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Changes to the energy policy landscape and potential impacts on Scotland's consumers: Distributional impact modelling

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Executive summary

This study, completed in 2019, looks at the consumer impacts of future changes in the energy landscape. It builds on work mapping out these changes and reviewing the literature on consumer impacts – both positive and negative. The research was commissioned by ClimateXChange on behalf of the Scottish Government Energy and Climate Change Directorate.

We have modelled the distributional consumer impacts – or who will be impacted, where, and by how much – across a subset of key policies. Impacts are presented by consumer segmentation type, employing a bespoke segmentation model developed for the Scottish Government for this purpose.

Key policies

Time of Use (TOU) tariffs are one of the first ways in which consumers can start to use the full functionality of smart meters. We use evidence on who is likely to take up smart meters and TOU tariffs – generally older, affluent, risk-averse home owners – together with the benefits of doing so (lower bills), to model impacts.

Research suggests **electric vehicles (EVs)** are currently popular with a small subset of the population (mainly affluent males), yet we all share the costs of upgrading the network to accommodate the charging infrastructure.

We look at **Low carbon technologies in the home**, e.g. installation of heat pumps and solar PV panels. This draws on available evidence suggesting that there is a bias towards financially well-off households who can afford the high up front capital, unless this is counter-balanced by grant support and / or investment by social housing providers (who have installed significant numbers of air source heat pumps).

Key findings

Table E1 – Uptake of TOU tariffs and EVs

Energy consumer archetype	Uptake	TOU Proportion of archetype (projected by 2025)	EV Proportion of archetype
Archetype 1: Single low income renters using electricity for heating	No	89%	99.0%
	Yes	11%	1.0%
Archetype 2: Urban very low income single older adults	No	94%	98.8%
	Yes	6%	1.2%
Archetype 3: Switched on wealthier couples and families	No	60%	95.0%
	Yes	40%	5.0%
Archetype 4: Families or younger couples in urban areas	No	87%	98.3%
	Yes	13%	1.7%
Archetype 5: Wealthy rural families	No	68%	94.9%
	Yes	32%	5.1%
Archetype 6: Older urban couples who own their homes outright	No	76%	97.5%
	Yes	24%	2.5%
Archetype 7: Urban social renters with long term health problems	No	88%	99.4%
	Yes	12%	0.6%
Archetype 8: Rural, less affluent older adult households	No	81%	98.1%
	Yes	19%	1.9%
All households	**No**	**79%**	**97.5%**
	Yes	**21%**	**2.5%**

Table E2 – Anticipated uptake of heat pumps and solar PV systems by 2025

Energy consumer archetype	current heat pump (all) (%)	future heat pump (all) (%)	Proportion of current solar PV installations (%)	Proportion of projected future solar PV

				installations by 2025 (%)
Archetype 1: Single low income renters using electricity for heating	48%	44%	7.7%	0.0%
Archetype 2: Urban very low income single older adults	3%	2%	6.0%	0.0%
Archetype 3: Switched on wealthier couples and families	4%	11%	25.8%	68.4%
Archetype 4: Families or younger couples in urban areas	5%	5%	5.9%	10.2%
Archetype 5: Wealthy rural families	14%	14%	7.4%	7.0%
Archetype 6: Older urban couples who own their homes outright	9%	8%	23.6%	8.5%
Archetype 7: Urban social renters with long term health problems	0%	0%	3.4%	3.5%
Archetype 8: Rural, less affluent older adult households	17%	16%	20.0%	2.4%
All households	**100%**	**100.0%**	**100.0%**	**100.0%**

Conclusions

Having financial resources and being less risk-averse are likely to be significant factors in determining whether energy consumers will participate in the evolving smart energy market and adopt newer energy technologies. As a result, benefits from new technologies and energy market solutions are likely to favour those with higher incomes. The energy consumers most likely to benefit from the future energy market are those identified as *Switched on wealthier couples and families* (Archetype 3) and *Wealthier rural families* (Archetype 5).

There is likely to be a premium paid by those who are unable or unwilling to engage in future energy market changes. In particular, it is anticipated that as ToU tariffs become more common and households switching to these are able to shift energy usage to reduce costs, those left on standard tariffs could see their bills rise to cover losses in energy supplier revenues.

All consumers are likely to see electricity bills increase to cover the costs of reinforcing the electricity network in order to handle increasing demands of EV charging. It was estimated that electricity bills could increase by approximately £13 per annum to cover the costs of reinforcing low voltage (LV) substations across Scotland.

This research is independent and does not necessarily reflect Scottish Government policy.

Please also note that, although published in late 2020, this research was finalised in 2019.

Contents

Introduction

ClimateXChange has commissioned a review of the changing energy landscape and consumers, on behalf of the Scottish Government's Energy and Climate Change Directorate. Its primary purpose is to inform the development of a vision and action plan which will set out how the Scottish Government will deliver a consumer-focused low carbon transition. The research is primarily to encourage and support policy makers across the energy landscape to think about consumers in all their different guises.

Phase 1 of the review examined how the energy landscape is changing and how this will impact on, and alter, the consumer experience – both positively and negatively. The phase 1 report, *Changes to the energy landscape and potential impacts on Scotland's consumers*, provides an overview of how consumer capabilities and vulnerabilities could play out in the context of future developments in energy.

This report presents the findings from Phase 2 of the review, a distributional impact assessment which adds depth and breadth to the *who*, *how much*, and sometimes *where*, these impacts are being or will be felt. It has used a newly-developed Scotland-specific segmentation model to characterise groups of consumers by their circumstances and attitudes. The segmentation model is described in a sister report, *Domestic energy consumer archetypes: segmentation profiles*.

Phase 2 includes forthcoming changes that are emerging as part of a transition to a more 'smart' energy system and market, modelling implications of changes to low carbon energy policies. Specifically: a switch to time of use (TOU) tariffs, increased uptake of electric vehicles (EVs), and the future for domestic heat pumps and solar photovoltaics (PV) systems. The analysis has considered changes that might occur over a six year period between now and 2025.

The report includes three further sections. Section 0 provides a summary of the approach taken to forecast and model an increased take up of ToU tariffs, EVs and domestic low carbon heat technologies, as well as the impact of removing support for domestic low carbon electricity. Distributional impacts revealed by the model are presented in Section 0, and the report concludes in Section 4 with some overall observations derived from the modelling results.

Modelling approach

This section presents an overview of the modelling used to investigate potential distributional impacts of the ongoing transition to a more 'smart' energy market, and the changes in uptake of EVs and domestic low carbon energy systems. The modelling has considered a near-term forecast projecting a transition up to 2025.

This section includes a list of assumptions applied in the modelling and a discussion on some of limitations of the approach.

