUMMARY

These results indicate that the number of turbines and setback distance are important factors in terms of the local acceptance of wind farm development in Ireland, and generally the concept of exporting wind energy has a negative impact on preferences. Our results indicate that if existing wind farms have provided employment, information, financial support and proactive participation respondents are generally more accepting but may also view the introduction of development for export more favourably. Our findings from the choice experiment indicate that respondents are particularly wary of export projects if they involve shares, if respondents have strong place attachment (Devine-Wright and Howes, 2010) or perceive that the benefits are not reinvested in the area, or to have been exaggerated. If respondents do not trust the developer or if the wind farm ownership does not involve the state then they are also less likely to be in favour of export projects (Brennan, 2017). Some respondents appear to have a preference for renewable energy produced locally to be consumed locally or at least nationally and are also concerned about avoiding fines for not meeting EU targets. Subjects living in areas that offered share options are least in favour of development for export yet this is inconsistent with our finding for domestic wind farms noted above. It is possible that share schemes create an attachment to the wind farm and its energy. By this reasoning the energy becomes "ours" and we therefore prefer to consume it locally. Alternatively, it may simply be that exports are perceived as a more risky endeavor for communities until experience of actual projects proves otherwise. On the other hand, the benefits associated with greater acceptance of an export project for respondents include employment opportunities, cash payments and reduced electricity bills. The following section further explores the concept of community compensation and its corresponding impact on preferences for exporting wind energy.

OBJECTIVE 2: IMPACT OF COMMUNITY COMPENSATION ON PREFERENCES FOR EXPORTING WIND ENERGY

In this section we outline the results relating to the provision of community benefits and engagement for wind energy developments involving trade in Ireland. Results are outlined based on the focus groups, the national online survey provided to 1107 respondents across Ireland and the local face-to-face choice experiment provided to 253 individuals.

FOCUS GROUP RESULTS

During the public focus groups, several participants stated that if a project was planned for their area they would be interested in being involved and giving up time in order to find out how they might be impacted. It was preferred that engagement with the community being from the start and continue throughout the project. Participants discussed the possibility of meetings to establish the pros and cons of development, although it was stated the developer may be biased and so it was suggested to also have a representative from the local council to record proceedings. Most participants did not believe that locals would have the knowledge required to design a wind farm project.

Education in communities and schools on how energy is produced, and the possible negatives and positives was stated as a requirement. It was suggested that councils provide support for co-ops and publicise available grants and also possible financial benefits of projects. It was stated that developers need to invest more in communities where wind farms are located, to “put something back”. If wind farms were placed in the right areas and communities were gaining then most participants indicated that they would not have an issue with developments. When asked what form this benefit could take, lower electricity bills was suggested. For many participants exporting excess wind energy was not seen as problematic as long as the financial benefits come back to Ireland.

As highlighted in the previous section, during the group exercise participants preferred that most or all of the wind farm developed was community owned as it was assumed more benefits would remain locally. While Group 1 initially preferred the highest electricity discount as a personal benefit, they agreed that this may be unrealistic and moved to the second highest level. Although Group 2 generally preferred the highest level of electricity discount, they felt this could cause divisions in the local community. In this Group, a “Green Fund” to provide energy upgrades to residents was suggested by one participant as a potentially less divisive local benefit.

During the developer focus group, it was suggested that there was a need to educate the general public as to the opportunities of development. It was noted that community investment part of RESS enables communities to take part in wind energy generation and that future RESS designs might include an investment portion for locals. One participant noted that some members of the public may see the provision of benefits as bribery if some receive benefits and others don't. It was suggested that other non-monetary wind farm benefits such as cycle paths, nature conservation areas etc. might be a preferable benefit and could be used by all.

One participant suggested that the Local Authority Renewable Energy Strategy System (LARES), which is deployed at local authority level, could be used at a local level. It was suggested that there could be a role for the community to become involved in certain elements of project design, particularly in the benefit outcomes, but that more technical elements should be left to experts.

NATIONAL SURVEY RESULTS

In order to assess attitudes towards the provision of local benefits from wind energy development, in the online national scale survey respondents were asked questions related to community benefit funds. Of the 1107 respondents, 961 stated that they would be in favour of a developer providing a community benefit fund. The 146 respondents who indicated that they would not support a benefit fund were asked to elaborate on their reasons for this viewpoint. The most common reason was due to perceptions of bribery (30 respondents):

> It may be perceived as a bribe, I will give the community this if I can build a wind farm in your area. It could cause a lot of arguments among locals as some will want and some will not. [Respondent 1055]

> I am not in favour of any developers, of any type or from any industry, providing local benefit funds because I just see it as just a way of throwing money at people to keep them quiet and buying their agreement. [Respondent 1440]

The next most frequent reason was due to opposition to wind farms in general (27 respondents).

> Wind farms ruin lives, no amount of money in a local benefit fund can make up for countless amounts of health issues, property value decreasing and eye sores.
>
> [Respondent 736]

> Because I don't want a wind farm near my house or in my local area, and for me to be in favour of a fund means this could possibly happen. Plus I don't think it's a requirement. Money is needed… in other areas rather than this.
>
> [Respondent 1198]

Other reasons for opposition include lack of knowledge on the topic (18 respondents), lack of trust in such a scheme (10 respondents), concern about the governance structure (9 respondents), the belief that such a scheme is not necessary due to the environmental benefits of wind farm development (9 respondents) and concern about the cost (5 respondents), amongst others.

Those who indicated that they were in favour of such a fund were provided with a follow up question to rank their preferred benefit recipient from most preferred to least preferred. Approximately 58% selected residents within 1-2Km of the wind farm as their first or second preference to receive benefits and approximately 32% selected residents greater than 2km from the wind farm as their first or second preference. At the other end of the scale, approximately 35% of respondents selected the local GAA club as their least preferred option and 20% selected residents nearest development as their least preferred recipient of benefits. Although residents living closest to the wind farm ranks quite low, this is due to the larger proportion of respondents selecting it as the second worst option (33%).

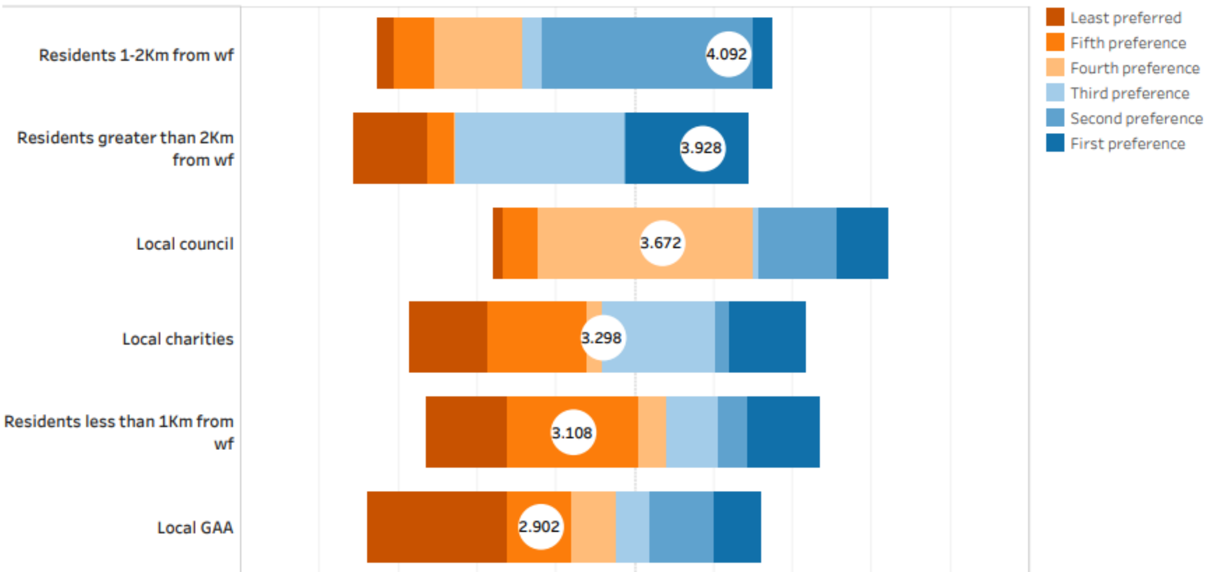

Figure 13: Who should benefit first?

It is possible that respondents selected the nearest neighbours as a less preferable beneficiary because so few of them live very close to a wind farm. 11 respondents (approximately 1% of the sample) indicated that they reside 500m or less from a wind farm.

Table 10: Respondent distance to wind farm

Distance	No of respondents	% of total
500m or less	11	1.0%
1Km-2Km	52	4.7%
2Km-4Km	62	5.6%
4Km or more	236	21.3%
I do not live near any wind farm	478	43.2%
Don't know	268	24.2%
Grand Total	1,107	100.0%

Respondents were also asked at what stage during their local wind farm development (if any) they moved into their home.

Table 11: Experience with wind farm construction

Moved into home	No of respondents	% of total
Before the wind farm was built	190	17.2%
During construction of the wind farm	17	1.5%
Shortly after the wind farm was built (<1 year)	10	0.9%
After the wind farm was built (>1 year)	73	6.6%
I don't know or not relevant	71	6.4%
Not living near wind farm	746	67.4%
Grand Total	1,107	100.0%

While the majority of respondents (67%) indicate that they are not living near a wind farm, 17% moved into their home before a local wind farm was built.

The 361 respondents who live near a wind farm were asked if a community representative was made available to interact with and engage with local residents about the wind farm. 47 respondents indicated yes (13%), 90 indicated no (25%) and 224 stated they didn't know (62%).

The respondents who live near a wind farm were also asked if their experience with their local wind farm developer made them feel more positive, no different or more negative about future wind energy developments in Ireland. Most respondents felt that it made no difference to their opinion, but for those that did, their experience changed their opinion positively rather than negatively. Of the

53 positive respondents, 21 state that there was a community rep present as opposed to just 4 of the respondents who view developments more negatively.

Table 12: Impact of local experience on attitudes to future wind energy development

Developer experience	No of respondents	% of total
More positive	53	15%
No different	281	78%
More negative	27	7%
Grand Total	361	100%

LOCAL CHOICE SET MODEL RESULTS

This section outlines the marginal willingness to accept (WTA) values for the three estimated models outlined in the previous objective. These results are derived from the choice set analysis of the 253 face-to-face surveys and outlined in Table 13. The results for the MNL model are insignificant in most cases, and only EXPORT 100% and SETBACK 1500M are significant at 10%. Therefore the following discussion will only consider the more appropriate fitting RPL models.

In both RPL models, the predicted WTA for the turbines is positive. For every new turbine added to the wind farm, respondents demand an annual electricity discount of between €10 and €14. Both export variables also result in positive WTA. For the medium export level compensation of between €200 and €340 is required whereas the higher level of export requires between approximately €400 and €460 per household per annum.

On the other hand, the estimations for the setback variables show negative WTA amounts. This suggests that the amount of compensation required decreases as the distance between the turbines and the respondents' residences grows. For increases from a base of 500m to 1000m, respondents are willing to accept reductions in compensation of between €360 and €660 per annum and between €460 and €880 less in compensation for a setback increase to 1500m.

Table 13: Local respondents marginal WTA estimates

	MNL € /H.H,P.A	**RPL € /H.H,P.A**	**RPL with interactions € /H.H,P.A**
TURBINES	3.45	9.72**	13.80**
	(8.86)	(4.96)	(5.51)
EXPORT 50:50	739.66	342.69***	201.92*
	(507.68)	(106.49)	(115.52)
EXPORT 100%	1451.41*	457.97***	397.32***
	(846.12)	(117.41)	(125.14)
SETBACK1000M	-1205.91	-658.64***	-356.63***
	(743.07)	(135.54)	(125.77)
SETBACK1500M	-1930.11*	-876.25***	-462.24***
	(1153.31)	(168.88)	(128.38)
CITIZEN MED	616.43	-37.10	-191.79**
	(493.98)	(90.07)	(97.71)
CITIZEN HIGH	1206.68	227.51**	259.47**
	(788.67)	(112.66)	(121.27)
Log- Likelihood	-3292.6824	-2204.7028	-2183.5438
McFadden Pseudo R^2	0.33	0.34	0.35
No. of respondents	253	253	253
No. of observations	3036	3036	3036
No. of Halton draws		500	500

The medium level of citizen engagement would result in a compensation reduction of between €37 and €190 per household per annum. However, the higher level of engagement with active negotiation between the community and the developer throughout the project actually requires a compensation payment. Respondents require between €230 and €260 more in compensation per annum for more active participation in a wind farm development. This lack of willingness to engage in wind farm management to a greater extent has been noted in the literature (Hyland and Bertsch, 2018).

OBJECTIVE TWO RESULTS SUMMARY

Our findings show that respondents regard distributive aspects of wind farm development as important. Respondents reveal strong preferences in favour of wind farms to supply domestic requirements compared with exports even for cases where 50% of the power is retained for domestic consumption. This is consistent with research in a number of other studies (Liebe et al., 2017, Brennan, 2017, Dutton and Lockwood, 2017). We do not find a NIMBY reaction to wind farms for exports but they may cost more in terms of community benefits than domestic projects. Only 20% of the sample favoured wind farms for export, yet the choice experiment indicates that most (only 30% selected either SQ or 0% export in each set) respondents are willing to trade-off electricity exports against changes in their electricity bill. Respondents are willing to accept the highest level of wind energy exportation in exchange for electricity discounts of between €400 and €460 per household per annum. Hence, wind farm development for export is generally accepted when certain conditions are met even in counties where such opposition is strongest. The next section explores methods of minimising the cost of community compensation in an integrated energy network involving trade.

