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FINANCIAL INCENTIVES FOR LOW-CARBON TRANSITION:

FROM CITIZENS TO PROFESSIONAL INVESTORS

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Declaration

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

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Joseph Curtin

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Abstract

Decarbonisation of the global economy requires an energy transition of exceptional scope, depth and speed, and a doubling of the current level of investment in low-carbon technologies. However, the risk perception of individual market participants—a key determinant of the pace at which these technologies will be deployed—is an under-addressed theme in the academic literature.

In this thesis the risk-return preferences and investment attributes that are attractive to different types of investors are investigated, with a view to informing the design of financial incentives introduced by Governments. In Chapter 2 the literature assessing the impact of technology-specific financial incentives on the levels of investment in low carbon technologies from local citizen investors is evaluated. It is concluded that feed in tariffs, grants and tax incentives can be successful in mobilising greater levels of investment from non-traditional investors, but that soft loans are less effective as a stand-alone instrument. In the following chapter, a novel analytical approach is introduced to explore the use of financial incentives in key jurisdictions to overcome barriers to investment from local citizen actors. The importance of instrument design over instrument choice emerged from this analysis. The requirement for incentives at feasibility and development stages of renewable projects also emerged as a distinguishing feature of projects with citizen involvement, reflecting the high risk-aversion of these actors, as well as their inability to manage risk across a portfolio of projects. At later project stages, market-independent supports (feed in tariffs, grants and tax incentives) were found to have been effectively deployed, however, more market-based instruments (feed in premiums and quota schemes) were also found to be effective *if* tailored to the specific needs of citizen investors. In Chapter 4 the risk-return preferences of a representative sample of citizen investors in Ireland—a market with no citizen investment tradition—were explored using a choice experiment. A high level of interest in investing in wind, solar, biomass and waste-to-energy projects was uncovered, however, a majority of citizens were found to be highly risk-averse, and investment amounts were low compared to equity required for larger projects.

These findings suggest that greater levels of investment capital could be mobilized from citizen investors using specifically tailored incentives. However, these actors can only make a limited overall contribution, and promoting greater levels of investment from professional investors is crucial if climate objectives are to be met. In Chapter 5, semi-structured interviews and an on-line survey were therefore used to compare attitudes to stranding risk for investors in power generation assets with investors in financial assets. Asset stranding risk was found to be a more prominent issue for the former cohort, suggesting that as you move along the investment chain—away from physical assets and towards financial assets—far less is known about climate risk, and it becomes increasingly challenging for investors to manage it.

Managing the risks face by different investor cohorts emerges as an important means of mobilising greater levels of investment and reducing the cost of capital for low-carbon technologies, which in turn has the potential to increase the speed of energy transition. Understanding the risk-return preferences of different cohorts of investors, however, remains both understudied and underappreciated in the climate policy and climate finance literature. The findings from this study both address this literature gap and uncover several themes meriting further analysis and investigation.

LIST OF ABBREVIATIONS

ACA	Adaptive Conjoint Analysis
ACBC	Adaptive Choice-Based Conjoint
BMWi	The Federal Ministry for Economic Affairs and Energy
BYO	Build Your Own
c/kWh	Cent per Kilowatt Hour
CBC	Choice-Based Conjoint
CCEA	Convergent Cluster & Ensemble Analysis
CEE	Centre for Energy and Environment
CHP	Combined Heat and Power
CO_2	Carbon Dioxide
CRI	Community Renewables Initiative
CSO	Central Statistics Office
CTI	Carbon Tracker Initiative
DCCAE	Department of Communications, Climate Action and Environment
DECC	Department of Energy and Climate Change
EAI	The Electricity Association of Ireland
EFI	Economic and Financial Incentive
ESG	Environmental, Social and Governance
EU	European Union
FiP	Feed in Premium
FiT	Feed in Tariff
GEGEA	Green Energy and Green Economy Act
GHG	Greenhouse Gas
HB	Hierarchical Bayes
ICBC	Industrial and Commercial Bank of Chin
IEA	International Energy Agency
RETP	Renewable Energy Technology Platform
IESO	Independent Electricity System Operator
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency

J	Attribute Level
KfW	Kreditanstalt für Wiederaufbau
Km	Kilometres
LCT	Low Carbon Technology
Max	Maximum
MW	Megawatt
N	Number
N/A	Not Applicable
NESC	National Economic and Social Council
NFFO	Non-Fossil Fuel Obligation
NIMBY	Not In My Back Yard
OECD	Organisation for Economic Cooperation and Development
OFGEM	The Office of Gas and Electricity Markets
P	Price
PV	Photovoltaics
R&D	Research and Development
REFIT	Renewable Energy Feed in Tariff
RESOP	Renewable Energy Standard Offer Program
RO	Renewables Obligation
ROI	Return on Investment
SEAI	Sustainable Energy Authority of Ireland
Sig	Signature
SNI	Sustainable Nation Ireland
SWH	Solar Water Heating
TCFD	Task Force on Climate-related Financial Disclosures
TGC	Tradable Green Certificate
U	Part Worth Score
UK	United Kingdom
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States

VAT	Value Added Tax
WRI	World Resources Institute
WTA	Willingness to Accept

Publications based on this PhD thesis

Chapter 2. Curtin, Joseph; McInerney, Celine; Ó Gallachóir, Brian. 2017. *Financial incentives to mobilise local citizens as investors in low-carbon technologies: A systematic literature review.* Renewable and Sustainable Energy Reviews 75:534-47.

Chapter 3. Curtin, Joseph; McInerney, Celine; Johannsdottir, Lara. 2018. *How can financial incentives promote local ownership of onshore wind and solar projects?* Case study evidence from Germany, Denmark, the UK and Ontario." Local Economy 33 (1):40-62.

Chapter 4. Curtin, Joseph; McInerney, Celine; Ó Gallachóir, Brian; Salm, Sarah. 2019. *Energizing local communities—What motivates Irish citizens to invest in distributed renewables?* Energy Research & Social Science 48, 177-188.

Chapter 5. Curtin, Joseph; Celine McInerney; Ó Gallachóir, Brian. 2019. *A risky business? Attitudes amongst Irish investors in the power and finance sectors to risks of stranded assets arising from climate change mitigation.* Under Review: Journal of Sustainable Finance and Investment.

Chapter 1: Introduction

1.1. Background and context

If 'dangerous' climate change is to be avoided, immediate and rapid decarbonisation must be achieved over the coming decades, particularly in developed economies (Anderson & Bows, 2011; Rogelj et al., 2010; Edenhofer, 2014). Parties to the Paris Agreement of December 2015 agreed to maintain global temperatures *'well below 2° C above pre-industrial levels'*, and to *'pursue efforts'* to limit temperature increases to below 1.5 degrees (UNFCCC, 2015). Staying within the 2° C temperature target would require an energy transition of exceptional scope, depth and speed, and an estimated $3.5 trillion in energy-sector investments each year until 2050 across the energy generation, industry, transport and buildings sectors (Covington, 2017; IEA, 2018), which is about double the current level of investment.

In comparison to traditional technologies in the power, heat and transport sectors that rely on fossil fuels, many low-carbon technologies such as solar photovoltaics (PV), wind turbines, combined heat and power (CHP) installations and biofuel boilers are modular, relatively small scale (typically <50 MW installed capacity) and decentralized. These new technologies are expected to play an increasingly important role in transition to a low carbon economy over the coming decades (Ruggiero, Varho & Rikkonen, 2015; Sioshansi, 2016), and many countries are therefore incentivising their up-take (IEA, 2015). The widespread deployment of these new technologies, however, is potentially disruptive for traditional business models (Engelken et al., 2016; Johnson & Suskewicz, 2009), which poses challenges for traditional investors, and opens up business opportunities for new types of investors.

Over the last decade, investor perceptions of risk and return have become an important stream of research in the energy finance, energy policy and energy economics literature. The importance of the risk and profitability characteristics of investments have traditionally been accepted as highly influential over investor behaviour for all investors—from local citizens to institutional investors (Markowitz, 1952; Dinica, 2006). Modern Portfolio Theory, for example, suggests that the risk and return characteristics of specific technologies or investment opportunities should not be viewed alone, but evaluated in terms of how the investment affects the risk and return of the entire portfolio (Markowitz, 1952), while the ‘asset pricing’ branch of the finance literature explores, inter alia, the extent to which investors correctly price risk into asset values (Sharpe, 1963). Portfolio theory has also been applied to managing risk and maximising performance for power sector investors, because the generation portfolios of energy companies are similar, at least in some respects, to financial portfolios (Bazilian & Roque, 2008).

Much of this literature therefore assumes that investors, whether electric utilities, insurance companies, pension funds, or citizen and community investors, are rational, rent-seeking agents who compare opportunities according to the perceived risk-adjusted returns. Lower risk perception for renewable energy projects or higher risk perception for fossil fuel projects could therefore affect investors' cost of capital, which in turn is a key factor for determining the rate of technology diffusion and the pace of low-carbon transition.

1.1.1 The need for financial incentives

We are in the midst of an energy transition, but there is a considerable shortfall in private finance provided by traditional investors compared to the requirements for global decarbonisation (Eleftheriadis & Anagnostopoulou, 2015; Haigh, 2011; Simshauser, 2010; McInerney & Johannsdottir, 2016). An extensive literature points to a combination of technological, economic, institutional and political barriers which result in sub-optimal levels of investment in low-carbon technologies (Polzin, 2017). Several factors have been highlighted within this context.

First, the characteristics of the technologies themselves may affect risk-return perceptions. For example, low-carbon technologies may have longer payback periods and higher upfront investment costs (Zhang, Shen & Chan, 2012). Second, investors may have biased perceptions and preconceptions that favour status quo energy production models over innovative alternatives (Masini & Menichetti, 2013); or they may perceive new technologies to be riskier and unreliable (IPCC, 2011). Third, these challenges have been exacerbated since the financial crisis of 2008, which resulted in a very significant increase in short-term and speculative investments (Jones, 2015). Fourth, traditional banks are also struggling with stricter reserve requirements under Basel III, while sovereign and utility balance sheets are beset with considerable challenges (Eleftheriadis & Anagnostopoulou, 2015; Haigh 2011; Simshauser, 2010). While professional investors, such as financial institutions, utilities and businesses, have therefore been active in providing private finance for distributed power generation technologies, these technologies face a number of barriers to optimal deployment.

According to the Intergovernmental Panel on Climate Change (IPCC), there is a role for public policy in overcoming these barriers to investment under these circumstances, so that the full mitigation potential of distributed low-carbon technologies can be realised (IPCC-WGIII 2001, 752).

The requirement for better Government engagement with the private sector to mobilise new resources, spur innovation and advance know-how is commonly recognised (Morgado & Lasfargues, 2017). The most obvious means of engagement is through the provision of financial incentives, which can be crucial in affecting investor risk-return perceptions. Distributed energy technologies, such as on-shore wind and solar PV, are increasingly cost-effective, yet they generally require some form of Government support to galvanise investment. There is a comprehensive literature exploring the effectiveness of different types of financial incentives in mobilising investment from professional investors (Abolhosseini & Heshmati, 2014; Bobinaite & Tarvydas, 2014; Marques & Fuinhas, 2012; Mickwitz, 2003; Oak et al., 2014; Ozcan, 2014; Polzin et al., 2015; Somanathan et al., 2014). One finding emerging from this literature is that both the choice and design of financial incentives, including feed in tariffs and premia, quota based systems, tax incentives, grants, and soft loans, can be highly influential over investor risk-return preferences (Fouquet & Johansson, 2008; Butler & Neuhoff, 2008; del Río & Bleda, 2012; Saunders, Gross, & Wade, 2012; Couture & Gagnon, 2010).

1.1.2. Citizen investors

Within this context, one important theme in the finance literature which has been less comprehensibly addressed is how to mobilise investment from non-traditional actors, such as citizens and community groups. The design of appropriate financial investments targeting this cohort of investors is a relatively underexplored theme.

This literature takes as its starting point that distributed low carbon technologies will become increasingly important in low-carbon transition. The International Energy Agency, for example, estimate that wind and solar PV alone have the potential to contribute 22% of electricity sector emissions reduction by 2050 (IEA, 2015). Furthermore, these technologies have characteristics that make them particularly attractive to local citizen investors, acting either individually, as members of a community group, or as party to a project by a professional developer (Enzensberger, Fichtner & Rentz, 2003), not least their maturity, modularity, high reliability, the simplicity of the energy generation process, and availability of technical service providers (Yildiz, 2014). Citizen participation schemes and local community ownership have therefore been identified as a potential new source of private finance for low carbon technologies (Bergek & Berggren, 2014).

The wider social science literature identifies a second potential benefit from mobilising citizen investment in low-carbon technologies—enhancing social acceptance of these technologies. A lack of "social licence" to operate has been identified as a key factor in preventing distributed energy projects from proceeding, even in cases when capital is available, and local discontent can be highly costly and even fatal for projects (Van Rensburg, Kelley & Jeserich, 2015). Wustenhagen et al.'s (2007) *Social Acceptance of Renewable Energy Innovation* framework, identified three dimensions of social acceptance: procedural justice related to decision making; trust between the community and developers; and how costs and benefits are distributed (Figure 1) (Wüstenhagen, et al., 2007). An extensive literature has explored these discrete aspects of societal acceptance (Borch, 2018; Shackley & Green, 2007; Sovacool & Lakshmi Ratan, 2012; Stokes 2013; Szarka et al., 2012; Walker, 2011; Wolsink, 2007).

Focusing on the third aspect of Wustenhagen's framework—how costs and benefits are distributed—promoting local ownership of distributed renewable energy technologies has been identified as one means of ensuring that the benefits of low-carbon transition are widely distributed across society (Bergek et al., 2013; Linnerud & Holden, 2015, Ruggiero et al., 2015). This work suggests that promoting greater levels of citizen investment from community and citizen groups could contribute to addressing both the investment shortfall *and* the social licence to operate.

Much research has been undertaken on the benefits of community and citizen investment, (Bergman & Eyre, 2011; Bolton & Foxon, 2015; Devine-Wright, 2014; Viardot, 2013), however, little is known about citizen investor preferences for distributed renewables (Borgers & Pownall, 2014; Gamel, Menrad & Decker, 2017; Salm, Hille & Wüstenhagen, 2016), and a lack of rigorous academic research on the risk-return preferences of these investors has been noted in previous studies (Salm, Hille & Wüstenhagen, 2016; Gamel, Menrad & Decker, 2017). Furthermore, while the importance of financial incentives and subsidies have been underlined by many studies (Curtin, McInerney & Ó Gallachóir, 2017; Curtin, McInerney and & Johannsdottir, 2018; Gamel, Menrad & Decker, 2017; Fleiß et al. 2017; Yildiz, 2014), the design of financial incentives that are attractive to local citizen investors, and which would be effective in mobilising investment, is another underdeveloped theme in the academic literature (Stigka, Paravantis & Mihalakakou, 2014; Yildiz 2014; Curtin, McInerney & Ó Gallachóir, 2017). According to Yildiz (2014, p. 678) "*the literature on citizen participation in the financing of renewable energy infrastructures is sparse considering its empirical importance*". Coming to a better understanding of the unique risk-return preferences of citizen investors, and designing incentives that are attractive to them, could reduce the overall costs to society of low-carbon transition while increasing its pace.

1.1.3. Professional investors

There is a recognition that local citizen investors can make a greater contribution to low carbon transition as investors, however, the importance of mobilising greater levels of investment from traditional investors has also been identified in many studies (Polzin et al., 2015; Polzin, 2017; OECD, 2017; Task Force on Climate-related Financial Disclosures, 2017; Covington, 2017). There is a growing literature which explores the ways in which energy transition itself could affect risk-return perception of professional investors. Krause, Bach and Koomey (1989) first applied the concept of "stranded assets" to the climate policy arena by identifying the potential for "early obsolescence" of infrastructures built up around fossil fuels under low-carbon transition, which they determined could pose risks to the value of physical and financial assets (Simshauser, 2017).

This is a theme that has garnered greater analytical attention as international political momentum to address climate change has gathered pace over the past decade. For example, Article 2.1 c of the Paris Climate Agreement included the objective of "*making finance flows consistent with pathways towards low greenhouse gas emissions and climate resilient development*" (UNFCCC, 2015). A parallel scientific development is the increasing prominence given to carbon budgets: that is, the amount of cumulative greenhouse gas (GHG) emissions in the atmosphere consistent with meeting a particular climate objective. The first budget estimates were provided by Meinshausen *et al.,* (2009) and Allen et al., (2009). Further estimates have subsequently been provided under different assumptions in a wide number of studies (Rogelj et al., 2016). The concept was mainstreamed into climate policy analysis by the IPCC's synthesis report of 2014, which provided estimates for budgets consistent with various levels of warming. Recent budget estimates have focused on achieving the 1.5 °Celsius target (Goodwin et al., 2018; Millar et al., 2017). These carbon budget estimates gave rise to the concept of "unburnable carbon", which refers to the fossil fuel reserves that cannot be burned which is consistent with staying within a particular carbon budget (Carbon Tracker Initiative, 2011), an idea that has attracted considerable analytical and public attention (Ben Caldecott 2017; Griffin, Jaffe, Lont, & Dominguez-Faus, 2015; Task Force on Climate-related Financial Disclosures, 2017; Vergragt, 2004), and has clear implications for investor risk perception and capital allocation decisions.

If these assets are effectively "unburnable", their worth could be vastly reduced and they could therefore fail to produce the return hoped for (Caldecott, Tilbury & Carey, 2014). In other words, these assets may become "stranded". While there are a number of possible definitions of stranded assets, we adopt the definition proposed by Caldecott (2014, p 7), that 'stranded assets are assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities". In September 2015, the Governor of the Bank of England, Mark Carney, warned that there was a danger that assets of fossil fuel companies could be left stranded by tougher rules to curb climate change, and that investors faced "potentially huge" losses because this action could make vast reserves of oil, coal and gas "literally unburnable". The Financial Stability Board, which reports to G20 governments and is chaired by Governor Carney, subsequently launched a Task Force on Climate-related Financial Disclosures (2017), which recommended that climate-related financial disclosure should be incorporated into mainstream public annual financial statements (Task Force on Climate-related Financial Disclosures, 2017). The European Commission, meanwhile, has proposed a regulation which introduces obligations on how institutional investors and asset managers integrate environmental, social and governance (ESG) factors in their risk processes. Nor is this threat of "stranding risk" just theoretical—Ernst and Young (2017) estimated that €143 billion has already been written off against assets that had lost value between 2010 and 2016, which they largely attributed to energy transition (EY, 2017); while Blackrock, the world's largest fund manager, has begun requiring investment managers to incorporate climate risk into investment appraisals (Financial Times, 2016).

Central to the question of stranding risk, therefore, is the extent to which climate risks are appreciated by actors in the financial system, and the extent to which they are integrated into the price of assets across the investment chain, both physical and financial (Chenet, Thomä & Janci, 2015). Stranding risk has clear implications for physical assets which tend to be the most illiquid, including both the underlying fossil fuel reserves, and infrastructures that rely on fossil fuels (power stations, transport assets, real estate etc.). However, asset impairment can also affect more liquid financial assets such as stocks and bonds, which, in turn, could feed through to investment portfolios owned by institutional investors, or indeed the balance sheets of financial institutions. Finally, the value of portfolios and creditworthiness of financial institutions has the potential to feed into systems risk, and to undermine the stability of the financial system (Partington, 2018). The premise of the stranding literature is that stranding risks may be mispriced for a number of reasons at various points along the investment chain (Harnett 2017; Silver 2017; Thomä & Chenet, 2017).

Notwithstanding its crucial importance for the pace of low-carbon transition, however, the climate risk perception of professional investors has been left "almost unaddressed" until recent times (West, 2019). While there is a literature exploring stranding risk focused on either physical or financial assets (See Chapter 5), there are no studies that look across the investment chain, that compare and contrast perceptions on stranding risk for owners of physical compared to owners of financial assets. Perception of stranding risk, and how it could affect investment decisions therefore remains an understudied theme and an open question within the climate finance and climate policy literature, despite the clear implications of these issues for capital allocation decisions, and even for the stability of the financial system.

1.2. The Irish Policy Context

There are notable differences across countries in terms of how investors perceive the risk-adjusted returns of investment opportunities and there is, therefore, considerable value in exploring different country frameworks individually. Ireland is a particularly interesting case to study. As an EU Member State, it is required to reduce emissions from non-emissions trading sectors (buildings, transport and agriculture) by 20% by 2020 and 30% by 2030. In addition, 16% of energy must come from renewable sources by 2020 (European Commission, 2008). Policy, in particular the introduction of a FiT (the Renewable Energy Feed in Tariff (REFIT) Scheme) in 2006, has been successful in attracting investment capital into the wind sector. Renewable electricity generation has expanded rapidly: only 7% of electricity was generated from renewables in 2005, but by 2017 this had increased to 30% (SEAI, 2018). However, notwithstanding this progress, according to the European Commission Ireland lags considerably behind in achieving its renewable energy targets, leaving an exposure to potential fines and/or compliance costs to make up the shortfall (Deane, 2017).

A second interesting characteristic of the Irish case is that investment activity has been dominated by traditional investors, such as utilities, professional project developers and financial institutions (Curtin, McInerney & Johannsdottir, 2018). There is only one wind farm of 3.9 megawatt (MW) held in community ownership from a total installed capacity of over 3000 MW. In countries such as Denmark and Germany, by contrast, over half of total investment has come from local citizens (BMWi, 2016; Danish Energy Agency, 2014; Curtin, McInerney & Johannsdottir, 2018; Mey & Diesendorf, 2018). Furthermore, a "*sea change in social support"* against wind power has been noted (NESC, 2014). The Government's Irish Energy White Paper (2015) acknowledges the important of having a "social licence to operate" and envisages transitioning from an energy system "*from one that is almost exclusively Government and utility led, to one where citizens and communities will increasingly be participants*", and includes commitments to use economic incentives to support the growth of citizen investment (DCCAE, 2014), and a new renewables support scheme requires developers to invite citizen community groups within a 5 km radius to invest in their project (DCCAE, 2018)

Prior research has found that the different levels of citizen investment across countries grounds in country-specifics including, *inter alia*, the regulatory environment, support from local advisory organisations, a tradition of local activism, a relatively high sensitivity to environmental issues among citizens, and the presence of citizens with the financial resources to invest (Dewald & Truffer, 2011; Romero-Rubio & de Andrés Díaz, 2015; Gamel, Menrad & Decker, 2017). However, there is also an extensive literature which explores the motivation of citizen investors, which tends to focus on identifying more generalisable characteristics across countries (Fleiß et al., 2017). It is an open question in the literature if the successes achieved in countries such as Denmark and Germany in mobilising citizen investment can be replicated in countries such as Ireland, Spain or the US, which do not have the same long-standing citizen investment tradition.

In addition to the rapid deployment of distributed renewables, Ireland also has a well-developed financial services sector. Sustainable and green finance forms a key strategic priority in Ireland's International Financial Services strategy. Euronext Dublin is already the exchange of choice for many leading international listings of debt, and the development of European Green Bond standards will fuel further growth, with €6 billion in green bonds already listed on the exchange. It is one of the leading hedge fund service centres in Europe focused on administration, insurance, aircraft leasing and payments. A thriving green finance cluster has emerged within this sector in recent years, and a considerable number of professional services providers are focused on supporting green asset management (Sustainable Nation, 2018).

For these reasons, Ireland provides a useful testing ground for evaluating the risk-return perspectives of traditional and non-traditional investors across the investment chain.

1.3. Research objectives and methods

Within the context of the global investment trends in low-carbon assets outlined above, the overarching aim of this study is to investigate how the risk-return perceptions of investors affect investment decisions in low-carbon assets.

The specific research objectives are:

1. To explore the risk-return preferences and investment attributes that are important for citizen investors, and to identify barriers to these investors at different project stages;
2. To investigate how financial incentives can be designed that are attractive to citizen investors; and
3. To measure, compare and contrast perspectives on stranding risk from climate change for owners of physical and financial assets.

A variety of methods are employed to explore these questions. Overall, the research approach involves progressing from a broad and general to an increasingly specific analytical focus. Each chapter of this thesis represents an individual published paper (Chapter 5 is under review at the time of writing), and for this reason each employs a different methodology. In Chapter 2 a “systematic literature review” methodology was used, which is a common approach employed for presenting summaries of empirical evidence from across a range of disciplines. To ensure the robustness of the findings, clear inclusion and exclusion criteria were developed which were used to screen research results and to identify relevant studies. The general findings from this study fed into the research approach and focus of Chapter 3, where a comparative case study methodology was employed. Case studies are considered suitable for documenting “how” and “why” questions, including processes such as market innovation, where the focus is on exploring contextual conditions (Yin, 2003). They tend to report more information than, for example, a statistical study covering the same cases, and therefore provide a strong empirical grounding for a hypothesis (Odell, 2001), as was required in this study.

This finding in turn fed into the more quantitative approach employed in Chapter 4, a survey on a representative sample of Irish citizen investors, using an online survey, developed over a number of iterations, incorporating an Adaptive Choice-Based Conjoint (ACBC) to explore risk-return preferences for renewable energy investment options and attributes. This approach has been used extensively in the general investment decision literature (Clark-Murphy & Soutar, 2004; Franke et al., 2006; Shepherd, Zacharakis & Baron, 2003; Shepherd, 1999), as well as the renewable investment literature (Salm, Hille & Wüstenhagen, 2016; Lüthi & Wüstenhagen, 2012). The primary output from the ACBC were derived utility values for each respondent that illustrated their relative preference for one investment attribute over another investment attribute, and their risk-return preferences.

Finally, in order to assess attitudes to and awareness of stranding risk from climate change across the Irish investment chain, in Chapter 5 semi-structured interviews were combined with an online survey of key figures in the Irish asset management and ownership community. The semi-structured interviews targeted key ‘gatekeepers’, following the approach employed by Harnett (2017) and Eleftheriadis and Anagnostopoulou (2015), and akin to the iterative approach suggested by the Delphi method (Okoli & Pawlowski, 2004). As proposed in Rice (2015), responses were used to refine the on-line questionnaire, thereby ensuring that it was focused on key issues relevant to skills and expertise of prospective respondents. This “convenience sampling” approach is common within qualitative business studies to evaluate the preference of “elite” figures from business and finance, and is considered more apt than a more systematic sampling techniques (Eriksson & Kovalainen, 2008).

While the specific focus in Chapters 4 and 5 is on Irish citizen and institutional investors respectively, the themes that emerge have clear ramifications beyond Ireland. The findings are relevant to researchers and policy makers in countries seeking to understand the risk-return preferences of different types of investors under energy transition, and seeking to promote greater levels of investment in low-carbon technologies from these actors.

1.4. Contents Summary

In order to achieve these objectives, the chapters of this thesis are constituted of academic papers. Chapters 2, 3 and 4 have been peer reviewed and published in academic journals, while Chapter 5 is currently under review. The content of each chapter is briefly set out below.

In Chapter 2 a systematic review of the literature assessing the impact of technology-specific economic and financial incentives promoting greater levels of investment in low carbon technologies from local citizen investors is presented. This paper focused in particular on the impact of feed in tariffs compared to quota schemes, grants, tax incentives and soft loans. The analysis underscored the importance of understanding the preferences of target demographics, the local context, as well as the characteristics of the technologies in question, and suggested that interventions should be considered as part of wider policy packages. While identifying challenges to be overcome through instrument design, it found that feed-in tariffs, grants and tax incentives can be successful in mobilising greater levels of investment from local citizen investors, but that soft loans tend to be less effective as a stand-alone instrument.

To investigate what types of financial incentives are effective at the feasibility, development, construction, and operation stages of project development, a comparative case study of their use in Denmark, Germany, the UK, and Ontario, Canada is presented in **Chapter 3**. A requirement for incentives such as grants and soft loans at the feasibility and development stages emerged as a distinguishing feature of projects with citizen involvement, reflecting the greater risk aversion, lack of technical experience and financial capacity and inability to balance risk across a portfolio of projects for these actors. At later project stages, market-independent supports (FiTs, grants and tax incentives) were found to have been effective in mobilising investment, but it was also found that market-based supports (feed in premiums and quota schemes) could be tailored to the specific needs of local community actors.

Little is known about citizen investor preferences outside of mature markets such as Denmark and Germany, or if the experiences in these countries can be replicated elsewhere. For this reason, in **Chapter 4** the results from a survey exploring the attitudes of 1,280 Irish citizens to investing in wind, solar, biomass and waste-to-energy projects are presented. A high level of interest in investing in these technologies was discovered, particularly among high-income households with some investment experience. Investment amounts, however, were low compared to equity required for large projects, suggesting that citizen investors may not be a significant source of finance in these cases. Key barriers identified included lack of savings and no access to loan finance. A majority of citizens were found to be highly risk-averse and were motivated by financial attributes such as return and minimum investment holding period.

Finally, the extent to which ‘stranding risk’ was affecting risk-return preferences of professional investors was investigated in **Chapter 5**. Semi-structured interviews were combined with an on-line survey to determine if attitudes to stranding risk, and methods used to value and manage it, were similar for investors in power sector and financial assets. Stranding risk emerged as a more prominent issue for power sector investors, who were more confident in their ability to assess and manage stranding risk and had taken more decisive actions. Respondents also emphasized the greater significance of stranding risk for the least liquid asset classes, and also the importance of portfolio diversification for risk management.

In **Chapter 6** the key findings of this thesis are presented in relation to the three research questions outlined above. The overall contribution of this dissertation to the academic literature is set out, and policy implications are explored. Finally, several promising avenues for future research are identified.

Chapter 2: Financial incentives to mobilise local citizens as investors in low-carbon technologies: a systematic literature review

2.1. Introduction

If the ambitious objectives of the international community, agreed in the Paris Agreement of December 2015, are to be met, rapid emissions reductions must be achieved over the coming decades. Two of the key policy challenges faced by Governments in meeting this challenge are investment shortfalls in low carbon technologies (and the consequent need to mobilise greater levels of private finance) and lack of citizen "buy-in" for low-carbon transition.

The International Energy Agency has estimated that investment of $44 trillion in a portfolio of low carbon technologies (LCTs) is required in the period 2015-2050 in order to decarbonise the energy system in line with a 2°C climate mitigation target (IEA, 2014). There is widespread agreement that given the state of sovereign and utility balance sheets, and with traditional banks struggling with stricter reserve requirements under Basel III, new sources of capital for investment in low-carbon assets are required (Eleftheriadis & Anagnostopoulou, 2015; Haigh, 2011; Simshauser, 2010; Yildiz, 2014).

While traditional investors, such as financial institutions, utilities or businesses, have been active in providing private finance for LCTs,[1] there is potentially a much greater role to be played by local citizen investors. These actors can be engaged in three distinct ways: as private individual investors in LCTs; as investors in a community-owned project; or as investors in a local project led by a professional developer (Enzensberger et al., 2003).

LCTs are modular, often relatively small scale (typically <50 MW installed capacity) compared to traditional fossil fuel and nuclear generation (typically hundreds of MW), and decentralized, making them more financially appealing to local citizen investors and somewhat less so to traditional investor classes (Yildiz, 2014). Furthermore, individuals tend to control more funds than has historically been the case because of changes in pension regulation and administration (Foreign and Colonial, 2013). Citizen participation

[1] For the purposes of this paper, the definition of LCTs is limited to technologies for individual usage (for example electric vehicles, photovoltaic panels, solar thermal systems, etc.) and larger renewable energy supply technologies (for example wind farms, biogas technologies, and solar PV farms). Nuclear energy is therefore excluded.

schemes and local community ownership have therefore been identified as a potential source of private finance for LCTs (Bergek et al., 2013; Viardot, 2013; Yildiz, 2014).

With respect to citizen "buy in", national accounts of the successes and failures of LCT deployment identify community and societal acceptance as a potentially significant barrier, but also a key enabler of success (Shackley & Green, 2007; Sovacool & Lakshmi Ratan, 2012; Stokes, 2013; Szarka et al., 2012; B. J. A. Walker et al., 2014; G. Walker, 2011; Wolsink, 2007; Wüstenhagen et al., 2007).
The ability to share local value is one of the key means of building social support for low carbon transition. Engaging local citizens as investors can help to promote behaviour changes such as conserving energy and reducing emissions (Heiskanen et al., 2010). Community group and individual citizen investment in LCTs can generate local income, result in more locally appropriate developments that are more likely to secure planning permission, contribute to understanding of climate and energy security issues, and create niches which positively interact with the wider regime in various ways (Bergman & Eyre, 2011; Bolton & Foxon, 2015; Devine-Wright, 2014; Devine-Wright, 2005; Dóci et al., 2015; Li et al., 2013; Palm & Tengvard, 2011; Parag et al., 2013; Rogers et al., 2008; Slee, 2015; Viardot, 2013; B. J. A. Walker et al., 2014; Wüstenhagen et al., 2007; Yildiz, 2014; Yildiz et al., 2015). The experience of investing in a LCT can also positively dispose citizens to making future low-carbon investments (Boon & Dieperink, 2014; Dobbyn & Thomas, 2005; Keirstead, 2007), and greater levels of local ownership have also been found to coincide with higher rates of wind power deployment than "remote, corporate ownership" (Toke et al., 2008).

