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A study on the implementation of renewable heating technologies in the domestic sector in Ireland with implications on consumers' decision-making

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ABSTRACT

The paper critically reviews and explores the impact of renewable energy heat policies to induce technological change in Ireland. It is in response to the challenge of better understanding the broad effects and attributes of renewable energy policy instruments in Ireland and beyond. Using the Irish residential sector as a case study, and analysing data of more than 31,600 technology installations under the Irish Government's Greener Homes Scheme [GHS], the paper assesses the extent to which policy makers may be informed of the willingness of consumers to adopt these technologies in their homes. In doing so, it attempts to provide valuable guidance for policy evaluation in relation to renewable energy in the residential sector. It represents investment decisions and technological choice by the end user and reflects the growing concern among energy policy markets regarding the representation of user preferences. The overall intent is to investigate the implications of analysing different variables and their contribution to making more balanced renewable energy policies. It provides a critical analysis of the Greener Homes Scheme, the key instrument for implementing Ireland's renewable heating policy from 2006 to 2010, established to induce technological change within the residential sector. In assessing the impact of the Scheme, attention focuses on decision frameworks for technological choice and the treatment of market and behavioural failures. It considers how consumers have responded to new technological policies aimed at deploying renewable heat technologies, and the specific policies aimed at advancing certain technologies over others. Through a case study investigation, the paper explores the relationship and dependencies that influence consumers' decision-making regarding the choice of renewable energy heating technologies in the domestic sector in Ireland. Consumer preferences and their subsequent investment decisions, motives and technological choice are reflected. It concludes that while economic factors are important, a much broader variety of determinants is required when analysing the process of adoption of technology.

1. Introduction

In moving towards the long term imperative of a carbon-free energy system, Irish energy policy makers have placed attention on accelerating the development and adoption of technologies to exploit renewable energy sources. Considering the significant growth of energy prices and the reduce availability of oil over the past decade, renewable sources are becoming more and more indispensable in the current global energy landscape. The requirement to incorporate a renewable energy portfolio can also be attributed to growth in energy demand, global warming, fluctuating fossil fuel prices (Cetin et al., 2009) and large fossil import dependency (89% in Ireland in 2009). While the end-point is carbon-free, indigenous energy inputs into a system that emphasises electricity as the carrier, the starting point involves building the confidence of consumers in the residential market through the deployment of renewable energy technologies (RET), thereby achieving an increased penetration of renewable heating in homes. An important tool to assess the viability of options is user behaviour (Natarajan et al., 2011).

The advantages of most renewable energy technologies include that, once in operation, they have no fuel costs, they exhibit very

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few unexpected outages and in several cases, less maintenance is required to keep them functioning (International Energy Agency, 2005). Accepting this international perspective, it is worth acknowledging that most RET (with the exception of large hydropower) do need some form of subsidy to compete with other technologies. Investments in RET are cost effective, resulting in significant societal benefits (Allen et al., 2008). The hope of industrial policy makers is that RE technologies will become more price-competitive once they are more developed and the external effects of CO_2 emissions are priced in. Indeed, the predominant economic approach behind most sustainable energy policies assumes that improving the cost-benefit ratio of technologies via grants and subsidies will automatically incentivise consumers to invest in renewable energy technologies (Claudy and O'Driscoll, 2008). Put within the context of the EU Climate and Energy Package, RET targets remain relative targets, in that they depend on decreasing final energy demand and deploying RET.

Significant research is based around consumers' assessment of technology choice using economic or engineering evaluation decision criterion. These studies analyse the uptake of both renewable energy and energy efficiency technologies in the residential market by addressing policy instruments through the cost of technology measures and associated technical variables. These decisions are based on cost or monetary aspects (Natarajan et al., 2011). Various studies (Jeeninga et al., 2001; Haas et al., 1998; Linden et al., 2006; Guerra Santin, 2011) have suggested that occupant behaviour exerts a strong influence on energy consumption. Indeed, "besides technical parameters, consumer behaviour is the most important issue with respect to energy consumption in households" [7, pp. 195] representing a complex interplay of socio-cultural, economic and contextual factors at play (Stieb and Dunkelberg, 2012). The Fourth Assessment Report of the Inter-governmental Panel on Climate Change on mitigation highlights the importance of 'consumer choice and the use of technology' as major determinants of energy use in buildings (Intergovernmental Panel, 2007). This also features in the theory of consumer choice of values where consumer decisions may be affected by personal factors where behaviour is influenced by functional, social, emotional and epistemic values (Van Raaij and Verhallen, 1983). This paper attempts to explore the patterns and co-occurrence of consumers' decision making regarding their choice of technology under Ireland's Greener Homes Scheme.

In establishing the Greener Homes Scheme, the focus of Irish energy policy was placed on building a renewable energy market that was based on quality, confidence and proven performance. The specific policy goal was meeting Irish renewable energy heating targets (RES-H: 5% by 2010; 12% by 2020). The overall aim was to drive a decarbonisation of energy supply, and raising standards in renewable energy products and services that were to be deployed to market. The steps on the pathway involved setting out a roadmap for maximising Ireland's ability to meet heat energy demand across residential buildings and creating consumer choice in relation to heat energy, based on reliable information and high standards throughout established supply and service chains. Energy modelling analysis predicted that the electrification of residential heating to 2020 would produce 2.7 million kt. Consequently, heating improvements within the existing building stock would afford considerable scope for reducing Ireland's energy consumption.

By early 2010, Irish Government energy policy had focused on promotion of energy efficiency measures in the residential and industrial sector. The launch of Ireland's Home Energy Savings Scheme (HESS), a grant scheme aimed at energy efficiency improvements in the residential sector, may have impacted on number of applications to GHS. The HESS brought more competition for available, yet scarce, consumer disposable income, thereby impacting on the numbers of consumers that installed RET. Enhanced marketing campaigns targeting efficiency upgrades and payback periods for homeowners were impacting upon consumers and, by end 2010, Irish consumers had installed over 64,000 energy efficiency technologies in their homes under the HESS (see Table 1), resulting in consumer expenditure of nearly €115 million directed to efficiency upgrades rather than RET installations. The Irish Government was also engaging with Ireland's dominant utility in providing both subsidized and free home energy audits for consumers wishing to avail of grant incentives for efficiency upgrades.