OBJECTIVE 3: MINIMISING COMMUNITY COSTS IN AN INTEGRATED ENERGY NETWORK INCLUDING TRADE

In this section, we outline the results relating to cost minimisation for an integrated energy network including aspects of renewable energy development and trade, grid infrastructure development, storage and demand side management. These results are based on the focus groups, the national survey and choice experiment provided to 1107 individuals across Ireland and the local WTA measures outlined in the previous objective.

FOCUS GROUP RESULTS

To assess perspectives related to the need for renewable energy development, public focus group participants were asked how they felt about renewable energy targets.

Many participants indicated knowledge that Ireland was missing their required targets and stated this was due to starting late in renewables despite having “everything required” to generate energy. Respondents discussed amongst themselves how Ireland compares with other countries (China in particular). Many believed the targets to be unrealistic, particularly stating that the country was not set-up currently to support electric cars and that it may require too much change for the public to accept. Some indicated that polluting producers should share the burden, highlighting the example of excessive plastic in products. Some participants indicated that more could be done by the government in the form of grants and free installations for home energy improvements and solar panels. Generally there was the belief amongst many participants that the government was self-interested and only concerned with profit making and were not investing enough to achieve targets.

Overall, participants believed that targets were important for the planet, although one individual indicated their scepticism regarding man-made climate change and another was critical about the environmental “agenda”. Others indicated the importance of education on the importance of target achievement, particularly amongst older residents. Other forms of energy were suggested as potential methods of achieving energy targets including offshore wind, wave power, solar energy and methane gas use by the agriculture sector. Group 2 highlighted what they felt was an “urban-rural divide” as energy prices were increasing more in rural areas due to the lack of gas supply leading to a reliance on carbon intensive and costly fuel such as coal and peat.

When asked how they personally were trying to reduce their environmental impact, participants stated that they were recycling their waste, walking and cycling rather than using cars, not purchasing bottled water, leaving plastic packaging in the shop and turning off lights to save energy and money. Others indicated that they had retrofitted their homes with air to water heat pumps and solar panels.

Public participants were also asked which methods they believed were the most appropriate to deal with intermittency management from wind energy. Battery storage was seen as the primary solution to intermittency. Several respondents indicated that it could also prevent the grid being overloaded. One participant suggested that battery plants should be developed at each wind farm site. Some participants also believed that stored energy should make electricity cheaper because it would be more dependable. Some indicated the lack of information about what batteries were composed of and how they would be disposed of at their end of life. Participants indicated that meetings and leaflets with greater information should be provided. Potential health and environmental impacts from battery storage developments were discussed in both groups as key concerns and that non-biased information was crucial. Trust was raised as a concern, and several participants indicated that people don't trust the government due to mistakes made in the past. It was suggested that there was a need for a body set up by the government, but operated independently of the government, to provide expertise from universities and the ESB and others but it was important that this be impartial and not biased by funding. They also suggested that there was a role for the public to become involved in such a body to ask the "normal" questions and be represented, with the public members having the same voting rights as experts.

When asked about electricity trade as a solution to intermittency, many respondents indicated their belief that this is what was currently happening. Some indicated that there must be too much energy generated if developers needed to export. Others indicated that profit from trade should not leave the local development area.

It was preferred that potential additional cabling required for export would be placed underground. One benefit of this was that the project would be less susceptible to storms. On the contrary, one benefit of over-ground cabling suggested was the ease of repair if necessary. It was stated by a participant that if grid expansion was required for the benefit of the country then they would not want to hold back development. However, it was noted that development needed to be sympathetic to views and be mindful of wildlife, local communities and individuals. One participant indicated that there was opposition to nearby pylons in the past but that this was forgotten with time. It was also stated that there would be stronger preference for export if the wind farm was a co-operative as the profits would remain locally, but it was stated that there was a lack of government support for such a framework.

As highlighted previously in Table 2, during the exercise both Groups preferred to retain all grid development underground. For Group 1, initially the lowest level of energy export was preferred but they compromised and moved this to a 50% level due to the greater potential for local benefits. This Group preferred the highest level of battery storage and would not compromise on this, as it also had a potential to provide local energy security and benefits. Group 2 could not agree on their best start position for export level or battery storage, citing the need for greater information. It was discussed that although smaller battery storage plants might be preferable, perhaps they would be too small to be useful. Participants in Group 2 agreed that they would be very much in favour of storage development if they knew there were no negative environmental impacts.

In the developer focus group, interconnection with other jurisdictions was seen as a big potential solution to intermittency. Participants noted that this was likely to be controversial, as some planned developments have already faced local opposition. It was noted that this type of development requires careful management at local level. In terms of wind turbine design, although larger rotors can reduce variability and result in higher capacity factors, this results in greater visual impact. It was noted that battery storage developments are likely to have their own issues and while they represent a good option for short-term storage, they don’t offer solutions to long term variability. It was concluded that there is a significant challenge placed on policy makers, planners, developers and the general public to get up to speed on the range of new technology that will be required to meet Ireland’s electricity needs through renewables by 2030.

NATIONAL SURVEY RESULTS

The survey contained several questions to establish the general public’s attitudes towards climate change and environmental issues.

Respondents were asked to select the stance that most represented their opinion in terms of the balance between the environment and the economy. Most respondents (59%) believed that although both were important, the environment should come first.

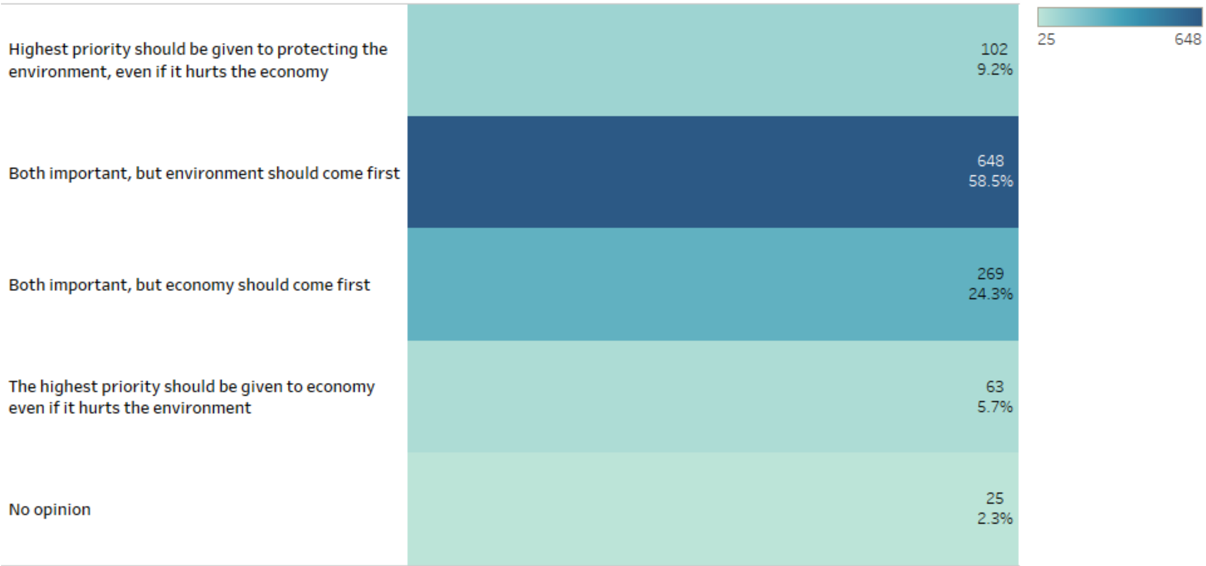

Figure 14: The environment vs the economy

Following this, respondents were asked to indicate how serious climate change is and what should be done about it. The majority of respondents (92%) believe that some action should be taken to address it and most (52%) believe it is a serious problem requiring immediate action.

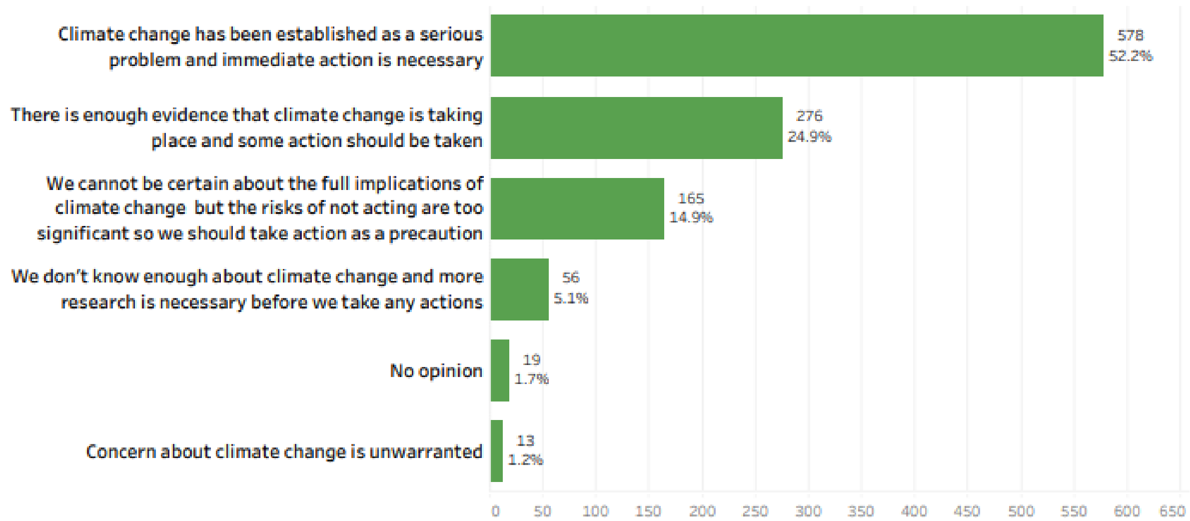

Figure 15: Attitudes towards climate change

Respondents were then asked what they believed would be the most likely solution to climate change. The majority of respondents (62%) believe that the public will have to change their lifestyles to reduce energy consumption in order to tackle climate change. This suggests that more respondents agree with the "prophet" stance on climate change resolutions; i.e. regulatory social change; over the "wizard" perspective which favours innovation and technological solutions (9%) (Mann, 2018).

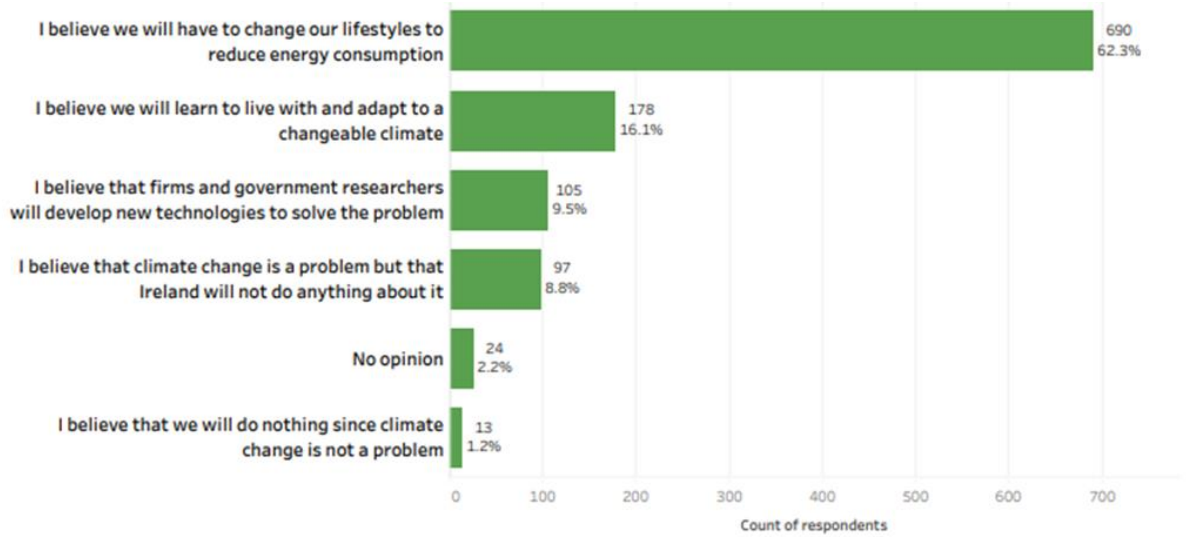

Figure 16: Climate change solutions

In order to assess readiness to address personal behaviour, respondents were asked to indicate their willingness to change their day-to-day energy usage to ease demand on the electricity system. Very few respondents indicate unwillingness to make any changes, and the majority are willing to make moderate or even significant changes:

Table 14: Willingness to adapt day-to-day energy usage

Willingness	No. of respondents	% of total
I am willing to make significant changes	375	33.9%
I am willing to make moderate changes	423	38.2%
I am willing to make small changes	210	19.0%
I am already extremely energy efficient and do not need to make changes	71	6.4%
I am not willing to make any changes to my current energy use	28	2.5%
Grand Total	1,107	100.0%

As a follow-on, respondents were asked to select the factors that would make them more likely to change their energy usage. 73% of respondents indicated that grants for more energy efficient appliances, smart meters or electricity generation systems would help. The next most popular methods both relate to information, one on the easiest ways to change (49%) and the other on cheapest times to use electricity (42%). 18% of respondents indicate that seeing their friends and family make changes would make them more likely to change their personal energy usage.