Modelling method

Preparing a model dataset

A separate but related ClimateXChange project[1] has derived a Scotland-wide energy consumer data set. This represents all households in Scotland, and is based on the Scottish Household Survey (SHS) (2014-16), the Scottish House Condition Survey (SHCS) (2014-16) and the Ofgem Energy Consumer Engagement survey (2017). The data set includes socio-demographic data, information on housing characteristics, and details of the energy behaviour of households. As part of the project, the data set was used to segment energy consumers into eight distinct and separate energy consumer archetypes, which are used within this study to assess distributional impacts. The Scottish energy consumer data set was further developed for this follow-on project, using reported expenditure on electricity, gas and other fuels, and historic fuel price statistics (i.e. those matching the survey years of the data) to derive fuel consumption levels for households.

Reported expenditure on different fuels was incomplete in the data (it was only reported by a subset of those surveyed for the SHS). Thus, to impute missing fuel expenditure values, predictive models were derived from other information contained in the survey. Energy consumption for each household in the data set was estimated by applying regional fuel price statistics to the reported energy expenditures and imputed energy costs. Final energy consumption values for electricity, mains gas and coal were then adjusted to align with national statistics on total domestic energy consumption levels by fuel type.[2] Finally, baseline fuel costs were calculated using these derived energy consumption figures and the latest domestic fuel price statistics for electricity and mains gas[3], and Sutherland Tables data[4].

Overall modelling approach summary

ToU Tariffs

Modelling a switch to TOU tariffs was performed by selecting a subset of the population as the most likely candidates to engage in TOU tariffs, based on social demographic data,

[1] *Domestic energy consumer types: Proposed segmentation.*
[2] http://statistics.gov.scot/data/energy-consumption
[3] https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics
[4] http://sutherlandtables.co.uk/

location and engagement in the energy market. Energy consumption behaviour was then anticipated and fuel bills recalculated by dividing up annual energy consumption into different time of use bands and applying different fuel prices to these. A distributional impact assessment then assessed the numbers and types of different households reported as engaging with TOUs, as well as the likely extent to which they may benefit.

Electric Vehicles

EV uptake was modelled by considering the most likely households or consumers to switch to EVs and apply an estimate of the numbers of households doing so by 2025, based on UK government and energy industry projections. Further research was conducted to assess cost estimates of upgrading electricity distribution infrastructure to cater for the additional demands of EVs. In anticipation of how these costs might be recuperated, the estimated electricity distribution upgrade costs were shared equally across all electricity consumers as a levy. The modelling did not consider the variation in transport fuel costs experienced by consumers switching to EVs, but instead sought to focus on and highlight the types of households most likely to be EV owners in the near-term, while recognising that all consumers are likely to pay for electricity network reinforcement costs through their electricity bills.

Heat pumps and solar PV systems

Models were also created that projected the uptake of heat pumps and solar PV systems up to 2025. These are or have been supported financially by the Renewable Heat Incentive (RHI) and Feed-in-Tariff (FiT) respectively. The RHI is only scheduled to run until March 2021 and the FiT scheme was closed to new applicants in 2019. Therefore it was assumed that the significant majority of households installing these technologies will be able-to-pay consumers, and specifically those with the desire to switch to low carbon technologies and with suitable homes to install them. In addition to these consumers, it was assumed that some of these technologies are likely to be installed by social housing providers in order to help meet increasingly stringent energy efficiency targets. The impacts of these systems were derived from the National Household Model (NHM), with average impacts determined by dwelling type, dwelling size and main heating fuel.

Further model details and some assumptions behind each aspect of the modelling are provided below, followed by some caveats and limitations.

Time of Use tariff modelling assumptions

Time of use tariff switchers

The newly emerging market of TOU tariffs in the UK is associated with the smart meter roll out and relies on the availability of half hourly settlement data. Thus to participate in the new TOU market consumers will need to have a smart meter installed in their home. A review of the Ofgem Consumer Segmentation 2017 survey provides some key characteristics and profiles of households most likely to have smart meters installed in their homes. In 2017, around 10.5% of households across Great Britain reported having smart meters installed in their homes.[5] Typically, these tend to be people who own their own homes, on higher incomes, aged over 35, in employment (full time or part time) and are regular or frequent users of the internet, and have reasonable levels of trust and/or engagement in the energy market. Conversely, those who are more risk adverse, the least educated and who rent their homes are some of the least likely to have a smart meter installed and to consider a switch to a TOU tariff. As such, we have developed a model that identifies and selects a subset of the population most likely to have a smart meter and switch to a TOU tariff. However, a broader section of the population are likely to switch to TOU tariffs over the next decade, and while the model prioritises these 'most-likely' households, it also samples other households for inclusion.

For the purposes of this modelling exercise, a future scenario has been forecast whereby 21% of Scottish households have had a smart meter installed and have switched to a smart three-tiered TOU tariff. That is to say, we have envisaged a scenario whereby twice the number of people who reported having a smart meter in 2017 will have a smart meter and will be signed up to a TOU tariff within the next five to ten years. Some survey results have suggested that approximately 30% of the GB public would consider moving to a TOU tariff[6], or are in favour of switching to a three-tiered smart TOU tariff[7]. However, the latter identifies how intentions to switch to these newer tariffs are often tempered by loss aversion. Nevertheless, others have estimated that up to 43% of the population could switch to TOU tariffs if efforts are made to shift this intention-action gap.[8] Thus we consider 21% to be a reasonable (modelled) estimate of the proportion of households likely to move to smart TOU tariffs within the next decade or so. In addition, modelling a reasonable uptake of these tariffs also allows for a more distinct assessment of the potential distributional impacts of changes to the energy market. However, it should be clarified that predicting the numbers of people who are likely to switch to TOU tariffs remains open to high levels of uncertainty.

Time of use tariffs

TOU tariffs are available in three main forms: static tariffs, dynamic tariffs and real-time pricing (although other variations on these are also emerging). Dynamic tariff price points are fixed, but the times at which they apply vary from day to day. For example, there may be low, medium, and high price periods, and customers are notified in advance between which times those prices will apply. In real-time pricing TOUs, prices vary in real-time (e.g. to the hour or

[5] https://www.ofgem.gov.uk/publications-and-updates/consumer-engagement-survey-2017

[6] Smart Energy GB. 2015. Is it time? Consumers and time of use tariffs. Available at: https://www.smartenergygb.org/en/~/media/SmartEnergy/essential-documents/press-resources/Documents/UCL-research-into-time-of-use-tariffs.ashx

[7] Nicolson, M; Huebner, G; Shipworth, D; (2017) Are consumers willing to switch to smart time of use electricity tariffs? The importance of loss-aversion and electric vehicle ownership. **Energy Research & Social Science** , 23 (C) pp. 82-96. 10.1016/j.erss.2016.12.001.