Lessons can be learned from the implementation of renewable heating technologies in the United Kingdom's domestic sector where hidden costs associated with RET technology featured. In addition to the high financial costs associated with the uptake of renewable heat, impact assessment analysis by Enviros for the Department of Energy and Climate Change Renewable Heat Incentive Model (Enviros Consulting, 2011) showed that investors could face significant non-financial barriers when deciding whether to invest in renewable heat (e.g. the hassle of taking fuel deliveries for biomass boilers). Consideration of such hidden and missing costs is important for all policy makers in developing RET schemes and for consumers in influencing technology selection. These costs could also include obtaining planning permission, construction management, cost of disruption, hassle cost of fuel deliveries and costs of additional works. Scott (1997) described how the lack of information, due to hidden costs, was the main reason for underinvestment in energy efficiency measures in Irish households, while Banfi et al. (2006) confirmed this in a similar study for Swiss households. Privitera et al. (2011), in describing a set of factors required to assess the viability of renewable technologies, include consideration of capital costs, maintenance costs and payback of RET investments. Often consumers are required to have access to specialist information and expert knowledge concerning the performance of various technology options, their reliability, associated costs and benefits and compatibility with existing energy systems. (Stieb and Dunkelberg, 2012).

The paper has the following aims:

- to assess the technology take-up by consumers within the Irish Government's Greener Homes Scheme, a grant-aid scheme that from 2006 to 2010 focused on the deployment of renewable energy (heat) technologies in the residential sector in Ireland [see Appendix A]
- to explore the decision-making framework for choice, evaluate policy instruments, and present an understanding of market failures.
- to analyse the various technology selection choices that were made by consumers within the Greener Homes Scheme and the relationship and dependencies that may have influenced such decisions.
- to consider the impact of various variables that may have influenced technology take-up in terms of changing consumer confidence levels in technologies and changing national economic circumstances.

Table 1
Consumer take-up under Ireland's Home Energy Savings Scheme (HESS).

HES	2009	2010	2011
Grant spend €M	16.34	45.27	56.70
% grant of total cost	35%	35%	32%
Total spend implied €M	47.2	129.3	162.0
Number of homes	18,152	45,940	48,707

It will build on work by Van Raaij and Verhallen (1983) and Guerra Santin (2011) who characterised attitudes relating to energy under variables, including price, environment concerns and comfort levels.

2. Methodology and data

This paper presents a study on the implementation of renewable heating technologies in the domestic sector in Ireland with implications on consumers' decision-making.

Data is based on successful participants under the Sustainable Energy Authority of Ireland's (SEAI) renewable energy heating scheme (branded as the Greener Homes Scheme). All dwellings underwent renewable energy improvements, such as biomass boiler, solar panel and geothermal installations. The paper's methodology is exploratory rather than confirmatory and accesses the key influences of consumer technology take-up from 2006 to 2010. It presents its analysis from the perspective of the policy maker.

As a way of exploring the relationship and dependencies that influenced consumer choice, the paper looks across the three phases of the GHS to determine the impact of three (grouped) RET, namely bioenergy, solar and heat pumps. Assuming that technological choice is driven by a number of economic variables such as energy prices, operational and maintenance costs, discount rates and market information about the efficiency of certain technological choices, the paper explores some behavioural variables that may have impact on the renewable energy policy. The paper examines the effect of various attitudinal and behavioural variables on RET selection in the Irish residential sector.

2.1. Characterization of the Greener Homes Scheme

The SEAI has the statutory responsibility for the management of schemes aimed at promoting the deployment of energy technologies and raising awareness of energy efficiency by providing information, advice and publicity on best practice in the energy environment. These schemes are designed to implement part of Ireland's sustainable energy policy, which is focused on a combination of improved energy efficiency and the wider exploitation of renewable energy. SEAI's strategic goal to 2025 states that "renewable sources represent over 40% of electricity supply, within an active, smart grid, with newer sources such as ocean starting to show a significant contribution renewable sources for heat are the norm" (Sustainable Energy Authority of Ireland, 2010a).

Today, like most industrialised countries, renewable energy technologies in Ireland are supported by government policy schemes and subsidies to bring this option to the market. In 2006, SEAI established the GHS. This scheme enabled new RET to become available on the Irish market that could reduce carbon emission dioxide emissions and slow resource depletion. As wind power approached the stage of commercial operation in Ireland, renewable energy for heating technology was also regarded as a high potential energy source, but one which came at a high cost of supply. This had two important consequences on public opinion: (ii) It prevented the widespread update of renewable energy systems regardless of their environmental soundness and (ii) it placed a requirement for public funding to support RET development. The Irish Government assumed that, as consumers became positively aware of the ability of RET to mitigate environmental damages, they would attach a value to RET and influence their willingness to pay. These findings were also recorded in the Italian market where the residential sector's willingness to pay would augment the premiums that they are potentially appropriate to pay for such new technology and, potentially, reduce the needed amount of public funding (Bollino, 2009). Indeed, this is the approach being adopted by SEAI, post 2010, as it plans the introduction of a Pay as You Save scheme.

The GHS's first intervention in 2006 involved supporting householders wishing to install renewable-energy heating technologies, including wood pellet and chip stoves and boilers, solar panels and geothermal heat pumps in their homes. The programme aimed to facilitated the wider deployment of RET in the residential sector and support the development of a sustainable heat market, resulting in reduced dependence on fossil fuels and in lower CO_2 emissions. By the end of 2009, the GHS resulted in the installation of over 26,600 renewable energy heating technologies in homes across Ireland, with cumulative expenditure of € 66.91 m. This extended to 31,150 by end 2010. Residential energy use had decreased by 2.7% in 2009. When corrections for climate effects are taken into account the decrease was 2.9%, energy consumption per household was 5.3% lower in 2009 than in 2008.