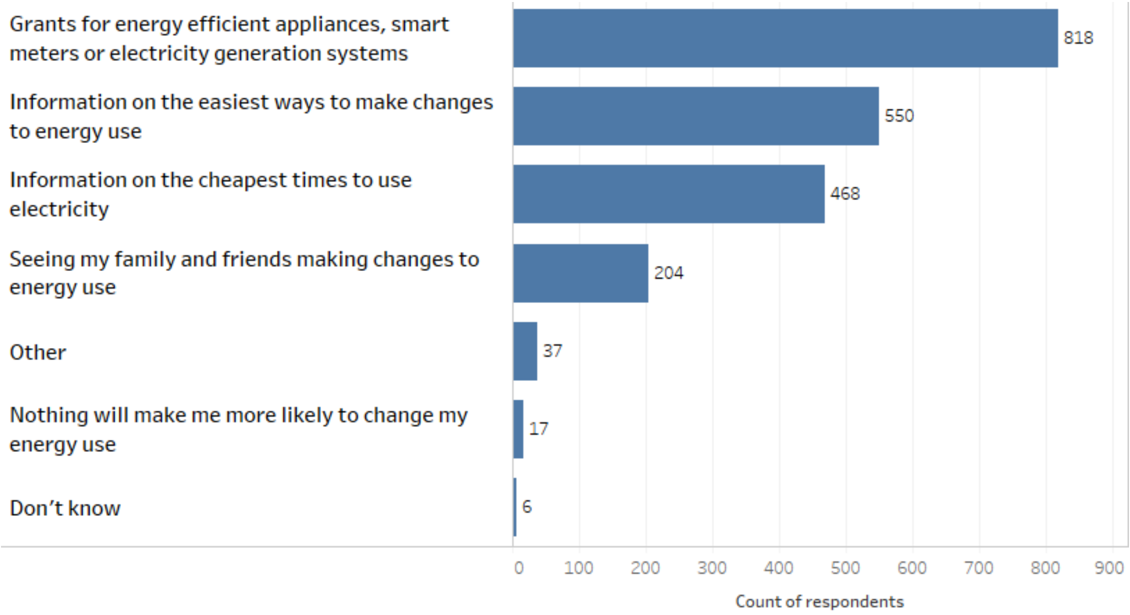

Figure 17: Factors to encourage energy usage change

Respondents were asked to indicate how they feel about the level of battery storage in Ireland currently. Most respondents (55%) indicated a lack of knowledge about the topic while about 34% indicated that the level was not enough.

Table 15: Attitudes towards battery storage levels in Ireland

Battery storage level	No of respondents	% of total
There is not enough battery storage for wind farm electricity	373	33.7%
The level of battery storage for wind farm electricity is about right	97	8.8%
There is too much battery storage for wind farm electricity	24	2.2%
Don't know	613	55.4%
Grand Total	1,107	100.0%

Respondents were asked to rank their level of concern from 1 (not at all concerned) to 5 (very concerned) about a number of possible issues related to battery storage. Don't know was ranked as 0. Respondents generally appear neither concerned nor unconcerned about many of the issues, which is likely due to a lack of knowledge on the topic.

Figure 18: Concerns about battery storage for wind energy

Similarly, respondents were asked to rank their level of concern from 1 (not at all concerned) to 5 (very concerned) about the same issues but related to above ground grid development.

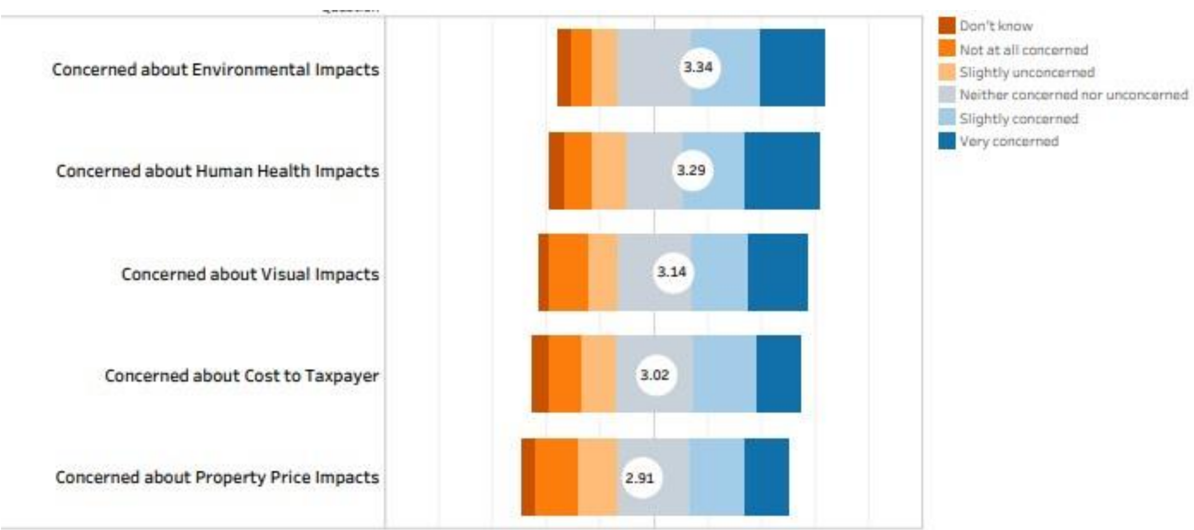

Figure 19: Concerns about above ground grid development

Fewer respondents indicate "don't know" for these concerns then for battery storage development. The most important factors for respondents relate to the environmental and human health impacts about above ground grid development and the least important factor is the potential property price impact.

Finally, respondents were asked to rank their level of concern from 1 (not at all concerned) to 5 (very concerned) about the same issues but related to below ground grid development. In comparison to the above ground grid, respondents are much less concerned about each potential impact. 44% of respondents are not at all concerned about the visual impact compared to 14% of respondents for the above ground grid. 11% of respondents are very concerned about the environmental impacts of below ground grid compared to 24% for above ground grid.

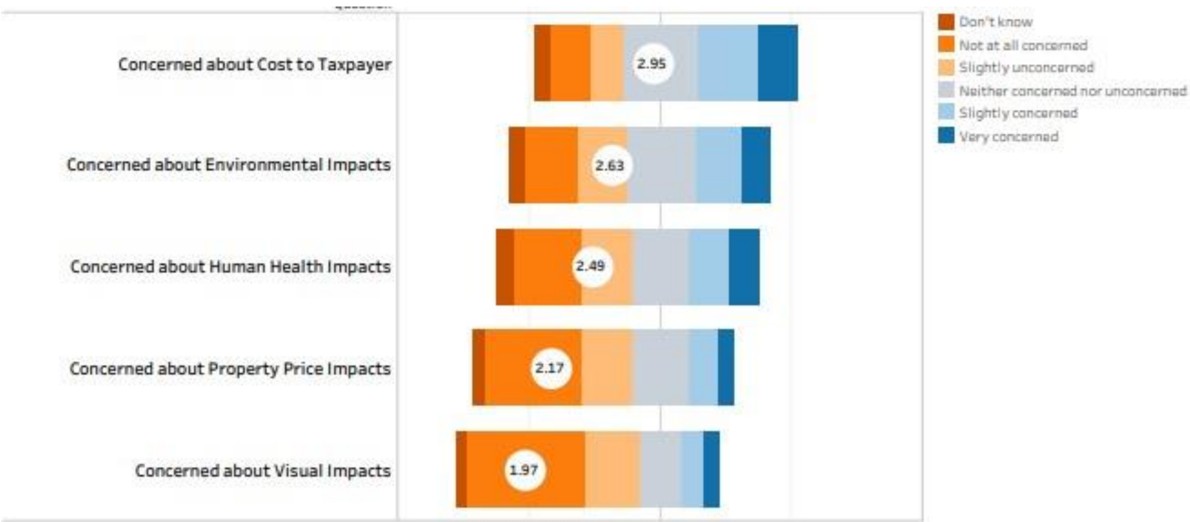

Figure 20: Concerns about below ground grid development

Following this, respondents were asked their willingness to accept battery storage development, over ground grid infrastructure and underground grid infrastructure within 1Km of their home.

Table 16: Willingness to accept energy infrastructure development within 1Km of home

Answer	Development	No of respondents	% of Total
Yes	Battery storage	497	44.9%
	Overground grid	409	37.0%
	Underground grid	742	67.0%
No	Battery storage	219	19.8%
	Overground grid	393	35.5%
	Underground grid	135	12.2%
Don't know	Battery storage	391	35.3%
	Overground grid	305	27.5%
	Underground grid	230	20.8%
Total		**1107**	**100.0%**

While the majority of respondents are willing to accept below ground grid development, respondents are more cautious about over ground grid and battery storage development. Notably, a large proportion of respondents are unsure about their attitudes towards these developments, and selected the "Don't Know" option provided. There also appears to be a gender difference in willingness to accept infrastructure with more women than men responding no to battery storage (+41%), above ground grid (+25%) and underground grid (+55%). Female respondents are also much more likely than their male counterparts to indicate “don’t know” to each of the options.

Lienert et al. (2018) find that increased information on the impacts of underground grid development can influence acceptance, and so respondents who indicated that they would accept underground grid development, or were unsure if they would accept were provided with a follow up question. Respondents were asked if they would still be willing to accept underground grid development within 1Km if it restricted the possible land use above it (e.g. limits to agricultural use). Once provided with additional information, the number of respondents willing to accept underground grid development fell by 27%. More female respondents than male changed their mind, with a reduction in acceptance of approximately 33% for female respondents and 22% for male.

NATIONAL CHOICE EXPERIMENT MODEL RESULTS

This section outlines the results for the online choice experiment provided to 1107 members of the public in Ireland.

Firstly, a Principal Component Analysis (PCA) was applied to the attitudinal scales, which were either scaled from 1 (no agreement) to 5 (full agreement); or 1 (not at all concerned) to 5 (very concerned) (see Appendix for full question structure. Table 17 summarizes the component correlation matrix data obtained using Alteryx Designer 2020.4, with stronger correlations for each component noted in bold. The first component accounts for approximately 35% of the total variance in the data. This group is more concerned about any potential harm associated with the growth of the above and below ground grid, including potential effects on human health. This group is defined as “Concerned citizen”. The second component accounts for approximately 11% of the variance in the data. The elements most correlated with this component are the statement related to export acceptance, onshore wind acceptance and the impact of underground grid. Respondents with a high score for this factor are more likely to view electricity trade negatively, less likely to accept new onshore wind farm developments but view underground grid development as less negatively impactful. This group is defined as “Wind energy sceptic”. The final component accounts for approximately 9% of the total variance. This group are more likely to agree with onshore, offshore and wind energy for export. This group still has reservations about the potential negative impacts of above ground grid development but not for the other forms of electricity infrastructure. Members of this cohort are defined as “Wind energy advocate”.

These components are included in a Latent Class logit model to assist in explaining potential heterogeneity in the results.

Table 17: Principal components analysis correlation matrix

	Concerned citizen	***Wind energy sceptic***	***Wind energy advocate***
I am in favour of onshore wind farm development	-0.143	**-0.248**	**0.296**
I am in favour of offshore wind farm development	-0.104	-0.119	**0.258**
I am in favour of building wind farms in Ireland specifically to export wind energy to other countries	-0.118	**-0.464**	**0.384**
Exporting wind energy offers high monetary benefit to the Irish state	-0.045	-0.157	0.195
Exporting wind energy will lead to many jobs	-0.035	-0.193	**0.213**
Battery storage: Environmental impact concern	**0.215**	0.096	-0.071
Battery storage: Visual impact concern	**0.248**	0.196	0.029
Battery storage: Property price impact concern	**0.273**	0.174	-0.001
Battery storage: Cost to taxpayer concern	**0.233**	0.096	-0.123
Battery storage: Human health impact concern	**0.283**	0.106	-0.095
Above ground grid: Environmental impact concern	**0.236**	0.065	**0.280**
Above ground grid: Visual impact concern	**0.251**	0.155	**0.424**
Above ground grid: Property price impact concern	**0.286**	0.100	**0.312**
Above ground grid: Cost to taxpayer concern	**0.254**	0.014	0.133
Above ground grid: Human health impact concern	**0.281**	0.040	**0.299**
Underground grid: Environmental impact concern	**0.233**	**-0.348**	-0.190
Underground grid: Visual impact concern	**0.236**	**-0.324**	-0.126
Underground grid: Property price impacts concern	**0.263**	**-0.308**	-0.140
Underground grid: Cost to taxpayer concern	**0.206**	**-0.228**	-0.112
Underground grid: Human health impact concern	**0.264**	**-0.369**	-0.196
Proportion of Variance	0.35	0.11	0.09

Table 18 outlines the statistics for up to 5 segments for the Latent Class model. As the Pseudo R^2 does not penalise for increased numbers of parameters, other statistics which do; such as the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC); can be more useful in model selection. Both measures are useful in terms of determining goodness-of-fit and neither has clear advantages over the other (Greene, 2003). The best BIC, AIC and Pseudo R^2 arise from the 4 segment model. While the 5 segment model indicates the same Pseudo R^2 score, this does not show an improvement on the 4 segment model in terms of the BIC and AIC results. The 4 segment model indicates an improvement across all goodness-of-fit scores compared to the 2 and 3 segment model and a significant improvement over the baseline 1 segment approach. Although the 4 segment model contains a class with no significant preferences for any attributes (class 3), this was selected as the appropriate model due to the overall significance of parameter estimates. In the end, the analyst's assessment of how to interpret the findings should also influence the choice of the appropriate number of classes (Scarpa and Thiene, 2005, Louviere et al., 2000).