There is a long traditional in countries such as Denmark and Germany of mobilising local citizens as investors in low carbon assets, both as individuals or members of community groups. There is, however, a growing interest among policy makers in other countries in approaches to incentivising and mobilising investments from these actors. For example, the UK Energy Infrastructure Act (2015) sets out a framework pursuant to which the Secretary of State may introduce regulations under which local residents and communities would have the right to a buy a minimum 5% equity ownership in renewable energy projects in their area (DECC, 2015); the Scottish government outlined policies in 2015 where wind farm developers have to demonstrate that at least 10% equity ownership has been offered to local individual and community groups before applying for planning permission (Scottish Government, 2015); the Irish Energy White Paper (2015) places a considerable emphasis on individuals and community groups as potential investors in low carbon technologies (DCENR, 2015); and Ontario's Green Energy and Green Economy Act (GEGEA) of 2009 introduced a FiT regime with strong incentives for community owned projects (Government of Ontario, 2009).

These two key barriers to low-carbon transition, the investment shortfall and societal "buy-in", have traditionally been addressed in policy with different instruments. Economic and financial incentives (EFIs), measures that provide actors with monetary compensation to adopt LCTs, in the form of taxes, grants, soft loans and other forms of subsidy (Bergek & Berggren, 2014; Mickwitz, 2003), have typically been introduced to mobilise greater levels of capital investment (De Serres et al., 2010; IEA, 2003; Painuly, 2001). On the other hand, education, information, labelling, community involvement in policymaking, community engagement and awareness raising campaigns are recommended to address citizen and community acceptance issues (Owen, 2006; Verbruggen et al., 2010). What is less commonly recognised is that these barriers are interrelated, overlapping, and to some extent, mutually reinforcing (Juntunen & Hyysalo, 2015; Yildiz, 2014).

EFIs are often critical to the success of community energy projects (Parag et al., 2013), yet designing incentives appropriate for and/or specific to individual citizens and community groups is challenging. LCT investors have traditionally been characterized as rational, rent-seeking agents, but economic motivations and "rational" economic behaviour may not adequately explain LCT investment decisions (Masini & Menichetti, 2013; Salm et al., 2016; Wüstenhagen & Menichetti, 2012), and this may particularly be the case at individual and community level.

While the case for promoting citizen and community investment in LCT projects is well developed, it is an open question in the literature as to which EFIs have been successful in mobilising local citizen investment in LCTs. While there have been many studies evaluating citizens willingness to pay a premium, usually via energy bills, for renewable power (Kostas & Sardianou, 2012; Soon & Ahmad, 2015), by contrast, the literature on citizen participation in the financing of in LCTs is under-developed (Stigka, Paravantis & Mihalakakou 2014; Yildiz 2014), and the design and use of EFIs worldwide (for example, for promoting uptake of energy efficiency technologies) has not been comprehensively studied (de la Rue du Can et al. 2014). According to Yildiz (2014, p. 678) "*the literature on citizen participation in the financing of renewable energy infrastructures is sparse considering its empirical importance*".

Within this context we undertake a systematic literature review of EFIs directed towards local citizen investors, which are aimed at mobilising investments in LCTs. This paper makes a number of important contributions addressing gaps in the literature: first, it provides a comprehensive analysis of the literature on EFIs aimed at promoting investment by local citizens, a subset of the overall literature on EFIs; second, it assesses the critical factors in their success or failure; and finally, it sets out policy lessons for the design of these incentives.

We proceed as follows: The following section presents a methodology for the systematic literature review; this is followed by an analysis of the findings of relevant studies identified, highlighting strengths, weaknesses and opportunities for further research; and we conclude with key policy insights.

2.2. Methodology

Systematic literature reviews offer an established methodological approach for presenting summaries of empirical evidence from across a range of disciplines, and generally incorporate the findings from both quantitative and qualitative studies (Keele, 2007). They are commonly used to consider whether a particular intervention has been successful in relation to a given societal problem (Hansen & Rieper, 2009; Keele, 2007; Petticrew & Roberts, 2008).

In order to ensure the scientific validity of a systematic literature review it is important to precisely define the research question and to determine the type of primary studies the review is trying to locate. This is achieved by developing clear inclusion and exclusion criteria. These criteria are used to screen research results and to identify relevant studies, the findings of which are critically appraised (Keele, 2007; Petticrew & Roberts, 2008).

2.2.1. Determining studies of interest

We proceed to defining a clear search strategy and identifying explicit inclusion and exclusion criteria. According to the Intergovernmental Panel on Climate Change (IPCC), qualitative analyses and case studies complement statistical analyses by capturing the effects of policies and institutions on other aspects of the system, and the effect of institutional, social and political factors on policy success (Somanathan et al., 2014). We therefore consider both quantitative and qualitative *ex post* assessments covering the impact of policy interventions, including reviews of empirical evidence, and interviews with and surveys of individual citizens and community groups. We exclude *ex ante* forecasts using economic models, as well as consultants' reports and evaluations by Governments of incentive programmes.

"Downstream" incentives targeting individuals and communities are our primary focus. We exclude evaluations of "upstream" incentives targeting manufacturers and "midstream" incentives targeting retailers (de la Rue du Can et al., 2014). Energy efficiency obligation schemes and emissions trading schemes, which are targeted primarily at companies, are therefore excluded, as are evaluations of how EFIs affect investment decisions by companies. We also exclude studies focusing on institutional investors (Barradale, 2014; Bolton & Foxon, 2015; Mathews et al., 2010; Wustenhagen & Teppo, 2006) and general assessments of the effectiveness of EFIs (Abolhosseini & Heshmati, 2014; Bobinaite & Tarvydas, 2014; Marques & Fuinhas, 2012; Mickwitz, 2003; Oak et al., 2014; Ozcan, 2014; Polzin et al., 2015; Somanathan et al., 2014) that do not explicitly consider implications for local citizen investors.

EFI's are generally distinguished from regulatory instruments (command and control), informational, and cooperative (or voluntary) policy interventions (Mickwitz, 2003), and studies covering these policy interventions are therefore also excluded. EFIs can be further sub-divided into those that are technology-specific or technology-neutral. The former might include, for example, an incentive to purchase a low-carbon vehicle or low-carbon heating system. The latter, on the other hand, would include instruments such as carbon taxation (Bergek & Berggren, 2014; Sierzchula et al., 2014). We include technology-specific economic incentives in this review, but studies that address general instruments such as carbon taxation will only be included insofar as they are relevant to assessing the merit of a technology-specific incentive.

In practice, this implies a focus on a specific set of EFIs. Further to analysis of IEA's comprehensive database of economic incentives which have been implemented in the buildings, energy and transport sectors to promote LCTs,[2] the IPCC's typology of sector-specific economic incentives (Somanathan et al., 2014, p. 1158), and reviews of several comprehensive analyses on financial incentives for renewables (Cansino et al., 2011; Solangi et al., 2011), we identified the following four categories of incentive for inclusion:

- Feed in tariff (FiT), Feed in Premium (FiP) and quota schemes[3]
- Tax incentives
- Grants and subsidies
- "Soft" loans

[2] https://www.iea.org/policiesandmeasures/climatechange/

[3] A FiT is an agreement to pay a guaranteed amount over a set period of time for certain types of renewable heat and electricity. A guaranteed price tariff is a FiT scheme where a set rate is paid for each unit of electricity generated and supplied to the grid. FiPs are similar to FiTs, except that in this case a fixed premium is added to the market price when exporting electricity to the grid (Couture and Gagnon, 2010). There are two broad category of quota scheme. Quotas with tradable green certificates (TGCs) are certificates issued for every unit of renewable electricity. They allow generators to obtain additional revenue from the sale of electricity. Demand for TGCs originates from an obligation on electricity distributors to surrender a number of TGCs as a share of their annual consumption (quota). Under tendering/bidding systems, on the other hand, government invites renewable electricity generators to compete for either a financial budget or renewable electricity generation capacity. Within each technology band, the cheapest bids are awarded contracts and receive the subsidy (del Río and Bleda, 2012)

Several of these EFIs (in particular FiTs and quota schemes) often target large investors, and therefore only studies that explicitly consider the impacts on individuals and communities will be included.

Not all studies that fit our inclusion criteria, however, fell into one of the four categories above. Many studies deal with incentives relevant to local citizen investors in a general manner, without focusing on a particular EFI. We therefore include a fifth category evaluating this literature (Section 3.1 below).

2.2.2. Undertaking the research

Based on a preliminary review of the literature, "economic incentive" and "financial incentive" were identified as terms that are used interchangeably in the literature to refer to instruments that provide actors with monetary compensation to engage in a particular activity. These terms are combined with "low-carbon" and "renewable energy" given the focus on LCTs. Finally, in order to ensure a focus on studies that address citizens and communities we further refined our search terms using the words "behaviour" and "community". This resulted in the eight key word combinations given in Table 2.1.

Table 2.1 Search word combinations

1	Financial incentive	Low carbon	Behaviour
2			Community
3		Renewable energy	Behaviour
4			Community
5	Economic incentive	Low carbon	Behaviour
6			Community
7		Renewable energy	Behaviour
8			Community

The following electronic databases were searched using these key word combinations to uncover relevant studies:

- Web of Science
- ABI/INFORM
- Science Direct

In Web of Science, the eight phrases were entered as basic searches; in ABI/INFORM entire documents were searched using the eight phrases; and all fields were also searched using the eight key phrases in Science Direct. We used Google Scholar to identify further relevant journal articles using the same keyword combinations. In all cases, findings were restricted to English language peer reviewed articles published since 2005. Finally, the bibliography of key publications was used to identify further relevant publications.

2.2.3. Critically appraised findings

Systematic reviews specify the information to be obtained from each primary study against pre-determined evaluation criteria. While our primary objective is to exploring the effectiveness of EFIs in mobilising investments in LCTs, it is important to consider other evaluation criteria in order to come to a broader understanding of the "success" of a particular EFI.

In addition to environmental effectiveness, IPCC proposed the following evaluation criteria for climate change policy: economic effectiveness (cost-effectiveness and economic efficiency), distributional equity and broader social impacts, and institutional, political, and administrative feasibility and flexibility (Somanathan et al., 2014). In our appraisal of studies, we consider these criteria where possible when evaluating the impact of a particular EFI (although, as discussed in the conclusions section, few studies implicitly or explicitly consider more than one of these criteria).

2.3. Results and discussion

Initial search returns are detailed in Table 2.

	ABI/INFORM	Science Direct	Web of Science	Google Scholar
Financial incentive low carbon community	1,642	6,181	10	16,900
Financial incentive low carbon behaviour	1,428	5,634	5	17,400
Financial incentive renewable energy community	1,250	5,073	21	18,100
Financial incentive renewable energy behaviour	1,514	6,034	6	18,000
Economic incentive low carbon community	3,065	9,434	16	17,300
Economic incentive low carbon behaviour	2,848	9,092	14	17,500
Economic incentive renewable energy community	2,184	8,110	30	17,800
Economic incentive renewable energy behaviour	1,903	7,676	18	18,000

Table 2.2 Search results

The inclusion and exclusion criteria were rigorously applied to these returns. Papers were discounted further to a review of the abstract or further a review of the full paper as necessary. In some cases, however, it was possible to discount search returns based on the title of the paper. In the case of all eight key word searches, it was unnecessary to scan returns after the first 500 entries because returns became consistently irrelevant. Finally, the bibliography of key publications was used to identify further relevant publications. In Table 3 (see Appendix) we present an overview of the 55 studies that met these criteria, and a summary of the key relevant findings in each case.

2.3.1. Do EFIs mobilise citizen investment?

There is a significant body of research that is not specific to a particular type of EFI, which identifies factors that influence the attractiveness of these incentives to local citizen investors. This work, much of it from the field of behavioural economics, suggests that while some individual citizens may respond in an "economically rational" manner to EFIs, this will not always be the case. For example, Frederiks et al., (2013), Schultz (2015), Allcott (2011), Costa and Kahn (2013) and Palm and Tengvar (2011) identified the potential importance of social comparison and the influence of peers and neighbours in the community as a factor that can have a positive or negative impact on LCT investment decisions.

Frederiks et al., (2013) identified several behavioural factors that need to be considered when designing EFIs, including myopia (high discounting of future benefits) and status quo biases. The prevalence of myopia in low car purchasing decisions is a particularly well-developed theme (Metcalf & Dolan, 2012; Lane & Potter, 2007), which may render individuals resistant to investing in LCTs even when EFIs are strong. Schultz (2015) found that in addition to EFIs, strategies such as prompts, commitments, feedback, and convenience can effectively promote pro-environmental behaviour – at least in some contexts, for some behaviours, and for some individuals. Frederiks et al., (2013) and Rode et al., (2015) identified the potential for EFIs to ‘crowd out’ intrinsic motivation, highlighting the importance of anticipating changes in individual’s motivational structures prior to “large-scale implementation” of EFIs so that negative or unintended impacts are avoided.

These findings highlight the importance of considering EFIs as part of wider policy interventions (Michelsen & Madlener, 2016), and the need for complimentary, or in some cases supplementary, policy interventions in addition to EFIs (Lane & Potter, 2007) to promote investments in LCTs from local citizens. These interventions could include, *inter alia*, information provision or using the power of social comparison. It should be noted, however, that Momsen and Stoerk (2014) found using social comparison as a “nudge” to be ineffective in prompting individuals to choose renewable energy.

A further strong conclusion from the literature is the importance of considering the target demographic when design EFIs, and the importance of avoiding “one size fits all” solutions. Kosenius and Ollikainen (2013), Fraune (2015), Greenberg (2009), and Egbue and Long (2012) found that demographic characteristics such as gender, age, and income are important factors in determining likelihood to invest in LCTs. Kosenius and Ollikainen (2013) additionally found that that regional differences existed in preferences for renewable energy in Finland. It is not just demographic characteristics that are relevant, however. Coad et al. (2009) found that responsiveness to EFIs will vary by personality type, while West et al., (2010) found that "worldview" would also influence responsiveness to EFIs.

These findings underscore the importance of market segmentation techniques to identify sections of the public that are more likely to invest in a particular LCT, such as early adopters (Lane & Potter, 2007), and to tailor incentives and measures to these markets. For example, information provision policies (such as the energy labelling for cars) may be effective in encouraging certain intrinsically motivated consumers to adopt green cars, whereas EFIs may be more persuasive for extrinsically-motivated consumers (Coad et al, 2009). It should be noted, however, that the potential downside of this approach is that it could mobilise opposition from excluded sections of society (West et al., 2010). Furthermore, where EFIs are not cost-effective, they can result in increased electricity prices or taxes with the potential to undermined "buy-in" from wider society (see also Sections 3.2 and 3.3).

A related though somewhat less developed theme explores differences between traditional investors and "new" local citizen investors. Bergek et al. (2013) and Linnerud and Holden (2015) found that investors in LCTs come from heterogeneous groups, from traditional investor classes to non-traditional small-scale investors such as farmers' associations and individuals. Non-traditional investors may have varied levels of experience and divergent motivations for investing (Bergek et al., 2013; Linnerud and Holden, 2015), may have less business experience and financial strength than traditional investors (Bergek et al., 2013; Salm et al., 2016) and may have different investment preferences as a result (Salm et al., 2016). What therefore emerges from this subset of the literature is the need for discrete EFIs specifically targeted to the needs of local citizen investors, who will have different experiences, capacities, priorities and motivations compared to professional investors. There are opportunities to explore the specific types of incentives that might be attractive to these groups.

There are a considerable number of studies that identify the importance of the characteristics of the technology itself in the effectiveness of EFIs in motivating investments in LCTs. Some studies, such as Palm and Tengvar (2011), Stigka et al. (2014) and Claudy et al. (2010) found that, as well as socio-economic characteristics, trust, acceptance, knowledge, and understanding of the LCT in question can impact willingness to pay and invest in a particular LCT. These factors may also be prevalent when it comes to purchasing Electric Vehicles, where a lack of consumer confidence (Steinhilber et al., 2013) or uncertainty associated with the reliability of battery technology (Egbue & Long, 2012) may render EFIs ineffective in mobilising LCT investments. These studies highlight the importance of technology maturity, and the perceived advantages of one technology over another (Claudy et al., 2010; Egbue & Long, 2012), in motivating individual investment decisions, and underscore the importance of supplementary policies aimed at promoting understanding and acceptance of emerging technologies in addition to strong EFIs. This may including education and awareness raising, establishing trusted standards and regulations, or supporting strong warranties on emerging technologies.

While some literature exists on the effectiveness of EFIs in incentivising individuals to investment in LCTs, there are comparatively few studies that assess the general effectiveness of EFIs in promoting participation in community energy schemes. While Hoffman and High-Pippert (2010) found that participants in community renewable energy schemes are motivated by contributing to the community as well as by economic considerations, by contrast Dóci and Vasileiadou (2015) found that personal gain was the primary motivating factor, although they also noted that other secondary hedonic and environmental motivations were also present. There is an opportunity, therefore, for further research to explore the relative importance and effectiveness of EFIs in motivating participation on community energy schemes (Sections 3.2 and 3.3).

Finally, several studies highlight institutional and regulatory barriers, such as applying for planning permission, as important factors when considering LCT investment decisions. Palm and Tengvar (2011) find, for example, that rules by grid companies and regulations are considered a hindrance to investment in micro-LCTs, whereas other studies highlight fragmented infrastructure (Egube & Long, 2012) or the absence of standards and regulations standards (Steinhilber et al., 2013), as factors which may render EFIs less effective, and potentially less attractive to local citizens unless they can be addressed.

2.3.2. FiTs, FiPs and quota-based schemes

The most popular EFIs to promote the adoption of renewable electricity are guaranteed price FiT and quota systems (Dusonchet & Telaretti, 2010), while FiPs are becoming an increasingly common instrument (Ragwitz, et al., 2012. FiTs have also been used to promote the adoption of renewable heating systems, though less commonly (Cansino et al., 2011). For the most part these EFIs have been used to mobilise investments from professional investors, project developers and utilities (Cansino et al., 2011), although the focus here is their attractiveness to citizens and communities.

Some studies indicated that FiTs have advantages over quota-based schemes when it comes at promoting growth in community-owed generation (Meyer, 2003; G. Walker, 2008; West et al., 2010). An important factor here is the actual FiT level as some countries offer higher FiT rates than others, and these have generally witnessed greater renewables deployment but reduced economic effectiveness. Fouquet and Johansson (2008) found that FiTs could be more appropriate for small and medium size investors, whereas quota schemes could create investment risk for independent power producers and opportunities for market dominance by larger players. Butler and Neuhoff (2008), Del Rio and Bleda (2012) and Mabee et al. (2012) found that FiTs could boost social legitimacy for deployment of wind turbines, while Feurtey et al. (2015) and Del Rio and Bleda (2012) found that quota schemes had tended to favour large wind farms at the expense of smaller independent producers, and had resulted in a geographical concentration of development, whereas FiTs had promoted geographically distributed development.

A integral design feature of FiTs that makes them attractive to local citizen investors is the guaranteed level of support they provide over time, which results in additional

investment security (Dóci & Vasileiadou, 2015; Mabee et al., 2012; Lipp, 2011; Saunders, Gross & Wade, 2012). Sovacool and Lakshmi Ratan (2012) found that the certainty provided by the long-term FiTs resulted in access to lower cost finance for German individual investors, while Dóci and Vasileiadou (2015) concluded that Governmental policies should provide long-term and calculable EFIs such as FiTs to support these groups. This may be a particularly important consideration for local citizen investors given their relative lack of capital compared to traditional investors.
It is unclear, however, if FiTs themselves are superior when it comes to attracting local citizen investors. Some studies identify the importance of specific design features of an EFI over instrument choice. Mabee et al. (2012), for example, found that the German FiT system identified a wider range of project sizes compared to a Canadian FiT scheme, thus offering more opportunities for local benefit; Saunders, Gross, and Wade (2012) found that a quota scheme introduced in 2002 in the UK was unattractive to community groups because of a number of unattractive design features, including the complexity of the scheme; while Linnerud and Holden (2015) found that the short duration and the abrupt termination of the quota and tradable green certificate scheme in Norway compared to a Swedish scheme contributed to additional risk and transaction costs, making it less attractive to new investor classes. Feurtey et al. (2015) found that a specifically designed community quota, stipulating that at least 30% of profits were to be redistributed to local communities, had contributed greatly to improving the level of local acceptance in Quebec. They therefore conclude that FiTs may be suitable for small projects (under 10MW), while quotas could be more suited for medium and large projects, but that in both cases mandatory financial participation criteria may be required to ensure fair outcomes for local citizen investors.

These studies highlight the importance of designing EFIs with the needs of local citizen investors in mind (Section 3.1), whatever the choice of EFI, and align with other research focussing on cost effectiveness, which also emphasises the importance of EFI design over choice of instrument (Huber at al., 2007). Few studies, however, explicitly consider the design features that are most attractive to local citizen investors and in many case these findings are implied rather than explicitly stated. These are therefore questions that merit further research and investigation.

A weakness in this literature is the absence of studies comparing the impact of FiTs compared to FiPs on local citizen investors. There is growing policy focus on FiPs, particularly within the EU in light of EU State Aid Guidelines, which foresee the gradual replacement of FiTs with the more market-price dependent FiPs (European Commission, 2014). There is some evidence from Denmark to suggest that FiPs may be off-putting to local citizen investors compared to FiTs (Gotchev 2015; Meyer 2007) because these investors may be highly risk averse. It is unclear, however, whether it is the level of the financial incentive provided or the choice of instrument itself that is more important factor as far as local citizen investors are concerned and this is an area meriting further analytical attention.

Other studies touch on the importance of complementary measures to support the central EFI, be it a FiT, FiP or quota-based scheme. Sovacool and Lakshmi Ratan (2012) for example, identified excellent information around tariffs as an important supplementary measure to the Germany FiT. In many cases, complementary measures have been deployed to address access to capital, which has been identified as a key barrier to local citizen participation (Lipp, 2011), particularly at the riskier early project stages, such as feasibility assessments, pre-planning development work, and planning applications. Yildiz (2014), Romero-Rubio and de Andrés Díaz (2015) and Saunders, Gross and Wade (2012) all highlighted the availability of publicly supported soft loan programs as an important success factor which complemented FiTs in promoting the growth of local citizen investment in LCTs in Germany. There are opportunities for further research into the most effective way of addressing early stage project risk for local citizens, drawing on the experiences of different countries, as these experiences have not been comprehensively studied.

Context-specific factors have also been identified in several studies and an important consideration in successful FiT implementation. Sovacool and Lakshmi Ratan (2012), Dewald and Truffer (2011) and Romero-Rubio and de Andrés Díaz (2015) found that the support of local citizen associations focused on energy and local decision-making provided the necessary background for successful deployment of LCTs in Germany. Dewald and Truffer (2011) found that market success was not sustainable in Spain because, by contrast, these necessary pre-conditions for success were not in place. These findings are consistent with Romero-Rubio and de Andrés Díaz (2015) who found that the greater focus on community energy in Germany compared to Spain in response to FiTs could be explained a number of context-specific factors including, *inter alia*, a relatively high sensitivity to environmental issues and a high number of people with sufficient financial resources to invest. These findings attest to the dangers associated with coming to general conclusions from the experiences of a particular country.

Finally, some studies also identify a tension between mobilising local citizen investors and increasing electricity prices, which would have a countervailing impact on social legitimacy for LCTs (Section 3.1). For example, Del Rio and Bleda (2012) and Butler and Neuhoff (2008) found that total costs of FiT schemes have significantly increased in countries such as Spain and Germany, while Martin and Rice (2012) found that FiTs were a success in terms of promoting new investors in small-scale PV in New South Wales, but that the level of investor participation had been underestimated, resulting in cost overruns. While there is some evidence that using FiTs, quota-based schemes and other EFIs to mobilise local citizens as investors can reduce the overall costs to society or low-carbon transition (by, for example, opening up optimal sites for renewables deployment (Nelson et al. 2016)), this is not a topic that has been explored in the academic literature. These findings highlight the importance of careful ex ante analysis of incentive programmes to ensure that they deliver the anticipated outcomes.

2.3.3. Grants

Grants, generally applied as a percentage of either the total installed cost or capital cost of an investment, are a widely used instrument employed to promote individual and community investment in LCTs. In 2010, grants and rebates were available in 42 out of 195 countries globally to promote low-carbon heating, cooling and electricity generation

(Bobinaite & Tarvydas, 2014). Grants are the most widespread measure of support for the use of renewable energy sources for heating in the EU (Stevanović & Pucar, 2012), and are also commonly used in the US (Mundaca & Luth Richter, 2015).

Several studies illustrate the effectiveness of grants in mobilising investment from individuals. It is clear from these studies that grants can encourage the adoption of capital-intensive LCTs by reducing high up-front costs, which is often cited a key barrier to investment (Painuly, 2001; Saunders et al., 2012). For example, Roulleau and Lloyd (2008), in an evaluation of grant incentives to promote uptake of solar water heating (SWH) internationally, found that grant programmes were generally successful in promoting technology adoption. Mahapatra and Gustavsson (2008) found that a grant programme was necessary for deployment of micro-LCTs to achieve critical mass in Swedish households. Chang et al., (2011) concluded that grants were successful in promoting SWH uptake in Taiwan, while Yang and Zhao (2015, in press) found that a Chinese grant (covering approximately 10% of cost) for LCT appliances was effective in targeting some segments of the population.

Grant programmes have also been identified as important in promoting community renewable energy initiatives in some studies. Madlener (2007) found that rapid diffusion of wood fuelled district heating schemes in Vorarlberg, Austria, many of which were promoted locally and owned by communities and agricultural cooperatives, was dependent on the provision of attractive up-front capital grants, and, to a lesser extent, soft loans. Seyfang et al., (2013) and Saunders et al., (2013) found that many UK community energy groups were able to take advantage of EFIs, in particular grants but also FiTs, while Yin (2012) found that a grant programme was helpful for community wind initiatives in Oregon.

Comprehensive assessments of grants programmes are, however, not common in the academic literature, nor are *ex ante* studies considering the cost-effectiveness of these programmes. While Roulleau and Lloyd (2008) found a German grant programme to be cost-effective, they found cost-effectiveness assessments were not common in the programmes they evaluated.

On the other hand, several potential downsides of grants programmes are identified in the literature. One potential weakness is that grants can increase capital and installation costs (Cansino et al., 2011). Chang et al., (2011) found, for example, that significant unit cost increases has occurred over the lifetime of the grant programme, leading to grant increases and supplementary incentives from local authorities. It has also been suggested that to avoid technology cost increases, grants based on total installed costs (Chang et al., 2011) or use of both performance and cost criteria in grant programme design might be considered, but the success of schemes would then depend on the extent which industry can provide both high performance & low cost systems (Roulleau & Lloyd, 2008). Madlener (2007) identified techno-economic performance guidelines that greatly improved the technical efficiency and economic viability of plants as a key success factor in ensuring a cost-effective programme, and Chang et al., (2011) concluded that greater coherence between national and regional initiatives could improve cost-effectiveness.

A further challenge is that grants can lead to stop-start investment cycles (Cansino et al., 2011) arising from the sudden termination of support, rathar than the creation of a sustainable market for the LCT in question. Indeed Roulleau and Lloyd (2008) found evidence of stop-start investment cycles in a number of the programmes they evaluated. Seyfang et al. (2013) and Saunders et al., (2013) found that grants were important for community energy projects, but that a stable supply of funding is important for these local organisations to operate effectively over the longer term (Saunders et al., 2012; Seyfang et al., 2013). Seyfang et al. (2013) found that policy and regulatory threats and unpredicted policy changes were a real problem for many projects, while Saunders et al., (2013) found that constantly chasing grants was taking up too much of members' time. The long duration of the programmes, which gives confidence to consumer and suppliers, has been identified as important design feature to counter policy and regulatory uncertainty (Chang et al., 2011; Roulleau & Lloyd, 2008).

There are also several studies that consider non-financial success factors in grant programmes. It has been argued that the administrative burden of applying for grants can be off-putting to potential investors (Cansino et al., 2011) and it is unsurprising therefore that Yin (2012) and (Madlener, 2007) identified the simplicity of application procedure as a key success factor. Mahapatra and Gustavsson (2008) highlighted the importance of technology reliability, trust in installers and personal contacts for information around the technology, while Yang and Zhao (2015, in press) highlighted the importance of knowledge, awareness and attitude to products and the subsidy program itself. These factors highlight the importance of supplementary measures to EFIs (Section 3.1 and 3.2) targeting additional barriers to investment, and the need for these incentives to be considered as part of wider policy packages.

Some studies also highlight the differences in responsiveness to grant programmes in different geographical locations and different demographic cohorts. Mahapatra and Gustavsson (2008), for example, identified differences in individual preferences between Swedes and other nationalities, while Yang and Zhao (2015, in press) concluded that moderate grants do not significantly influence the entire population, but effectively influence people from high-income households. The study concluded that the subsidy programme should target higher-income groups to maximize the policy effect, and that a tailored programme would be required to target low-income groups. Madlener (2007) identified the pioneering work of innovators and early adopters as a key success factor in widespread technology adoption and diffusion in society. There are, however, potential downsides to these market segmentation techniques (Section 3.1).

2.3.4. Tax incentives

Tax incentives are the most widely used policy instrument globally to promote LCTs (Bobinaite & Tarvydas, 2014). The most commonly used tax incentives are deductions, exemptions or reduced corporate tax rates for businesses and income tax rates for individuals, but some countries have also introduced reduced property taxes and VAT rates to promote LCTs (Cansino et al., 2010; Cansino et al., 2011; Chandrasekar and Kandpal, 2005; Mundaca & Luth Richter, 2015; Solangi et al., 2011).

While there has been considerable empirical focus on the cost-effectiveness of carbon tax versus other EFIs (Lin & Li, 2011; Markandya et al., 2009; Montag, 2015), there has been a comparatively limited focus in the academic literature on the effectiveness of tax incentives in mobilising LCT investment.

From evaluations with a focus on local citizens, it is clear that, like grants, tax incentives can be effective in mobilising investment from these actors. Roulleau and Lloyd (2008) found that a France scheme where a reduced VAT rate was introduced to complement an income tax rebate effectively promoted SWH deployment, as did a Greek scheme which offered a income tax rebates on the total installation cost. Black et al. (2014) found that a variety of state-level tax incentives, some of which were directed at individuals (including capital cost rebates, sales tax exemptions, and property tax exemptions), had a significant positive impact on wind energy growth in the Western States of the US. Solangi et al. (2011) in a review of solar policy globally, found that income tax credits for solar PV (used by both households and businesses) was the most important component in the growth in solar PV in the United States. Tax incentives have been particularly commonly used to promote the purchase of low-carbon vehicles, and their impact and effectiveness has been quite widely evaluated compared to impact of tax incentives on other LCTs. Sierzchula et al., (2014) found EFIs (reductions to registration taxes and annual car tax), positively correlated to a country's electric vehicle market share, in the 30 countries examined, while Kok (2015) and Rogan et al., (2011) found that the strong tax incentives introduced in Holland and Ireland respectively were highly effective in promoting purchasing behaviour towards lower CO_2-emitting vehicles.

As with grants, few of the studies provide comprehensive ex post assessments of the strengths and weaknesses of the instrument, and assessments of cost-effectiveness are somewhat uncommon. Where cost-effectiveness is considered, results are mixed. While Black et al. (2014) concluded that sales and tax rebate programmes had positive revenue effects without considering the additional wider positive economic impacts in society, other studies have identified cost-effectiveness concerns. Kok (2015) and Rogan et al., (2011) found that a rapid fall in government revenue resulted from the introduction of tax incentives for low carbon vehicles, although the wider societal costs and benefits are not evaluated in these studies, while Roulleau and Lloyd (2008) found that France income tax rebates resulted in significant capital cost increases, which may have been attributable to the fact that the magnitude of the tax credit depended on the cost of the technology. Considering the wide usage of tax incentives globally, the absence of comprehensive cost-effectiveness evaluations in the academic literature is notable.

Stop-start investment cycles were identified as an issue with tax incentives in the case of some schemes, highlighting the importance of long-term policy signals and programmes. For example, Roulleau and Lloyd (2008) found that policy changes resulted in market uncertainty in the case of the Greek scheme, and Solangi et al. (2011) found that an income tax credit for solar PV in the US was subject to continuous political uncertainty undermining its effectiveness.