2.2. Characterization of the residential sector in Ireland

Ireland aims to reduce Non-Emissions Trading Scheme sector CO_2 emissions (primarily residential, services, transport, and agriculture) to 20% below 2005 levels by 2020. In Ireland, alongside many industrialized countries, the residential sector accounts for more than 24% of energy consumption, the overwhelming share of which is consumed for space heating and hot water preparation. Placing this in a global perspective, commercial and residential buildings consume about 30% of global electrical energy consumption (Prasartkaew and Kumar, 2010) and over 50% of carbon dioxide emissions come from the building sector, with solar energy technology expected to 50% of total energy consumption in buildings by 2010 (Rezaie et al., 2011). Within the European Union, the building stock is responsible for about 40% of primary energy consumption and about 25% of the CO_2 emissions (Uihlein and Eder, 2010; OECD/IEA, 2008).

Within Ireland residential final energy use grew by 37% (1.7% per annum) over the period 1990–2009 [to a figure of 3.1 Mtoe] (Fig. 1). During this time the number of households in the State increased by 53% from approximately 1.0 million to 1.5 million (Central Statistics Office, 2007).

Table 2 (Sustainable Energy Authority of Ireland, 2010b) highlights the significant changes that have taken place in Ireland, since 1990, in the fuel mix in the residential sector. New houses built in the 1990s predominantly had oil or gas-fired central heating and there has also been a recent trend to convert existing back-boiler systems to either oil or gas. It is estimated that the building sector is responsible for more than 40% of energy use in most countries, thereby offering a significant opportunity to mitigate greenhouse gases (World Business Council for Sustainable Development, 2009). Table 2 displays the significant deployment of direct renewable energy usage in households in Ireland. Indeed, this Table also depicts a reduction in RET deployment from 1990 to 2000 as consumers abandoned using solid fuel to heat their homes and installed central heating. However, by 2009 RET usage had increased by 19%, equivalent of 52,000 t of oil (ktoe). The Irish residential sector was the second largest (after transport) and energy-related CO_2 emissions were 11,557 kt CO_2 representing 27% of the total (energy related) emissions (Sustainable Energy Authority of Ireland, 2010b).

2.3. Data collection, analysis, programme expenditure and overall installations

SEAI provided anonymised application data for over 31,600 technology installations under the Greener Homes Scheme was obtained across three phases. A database was developed where

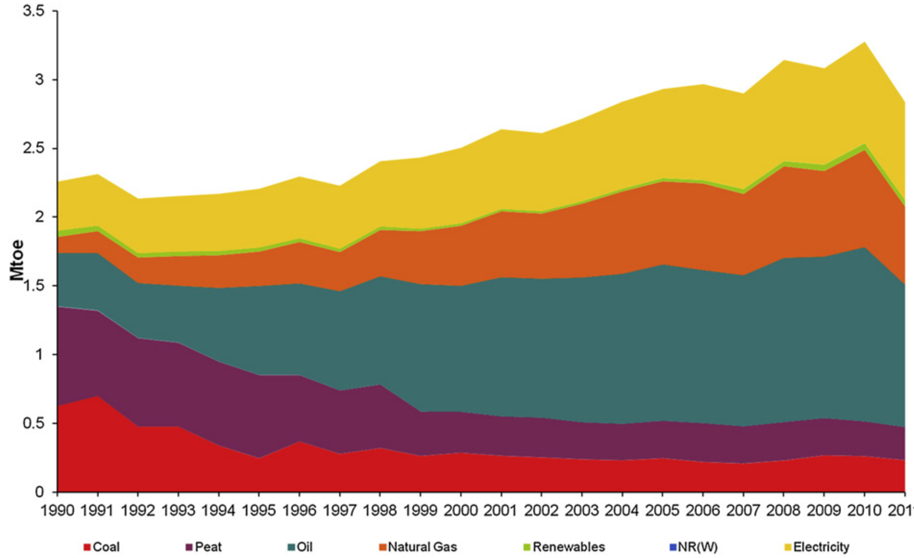

Fig. 1. Residential final energy use by fuel (Sustainable Energy Authority of Ireland, 2010).

data was organised into three distinct 'calendar' phases in which the GHS was delivered from March 2006 to December 2010: (a) Phase 1 (04/2006–09/2007) (b) Phase 2 (09/2007–09/2008) and (c) Phase 3 (09/08–12/10). To ensure sufficient data was available on measure or technology type (see Table 3), property type, grant type and amount and property age, only grant beneficiaries were included. The data was cleaned to remove applicants that had accepted the grant offer but had not drawn down the offer within the programme timescale.

Findings were extrapolated from the technologies that consumers applied for through these three phases. This enabled an analysis of consumer take-up by renewable energy technology. Technology uptake was categorised by technology type and numbers of technologies deployed by phase. Technology types applied for under each phase were also placed into subcategories of grant type. For example, a heat pump (technology type) was subcategorised into three grant types, namely vertical ground collector, horizontal ground collector, and air source.

Changing financial support levels, associated with grants, were mapped and analysed by technology type and by programme phase. The database also captured changing (non financial) conditions associated with eligibility of applicants to the GHS. Further exploration was made of changing consumer confidence levels in technologies and the impact of hanging national economic circumstances.

An analysis of the data of more than 31,600 applications (see Tables 4 and 5) reflects a significant deviation in technology take-up across the three phases of the GHS. This equated to an investment of over €73 million of government exchequer financing, equating to approximately a 30% grant aid investment.