[8] Nicolson, M; Fell, MJ; Huebner, G; (2018) Consumer demand for time of use electricity tariffs: a systematized review of the empirical evidence. **Renewable and Sustainable Energy Reviews**, 97 pp. 276-289. 10.1016/j.rser.2018.08.040.

half hour) depending on the current wholesale cost of electricity. In terms of modelling, these two options would require a complex modelling approach that is difficult to design with any degree of predictability or guaranteed accuracy.

However, static tariffs have fixed rates at different times of the day, typically using three of four different periods and different tariffs allocated to these times of day. These are also some of the most commonly emerging tariffs. A typical example is the TOU tariff trialled during the Customer Led Network Revolution (CLNR) project, which split a 24 hour day in three different bands; day, evening and night.[9] During the trial, the energy tariffs for each of these times of day were determined using the structure shown below in Table 1. This has been used as a basis for modelling TOU tariffs in this study. (Using this formula allows for TOU tariff to be calculated as a function of the most recent fuel price statistics.) The modelling has used standard electricity tariffs from the domestic energy prices statistics series for 2018 as a reference.[10]

Table 1: Time of use tariff details for the CLNR trial

Time Period	Description	Rate
07.00 – 16.00	Day	4% below standard rate (i.e. 0.96 x standard tariff)
16.00 – 20.00	Evening	99% above standard rate (i.e. 1.99 x standard tariff)
20.00 – 07.00	Night	31% below standard rate (i.e. 0.69 * standard tariff)

Energy consumption behaviour and energy company revenue balancing

Some studies report either reduced energy consumption or energy behaviours that result in reduced electricity bills as a result of households switching to TOU tariffs, or both. For the purposes of this modelling, we have assumed that overall annual energy consumption remains the same for all households after switching from standard tariffs, but that switching to TOU tariffs will allow consumers to switch some of their consumption to cheaper times of the day and enable their overall annual electricity costs to reduce a small amount. We have allocated energy consumption values as illustrated in Table 2 below.

Table 2: Anticipated proportion of energy use by time period

[9] Customer-Led Network Revolution (2015) High Level Summary of Learning: Domestic Smart Meter Customers on Time of Use Tariffs. Available at: http://www.networkrevolution.co.uk/wp-content/uploads/2015/01/CLNR-L243-High-Level-Summary-of-Learning-Domestic-Smart-Meter-Customers-on-Time-of-Use-Tariffs.pdf

[10] https://www.gov.uk/government/statistical-data-sets/annual-domestic-energy-price-statistics

Time Period	Description	Allocation of energy consumption (annual average split) Previously on standard electricity tariff	Allocation of energy consumption (annual average split) Previously on Economy 7 tariff
07.00 – 16.00	Day	65%	40%
16.00 – 20.00	Evening	15%	10%
20.00 – 07.00	Night	20%	50%

Different consumers are likely to respond to price signals in different ways, and some households – particularly those who have the least flexibility to shift their demand patterns – are likely to see bill increases as a result of switching to ToU tariffs. However, recent analysis of ToU trials has shown that the overall net impact across a group of consumers using ToU tariffs is a reduction in electricity bills, compared to 'standard' tariffs. This will translate to decreased revenues for energy suppliers from these customers. Thus, in anticipation of how energy companies may respond to this, we have assumed that any lost revenues from customers on TOU tariffs will be recouped by increasing fuel tariffs for all other households uniformly (i.e. the cost of recuperating any lost revenues will be evenly levied on those remaining on standard tariffs). The model has been designed so that the total sum of all electricity costs for all households before and after a modelled switch to TOU tariffs are constant. This is follows a modelling approach that has been used in previous tariff and distributional modelling analysis.[11]

Electric vehicle uptake modelling assumptions

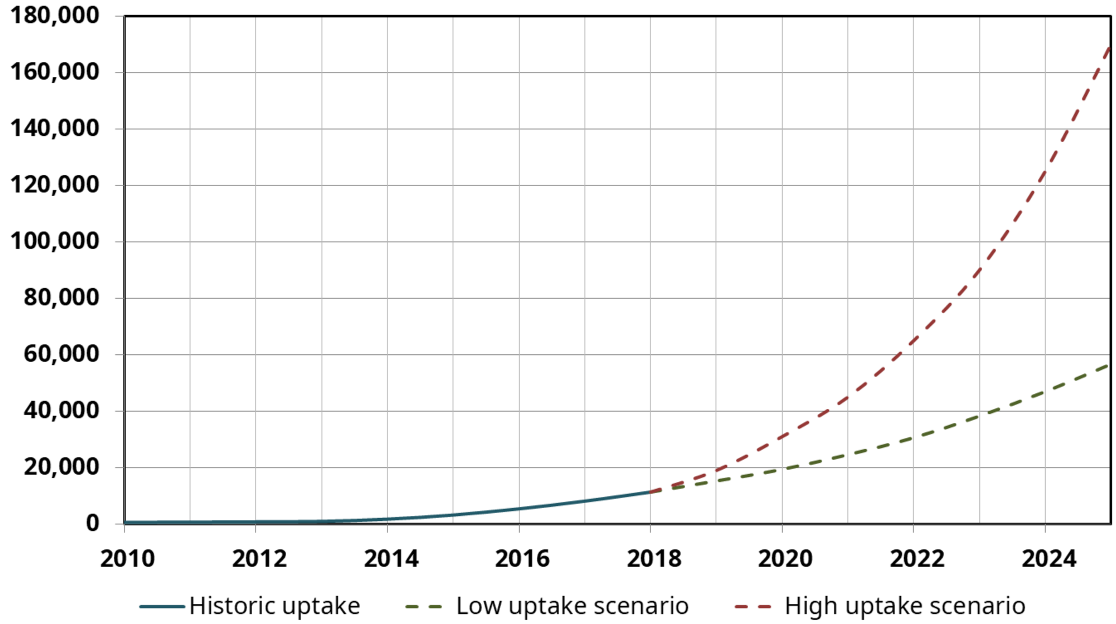
The numbers of EVs on the roads of the UK has increased significantly in recent years. By the end of 2018, there were 11,349 licensed ultra-low emission vehicles in Scotland (up from an estimated 1,000 in 2013). The UK government has estimated that the numbers of EVs in the UK could increase to between 3 million and 10 million by 2030.[12] In the Future Energy Scenarios modelling by the National Grid[13], all four future scenarios assume that most vehicles will be electric sometime between 2033 and 2040.