Other studies focus on the importance of design characteristics of tax incentives to improve effectiveness and their attractiveness to local citizens. Kok (2015) identified the "salience" of the tax (the visibility, transparency and the attention drawn to tax incentives) as an important success factor, while Yin (2012) found that neither a Production Tax Credit nor an Oregon Business Energy Tax had been designed with communities in mind and were not therefore conducive to community investment. These findings again highlight the importance of designing EFIs with local citizens in mind (Section 3.2).

There are also a number of studies that compare tax incentives to other EFIs. Compared to grants, tax incentives have the disadvantage that they do may not generally address the upfront investment costs barrier (Cansino et al., 2011) and indeed Kok (2015) concluded that the upfront nature tax incentives is an important design consideration, while Roulleau and Lloyd (2008) found that the *ex post* reimbursement of investors (who received compensation when tax returns were filed) may have undermined the effectiveness of the programme.

As with grants and FiTs, the importance of wider context-specific considerations is identified as an important consideration in Sierzchula et al (2014), who concluded that and tax incentives alone are important but not sufficient to guarantee high technology adoption rates. Finally, the overall impact of tax incentives on social acceptability of technology is not widely discussed in the literature. It should be noted, however, that tax incentives necessarily target tax-payers, and in some cases provide a higher level of relief to wealthier cohorts in society. The equity implications of a Greek tax incentive programme are questioned on this basis (Roulleau & Lloyd, 2008).

2.3.5. Soft loans

A loan is "soft" when the rate of interest charged on the loan is lower than the commercial rate charged by the banks and other financing institutions for commercial loans (Chandrasekar & Kandpal, 2005). Loans are a common LCT financing instrument, particularly in Germany where their use is important. Soft loans are often provided by commercial banks supported by Government, however, governmental organizations can also act as lenders (Bobinaite & Tarvydas, 2014).

There is mixed evidence on the effectiveness of soft loans as a stand-alone EFI, based on limited evidence and few studies. Zhao et al. (2012) found that homeowners were attracted to financial incentives, but valued tax credits much higher than interest-free loans when it came to investing in LCTs, in part because local citizens were debt averse. Similarly, Chandrasekar and Kandpal (2005) found that an interest subsidy scheme provided for select LCTs by the Indian Government was not as attractive as an income tax benefit. According to Roulleau and Lloyd (2008), New Zealand introduced an interest-free loan for solar SWH appliances in 1978, covering 60% of cost, though the scheme was not found to be attractive to consumers, and was discontinued due to low take-up. Under the UK Green Deal scheme, loans were made available to homeowners to promote building retrofit. Marchant et al., (2015) found that while the concept was appealing, the cost of finance on offer (8 - 10%) was one of the key barriers to uptake. This finding is supported by *ex-ante* studies, which predicted uptake would be low unless much lower interest rates could be offered (Dowson et al., 2012; Hough, 2014). It should be noted, however, that it is questionable if the loan could be considered "soft" in this case, and factors such as limited awareness of the programme and up front cost barriers were also identified as problematic (Marchant et al., 2015).

In many cases, however, a soft loan may be combined with another financial incentive to make it more attractive as an EFI (Cansino et al., 2010, 2011). Perhaps the most important example of soft loans are those provided by the German state-owned KfW Bank. Strupeit and Palm (in press) and Yildiz (2014) found that while tax incentives and FiTs had been a central element to the German offering, the availability of low-interest loans, provided by KfW and issued through local banks, was an important success factor in the deployment of Solar PV in Germany. Overall there are few assessments of the effectiveness of soft loan programmes, and fewer still that evaluate soft loans as a stand-alone EFIs, and their attractiveness and effectiveness in mobilising local citizen investors therefore emerges as another opportunity for further research.

2.4. Conclusion and Policy Implications

In this study we undertake a systematic review of literature assessing the effectiveness of EFIs in mobilising local citizens as investors in LCTs. We do so in light of the potential financial contribution that this new and mostly un-tapped investor class could make to low carbon transition, and within the context of the relatively limited research focus on these actors.

There are a number of limiting factors in this study. First, it is restricted to a review of technology-specific EFIs and their effectiveness in mobilising local citizens. It does not therefore assess the effectiveness of EFIs on actors such as businesses, professional developers, or utilities. Given the narrow focus, in several places the literature is sparse. While this makes drawing policy implications more challenging, it has allowed us to highlight several opportunities for further research.

Second, consistent with de la Rue du Can et al., (2014) a key weakness we identify in the literature is that studies tend not to systematically and consistently evaluate the impact of

EFIs. Even where more comprehensive evaluations or cost-effectiveness evaluations were undertaken, the vast majority of studies did not systematically assess policy success using the IPCC evaluation criteria identified in section 2.3.

Furthermore, the absence of well-defined objectives in the case of many programmes and interventions (Roulleau & Lloyd, 2008) makes their impact difficult to evaluate. Other complicating factors relate to context-specificity (Delmas & Montes-Sancho, 2011; Somanathan et al., 2014), the use of instruments in combination with other measures (Cansino et al., 2010), and co-benefits and negative spillovers from policy interventions that are difficult to consider within a single analytical framework (Somanathan et al., 2014). Finally, as with other studies (Bergquist et al., 2013; Brouillat & Oltra, 2012; Kemp & Pontoglio, 2011) we find a great diversity of subtly different instruments within each category, and a relatively limited numbers of studies dealing with each instrument, all of which makes definitive conclusions difficult to draw.

Notwithstanding these limiting factors, we proceed to drawing policy implications. Our review suggests that while some individual citizens may respond in an "economically rational" manner to EFIs, this will not always be the case. Considering the behavioural, social, institutional and regulatory barriers to investment faced by local citizens can therefore enhance the effectiveness of policy interventions.

We find that FiTs and quotas, grants and tax incentives can be successful in mobilising greater levels of investment from local citizens, but that soft loans tend to be less effective as a stand-alone instrument. Our review also identifies potential disadvantages of using these instruments that need to be considered carefully, including cost-effectiveness and social equity concerns. However, we identify approaches to mitigating these downsides through instrument choice and design. Overall we find that there is a need to come to a greater understanding of the costs, benefits and distributional impacts for society of mobilising local citizens as investors using EFIs, and for potential downsides to be carefully monitored so that social legitimacy is enhanced and not undermined.

Our findings highlight the importance of understanding and responding to the specific needs of local citizens in EFI design. There may often be a requirement to include specific design features into FiTs, quotas, grants, and tax incentives, that will cater to the specific needs of this cohort. Providing regulatory stability and policy certainty emerges as an important success factor, as is understanding the characteristics of the target demographic, and indeed the characteristics of the LCT in question: if these factors are not considered in policy design, an EFI may not have the desired or predicted impact. Our findings also highlight the importance of introducing EFIs as part of policy packages (Michelsen and Madlener, 2016), where complementary measures can address non-financial barriers, such as lack of familiarity with the technology, technology immaturity, or low awareness of the incentive programme itself.

Many studies also highlight the importance of context–specific considerations (Dewald & Truffer, 2011; Romero-Rubio & de Andrés Díaz, 2015). We concur, therefore, with Delmas and Montes-Sancho (2011) that understanding the natural, social, policy and regulatory context under which economic incentives operate is necessary in order to measure success.

Overall EFIs targeting local citizens that are carefully designed emerge as a potentially important means of mobilising private finance in LCTs. This in turn can engender greater levels of societal support for low carbon transition and contribute to addressing climate change.

Appendix

Table 2.3 Studies of interest

Year	Author	Title	Journal	EFI	Key findings
2009	Allcott, Hunt	Social norms and energy conservation	Journal of Public Economics	General	Energy consumers are motivated by social comparison
2013	Bergek, Anna; Mignon, Ingrid; Sundberg, Gunnel	Who invests in renewable electricity production? Empirical evidence and suggestions for further research	Energy Policy	General	Investors come from heterogeneous groups and may be respond different to policy interventions.
2011	Bergman, N; Eyre, N	What role for micro-generation in a shift to a low carbon domestic energy sector in the UK?	Energy Efficiency	General	Subsidies and information activities alone were not sufficient to promote uptake of micro-generation technologies in the UK. Supporting niches recommended.
2014	Black, Geoffrey Holley, Donald Solan, David Bergloff, Michael	Fiscal and economic impacts of state incentives for wind energy development in the Western United States	Renewable and Sustainable Energy Reviews	Tax incentive	Tax incentives can be cost-effective and positive impact government revenues
2008	Butler, Lucy; Neuhoff, Karsten	Comparison of feed-in tariff, quota and auction mechanisms to support wind power development	Renewable Energy	FiT/Quota	FiTs reduced costs to consumers and resulted in greater deployment of LCTs compared to quotas, and resulted in greater local benefits.

2005	Chandrasekar, B Kandpal, Tara C	Effect of financial and fiscal incentives on the effective capital cost of solar energy technologies to the user	Solar Energy	Soft loan	Income tax credits may be more attractive to consumers than the provision of a low interest loan
2011	Chang, Keh-Chin; Lin, Wei-Min; Lee, Tsong-Sheng; Chung, Kung-Ming	Subsidy programs on diffusion of solar water heaters: Taiwan's experience	Energy Policy	Grant	Grants were successful in mobilising investment but resulted in significant unit technology cost increases.
2010	Claudy, M; Michelsen, C; O'Driscoll, A; Mullen, M	Consumer awareness in the adoption of micro generation technologies: An empirical investigation in the Republic of Ireland	Journal of Cleaner Energy Production	General	Awareness of a technology is a prerequisite for adoption and consumer awareness varies according to demographic characteristics.
2009	Coad, A; de Haan, P; Woersdorfer, J	Consumer support for environmental policies: An application to purchases of green cars	Ecological Economics	General	Considerable heterogeneity in terms of support of information-provision or financial incentive policies to promote green car purchasing decisions.
2013	Costa, Dora L; Kahn, Matthew E	Energy conservation "nudges" and environmentalist ideology: evidence from a randomized residential electricity field experiment	Journal of the European Economic Association	General	Social comparison between neighbours can be an important motivator of behind energy conservation
2012	del Río, Pablo; Bleda, Mercedes	Comparing the innovation effects of support schemes for renewable electricity technologies: A function of innovation approach	Energy Policy	FiT/Quota	Feed-in tariffs are likely to attract a wider variety of investors, deliver greater levels of local benefit result in less local opposition compared to quotas.

2011	Dewald, U; Truffer, B	Market formation in technological innovation systems—diffusion of photovoltaic applications in Germany	Industry and Innovation	FiT/General	Social legitimacy needs to be established for FiTs, and specific design features are also important for individual and community investment to be mobilised successfully.
2015	Dóci, Gabriella; Vasileiadou, Eleftheria	"Let's do it ourselves" Individual motivations for investing in renewables at community level	Renewable and Sustainable Energy Reviews	General	Economic and normative motivations are important motivating factors for participation in community energy initiatives
2015	Dóci, Gabriella; Vasileiadou, Eleftheria; Petersen, Arthur C	Exploring the transition potential of renewable energy communities	Futures	FiTs	Long term and stable EFIs like FiTs are important enablers of community energy groups
2012	Egbue, Ona; Long, Suzanna	Barriers to widespread adoption of electric vehicles: An analysis of consumer attitudes and perceptions	Energy Policy	General	Financial and non financial measures are required to mobilise adoption of EVs among early adopters
2015	Feurtey, Evariste; Ilinca, Adrian; Sakout, Anas; Saucier, Carol	Lessons learned in France and Quebec regarding financial and legal mechanisms to develop renewable energy: A hybrid model as an acceptable solution for onshore wind?	Renewable and Sustainable Energy Reviews	FiT/Quota	Quotas and FiTs can be designed to promote greater levels of community and individual ownership
2008	Fouquet, Doerte; Johansson, Thomas B	European renewable energy policy at crossroads—Focus on electricity support mechanisms	Energy Policy	FiT/Quota	FITs are more appropriate than quota-based schemes for small and medium size investors in EU member states

2015	Fraune, Cornelia	Gender matters: Women, renewable energy, and citizen participation in Germany	Energy Research & Social Science	General	Lower ownership rate and average investment sum for women compared to men in community owned projects in South Westphalia
2015	Frederiks, Elisha R. Stenner, Karen Hobman, Elizabeth V	Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour	Renewable and Sustainable Energy Reviews	General	Individuals are highly influenced by social comparison, neighbours and members of the community
1998	Gonzales, Marti Hope; Aronson, Elliot; Costanzo, Mark	Using Social Cognition and Persuasion to Promote Energy Conservation: A Quasi-Experiment	Journal of Applied Social Psychology	General	Using social-psychological principles in interactions with small-scale investors is effective in promoting LCT uptake
2009	Greenberg, M	Energy sources, public policy, and public preferences: Analysis of US national and site-specific data	Energy Policy	General	Differences in preferences for energy sources emerge by age, ethnicity/race and other demographic characteristic in US
2010	Hoffman, Steven M; High-Pippert, Angela	From private lives to collective action: Recruitment and participation incentives for a community energy program	Energy Policy	General	Community participants are not exclusively economically motivated in community energy initiatives in the US
2015	Kok, Robert	Six years of CO2-based tax incentives for new passenger cars in The Netherlands: Impacts on purchasing behavior trends and CO2 effectiveness	Transportation Research Part A: Policy and Practice	Tax incentives	Vehicle registration and annual car taxes are effective in promoting low-carbon vehicle uptake, and the “salience” of the tax is a key success factor. The cost-effectiveness of the instrument needs further attention.

2013	Kosenius, Anna-Kaisa; Ollikainen, Markku	Valuation of environmental and societal trade-offs of renewable energy sources	Energy Policy	General	Willingness to pay for renewables is different for different groups in society.
2007	Lane, Ben; Potter, Stephen	The adoption of cleaner vehicles in the UK: exploring the consumer attitude–action gap	Journal of Cleaner Production	General	Targeting early-adopters and combining non-financial interventions might be required to promote LCT vehicle purchases
2015	Linnerud, Kristin; Holden, Erling	Investment barriers under a renewable-electricity support scheme: Differences across investor types	Energy	Quota	Design considerations such as duration of the scheme can impact the extent to which quota schemes to can mobilise new investors. New investor classes have different motivations and characteristics compared to traditional investors.
2011	Lipp, Judith	Highs and lows for Canada solar co-op	Renewable Energy Focus	FiT	Certainty provided by FiTs can support community energy initiatives
2012	Mabee, Warren; Mannion, Justine; Carpenter, Tom	Comparing the feed-in tariff incentives for renewable electricity in Ontario and Germany	Energy Policy	FiT	FiTs enable individual and community investment and a wider range of project sizes has the potential to generate greater local benefits.
2007	Madlener, Reinhard	Innovation diffusion, public policy, and local initiative: The case of wood-fuelled district heating systems in Austria	Energy Policy	Grant/Soft loan	Grants can effectively and economically efficiently promote LCT investments by community groups, but design features of programmes as well as context-specific factors are important.
2008	Mahapatra, Krushna; Gustavsson, Leif	An adopter-centric approach to analyze the diffusion patterns of innovative residential heating systems in Sweden	Energy Policy	Grant	Grant programmes can be effective but need to be combined with other measures such as information campaigns and context-specify needs to be considered in programme design.

2015	Marchand, Robert D. Koh, S. C. Lenny Morris, Jonathan C	Delivering energy efficiency and carbon reduction schemes in England: Lessons from Green Deal Pioneer Places	Energy Policy	Soft loan	Soft loans may not be effective unless they provide an attractive proposition to households
2013	Martin, Nigel; Rice, John	The solar photovoltaic feed-in tariff scheme in New South Wales, Australia	Energy Policy	FiT	FiTs are effective at mobilising new investors, but measures to control cost-effectiveness are required.
2013	Masini, Andrea; Menichetti, Emanuela	Investment decisions in the renewable energy sector: An analysis of non-financial drivers	Future-Oriented Technology Analysis	General	Investors in renewables are influenced by social and institutional norms and financial incentives may not be successful in overcoming these status quo bases and need to be flanked by additional measures.
2012	Metcalfe, Robert; Dolan, Paul	Behavioural economics and its implications for transport	Journal of transport geography	General	Behavioural factors are highly prevalent in car purchase decisions
2014	Momsen, Katharina; Stoerk, Thomas	From intention to action: Can nudges help consumers to choose renewable energy?	Energy Policy	General	The default nudge increased the share of individuals who choose renewables while all other nudges prove ineffective among German students
2011	Palm, J; Tengvard, M	Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden	Sustainability: Science, Practice, & Policy	General	The perceived relative advantage of the technology, the complexity of the innovation, social influence, and knowledge of grants and costs can influence household responsiveness to EFIs in Swedish households.
2015	Rode, J; E Gomez-Baggethun; Krause, T	Motivation crowding by economic incentives in conservation policy: A review of the empirical evidence	Ecological Economics	General	Financial incentives may in some circumstance "crowd out" altruistic motivation resulting in unintended and negative policy outcomes.

2011	Rogan F; Dennehy E, Daly H. E; Howley M; and Ó Gallachóir B. P.	*Impacts of an Emission Based Private Car Taxation Policy – One Year Ex-Post Analysis.*	Transportation Research	Tax incentives	Tax incentives can be effective in mobilising investment in low-carbon vehicles but impacts on Government revenues need to be considered in instrument design.
2015	Romero-Rubio, Carmen;de Andrés Díaz, José Ramón	Sustainable energy communities: a study contrasting Spain and Germany	Energy Policy	FiT/Soft Loan	The ability of FiTs to support community energy is enabled by social, economic, institutional and financial pre-conditions being in place
2008	Roulleau, T; Lloyd, C. R	International policy issues regarding solar water heating, with a focus on New Zealand	Energy Policy	Grant/Tax incentive/Soft loan	Grants and tax incentives can be effective in promoting individual LCT investments, but cost-effectiveness issues need to be considered and addressed in programme design. Grants have the advantage of addressing the upfront investment barrier more effectively, and but EFIs can result in stop-start investment cycles and raise equity concerns. Soft loans may not be effective unless attractive terms are offered
2016	Salm, S; Lena Hille, S; Wustenhagen; R.	What are retail investors' risk-return preferences towards renewable energy projects? A choice experiment in Germany	Energy Policy	General	Local citizen investors may use simple heuristics to make investment decisions compared to traditional investors in LCTs.
2012	Saunders, R. W.; Gross, R. J. K.	Can premium tariffs for micro-generation and small scale renewable heat help the fuel poor, and if so, how? Case studies of innovative finance for community energy schemes in the UK	Energy Policy	FiT/Quota/Grant/soft loan	Grants can be effective in getting community organisations off the ground, but the stable source of finance offered by FiTs over time may be essential for these of organisations to operate effectively over time. FiTs con be effectively combined with low interest finance.

2015	Schultz, P Wesley	Strategies for Promoting Pro-environmental Behavior	European Psychologist	General	Prompts, commitments, feedback, social norms, incentives, and convenience can effectively promote pro-environmental behaviour
2013	Seyfang, Gil; Park, Jung Jin; Smith, Adrian	A thousand flowers blooming? An examination of community energy in the UK	Energy Policy	Grant/FiTs	Grant and FiT funding is important for community energy groups and policy and regulatory uncertainty is a problem for these groups.
2014	Sierzchula, William Bakker, Sjoerd Maat, Kees van Wee, Bert	The influence of financial incentives and other socio-economic factors on electric vehicle adoption	Energy Policy	Tax incentives	Vehicle registration and annual car taxes are effective in promoting EV uptake, but need to be combined with other policy interventions.
2015	Solangi, K. H. Islam, M. R. Saidur, R. Rahim, N. A. Fayaz, H.	A review on global solar energy policy	Renewable and Sustainable Energy Reviews	Tax incentive	Tax incentives can be effective in promoting solar PV growth, but are be undermined by regulatory uncertainty.
2012	Sovacool, Benjamin K; Lakshmi Ratan, Pushkala	Conceptualizing the acceptance of wind and solar electricity	Renewable and Sustainable Energy Reviews	FiT	The certainty provided by a long term FiTs resulted in access to lower cost finance for individuals

2013	Steinhilber, Simone; Wells, Peter; Thankappan, Samarthia	Socio-technical inertia: Understanding the barriers to electric vehicles	Energy Policy	General	Financial and non financial measures are required to mobilise adoption of Evs in German and UK
2014	Stigka, Eleni K; Paravantis, John A; Mihalakakou, Giouli K	Social acceptance of renewable energy sources: A review of contingent valuation applications	Renewable and Sustainable Energy Reviews	General	Socio-economic characteristics and knowledge of LCT can impact willingness to invest in LCTs.
In press	Strupeit, Lars Palm, Alvar	Overcoming barriers to renewable energy diffusion: business models for customer-sited solar photovoltaics in Japan, Germany and the United States	Journal of Cleaner Production	FiT/Soft loan	Soft loans effectively complement FiTs by providing an attractive financial proposition to risk-averse small-scale investors
2010	West, J; Bailey, I; Winter, M.	Renewable energy policy and public perceptions of renewable energy: A cultural theory approach	Energy Policy	General	Whether individuals are individualistic, hierarchical or egalitarian in word view can impact on the effectiveness of EFIs
2015/in press	Yang, Shu Zhao, Dingtao	Do subsidies work better in low-income than in high-income families? Survey on domestic energy-efficient and renewable energy equipment purchase in China	Journal of Cleaner Production	Grant	Grants can effectively target some but not all segments of the population and need to be combined with information campaigns to increase effectiveness.

2014	Yildiz, Özgür	Financing renewable energy infrastructures via financial citizen participation – The case of Germany	Renewable Energy	FiTs/Soft Loans	FIT-system combined with a publicly supported loan programs had a decisive impact on community energy growth
2012	Yin, Yao	A socio-political analysis of policies and incentives applicable to community wind in Oregon	Energy Policy	Grant	Grant programmes can effectively support community energy initiatives by alleviating the burden of raising upfront capital, and simplicity of application procedures can also be important
2012	Zhao, Tingting; Bell, Lindsey; Horner, Mark W; Sulik, John; Zhang, Jinfeng	Consumer responses towards home energy financial incentives: A survey-based study	Energy Policy	Tax incentive/Soft loan	Income tax credits may be more attractive to consumers compared to interest-free loans, because consumers may be reluctant to become indebted

Chapter 3: How can financial incentives promote local ownership of on-shore wind and solar projects? Case study evidence from Germany, Denmark, the UK and Ontario

3.1. Introduction

If 'dangerous' climate change is to be avoided, immediate and rapid decarbonisation must be achieved over the coming decades, particularly in developed economies (Anderson & Bows 2011; Rogelj et al. 2010; Edenhofer 2014). Many industrialized countries are incentivizing the up-take of decentralized electricity supply technologies such as wind and solar photovoltaic (PV), which alone have the potential to contribute 22% of electricity sector emissions reduction by 2050 (IEA 2015). The widespread deployment of distributed generation technologies is potentially disruptive for traditional utility business models (Engelken et al. 2016; Johnson & Suskewicz 2009), and opens up business opportunities for new actors. These technologies, however, face several barriers to widespread deployment. For example, they are affected by a shortfall in private finance (McInerney & Johannsdottir 2016), driven to some extent by the unwillingness or inability of traditional investors such as utilities to provide sufficient funding (Eleftheriadis & Anagnostopoulou 2015; Haigh 2011; Simshauser 2010).

Moreover, individuals and communities may be slow to accept new technologies for various reasons (Wüstenhagen, Wolsink, & Bürer 2007). In particular, there have been growing levels of local community opposition to on-shore wind energy projects in "remote, corporate ownership" (Toke et al., 2008). Local discontent with renewable projects can be highly costly and indeed fatal for projects (Van Rensburg, Kelley, & Jeserich 2015), which provides a compelling policy imperative to understand how these objections can be addressed. Within this context it is notable that solar PV and on-shore wind power are particularly accessible for local citizen investors acting either individually, as member of a community group, or as party to a project by a professional developer (Enzensberger, Fichtner, & Rentz 2003). This is because of the maturity, modularity, high reliability, the simplicity of the power generation process, and availability of technical service providers for these technologies (Yildiz, 2014). There is considerable academic interest and interest from international bodies such as the International Energy Agency's Renewable Energy Technology Platform (IEA-RETP) in exploring how sharing local value in renewable projects can build social support for low carbon transition. This literature suggests that local investment from citizen and community groups within proximity of a development, can generate local income (Callaghan & Williams 2014), create jobs (Carpenter 2014), build autonomy and resilience, strengthen community cohesion, result in more locally appropriate developments, contribute to understanding of climate and energy security issues more generally, and create niches which positively interact with the wider regime in various ways (Bergman & Eyre 2011; Bolton & Foxon 2015; Ricardo Energy and Environment 2017; Devine-Wright 2014; Palm & Tengvard 2011; Dóci and Vasileiadou 2015; Slee 2015; Viardot 2013; IEA-REDT 2016).

There is also a growing literature that explores structural factors influencing the development of community and citizen renewable projects, which attempt to explain the concentration of local community energy projects in some countries and jurisdictions, and their absence in others. These include: grid connection and planning regulations, societal norms, a tradition of cooperatives[4] and cultures of local energy activism (Bauwens, Gotchev, & Holstenkamp 2016; Bolinger 2005; Breukers & Wolsink 2007; Toke, Breukers, & Wolsink 2008; Van Rensburg, Kelley, & Jeserich 2015).

While technologies such as on-shore wind and solar PV are increasingly cost-effective, they generally require some form of Government support to galvanise deployment. There is a wide literature exploring the effectiveness of different types of financial incentives in mobilising investment from professional investors (Abolhosseini & Heshmati, 2014; Bobinaite & Tarvydas, 2014; Marques & Fuinhas, 2012; Mickwitz, 2003; Oak et al., 2014; Ozcan, 2014; Polzin et al., 2015; Somanathan et al., 2014). For this reason, there is also interest from an academic and policy perspective in determining what types of financial incentives[5] are most attractive to local citizen investors. These incentives in the form of taxes, grants, soft loans, feed in tariff (FiT), feed in premium (FiP) and quota schemes[6], have been identified as a crucial factor in growth of locally-owned renewable energy projects in certain jurisdictions (Parag et al. 2013; Curtin, McInerney, & Ó Gallachóir 2017a). Their use, however, has received less analytical attention. While there are some studies exploring the use of financial incentives to promote community energy (Bolinger 2001; Bauwens, Gotchev,

[4] A cooperative (also known as co-operative, co-op, or coop) is "an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise"
[5] Measures that provide actors with monetary compensation to adopt low-carbon technologies (Bergek and Berggren, 2014; Mickwitz, 2003)
[6] A FiT is an agreement to pay a guaranteed amount over a set period of time for certain types of renewable heat and electricity. A guaranteed price tariff is a FiT scheme where a set rate is paid for each unit of electricity generated and supplied to the grid. FiPs are similar to FiTs, except that in this case a fixed premium is added to the market price when exporting electricity to the grid (Couture and Gagnon, 2010). There are two broad category of quota scheme. Quotas with tradable green certificates (TGCs) are certificates issued for every unit of renewable electricity. They allow generators to obtain additional revenue from the sale of electricity. Demand for TGCs originates from an obligation on electricity distributors to surrender a number of TGCs as a share of their annual consumption (quota). Under tendering/bidding systems, on the other hand, government invites renewable electricity generators to compete for either a financial budget or renewable electricity generation capacity. Within each technology band, the cheapest bids are awarded contracts and receive the subsidy (del Río and Bleda, 2012)

& Holstenkamp 2016; Shi, Liu, & Yao 2016), comprehensive assessment of the effectiveness of particular incentives are not common (Curtin, McInerney, & Ó Gallachóir 2017a) and designing incentives that are appealing to local citizen investors within different contexts is challenging (Masini & Menichetti 2013; Wüstenhagen & Menichetti 2012; Yildiz 2014; Curtin, McInerney, & Ó Gallachóir 2017a; Stigka, Paravantis, & Mihalakakou 2014; Salm, Hille, & Wüstenhagen 2016; Linnerud & Holden 2015).

Within this context, the research question proposed in this paper is how financial incentives can be used to promote local community ownership of on-shore wind and solar PV projects. Our aim is to investigate the use of financial incentives in key jurisdictions to promote local citizen investment in solar PV and on-shore wind projects, and to determine which policy supports have been successfully employed. In particular, we focus on understanding the risk and return for community investors at different stages of project development, from the early feasibility and development to the later construction and operational phases This paper contributes to a growing body of research that explores the effectiveness of financial incentives at mobilising citizen and community investment, and explores the potential applicability of these findings for promoting citizen investment in jurisdictions with limited experience of citizen participation. On this basis we present a framework which summaries key policy solutions to overcome barriers for these investors at different renewable project stages.

The paper is structured as follows: Section 2 describes the research approach; in section 3 the case study findings are presented focusing on "the unique patterns of each case" (Eisenhardt 1989, 540); in Section 4 we discuss "patterns across cases" (Eisenhardt 1989, 540); Section 5 concludes.

3.2. Research Approach

This paper employs a comparative case study methodology. Case studies are considered suitable for documenting "how" and "why" questions, including processes such as market innovation, where the focus is on exploring contextual conditions (Yin 2003). They tend to report more information than, for example, a statistical study covering the same cases, and therefore provide a strong empirical grounding for a hypothesis (Odell 2001). Furthermore case studies can be used to synergistically combine quantitative and qualitative data from a variety of sources (Eisenhardt 1989), as is required in this study.

We have chosen Germany, Denmark, the United Kingdom (UK) and the Canadian state of Ontario[7] as our cases based on several criteria. First, in all cases financial incentives have successfully been introduced to promote deployment of on-shore wind and solar PV technologies. The cases selected are therefore distinguishable from countries where community and local citizen involvement in renewables is in its infancy, such as Ireland, Spain, and many parts of the United States. Second, these incentives have specifically targeted local citizen investors in all cases. Third, it is recommended that selected cases illustrate a difference in a particular phenomenon by comparing instances in which it occurs with instances where it does not (Odell 2001). For this reason, we selected the cases of Denmark and Germany because mobilising local citizen investors has been a key feature of low-carbon transition in these countries for several decades. By contrast, the use of financial incentives targeting local citizens is a more recent occurrence in the other two cases. The choice of cases therefore allows us to explore the role of financial incentives within different contexts, and to compare the differences between countries, but also intertemporal within countries. This is particularly important in considering the implications of our findings for promoting investment from citizens in countries without a tradition of community investment in renewables.

To build our cases we followed the following steps (Fig. 1):

1. We undertook a systematic literature review of relevant academic literature (Curtin and McInerney, 2017), and a review of relevant "grey literature" reports from consultancies and community groups;
2. We conducted a detailed desk analysis of relevant legal acts, policy frameworks and official government policy documentation in the four jurisdictions;
3. We reviewed statistical data on renewable deployment and local citizen investment trends in each case;
4. In some cases, it was not possible to determine the impact of a particular incentive on local citizen investment trends based on the above steps. For this reason, we undertook interviews with experts with intimate knowledge of the use of financial incentives to promote citizen investment in Denmark and Ontario, to enhance our understanding of the effectiveness or particular instruments;

[7] While Ontario, unlike the other cases, is a state, and therefore guided by the Federal Government in its energy policies to some extent, electricity generation is primarily governed at the provincial level (Krupa, Galbraith, and Burch 2015).

5. Finally, we conducted a one-day workshop in Ireland with 60 key stakeholders, which included presentations from experts on community energy from the UK and Germany/Switzerland, as well as many Irish experts. The objective was to present interim research findings, and to elicit feedback on the theoretical, policy and practical relevance of these conclusions for promoting citizen and community development in an immature market.

Figure 0.1 Methodology

A comprehensive list of sources is given in the Appendix.

3.3. Case Study Findings

In presenting our results we first present a short historical overview of the importance of wind and solar PV in the power generation mix, highlighting the participation of local citizen investors. In each case, we then assess the use of financial incentives and the emergence of "typical" business models. Key data from each case are summarized in the Table 1 below.

Table 3.1 Key data of case studies

	Proportion of total electricity generation (%, 2014)			**Local Ownership**
	Renewables	**Wind**	**Solar PV**	
Denmark[8]	53	40.5	.2[9]	Over half of total wind investment from local citizen investors.

[8] Danish Energy Agency (2015) Energy in Denmark 2014 (Danish Energy Agency 2014)
[9] Energinet DK (2015) Electricity Generation (Energienet 2015)

Germany[10]	25.8	9	5.0	Over half of total investment in wind and solar from local citizen investors.
UK[11]	19.1	9.5	.6	Low initial level of local citizen investment, growing gradually from 2000 and more rapidly from 2009 to 2015.
Ontario[12]	28.7	4.4	Less than .1	Low levels of community and citizen ownership, growing rapidly from 2009.

3.3.1. Denmark

Investments in wind and solar PV from local citizens

Denmark is a pioneer in the development of wind energy technologies (Ratinen and Lund 2015), and is a leader in the deployment of wind energy supported by local citizens. In 2014 over half of Denmark's electricity was generated from renewables, with wind accounting for 40% of total generation (Table 1). Of total wind generation, 40% was from off-shore turbines (Energienet 2015).