A number of techno-economic variables were identified as determinants for technology choice. From a (technical) non-economic perspective variables included the perceived confidence in an available technology, technology support and maintenance systems and suitability. From an economic perspective variables included the availability of 'grant-based' financial assistance, the hidden costs associated with technology installation, overall project costs and level of disposable income of homeowners. For example, the residential sector responded very favourably to the introduction of biomass [boilers and stoves] in Phase 1, but did not engage in similar levels of technology take-up in Phases 2 and 3. Indeed, using solar technologies and low grade heat technologies, such as biomass, contribute to a significant reduction in CO_2 emissions (Prasartkaew and Kumar, 2010). This reflects the case study findings from Rezaie et al. (2011) where solar panels were identified as a good choice to heat domestic water due to their ease of installation and low maintenance costs.

3. Results and discussion

The results of this paper add considerably to the understanding of technology choice in the domestic sector. Through a case study investigation and analysis of over 31,600 applications, we draw conclusions that consumers responded to the introduction of the

Table 2
Growth rates and shares of final consumption in residential sector (Sustainable Energy Authority of Ireland, 2010b).

	Growth %	Average annual growth rates %						Shares %	
	1990–2009	'90–'09	'90–'95	'95–'00	'00–'05	'05–'09	2009	1990	2009
Fossil fuels (Total)	27.1	1.3	−1.1	2.2	3.2	0.8	−1.9	82.3	76.2
Coal	−59.0	−4.6	−17.0	3.0	−3.0	1.1	12.4	27.7	8.3
Peat	−62.5	−5.0	−3.5	−13.2	−1.8	−0.1	−2.9	32.1	8.8
Briquettes	−33.5	−2.1	−5.0	0.0	−5.5	3.4	−2.6	6.9	3.3
Oil	209.8	6.1	10.9	7.3	4.6	0.9	−1.8	17.3	39.0
Gas	432.7	9.2	16.5	11.8	6.7	0.7	−6.6	5.2	20.2
Renewables	17.1	0.8	−7.8	−10.4	7.9	20.1	18.9	2.0	1.7
Combustible fuels (Total)	25.6	1.2	−1.2	2.0	3.2	0.9	−1.7	84.2	77.1
Electricity	92.4	3.5	3.7	5.1	3.3	1.5	−6.5	15.8	22.1
Total	37.2	1.7	−0.4	2.6	3.3	1.2	−2.7		
Total climate corrected	36.9	1.7	0.2	2.1	4.0	0.2	−2.9		

Table 3
The various measures included in GHS.

Measures under GHS	Technology type
	Air source heat pump
	Ground source heat pump
	Vertical ground collector heat pump
	Well to water heat pump
	Biomass Boiler
	Biomass stove
	Biomass stove with backboiler
	Wood gasification boiler
	Solar tube (evacuated)
	Solar flat plate
	Solar thermal (Heating & Space)

GHS by choosing and advancing certain technologies over others. We explore a number of factors that may have influenced consumer behaviour in their take-up of technologies. While the provision of grant assistance to consumers and subsequent changing of grant conditions may have influenced RET decisions, thereby achieving the desired market (barrier eroding) effect for policy makers, our analysis shows that a number of variables may have also influenced and impacted upon consumer behaviour. These variables including changes to (non-financial) conditions associated with eligibility of applicants to the Scheme, confidence levels of selective RET, RET product supply chains, uncertainty surrounding security of supply and the impact of the green agenda. This paper's analysis is presented across the GHS's three programme phases.

3.1. Technology take-up by phase, changing support levels and eligibility conditions

3.1.1. Phase 1

Heat pumps, biomass boilers and solar thermal for heating and space constituted significant technology take-up by consumers in Phase 1 of the GHS (see Figs. 2 and 3). Geothermal technologies, including air, vertical and ground source heat pumps, introduced in Phase 1, experiencing limited success in terms of consumer take-up.

From the commencement of the GHS and throughout Phase 1, bioenergy boilers and stoves were the most successful technology deployed in Irish homes. Biomass boilers were introduced into the Irish market on a large scale in 2006. Consumers opted for biomass boilers and stoves rather than geothermal or solar panels. SEAI financial assistance/grants targeted this technology over solar technology in Phase 1 with over 4500 successful bioenergy deployments in Phase 1. Growth in this technology was aided by the lack of grant support for solar tube or flat plate in Phase 1. Furthermore, the availability of fuelling sources, such as wood pellets and woodchips, were actively communicated through media channels. A significant industrial supply chain was established that promoted and installed bioenergy boilers throughout 2006 and 2007.

Consumer take-up of bioenergy technologies changed towards the end of Phase 1 of the GHS. Given the high technology take-up of bioenergy technologies in Phase 1, it is understandable that a slight shift in technology take-up may occur in subsequent phases as many of the early adopters had applied for support for bioenergy, resulting in a reduced pool of willing consumers to apply for grant assistance in Phases 2 and 3.

Research case studies have also explicitly referred to the importance of the institutional and market conditions surrounding where the technology is deployed (Greening and Bernow, 2004). Support systems for RET in 2006 were immature and not prepared to match RET take-up in phase 1 of the GHS. Local enterprise product support regimes for bioenergy technologies were not in place in Ireland when mass RET were deployed. By the time the market had responded and put in place bioenergy product supports, confidence in bioenergy, as a technology, had eroded. Concerns were raised surrounding the quality factors for both wood chip and pellets, including moisture content, chip size and contaminants, durability, calorific value and ash content and the requirement for a certification system to be put in place.

Table 4
Planned costs, out-turn and number of installations for the scheme for 2006-2009.

	2006	2007	2008	2009	2010	Total
Planned costs €m	4.9	28.2	22.5	12.35	6.0	73.95
Outturn €m	5.04	27.67	22.55	11.65	6.3	73.21
No. installations	1338	8387	9643	7311	4957	31,636

3.1.2. Phase 2

The take-up of both geothermal and biomass technologies (bar solar thermal which was stopped after Phase 1) had significant fall off in Phase 2 and Phase 3.