For the modelling, the lower rate of uptake estimated by the UK government has been used as a basis for EV projections. This equates to approximately 60,000 EVs in Scotland by 2025, as illustrated in Figure 1. It remains uncertain how many EVs will be owned by Scottish

[11] For example: https://www.citizensadvice.org.uk/about-us/policy/policy-research-topics/energy-policy-research-and-consultation-responses/energy-policy-research/energy-tariff-options-for-consumers-in-vulnerable-situations/
[12] https://www.spenergynetworks.co.uk/userfiles/file/Electric_Vehicle_Uptake_Forecasts.pdf
[13] http://fes.nationalgrid.com/

households in future, but the shift to EVs is gathering pace and based on current projects this appears to be a conservative estimate.

Figure 1: Number of licenced ultra-low emission vehicles (2010 – 2018) and future projected uptake scenarios (2019- 2025) in Scotland



Existing studies have reviewed and profiled existing EVs and those considering purchasing EVs in the near future.[14] This is summarised below in Table 3. Overall the research suggests that these households typically tend to be more affluent, degree educated, have more than one car, be over 35 and live in more urban areas. Data from a Department of Transport study has also previously reported that EV owners are more heavily concentrated in the 40-69 age group than new car buyers in general, and are more likely to have a high social grade, have a degree or diploma, and live in a multi-car household.[15] According to the research, early adopters of EVs also were also predominantly male. However, it is worth recognising that this trend is also present in standard vehicle ownership and women still only account for 35% of all registered vehicle owners (up from 30% in 1998).[16] This doesn't infer that women are either not involved in the decision making process to purchase EVs or have limited access to

[14] Thornton, A., Evans, L., Bunt, K., Simon, A., King, S., and Webster, T. (2011) Climate Change and Transport Thornton et al (2011) Choices: Segmentation Model - A framework for reducing CO2 emissions from personal travel. Available at: https://www.newark-sherwooddc.gov.uk/media/newarkandsherwood/imagesandfiles/strategiesandpolicies/pdf/test/climate-change-transport-choices-full_2.pdf

[15] Thornton, A., Evans, L., Bunt, K., Simon, A., King, S., and Webster, T. (2011) Climate Change and Transport Thornton et al (2011) Choices: Segmentation Model - A framework for reducing CO2 emissions from personal travel. Available at: https://www.newark-sherwooddc.gov.uk/media/newarkandsherwood/imagesandfiles/strategiesandpolicies/pdf/test/climate-change-transport-choices-full_2.pdf

[16] https://www.gov.uk/government/statistics/vehicle-licensing-statistics-2018

drive them. However, as with standard vehicle ownership, it is likely that proportionally more women own EVs in the future.

Table 3: Socio-demographic characteristics of current EV owners[17]

Characteristic	UK Evidence (Hutchins et al, 2013)	Other Evidence (various)
Age	7% age 21-39 23% age 40-49 29% age 50-59 23% age 60-69 17% age 70+	75% of EV owners in California are aged 35-64 (Center for Sustainable Energy, 2015). 82% of EV owners in Norway are aged 35-66 and their average age is 47. (Figenbaum et al, 2014)
Gender	89% male 11% female	The majority of EV owners in the Netherlands, Norway and California are male (Velthuis, 2012, 2014; Figenbaum et al, 2014; Center for Sustainable Energy, 2015)
Income	This was directly asked, but 72% of respondents of survey were identified as being in the DfT segment “Educated suburban families”. The majority of this segment has an annual income of £35,000+ and for over a quarter it is £60,000.	75% of EV owners in California have an annual household income of over £65k (Center for Sustainable Energy, 2015). 81% of EV owners in Norway have an annual household income of over £55k (Figenbaum et al, 2014).
Education	69% had degree or diploma	89% of current EV owners in California (Center for Sustainable Energy, 2015) have a degree or equivalent, as do 79% of current EV owners in Norway (Figenbaum et al, 2014).
Location	71% urban 18% town and fringe 11% hamlet/village/other	90% of EV owners in Norway live in a big city, city, or densely populated area. (Figenbaum et al, 2014)
Cars in household	80% 2 or more cars 20% 1 car	94% of EV owners in California have 1 or more cars in their household in addition to their EV (Center for Sustainable Energy, 2013)

Based on this research, households matching these criteria were selected as being the most likely to own EVs in future, compared to other demographic groups. (Gender was not used a

[17] Brook Lyndhurst (2015) Uptake of Ultra Low Emission Vehicles in the UK: A Rapid Evidence Assessment for the Department for Transport. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/464763/uptake-of-ulev-uk.pdf

principle selection criteria.) However, the model did not exclusive select these consumers. Other consumer types were also considered as future EV drivers, but allocated lower probabilities of EV ownership.

Finally, it should be recognised that an increased uptake of EVs will place constraints and additional infrastructure requirements on the electricity network grid. In particularly, these will require upgrading and reinforcing substations where high numbers of households are likely to regularly charge their EV batteries. The costs of this are likely to be borne by all consumers through electricity bills.

Analysis from the 'My Electric Avenue' study indicated that 312,000 low voltage (LV) feeders would need reinforcement due to EV growth of 40% penetration or more.[18] Using this information and figures from UKPN's published ED1 RIGs, a study conducted for the Electricity Network Association's Open Networks Future Worlds project[19] went on to estimate the total costs of LV feeder reinforcement across the UK. The analysis estimated that the total costs of these reinforcements would be in the order of £8.5bn. We have used this figure and assumed a linear spend between now and 2050 to estimate the additional annual costs that might be added to electricity fuel costs in Scotland by 2025 to cover this investment.

Heat pump uptake modelling assumptions

The Renewable Heat Premium Payments (RHPP) 1 scheme was evaluated in 2013 and produced a summary profile of consumers engaging in this policy.[20] Using this as a basis, it was assumed that the most likely consumers to install ground source heat pumps (GSHPs) in the near future met the following criteria:

- Had a net household income of at least £40,000
- Were over 40 years of age
- Owned their own homes
- Living in larger[21] detached or semi-detached homes. (GSHPs require a reasonably large outdoor space to bury heating coils.)
- Lived in homes that had an SAP energy efficiency rating of D or higher (heat pumps work best in dwellings which are well insulated, and the SAP energy efficiency rating is a reasonably reliable indicator of this)
- Used an 'off-gas' fuel to heat their homes (e.g. oil, LPG, coal or electricity) – switching from mains gas to heat pumps is likely to cause heating costs to increase.