Table 18: Latent Class selection criteria

No. of classes	No. of parameters (k)	Log likelihood	AIC[5]	BIC[6]	Pseudo R^2[7]
1 (MNL)	8	-6034.44	12084.88	6062.48	0.17
2	23	-5095.15	10236.3	5175.76	0.30
3	38	-4991.53	10059.06	5124.71	0.32
4	53	-4827.70	9761.4	5013.45	0.34
5	68	-4800.04	9736.08	5038.36	0.34

Table 19 outlines the results for a baseline MNL model and the 4 segment Latent Class Model estimated using Nlogit 5. The baseline MNL model outlines positive utility for all intermittency measures, local community benefits, personal benefit in the form of an electricity discount and insignificant utility for the status quo (SQ) of no new wind farm.

The Latent Class Model has been estimated using a range of socio-economic, demographic and attitudinal variables. Based on the goodness of fit estimates the optimal model output included the three principal component criteria outlined above (*Concerned citizen; Wind energy sceptic; Wind energy advocate*) home ownership (*Homeowner*: Taking the form of a dummy variable; 1 if yes, 0 if no) and education to primary level only (*Primary educated*: Taking the form of a dummy variable; 1 if yes, 0 if no). Other variables were assessed, including income, age, gender and wind farm experience but do not significantly influence class membership probabilities.

The results for the first class of respondents are comparable to those from the MNL model in that they indicate that respondents derive substantial positive utility from all forms of intermittency measures, each of the benefit options, and the electricity discount, but this group derives substantial negative utility from the SQ. Class 1, which makes up roughly 62% of the sample, is more likely to be made up

[5] AIC measures the quality of models for a given set of data with lower numbers signifying a better model fit. AIC= -$2/(LL - k)$.

[6] BIC is also used as a criterion for model selection, again the lowest BIC is preferred. BIC= $-LL + [(k/2)Ln(N)]$.

[7] In the McFadden pseudo R^2 the log likelihood of the intercept model is interpreted as the total sum of squares and the log likelihood of the entire model as the error sum of squares. Although the pseudo R^2 can't be directly compared to those of linear model, results of between 0.30 and 0.40 are generally considered similar to those of between 0.60 and 0.80 in a linear model (Domencich and McFadden, 1975; Hensher et al., 2005).

of homeowners and wind energy supporters and is less likely to contain respondents who are worried about infrastructure, wind energy sceptics, or less educated individuals.

Table 19: MNL and Latent Class Model (4 classes):

Attribute	MNL	LCM (4 Classes)			
		Class 1	Class 2	Class 3	Class 4
Utility model					
Trade	0.590***	0.685***	1.085***	26.198	-0.161
	(0.049)	(0.070)	(0.313)	(1047.642)	(0.206)
Battery	0.455***	0.785***	-0.715***	-16.621	-0.133
	(0.049)	(0.077)	(0.275)	(4716.550)	(0.213)
Price Alert	0.369***	0.590***	-0.024	11.855	-0.039
	(0.048)	(0.072)	(0.279)	(523.820)	(0.201)
Benefit: LA	0.526***	0.769***	-0.012	41.896	0.525***
	(0.040)	(0.058)	(0.279)	(3151.681)	(0.176)
Benefit: GF	0.699***	0.883***	1.446***	15.418	0.555***
	(0.042)	(0.060)	(0.232)	(2972.465)	(0.180)
Rep	0.396***	0.413***	1.021***	-0.499	0.417**
	(0.033)	(0.051)	(0.251)	(1.625)	(0.164)
Elec discount	0.002***	0.005***	0.008***	-0.076	0.001*
	(0. 8603d-04)	(0.000)	(0.001)	(3.081)	(0.000)
Status quo	0.018	-2.225***	0.096	36.384	0.888***
	(0.086)	(0.236)	(0.678)	(3055.781)	(0.336)
Class probability model					
Constant		1.769***	0.860***	-1.986***	0
		(0.227)	(0.242)	(0.397)	
Concerned citizen		-0.279***	-0.273***	0.152**	0
		(0.047)	(0.050)	(0.069)	
sceptic		-0.169**	-0.128	0.414***	0
		(0.074)	(0.079)	(0.099)	
Wind energy advocate		0.188**	0.203**	-0.434***	0
		(0.089)	(0.095)	(0.124)	
Homeowner		0.665**	0.426	0.736*	0
		(0.272)	(0.283)	(0.387)	
Primary educated		-1.334*	-3.025***	-30.884	0
		(0.752)	(1.072)	(0.3675D+07)	
Average class probabilities		0.62	0.23	0.06	0.10
Log-Likelihood	-6034.44	-4825.624			
McFadden Pseudo R^2	0.17	0.34			
No. of observations	6642	6642			
No. of respondents	1107	1107			

The second class receive significant positive utility from trade as a form of intermittency management but significant negative utility from battery storage. Respondents in this cohort strongly prefer a green fund to a local authority payment, and derives positive preferences for community representation and the electricity discount. This group, making up about 23% of the sample, is less likely to contain those concerned about energy infrastructure or those who are primary educated but more likely to contain those who have pro wind attitudes and homeowners.

The third class derives no statistically significant utility from any of the attributes. This group, comprising approximately 6% of the sample, is more likely to contain respondents concerned about energy infrastructure, wind energy sceptics and homeowners and is less likely to contain individuals who appear positive about wind energy.

The final class, which is the reference class, do not derive any significant utility from solutions to intermittency. This cohort, making up approximately 10% of the sample, appears to only value benefits, both personal and for those in development areas, engagement with the representative and the status quo, which is positive and significant. This group is more likely to be primary educated and be concerned about the infrastructure associated with renewable electricity generation.

Table 20 outlines the willingness to accept estimates for the MNL model and the LCM 4 class model, and only includes estimates for significant coefficients. These estimates highlight the significant heterogeneity in preferences for solutions to intermittency and the benefit options outlined. Respondents Class 1 and Class 2 (approximately 85% of the sample) are likely willing to forgo some amount in personal compensation to support electricity trade. The amount differs greatly across Class 1 and 2 however this is in part due to the increased utility from the electricity discount for members in Class 2. A slight majority (Class 1: 62%) are more likely to forgo compensation to allow for increased battery storage, however 23% of the sample are likely to require increased compensation (Class 2). It is not entirely clear why this cohort display negative utility for battery storage, however it does not appear to be due to fears over the environmental, health or property price impacts as these individuals are less likely to be “concerned citizens”.

While a slight majority (Class 1: approx. 62%) of respondents are likely willing to forego compensation to allow for demand side management through price alerts the remainder indicate insignificant preferences for this solution. It is possible that this reflects the low number of respondents (9.5%) who believe that new technologies will be developed as the primary solution to tackling climate change concerns, as highlighted earlier in Fig. 14.

Table 20: WTA estimates (Significant coefficients only)

Attribute	MNL	LCM (4 Classes)			
		Class 1	Class 2	Class 3	Class 4
Trade	-388.15***	-1427.94***	-129.96***	-	-
Battery	-299.27***	-1636.13***	85.58**	-	-
Price Alert	-242.79***	-1228.35***	-	-	-
Benefit: LA	-346.54***	-1601.83***	-	-	-708.89***
Benefit: GF	-460.33***	-1838.92***	-173.13***	-	-749.38***
Rep	-260.40***	-861.40***	-122.25***	-	-563.05***
Average class probabilities		0.56	0.24	0.07	0.14
Log-Likelihood	-6034.44	-4825.624			
McFadden Pseudo R^2	0.17	0.34			
No. of observations	6642	6642			
No. of respondents	1107	1107			

It is estimated that most respondents (Class 1 & Class 4: approx. 72%) are likely willing to forego personal compensation to ensure that local authorities in development areas receive a one-off monetary payment. Even more are estimated to be willing to forgo compensation to ensure that residents in local areas receive a Green Fund (Class 1, Class 2 & Class 4: 95%). Fewer than 10% of respondents indicated that the likelihood of wind farm development in their location was "likely" or "certain" and less than 10% of respondents live less than 3Km from a wind farm, so this attitude does not appear to be determined by personal experience of wind energy or likelihood of personally receiving benefit funds. Similarly approximately 95% of the respondents (Class 1, Class 2 & Class 4) are likely to derive positive utility from forgoing personal compensation in order to allow for local representation for those living in wind farm development areas.

SCENARIO SIMULATION

Figure 21 outlines the willingness to accept estimates for the MNL model outlined in the previous section. These results highlight that the general public are willing to forgo significant personal benefits in the form of an annual electricity discount to allow for the development of intermittency solutions. In particular, the public are willing to forego €388.15 P.A. if excess wind energy is exported when not needed and imported when required.

Public respondents are willing to forego the most personal benefits, however, to allow for the provision of a local Green Fund for residents in impacted areas (€460.33 P.A.). This indicates that the public have strong preferences for wind farm developments which incorporate trade as an intermittency solution and provide benefits to local residents, even if they are unlikely to receive this benefit.

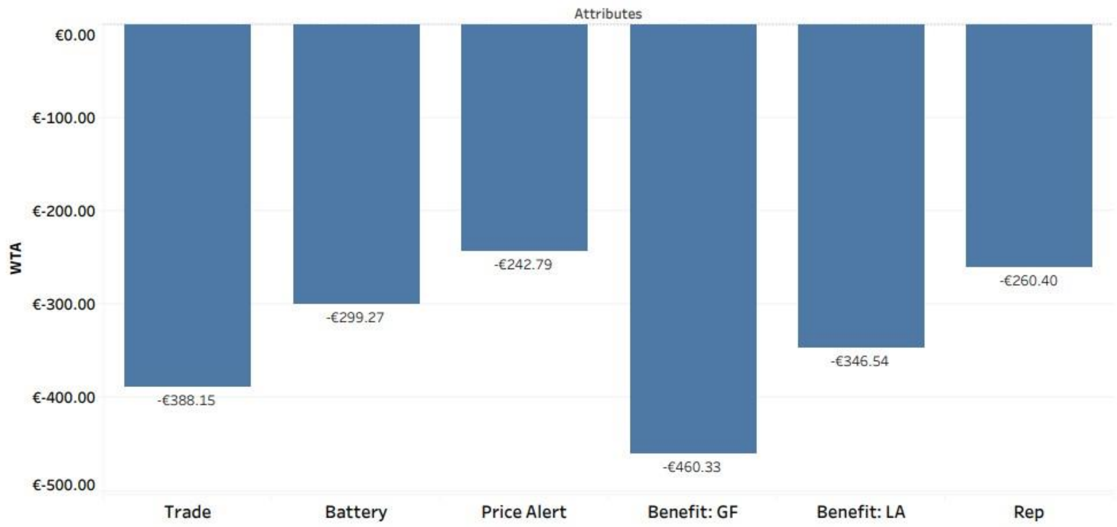

Figure 21: National choice experiment WTA estimates for MNL model

The public respondents indicate positive utility for exporting excess wind energy and, during the public focus groups, participants indicated that they would not mind exporting wind energy from local developments as long as benefits were provided. Results from the previous objective has indicated that local residents may have negative utility from the exportation of wind energy from nearby developments and so combining the data from this research on public preferences with the data on local preferences, we assess the impact of the provision of local benefits.

Figure 22 outlines the total WTA for individuals residing in wind farm development areas based on 20 wind turbines, at a distance of 1000m and 1500m from their place of residence and based on two electricity export levels: one based on retaining 50% for use in Ireland and 50% export and the other at 100% export. Then the public WTA for the various benefit schemes outlined in Figure 21 is added to this analysis.

Figure 22: WTA payments required based on export level, setback distance and local benefit

This indicates that in a scenario without a local benefit scheme, residents require approximately €121 P.A. for a 20 turbine wind farm, located at 1000m from their home when 50% of the energy is retained for use in Ireland, and €317 P.A. if the same wind farm was to export 100% of the energy. At a 1500m setback distance, this compensation level reduces to approximately €16 and €211 for 50% export and 100% export respectively. Adding the local authority benefit results in a negative WTA amount, this suggests that residents no longer require additional compensation in the form of an electricity discount and are actually willing to forego personal benefits when a wind farm is developed with a local authority payment in place. Residents are willing to forego between €31 and €331 in personal annual electricity discounts depending on the setback distance and level of export. Finally, the analysis suggests that the provision of a Green Fund results in the highest welfare outcome for residents in development areas. Residents are willing to forego between €144 and €445 in personal electricity discounts when a wind farm incorporating trade is developed which provides funding for green initiatives for locals.