Our analysis shows a significant deterioration in take-up of bioenergy technologies beyond Phase 1 with technology take-up of less than 500 technologies across the three bioenergy technology types in Phase 2 (See Table 5). One of the potential reasons for this shift in consumer choice may be a change in GHS grant support criteria for consumers installing bioenergy in Phase 2. Since many possibilities existed for the combining of different renewable technologies, the associated capital installation costs of installation vary widely (Uihlein and Eder, 2010). The grant support levels available for bioenergy reduced from €4200 to €2500 (boiler), from €1100 to €800 (stove) and from €1800 to €1400 (stove with backboiler) (See Table 6).

A competing technology to bioenergy, namely solar, was introduced into the GHS at the commencement of Phase 2, resulting in the number of grants deployed to solar technology in the residential sector increasing throughout phases 2 and 3 of the GHS. Data analysis [per annum] shows that RET, such as solar tubes and flat plates, introduced at the commencement of Phase 2 of the GHS, experienced considerable growth throughout Phase 2 and Phase 3. Furthermore, consumers responded favourably to the introduction of biomass [boilers and stoves] in Phase 1, but did not engage in similar levels of technology take-up in Phases 2 and 3. Indeed, using solar technologies and low grade heat technologies, such as biomass, contribute to a significant reduction in CO_2 emissions (Prasartkaew and Kumar, 2010). Unlike in Phase 1 with bioenergy, in phase 2, when mass solar technology was deployed, a rigorous product support scheme had been developed thereby providing confidence in solar technology to the market.

Throughout Phase 2 and 3 of the GHS, the average installation costs of solar significantly reduced from €7000 to €3,400, thereby stimulating uptake, while the grant levels available to consumers did not significantly reduce. Table 5 displays the growth in the number of grant deployed to solar technology in the residential sector. Table 5 displays the significant alteration in grant supports across the three geothermal technologies throughout the phasing of the GHS, with grant reductions of 40–50%.

A number of eligibility criteria were added into the GHS by SEAI in Phase 2. For example, in order to be eligible for grant assistance in Phase 2, homeowners must have occupied their homes prior to June 2008. While this change in eligibility criteria may have impacted upon the take-up of bioenergy technology from its introduction in Phase 2, it does not explain the continued growth in solar tube and flat-plate technologies post the changes to eligibility criteria. Rather it could be argued that, given installation of

Table 5
Number of grants by technology.

	Phase 1 (04/06–09/07)	Phase 2 (09/07–09/08)	Phase 3(09/08–12/10)	Total
Air source heat pump	625	271	168	1064
Ground collector heat pump	2433	722	91	3246
Vertical ground collector heat pump	897	371	93	1361
Well to water heat pump	82	33	17	132
Biomass boiler	3487	214	155	3856
Biomass stove	608	237	300	1145
Biomass stove with backboiler	457	21	144	622
Wood gasification boiler			125	125
Solar tube (evacuated)		1770	4545	6315
Solar flat plate		3208	4501	7709
Solar thermal (heating & space)	5584			5584
Total	14,173	6847	10,139	31,159

bioenergy technology is limited to houses with access and storage facilities, post Phase 1, there was a reduced available market share for this technology.

In analysing consumer take-up of RET we analysed the utility associated with each technology and identified a number of suitability factors. The suitability of bioenergy technology to mass consumers is questionable: for example, a 3 tonnes bulk storage unit is often required to ensure the fuel source remains moisture free and consumers express air quality concerns surround biomass combustion. The maximisation of the value of bioenergy technology deployment is related to proximity to the supply chain of bioenergy pellet and chip providers (within a 100 km radius). This may have also reduced the potential market for technology uptake across Phase 2 and 3. A more mature market highlighted the disadvantages of geothermal as a RET in its inability to produce the required grade of heat.

As part of its governance function, SEAI, as the managing authority of the GHS, developed an inspection systems and installer registration regime and this had become more rigorous in Phase 2. SEAI identified gaps in the capacity of installers to install technologies in line with GHS guidelines and established a mandatory training for installers (after Phase 1). Strengthened inspection regimes and associated training initiatives aimed to encourage best practice to installation and remove unscrupulous installers that were identified throughout the early stages of the GHS. In 2006, it was planned that 10% of installations were to be inspected each year. By December 2009, 2255 inspections had been completed which represents 8.5% of all installations. Inspections found that 1477 installations or (65% of all work inspected) required a revisit and resolution by the installer (see Table 7). The approach taken to inspection was a risk-focused approach. The results of inspections fed into training programmes, continuous development workshops for installers, newsletters for installers identifying common reasons for rework and identifying remedies. Combined with the introduction of mandatory training in 2008, this had led to a reduction in the level of rework following inspections in later years of the scheme. It provided confidence to consumers who wished to apply for grant aid and deploy RET.

3.1.3. *Phase 3*

Of the systems installed by Phase 3, in 2009, solar technology systems proved the most popular with about three quarters of all homes opting for this RET. If consumers were making decisions based on investment costs alone (excluding performance metrics), solar water panels provide the lowest upfront cost, especially for a residence with high energy consumption and so could be seen as the most attractive technology choice.

Throughout the three phases of the GHS, the average costs of solar significantly reduced from €7000 to €3,400, thereby stimulating uptake, while, unlike bioenergy, the grant levels available did not significantly reduce. The reducing cost of solar was a worldwide trend as the panels achieve mass deployment (Lawrence Berkeley National Laboratory, 2009). Furthermore, the installation of the size of solar panel being deployed by consumers had reduced in size, mirroring the economic downturn in Ireland. This development reflects microeconomic theory where the Homo Econmicus seeks to maximize utility within given budget constraints (Claudy and O'Driscoll, 2008).