[18] http://myelectricavenue.info/sites/default/files/documents/Close%20down%20report.pdf
[19] http://www.energynetworks.org/electricity/futures/open-networks-project/future-worlds/future-worlds-impact-assessment.html
[20] https://www.gov.uk/government/publications/analysis-of-customer-data-from-phase-one-of-the-renewable-heat-premium-payments-rhpp-scheme
[21] Large homes were identified as those with 4 or more bedrooms

Based on the same research, it was also assumed that the most likely consumers to install air source heat pumps (ASHPs) in the near future had the following profile:

- Had a net household income of at least £35,000 (ASHPs are typically less expensive than GSHPs, and evidence points to a lower income threshold for households purchasing ASHPs)
- Were over 40 years of age
- Owned their own homes
- Mostly lived in homes with 3-4 bedrooms. (This contrasts with GSHPs which were typically installed in homes with 4 or more bedrooms.)
- Lived in homes that had an SAP energy efficiency rating of D or higher (heat pumps work best in dwellings which are well insulated, and the SAP energy efficiency rating is a reasonably reliable indicator of this)
- Used an 'off-gas' fuel to heat their homes (e.g. oil, LPG, coal or electricity) –switching from mains gas to heat pumps is likely to cause heating costs to increase.

It was also assumed that a smaller number of households who meet the above criteria but who currently heat their homes with mains gas would switch to ASHPs as a low carbon heating alternative for environmental reasons. Finally, it was assumed that a reasonable proportion of number of ASHPs are likely to be installed in social housing flats that were in SAP band D or higher, based on historical installations from the RHI in Great Britain (see Table 4).

Table 4: RHI Accreditations by tenure, Great Britain, April 2014 to August 2018 (statistics not published for Scotland) [22]

Tenure	Air source heat pump	Ground source heat pump
Private Landlord	989	353
Social Landlord	12,394	1,009
Owner Occupier	19,506	7,954
Total	**32,889**	**9,316**

The numbers of heat pumps installed in Scotland through the domestic RHI from April 2014 to March 2019 are shown below in Table 5. The RHI is due to close in March 2021 and there are no published plans available that go beyond then. In the absence of any other information and for the purposes of this study, we have assumed that the current rates of heat pump installations observed since the inception of the RHI will continue, and that the numbers of heat pumps installed between now and 2025 will be similar to the numbers installed between

[22] https://www.gov.uk/government/statistics/rhi-deployment-data-august-2018

2014 and February 2019. In other words, we have assumed that the RHI payments will continue at the current rate up to 2025 and that therefore the incentive for households to install these systems will continue. These figures are also presented in Table 5. It is worth noting that this is one of potential future scenarios and is not necessarily the most likely.

Table 5: Number of domestic RHI accredited applications by technology, Scotland, April 2014 to March 2019

Technology	Number of accredited applications (Feb 2019)	Project number of additional installations by 2025
Air source heat pump	7,077	7,000
Ground source heat pump	1,289	1,500
Biomass	3,816	*n/a*
Solar thermal	1,178	*n/a*
Total	**13,360**	***n/a***

As above, we note that the current RHI is due to close in March 2021. Given the policy imperative to decarbonise heating and the likelihood that public funding for renewable heat will continue in some form, we did not model a drop in the number of heat pumps installed. The impacts from installing heat pumps and switching from a traditional heating system have been modelled in the National Household Model (NHM). The modelling outputs were used to create average bill savings statistics disaggregated by dwelling type, dwelling size and main heating fuel (before installation of heat pumps). In the results section below, the impacts on bills are presented in terms of both the total financial change in bills and as a percentage of the total fuel bill before heat pump installation. Payments from the RHI have been considered as an income stream and are not included in any reporting on bill changes.

Solar PV modelling assumptions

The feed-in tariff closed to new applications in March 2019. This was the main financial support mechanism subsiding domestic solar PV installations in the UK. However, since its inception costs of solar PV systems have reduced substantially and continue to offer a long-term financial benefit to those installing them. As such, they are still likely to be considered by consumers who are able to afford them and who are looking to improve the efficiency of their home and/or improve their environmental footprint. We have therefore assumed that solar PV systems will continue to be installed by certain consumers on certain dwellings but at half the rate seen over the lifetime of the FiT (i.e. when subsidies were available)

Table 6: Cumulative installations confirmed on the Central Feed-in Tariff Register in Scotland, March 2019

Technology	Domestic	Total	Project number of additional installations by 2025
Photovoltaics	56,192	58,515	30,000
Wind	2,006	3,184	*n/a*
Hydro	132	572	*n/a*
Anaerobic Digestion	-	39	*n/a*
MicroCHP	27	28	*n/a*
Total	**58,357**	**62,338**	***n/a***

The SHCS data includes a field that identifies whether dwellings currently have solar systems installed, and if not whether they are suitable for solar PV installations. Based on this and existing profiles for households engaging in the RHPP phase 1 (see above), it was assumed that the most likely consumers to install solar PV over the next five years would:

- Live in a dwelling identified as being suitable for solar PV
- Have a net household income of at least £35,000
- Be over 40 years of age
- Own their own homes
- Live in homes that have an SAP energy efficiency rating of D or higher (historically solar PV systems only qualified for the higher FiT tariff if this was the case. It remains the case that there are still more cost effective solutions to solar PV that will increase the energy efficiency of a dwelling and reduce fuel costs.)

As with ASHPs (see above), it was also assumed that some social housing landlords are likely to install solar PV systems to help meet energy efficiency targets required of the sector.

In a similar approach to that used for heat pump analysis, the impacts from installing solar PV systems have been modelled in the National Household Model (NHM). The modelling outputs were used to create average electricity bill savings disaggregated by dwelling type, dwelling size and main heating fuel (before installation of solar PV systems). These were then used to present the impacts on bills in terms of both the total financial change in bills and as a percentage of the total electricity bill before solar PV installation.

Limitations to the modelling

Time of Use tariffs

The modelling performed for ToU tariffs represents a simplification of ToU tariffs themselves and the predicted energy behaviours of those switching these tariffs. It should be noted that different households have different energy needs that vary throughout the day and will be significantly more complex than we have allowed for here. For example, some households will be able to be more flexible than others in when and how they use electricity over a day, a week or a year. For example, work and school routines, plus other lifestyle situations, can limit the times of day that certain households can use energy. In addition, some consumers may be better placed to access and use additional kit or to purchase 'smart' devices and appliances that enable more automated control over energy consumption. Typically, this requires financial, technical and intellectual capabilities that may limit the extent to which less affluent, less educated and less risk-averse households can interact with these innovations.

However, anticipating individual energy behaviours is notoriously difficult and problematic, and we have not attempted to that here with any complexity. An overarching approach for this modelling has been to consider a future possible scenario underpinned by existing research, and to model this focusing on the overall net distribution impacts for different types of households under such a scenario. Nevertheless, it should be recognised that in practice the impacts of switching to ToU tariffs experience by individual households are likely to vary considerably. While the modelling itself has not assessed impacts at an individual household level, a discussion on how to best support those least capable of benefiting from these tariffs (and other energy market innovations) can be found in the final section of this report.