There are caveats associated with this analysis. The results vary depending on the number of wind turbines, the analysis is fixed at 20 turbines. The analysis combines the preferences derived from the general public and from residents in local areas. It is possible that the public have a different WTA than local residents for benefit provision, although it is most likely that those living nearby would derive greater utility from local benefits than the public who are unaffected, and so the results in Figure 22 may be conservative, particularly for the Green Fund. It is also likely that public respondents have heterogeneity in preferences and so may not all derive positive utility from benefit provision, although the results from the LCM suggest that the majority (representing approximately 95% of the sample) derive positive utility from the provision of a local Green Fund.

OBJECTIVE THREE RESULTS SUMMARY

The majority of public respondents find renewable energy intermittency to be an important issue and derive positive utility from solutions to reduce it, particularly electricity trade. In the choice experiment, electricity trade is portrayed as a solution to intermittency, whereby excess wind energy is exported when not required and imported when needed. In the latent class model, a significant majority of respondents are willing to forego a discount in their electricity bill to permit electricity trade.

In order to address intermittency, the trade attribute in the choice experiment was presented as a trade in excess wind energy rather than as a specific export attribute involving 100% electricity exports. Participants in focus groups indicated concerns about an excessive reliance on imported electricity, particularly in light of the Brexit-related uncertainty. Support for the required grid infrastructure suggests a preference for underground cabling over above-ground cabling, but in line with Lienert et al. (2018), this preference for the former may be impacted by a lack of knowledge about the disadvantages of undergrounding. While below-surface cabling can be cost effective (Navrud et al., 2008, Fenrick and Getachew, 2012, Glass and Glass, 2019) it may not be the ideal solution due to their stronger electromagnetic fields (National Grid, 2015), visual impact (Bertsch et al., 2016) and land use restrictions above the cabling (National Grid, 2015). Individuals who are very concerned about the expansion of the above and below ground electrical grid are also less inclined to support the construction of wind farms and the related intermittency control.

This study emphasizes the significance of local benefits provision and participation in all facets of renewable electricity infrastructure, even when the public do not reasonably expect to receive these benefits. The Green Fund in particular; which was suggested by participants in a focus group; results in positive utility for most respondents in all classes.

Benefit distribution is widely recognized as a way to increase affected communities' acceptance of renewable energy and related infrastructure (Kermagoret et al., 2016, Walker et al., 2014a, Ferreira et al., 2019, Gebreslassie, 2020), but this study suggests that it also has the potential to have a positive influence on wider public acceptance outside of these areas. Our respondents appear to acknowledge the potential impacts of renewable energy infrastructure on others but they are prepared to pay for it even when the issues do not directly affect them, i.e. at a national level. This suggests that the general public are aware of the possible negative effects of renewable energy infrastructure on others. To explore cost minimisation techniques, the scenario simulation uses the national respondents WTA amounts from the MNL model for the Green Fund (€460.33) and Local Authority benefit (€346.54) and incorporates this with local respondents WTA amounts for 20 wind turbines at various setback distances and different levels of export. The simulation indicates that the provision of a Green Fund in particular could help minimize the social cost of wind energy development incorporating trade at both a local and national level. This research is in line with that of Ek and Persson (2014), who find that the general public are concerned with the local governance of renewable electricity generation and that increased local involvement can positively influence general acceptance. It is also consistent with Devine-Wright and Batel (2013) who observe that public respondents can relate to issues at a local level contesting the view of the energy user as being only concerned with issues that impact them directly.

DISCUSSION

With respect to our first objective, our findings from the local studies show that respondents regard distributive aspects of wind farm development as important. We find considerable variation regarding the extent to which wind farm developers are perceived to have responded to distributional and procedural justice issues. There is a lack of awareness of financial benefits with 40% of the sample having no knowledge of any benefits arising from their local wind farm. The benefits most favoured by respondents include cash payments/reduced electricity bills and employment and although respondents living in areas offered a shareholding are strongly in favour of wind farm development for domestic use this pattern changes for exports, as discussed below. Our findings show that if existing wind farms have provided employment, information, financial support and proactive participation respondents are generally more accepting of wind farms but may also view the introduction of wind farms for exports more favourably.

Few areas in Ireland have greater exposure to wind farms than Donegal and yet these residents generally agree that their local wind farm developer cooperated, provided information and financial support. This is in marked contrast to Galway where respondents do not. The wind farm in the Galway survey location; appealed unsuccessfully by local residents in 1998; has breached several European Directives, despite repeated warnings from the EU, which has resulted in a recent €5 million fine plus €15,000 daily penalty for the Irish state (Kiernan, 2019, McGrath, 2019, European Commission, 2018).

There are two issues here of relevance. The first is that it is possible individuals become more accepting of wind farms over time as they gain greater experience of them even if they do not benefit from them or developers are not proactive in terms of participation, although the evidence for this is mixed (Kaldellis et al., 2013, Eltham et al., 2008). The second concerns cases where developers do in fact work closely with communities to resolve concerns related to process benefits and participatiion. One problem is that very little qualitative research has been conducted in order to examine these two cases separately to test what works for communities and what doesn't. This is a subject for future research.

By way of answer to objective 2, we do not find a NIMBY reaction to wind farms for exports but they may cost more in terms of community benefits than domestic projects. For the local surveys only 20% of the sample favoured wind farms for export, yet the choice experiment indicates that most (only 30% selected either SQ or 0% export in each set) respondents are willing to trade-off electricity exports against changes in their electricity bill. Hence, wind farm development is generally accepted for exports when certain conditions are met even in locations where such opposition is strongest.

Respondents reveal strong preferences in favour of wind farms to supply domestic requirements compared with exports even for cases where 50% of the power is retained for domestic consumption. This is consistent with research in a number of other studies (Liebe et al., 2017, Brennan et al., 2017, Dutton and Lockwood, 2017, Plum et al., 2019). Our findings from the focus groups and the choice experiment indicate that respondents are particularly wary of export projects if they involve shares, if respondents have strong place attachment (Devine-Wright and Howes, 2010) or perceive that the benefits are not reinvested in the area, or to have been exaggerated. If respondents do not trust the developer or if the wind farm ownership does not involve the state then they are also less likely to be in favour of export projects (Brennan et al., 2017). Some respondents appear to have a preference for renewable energy produced locally to be consumed locally or at least nationally and are also concerned about avoiding fines for not meeting EU targets. Subjects living in areas that offered share options are least in favour of development for export yet this is inconsistent with our finding for domestic wind farms noted above. It is possible that share schemes create an attachment to the wind farm and its energy. By this reasoning the energy becomes “ours” because the wind farm is ours, we therefore prefer to consume it locally. It may also simply be that exports are perceived as a more risky endeavour for communities until experience of actual projects proves otherwise. On the other hand, the benefits associated with greater acceptance of an export project for respondents include employment opportunities, cash payments and reduced electricity bills.

On the whole respondents prefer greater levels of participation than currently offered but do not favour high levels of participation. Results from the focus groups suggest that accurate information supplied from developers to affected residents may dispel any fears regarding wind farms. But higher levels of participation requires that engagement is reciprocal, time and resources set aside toward active engagement with a developer in wind farm design - a complex multifaceted endeavour requiring long term commitment. It is possible that for many respondents this is simply too time consuming. 40% of respondents either stated they were not aware of any financial benefit or declared there was none. Without financial benefits, respondents may be reluctant to engage in participation at a higher level. Having said this, the benefits of active participation by affected residents during the early stages of a project are widely reported in the literature. Experts consider the lack of regulation and community opposition to be among the greatest causes of project bottlenecks (European Commission, 2007; Battaglini et al., 2012).

Aside from a few committed enthusiasts, it is probably unrealistic to expect active participation without financial reward but it is possible that this could be encouraged if communities benefit. We find evidence to indicate that distributional and procedural justice issues may be linked. Respondents reporting a positive experience of financial benefits from wind farms are also more likely to engage in the design and development of a wind farm. Those living in areas that experienced jobs and community representation from prior wind farm development are most in favour of export projects.

In terms of the third objective, the trade in renewable energy in Europe is likely to become increasingly common as countries expand the sector to meet ambitious targets. Concerns related to intermittency are likely to become more pressing. It is also important to identify cost effective solutions to interconnectivity and trade that minimizes social costs. Trade offers a solution to the problem but it is important to assess the public reaction toward its use.

The national sample provides more context to the discussion of energy trade. One could speculate that national respondents may also view the export of renewable energy in a negative light given findings elsewhere which indicate the public can have strong preferences to retain the renewable energy generated nationally, regardless of their proximity to a development (Westskog and Winther, 2014). While the public respondents indicated similar low levels of agreement with wind energy development for export only; they derive positive utility from wind energy trade, particularly when this relates to exporting excess wind or as a form of intermittency management. The majority of respondents find renewable energy intermittency to be an important issue and derive positive utility from solutions to reduce it, particularly electricity trade. The focus group respondents also view the exportation of excess wind energy as unproblematic, as long as local benefits are provided and externalities are minimised.

One could also speculate that those who reside in areas unlikely to be impacted by future development; those living in urban areas for example; may care more about their personal electricity discount than the physical attributes of wind farm development. We did not find this to be the case. Instead, the national study highlights the importance of the provision of local benefits and engagement in all aspects of renewable electricity infrastructure, even when the public do not reasonably expect to receive these benefits (Ek and Persson, 2014). The Green Fund in particular; which was suggested by participants in a focus group; results in positive utility for most respondents in all classes.

Benefit provision is widely recognised as a method of increasing the acceptance of renewables and associated infrastructure amongst affected communities (Kermagoret et al., 2016, Walker et al., 2014a, Ferreira et al., 2019, Gebreslassie, 2020) however, this study indicates that it also has the ability to positively impact wider public acceptance outside of these areas. Our respondents appear to acknowledge the potential impacts of renewable energy infrastructure on others but they are prepared to pay for it even when the issues do not directly affect them, i.e. at a national level. This work is consistent with (Ek and Persson, 2014) who find that the general public are concerned with the local governance of renewable electricity generation and that increased local involvement can positively influence general acceptance. It is also consistent with Devine Wright and Batel (2015) who observe that public respondents can relate to issues at a local level contesting the view of the energy user as being only concerned with issues that impact them directly. The simulation outlined in objective 3 indicates how the provision of local benefits, via a Green Fund in particular, can increase welfare in local wind farm development areas, even in situations of high levels of energy export and at relatively close setback distances. The provision of such a fund is likely to be positively received by both those living in development areas and the public who are unlikely to benefit from it directly. This could also increase the acceptance of wind energy in general in Ireland.

CONCLUSION

In terms of the first objective of the study the externalities associated with wind farm development are well documented in the literature and include concerns regarding visual impacts, environmental degradation, property price reductions and health impacts (Álvarez-Farizo and Hanley, 2002, Bergmann et al., 2006, Groothuis et al., 2008, Heintzelman and Tuttle, 2012, Brennan and Van Rensburg, 2016). This is consistent with our focus group findings. Our results suggest that for affected residents these concerns are more pronounced for projects involving electricity trade. This phenomenon has been reported in a number of recent papers (Brennan et al., 2017, Liebe et al., 2017) but this has never been quantified empirically until this time. This is the first study to quantify and define a monetary measure of this external effect and this represents an international contribution to the state of the art on the subject. Those surveyed are willing to trade-off electricity exports against changes in their electricity bill but nonetheless indicate strong preferences for wind farm projects that supply an Irish market. Part of the explanation for this is due to distributive justice concerns. Our results suggest that affected residents regard the benefits from wind farms as very important.

Respondents also indicate strong preferences for greater setback distances, a finding consistent with the literature (Ladenburg and Dubgaard, 2007, Westerberg et al., 2013, Mariel et al., 2015, Krueger et al., 2011, Bishop and Miller, 2007, Kim and Chung, 2019), indicating increasing exposure to externalities felt by those closest to wind farm development. We find this to be the case for both onshore and offshore wind. We recommend that any benefit or compensation scheme should be provided on a sliding scale starting with those most likely to be impacted first in order to efficiently correct for the externalities associated with development. Community benefit schemes or share options which fail to correct for this “near neighbor” effect should be avoided.

The experience individuals in the community have about wind farm developments may be important. Local residents living near wind farms that provided employment or financial gain (but not share options) viewed projects involving trade more favourably than individuals which did not benefit.

Notably, results from our national study reveal that respondents also acknowledge the need to address local procedural and distributional justice concerns associated with renewable energy infrastructure even when they are unlikely to be personally impacted. We find unequivocal support for community benefit schemes and community engagement for affected individuals and communities. This is an important finding which does suggest the public at large are not indifferent to the concerns faced by local communities and prepared to support community benefit arrangements applicable to individuals living in close proximity to developments. This is the first published study in Ireland to record such a phenomenon and this represents a contribution to the state of the art on the subject.

In terms of the second objective, our findings show that distributional and procedural justice concerns may need to be considered jointly. Our results indicate that respondents want greater levels of participation and engagement in wind farm planning and design than is currently permitted under statutory legislation.