Solar technology is seen as being passive by reputation (it does not require fuel to be sourced), is readily accessible, and by Phase 3 market confidence in solar as a technology was high, especially when compared to other RET such as bioenergy and geothermal

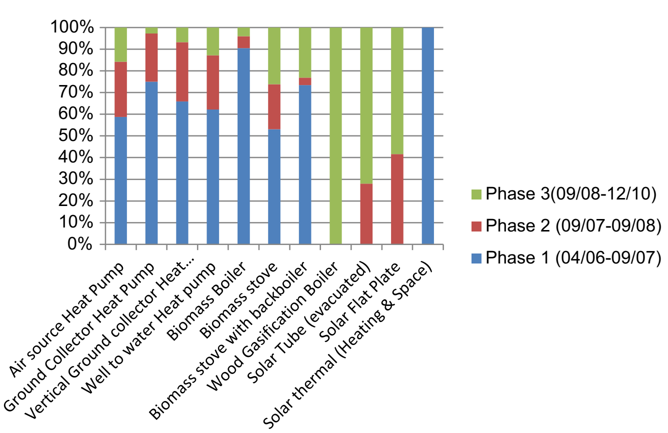

Fig. 2. Technology take-up by phase.

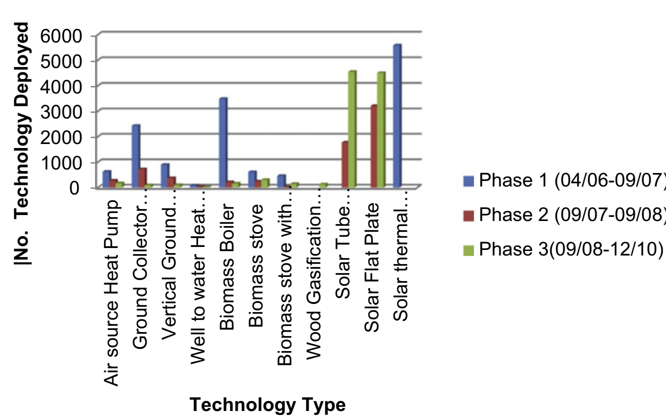

Fig. 3. RET by Phase as % of total RET.

Table 6
Grant support/financial assistance by RET across phases.

	Phase 1 (04/06–09/07)	Phase 2 (09/07–09/08)	Phase 3 (09/08–12/10)
Air source heat pump	€4000	€2000	€2000
Ground collector heat pump	€4300	€2500	€2500
Vertical ground collector heat pump	€6500	€3500	€3500
Well to water heat pump	€4300	€2500	€2500
Biomass boiler	€4200	€3000	€2500
Biomass stove	€1100	€1100	€800
Biomass stove with backboiler	€1800	€1800	€1400
Wood gasification boiler			€2000
Solar tube (evacuated)		€1206	€1187
Solar flat plate		€1324	€1274
Solar thermal (Heating & Space)	€1639		

energy. Further research [20, pp 60] noted that, for domestic buildings, "a geothermal system is the most reliable energy system, which requires specialized initial installation, but with low maintenance cost". Indeed, from a solar panel perspective, the cost of a fully installed solar energy system varies. Often the variables include: (a) age of roof provides an added cost of solar installation. (b) depending on the type of solar panel installed, the consumer's per-watt cost will vary. Research conducted by Rezaie et al. (2011) found that, based on a number of case studies that analysed energy options for detached residential buildings, solar thermal options for hot water and space heating were the most cost effective, while ground source heat pumps were attractive in terms of environmental impacts, yet require significant maintenance.

There are two possible competing reasons that impacted upon solar panel take-up in Phase 3 of the scheme: The price of oil significantly fell from 2008 to 2010 (See Fig. 4), thereby potentially impacting consumer choice towards deploying solar for security of supply reasons, and this, coupled with the ease of solar deployment may have shifted trends in consumer takeup. This, coupled with mature supply chain systems and the flexibility of technology deployment (in scale) may also have been a factor The environmental agenda and associated considerations were heavy on societal consciousness, potentially making the external visibility of solar panels very attractive for consumers. This could be linked to the consumers' conditional value and epistemic value of their selected technologies where consumer behaviour and RET choice could be linked to the RET novelty (Lin and Huang, 2012). Empirical research describes how such "behavioural factors explain a great amount of variation in pro-environmental behaviour and provide valuable insights for policy makers and analysts" (Claudy and O'Driscoll, 2008; Stern, 1986; Bang et al., 2000). Stieb and Dunkelberg describe how consumers motives and goals concerning low carbon technology adoption include a willingness to contribute to climate protection, to become less dependent on fossil fuels or to support a low-carbon lifestyle (Stieb and Dunkelberg, 2012). Quigley and Rubenfeld (1989) analysis addresses the effect of changes in energy prices on the consumption of housing, residential energy and other goods.

Table 7
Inspection and severity levels of issues.

	2006	2007	2008	2009	Total to end 2009
Level 1a	21	81	105	36	243
Level 2b	124	419	399	292	1234
Level 3c	31	125	126	131	413
No issues		116	134	115	365

a potential health and safety risk, required return visit.
b matters that have capacity to impact the system performance, required return visit.
c issues identified to installer, not requiring return visit.

Uitdenbogerd (2007) describes how the household decision determinants may not focus on whether to adopt a sustainable energy technology, but rather what version of type of the technology should be chosen. The decision to opt for solar above both geothermal and bioenergy as the consumer choice of RET reflects the case study findings from (Rezaie et al., 2011) where solar panels were identified as a good choice to heat domestic water due to their ease of installation and low maintenance costs. Indeed, contrary to the findings of Rezaie et al. (2011), where reliability and cost effectiveness were strengths of geothermal, Irish consumers elected more towards solar, potentially based on a shift towards building retrofitting rather than new build development.

Significant consumer confidence issues impacted upon bioenergy as a fuel source in 2008 and 2009. This confidence may have eroded due to the fuel versus food bioenergy debate and debates concerning the security of supply and availability of bioenergy products as an energy resource in Ireland as wood fuel availability decreased in 2008/2009. Indeed, the increasing penetration of RET has caused concerns over the inconsistency of supplies (Uitdenbogerd, 2007). Confidence levels were further eroded due to a lack of infrastructure (Breen, 18 November 2008) and technology support in the market and a small number of deaths resulting from wood pellets. This aligns with research conducted by Stieb and Dunkelberg (2012) where the adoption of low carbon technologies were not solely driven by economic considerations alone, rather personal and contextual socio-cultural factors (including education, income and age) influence consumers decisions.