Electric vehicles

Households who use an EV are likely to see their electricity consumption and costs increase as a result of charging EV batteries. However, this is not guaranteed and in urban areas and at places of work there are options for EV user to charge away from the home for free or lower costs that won't appear on domestic electricity bills. Anticipating 'charging behaviour' has not be attempted here. In addition, we have not attempted to model the cost differentials of switching from petrol or diesel cars to EVs, although several websites offer a cost calculator and demonstrate that there are likely to be significant individual consumer savings from switching to EVs. Instead, the results of the modelling have focused on highlighting which consumers are those most likely to (be able to) buy or lease EVs, and the small additional costs that are likely to be levied on all energy consumers to fund the upgrades required of the electricity distribution systems, i.e. to cater for additional EV charging infrastructure. In future, EV owners may also be able to return electricity to the grid from car batteries (e.g. to help balance the grid during peak electricity demand), and receive a financial reward for doing so. This is unlikely to be commonplace over the timescales considered in this project and has not been considered here. However, while potential revenues from this have not be quantified here, it should be recognised that this could present an additional benefit for EV owners in additional to lower (transport) fuel costs.

Heat Pumps and Solar PV

Identifying households most likely to install low carbon heating and power systems has relied on existing research that has profiled those who have recently installed these systems, based on existing support schemes. The lack of availability of Scotland-specific evaluations has meant that this has had to draw on UK and European-wide research. However, as discussed above, the numbers of installations has been based on historical trends from Scotland-specific data. This has been used to make an informed judgement on the most typical types of consumers who are likely to install these technologies in the future. This approach has used previous trends and consumer profiles and assumed that these will continue in the near future. Similarly, assumptions have also been made on the total number of these systems that will be installed in the next five years. However, it should be recognised that this may be a simplistic approach and that consumer behaviour may vary or other market factors may affect a) who installs these systems, and b) how many are installed in Scotland over the next few years.

Modelling results

The following section presents summary results and analysis derived from modelling future uptake of TOU tariffs, EVs, domestic heat pumps and solar PV systems. Each aspect is presented separately, and results focusing on distribution impacts by the energy consumer archetypes derived from the *Domestic energy consumer types: Proposed segmentation* project.

Time of Use of tariffs

Summary results from the time of use tariff switching model are presented below in Table 7. The distributional impacts from modelling a TOU tariff switch are presented in Table 7 by energy consumer archetype. Overall, 520,000 Scottish households (21%) were anticipated to switch to a TOU tariff, which resulted in an annual electricity bill saving of approximately £47 or 6% on baseline (pre-TOU tariff) electricity fuel bills for these households.

However, the distribution of TOU switchers across different households varies significantly. Approximately 220,000 Archetype 3 (Switched on wealthier couples and families) households were modelled as switching to a TOU tariff, representing 40% of all Archetype 3 households and around two-fifths of all those switching to a TOU tariff. Other archetypes which had high proportions of switchers included Archetype 6 (Older urban couples who own their homes outright) and Archetype 5 (Wealthy rural families), which saw 76,000 (24%) and 31,000 (32%) switch to TOU tariffs respectively.

Households least likely to switch to TOU tariffs included those in Archetype 2 (Urban very low income single older adults) where only 17,000 (6%) households took up a TOU tariff, and Archetype 1 (Single low income renters using electricity for heating) where only 26,000 (11%) were modelled as having engaged – and benefitted – from smart tariffs. The modelling suggests that households in these archetypes not switching to TOU tariffs (i.e. not engaging in smart energy tariffs) could see their annual electricity bills increase by between £10 and £17 to compensate for reductions in energy company revenues resulting from those benefitting from the flexibility of TOU tariffs.

The numbers and proportion of households switching to TOU tariffs by local authority is presented in Table 8 and Figure 2. Local authorities such as East Renfrewshire, East Dunbartonshire, Renfrewshire, Angus and South Ayrshire saw high proportions of households switching to TOU tariffs. Glasgow City, City of Edinburgh and Fife saw the highest overall numbers of switchers; 52,000 (22%), 46,000 (16%) and 42,000 (26%) households from these local authorities switched to TOU tariffs, respectively. The Highlands and Islands experienced the lowest rates and lowest numbers of households switching to smart TOU tariffs, with only 10% of households in Na h-Eileanan Siar transferring from standard electricity tariffs (compared to a nationwide average of 21%).

This mimics the historically low levels of standard tariff switching rates in these regions of Scotland. For example, data recently published by Citizens Advice showed that the five local authorities with the lowest electricity tariff switching rates in 2018 were Shetland Islands, Na h-Eilean Siar, Highland, Argyll & Bute and Orkney Islands.[23]

[23] https://www.cas.org.uk/news/new-data-shows-huge-differences-across-scotland-energy-switching-rates