Local citizen ownership has been a key aspect of the Danish model. As early as 1990 several thousand wind energy guilds existed. These were often small projects owned by farmers, private households or local companies (Oteman, Wiering, and Helderman 2014). By 2001, 150,000 households owned or held shares in wind projects (Walker 2008). In 2015 small private wind energy operators were responsible for 50% of total electricity market share (Vindenergi Danmark 2015).

The use of financial incentives to promote local citizen investment

The development of renewable energy in Denmark gained impetus following the energy crises of the 1970s. High energy taxes were introduced (supplemented by carbon taxes since 1992) to promote energy efficiency, creating an early incentive to explore alternatives to fossil fuels (Nachmany et al. 2014).

In 1979, a grant covering 30% of the purchase price of a wind turbine was introduced. As wind power economics improved during the 1980s, the investment subsidy was gradually reduced before elimination in 1989 after a total Government investment of €38 million (Meyer 2003). While early producers received a price for their electricity relative to retail rates, the grant proved attractive to local citizen investors (Oteman, Wiering, and Helderman

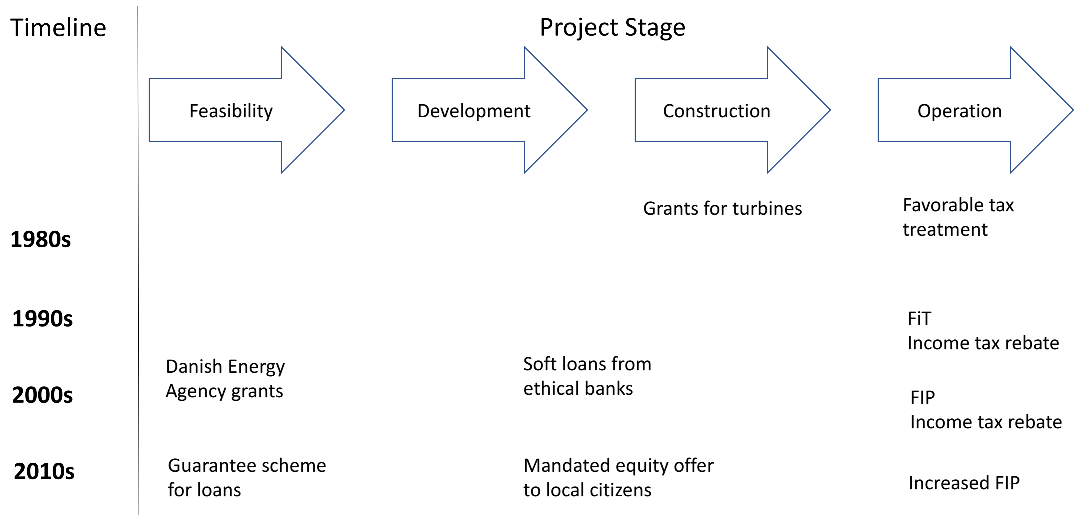
[10] BMWi (2016) Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland (BMWi 2016)
[11] DECC (2015) Digest of United Kingdom Energy Statistics 2015 (DECC 2015a)
[12] ISEO (2015) 2014 Electricity Production, Consumption, Price and Dispatch Data (ISEO 2015)

2014), who were responsible for all early investment. In this period, the income from wind farms received favourable tax treatment, interest on loans for purchase of shares in a wind turbine was tax deductible, and businesses could depreciate the value of a wind turbine by up to 30% annually (Bolinger 2001).

A fixed FiT was introduced by the Danish Government in 1993 (IRENA 2012). This was combined with a tax refund for income from wind power generation for individuals who participate in wind energy co-operatives, introduced in 1997 (IEA 2016). Together these incentives delivered strong growth in wind capacity through the remaining part of the 1990s (Meyer 2007). Furthermore, grants were available by the Danish Energy Agency to covering feasibility assessments (Middelgrunden Cooperative 2000). By 2002, wind already accounted for 15% of the country's electricity generation, and 40% of installations were run by local wind energy guilds (Gotchev 2015). Income from shares in wind farms remained tax deductible up to a certain limit. In these early years, projects were smaller and easier to finance, not least because of the presence of "ethical" banks such as Fælleskassen providing loans for wind turbines at below-market rates (Bolinger 2001).

The intention to move to a more market-orientated support scheme was flagged in the Electricity Reform Act (2001). However, implementation was postponed several times (Danish Ministry of Economy & Trade, 2003; Meyer & Koefoed, 2003) and a FiP was eventually introduced in 2003. These developments resulted in slow-down in investment. Since 2009, wind investment has begun to recover. This has been attributed to an increase in the premium available to wind energy producers, and the reforms introduced in the Promotion of Renewable Energy Sources Act (2008). This Act introduced a number of initiatives to promote local acceptance and participation, deemed necessary given increased local objections to wind developments, as well as the progression towards larger and more complex wind turbines (Danish Energy Agency 2012; Oteman, Wiering, and Helderman 2014). The Act required projects developers to offer for sale at least 20% of the ownership shares to the local population within 4.5 km of developments. It also introduced a specific measure to mitigate early-stage project risks for citizen investors in the form of loans to local groups covering project feasibility studies, up to a maximum of approximately €70,000. In addition to the state guarantee, local citizens tend to have access to project finance, generally from commercial banks, as projects have an established track record and are considered low risk. [13]

Figure 3.2 Danish incentives over project time and stage



3.3.2. Germany

Investments in wind and solar PV from local citizens

Germany is a pioneer in the deployment of distributed renewable energy technologies for electricity generation, and also in the involvement of local citizen as investors in low-carbon transition. In 2014 nearly 26% of Germany's electricity was generated by renewables with wind and solar PV accounting for over 9% and 5% of this total respectively (Table 1). Citizen-led energy initiatives are a cornerstone of the German energy transition. Almost 46% of all investment across wind, solar and other renewables has come from individual and community groups (Trend Research 2013). Of total citizen investments, 54% comes from individuals, 26% from shareholdings in renewable projects and 20% from cooperatives (Trend Research 2013). Collective citizen ownership of renewable energy technologies is particularly widespread in the area of onshore wind power and solar PV, as well as biomass technologies.

The use of financial incentives to promote local citizen investment

[13] Interview Asbjørn Bjerre, Danmarks Vindmølleforening, 11 April 2016

Public concern around nuclear power spurred the German Government to introduce Research and Development (R&D) policy supports to promote renewables in the late 1970s. However, by the end of the 1980s Germany's electricity supply system was dominated by very large utilities relying on coal and nuclear generation (IRENA 2012). The appearance of climate change as a concern and the 1986 Chernobyl nuclear accident acted as catalysts for change. Following a pilot programme which provided grants for wind power deployment in 1989, the first Electricity Feed-In Act (1990) introduced a FiT for renewable electricity. The Act obliged utilities to connect new independent power producers to the grid, thereby reducing the risk that FiT-approved would not achieve grid connection, and de-risking the early stage investments. Subsequent incentives have focused to a greater extend on the construction and operation phases of project development.

The introduction of the FiT is widely considered a turning point for both the deployment of wind power and the role of local citizen investors in Germany's electricity market (Jacobsson & Lauber 2006; IRENA 2012). By offering an undifferentiated FiT, in practice on-shore wind power, the most cost-effective renewable energy source, was favoured. Additional supports for wind power included loans at preferential rates and significant tax advantageous. For example, citizen investors in German wind partnerships could aggressively write off depreciation against all forms of income, including wage income until the late 1990s (Bolinger 2001). As a result of these incentives early investors were mainly small independent power producers, including individual citizens and collectively owned projects (Jacobsson & Lauber 2006; Bolinger 2001).

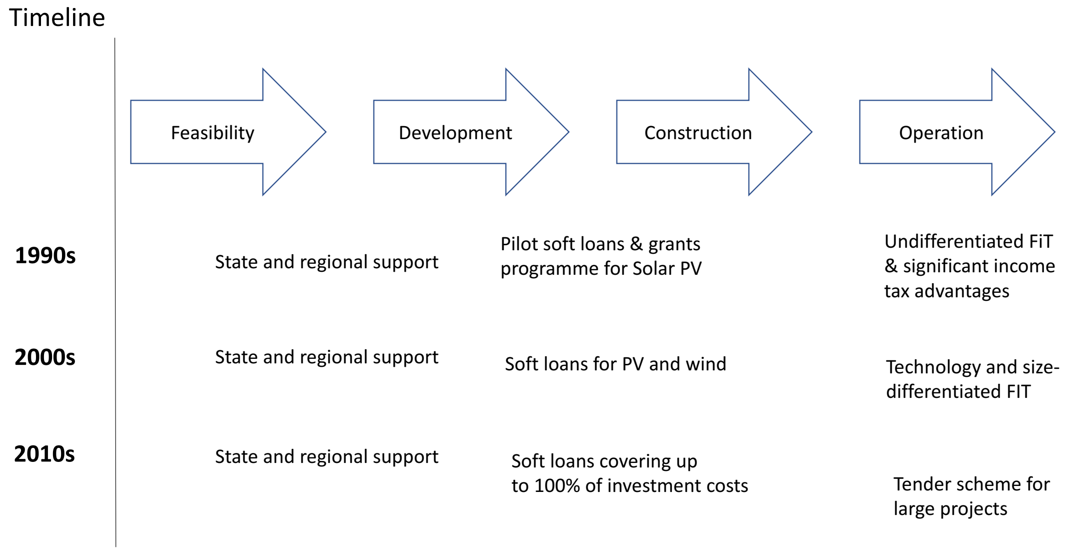
While the first FiT was not financially attractive for solar PV investments, some utilities began offer local supports for PV (Jacobsson and Lauber 2006). More significantly, the *1,000 Solar Roofs Initiative,* a grant programme launched in 1991, provided up to 70% of upfront costs for these installations. This grant programme was followed in 1999 with the *100,000 Solar Roofs Initiative*, under which German state-owned development bank (KfW) offered loans to individuals and small companies at low interest rates (under 2%) covering the full cost of projects, with the objective of delivering 300 megawatts (MW) of installed capacity (Weiss & Sprau 2002). These soft loan programmes were expanded to cover all renewable projects, with finance covering both development and construction costs (IEA-RETD 2016). While applications for preferential loans programmes were initially low, this changed with the Renewable Energy Act (2000/305), which introduced a FiT regime differentiated according to technology type and project size, including a much more attractive tariff for solar PV projects. The Act has undergone four amendments (2004, 2009, 2012, and 2014). Several studies point to the combined impact of the FiT and the widespread availability of soft loans covering development and construction costs as key success factors in the German case (Yildiz 2014; Strupeit&Palm 2016; IEA-RETD 2016).

A number of reforms to incentive programmes have been introduced in the since 2012 with the objective of transition toward more market-based support mechanisms. This have included significant cutbacks in the FiT levels for new projects (2012 and 2014), and replacing the FiT with an optional (2012) and then mandatory (2014) FiP for new projects based on a contracts for difference[14] approach. As of 2017, the FiT will be replaced by a competitive bidding model (tenders) for larger projects. These changes have created challenges for smaller independent producers (Bauwens, Gotchev, & Holstenkamp 2016; Wassermann, Reeg,&Nienhaus 2015). None of the successful bids for the Federal Government´s first solar park tender for 157 MW came from individuals or smaller independent producers, suggesting that the new scheme may have created barriers to entry for these actors (IEA-RETD 2016).

Finally, a proliferation of regional and local level advisory services and citizens groups provided expertise and management services, often on a pro bono basis, to community projects (Schreuer 2015). Indeed regional clusters of energy community energy projects are located in places where support services are offered (Holstenkamp&Müller 2013).

Figure 3.3 German incentives over time and project stage

[14] Under this approach generators sell energy into the market but to reduce exposure to changing electricity prices, a variable top-up from the market price to a pre-agreed. At times where the market price exceeds the strike price the generator is required to pay back the difference.



3.3.3. The UK

Investments in wind and solar PV from local citizens

In contrast to Denmark and Germany, the UK has been a relatively late adopter of distributed renewable energy technologies such as solar PV and wind. In total 19% of electricity was generated from renewables in 2014. 9% of this total came from wind and less than 1% from solar PV (Table 1). By 1990 there was virtually no locally owned renewable energy generation (Breukers & Wolsink 2007). Since the year 2000, however, there has been an increase in local citizen investment (Bolinger 2005; Toke, Breukers,&Wolsink 2008). By 2013 the level of community renewable electricity capacity installed had risen to 66 MW, with another 200 MW was in development, 85% of which were in wind was accounted for by wind and 14% by solar PV (Carpenter 2014). A number of partnership projects between community groups and professional project developers were also in development or completed (DECC 2015d). While the role of local citizen investors therefore remains marginal, it is growing fast.

The use of financial incentives to promote local citizen investment

Renewable energy deployment in the UK[15] traditionally focused on large-scale, utility and private-sector driven wind power applications (Walker et al. 2007; Breukers & Wolsink

[15] The UK consists of four countries: England, Scotland, Wales, and Northern Ireland. While overall energy policy is coordinated centrally, each country has considerable autonomy in energy policy development and for the introduction of financial incentives.

2007). The early liberalisation of the UK energy sector (1989) was followed by the introduction of a Non Fossil Fuel Obligation (NFFO), introduced in the Electricity Act of 1989, which required electricity distribution operators to purchase a specified amount of non-fossil fuel energy from suppliers. Contracts were awarded to the lowest cost projects following a competitive tendering process, thereby favouring large companies with strong financial backing. The administrative burden to participate in the scheme as well as the absence of tax incentives and capital investment subsidies at this time further undermined the attractiveness for local citizens (Bolinger 2005; Breukers & Wolsink 2007).

A Renewables Obligation (RO) (Utilities Act, 2000) scheme followed in 2002, required electricity suppliers in England and Wales to supply an increasing portion of electricity from renewables. This scheme was equally unattractive to community groups due to the higher costs associated with the smaller-scale projects that they tended to propose (Breukers & Wolsink 2007). Other barriers to community group participation included the complexity of application process and the perceived higher risk (Saunders, Gross, and Wade 2012). While the RO itself was phased out in 2016 and replaced with a contract for difference support scheme (DECC 2015b), community groups have identified a number of concerns with the latest scheme, including the high administrative and upfront costs, tight timelines, and penalties for contract withdrawal (DECC 2015c).

The beginning of the new millennium is often cited as a turning point with respect to local and community engagement in renewable energy projects (Bolinger 2005; Toke, Breukers, & Wolsink 2008; Walker et al. 2007). The change in direction came in part as a response to planning and permitting difficulties experienced by larger commercial wind projects. Giving the local community a financial stake in the success of a project came to be seen as a way to bolster community support (Bolinger 2005; Toke, Breukers, & Wolsink 2008; Walker et al. 2007; DECC 2014), but also as a way of educating the public (Walker et al. 2007).

In this period a number of pilot programmes were launched focused on providing grant support to exemplar community energy projects along with earlier stage advice and support, including the five-year Community Renewables Initiative (CRI), launched in 2002 (Walker 2008). This was followed by a Low Carbon Communities Challenge in 2009, under which advise and support on project development was provided and grant support was made available to cover investment costs for 20 ‘test-bed’ communities projects across England, Wales and Northern Ireland (DECC 2012). National programmes were supplemented at local and regional level with grants.

Many UK community energy groups were initially able to take advantage of grants, but found a stable supply of funding to be important to operate effectively over the longer term (Saunders, Gross & Wade 2012; Seyfang, Park & Smith 2013). A major turning point in supporting local community energy projects was reached with the introduction of technology and project size differentiated FiTs in the Energy Act (2008/21) (DECC 2014), which entered into effect in 2010. Payments through the mechanism replaced the RO for small-scale (5 MW, raised to 10 MW in 2015) projects (DECC 2015c). In general FiTs cannot be combined with grants programmes, although some exceptions have been made (DECC 2015c).

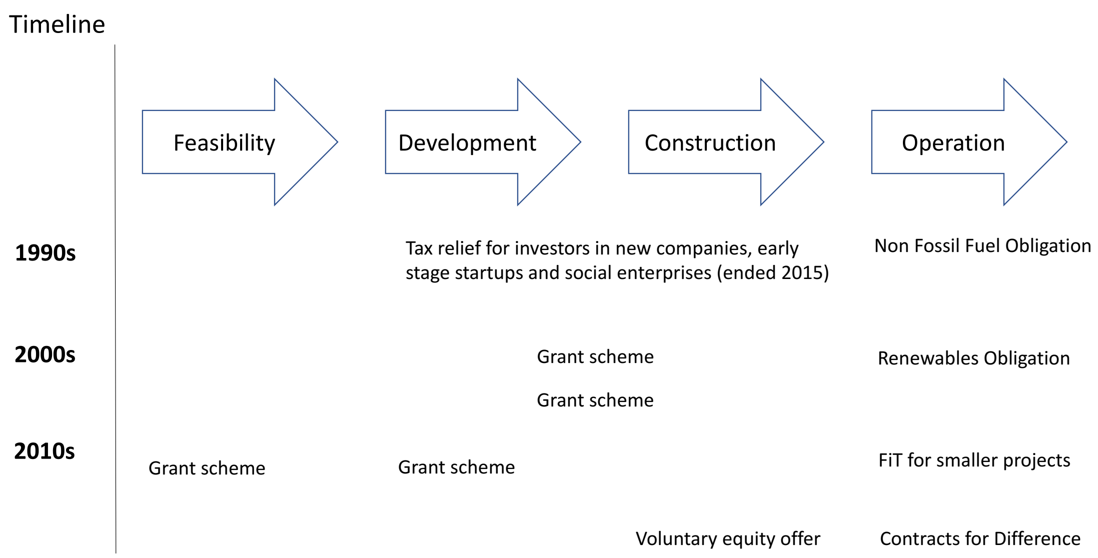
The rates of tariffs available under the programme have been subject to considerable uncertainty with cuts announced on several occasions, including in the first year of the scheme (DECC 2011), and in December 2015, along with a more stringent digression mechanism (OFGEM 2016). These have been justified on the basis of high take up and the declining cost of installation and hardware, especially for solar PV (DECC 2014) but community groups have complained that the cuts themselves have damaged confidence in the community energy sector (Quantum 2015).

FiTs, however, were not found to overcome all hurdles faced by community energy projects (Nolden 2013; Bauwens, Gotchev & Holstenkamp 2016). Particular challenges in raising early stage finance from the private sector were identified due to their weak balance sheets of community groups (DECC 2014). A grant of up to approximately €26,000 was therefore made available for feasibility assessments, and a non-recourse loan of up to €167,000 for pre-planning development work (DECC 2014). Similarly, schemes have been introduced by the Scottish and Welsh administrations (DECC 2015c).

A number of tax advantages were also available for community investors. This included schemes to provide up to 30% tax relief to investors in new companies, early stage start-ups and in social enterprises. In 2015, however, the UK Treasury announced that community energy projects benefiting from subsidies would be excluded from these schemes (CEE 2015). According to community groups, these changes will negatively affect the business case for projects. Challenges notwithstanding, the package of incentives, and the FiT in particular, has proven itself popular among community groups, and has driven the expansion of this sector (CEC 2015).

Finally, there has been a growing emphasis on encouraging communities and industry to work collaboratively together on schemes of mutual interest (DECC 2015d). To this end, a voluntary approach was trialled whereby developers offer between 5-25% of shares to local communities where project size exceeds €3.2 million (DECC 2015d). The UK Government has legislated to create reserve powers within the Infrastructure Act (2015/7) that, if exercised, would make this voluntary approach mandatory.

Figure 3.4 UK incentives over time and project stage



3.3.4. Ontario, Canada

Investments in wind and solar PV technologies from local citizens

The Canadian state of Ontario has been a relative latecomer to deploying wind and solar energy, but has sought to mobilize local citizens as investors as a central dimension of its low-carbon transition. While in 2006 virtually no wind or solar PV electricity was generated, by 2014 renewables accounted for 24% of electricity generated with over 4% coming from wind and under 1% from solar PV (Table 1).

Between 2010 and 2015, 4,627 MW of renewable contracts have been awarded by the Independent Electricity System Operator (IESO). Community equity participation has been a central feature with some form of community and/or Aboriginal (First Nation and Métis) participation in 22% of total contracts issued (IESO 2015).[16] Furthermore, an additional 20,000 micro FiT contracts have been issued for small solar PV installations representing 181 MW of capacity (IESO 2015), which included applications from many farmers, business owners and homeowners. Some community groups pursued their first projects as a result of the micro-FiT programme by aggregating a number of these contracts (Lipp 2016).

The use of financial incentives to promote local citizen investment

The Renewable Energy Standard Offer Program (RESOP) (2006) introduced a FiT for renewable energy in Canada. This programme encouraged a high concentration of larger developers due to high costs of applications, among other factors. This was followed by the Green Energy and Green Economy Act (2009/12), which introduced a technology differentiated FiT, offering stable prices and long-term contracts. Compared to the RESOP the price schedule for the FIT offered a considerably more attractive return for investors.

The new programme was divided into two streams, the FIT stream and the micro-FiT stream. The micro-FiT programme for projects not exceeding 10 kW focused on homeowners and small businesses. It also introduced streamlined application and contract issuance procedures. Ontario's FiT policy has been compared to the German FiT scheme. It comprises a set of prices for multiple technologies, differentiated according to project size – in both cases as the project size decreases the tariff increases (Stokes 2013; Mabee, Mannion & Carpenter 2012), although the German scheme has a greater number of options (Mabee, Mannion & Carpenter 2012).

A distinctive design feature of the 2009 FiT was the strong additional incentives and supports for community-owned projects. There was a particular emphasis on promoting projects owned by Aboriginal communities, who are an acutely disadvantaged minority in Ontario. Aboriginal peoples face even greater barriers in participating in renewable projects than ordinary community groups (Krupa 2013, 2012), yet nearly all future electricity developments will occur within their territories (Krupa, Galbraith & Burch 2015).

[16] This includes a small number of hydro and biomass projects.

The key incentive mechanism was an “adder” to the FiT, an additional amount per kilowatt-hour of energy produced over standard FIT rates, related to the percentage of equity ownership by Aboriginal and other community groups (Cameron 2011). As can be seen from Table 2 below, this “adder” varied by technology, and was higher for Aboriginal groups than other local community groups. In addition to the “adder” Aboriginal groups in Canada are exempt from taxation for many activities.[17]

Table 3.2 Maximum adder to FiT price schedule (c/KWh)

	Aboriginal Groups	Other Community Groups
Wind	1.5	1
Solar PV	1.5	1
Hydro	.9	.6
Biogas	.6	.4
Biomass	.6	.4
Land Fill	.6	.4

Source: (Cameron 2011, 12)

A 2011 review of the programme found that the FiT rules using a first come, first served approach disadvantaged community/Aboriginal participation, because these project types tended to take more time to organize and were more challenging to finance (ISEO 2012). Subsequently, under the second phase of the FiT, commercial projects with equity participation of 15% from local or Aboriginal communities received additional points on their application. Furthermore, 25 MW of the FiT was set aside projects that had 50% equity ownership from cooperatives (this legal form was given specific recognition) and a further 25 MW was set aside for projects with 50% equity ownership from Aboriginal groups (Lipp 2016). Further to these requirements, a significant number of FiT contracts were issued involving community participation, and a majority of cooperatives active in the renewable sector were established in response to FiT 2 (People Power Planet 2016).

In 2013, as a result of concerns around the cost to the exchequer (Krupa, Galbraith & Burch 2015), it was announced that ‘large’ renewable projects (over 500 kW) would be removed from the FiT programme (IESO 2013). A competitive tendering process was introduced for these projects. The degree of community engagement and ownership, including equity ownership from cooperatives, Aboriginal groups, local landowners and municipalities, were included as important criteria in this tendering process. As a result 13 of the first 16 projects

[17] Correspondence with Dr. Joel Krupa, University of Toronto, 14 April, 2014

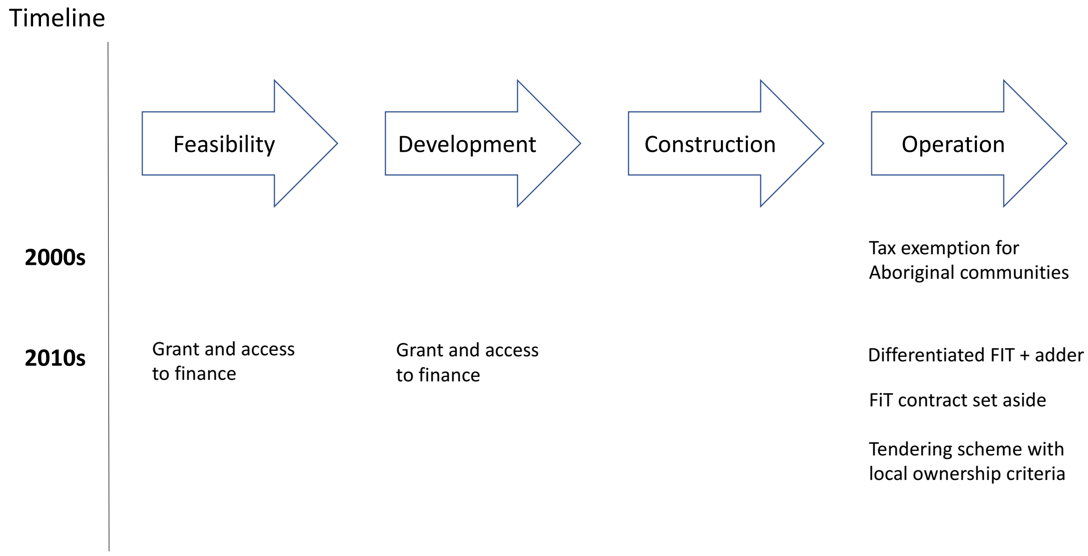
(5 wind, 7 solar PV and 4 hydroelectric) contract offers included participation from one or more Aboriginal communities, including five with more than 50% Aboriginal participation. Additionally, 75% of the successful proposals had received support from local municipalities, and more than 60% had support from abutting landowners. None of the projects, however, involved participation from a cooperative or a non-Aboriginal community group.[18]

Under the FiT for medium sized projects (10kW to 500kW), which remains in place, 968 applications have been received representing a total of 582 MW. Of these 13% had Aboriginal community participation, 35% had municipal and public sector participation and 25% had community participation (IESO 2016). Finally, under the micro-FiT approximately 50 MW of solar PV is to be procured between 2013 and 2017, and the majority of this will come from individuals, small business and some community groups. [19]

The FiT, however, was not the only support introduced for community projects. A number of incentives were made available to address key barriers to community participation, such as access to finance to cover establishment and early stage project feasibility assessments and planning applications studies (The Federation of Community Power Co-ops 2015). These programmes were streamlined into the Energy Partnership Program, which provides grant funding to cover the early-stage legal, technical, financial and due diligence and soft costs of community energy projects supported by the FiT. Charities, not-for-profits and cooperatives are eligible for the fund as well as projects developed by individual Ontario residents, such as farmers. These grants have been an important factor in getting community projects off the ground (The Federation of Community Power Co-ops 2015).

Figure 3.5 Ontarian incentives over time and project stage

[18] Interview with Dr. Christine Koenig, Ontario Sustainability Services Inc. Tuesday 5 April, 2016
[19] https://ieso-public.sharepoint.com/Documents/Ministerial-Directives/FIT-4-Minister-Direction-June-24-2015.pdf



3.4. Discussion

This aim of this study is to systematically investigate the use of financial incentives to promote local citizen investment over the different stages of solar PV and on-shore wind energy project development, with a view to determining which have been effective in mobilising investment for local citizen and community actors. Our case studies reveal the importance of introducing financial incentives at both the early and later stages of these projects in order to establish a business case for local citizen participation.

Our case studies reveal the crucial importance of incentives to overcome early risks at the feasibility and development stages of project development. Attendees of our workshop emphasised the importance of this insight and underlined the importance of considering the needs of citizen investors at the early high-risk project development stage. One attendee with community project development experience emphasised that professional developers can generally offset these risks by developing a portfolio of projects, whereas this is an option not generally available to local citizens. Early-stage project supports are particularly evident in the cases of Ontario and the UK, and, in more recent years, in Denmark. In these three cases, non-recourse loans and grants were introduced to cover feasibility and development costs for local citizen initiatives. In Germany, however, while soft loans were available to cover some of the development costs, examples of specific financial incentives targeting feasibility assessments are less common. The low risk environment in Germany for citizen investment was emphasised by attendees of our workshop. This can perhaps be attributed to the approach to project approval in Germany that aligns planning, grid access and FiT contracting application, thereby reducing early-stage project risks (IEA-RETD 2016). It perhaps also reflected the proliferation of local and regional groups and agencies available to support local citizen groups (Romero-Rubio & de Andrés Díaz 2015; Dewald & Truffer 2011), and the high numbers of developer-led initiatives in the wind sector where early stage project risks are ameliorated by the professional entity.

In all cases, incentives have also been introduced at the later (construction and operation) phases of project development. Stakeholders and experts that attended our workshop emphasised the challenges that community and citizen investors tend to experience as they seek to move to the construction phase of a project, in particular raising private debt finance to supplement grants, soft loans and their equity stake. We find that, while in the UK, Denmark and Germany early adopters and pilot projects were encouraged using grant-based supports, the introduction of a FiT was a crucial turning point and critical success factor in mobilising local citizen investors at scale in all four cases. A key characteristic of FiTs is that they provide a stable long-term income stream, and therefore reduced risk and make it easier to access bank funding, which appears particularly important for local citizen actors. In all cases, the favourable tax treatment of income from renewable energy projects emerges as an important supplementary consideration. Indeed, the removal of tax incentives in the UK has undermined the business case for many renewable energy projects since 2015.

These findings could be interpreted to support claims of the attractiveness of the FiTs themselves for local citizen investors (Fouquet & Johansson 2008; Butler & Neuhoff 2008; del Río & Bleda 2012; Saunders, Gross & Wade 2012; Couture & Gagnon 2010). This would be of concern within the context of the transition from FiTs to increasingly market-based supports, which is evident in all four cases. It is noteworthy, for example, that when Denmark transitioned from a FiT to a FiP in 2003, no new guilds were established in the period from 2003 to 2007 (Gotchev 2015; Meyer 2007), and several existing guilds ceased to exist (Gotchev 2015).

However, our cases reveal that there are more important considerations than the choice of instrument per se. For example, specific design features were an important factor in the success of FiTs. In Ontario, the UK and Germany, FiT programmes were differentiated according to project size and technology type, opening up niche opportunities for local citizen actors the UK. In Ontario, adders, set asides and mandates have been used to counteract the advantages of commercial organisations in bringing capital-intensive projects to fruition and in accessing finance. However, it is notable from the Ontarian example that consistent and increasingly strong supports were required to get community projects over the line, underlining the challenge of technical capacity for community groups. This was a point repeatedly emphasised by attendees of our workshop, and the role of trusted intermediaries in providing training, skills development and access to expertise was identified as an important success factor if specifically tailored financial incentives are to be available of by citizens and community actors.

Furthermore, while the case of Denmark demonstrates that the transition from a FiT to the FiP was not seamless, the 2009 reforms illustrates that the latter incentive can be designed so that it is attractive to community groups. Additionally, the case of Ontario illustrates that quota-based tendering schemes can also be designed in a manner which is advantageous to local community groups. The German and UK quota/tendering schemes, however, appear not to have been designed with these actors in mind and have created barriers to entry for these actors. Ultimately, therefore, we would concur with the findings of studies (Feurtey et al. 2015; Curtin, McInerney & Ó Gallachóir 2017a) that emphasise the importance of specific design features, and the importance of provision of stable financial revenues (Simcock, Willis & Capener 2016), as opposed to the choice of financial incentive per se. This could be particularly important with the context of migration to more market-based supports within the EU (Ragwitz et al. 2012) and elsewhere.

Our cases illustrate that the cost-effectiveness of FiT schemes has been questioned, which has resulted in abrupt changes to the levels of support available. This regulatory uncertainty has clearly undermined the confidence of local citizen investors, who appear less resilient in the face of these changes than more traditional investor classes. Governments would argue that controlling the cost of low-carbon transition is a necessary priority to deliver continued societal buy-in. On the other hand, local citizens often provide their time on a voluntary basis (Rijpens 2013; IEA-RETD 2016), and their participation in projects has been found to open up access to optimal sites (for on shore wind, or for example, south-facing roof tops), thereby reducing cost (Nelson et al. 2016). In many cases community objections greatly delay and increase the cost of community projects (Van Rensburg, Kelley & Jeserich 2015), and involving communities could reduce these project risks and costs. The net cost-effectiveness of involving local citizens as investors therefore requires further evaluation.