New build applicants were restricted from applying for financial assistance/grants across the technologies in Phase 3. Undoubtedly, consumer take-up of both bioenergy and geothermal technologies is more attractive for consumers when entering into new build of their home rather than retrofitting an existing home. This may also explain the low levels of take-up of both technologies. Indeed, across the three phases, geothermal heat pumps were seen by the market as an expensive (in terms of upfront cost) technology for large extensions and for non occupied homes. This reflects work by Kempton and Montgomery (Kempton and Montgomery, 1982) concerning energy efficiency technology take-up. They found that consumers apply heuristic approaches to decide on their energy use in which purchase costs are ascribed a higher priority than the common determinants of technology choice, namely operational costs and resulting savings. Indeed, the importance of these common determinants is often not fully comprehended by consumers (Mundaca et al., 2010; Levine et al., 2007) as non-economic determinants drive consumers' energy-related decisions regarding technology choice. This is especially relevant for energy efficiency technology choice where determinants include improved comfort, noise reduction, functionality, performance, quality, reliability, and design (Mundaca et al., 2010; Levine et al., 2007; Mills and Rosenfeld, 1996; Lutzenhiser, 1993).

It is plausible to assume that changing market and economic circumstances impacted significantly on the consumer choice of RET. When the GHS was launched in 2006, Ireland was at its peak of its economic 'boom' and the economic downturn commenced in Phase 3 (2008/2009). Taken on its own merit, reductions in various technology choices could be mirrored with Ireland's economic circumstances and consumer disposable income levels. The changing economic circumstances impacted on householders' perceived personal capabilities and associated financial resources. This is also reflected in research conducted by Stieb and Dunkelberg

Fig. 4. Changing price of oil over GHS phases (U.S. Energy Information Administration, 22 November 2012).

(2012) who identified how the unwillingness for consumers to go into debt and the lack of available financial resources present serious hindrances to low carbon technology adoption. This is contrary to research that found that technology quality and price are not significant impacts on consumer choice behaviour as consumers are increasingly willing to pay more for green products [128].

3.2. Market barriers influencing technology uptake

Any analysis of consumer takeup of RET policies requires a focus on decision frameworks for technological choice and an understanding of market and behavioural failures.

The potential adoption of low carbon technologies is the result of an alliance of economic and non-economic motivations and considerations, including personal factors associated with attitudes and motives including economic, ecological and technical concerns (Stieb and Dunkelberg, 2012). There are numerous non-economic determinants affecting technology choice, including non energy benefits such as performance, reliability, quality systems and design (Stern, 1986). Indeed, SEAI had focused attention from 2005 to 2006 in eroding some of the misperceptions surrounding renewable energy technology and improving consumer confidence. These misperceptions focused on technology cost, reliability and performance, technology maturity, impact on energy demand and availability of raw materials/fuels within the Irish market. Researchers have determined how different knowledge, environmental feeling and social class are crucial determinants of individual preferences (Roe et al., 2001).

Individual valuation process is often pervaded by uncertainty (Wang, 1997). While the decision to deploy renewable energy technology, especially linked to the GHS, may be driven by two determinants, investment costs and the savings from reduced energy, the household choice is difficult to anticipate due to several uncertainties. These uncertainties surround expectations of future energy prices, and many households may face information deficits as well as high costs of information acquisition concerning various renewable energy technologies to be deployed in homes. This may explain the take-up of solar technologies throughout the life of the GHS while take-up of bioenergy technology significantly diminished.

Consumers' real world decisions deviate from ideals of preference maximisation ('bounded rationality'). Often, throughout their technological choice, consumers fail to consider hidden costs associated with a technology (such as noise and dirt from technology deployment), leading to heterogeneity with respect to the household's net benefits. One of the many assumptions made by the United Kingdom's Department of Energy and Climate Change on their study relating Renewable Heating Incentives (Element Energy and Enviros, 2011), referred to up-take of renewable technologies being highly dependent on the relative costs of heat generation from a renewable source compared to conventional fossil fuel heating. Within this there are a number of hidden costs specifically relevant to installing a bioenergy chip pellet boiler. These hidden costs range from €946 to €4133 and are much smaller than the equivalent costs for solar tubes and panels, ranging from €571 to €1746 (see Figs. 5 and 6). These RET assumptions are based on costs, performance and suitability characteristics, fuel costs, RET supply chain capacity, the extent and cost of overcoming non-financial barriers.

Whereas capital and operational costs are certainly relevant, they do represent only a part of the determinants that drive consumers' energy related decisions regarding customer choice (Mundaca et al., 2010). In considering adoption of RET, and associated energy improvements in the residential sector, many consumers are not aware of the market barriers associated with take-up. These may include the costs of maintenance, fuel availability, and information asymmetries. The predominant economic approach behind government policies assumes that the abolition of these market barriers will incentivize householders to invest in RET (Sorrell et al., 2004). This implies that the same framed policies have a great understanding of consumer needs and behaviours. Furthermore, uncertainty prevails throughout decision making as "the individual is able to express preferences or evaluation of some good or service in a way that is not mathematically or certain" [18. p. 85]. Due to prevailing market barriers, consumers may not minimise the costs of obtaining energy services, may be misinformed and may have trouble when making 'correct choices' when given full information.

Changing market and economic circumstances impacted significantly on the consumer choice of RET. This is what Stern

Hidden Cost		Low	high	units	Calculation	Cost (€/installation) Low	high
Project Identification		0.5	2	Hrs	Hours * time cost	€ 2.87	€ 11.48
Research & Scoping		5	20	Hrs	Hours * time cost	€ 28.70	€ 114.81
Construction and installation	Construction management	5	15	Hrs	Hours * time cost	€ 28.70	€ 86.11
	Additional Engineering	5%	10%	Of capital costs	% * capex * plant size	€ 600.00	€ 1,200.00
Hassle Costs	Production Disruption	0%	0%	Of capital costs	% * capex * plant size	€ 0.00	€ 0.00
	Space for fuel tank/water t	1	1	yes/no	space cost * footprint	€ 285.84	€ 1,084.55
	Spare	1	1	yes/no	standard cost	€ 0.00	€ 1,636.23
	Garden being dug up?	0	0	yes/no	standard cost	€ 0.00	€ 0.00
Ongoing management		0	0	Hrs/yr	NPV of (hours * time cost * lifetime)	€ 0.00	€ 0.00
biomass boiler					Total included Cost	€ 946.11	€ 4,133.17

Fig. 5. Hidden costs associated with a biomass chip pellet boiler.