For policy makers and industry it is important to highlight two key findings related to the experience members of the public have of onshore wind farms. Local residents living near wind farms that provided employment or financial gain (but not share options) are generally more accepting of wind farms and viewed projects involving trade more favourably than individuals which did not benefit. Individuals with experience of local community representation in the planning process are also more in favour of export projects and less likely to select the SQ option of “No new wind farm”. These are both important findings because they appear to suggest that the demands made by communities in terms of improved wind farm governance outcome and process based on actual experience seems to matter.

However, policy makers and industry cannot expect local residents to take the initiative in being pro-active in terms of engaging with local authorities and developers. Respondents indicate preferences for moderate levels of engagement with wind energy developments. Communities need to be supported if they are to be actively involved in the process of development. Our focus groups and survey results indicate respondents do not wish to be actively involved in the wind farm process to a high degree without some form of financial benefit. Policy makers need to respond to this and the response is going to have to be especially persuasive to convince communities to support projects involving exports. Clearly benefits and employment matter but claims regarding employment and financial benefits need to be realistic and tangible and this needs to be communicated effectively to affected residents and they should be involved. The first step in this process would be to engage a community representative or initiate working groups or some form of community forum to provide communication and information between the developer and the local community. Such groups will help developers identify the particular needs of any given community. This may range from the development of an amenity to long-term employment or sustainable income generating activities. Our empirical modeling suggests there is heterogeneity in terms of the likely interest, skills, experience and commitment to this process. It is important to identify these individuals and support them.

Developers that do form project partnerships with such individuals and groups could strengthen social capital through the creation of community synergies in the formation of supported wind energy projects. Four factors appear to be critical to the success of such partnership arrangements. These are (i) commitment to engagement and supporting rather than undermining the sustainable development of communities, with the associated processes and goals; (ii) engagement with the implementers, statutory authorities; (iii) openness to listening and learning from communities and stakeholders; and (iv) adaptive design reflecting this learning.

What Devine-Wright et al. (2017) term the “middle actors” may also play a role here. These are intermediaries or system builders who circulate knowledge and information, formulate practices and help develop relevant agendas. Community representatives and working groups should be funded by the state. Middle actors, such as for example trusted intermediaries under the SEAI, could play an enabling role to ensure community representatives and working groups are supported in speaking to community concerns and that this endures over the life of a project.

This process will need to be resourced. We do find that there is public support for this in terms of our national study. Our results highlight that the general public acknowledge that the scaling up of renewable electricity generation and associated grid infrastructure will undoubtedly impose a greater burden on some members of the public than others. Our findings reveal that the vast majority of public respondents prefer renewable energy developments which provide local benefits and engagement in the decision making process and are willing to give up personal compensation to support it. This study posits that the provision of an earmarked Green Fund could be viewed positively both locally and nationally. The Green Fund, Local Authority Benefit and Community Rep were initially defined in the focus groups by study participants, and received positively by most survey respondents. Ultimately the Green Fund resulted in the highest utility for most survey respondents. Many countries throughout Europe, including Ireland, have introduced statutory polices for community benefit schemes or community ownership of wind energy developments (Kerr et al., 2017, Wind Europe, 2020, IRENA, 2019, Government of Ireland, 2018). Part of this funding could be centralised by government and granted to residents within a certain distance of a wind farm to provide “Green” upgrades such as home heating improvements, insulation, solar panels, smart meter installation, electric car purchases etc. This could increase the local and national acceptance of renewable energy projects, reduce the impact of intermittency on the system, and help those likely to be impacted by development, primarily in rural areas, become part of the energy transition.

Identifying demand side factors for improved wind farm governance from a community perspective is important as discussed above. However, what is less understood is the supply side response by the wind industry. Results from our focus groups indicate that some developers may be more effective than others at responding to this demand. However, this data is somewhat anecdotal. A formal in depth empirical assessment based on mixed methods research is critical to determine the type of industry actors that have the interest, capacity and comparative advantage to make a strong contribution to the process is required. This is a worthy topic of future enquiry.

Developers and policymakers should also be aware of the region-specific issues that may arise. This may be due to prior negative experience with wind farm developers or strong place attachment leading to the idea that the region "owns" the energy in it. These issues may be lessened through strong engagement and transparent information provision with communities (Devine-Wright, 2009).

Issues of scale are relevant and important. The midlands energy project (Brennan et al., 2017) was possibly the largest single wind energy project ever proposed in Ireland. Our empirical results from the local survey indicate that projects solely dedicated to exports are not acceptable to communities and our recommendations are that policies that support this approach should be avoided. Having said this, our findings do show that in principle individuals residing in close proximity to wind farms which involve trade will be acceptable provided certain conditions are met. This is a positive result for the sector but it is vital that these conditions are indeed met – the public outside of development areas also appear concerned with externalities and procedural and distributional justice.

In terms of scale, policy measures set out in RESS make particular provision for community wind. Recent legislation now in fact stipulates community wind energy projects (less than 5MW) should be 100% community owned. We do think there may be benefits to a hybrid model involving a joint project co-owned by communities and a developer. Executed in the right way this has the potential to resolve some of the procedural and distributional justice issues outlined above. It is crucial to avoid a two tiered system involving, on the one hand, small scale community wind which is the best in class in terms of its response to social acceptance concerns, and on the other hand, large scale (>5MW) development, that constitutes the mainstay of renewable power generation but continues to face social acceptance concerns which are not resolved. For this reason, we recommend that provision needs to be made to facilitate opportunities to support the hybrid model.

Respondents that are most concerned about Ireland achieving its own renewable energy targets are less likely to accept projects involved with trade in the belief that each country has an obligation to achieve their own energy targets. For local communities to perceive a development process and planning procedures as being fair and inclusive, developers must initiate engagement methods early in the process that provide accurate information and are accessible to all members of the community, engagement that takes account of local concerns and reflects those concerns in the final decisions (Walker and Baxter, 2017). Bi-directional engagement processes build relationships and trust between local communities and developers, and can channel social capital in the formation of co-operative, social networks, to sustain long-term empowering effects within the region. However, for this to work, it will require a significant shift in public policy away from viewing communities as consultees to one of active partners in the process.

Energy exports could play an important role in terms of revenue generation but also in responding to intermittency concerns. However, in terms of the third objective, cost effective solutions will have to be found in terms of interconnectivity and trade that minimizes social costs. In the case of exports, we do not find evidence of a NIMBY response at a local or a national level based on our survey data. It is clear though that resources will be required in terms of community benefits and to support participation. It is estimated that the majority of the public are willing to forego significant personal compensation (between €173 and €1838 in annual electricity discounts) to support the provision of a Green Fund for residents in development areas. The scenario simulation indicates how the provision of local financial support via a Green Fund results in significant welfare gains for local residents, even at relatively close setback distances and for wind energy developments involving 100% export. The provision of such a fund, which also results in significant positive utility for the public who do not directly benefit from it, could help minimize the social cost of wind energy development incorporating trade at both a local and national level.

Our findings from the national survey suggest that most respondents do not dismiss intermittency as a specialist technical topic of little relevance to them but acknowledge it as an important topic worthy of engagement. This is consistent with a study involving a survey and focus groups by Caporale et al (2020) who find the amount of energy produced by wind farms to be an important determinant of social acceptance in Italy. Latent class 1, the largest class in our national sample, support all the intermittency solutions provided including trade, battery storage and demand side management, do not prefer the status quo level of wind farm development and are less likely to be concerned about the impact of energy infrastructure. Future responses by policy makers to address intermittency are likely to combine a mixture of intermittency solutions. Our findings suggest most individuals we sampled would support this approach. This is the first study to quantify and define public preferences for wind energy that incorporates intermittency solutions including trade, and this represents an international contribution to the state of the art on the subject.

The trade attribute is preferred by most respondents but we find substantial preference heterogeneity across the sample for several of the attributes which deviate significantly from the MNL model for many individuals. Respondents in latent class 2 do not endorse battery solutions. Price alerts as a demand side management solution is insignificant for all classes except latent class 1. Differences between the groups are apparent with respect to the possible negative impacts of energy infrastructure as revealed by the concerned citizen attribute. Individuals in latent class 3 and 4, which account for approximately 16% of the sample, do not accept any intermittency solutions. Latent class 3 respondents are particularly concerned about the impact of energy infrastructure.

Our respondents have yet to fully comprehend the implications of trade as a solution to variable power generation. A significant minority have clear reservations about the benefits of trade and the environmental, health, visual and property price impacts of the grid and energy storage in particular. It would be a mistake for policy makers to ignore this. Given the level of public understanding and the interest in the topic, we propose a public debate on the subject. We also advise that early engagement, flexible development design, independent environmental and health monitoring, protection and reporting, education, the provision of local benefits and political support are all required to reduce the likelihood of opposition to grid expansion (European Commission, 2019b). The benefits of increased trade in renewables as a method of balancing the system (Bahar and Sauvage, 2013, Becker et al., 2014) and delivering cost reductions (Cleary et al., 2016, Abrell and Rausch, 2016) should also be communicated to the public. In general, our results suggest that the majority of the public are willing to forgo electricity discounts to allow for intermittency management. This implies that funds raised by the PSO levy through electricity bills could be used in part to support public knowledge of intermittency management solutions and to adequately compensate consumers for changes in behaviour. More energy storage, along with enhanced interconnection, forecasting, increased engagement and benefit provision could improve the flexibility of renewable electricity delivery and increase the acceptance of renewable electricity development and trade (Strbac et al., 2015, Schlachtberger et al., 2017, European Commission, 2007a, Brennan et al., 2017).

APPENDIX

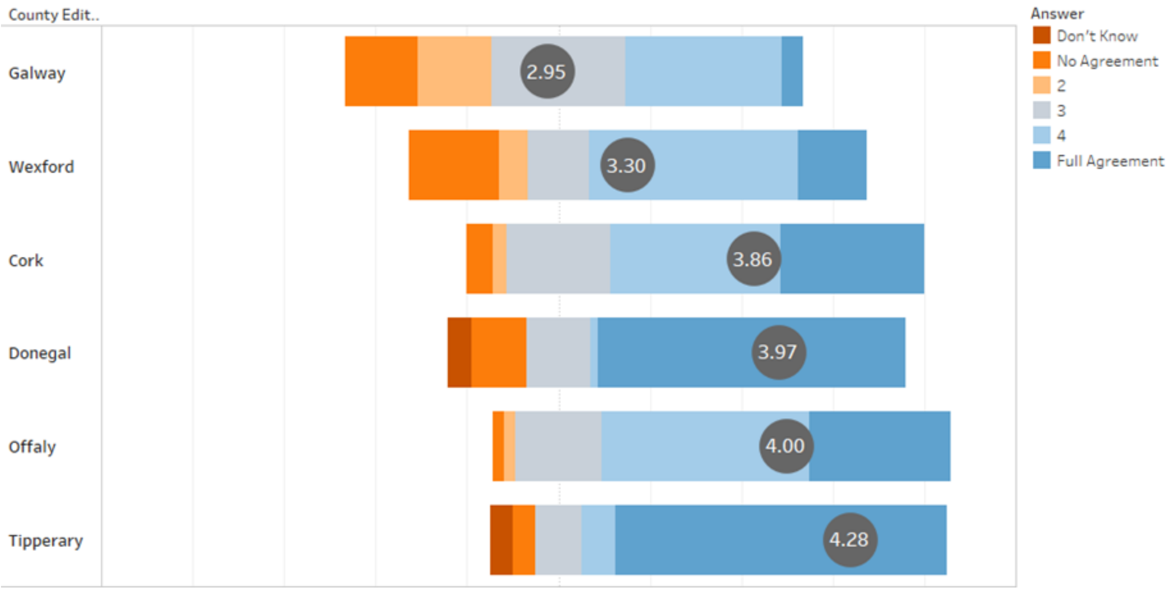

Figure 23: Attitudes to onshore wind by location:

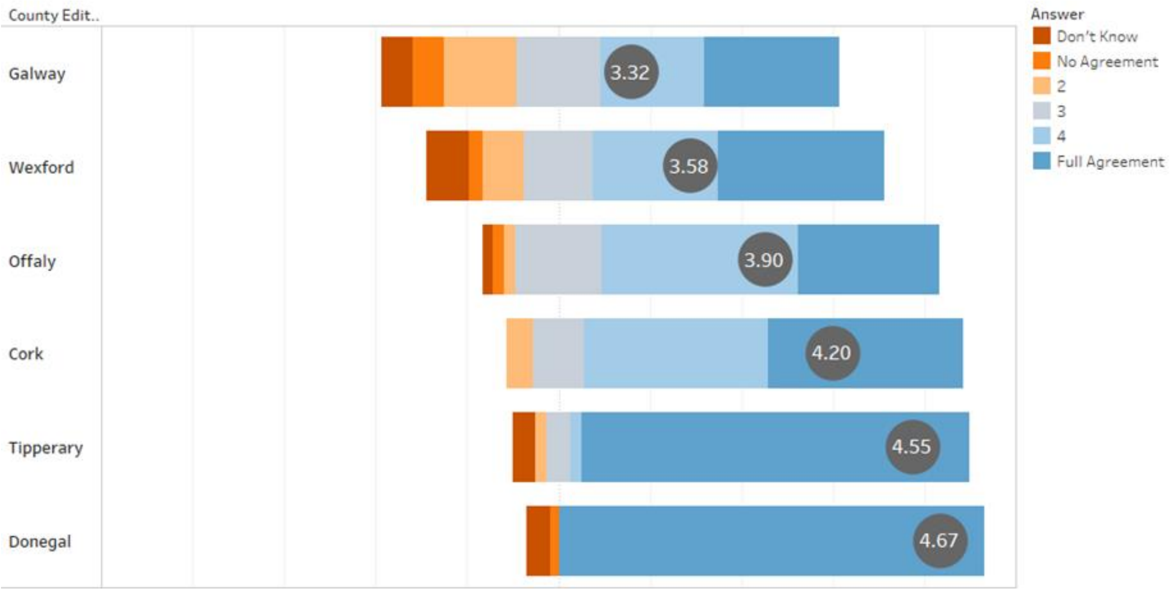

Figure 24: Attitudes to offshore wind by location:

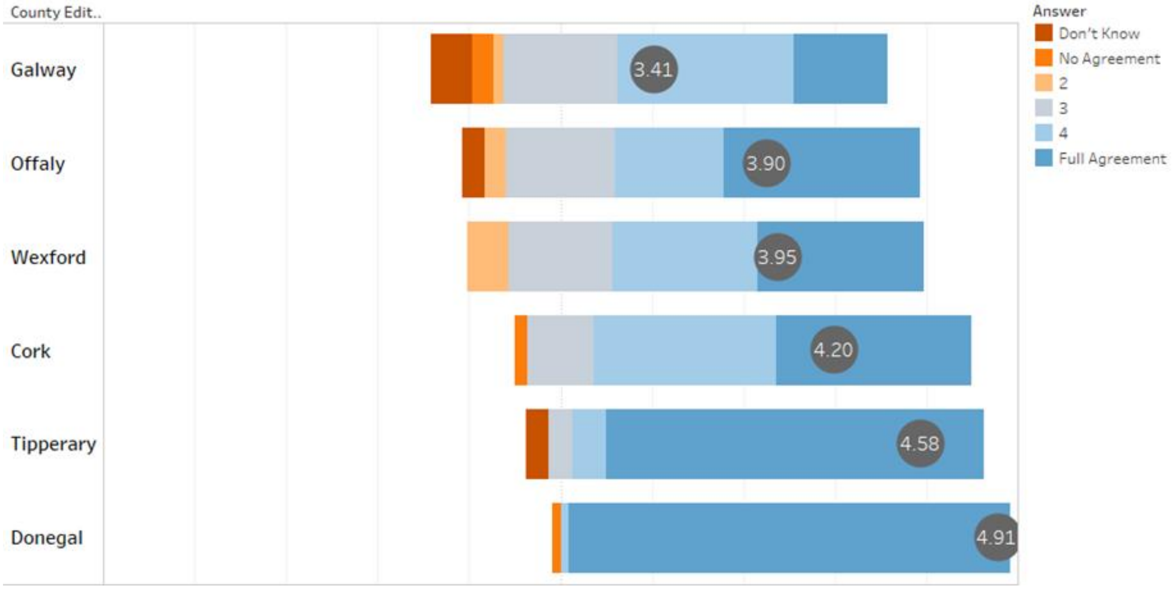

Figure 25: It is important for Ireland to achieve its targets

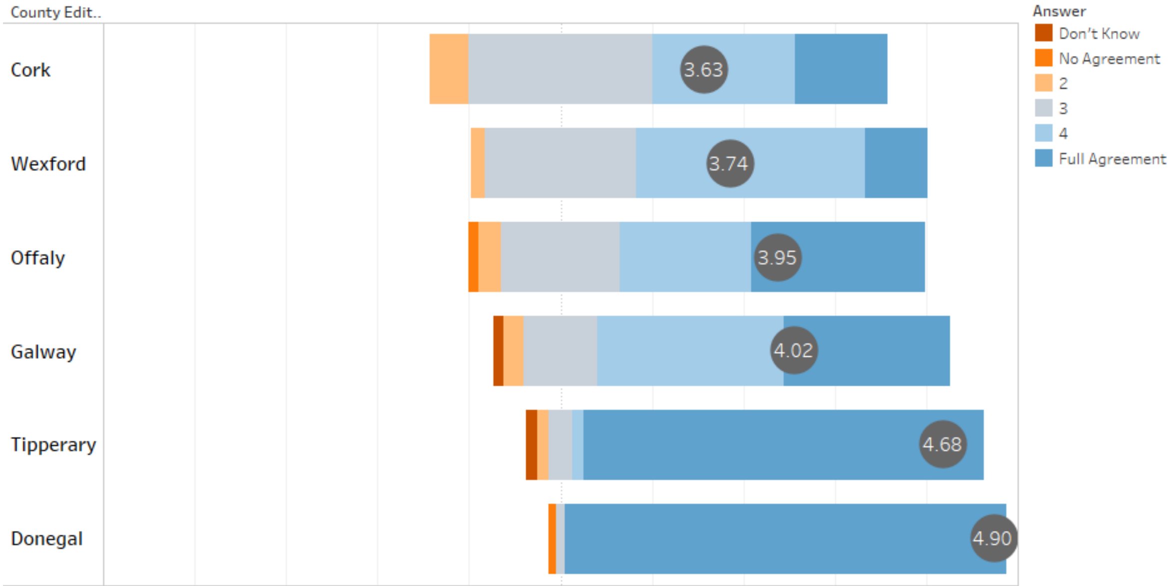

Figure 26: Each country should generate their own energy to meet targets:

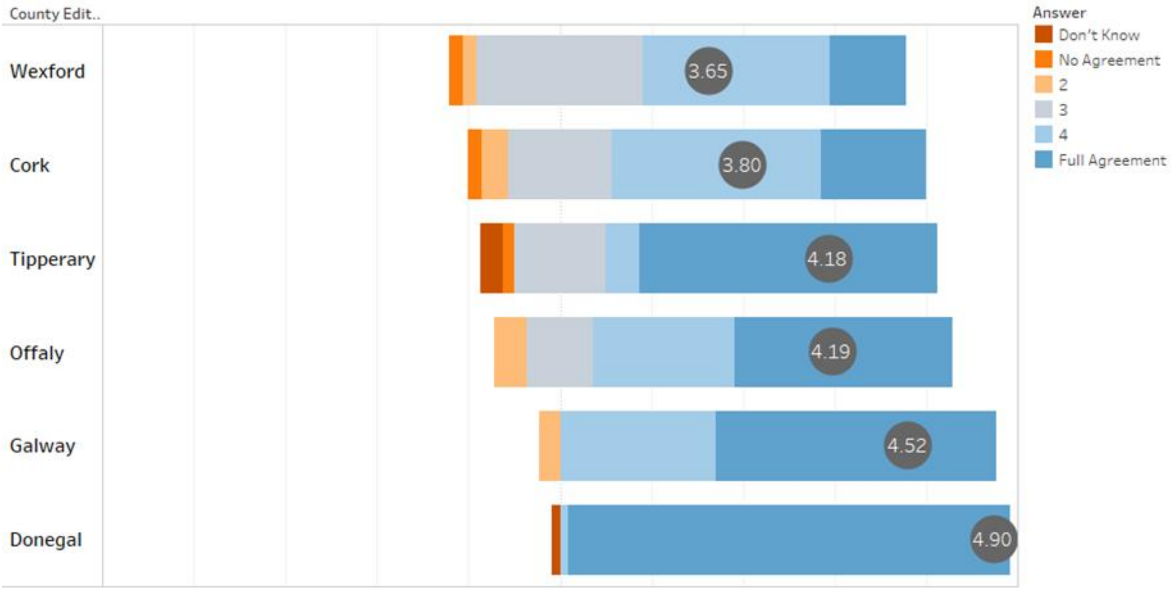

Figure 27: Energy created locally should be used locally:

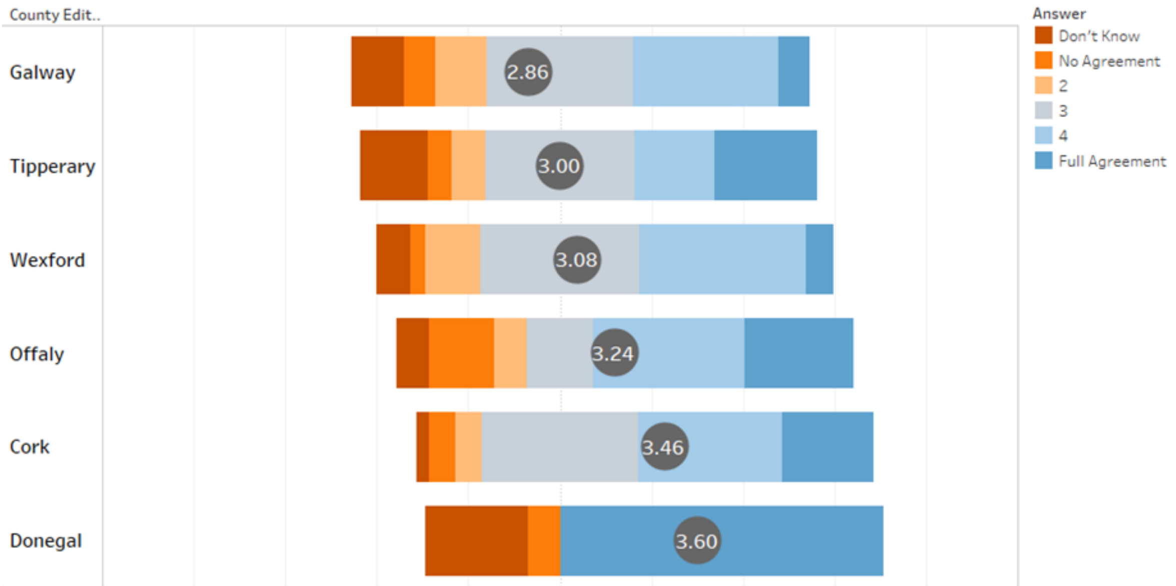

Figure 28: Limiting wind energy exports will ensure fewer wind farms will be constructed:

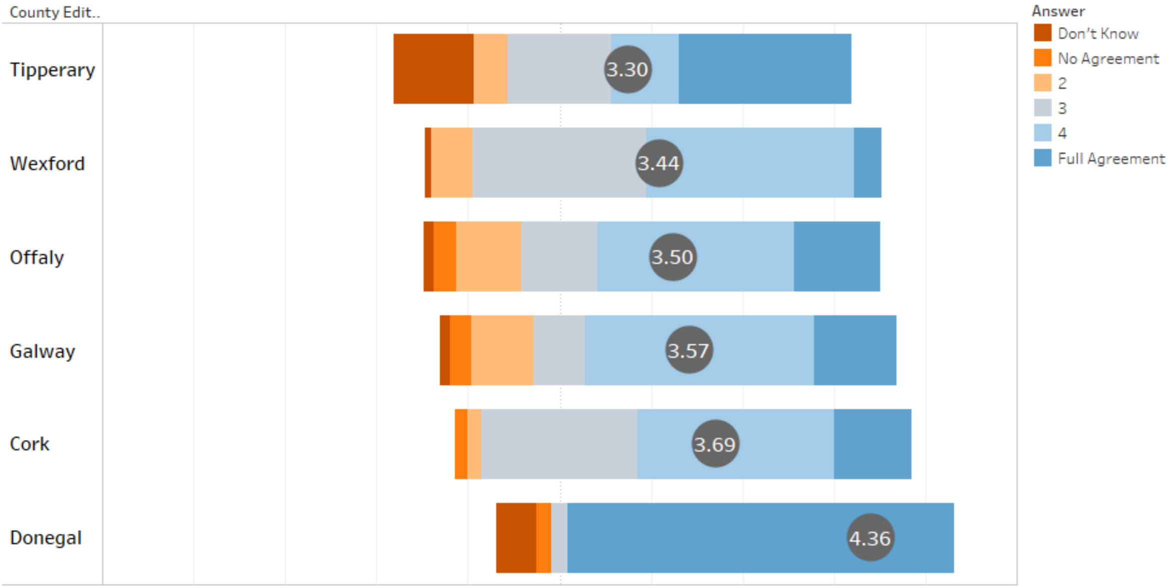

Figure 29: Limiting wind energy exports will ensure that Irish consumers benefit from clean energy instead