3.5. Conclusions

In this study, we evaluated the use of financial incentives introduced at different solar PV and wind project stages, and their importance in mobilising local citizen investment in Germany, Denmark, the UK and the Canadian state of Ontario. This study is, however, limited by a number of factors. First, it is restricted to the study of financial incentives, and we intentionally exclude consideration of socio-cultural and political traditions that are important in explain the success or failures of community-led renewable energy projects, particularly in Germany and Denmark. Unlike the use of financial incentives, these factors have been discussed exhaustively in the literature. However, cultural and political traditions cannot be replicated across jurisdictions and out interest here is in considering the lessons from these countries that *can* be applied in third countries. Second, we restrict ourselves to cases where community energy is somewhat developed in order to identify lessons for jurisdictions where community energy is in its infancy. e. Finally, we acknowledge that our findings are based on a qualitative evaluation. We consider this study explorative in nature, with the intention of opening up new areas for further empirical evaluation, and we do not therefore present our conclusions as a definitive last word on this topic.

Notwithstanding these limiting factors, we proceed to draw conclusions and implications, summarised in Table 3.

Table 3.3 Overview of findings

	Feasibility	Development	Construction	Operation
	Early Stage		Late stage	
Financial barriers	- Inability to balance risk across portfolio of projects - Lack of investment capital and weak balance sheets - High financial exposure - Technical skills deficit		- High risk aversion than traditional investors - Accessing loan finance - Technical skills deficit	
Incentives & Measures	- Grants	- Grants - Soft and non-recourse loans	- Feed in tariffs reduce market risk - Quota-based auctioning schemes can be tailored for citizen investors (using contract set asides or adders) - Favourable tax treatment	
	- Access to technical advice and expertise			

Previous studies have identified context-specific factors to explain the concentration of community energy in certain jurisdictions. While we do not deny the importance of factors such as a strong tradition of local activism, it is clear that citizens and communities respond to financial incentives, even in the absence of such a tradition, for example in the UK. This suggests that even without context-specific advantages, the introduction of specifically tailored financial incentives can be effective in mobilising citizen investment. Our findings suggest that financial incentives must be considered at both the early and later stages of a project's lifecycle. The requirement for early-stage incentives is a distinguishing feature of projects with citizen involvement, and appears central to the value proposition of many successful projects. This reflects the greater risk aversion of this cohort of investors, and their inability to balance risk between a portfolio of projects, as is the case with professional project developers. Incentives are therefore required at the feasibility and development stages to mitigating these higher early-stage project risks, although other measures such as setting out clear planning, grid access and other procedures are also important. The importance of early stage support for local community energy projects, while commonly acknowledged in the policy world, is not a topic that has received attention in the academic literature. It is therefore an area which merits further exploration.

With respect to incentives introduced at later construction and operation phases, we conclude that market-independent supports such as FiTs and grants have been important in mobilising local citizens as investors. However, in contrast to previous literature, an implication from this study is that market-based supports such as FiPs and quota-based schemes, which are becoming increasingly popular within the EU and globally, can also be designed in a manner that is attractive to citizen investors. However, market-based supports, which are becoming more widespread in their use as wind and solar PV mature, have a mixed track record when it comes to mobilising local citizen actors — while they *can* be deigned with these actors in mind, this has not always been the case. The timelines for citizens and community groups to organise project will tend to be longer due to their lack of technical skills and expertise, and the greater difficulty they are likely to experience in accessing finance, and this is an important consideration in designing support mechanisms, in particular market-based approaches such as auctioning or tendering schemes. Areas we highlight for further research include: the extent to which local citizens are put off by the greater investor risk associated with market-based incentives merits further exploration; and the net cost-effectiveness of incentivising citizen and community investors in low carbon transition. These findings add a new dimension to the growing academic and policy debate about how Governments can effectively mobilise investment from local communities and citizens in distributed renewable technologies. Findings should be of particular interest to policy makers in countries such as Ireland, Spain, and many parts of the United States, where community energy is in its infancy.

Chapter 4: Energizing local communities—What motivates Irish citizens to invest in distributed renewables?

4.1. Introduction

Distributed energy generation technologies such as solar photovoltaics (PV), wind turbines, combined heat and power (CHP) installations and biofuel boilers are expected to play an increasingly important role in transition to a low carbon economy over the coming decades (Ruggiero, Varho & Rikkonen 2015; Sioshansi 2016)**.** These technologies may be particularly attractive for local citizen investors because of their maturity, modularity, high reliability, the simplicity of the power generation process, and availability of technical service providers (Yildiz, 2014).

In pioneering countries like Denmark and Germany, over half of total investment has come from local citizens (BMWi 2016; Danish Energy Agency 2014; Curtin, McInerney & Johannsdottir 2018; Mey & Diesendorf 2018). However, in many other countries that are rapidly deploying distributed renewables (such as Ireland, Spain, and the UK), investment has been dominated by traditional investors, such as utilities, professional project developers and financial institutions (Curtin, McInerney & Johannsdottir 2018).

The social acceptance of distributed renewables has emerged as a major factor in hindering technology deployment (Walker, Wiersma & Bailey 2014; Sovacool & Lakshmi Ratan 2012; Wüstenhagen & Menichetti 2012), but also as a key enabling factor in low-carbon transition (Shackley & Green 2007; Sovacool & Lakshmi Ratan 2012; Stokes 2013; Szarka et al. 2012; Walker 2008, 2011; Wolsink 2007; Jami & Walsh 2017). Encouraging citizen investment in local projects has been identified in a wide-ranging literature as one means of galvanising buy-in and acceptance for distributed renewable technologies (Bergman & Eyre 2011; Bolton & Foxon 2015; Dóci, Vasileiadou & Petersen 2015; Palm & Tengvard 2011; Parag et al. 2013; Rogers et al. 2008; Wüstenhagen, Wolsink & Bürer 2007; Yildiz et al. 2015; Devine-Wright 2014). Greater levels of local ownership has, for example, been found to increase the pace of technology deployment in some cases (Toke, Breukers & Wolsink 2008). However, the extent to which citizen investors are willing to provide investment capital for these projects is an open question.

Prior research has found that the high levels of citizen investment in some countries grounds in country-specifics including, *inter alia*, the regulatory environment, support from local advisory organisations, a tradition of local activism, a relatively high sensitivity to

environmental issues among citizens, and the presence of citizens with the financial resources to invest (Dewald & Truffer 2011; Romero-Rubio & de Andrés Díaz 2015; Gamel, Menrad, and Decker 2017). These differences in contexts suggest that the experiences of countries with high citizen investor participation might not be replicable elsewhere.
However, there is also an extensive literature which explores the motivation of citizen investors, which tends to focus on identifying more generalisable characteristics of this cohort across countries. Some studies identify the primacy of financial motivation (particularly within the current low-interest rate environment) (Fleiß et al. 2017). On the other hand, many studies have found that economic motivations and "rational" economic behaviour may not adequately explain citizen investment decisions (Masini & Menichetti 2013; Wüstenhagen & Menichetti 2012; Borgers & Pownall 2014; Gamel, Menrad & Decker 2016; Salm, Hille & Wüstenhagen 2016). Citizens appear to judge investments differently to professional investors (utilities & financial institutions, for example), & a variety of non-financial factors have been identified which significantly influence attitudes towards investments in renewables (Gamel, Menrad & Decker 2017). For example, citizen investors may have less business experience and financial strength than traditional investors (Salm 2017; Bergek, Mignon & Sundberg 2013) or may be influenced by their attitude towards a particular technology (Claudy, Peterson & O'Driscoll 2013). The importance of non-financial factors can be explained to some extent because citizens do not need to satisfy the minimum return requirements of shareholders and/or clients (Salm 2017; Bergek, Mignon & Sundberg 2013).

Notwithstanding these findings, little is known about citizen investor preferences for distributed renewables (Borgers & Pownall 2014; Gamel, Menrad & Decker 2017; Salm, Hille & Wüstenhagen 2016), and a lack of rigorous academic research on the risk-return preferences of these investors has been noted in previous studies (Salm, Hille & Wüstenhagen 2016; Gamel, Menrad & Decker 2017). Furthermore, while the importance of financial incentives and subsidies have been underlined by many studies (Curtin, McInerney & Ó Gallachóir 2017b; Curtin, McInerney & Johannsdottir 2018; Gamel, Menrad & Decker 2017; Fleiß et al. 2017; Yildiz 2014), the design of financial incentives that are attractive to local citizen investors, and which would be effective in mobilising investment, is another underdeveloped theme in the academic literature (Stigka, Paravantis & Mihalakakou 2014; Yildiz 2014; Curtin, McInerney & Ó Gallachóir 2017a).

Grounded on the necessity to study different country frameworks individually, as well as the lack of research on the design of financial incentives, in this paper we focus on mobilising financial participation from local citizen investors in Ireland. The introduction of a competitive bidding system in 1993, and its subsequent replacement by a Feed in Tariff (FiT) scheme in 2006, has been successful in attracting investment capital into the Irish wind sector (O'Gallachoir, Bazilian & McKeogh 2010) and wind energy accounts for 24% of total electricity generated in 2014 (SEAI 2016a). However, under Ireland's current trajectory there may be a shortfall in meeting Ireland's EU renewable energy target for 2020 (SEAI 2017). Objections to planning permissions against wind farms, pylons and transmission cables have been an important factor in slowing the pace of deployment (Mullally & Byrne 2015), causing significant delays, and in some cases the abandonment of projects.

In contrast to Germany and Denmark, investment has been almost entirely dominated by utilities and private developers. There is only one wind farm of 3.9 megawatt (MW) held in community ownership from a total installed capacity of over 3000 MW. While there has traditionally been popular support for technologies such as wind power, a "*sea change in social support"* has been identified (NESC 2014). For this reason, the Government's Irish Energy White Paper (2015) envisages transitioning from an energy system "*from one that is almost exclusively Government and utility led, to one where citizens and communities will increasingly be participants*", and includes commitments to use economic incentives to support the growth of citizen investment (DCCAE 2014).

There has been some academic focus on understanding citizen acceptance of renewables projects within an Irish context (Van Rensburg, Kelley & Jeserich 2015; Brennan & Van Rensburg 2016). One study that explored citizen preferences between different models of participation found a preference for lower levels of risk and involvement (Hyland & Bertsch 2018b), but without considering citizen risk-return trade-off and investment preferences.

Within this context, key research questions addressed in this paper are as follows: are citizens from a country lacking a tradition of citizen investment like Ireland interested in becoming investors in distributed renewable energies? If so, what is the risk-return trade-off favoured, and what other financial characteristics and investment attributes are important for potential citizen investors, and what key barriers to investment exist? We seek to draw implications from our findings for the design of financial incentives. These are questions of significant interest to researchers and policy makers seeking to understand how to motivate local citizen investment in distributed renewable technologies.

We proceed as follows: Section 2 introduces the research framework and the methodology that will be used in the study; Section 3 presents an overview of the data; Section 4 discusses the results; in Section 5, the implications of these results are analysed within the context of the research questions. Section 6 sets out conclusions along and policy recommendations, and identifies areas for future research.

4.2. Methodology

In order to better understand citizen investment preferences for distributed renewables, we undertook a survey of Irish citizens which contained an adaptive choice-based conjoint (ACBC) experiment. This involved undertaking an online survey, developed over a number of iterations, which employed a stated preference approach to investigate retail investors' preferences in renewable energy projects.

4.2.1. Stated preferences

Revealed preferences approaches are often preferred over stated preferences because they infer from known data and observed choices, rather than relying on subjective preferences, which cannot be observed. However, stated preferences can, in certain cases, support the investigation of individual preferences in markets where there is a lack of historical data (Louviere 2000). This is the case for citizen investment in distributed renewables in Ireland, which is an immature market. Furthermore, we decided to apply a stated preference approach because past behaviour cannot necessarily predict future decisions in the renewable energy sphere, because the market is highly dynamic in response to a variety of factors, including changes in incentive design, technology maturity and economies of scale (Golden 1992). A final consideration when applying a stated preference approach was that when conducting interviews with reference to past actions, survey respondents may experience difficulties to retrieve accurate details, or may have a tendency to give incorrect answers to hide "negative" behaviour.

4.2.2. ACBC

Within the broad range of stated preferences approaches, we applied a conjoint analysis, more specifically an ACBC featured by Sawtooth Software. Both choice-based conjoint analysis (CBC) and adaptive conjoint analysis (ACA) provided alternatives, however, ACBC offered a number of advantages. ACBC includes features from both CBC (e.g. entire investment opportunities are presented and compared against other investment opportunities) and ACA (e.g. it is very interactive and the survey adapts to respondent's answers) (Sawtooth Software 2014; Hauser, Ding & Gaskin 2009). While, *ceteris paribus*, an ACBC will be longer, it tends to capture more data from each respondent due to its adaptable design. It also recognises non-compensatory[20] decision-making rules (Orme 2009). These rules are derived when respondents eliminate non-acceptable options and then choose between the remaining alternatives. Furthermore, conjoint analysis has been used extensively in the general investment decision literature (Clark-Murphy & Soutar 2004; Franke et al. 2006; Shepherd, Zacharakis & Baron 2003; Shepherd 1999), as well as the renewable investment literature (Salm, Hille & Wüstenhagen 2016; Lüthi & Wüstenhagen 2012). The primary output from ACBC are derived utility values for each respondent that illustrate their relative preference for one investment attribute over another investment attribute.

4.2.3. Investment attributes and barriers

In order to set-up the components for the ACBC, consisting of attributes and their sub-levels, we proceeded to investigate major framework conditions that Irish citizens perceive as crucial to their potential engagement with distributed renewables. It is important to choose attributes and levels that are relevant to the problem being analysed. They should be credible, comprehensible and provide a meaningful context (Gamel, Menrad & Decker 2016).
To identify attributes and levels suitable to the Irish market, we began with an extensive literature review, drawing in particular from Salm *et al* (2016) and Gamel *et al* (2016). On this basis, we identified attributes and levels that were suitable for the Irish market, which we used as a basis for six semi-structured interviews with Irish experts,[21] including professional investors, community groups and government officials. On this basis, we identified the following six investment attributes that were deemed most important to Irish citizen investors: return on investment, technology, partner, minimum holding period, risk of losing investment capital and location.

In the case of return on investment, this was treated as a continuous pricing attribute with unique prices shown to respondents between 1.25% and 8.75%. Experts proposed this range to reflect the typical return on investment available in the Irish market, depending on the timing of the investment, risk profile and other investment characteristics. For each of the

[20] Where an attribute level is unacceptable and cannot be compensated by an increase in another desirable attribute level.
[21] Irish Wind Energy Association, Tipperary Energy Agency; NTR PLC; National Treasury Management Agency; Electricity Association of Ireland, and Department of Communications, Climate Action and Environment.

remaining five attributes, experts identified three levels (Table 1) to reflect investment characteristics that are typically available in the Irish market, or are likely to feature prominently in the next phase of low-carbon development. In the case of “technology”, on-shore wind is a mature technology, while solar PV and biomass-based technologies were deemed to have considerable near-term potential. In the case of “partner”, the scale and technical challenges of developing a project means that individuals will generally require a collaborator, and the three levels reflect the options deemed to be most likely. In the case of “minimum holding period”, an investment will often have a minimum period before which it can be sold for tax or other reasons, and the three options reflect options that are typically available. In the case of risk of losing investment capital, while every investment has some level of risk, we included a “no risk” option to reflect a case where project risk is fully taken on by another party (for example, a government entity through the provision of a non-recourse loan). Finally, the three levels for “location” reflect the degree of proximity of the project to the respondent’s local area.

Table 4.1 Attributes and levels

Attribute	Level
Return on investment	Between 1.25% and 8.75%
Technology	Wind on-shore
	Solar PV
	Biomass (heat and renewable gas generated from wood, manure and other organic materials)
Partner	A community group (such as a cooperative)
	A private sector project developer
	A public-sector company
Minimum holding period	2 years
	5 years
	10 years
Risk of losing investment capital	No risk (0% risk)
	Low risk (less than 10% risk)
	Moderate risk (between 10 and 25% risk)
Location	In your local area
	In the county where you live
	Anywhere in Ireland

In expert interviews, we also identified six potential barriers to investment that might be relevant to the Irish market, which survey respondents were required to rank (Table 2).

Table 4.2 Barriers

Not enough savings
Lack of experience making investment decisions
No access to loan finance
High level of risk
Lack of trusted information about renewable energy technologies
Opposition to renewable energy projects in my community

4.2.4. Survey structure

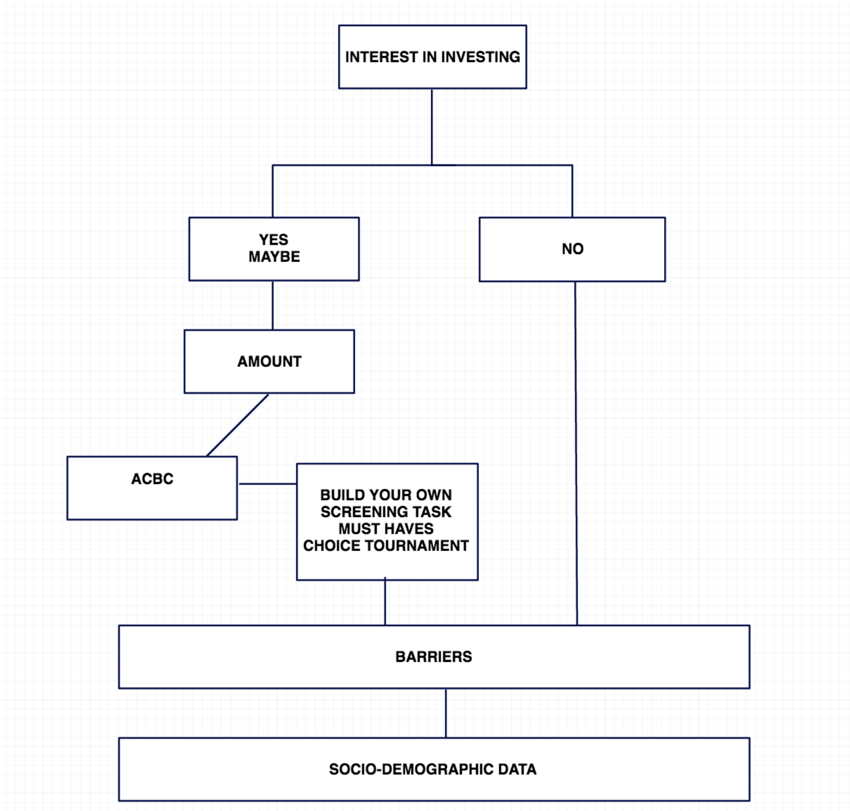
Given our objective was to assess the general appetite for investment among Irish citizens, as well as barriers to investment, it was necessary to situate the ACBC component within a broader questionnaire. The survey was therefore structured as follows: all respondents were asked if they were interested in investing in renewables “if their ideal investment criteria were met”. If they answered “yes” or “maybe” they were asked how much they would be willing to invest, and were then directed to the ACBC section.

The choice experiment itself was made up of four parts as follows:

1. “Build your own” (BYO): where respondents could select their ideal investment opportunity by choosing from one of the attribute levels in each attribute (this section excluded return on investment and risk, as respondents are expected to prefer high returns and low risk).
2. Screening task: where respondents evaluated four investment options at the same time, with different attributes, and were required to indicate if they were suitable or not. Respondents were offered 24 choices in total (6 windows), in which the options presented revolved around the BYO with one or two variations each time.
3. “Must haves” and “unacceptables”: where respondents were asked if a particular attribute levels were “must have” or “unacceptable”, based on previous response patterns.
4. “Choice tournament”: respondents were asked to choose between one of three competing investment options. This part of the survey was focused on exploring the remaining differences in the investment opportunities that had been identified, allowing for a better estimation of zero-centered utilities for the attribute levels of lower-tier important attributes.

Finally, all respondents (whether interested in investing or not) were directed to a barriers question, and were asked to provide basic socio-demographic information. The structure of the survey is given in Figure 1.

Figure 4.1 Structure of Survey



4.2.4. Data

Cint,[22] an international market research company that specialises in online consumer surveys, was recruited to provide a panel to complete the survey. [23] Cint has a panel book of over 58,000 Irish panellists. We requested them to fill a quota of 1,000 respondents to complete the full survey, representative of the Irish population by age and gender. A screening question was used to identify those with an interest in investing, and this group completed the choice experiment. After conducting a pilot survey to ensure respondents understood the choice cards, the survey was administered via email, incrementally inviting respondents until 1,000 had completed the choice experiment.

To fill this quota, 1,680 Irish adults partly or fully completed the survey. Of those, 400 only partially completed the survey, leaving n=1,280 completed surveys. Of these respondents, Table 3 gives a breakdown of responses to the screening question concerning willingness to invest. Only those who answered "yes" or "maybe" undertook the full choice experiment and "no"-respondents were directed to the barriers section (see Appendix for further details).

[22] https://www.cint.com/
[23] Undertaken between January 23 and February 7, 2017.

Table 4.3 Summary of responses

Willingness to invest	Number	%	Choice experiment	Barriers	Socio-demographic
Yes	515	40	Yes	Yes	Yes
Maybe	485	38	Yes	Yes	Yes
No	280	22	No	Yes	Yes
Dropped out	400				
Total	1,680				

4.3. Results

4.3.1. Interest in investing

The first research objective was to identify if Irish citizens demonstrated an interest in investing in distributed renewable technologies. 78% of respondents (n=1000) demonstrated some interest in investing (we describe these as the willing to invest cohort), of whom 40% responding "yes" and 38% responded "maybe" (Table 3). The remaining 22% (n=280), whom we describe as the not willing to invest cohort, responded "no".

Willingness to invest was associated with certain characteristics (Appendix). For example, household income was somewhat higher in the willing to invest cohort. While 65% (n=832) of households with income under €25,000 indicated a willingness to invest, this was a lower proportion than among wealthier households. Another difference is that the willing to invest cohort was significantly more likely to have some investment experience (nearly half having "some" or "a lot" of investment experience). By comparison 86% (n=241) of the not willing to invest cohort had no investment experience. Older males also appear somewhat overrepresented in the willing to invest cohort.

To test the statistical significance of these associations, we undertook Chi squared tests. As can be seen (Table 4), all citizen characteristics apart from "location" show a statistically significant association with willingness to invest at the two-sided 95% confidence intervals. To test the strength of associations we determined Cramer's V in each case, interpreting results with a qualitative scale (Rea and Parker 1992).

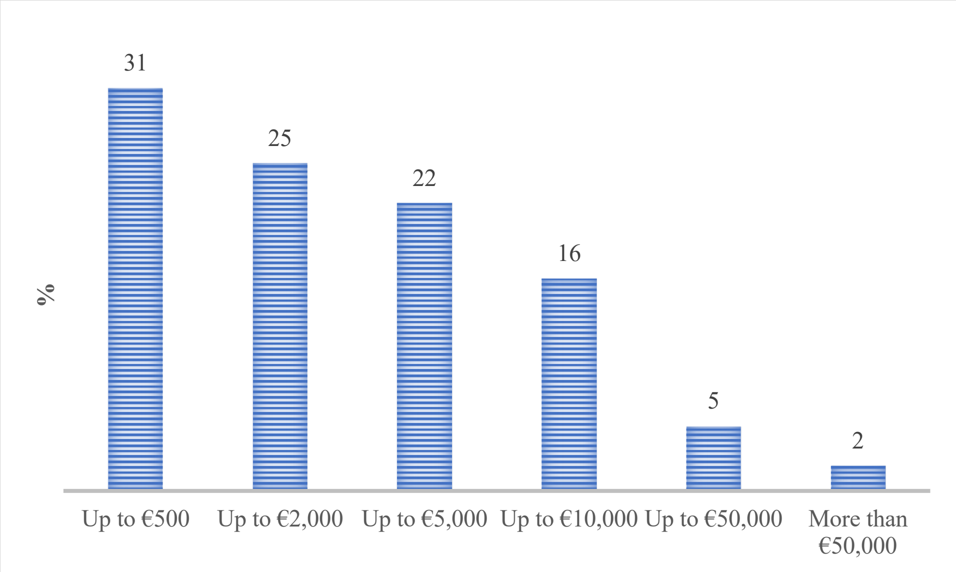
Household income and investment experience showed moderately strong associations with willingness to invest: as income and experience increased, so did willingness to invest. Age showed only a weak association, with older respondents slightly more likely to invest. We had anticipated that those living within close proximity to an existing renewable project might be less likely to consider investing. Our results show, however, that those closer to an existing wind energy development were slightly more likely to considering investing. This aligns with research which suggests that public objections to renewable energy projects may soften as the project progresses (Eltham, Harrison, and Allen 2008). There was a negligible association between willingness to invest and gender or location (whether a respondent lived in a city, town or rural area).

Table 4.4 Chi Squared and Cramer's V statistics ranked according to effect strength

	Pearson's Chi (X^2)	DF	Asymptotic Significance (2-sided)	Cramer's V	Interpretation
Income	108.00	5	0.00	0.29	Moderate association
Investment Experience	94.90	2	0.00	0.27	Moderate association
Age	17.30	4	0.00	0.12	Weak association
Proximity	14.4	2	0.00	0.11	Weak association
Gender	4.90	1	0.03	0.06	Negligible association
Location	1.30	2	0.52	0.03	Negligible association

The willing to invest cohort were asked how much they might be willing to invest. As can be seen in Figure 2, smaller investment amounts were more popular, with 31% (n=305) indicating that they would be willing to invest up to €500, while only 7% (n=68) would consider investment amounts of "up to €50,000" or "more than €50,000". On the other hand, 45% were willing to invest "up to €5,000".

Figure 0.2 Investment amount (% of willing to invest cohort)



In order to explore the effect size of household income on investment amount, we looked at the Spearman rank-order correlation coefficient statistic, which is a nonparametric measure of the strength and direction of association that exists between two variables measured on an ordinal scale (Rea & Parker 1992; Göktas & Isçi 2011). We found a statistically significant association ($p < .000$) between the investment amount and household income, with a moderate positive effect size (.344), meaning that households with higher income are likely to consider increased investment amounts (see appendix).

4.3.2. Investment characteristics

Focusing on the "willing to invest" cohort, we measured the importance of each investment attribute for citizen investors' choices. Importance scores are calculated by examining how much each attribute of the investment contributes to the overall utility of an investment option. They are standardized to sum to 100 for across all attributes (Orme 2010b).
The mean importance values given in the Table 5 illustrate that financial characteristics such as return on investment, risk of losing investment and minimum holding period are very important considerations for Irish citizen investors. Standard deviations are relatively high in all cases, suggesting considerable heterogeneity in the sample.

Table 4.5 Average importances of different investment attributes

	Average Importances	Standard Deviation
Return on investment	26.1	15.2

Risk of losing investment	20.8	13.0
Minimum holding period	19.4	11.1
Renewable technology	16.9	11.9
Project partner	10.7	7.6
Location	6.2	4.2

We proceeded to estimating part-worth utilities of attribute levels using a hierarchical Bayes (HB) model. This model is called "hierarchical" because it has two levels. At the higher level, it assumes that individuals' parameters (part worths or betas) are described by a multivariate normal distribution. At the lower level it assumes that, given an individual's betas, his/her probabilities of achieving some outcome (choosing an attribute in this case) is governed by a particular model, such as multinomial logit or linear regression. Initial crude estimates of betas are estimated for each respondent to use as a starting point. New estimates are then updated using an iterative process and in each iteration an estimate is made for each parameter, conditional on current estimates of the others. In other words, the HB algorithm produces betas that fit each individual's outcome reasonably well, but "borrows" information from other respondents to stabilize the estimates (Orme 2010a) .

The HB model fits well because it complements missing individual data by data from the overall group, and conjoint analysis is a prime example of an application that benefits from HB estimation (Orme 2007). For this reason, it has become increasingly prominent in market research over the past decade (Allenby, Bakken & Rossi 2004).

The part worth utility reflects the relative desirability of an attribute level compared to other levels within the same attribute. Within the attribute "minimum holding period", for example, it indicates the desirability of investments with a 2, 5 or 10 year holding period. The higher a utility, the more positively the specific attribute level influences decision-makers to opt for a certain investment (Tabi, Hille & Wüstenhagen 2014). They are zero-centred, meaning the values for each attribute sum to zero.

Table 6 presents the average utilities for the different attributes along with the standard deviations and with 95% confidence intervals (this gives a range of values designed to include the true value of the parameter with a minimum 95% probability). As can be seen, investors have a strong preference for high return, low-risk projects and investments with shorter holding periods. This is quite an intuitive finding. To a lesser degree, citizen investors prefer solar PV to wind projects, and both are preferred to biomass. It is not clear why investors expressed a preference for solar PV, as all technology options were presented on a like-for-like basis. It may be that individuals are more familiar with solar panels generally and may be pre-disposed to investing in a technology they are familiar with, or it may be that opposition to wind technology negatively affects their preferences (see discussion). The location of the project and potential project partners are less important, although citizens demonstrate a slight preference for community-led projects that are not located in their local area. Standard deviations are again relatively high, suggesting considerable heterogeneity in the sample.

Table 4.6 Zero-centred utilities and standard deviations at 95% interval of the posterior distribution (hierarchical Bayes model with normally distributed utilities)

Attribute	Attribute level	Average Utilities	Standard Deviation	95% interval of posterior distribution
Price	PRICE: 1.25	-68.9	58.8	-72.5 : -65.3
	PRICE: 8.75	68.9	58.8	65.3 : 72.5
Technology	Solar electricity	26.6	48.4	23.2 : 29.2
	Wind on-shore	-2.6	49.5	-5.7 : 0.5
	Biomass (wood and other organic material)	-24.0	49.8	-27.1 : -20.9
Partner	Private sector project developer	-4.4	34.2	-6.5 : -2.3
	Public sector company	1.6	29.2	-.2 : 3.4
	Community group	2.8	37.1	0.5 : 5.1
Location	In your local area	-0.6	20.3	-1.9 : 0.7
	In your county	-1.7	16.2	-2.7 : -0.7
	In Ireland	2.3	20.6	1: 3.6
Minimum holding period	2 years	31.6	49.1	28.6 : 34.6
	5 years	18.9	28.5	17.1 : 20.7
	10 years	-50.5	51.1	-53.6 : -47.4
Risk	No risk	45.6	43.9	42.9 : 48.3
	Low risk	13.3	24.2	11.8 : 14.8
	Moderate risk	-58.9	59.0	-62.6 : -55.2

These findings are reflected in the number of respondents who found a particular investment attribute unacceptable. Few respondents (under 5% in all cases) found a technology, project location or project partner attribute unacceptable, whereas over 13.7% (n=137) of respondents found investments with moderate levels of risk unacceptable and 13.1% (n=131) found a minimum holding period of 10 years to be "unacceptable" (Table 7).[24]

Table 4.7 Number of respondents who found a particular investment attribute unacceptable (% of "willing to invest cohort")

	%
Renewable technology	
Solar PV	1.8
Wind on-shore	3.9
Biomass (wood and other organic material)	4.7
Project Partner	
Private sector project developer	2.5
Public sector company	1.8
Community group	2.1
Location	
In your local area	1.9
In your county	1.3
In Ireland	2.0
Minimum holding period	
2 years	1.4
5 years	1.2
10 years	13.1
Risk of losing investment	
No risk	1.1
Low risk	1.4
Moderate risk	13.7

An intuitive way of exploring the risk-return preferences of citizen investors is by exploring how much they would need to be compensated in percentage return on investment (ROI) terms, to accept an alternative attribute level (say wind in the attribute "technology") to their preferred level (solar PV) of this attribute.

The average part worth utilities serve as a basis for calculating the marginal willingness to accept (WTA) a switch between different attribute levels. It is calculated by subtracting the part worth score (u) of a particular attribute level (j) from the maximum part-worth utility (uij_{max}) of the same attribute (i). This score is multiplied by the price (p) of one utility unit, which is derived from the highest return (p_{max}) less the lowest return (p_{min}) (8.75-1.25%)

[24] The number shown represents the % of respondents who considered the attribute to be unacceptable.