Hidden Cost		Low	high	units	Calculation	Cost (€/installation) Low	high
Project Identification		0.5	2	Hrs	Hours * time cost	€ 2.87	€ 11.48
Research & Scoping		5	20	Hrs	Hours * time cost	€ 28.70	€ 114.81
Construction and installation	Construction management	5	15	Hrs	Hours * time cost	€ 28.70	€ 86.11
	Additional Engineering	5%	10%	Of capital costs	% * capex * plant size	€ 225.00	€ 450.00
Hassle Costs	Production Disruption	0%	0%	Of capital costs	% * capex * plant size	€ 0.00	€ 0.00
	Space for fuel tank/water t	1	1	yes/no	space cost * footprint	€ 285.84	€ 1,084.55
	Spare	0	0	yes/no	standard cost	€ 0.00	€ 0.00
	Garden being dug up?	0	0	yes/no	standard cost	€ 0.00	€ 0.00
Ongoing management		0	0	Hrs/yr	NPV of (hours * time cost * lifetime)	€ 0.00	€ 0.00
					Total included Cost	€ 571.11	€ 1,746.94

Fig. 6. Hidden costs associated with installing solar tubes and panels.

(Stern, 2005) has described as ‘contextual factors’ and ‘personal sphere variables’. It is further explored by Natarajan et al. (2011) using Van Raaij and Verhallen’s behaviour model (Van Raaij and Verhallen, 1983), who identified that consumer uptake of a particular technology (here, double glazing) was influenced by three factors: (a) household income, (b) installation by neighbours, and (c) government policy in the form of fiscal incentives stimulate uptake.

4. Conclusion

This paper analyses the implementation of ‘Greener Homes Scheme’ from a policy makers perspective and explores how the Scheme was implemented and draws conclusions and lessons that will inform policy in Ireland by describing the co-occurrence of variables that influence choice during the implementation of the Scheme. It explored the relationship of variables that influence consumer behaviour and technology take-up across the Scheme. In doing so, it provides insight to policy makers when developing similar renewable heating programmes in other jurisdictions. In exploring the relationship of these variables insight into the representation of end user preferences and their subsequent investment decisions and technological choice is provided.

Our research found that Irish government energy polices tend to target GHG emission reductions and the achievement of energy savings without a full understanding of the determinants that consumers consider when making technology choices, not alone from fossil to renewable technology but also the nature of the renewable technology when compared to other technology types.

Economic factors are important when choosing RET, a much broader variety of determinants is required when analysing the process of adoption of technology. The issue of heterogeneity of actors and their preferences remains misunderstood by policy makers, along with the multi-agent decision nature of technology choice and interaction and complexities of household behaviour. In their attempts to make policy and set technology related goals across sectors, policy makers should consider both economic and non-economic determinants when delivering technology deployment schemes. A broad variety of determinants is required when analysing the process of adoption of technology. These could include social determinants, product reliability, product support systems, consumer confidence, environmental impact assessment and environmental awareness.

Policy makers need to consider how consumers will respond to certain technologies over others. As a result, future Government policy aimed at developing RET policies should consider how household behaviours, environmental impact assessments, decision making choice frameworks and associated market barriers lead to uncertainty. Indeed, a questionnaire survey targeting consumers could be considered to assist in determining the various influences on consumers’ decision to deploy RET.

Undoubtedly there is a level of uncertainty in representing the attitudes and decision making processes of Irish consumers. It has not been possible to gather Irish-specific empirical data (using surveys) to validate the assumptions within this paper and we recommend that further work is possibly undertaken in this area to provide additional confidence to this paper’s analysis.

Appendix A. Greener Homes Scheme

The Greener Homes Scheme was established in 2006 to provide grants for the installation of certain renewable energy technologies.

It had a planned duration of five years. The objectives of this scheme were to

- increase the number of households in Ireland that use renewable energy heating
- guide consumers and enhance awareness of renewable energy heating choices
- ensure that the market for the products, services and fuel continues to develop in a robust manner
- decrease Ireland's reliance on imports of fossil fuels benefit the environment by reducing emissions of carbon dioxide.

Budget

The budget for the Greener Homes Scheme for the period 2006–2010 was €27 million. The budget allocation increased to €57 million in 2007 to take account of higher than anticipated demand levels.

Eligible technologies

Technology installations in this category can include solar heating panels, heat pumps, wood chip\pellet stoves\boilers and wood gasification boilers. The level of grant support varied from €800 to €3500 per installation. An installer registered with SEAI must carry out installations. These installers have received qualifications under training schemes approved by Further Education Training and Awards Council.

Implementation arrangements

Applicants apply directly to SEAI for a grant. When they receive SEAI approval they may then proceed with the installation. The applicant hires an installer. The installer carries out the work and certifies that work performed meets the required standards. Payments are made directly to the applicants on foot of documented claims and installer's certification.

Outturn and costs

In 2009, the budget allocation for the scheme was €68 million. As at the end of 2009 a total of €67 million had been spent.

SEAI role

In delivering the GHS, SEAI adopted roles as an agency, academy and activator. It was required to ensure its new renewable heating programme was delivered effectively and efficiently (the agency role), that the necessary capacity and standards (academy role) were build whereby product and technology installers had access to appropriate training. Finally, and most importantly, government had to engage with energy consumers, raise awareness of the renewable energy product offering and change behaviours (the activator role).

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