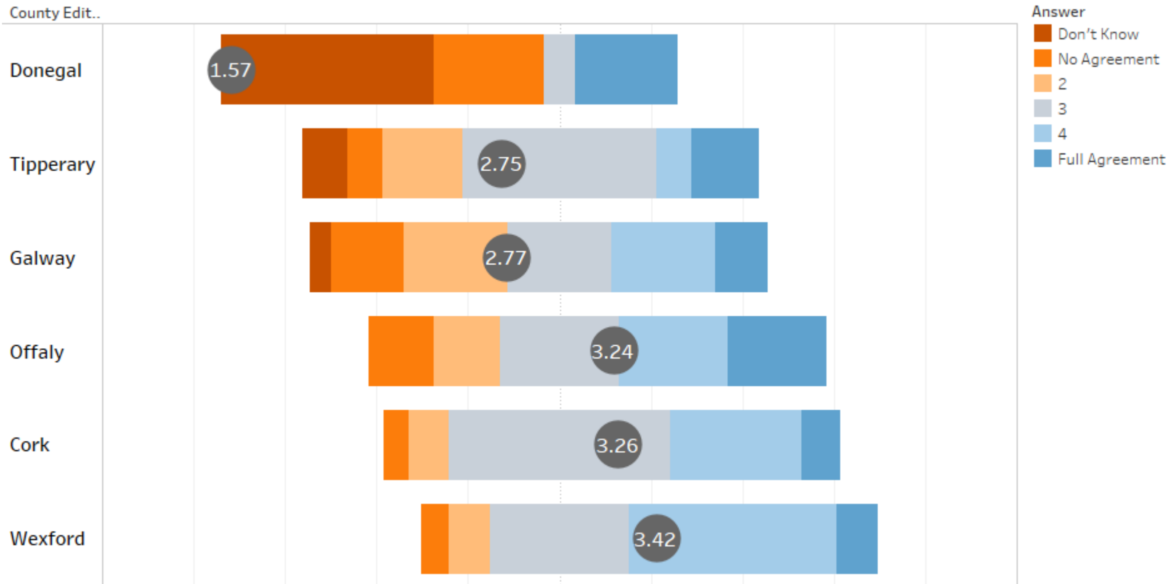

Figure 30: Exporting will lead to many jobs:

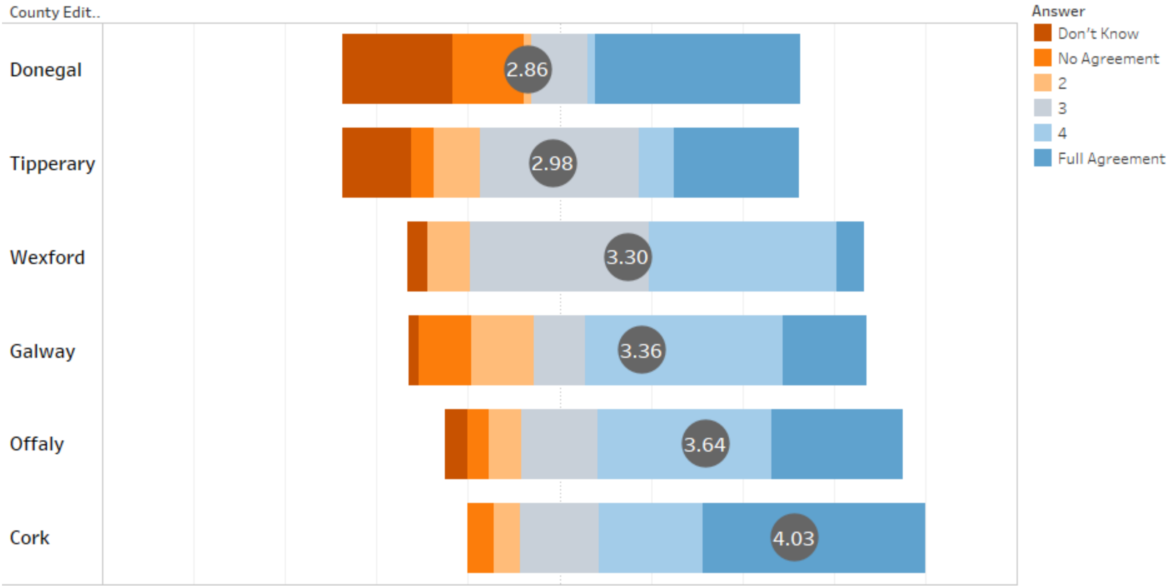

Figure 31: Exporting offers high monetary benefits to the Irish state:

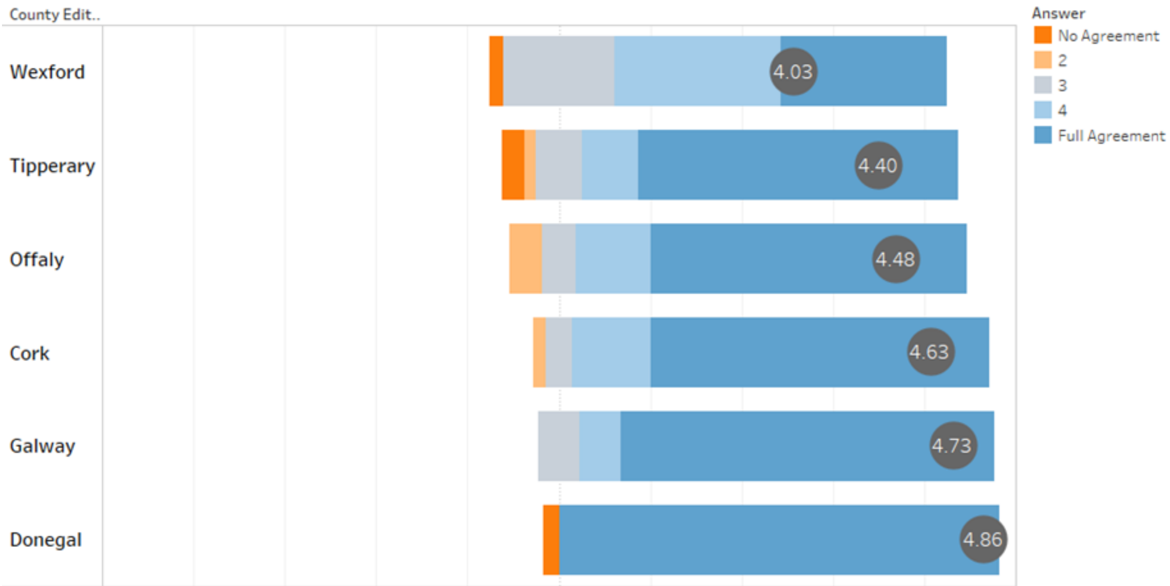

Figure 32: I know a lot about my local area:

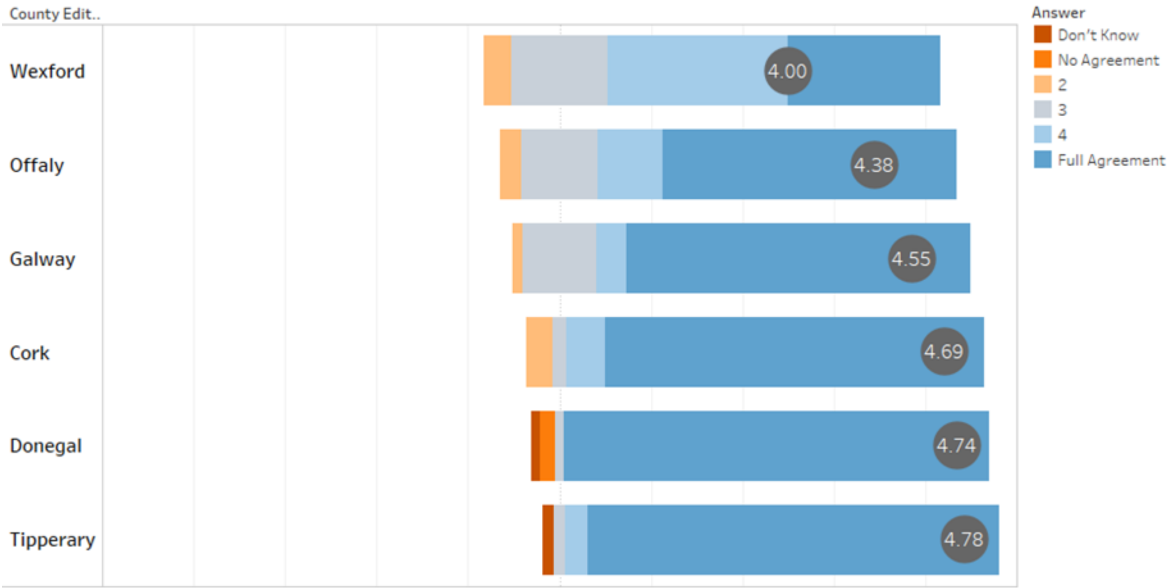

Figure 33: I miss my local area when I have been away too long:

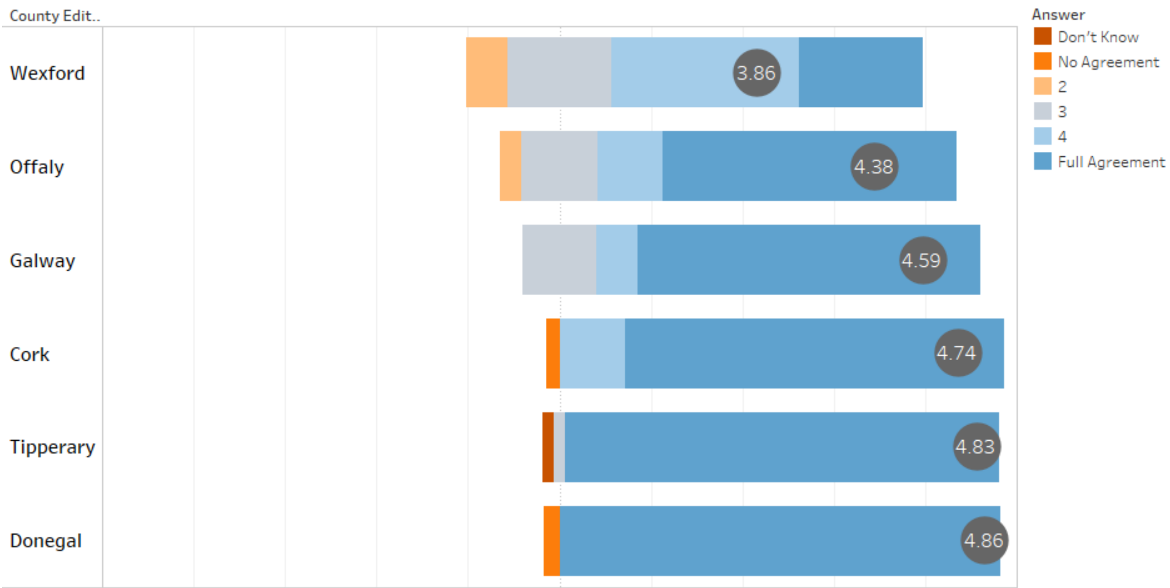

Figure 34: I would be happy to live in my area for a long time:

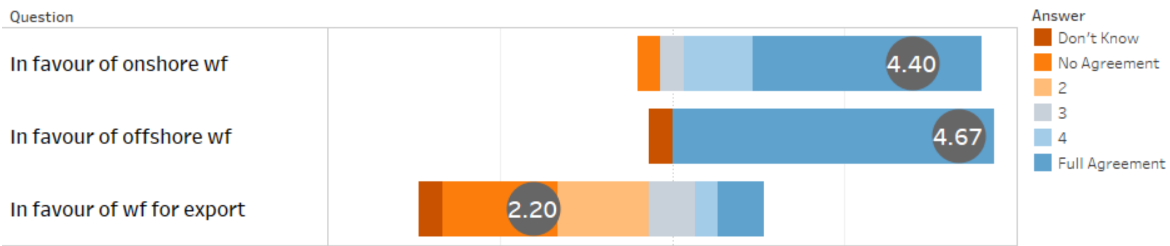

Figure 35: Impact of shares on attitudes to projects for domestic onshore, domestic offshore and export:

Table 21: Likert scale questions for Principal Component Analysis

How much do you agree with the following statements? ***No agreement*** ***Full agreement*** ***1*** *2* *3* *4* ***5*** *Don't know responses recoded as 3 on scale.*
I am in favour of onshore wind farm development I am in favour of offshore wind farm development I am in favour of building wind farms in Ireland specifically to export wind energy to other countries Exporting wind energy offers high monetary benefit to the Irish state Exporting wind energy will lead to many jobs
How concerned are you about the following with regards to battery storage for wind energy ***Not at all concerned*** ***Very concerned*** ***1*** *2* *3* *4* ***5*** *Don't know responses recoded as 3 on scale.*
Battery storage: Environmental impact concern Battery storage: Visual impact concern Battery storage: Property price impact concern Battery storage: Cost to taxpayer concern Battery storage: Human health impact concern
Above ground electricity development involves overhead power cables laid on poles. How concerned are you about the following with regards above ground electricity grid development? ***Not at all concerned*** ***Very concerned*** ***1*** *2* *3* *4* ***5*** *Don't know responses recoded as 3 on scale.*
Above ground grid: Environmental impact concern Above ground grid: Visual impact concern Above ground grid: Property price impact concern Above ground grid: Cost to taxpayer concern Above ground grid: Human health impact concern
Undergrounding is the replacement of overhead cables which provide electricity with underground cables. How concerned are you about the following with regards underground electricity grid development? ***Not at all concerned*** ***Very concerned*** ***1*** *2* *3* *4* ***5*** *Don't know responses recoded as 3 on scale.*
Underground grid: Environmental impact concern Underground grid: Visual impact concern Underground grid: Property price impacts concern Underground grid: Cost to taxpayer concern Underground grid: Human health impact concern

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