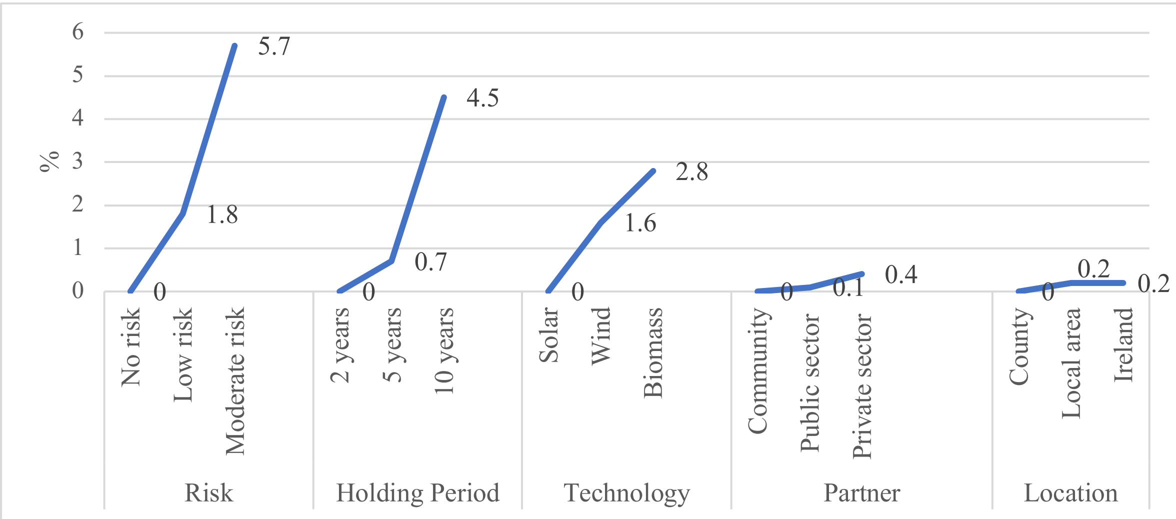
divided by the difference in their part-worth utilities ($u\ pj_{max}$ - $u\ pj_{min}$) (- 68.9 less 68.9). This formula is given in below (Figure 3).

Figure 4.3 Formula for willingness to pay

$$WTA(u_{ij}) = \left(u_{ij_{\max}} - u_{ij}\right) * \frac{p_{\max} - p_{\min}}{u_{pj_{\max}} - u_{pj_{\min}}}$$

We find that citizens require a very high level of annual compensation (5.7%) for moderately risky investments over investments with no risk, suggesting that they are highly risk averse. For investments with a 10-year minimum holding period, an annual risk premium of 4.5% is required compared to investment with a 2-year minimum holding period, which suggests that citizens are uncomfortable with long term investments. Citizens require an additional annual return of 1.6% if they are to invest in wind (compared to solar PV), and 2.8% ROI premium for biomass compared to solar PV (Figure 4), which suggests that PV is quite strongly favoured. However, the results with respect to "partner" and "location" suggest that citizens are relatively agnostic between these attribute levels.

Figure 4.4 Willingness to accept changes in preferred investment attribute for return on investment premium (%)



It is noteworthy that the standard deviations of the part-worth utilities were relatively high (Table 6). This points to considerable heterogeneity within the willingness to invest cohort. It is useful, therefore, to explore the extent to which typical types of investors within the overall "willing to invest" cohort can be identified. To do so we used respondents' individual utilities to identify segments within the willing to invest cohort.

This analysis was conducted with the Convergent Cluster & Ensemble Analysis (CCEA) module offered by Sawtooth. CCEA groups respondents based on their individual part-worth utilities for all attributes levels, starting with the "k-means" method, but also using density-based, distance-based and hierarchical solutions as inputs. CCAE therefore employs several different forms of cluster analysis. To determine a finding's reproducibility, each replication is compared with previous replications (Orme & Johnson 2008).

We chose a two-segment solution in our simulation with a 99% replicability level. We describe the first segment, which accounted for 63% (n=632) of the willing to invest cohort, as "risk-averse" (Table 8). The most important consideration for this group is avoiding even moderately risky investment options. They also prefer shorter investment periods, which could also be interpreted as a low appetite for riskier longer-term investment options. Finally, they are slightly more motivated by investing with community groups and public companies than their more yield-orientated compatriots. We describe the second segment, who accounted for the remaining 37% (n=368) of willing to invest cohort, as "pure yield". This group is primarily motivated by gaining a high return on investment and is somewhat more willing to consider riskier investment options, as long as they are compensated with a higher ROI (Table 8).

Table 4.8 Mean Attribute Level Per Segment

Group	Risk-Averse	Pure Yield
PRICE: 1.25	-55.74	-91.52
PRICE: 8.75	55.74	91.52
Solar PV	25.15	29.16
Wind on-shore	-1.91	-3.78
Biomass	-23.24	-25.39
Private sector project	-5.43	-2.76
Public sector company	2.54	0.01
Community group	2.89	2.75
In your local area	-1.44	0.72
In your county	-0.77	-3.28
In Ireland	2.21	2.56
2 years	42.32	13.13
5 years	17.27	21.66
10 years	-59.59	-34.79
No risk	54.82	29.67

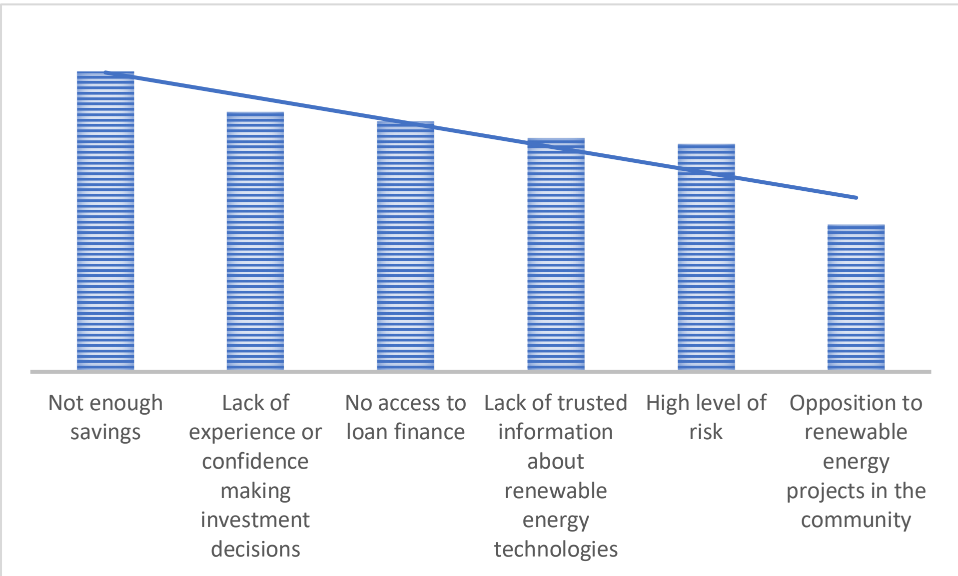
Low risk	17.66	5.93
Moderate risk	-72.48	-35.6
NONE	44.46	-131.71
Group Size	632	368

4.3.3. Barriers

We asked respondents, both the cohorts who were willing to invest and those who were not willing to invest, to rank the importance of key barriers that would prevent them from investing in renewable energy projects. To interpret results, we ascribed a value of between one (lowest ranked) and six (highest ranked) to each barrier. The relative importance of the barrier within each cohort is therefore important in interpreting results, not the absolute values.

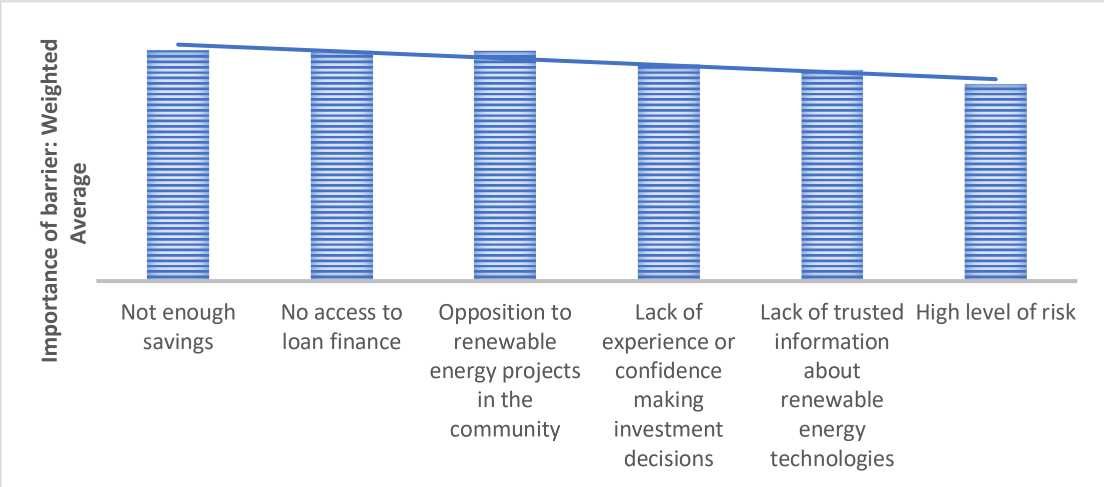
For those who were not willing to invest, the financial factors (insufficient savings and access to loan finance) were important, but a lack of confidence or experience making investment decisions was what differentiated this cohort from the willing to invest cohort (Figure 5).

Figure 4.5 Importance of barriers for not "willing to invest" cohort (weighted average of 280 responses)



Financial considerations, specifically, not enough savings and no access to loan finance were ranked as the most important barriers for the willing to invest cohort. However, opposition to renewable energy in the community was ranked considerably higher for this cohort, while lack of experience making investment decisions and risk were less important considerations (Figure 6).

Figure 4.6 Importance of barriers for "willing to invest" cohort (weighted average of 1,000 responses normalised)



4.4. Discussion

In this section, we consider our results within the context of our three research questions: are Irish citizens interested in investing in distributed renewable technologies; what investment characteristics and barriers are important to them; and what are the implications for the design of financial incentives?

4.4.1. Interest in investing and barriers

The findings of this survey indicate that there is a high level of latent interest in investing in renewable energies among Irish citizens. This suggest that trends in citizen investment evident (in Germany and Denmark, for example) could be replicated in countries such as Ireland, given the availability of appealing investment options.

Within the willing to invest cohort, over two thirds of respondents would be willing to invest "up to €2,000", with 45% willing to invest "up to €5,000". We found a moderately strong association between higher household income and investment amount, as well as a lower willingness to invest in households with lower income. In interpreting this result, it is important, therefore, to be cognisant of the fact that our sample was somewhat skewed towards lower income households. As can be seen (appendix) approximately 37% of our sample had a gross household income of €50,000 or above (44% of the willing to invest cohort), whereas 50% of Irish households have a gross annual household income of above

€50,522 (CSO 2017) (appendix). Nevertheless, for some households, unwillingness to invest reflects inability, as is clear from the high priority given to "not enough savings" as a barrier. To put the preferred investment amount in context, capital investment requirements for a typical windfarm development are in the region of €1.6 - €2million /MW (SEAI 2016b). This implies a capital investment requirement at least €6.4 million for a 4MW wind farm (the size of Templederry, the only community-owned wind farm in Ireland). and in the case of a 10 MW wind farm, the capital investment requirement would be at least €16 million. In both cases 75% would typically be financed with debt at financial close. Hence the equity requirement would be at least €1.6 million for a 4 MW - wind farm or €4 million in the case of the 10MW farm. With 200 community investors[25] the equity requirement would therefore be €8,000 (4MW) to €20,000 (10MW) for each investor in these examples.

It is also important to note that early stage development costs are estimated to be 8.6% of total engineering, procurement and construction costs (Mott MacDonald 2010). This would be at least €6,880 each on average for a 10 MW wind farm and €2,672 on average for a 4 MW wind farm (with 200 local investors). This must all be invested pre-financial close, and is therefore at risk before it is clear if the project is viable.

The vast majority of wind farms under operation or planned far exceed the 4 MW threshold. Our findings therefore suggest that partnership models between private developers and citizen investors are the most likely option for wind farm development, rather than fully community-owned projects. This is particular within the context of the longer timelines and technical challenges often faced by community-led projects (McDonnell 2014; Songsore & Buzzelli 2014). These findings align with an analysis which sought to inform Irish Government policy, which found that offering investment options to the community in developer-led projects could be less complex to implement (Ricardo Energy and Environment 2017). However, smaller wind farms such as Templederry could potentially be developed by community groups. Other options include seeking to attract a higher number of investors (than 200), or seeking participation from citizen investors interested in making a higher than average investment (more than €5,000).

[25] We use 200 community investors for illustrative purposes because this is the number of investors in Templederry wind farm. We acknowledge, however, that a greater number of investors might be attracted.

Solar PV is anticipated to become an important technology in the next phase of renewable deployment in Ireland (DCCAE, 2015), subject to the introduction of a support scheme which is currently under consideration. Based on interviews and available data (DCCAE 2017) we estimate an investment cost ranging from €1 – 1.75 million/MW (for large scale and domestic roof mounted respectively), of which 75% would be provided by debt. It is worth noting that although capital costs for PV are lower than those for wind power, the capacity factor for Solar PV in Ireland is in the region of 11% compared to approximately 30% for wind. Assuming 200 community investors, the equity stake would be up to €8,750 on average for a 4MW Solar PV project.

Given these investment requirements, medium to large solar farms of 10MW or greater would be more likely to be developer-led with citizen investment. The average size of a ground-mounted solar PV project in Europe, however, is approximately of 3MW (Statistica 2018), and small to medium scale projects proliferate in many countries such as Germany, Italy and the UK (IEA-REDT 2016; Castello & De Lillo 2013; CEBR 2014). Small to medium-scale solar farms could therefore offer the greatest potential for community-owned projects in Ireland, particularly given the opposition in some communities to wind projects. Our results suggest that the absence of a sufficient return on investment and access to capital are the biggest obstacles for many citizens: both for those who are willing to consider investing and for those who are not. This finding is reinforced by the fact that the willing to invest cohort was wealthier on average that the not willing to invest cohort. The social equity considerations of subsidising community and citizen investment therefore require careful consideration in policy design (Section 5.3).

The lack of business experience and financial strength of citizen investors identified in previous studies (Bergek, Mignon, and Sundberg 2013) is also supported by our results. This finding was reinforced by the moderately strong association between investment experience and willingness to invest, which was also noted.

4.4.2. Investment characteristics

Irish citizen investors are primarily concerned with the financial characteristics of investments. We find that the majority of citizen investors are highly risk averse, and do not like investments with long minimum holding periods. Our findings support studies that identify citizen investors as highly risk averse (Hyland & Bertsch 2018a; Gamel, Menrad, &

Decker 2017). However, from our cluster analysis, we find that there is a segment of investors who are primarily motivated by higher yields, and who have an appetite for a moderate level of risk.

This suggests that a majority of citizen investors would prefer to be involved with projects after financial close, when they have been substantially de-risked. This finding again underlines the potential role for partnership and joint venture approaches between local citizens and private developers. For example, private developers could grant preference shares at the very early stages of project development to local citizens. This would allow the local community to be part of the development without putting any capital at risk. Once the project is operational, the preference shareholders will receive dividends (subject to covenants of senior lenders). On the other hand, the "pure yield" investors may be willing to take on greater risk and may wish to have greater control over projects. These partnership models, it should be noted, have been subject to significant challenges in practice, and the importance of building relations of trust between actors has been identified in previous research (Goedkoop & Devine-Wright 2016).

Solar PV projects were more attractive to citizen investors compared to wind and biomass projects. These projects tend to have lower up-front investment costs and are generally smaller in scale compared to wind projects. For these reasons, countries such as Germany have found it easier to mobilise citizen and community investment in solar PV compared to wind, particular when it comes to fully community-owned projects (McInerney & Curtin 2017). Wind projects have also tended to illicitly greater levels of local opposition for a variety of factors, which may undermine the attractiveness of this technology for some citizens (Cashmore et al. 2018). Solar PV will likely be a central technology in many countries' decarbonisation pathways over the coming decades (IEA 2018), and our findings underline the key potential role citizens could play as investors in this technology, in Ireland and elsewhere.

Irish citizens are relatively agnostic when it comes to potential partners and location of the projects, and did not indicate a preference for local projects, for example. We do not therefore detect a strong "NIMBY" effect in our results, although it is worth pointing out that the "risk averse" cluster (Table 8) assigns the lowest part-worth utility to "in your local area". Our results suggest that citizens very marginally prefer partnerships with community groups over energy utilities, with both options slightly preferred to partnerships with private developers.

Some studies emphasize the importance of context-specific factors in explaining high levels of investment from citizens in countries such as Germany (Dewald & Truffer 2011; Romero-Rubio & de Andrés Díaz 2015). Similarly, Hyland & Bertsch (2018), cautioned policy-makers against assuming that findings from other countries can universally be applied. However, our finding point to the similarities in motivation between citizens across borders. The investment attributes that are attractive to Irish citizen investors (high return, low risk and a preference for small investment amounts) are similar to these identified in surveys of German (Salm, Hille & Wüstenhagen 2016; Gamel, Menrad & Decker 2016) and Austrian (Fleiß et al. 2017) citizens. However, "partner" was a relatively more important investment attribute for German citizens, who preferred community groups more strongly.
Perhaps the difference can be explained by the fact that our study includes a mechanism for exploring the risk-return trade-off facing citizens, whereas in Hyland and Bertsch (2018) no reward is offered for accepting a higher level of risk. It is perhaps inevitable that citizens would favour models with lower levels of risk when no reward for higher risk taking is offered.

4.4.3. Design of incentives

From a policy perspective, the high risk-aversion of citizen investors, and the importance of financial factors (no savings or low access to debt finance) as barriers, suggest that there might be a role for Government in managing risk and ensuring access to capital, particularly at the early riskier stage of project development.

Non-recourse loans, soft loans, and grants have all been introduced to address barriers to local citizens at early (feasibility and development) project stages in countries such as the UK, Denmark, Germany and Canada (McInerney & Curtin 2017). In Germany, for example, the widespread availability of soft loans covering development and construction costs has been identified as a key success factor (Yildiz 2014; Strupeit & Palm 2016; IEA-RETD 2016).

The high-risk aversion of citizen investors implies that market supports providing a guaranteed level of return might be more appropriate to mobilize this cohort. While previous research indicates that it is the design of incentives rather than their choice per se which is most important (Curtin, McInerney & Ó Gallachóir 2017a; Huber et al. 2007), our findings suggest that FiTs might be more attractive to citizen investors compared to other more market-based instruments (FiPs and quota-based schemes) because of the greater certainty they provide for citizen investors. These might be considered for projects of a smaller scale (say under 5 or 10MW). More market-orientated supports for larger projects (FiPs or quota-based schemes) can also be designed in a manner that incentivizes equity participation from citizen investors. For example, auctions can be designed with set-asides for community actors or with a points systems which favours citizen participation (Curtin, McInerney & Ó Gallachóir 2017b; Curtin, McInerney & Johannsdottir 2018). Higher levels of subsidy, however, could result in higher electricity costs.

For the cohort of "pure yield" investors identified in our segmentation analysis, increasing the ROI of investment opportunities is the main option for galvanizing their participation. The tax treatment of profits, and tax breaks for income from shares in community or other forms of community projects, might be highly effective in mobilising these actors.
Within the context of providing financial supports, the socio-economic distinction between the willing to invest and the not willing to invest cohorts needs to be considered. The latter tend to be poorer households. Policy must be designed to ensure that poor households are not cross subsidising wealthier households, i.e. to avoid a situation where those who do not have the ability to invest face higher electricity prices via the recovery of a subsidy through increased electricity charges. It is also important that investment is open to lower-income households and approaches to lowering barriers to entry (by ensuring access to low-cost capital, for example) might therefore be considered.

For those willing to invest less than €2,000 (55% of the willing to invest cohort), these amounts may not make a significant material contribution from a project finance perspective, and projects with smaller-scale investment amounts will be developer-led. Mobilising smaller-scale investors, however, can help build buy-in, understanding and societal support for low carbon transition. Options to mobilise these investors might therefore be explored, such as a Government-supported crowdfunding platforms that could aggregate very small capital offerings into investable amounts.

Finally, lack of experience making investment decisions emerges as an important barrier to investment. This is a challenging to overcome, but it could be addressed by providing independent and trusted advice on the technologies themselves, and on the technical, financial and legal aspects of making investment decisions.

4.5. Limitations and conclusion

Citizen investment in renewable energies can help build social support for low-carbon transition and can mobilise a new pool of capital for low carbon investment. In this study, we surveyed Irish citizens in order to understand their potential interest in investing in distributed low-carbon technologies. We explored their risk-return trade-offs and other investment attributes that are important for potential citizen investors, as well as the key barriers to investment, with a view to drawing implications for the design of financial incentives.

This study is limited by a number of factors. We depend on stated rather than revealed preferences of respondents. However, by providing engaging, realistic and real-time investment choices to respondents, we attempted to minimize social desirability bias. We also use a relatively large sample of potential investors. Nevertheless, we do not interpret these findings to suggest that all potential investors would act on their stated preferences immediately, even if an investment in which their "ideal investment criteria" became available. Further research might explore the attractiveness of renewable investment opportunities compared to alternatives, such as equities, bonds, pensions etc.

While we made efforts to ensure representativeness, our sample was somewhat skewed towards lower income households, and this needs to be considered when interpreting findings. For example, we found that investment amounts were relatively small compared to the requirements for many renewable energy projects, but that wealthier households were willing to consider higher amounts. A final limiting factor is the number of dropouts (n=400). One might speculate that these participant were less interested in the subject matter, and therefore less interested in investing. For this reason the very high numbers that were willing to consider investing (78%) might be interpreted with some caution. Finally, we did not explore the issue of whether investors' motivations are primarily economic or hedonic, a subject that has been the focus of previous research.

Notwithstanding these limitations, our findings illustrate that, despite the lack of tradition in investing in renewables, and the absence of exemplar pilot projects and models, there is an interest in investing in distributed renewables from a majority of citizens surveyed. However, our findings also suggest that the level of investment capital that might be forthcoming is low relative to the equity requirement for a typical wind farm.

The key barriers to investment relate to high risk aversion, lack of access to investment capital, but also a lack of confidence in making investment decisions. This underscores the importance of addressing barriers at the riskier early stage of project development, and of ensuring that low-cost investment capital, as well as trusted information and advice, is accessible to citizen investors. It also highlights the ongoing requirement for education and communication with citizens on renewable energy policy objectives.

The design of appropriate incentives that maximise cost-effectiveness depends on understanding these citizen investor preferences, and in particular their unique risk-return trade-off. On the one hand greater levels of subsidy may be required to mobilise citizens compared to professional investors. On the other hand local citizens often provide their time on a voluntary basis (Rijpens 2013; IEA-RETD 2016), and their involvement has been found to open up access to the optimal sites, thereby reducing project cost (Nelson et al. 2016). The net impact of these factors will determine the impact on overall electricity costs, and is a possible area for further research.

Finally, our findings contribute to the literature on exploring the extent to which "rational" economic behaviour explains low carbon technology investment decisions. Our conclusions support previous research (Dóci & Vasileiadou 2015; Gamel, Menrad & Decker 2016; Fleiß et al. 2017) which found that "personal gain" was the primary motivating factor behind citizen investment, but that secondary motivations were also present.

While this study focused on Ireland, the findings are relevant for the many other countries that are seeking to promote participation from citizens and community groups in the transition to a low carbon economy.

Appendix

Table 4.9 Socio-demographics characteristics

		Willing to invest		Total	% of Total
		Yes	No		
		1,000	280	1,280	
Gender	Male	453	106	559	44
	Female	547	174	721	56
Age	Under 21	43	22	65	5
	21-35	320	92	412	32
	36-50	351	86	437	34
	51-65	229	50	279	22
	More than 65	57	30	87	7
Income	Under 25,000	283	152	435	34
	25,000-50,000	279	91	370	29
	50,000-75,000	246	24	270	21
	75,000-100,000	124	0	124	10
	100,000-150,000	47	9	56	4
	More than 150,000	21	4	25	2
Location	A city	395	102	497	39
	A town	306	95	401	31
	A rural area	299	83	382	30
Experience	A lot	71	4	75	6
	Some	389	35	424	33
	No	540	241	781	61
Proximity	Very close	80	16	96	8
	Close	215	35	250	20
	Not close	705	229	934	73
Investment Amount	Up to 500	305	N/A	305	24
	Up to 2,000	248	N/A	248	19
	Up to 5,000	218	N/A	218	17
	Up to 10,000	161	N/A	161	13

	Up to 50,000	49	N/A	49	4
	More than 50,000	19	N/A	19	1

Table 4.10 Average gross household Irish income by gross income deciles (2015)

Decile	€
1st decile	10,271.04
2nd decile	17,039.36
3rd decile	24,636.04
4th decile	3,2190.6
5th decile	40,820.52
6th decile	50,522.16
7th decile	62,028.20
8th decile	75,999.56
9th decile	97,093.88
10th decile	159,996.72

Source: CSO (2017)

Table 4.11 ***Spearman's Rank-Order Correlation***

		Investment amount	Household income
Investment amount	Correlation Coefficient	1.000	.344**
	Sig. (2-tailed)		0.000
	N	1000	1000
Household income	Correlation Coefficient	.344**	1.000
	Sig. (2-tailed)	0.000	
	N	1,000	1,280

Chapter 5: A risky business? Attitudes amongst Irish investors in the power and finance sectors to risks of stranded assets arising from climate change mitigation

5.1. Introduction

Meeting internationally-agreed climate targets would require an estimated $3.5 trillion in energy-sector investments each year until 2050 (Covington, 2017; IEA, 2018), about double the current level of investment. Approaches to mobilising greater levels of capital investment in green assets has therefore garnered considerable analytical attention (Hall et al, 2017; OECD, 2017).

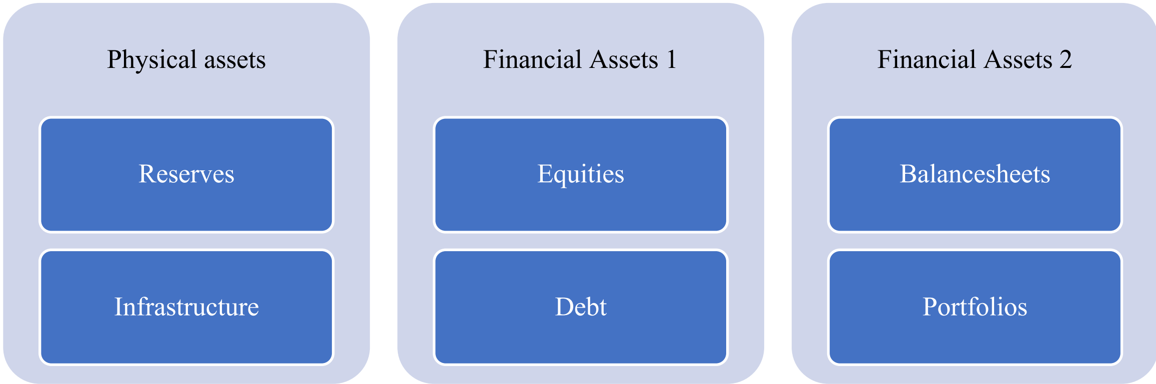
Within the finance literature, the ‘asset pricing’ branch takes the perspective of traders, and explores, *inter alia,* the extent to which investors correctly price risk into asset values. Modern Portfolio Theory, for example, suggests that the risk and return characteristics of specific technologies should be evaluated in terms of how the investment affects the risk and return of the entire portfolio (Markowitz, 1952), and the Capital Asset Pricing Model holds that investors hold well-diversified investment portfolios (Barber & Odean, 2013) or energy generation portfolios (Bazilian & Roque, 2008), consisting of the market portfolio and risk-free investments.

Within the energy sector, it is therefore widely held that investors—whether electric utilities, insurance companies, pension funds, or even retail investors—compare opportunities, and choose to buy and sell assets, according to perceived risk-adjusted returns (Wüstenhagen & Menichetti, 2012). High risk perception feeds into the cost of capital, which in turn is a central determinant of the pace that relevant technologies are deployed in the marketplace (Dinica, 2006; Barber, Huang & Odean 2016).

A particularly important risk that has come to the fore is that fossil fuel reserves and associated assets could face “stranding” in a carbon-constrained world. Stranded assets have been defined as *‘assets that have suffered from unanticipated or premature write-downs, devaluations, or conversion to liabilities’* from climate change (Caldecott, 2014, p 7). Numerous studies have found that rapid transition to a low carbon economy would render a portion of known fossil fuel ‘unburnable’ (Caldecott, 2017; Economist, 2013b; Griffin et al., 2015; Leaton, James; Ranger, Nicola; Ward, Bob; Sussams, Luke; Brown, 2013; McGlade, 2013; Vergragt et al., 2011). The primary focus of this literature has been on evaluating stranding risk at one point in the investment chain (Figure 5.1) (Chenet et al., 2015)—for physical assets. This includes known reserves of coal, oil and gas (CTI, 2011, 2013, 2015a; McGlade & Ekins 2015; Linquiti

& Cogswell 2016; Newell, Qian & Raimi 2016), but also power generation assets that are dependent on these reserves (Green & Newman 2017; Pfeiffer et al., 2016).

Figure 5.1 Stranded assets across the investment chain



Source: Adapted from (Chenet et al., 2015) & (WRI/UNEP 2012)

A secondary focus of this literature has been on evaluating stranding risk exposure for financial assets. This includes assessing the implications of stranding risk for the shares of fossil fuel companies (CTI, 2017, 2014, 2015b; HSBC, 2013; Heede & Oreskes, 2016; Byrd & Cooperman, 2018), for the quality of the debt issued by companies and countries exposed to stranding risk (Comerford & Spiganti 2015; Malova and van der Ploeg 2017; Global Footprint Network 2016; Mercer 2015), or for investment portfolios (Mercer 2015; Credit Suisse 2015; BlackRock 2016; Haslam et al., 2018) and the balance sheets of financial institutions (Weber, Fenchel & Scholz Roland 2006; Asset Owners Disclosure Project 2017). However, a common factor is that these studies focus at singular point in the investment chain, and there few studies which compare and contrast stranding risk for physical compared to financial assets.

Central to the question of stranding risk is the extent to which climate risks are fully appreciated by actors across the investment chain, and correctly priced. While the literature on investor perception of stranding risk is very limited considering its empirical importance, there have been some studies that indicate that financial and energy sector actors are unaware of stranding risk (Thomä & Chenet 2017; Harnett 2017; Silver 2017; Divestinvest 2018; Asset Owners Disclosure Project 2017), or that information asymmetries could affect perceptions of stranding risk for owners of physical assets compared to owners of financial assets (Global Investor Coalition on Climate Change 2013). One concern is that owners of financial assets may have less information on climate risks due to the absence of reported information (Task Force on

Climate-related Financial Disclosures, 2017). This, in turn, could have implications for systemic stability (Partington, 2018). Again, however, this literature which looks across the investment chain and compares perceptions of owners and managers of physical compared to financial assets is sparse, especially considering its empirical importance. In fact, the risk perception of market participants in the energy and financial sectors within the context of energy transition has been left "almost unaddressed" until recent times (West, 2019).

Within this context, the objective of this study is to measure, compare and contrast perspectives on stranding risk from climate change across the Irish investment chain; and to compare methods used to value and manage stranding risk, and barriers faced. We proceed as follows: Section 2 introduces the research framework and the methodology used in the study; Section 3 presents an overview of the data; Section 4 discusses the results; in Section 5, the implications of these results are assessed within the context of the research questions. Section 6 sets out conclusions and policy recommendations and identifies areas for future research.

5.2. Material and Methods

Ireland is an interesting case because it has a well-developed green investment sector spanning physical and financial assets. Low-carbon transition has proceeded rapidly in the power sector—only 7% of electricity was generated from renewables in 2005, but by 2017 this had increased to 30% (SEAI, 2018). Furthermore, within the Irish financial services sector—which is one of the leading hedge fund service centres in Europe, focused in particular on administration, insurance, aircraft leasing and payments—a thriving green finance cluster has emerged in recent years, wherein a considerable number of professional services providers are focused on supporting green asset management (Sustainable Nation, 2018).

In order to compare and contrast perceptions of stranding risk among owners and managers of physical compared to financial assets, we undertook interviews with, and an online survey of key figures in the Irish asset management and ownership community. Because of the focus on a limited number of key or "elite" figures, we employed an approach which is common within the more qualitative business studies (Eriksson & Kovalainen, 2008), which employs convenience sampling instead of more systematic techniques. This 'convenience sampling' approach allowed us to overcome the typical challenges associated with gaining access to a representative sample of key 'elite' figures in the business and finance world (Harnett, 2017; Eriksson & Kovalainen, 2008; McDowell, 1998; Harvey, 2011; Okoli & Pawlowski, 2004), which is generally considered infeasible. However, this methodological approach necessarily limits the study—we cannot assume that responses received are representative of the views of the wider market, only that they might be indicative of generally held perspectives.

We followed four steps to ensure that the views were as representative as possible within the context of these constraints. The first step was to undertake a literature review to uncover the key aspects of stranding risk that may be relevant for key actors across the Irish investment chain. In addition, the *Global Investor Survey on Climate Change* (2012) and *Inter-American Development Bank* (2016) were drawn upon to identify relevant questions. On this basis a draft survey was designed which identified the main aspects of stranding risk relevant to Irish stakeholders and experts.