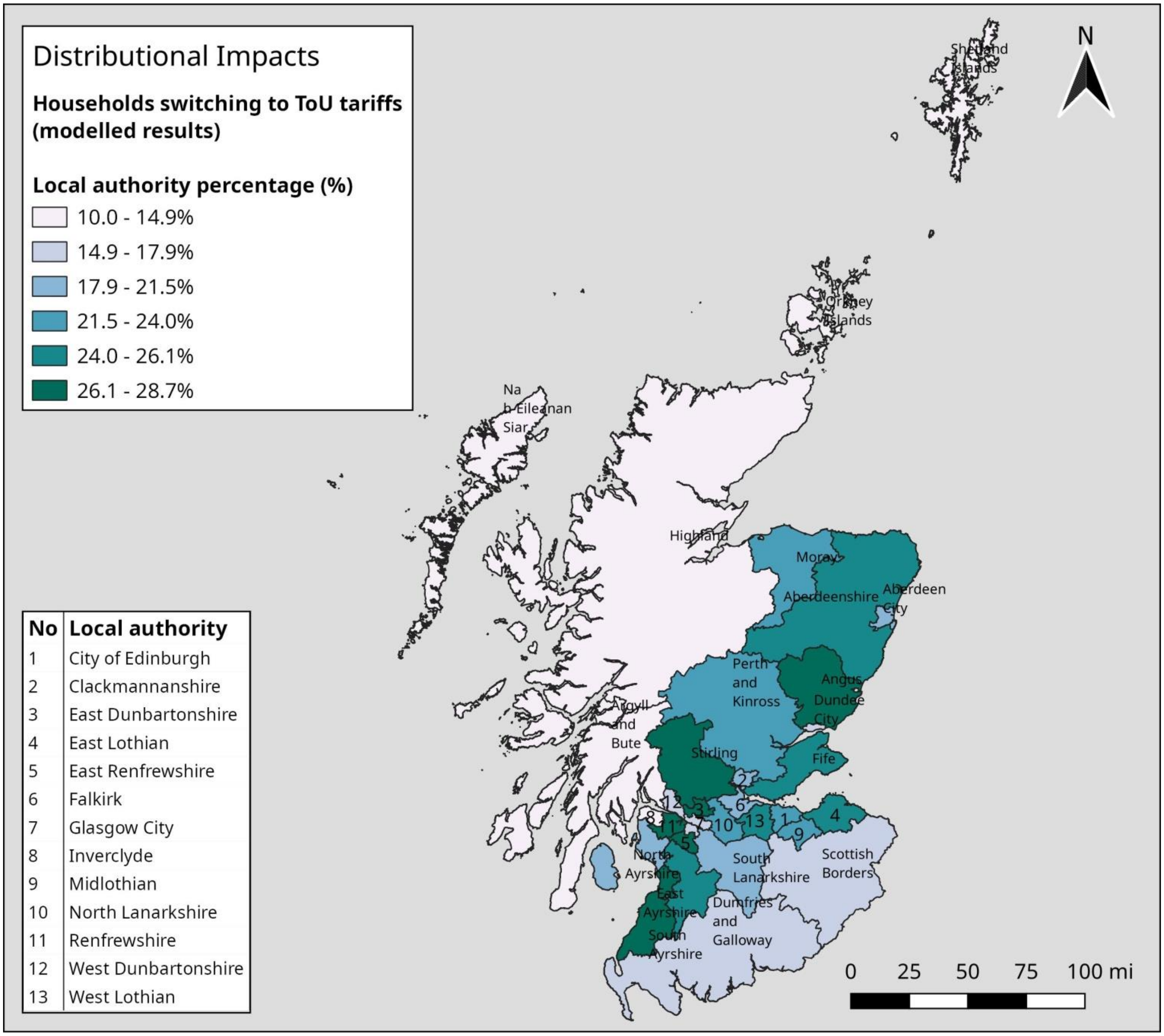
Table 7: Distributional impacts of TOU tariff switching by energy consumer archetype

Energy consumer archetype	TOU tariff switchers?	Number of households	Average bill change (£)	Average bill change (%)	Proportion of archetype
Archetype 1: Single low income renters using electricity for heating	No	219,200	£17	2%	89%
	Yes	25,800	-£106	-10%	11%
Archetype 2: Urban very low income single older adults	No	272,600	£10	2%	94%
	Yes	17,200	-£53	-8%	6%
Archetype 3: Switched on wealthier couples and families	No	358,200	£13	2%	60%
	Yes	238,800	-£40	-5%	40%
Archetype 4: Families or younger couples in urban areas	No	363,800	£11	2%	87%
	Yes	54,900	-£49	-8%	13%
Archetype 5: Wealthy rural families	No	67,900	£16	2%	68%
	Yes	31,400	-£42	-5%	32%
Archetype 6: Older urban couples who own their homes outright	No	244,500	£12	2%	76%
	Yes	76,000	-£46	-7%	24%
Archetype 7: Urban social renters with long term health problems	No	251,700	£11	2%	88%
	Yes	33,700	-£46	-7%	12%
Archetype 8: Rural, less affluent older adult households	No	142,100	£15	2%	81%
	Yes	32,400	-£46	-5%	19%
All households	**No**	**1,919,900**	**£12**	**2%**	**79%**
	Yes	**510,400**	**-£47**	**-6%**	**21%**

Table 8: TOU tariff switchers by local authority

Local Authority	Average bill change (£)	Average bill change (%)	Number of households	Proportion of local authority	Proportion of all TOU switchers
East Renfrewshire	-£41	-5%	10,900	29%	2.1%
East Dunbartonshire	-£47	-6%	12,500	28%	2.4%
Renfrewshire	-£42	-6%	22,700	27%	4.5%
Angus	-£52	-6%	14,400	27%	2.8%
South Ayrshire	-£45	-6%	14,000	27%	2.8%
Stirling	-£43	-5%	10,100	26%	2.0%
Fife	-£43	-6%	42,300	26%	8.3%
Aberdeenshire	-£45	-5%	27,700	25%	5.4%
East Lothian	-£44	-6%	11,100	25%	2.2%
East Ayrshire	-£43	-6%	13,500	25%	2.6%
West Lothian	-£45	-6%	18,200	24%	3.6%
North Lanarkshire	-£48	-6%	35,200	24%	6.9%
Midlothian	-£42	-6%	8,500	23%	1.7%
City of Edinburgh	-£46	-6%	52,000	22%	10.2%
Perth and Kinross	-£51	-6%	14,400	22%	2.8%
Moray	-£40	-5%	9,000	22%	1.8%
South Lanarkshire	-£44	-6%	30,600	21%	6.0%
Falkirk	-£41	-5%	14,800	21%	2.9%
North Ayrshire	-£48	-6%	13,200	21%	2.6%
Clackmannanshire	-£47	-7%	4,400	19%	0.9%
Aberdeen City	-£53	-7%	19,700	19%	3.9%
Dumfries and Galloway	-£36	-4%	12,100	18%	2.4%
West Dunbartonshire	-£53	-8%	7,300	17%	1.4%
Scottish Borders	-£53	-7%	9,300	17%	1.8%
Glasgow City	-£52	-7%	46,400	16%	9.1%
Dundee City	-£58	-8%	10,400	15%	2.0%
Inverclyde	-£45	-6%	5,600	15%	1.1%
Orkney Islands	-£62	-5%	1,400	14%	0.3%
Shetland Islands	-£76	-7%	1,200	12%	0.2%
Highland	-£54	-6%	11,600	11%	2.3%
Argyll and Bute	-£59	-7%	4,300	11%	0.9%
Na h-Eileanan Siar	-£61	-6%	1,300	10%	0.3%
All households	**-£47**	**-6%**	**510,400**	**21%**	**100.0%**

Figure 2: TOU tariff switchers by local authority



Electric vehicles

The numbers and proportion of each archetype projected to switch to EVs over the next five years is shown in Table 9. The table also presents EV owners in each energy consumer archetype as a proportion of all EV owners in 2025. The modelling assumed that the numbers of domestic EVs owned in Scotland will rise to at least 60,000, with 2.5% of households owning an EV in 2025. Based on the profile of future EV owners, some archetypes are more likely to own EVs than others.

The most likely consumer type to own EVs were Archetype 3 (Switched on wealthier couples and families). The modelling suggested that these households are likely to account for almost half (49%) of all future EV owners, with 5% of this group predicted as driving ultra-low emission vehicles by 2025. Their wealth rural counterparts, Archetype 5 (Wealthy rural families), also had rates of EV ownership that were higher than the predicted national average in 2025. However, there were higher numbers of EV owners in Archetype 6 (Older urban couples who own their homes outright) (8,000 versus 7,100). Overall, urban consumer archetypes accounted for over 80% of future EV owners, while rurally located consumer archetypes accounted for less than 15%.