We followed the literature review with semi-structured interviews with key 'gatekeepers', following the approach employed by Harnett (2017) and Eleftheriadis and Anagnostopoulou (2015), and akin to the iterative approach suggested by the Delphi method (Okoli & Pawlowski, 2004). Two specific 'gatekeeper' organisations were chosen because of the concentration of their members at particular points in the investment chain:

- **The Electricity Association of Ireland (EAI)**, the representative body for the Irish Power Sector, which was used to identify many of the key managers and owners of power generation assets.
- **Sustainable Nation Ireland (SNI)**, a platform for capital market participants, corporates, innovators and public-sector organisations focused on green finance, which was used to target key investment professionals/asset managers.

Within these gatekeeper organisations a number of key people were interviewed.[26] Interviewing these key 'gatekeeper' organisations served two purposes. First, as proposed in Rice (2015), we used responses and feedback to refine the draft questionnaire, thereby ensuring that it was targeted on issues relevant to skills and expertise of prospective respondents. The semi-structured interviews therefore ensured a degree of flexibility and responsiveness in our research design, which has been identified as important when interviewing elite figures from business and finance (Harvey, 2010; Okoli & Pawlowski, 2004). Issues raised in initial interviews provided questions for subsequent interviews (Ziebland & McPherson, 2006), and

[26] Dara Lynott and Stephen Douglas (Electricity Association of Ireland) and Laura Heuston and Stephen Nolan, (Sustainable Nation Ireland).

allowed us to design and refine an online survey so that we could reach a wider cohort of respondents.

Second, these 'gatekeeper' organisations were used to identify key relevant investors in the power and green finance sectors, who were owners or managers of assets, and were centrally involved in making investment decisions. These organisations recommended we contact other key figures to interview and to survey, and we therefore employed a 'snowballing' technique, which has been found to ameliorate the subjective choices of researchers (Atkinson & Flint, 2001).

5.2.1. Data

Interviews with gatekeeper organisations, and four individuals, were undertaken between March 26th and April 5th, 2018. A survey was subsequently circulated by email to approximately 203 key experts, divided evenly between the energy and finance sectors. The email was circulated on Monday 16 April, a reminder email was circulated on Monday 23 April, and the collector was closed on Friday 4 May, 2018. Overall, 54 responses were collected, which is in line with the numbers recommended for expert consultation exercises (Okoli & Pawlowski, 2004). Of these, however, 7 respondents failed to provide sufficient data for analysis. We were therefore left with 47 completed responses.

There were 24 completed responses from the sector, who were primarily comprised of energy transmission, distribution and power generation asset owners, but also included a smaller number of respondents from the Transmission System Operator. The second broad cohort was comprised of respondents from the finance sector, of whom there were 23. They included institutional and private investors, financial asset managers, lenders, investment consultancy and accounting firms (Table 1).

Table 5.1 Overview of respondents

	Stakeholders identified	Responses received	Completed responses
Power sector	103	28	24
Finance sector	100	26	23
Total	203	54	47

Respondents were generally at a high level ("middle management" or above) within their organisations. Of the 47 respondents, 23 were in senior management positions, while a further 17 were in middle management positions 14 of the 24 respondents from the energy sector were involved in 'policy, regulation and public affairs', while 8 were involved in 'business development' and 2 on 'investment', whereas in the finance sector, 11 respondents were focused on 'investment and only 6 on 'policy, regulation and public affairs' (Table 2).

Nearly all respondents from the power sector were involved with power generation and transmission assets, and about half of finance sector respondents also had some focus on these assets. More power sector respondents were focused on 'commodities', but fewer were involved with bonds and money markets and stocks compared to finance sector respondents (Table 2).

Table 5.2 Summary of respondent summary

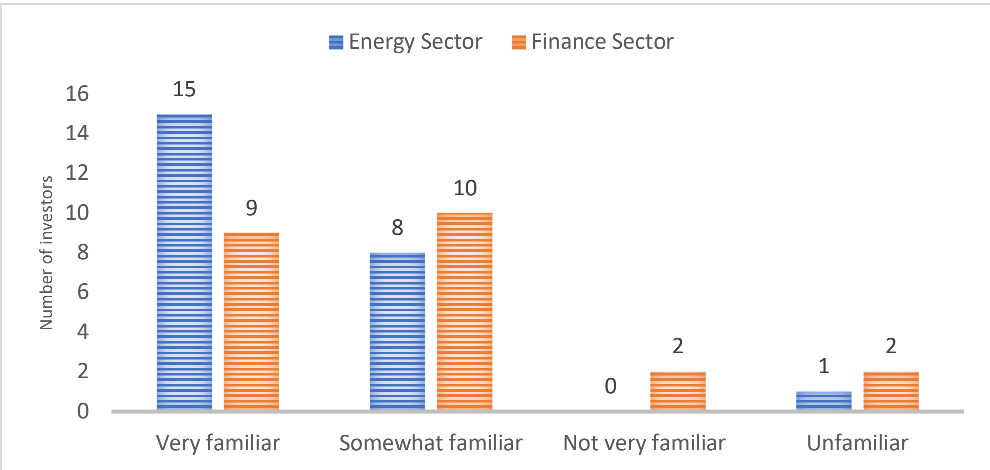
		Power sector	Finance sector	Total
Role in Organisation	Senior Manager	13	10	23
	Middle Manager	8	9	17
	Other	3	4	7
Key focus	Policy/Regulation/Public Affairs	14	6	20
	Investment	2	11	13
	Business Development	8	3	11
	Project Finance	0	2	2
	Other	0	1	1
Relevance of asset class to business activities	Stocks	3	14	17
	Fixed income or bonds	7	14	21
	Money market or cash equivalents	5	14	19
	Commodities	14	9	23
	Real estate and infrastructure	13	14	27
	Power generation assets	21	14	35
	Energy transmission/distribution assets	22	12	34
Total respondents		24	23	47

5.3. Results

In interviews conducted with the EAI, stranding risk 'from low-carbon transition' was identified as 'the most important topic' on the minds of their members at the time. By contrast, SNI observed that stranding risk was only be an issue for a subset of members focused on green finance, and that even within this cohort, knowledge and awareness of the issue was mixed. These observations were born out by survey results.

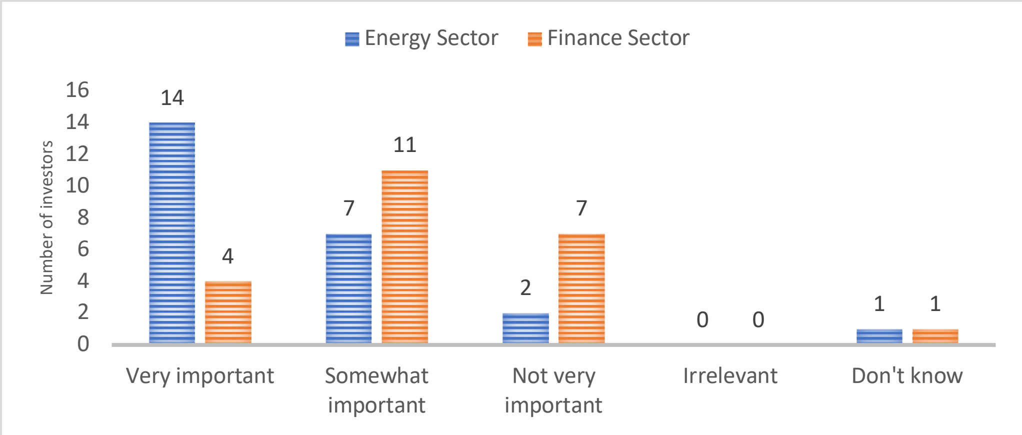
A large majority of survey respondents were 'very familiar' or 'somewhat familiar' with the concept of stranded assets, which was defined in the survey as *'assets that have suffered from premature write-downs, devaluations or conversion into liabilities because of the transition to a low carbon economy'*. Looking at familiarity by sector, we found a higher overall level of awareness of the issue among power sector respondents, with 15 of 24 respondents indicating that they were 'very familiar' with the concept, compared to only 9 of 23 for financial sector respondents (Figure 2).

Figure 5.2 Familiarity with the concept of stranded assets by sector



A large majority of respondents considered asset stranding a 'very important' or 'somewhat important' issue for their business, but there was a clear difference between power and financial sector respondents in terms of how important they considered the risk of asset stranding, with 14 of the power sector respondents considering it 'very important' compared to only 4 from the power sector (Figure 3).

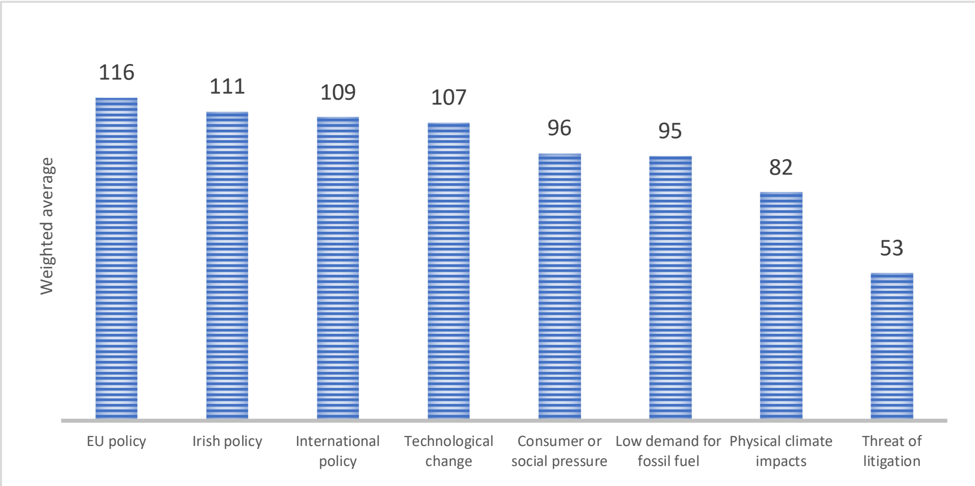
Figure 5.3 Importance of stranding risk to business and investment activities



In interviews with EAI, they emphasised the importance of the Irish policy context in determining stranding risk for their members. In particular they underlined *'the central importance of capacity auctions'* in determining the continued viability of certain fossil fuel generation plants, but also the importance of support schemes for renewables such as '*quota-based schemes and feed in tariffs'*. On the other hand, SNI had been less specific when it came to identifying specific sources of stranding risk for its members, and emphasised the 'general' nature of the awareness around 'green finance and responsible investment' issues. These observations were again bone out by survey respondents when they were asked to rate the importance of different sources of stranding risk for their business. When weighted averages were calculated,[27] the most important source of stranding risk that emerged was Irish policy, followed by EU and international policy. However, factors such as 'technological change', 'consumer or social pressure' and 'low demand for fossil fuels' were also considered to be significant sources of stranding risk (Figure 4).

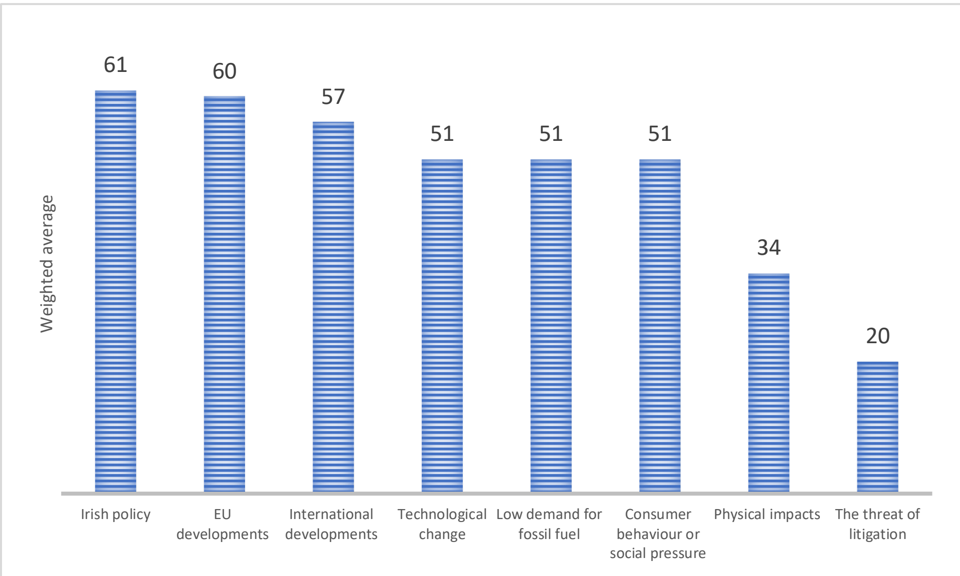
[27] In this case (and for subsequent rating questions), we ascribed weights to responses received to analyse results to calculate weighted averages. 'Very important' responses received a value of 3, 'somewhat important' responses a value of 2, and 'not very important' responses a value of 1, while 'irrelevant' and 'don't know' responses were ascribed a value of 0.

Figure 5.4 Importance of causes of stranding risk



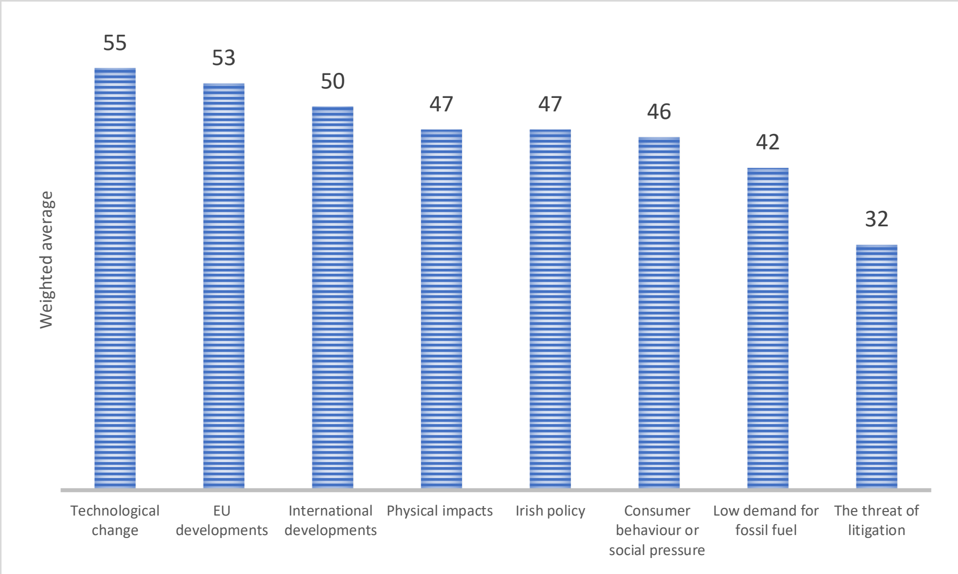
Looking at responses by sector, power sector respondents considered Irish, EU and International policy development as the most significant sources of stranding risk in that order, followed by technological change (Figure 5).

Figure 5.5 Importance of sources of stranding risk (power sector)



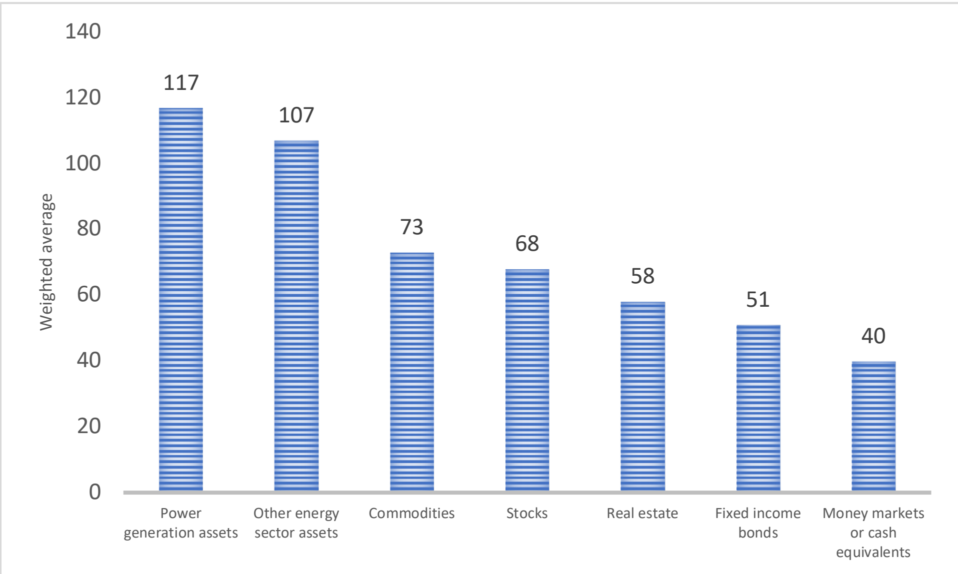
However, for the green financial sector, the most important source of stranding risk was technological change, followed by EU and international policy, perhaps hinting at the greater international focus of actors from this sector (Figure 6).

Figure 5.6 Importance of sources of stranding risk (Finance sector)



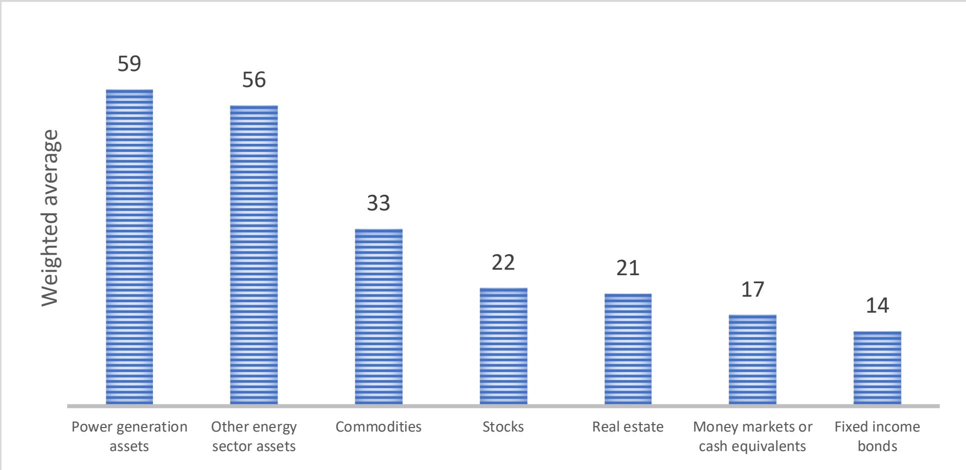
We also asked respondents to evaluate the importance of stranding risk for different asset classes, and calculated the weighted importance of responses. As had been suggested by interviewees, respondents rated stranding risk for power sector assets as very important, whereas stranding risk was considered far less important for all financial asset classes, with 'money markets or cash equivalents' rated as least exposed (Figure 7).

Figure 5.7 Importance of stranding risk by asset class



For power sector professionals, the importance of stranding risk for power sector assets was also emphasised as particularly important (Figure 8).

Figure 5.8 Importance of stranding risk by asset class (power sector)



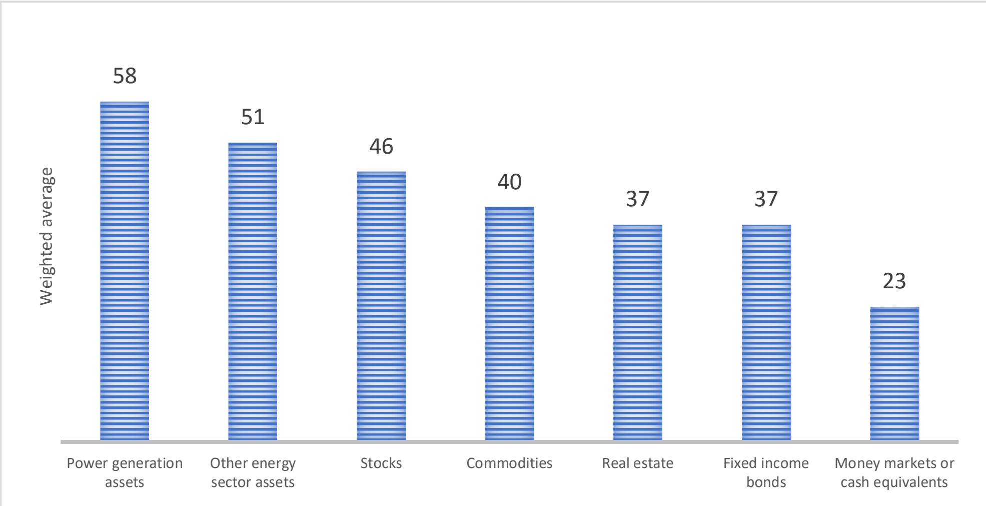
However, it should be noted that a high number of power sector professionals responded, 'don't know' when it came to stranding risk for financial assets like stocks, bonds, money market or cash equivalents, commodities and real estate assets, and these responses were weighted as '0' (the same value ascribed to 'irrelevant'). This suggests that the lower ranking for these asset classes reflected, at least to some extent, lack of knowledge rather than an assessment of low stranding risk *per se* (Table 3).

Table 5.3 'Don't know' respondents by sector (number of respondents)

	Stocks	Fixed income bonds	Money markets or cash equivalents	Commoditie s	Real estate	Power generation assets	Other energy sector assets
Don't know: (Power sector)	11	14	14	8	10	2	2
Don't know: (Finance sector)	3	3	4	3	2	0	3

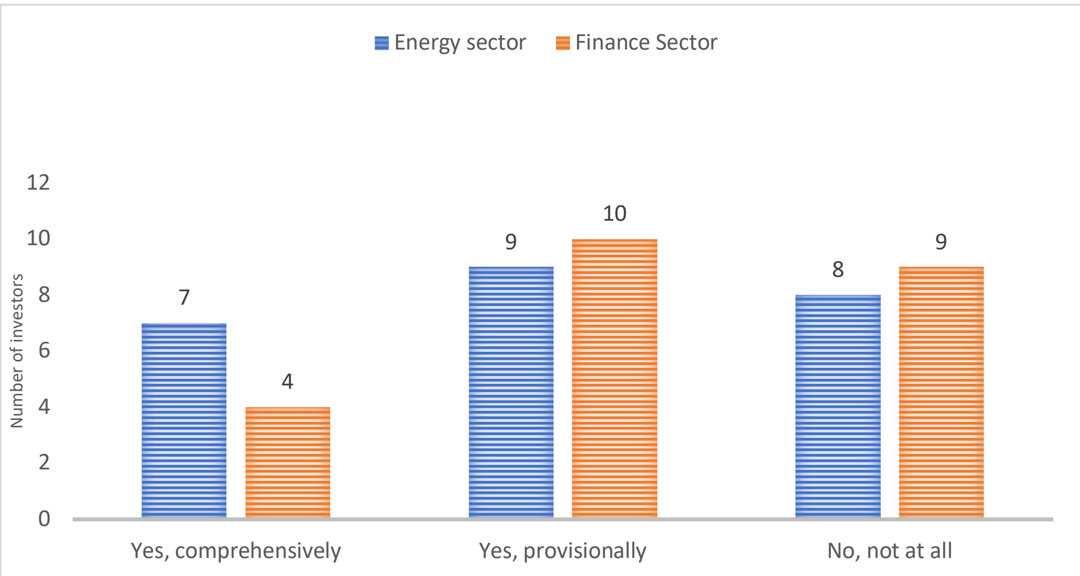
For green finance sector professionals, stranding risk was also considered to be most acute for power and other power sector assets. However, unlike power sector professionals, they also considered stranding risk to be important for stocks and commodities, and somewhat important for real estate and fixed income bonds (it is also notable that far fewer respondents answered 'don't know' for these asset classes). Only money markets and cash equivalents were considered to face low stranding risk by financial sector professionals (Figure 9).

Figure 5.9 Importance of stranding risk by asset class (finance sector)



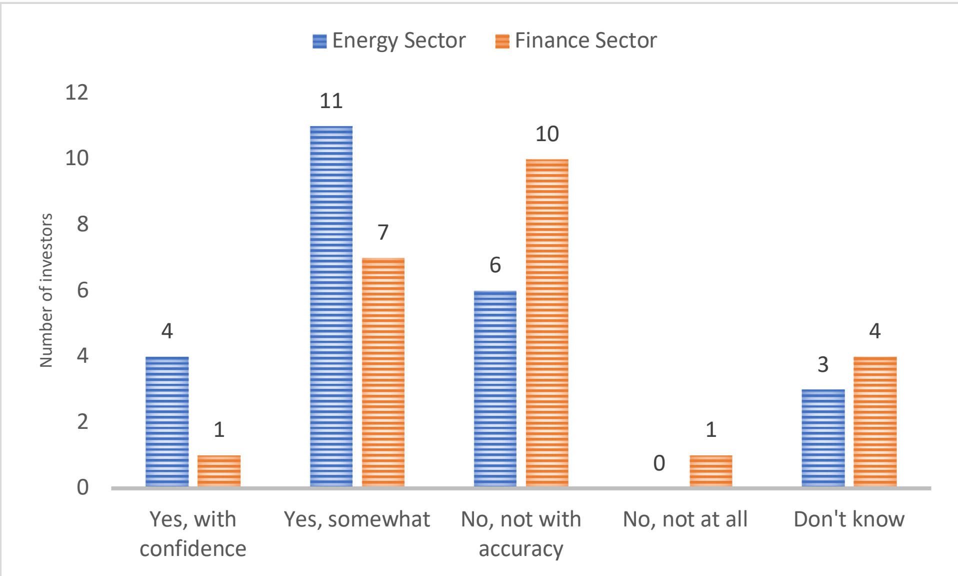
When it came to assessing and measuring exposure to stranding risk, few respondents (n=11) had 'comprehensively' assessed their risk exposure to asset stranding, however a significant number (n=19) had 'provisionally' examined their exposure to asset stranding. More power sector professionals (n=7) had 'comprehensively' assessed their exposure to stranding risk compared to green financial sector professionals (n=4) (Figure 10).

Figure 5.10 Assessment of exposure to stranding risk by sector



Few respondents could measure their exposure 'with confidence' (n=5), however, quite a number were 'somewhat' confident in their ability to measure stranding risk (n=18). Almost half of respondents were therefore somewhat confident or better in their ability to measure stranding risk. Again, the differences between green financial and power sector professionals was notable. 11 finance sector professionals responded 'no, not with confidence' or 'no, not at all', compared to 6 for the power sector (Figure 11).

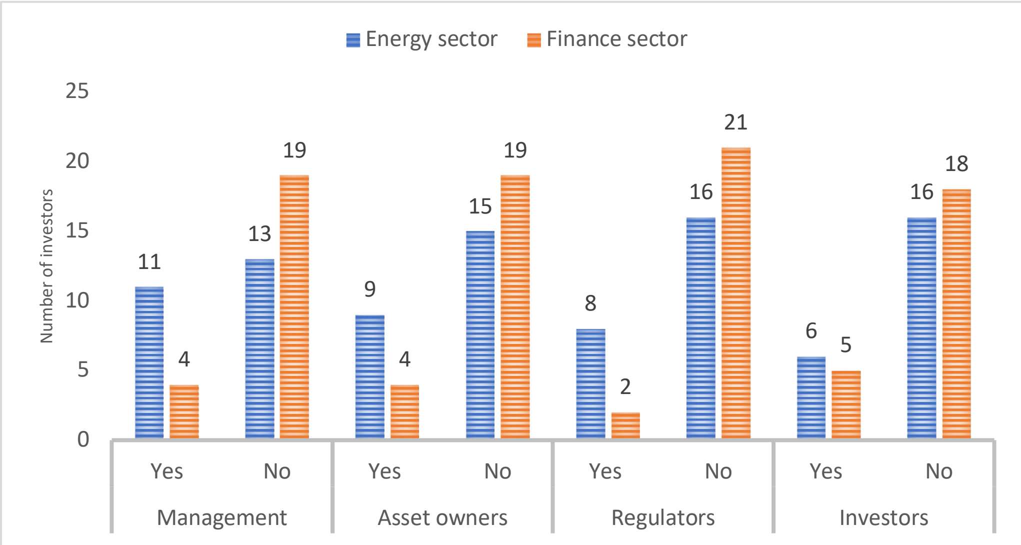
Figure 5.11 Ability to measures exposure to stranding risk by sector



When it came to the methods used to assess stranding risk, scenario analysis and risk analysis were the most popular, whereas stress testing, assessment of emissions testing of assets and asset impairment tests were less popular for both cohorts. No discernible differences were noted between power and financial sector professionals in this case.

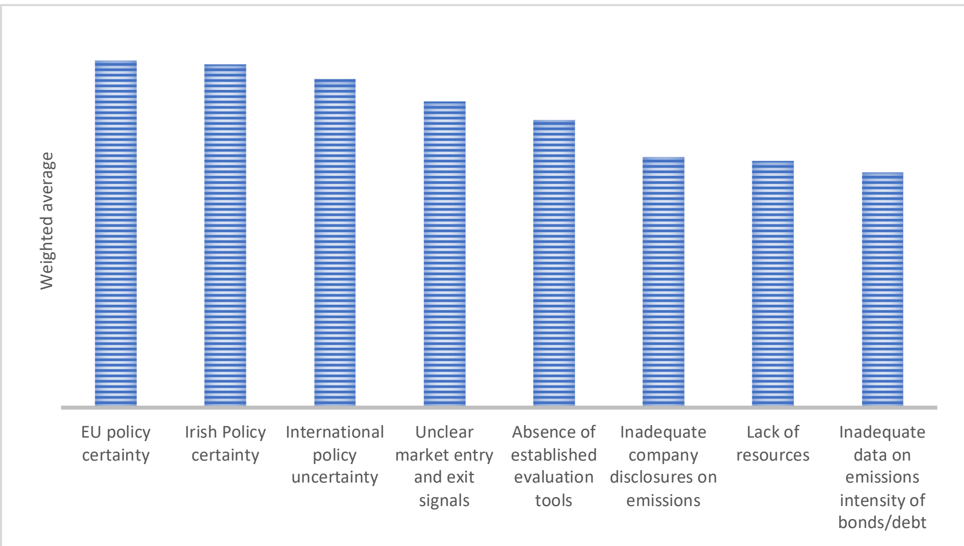
On reporting, less than one third or respondents had reported on stranding risk, and risks were more often reported to management and asset owners, and less often to regulators and investors. However, power sector respondents were more likely to have reported on stranding risk than financial sector professionals, very few of whom had reported on stranding risk to management, asset owners, regulators or investors (Figure 12).

Figure 5.12 Reporting on stranding risk by sector



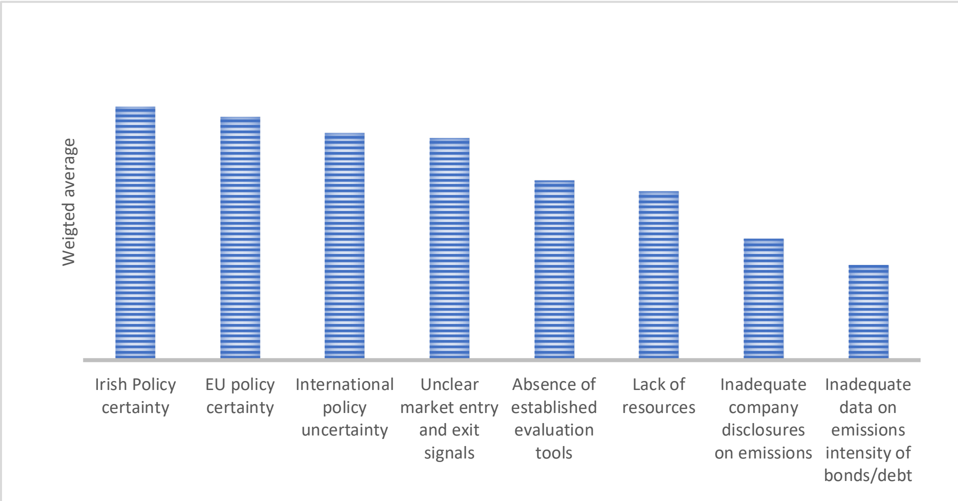
When it came to barriers preventing effective management of stranding risk, EAI had underlined the key importance of *'unclear market entry and exit signals due to changing policy direction'*, whereas SNI has offered a more general assessment of barriers to effective management 'arising from a number of interrelated issues'. Survey respondents reflected these perspectives to some extent. For example, policy uncertainty (national, EU and international) was the most important factor identified by respondents, however, 'unclear market signals' and the 'absence of well-established methodologies' were also cited as significant barriers. 'Lack of resources', and 'inadequate company disclosures' and 'inadequate data on emissions intensities' were considered less important barriers (Figure 13).

Figure 5.13 Importance of barriers to management of stranding risk



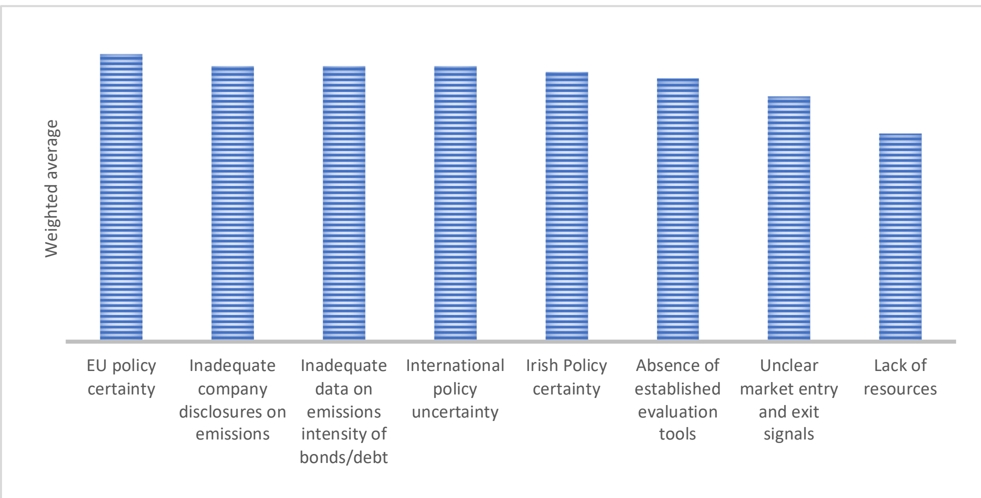
This ranking of barriers was reflected by the assessment of power sector professionals, for whom policy uncertainty (Irish, EU and international) also emerged as the key issue (Figure 14).

Figure 5.14 Importance of barriers to management of stranding risk (power sector)



However, for green finance professionals, barriers were ranked of roughly equivalent importance (with the exception being ‘lack of resources’, which was ranked of low importance by this cohort). However, the absence of data (‘inadequate company disclosures’ and ‘inadequate data on the emissions intensity of debt/bonds’) received a considerably higher ranking from the financial sector cohort than from power sector professionals (Figure 15).

Figure 5.15 Importance of barriers to management of stranding risk (finance sector)



Finally, we asked power and financial sector respondents to briefly describe actions they or their organisation had taken to 'manage stranding risk from climate change'. Many power sector professionals indicated that stranding risk had already affected investment decisions. For example, several respondents commented that they had 'delaying investment decisions', 'reassess investment strategy', 're-evaluated asset management investment case decisions' or 'reassessed investment decisions to manage stranding risk'. Several other respondents said that they had focused on investing in low-carbon technologies to manage stranding risk. For example, one commented that they had 'invested in renewable and emerging technologies', while another had invested in 'a broad range of renewable & innovative low carbon technologies to future proof' their asset portfolio, while another was 'focused on new technology'. Two respondents added that they already written down asset values in response to asset stranding.

By contrast, the green finance sector respondents were far less likely to have taken specific actions to address stranding risk. Several survey respondents responded: 'no action taken to date', 'nil' or 'none' or 'I have no idea'. Others responded that stranding risk was 'not very important in a diversified portfolio', or that they did not have 'any real exposure to stranding risk as a lender' or that they only managed 'a very small part of any portfolio, so not sure how relevant it is for us'. One respondent stated that their organisation was 'not specifically focused on stranded assets as key driver of climate risk' but that they took a 'broader view of risks and opportunities' from the transition to low carbon economy.

For those in the green finance sector who had taken specific actions to manage stranding risk, 'diversification' or 'diversification of portfolio', or 'invest heavily in alternative energy companies, minimise our investments in fossil fuel companies' was mentioned by a number of respondents. 'Ethical screening' and 'examination of information available in accessible published sources' were also cited by respondents, while 'risk analysis' was cited by two respondents and 'constant monitoring of assets' by another. Another added that their organisation had undertaken 'extensive research on the topic and have made investors aware of the risks'. One respondent stated that they had undertaken an 'Environmental, social and governance assessment of all asset managers including asset class specific risks from stranding', while another added that they had 'integrate carbon emission related data into our investment process'.

5.4. Discussion

In this section, we consider our results within the context of our research questions. First, we sought to examine if awareness of and attitude to the risk of asset stranding differs for actors across investment chain, using Ireland as a case study. Specifically, we looked at attitudes of senior professional investors in the Irish power sector compared to senior professionals in the green finance sector.

Interviewees had suggested that awareness of stranding risk would be more acute in the power sector compared to the financial sector, and this observation was borne out by survey responses. We found considerable differences in the level of awareness of stranding risk, with a lower proportion of finance sector respondents 'very familiar' and 'somewhat familiar' with the concept of asset stranding. Furthermore, power sector respondents were far more likely to consider asset stranding 'very important' for their business, whereas in comments provided, several finance sector respondents said that they did not know if stranding risk was an issue for their business or investments, hinting at an information deficit. Furthermore, all respondents, whether from the power or green finance sectors, ascribed the greatest risk of stranding for power generation and other energy sector asset, whereas financial assets were judged to be less exposed. However, it should be noted that financial sector actors also emphasised the importance of stranding risk for financial assets, in particular for stocks and commodities, and somewhat less so in the case of real estate and fixed income bonds, whereas power sector respondents were somewhat unfamiliar with the exposure of these assets.

Nevertheless, power sector assets were considered to be most exposed by both cohorts. This may be because of the diffusion of risk for financial institutions and investment managers across their investment portfolio, compared to the owners and managers of fossil fuel assets. Indeed, several financial sector actors emphasised their ability to diversify their portfolio of investments as an effective approach to managing stranding risk, and others pointed out that they already managed a diversified portfolio and that fossil fuel assets only formed a small part of this portfolio. It is inevitable that stranding risk would be more apparent to those managing or owning fossil fuel generation assets under these circumstances. Another possible explanation for the lower risk assessment by financial asset owners is because of the higher liquidity of financial compared to physical assets. It is notable that the most liquid asset class, 'money markets and cash equivalents', was rated by respondents as the least exposed to stranding risk, while the least liquid assets (power transmission and generation) were considered most exposed.

As had been anticipated by power sector interviewees, policy changes were perceived as the most important factor underpinning stranding risk overall, with Irish policy changes ranked as the most important issue. The importance of changes to subsidy regimes, including capacity auctions and feed in tariffs, was underlined by interviewees, and this view was reinforced by survey results. EU and international policy were also rated as important for power sector respondents. For financial sector actors, however, 'technological change' was identified as the most important source of stranding, while 'Irish policy' was considerably less significant. This perhaps reflects the greater international reach and global perspective of the Irish financial sector, whereas power sector is more domestic in nature, and therefore power sector actors would tend to be more specifically focused on the domestic context and national policy and market developments. Overall, power sector respondents therefore, had more awareness of and exposure to stranding risk than financial sector actors, and the sources of stranding risks were also perceived somewhat differently.

Second, we sought to assess if methods used to value and manage stranding risk, and key barriers to integrating stranding risk into decision-making, were different for actors across the two sectors. While power sector respondents were somewhat more likely to have 'comprehensibly' measured their exposure to stranding, the differences were not stark between sectors in this respect. Nor were there differences in the methods employed to measure stranding risk across sectors, with scenario analysis and risk analysis the most popular methods for both cohorts. On the other hand, many power sector respondents indicated that they had taken somewhat drastic action to manage stranding risk, including asset write-downs, revaluating their investment strategies, or by ensuring a greater focus on renewable technologies in their generation and investment portfolios. Financial sector respondents were less likely to have taken specific actions, and where actions had been taken, they were generally somewhat milder. For example, several mentioned methods that had been employed to promote awareness or to screen investment decisions, although it should be noted that some also mentioned diversification of investment portfolios.

Powers sector respondents had considerably more confidence in their ability to measure stranding risk, and they were also considerably more likely to have formally reported on these risks. However, even in the power sector, less than half of respondents had formally reported to management or externally on their potential exposure. When it came to managing stranding risk, policy uncertainty was identified as the most important barrier by respondents in both sectors. However, 'inadequate company disclosures' and 'inadequate data on the emissions intensity of debt/bonds' received a considerably higher ranking from the financial sector cohort than from power sector professionals. This indicates that the availability of accurate data is more of an issue in the financial sector than for power sector asset owners and managers, who are more concerned by factors outside of their control such as sudden policy changes. Information asymmetries therefore emerge as an important consideration underpinning investor perception.

Power sector actors have therefore been more proactive in taking decisive actions to managing stranding risk and are more confident in their ability to manage these risks. They were more likely to see risks arising from sudden changes in policy that were outside of their control than from an absence of data and information.

5.5. Conclusion

In order to meet climate targets, it will be necessary to mobilise a much greater level of investment in low carbon assets in the period to 2050. How different actors perceive investment risks can be highly influential over the cost of capital and investment decisions, and has therefore been a subject of growing analytical interest. The risk of asset stranding posed by the transition to a low-carbon economy is a particular issue of concern for owners and managers of physical and financial assets.

The objective of this study was to measures, compare and contrast perspectives on stranding risk from climate change for two groups in the Irish investment chain: investors in and managers of physical generation and transmission assets in the power sector, and green financial asset owners and managers. We sought to assess if awareness of and attitude to the risk of asset stranding differed for these two groups, and if the methods used to value and manage stranding risk, and perception of key barriers to integrating stranding risk into decision making were different.

It is limited by a number of factors. First of all, we used a convenience sampling approach and 'snowballing', rather than a more systematic technique. This method was chosen because of the challenge of identifying a representative sample of investors from the power and green finance sectors, who were the primary cohorts of interest. Second, we restricted our focus to Irish investors, a country with a highly developed financial sector, and a power sector which is relatively well advanced in transitioning to sustainability. Third, the number of respondents, while sufficient for the needs of a largely qualitative assessment of this kind, was relatively modest. On this basis, we cannot assume that our results are indicative of the views of the wider international market, and we therefore present our results as indicative and exploratory in nature.

Notwithstanding these limitations, our survey is the first of its kind which looks at how perceptions of stranding risk differ between investors in financial assets and physical fossil fuel assets, and therefore makes a unique contribution to an emerging literature. Our findings support the view that stranding risk is perceived to be a more prominent issue for investors and managers of power sector assets compared to financial assets, and that stranding risk is perceived to arise from different factors by these actors. The power sector investors were, for example, primarily concerned with the policy context, while the financial sector actors were more concerned with technological change. Power sector actors were also likely to have taken more decisive steps to manage stranding risk and were far more confident in their ability to assess and manage stranding risk. Financial market actors, by contrast, pointed to a lack of information or accepted methodologies for making these assessments, suggesting that information asymmetries underpin different perceptions. These findings therefore support previous research (Task Force on Climate-related Financial Disclosures, 2017), which points to information asymmetries as a key issue, and calls for greater reporting of climate-related financial risks.

These findings perhaps also reflect a greater diffusion of risk for financial institutions and portfolio managers, noted in previous studies (Global Investor Coalition on Climate Change, 2013), but also perhaps the greater liquidity of financial compared to physical assets. It may also be because risks that are typically considered by financial market actors (such as market, inflation, or interest rate) are measured on a short-term basis but climate risks demand longer time horizons. Power sector actors, by contrast, are used to evaluating investment decisions on a multi-decadal basis.

Overall, our findings suggest that the understanding and ability to accurately quantify stranding risk may be less developed for financial sector investors compared to the power sector cohort. The former may have not yet developed a comprehensive appreciation of stranding risk compared to the latter, and may therefore not be in a position to fully factor this risk into investment decisions.

If an information deficit prevents market actors from fully integrating climate risks from energy transition into the market prices of financial assets, this could constitute a material risk to financial stability. Under these circumstances there is an onus on regulators to ensure climate-related risks are disclosed to savers and investors in a standardised manner, to ensure some degree of comparability between green versus traditional brown asset classes. In a promising sign, the European Commission's action plan for sustainable finance (European Commission, 2018) seeks to establish such a framework, but it remains to be seen if these guidelines are sufficient to help regulators to manage climate risks in a systematic manner.

Chapter 6: Discussion and conclusions

6.1. Introduction

If 'dangerous' climate change is to be avoided, immediate and rapid decarbonisation must be achieved over the coming decades, particularly in developed economies. Staying within the 2° C temperature target would require an energy transition of exceptional scope, depth and speed, and about double the current level of investment in low-carbon technologies. The widespread deployment of these technologies poses challenges for traditional investors as well as opening up opportunities for new actors.

The aim of this study was to investigate investment attributes that are attractive to investors in low-carbon and renewable energy assets. A key focus was on understanding the risk-return perceptions of investors and how this could affect investment decisions. The risk perception of market participants within the context of energy transition is a key determinant of the pace at which technologies are deployed in the market place, yet it has been left "almost unaddressed" until recent times (West, 2019). Coming to a greater understanding of the risk preferences of market participants, from professional to citizen investors, allows for the design of financial incentives that are attractive to these actors, and could be highly influential over the cost and pace of low-carbon transition.

In previous chapters, a systematic literature review, case studies, a survey of Irish citizens' risk-return perceptions, and a survey of the perspectives of professional investors on asset stranding risk under energy transition, were presented.

The specific research objectives were as follows:

1. To explore the risk-return preferences and investment attributes that are important for citizen investors, and identify barriers to these investors at different project stages;
2. To investigate how financial incentives can be designed that are attractive to non-traditional (citizen) investors; and
3. To measure, compare and contrast perspectives on stranding risk from climate change for owners of physical and financial assets.

6.2. Key findings

In the section below, key findings are synthesised and analysed in terms of their implications for the three key research questions outlined above.

In the case of the **first research question**—understanding the risk-return perceptions and investment preferences of citizen investors and community groups—a key finding that emerged from the literature review and case studies was that citizens and community groups have responded to financial incentives, especially when that have been tailored to their unique preferences. This was the case both in countries with a tradition of local activism (Germany and Denmark), and also where no such tradition existed (Ontario and the UK). The survey of Irish citizens suggested that that financial participation could be achieved if investment options offering reasonable rates of return and low levels of risk were made available. This was particularly the case among wealthier cohorts in society with some experience of making investment decisions.

Survey findings pointed to the similarities in motivation between citizens across borders. While the findings from Chapter 2 suggested that citizen investors may have a variety of motivations and do not necessarily respond in an economically rational manner to these incentives, Chapter 4 illustrated that the financial characteristics of investments are of high importance to Irish citizen investors. Furthermore, the investment attributes that were attractive to Irish citizen investors (low risk and a preference for small investment amounts) were similar to these identified in surveys of German citizens. This suggested that even without context-specific factors identified as important in Chapter 2 and 3, the introduction of specifically tailored financial incentives could be effective in mobilising citizen investment in new markets. This finding was reinforced by the survey results presented in Chapter 4, which uncovered considerable interest in investing in low-carbon technologies among Irish citizens. However, there was an important caveat—less than half of respondents were found to be willing to invest "up to €5,000", a relative low level of investment compared to the typical equity requirement for a wind farm.

Solar PV projects were found to be more attractive to citizen investors compared to wind and biomass projects. These projects tend to have lower up-front investment costs and are generally smaller in scale compared to wind projects, and therefore appear to offer better potential for citizen investment. Irish citizens, however, were relatively agnostic when it came to potential partners and the location of the projects, and did not indicate a preference for local projects, for example. A strong "NIMBY" effect was not therefore identified.

From a policy perspective, the high risk-aversion of citizen investors, and the importance of financial factors (no savings or low access to debt finance) as barriers, combined with a lack of confidence in making investment decisions, suggests that there is a role for Government in managing risk and ensuring access to capital, particularly at the early riskier stage of project development.

When it came to the **second research question**—designing financial incentives attractive to non-professional investors—a number of novel findings relevant to the choice and design of specific incentives were uncovered. FiTs, FiPs, quota schemes, grants and tax emerged as effective in mobilising greater levels of investment. The introduction of a FiT, in particular, emerged as a crucial turning point and a critical success factor in mobilising local citizen investors in many jurisdictions. A key characteristic of FiTs is that they provide a stable long-term income stream, thereby reducing risk and making it easier to access bank funding, which appears to be a particularly important factor for local citizen actors. On the other hand, abrupt changes to FiT schemes undermined regulatory stability and market confidence. Introducing a FiT, however, did not emerge as a sufficient condition for success. In many countries, not least Ireland, FiTs have not resulted in investment from non-professional project developers.

In contrast to previous literature, an implication from this study is that market-based supports such as FiPs and quota-based schemes can also be designed in a manner that is attractive to citizen investors. FiPs have been deployed successfully in Denmark (combined with a mandatory share offer for local citizens) and quota-based schemes have also been designed in a manner which is advantageous to local community groups in Ontario and elsewhere. However, while market-based supports *can* be deigned with these actors in mind, this has not always been the case in practice. In many cases, these incentives were not designed with local citizen investors in mind, and while the intention may not have been to exclude these actors, this was the ultimate effect.

Overall, these findings suggest that instrument choice may be less important compared to instrument design. FiTs differentiated according to project size and technology type opened up niche opportunities for local citizen, and adders, contract set-asides and mandates have also been used to modify FiTs and make them more attractive to citizen investors. Market-based supports *can* also be designed with citizen investors in mind, which is an important finding within the context of the migration to this category of incentive within the EU

(Ragwitz et al., 2012) and Ireland. Another important conclusion is that the timelines for citizens and community groups to organise projects will tend to be longer due to their lack of technical skills and expertise, and the greater difficulty they are likely to experience in accessing finance. This is a particularly important consideration when designing market-based approaches, such as auctioning or tendering schemes.

The case studies and survey results also revealed the importance of introducing financial incentives at both the early and later stages of projects in order to establish a business case for local citizen participation. In particular, the case studies revealed the crucial importance of introducing incentives to overcome risks at the feasibility and development stages of projects, where risks are greatest. Professional developers can generally offset these risks by developing a portfolio of projects, but this option is not available to local citizens. These findings suggests that there may be a case for the introduction of a time-bound grant programme, or indeed non-recourse loans or soft loans, to promote the emergence of exemplar pilot community-led projects. Grants typically cover feasibility and development costs, but can also cover a proportion of construction costs. However, the intention should be to migrate to a more market-driven approach over time to control cost-effectiveness and reduce the impact on electricity prices. This is because grants, while effective at overcoming early stage project barriers, also can be challenging and costly to administer, and they can favour wealthier cohorts in society. They are dependent on annual funding allocations from the exchequer and changes to levels of support can lead to boom-bust investment cycles, which in turn can make the formation of a sustainable market challenging. In some cases, programmes can suffer from an element of path dependency. While grants no doubt, therefore, have an important role, their downsides need to be carefully considered and monitored.

The favourable tax treatment of income from renewable energy projects emerged as an important supplementary consideration. Indeed, the removal of various UK tax incentives in 2015 undermined the business case for many renewable energy projects with community participation. Another benefit of tax incentives is that they do not necessarily require annual budget allocations from the exchequer, they can be extended for pre-agreed periods of time and they tend to be considerably easier to administer and to access than grants (where a complex application procedure is generally required).

Carefully designed financial incentives emerged as a potentially important means of mobilising citizen investment. The benefits of using incentives, however, needs to be balanced against the cost to the tax payer of using these instruments. On the one hand, incentives require exchequer revenue or and funded by bill payers, and Governments would argue that controlling the cost of low-carbon transition is important for delivering continued societal buy-in and value for money. On the other hand, local citizens often provide their time on a voluntary basis (Rijpens, 2013; IEA-RETD, 2016) and their involvement has been found to open up access to the optimal sites for on-shore wind and solar PV development, thereby reducing cost (Nelson et al., 2016). Access to optimal locations for projects is a particularly prevalent concern in Ireland, where many sites cannot be accessed due to local opposition. Should local opposition to on-shore wind, biomass, waste to energy or solar plans prevent further project development, this would necessitate greater levels of off-shore wind development if decarbonisation objectives are to be met, thereby increasing the overall cost of meeting climate objectives.

Finally, the third research question— understanding how perceptions of stranding risk differ between investors in financial assets and physical fossil fuel assets (generation and transmission assets). Stranding risk emerged from this study as a far more prominent issue for investors and managers of power sector assets compared to financial assets. Stranding risk was also perceived to arise from different factors. Power sector investors were, for example, primarily concerned with the policy context, while the financial sector actors were more concerned with technological change. Power sector actors were also likely to have taken more decisive steps to manage stranding risk and were far more confident in their ability to assess and manage stranding risk. Financial market actors, by contrast, pointed to a lack of information or accepted methodologies for making these assessments, suggesting that information asymmetries underpin different perceptions.

These findings, therefore. support previous research (Task Force on Climate-related Financial Disclosures, 2017), which points to information asymmetries as a key issue, and calls for greater reporting of climate-related financial risks. These findings perhaps also reflect a greater diffusion of risk for financial institutions and portfolio managers, noted in previous studies (Global Investor Coalition on Climate Change, 2013), but also perhaps the greater liquidity of financial compared to physical assets. It may also be because risks that are typically considered by financial market actors (such as market, inflation, or interest rate) are measured on a short-term basis but climate risks demand longer time horizons. Power sector actors, by contrast, are used to evaluating investment decisions on a multi-decadal basis.

6.3. Unique contribution to the literature

In each chapter of this study, a number of distinct and unique contributions to the literature were made, which are summarised in Table 6. 1 below. In Chapter 2, the first systematic literature review of financial incentives that have targeted non-professional investors was presented. While previous research explored the use of financial incentives to promote renewable energy investment, the majority of this research focused on attracting investment from traditional investors. This study, by focusing on citizens and community groups, therefore makes a unique contribution by being the first of its kind, while also extending the literature on the choice and design of financial incentives.

In Chapter 3, analysing the use of financial incentives across typical project stages: feasibility, development, construction and operation also constitutes a unique contribution to the literature. The barriers faced by non-traditional investors are different across project stages compared to traditional investors. Specifically, greater barriers may be encountered at the early-stages of project development. Looking at incentives across project stages allowed for the identification of the key importance of early-stage incentives as a distinguishing feature of projects with citizen involvement, which emerged as central to the value proposition of many successful projects. Another insight that emerged from looking at incentives across project stages is that later-stage project supports are seldom designed with citizen investors in mind. In particular FiPs and quota schemes, which are becoming more widespread in their use as wind and solar PV mature, have a mixed track record when it comes to mobilising local citizen actors. Our unique contribution—assessing the use of incentives across project stages—therefore allows policy makers to identify barriers in a forensic manner, and to propose more targeted and appropriate policy responses. It also opens up a new and promising avenue for future research because the importance of early stage support for local community energy projects, while commonly acknowledged in the policy world, is not a topic that has previously received attention in the academic literature.

Table 6.1 My Contribution

Paper	Literature gap identified	My contribution	Literature extended	Contribution to policy
Chapter 2:	There is an extensive literature on the importance and benefits of mobilising	The first systematic literature review on the topic which draws	FiTs and quotas, grants and tax incentives can be successful in	Relevant doe policy makers

Systematic literature review	citizen and community investment, but the literature on citizen participation in the ***financing*** of renewable energy infrastructures is sparse considering its empirical importance (Yildiz, 2014). There is a comprehensive literature exploring the design of financial incentives attractive to professional investors (e.g. Barradale, 2014; Bolton & Foxon, 2015; Mathews et al., 2010; Wustenhagen & Teppo, 2006; Abolhosseini & Heshmati, 2014; Bobinaite & Tarvydas, 2014; Marques & Fuinhas, 2012; Mickwitz, 2003; Oak et al., 2014; Ozcan, 2014; Polzin et al., 2015; Somanathan et al., 2014). However, designing financial incentives that are attractive **to non-professional investors** has received less academic attention. Studies that exist have focused on type of incentive used, not their design, or are highly context specific.	together findings from dozens of studies focused on the effectiveness of technology-specific economic and financial incentives used to mobilise non-professional investors. Underlines the effectiveness of certain types of incentives, including FiTs, FiPs, quota-based schemes, grants, tax incentives, and soft loans, but also their potential downsides.	mobilising greater levels of investment from local citizens, but soft loans tend to be less effective as a stand-alone instrument, thereby extending literature on use of financial incentives to mobilise citizen investors Extends the literature (Dewald & Truffer, 2011; Romero-Rubio & de Andrés Díaz, 2015; Delmas & Montes-Sancho, 2011) that highlights the importance of understanding the natural, social, policy and regulatory context under which economic incentives operate is necessary in order to measure success. Extends the literature (Michelsen & Madlener, 2016), and highlights the importance of introducing financial incentives as part of policy packages.	in jurisdictions focused on mobilising more investment from citizens and communities.
Chapter 3. Case studies from leading jurisdictions	There have been many studies looking at the benefits and costs of mobilising investment from non-traditional actors (Bergman & Eyre 2011; Bolton & Foxon 2015; Ricardo Energy & Environment 2017; Devine-Wright 2014; Palm & Tengvard 2011; Dóci & Vasileiadou 2015; Slee 2015; Viardot 2013; IEA-REDT 2016), however, there have been far fewer studies exploring the risk-return preferences of non-professional investors, and assessing implications for the design of financial incentives. No one has examined how the risk-return perception of investors differ across project stages (feasibility, development, construction and operation) for renewable projects.	First to explore the importance and appropriateness of financial incentives by project stage: revealed the crucial importance of incentives to overcome risks at the feasibility and development stages of project development. Emphasised the importance of incentive design over incentive choice: market-based supports can be designed with non-professional investors in mind.	Extends the literature looking at the attractiveness of one type of financial incentive over another (Fouquet & Johansson 2008; Butler & Neuhoff 2008; del Río & Bleda 2012; Saunders, Gross & Wade 2012; Couture & Gagnon 2010). Different financial incentives may be appropriate at different project stages. Extends literature (Feurtey et al. 2015; Simcock, Willis & Capener 2016) exploring incentive design and use of market-based approaches.	Relevant for policy makers in mature markets seeking to transition from grants and FiTs to market-based approaches (quota-based schemes and FiPs). Also relevant to policy makers in new markets seeking to learn from policy experiences in mature markets.
Chapter 4	There has been a lack of rigorous academic research on the risk-return preferences of citizen investors, and the implications of their risk appetite for the design of financial incentives. Studies on mobilising community groups and citizens have exclusively focused on mature markets with high levels of citizen investment activity, including Denmark, Germany, Austria, parts of Canada and Scotland. Lessons from these cases cannot necessarily be applied to markets with no citizen investment tradition.	There is a high level of interest in investing in renewable energies among Irish citizens, which suggests experiences of leading players might be replicated in markets with less citizen investment tradition. Irish citizen investors are highly risk-averse, and are motivated by financial characteristics of investments. Investment amounts are low compared to typical equity requirements, suggesting that citizen investor funding will need to be complemented by capital from other sources.	Extends literature which explores the context of country-specifics in explaining the presence of citizen investors (Dewald & Truffer 2011; Romero-Rubio & de Andrés Díaz 2015; Gamel, Menrad & Decker 2017; Fleiß et al., 2017). Extends literature on risk appetite and investment attributes attractive to citizen investors (Dóci & Vasileiadou, 2015; Hyland & Bertsch, 2018; Gamel, Menrad & Decker, 2017; Fleiß et al., 2017; Salm et al., 2016; Gamel, Menrad & Decke,r 2016; Fleib, 2017).	Rrelevant for policy makers in jurisdictions without a citizen investment tradition, such as Ireland, Spain, parts of the US etc.
Chapter 5	The risk perception of market participants in the energy sector is crucial in understanding global energy sector investment trends within the context of low-carbon transition. Yet it has been left almost entirely unaddressed until recent times. While stranding asset risk has become an increasingly prominent focus in academia and policy, no studies have sought to assess how perceptions of stranding risk are different across the investment chain.	Compared stranding risk perception for power sector and finance sector elites. Suggested that the understanding and ability to accurately quantify and manage stranding risk may be less developed for financial sector investors compared to the power sector cohort.	Extends literature on asset stranding risk within the context of energy tradition (e.g. (Caldecott, 2017; Economist, 2013b; Griffin et al. 2015; McGlade, 2013; Vergragt et al. 2011). Extends literature looking at stranding risk perceptions across the “investment chain” (Thomä & Chenet, 2017; Harnett, 2017; Silver, 2017; Divestinvest, 2018; Asset Owners Disclosure Project, 2017)	Relevant for regulators (central banks, financial regulatory bodies etc.) seeking to understand and manage risks to financial stability.

It is generally agreed that understanding the natural, social, policy and regulatory context under which economic incentives operate is necessary in order to measure success, and many studies also highlight the importance of context–specific considerations when designing incentives for citizen investors (Dewald & Truffer, 2011; Romero-Rubio & de Andrés Díaz, 2015). However, previous research focused exclusively on investigating citizen investor preference in markets where there is a long history of local energy activism and a citizen investment tradition, such as Denmark, Germany and Ontario. In Chapter 4, however, the citizen investor preferences in Ireland, a market with no citizen investment tradition, were explored. While some differences were noted compared to more mature markets, overall, we identify many similarities between citizen investor characteristics across markets. This suggested that citizens are likely to respond to tailored financial incentives, even in the absence of a long tradition of local activism. By exploring citizen investor preferences in a market with no established tradition, this study added a new strand to a growing the academic and policy debate. These findings should be of particular interest to policy makers in other countries with a less developed citizen investment tradition, such as Spain and parts of the United States. The emerging literature which seeks to come to a greater understanding of the unique risk appetite and investment attributes that are attractive to citizen investors was also extended.

Finally, stranding risk from climate change is becoming a prominent focus in the finance literature. However, research focused on how professional investors across the investment chain perceive stranding risk is limited, especially considering its significance. For example, no previous studies have explored how stranding risk is perceived by investors in physical compared to financial assets. This study therefore made a novel and unique contribution to understanding this research question. Overall, the findings suggest that the understanding and ability to accurately quantify stranding risk may be less developed for financial sector investors compared to the power sector cohort. The former has not yet developed a comprehensive appreciation of stranding risk compared to the latter, and may therefore not be in a position to fully factor this risk into investment decisions. This insight has important implications for financial regulation.

6.4. Future research

The analysis presented in this thesis identifies several promising areas for future research. First, the findings from Chapter 2 and Chapter 3 suggest that comprehensive ex post evaluations of financial incentives are not common, and that even when evaluations have been undertaken, they tend not to be systematic or consistent, and this makes comparison challenging. Many case studies employ only one evaluation criteria (usually cost-effectiveness of economic efficiency), and there is generally less of a focus on distributional implications, institutional or administrative factors or social acceptability. Overall the ex post literature on the use of financial incentives, particularly those targeting citizen investors, is sparse, and this emerges as a useful avenue for further research.

Second, the ex post data on the costs of mobilising citizen investors is both sparse and inconclusive. There is also some evidence (see above) that mobilising local citizens as investors can reduce the overall costs to society of low-carbon transition, but other studies, identify a tension between mobilising local citizen investors and increasing electricity prices, which could have a countervailing impact on social legitimacy. For example, Del Rio and Bleda (2012) and Butler and Neuhoff (2008) found that total costs of incentives had significantly increased in countries such as Spain and Germany. The net costs and benefits of mobilising citizen investment is an area meriting comprehensive treatment within the context of findings from these disparate studies.

Third, the importance of early stage support for local community energy projects, while commonly acknowledged in the policy world, is not a topic that has received attention in the academic literature. What emerges from this study is that grants and soft loans have been effective at overcoming earlier stage barriers for risk-averse citizen investors. On the other hand, time-bound subsidies such as grants can lead to stop-start investment cycles (Cansino et al., 2011) arising from the sudden termination of support, rather than the creation of sustainable markets. Evaluating the use of financial incentives across project stages is a novel approach which helps develop a more nuanced picture of risk from a citizen investor perspective, and it could be built upon in future studies.

Fourth, while some challenges associated with designing market-based supports with citizen investors in mind are identified, there are few examples to draw conclusions from in practice. Future ex post studies might explore the effectiveness of market-based supports in attracting investment from citizens, as these incentives become more popular. The extent to which local citizens are put off by the greater investor risk associated with market-based incentives, including FiPs and quota-based schemes, is unclear from our research, and therefore merits further exploration.

Fifth, findings suggest that the understanding and ability to accurately quantify stranding risk may be less developed for financial sector compared to the power sector investors. The former have not developed a comprehensive appreciation of stranding risk compared to the latter, and may therefore not be in a position to fully factor this risk into investment decisions. However, there are limits to this study. It is restricted to one jurisdiction and the "snowball" methodology is exploratory in nature—it cannot therefore be assumed that responses received are representative of the views of the wider market. However, findings indicate that an information deficit may be preventing market actors from fully integrating climate risks from energy transition into the prices of financial assets, which could constitute a material risk to financial stability. Assessing perceptions of asset stranding risk from climate change from key actors across the investment chain is another area meriting further systematic research.

What ties the research together is a focus on the risk-return perception of different types of investors under conditions of rapid energy transition, including citizens and communities, but also professional investors in the power generation and financial sectors. Risk perception can alter the cost of capital for different technologies, and therefore the hurdle rates for investors, thereby radically affecting the cost and pace of energy transition. These dynamics remain understudied and underappreciated in the climate policy and climate finance field, and are areas meriting further research.

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