Table 9: Modelled EV owners by energy consumer archetype

Energy consumer archetype	EV owner in 2025	Number of households	Proportion of archetype	Proportion of all EV owners in 2025
Archetype 1: Single low income renters using electricity for heating	No	242,600	99.0%	
	Yes	2,400	1.0%	4.0%
Archetype 2: Urban very low income single older adults	No	286,400	98.8%	
	Yes	3,400	1.2%	5.5%
Archetype 3: Switched on wealthier couples and families	No	567,200	95.0%	
	Yes	29,700	5.0%	48.9%
Archetype 4: Families or younger couples in urban areas	No	411,600	98.3%	
	Yes	7,100	1.7%	11.7%
Archetype 5: Wealthy rural families	No	94,300	94.9%	
	Yes	5,000	5.1%	8.3%
Archetype 6: Older urban couples who own their homes outright	No	312,500	97.5%	
	Yes	8,000	2.5%	13.2%
Archetype 7: Urban social renters with long term health problems	No	283,600	99.4%	
	Yes	1,800	0.6%	3.0%
Archetype 8: Rural, less affluent older adult households	No	171,300	98.1%	
	Yes	3,200	1.9%	5.3%
All households	**No**	**2,369,500**	**97.5%**	
	Yes	**60,800**	**2.5%**	**100.0%**

The least likely households to use EVs were Archetype 7 (Urban social renters with long term health problems). Fewer than 2,000 households in this group were considered likely to own EVs, representing less than 1% of all future EV owners. It was estimated that electricity bills could increase by approximately £13 per annum to cover the costs of reinforcing the LV substations across the country. Therefore, the significant majority (around 99%) of this archetype and other lower income energy consumers are helping to fund improvements that allow EV owners to charge their vehicles, but are themselves are financially unable to own and benefit from EVs.

Interaction between ToU tariffs and EVs

Many EV owners who predominately charge their vehicles at home are likely to switch to ToU tariffs that allow them to benefit from cheap electricity at off peak times to reduce the costs of charging their car batteries. Table 10 presents modelling analysis showing the anticipated overlap between EV owners and those switching to ToU tariffs for different energy consumer archetypes. Overall, a significantly higher number of people were estimated to have switched to ToU tariffs than own EVs, but the majority (two-thirds) of EV owner where predicted to also have considered a ToU tariff. However, this is likely to vary by energy consumer archetype and levels of switching to ToU.

Overall, the modelling suggested that Archetypes 1 (Single low income renters using electricity for heating), Archetype 2 (Urban very low income single older adults), and Archetype 7 (Urban social renters with long term health problems) are the least likely to engage in future smart energy network changes, with 89% and 93% and 87% not predicted to either own an EV or have switched to ToU tariffs.

Table 10: EV owners and TOU tariff switchers by energy consumer archetype

Energy consumer archetype	Proportion of households			
	Switching to ToU tariffs and owning EVs	Owning EVs but not switching to ToU tariffs	Switching to ToU tariffs but not owning EVs	Neither switching to ToUs or owning EVs
Archetype 1: Single low income renters using electricity for heating	0.4%	0.6%	10.1%	88.9%
Archetype 2: Urban very low income single older adults	0.4%	0.7%	5.5%	93.3%
Archetype 3: Switched on wealthier couples and families	4.2%	0.8%	35.8%	59.2%
Archetype 4: Families or younger couples in urban areas	0.6%	1.1%	12.5%	85.8%
Archetype 5: Wealthy rural families	4.0%	1.1%	27.6%	67.3%
Archetype 6: Older urban couples who own their homes outright	2.0%	0.5%	21.8%	75.7%
Archetype 7: Urban social renters with long term health problems	0.2%	0.5%	11.7%	87.7%
Archetype 8: Rural, less affluent older adult households	1.2%	0.7%	17.4%	80.7%
All households	**1.7%**	**0.8%**	**19.3%**	**78.2%**

Heat pumps

This study has anticipated that around 1,500 GSHPs and 7,000 ASHPs will be installed in homes across Scotland by 2025. The majority of GSHP are likely to be installed in rural areas, in larger homes that have the sufficient outdoor space to allow for the burying of heating coils in the ground. Heat pumps are also likely to be adopted by more affluent households due to their high capital costs. ASHPs are suited to a wider variety of dwelling types than GSHPs, including smaller and more urban homes.

Modelling results for heat pump uptake across Scotland by energy consumer archetype are presented in Table 11 and Table 12. Archetype 5 (Wealthy rural families) is likely to install the most

GSHPs, with more than half installed over the next 6 years expected to be in the homes of these households. Archetype 8 (Rural, less affluent older adult households) are expected to be the other main group that install GSHPs. In addition to this, a handful of households in Archetype 3 (Switched on wealthier couples and families) and Archetype 1 (Single low income renters using electricity for heating) are also expected to install GSHPs. (For the latter, it is worth recalling that while the majority of these households are on low incomes, this archetype is also defined as being electrically heated and some of these households on higher incomes may be able to access finance that enables then to install GSHPs.)

The modelling suggests that the uptake of ASHPs is likely to be distributed across more archetypes than GSHPs. Through the RHI, a significant proportion of ASHPs have been installed in social housing (see Table 4 in Section 0), and we have assumed this will continue to 2025. Archetype 1 (Single low income renters using electricity for heating) – many of whom are social renters – currently have the largest numbers of heat pumps installed (according to SHCS data) and we have assumed this will continue to 2025, with a further 3,470 ASHPs installed in these homes. Households in Archetype 3 on higher incomes were also anticipated to install ASHP, many for environmental and long-term energy security reasons. Smaller numbers of ASHPs were predicted to be installed by Archetype 5 (Wealthy rural families), Archetype 4 (Families or younger couples in urban areas), Archetype 6 (Older urban couples who own their homes outright) and Archetype 8 (Rural, less affluent older adult households). However, the modelling suggested that no households in Archetype 2 (Urban very low income single older adults) or Archetype 7 (Urban social renters with long term health problems) are likely install either ASHPs or GSHPs over the next six years.

As detailed in Section 0, the impacts of heat pumps were taken from modelling results derived from the National Household Model (NHM), split by original fuel type, dwelling type and dwelling size (number of bedrooms). Results from the NHM suggest that switching to a heat pump results in bill savings when switching away from fuels other than mains gas. In the modelling only a smaller number of households currently using gas installed ASHPs (and no GSHPs). Any payments from the RHI have not been included in fuel bill savings.

When averaged across archetypes, all those installing heat pumps are likely to see significant reduction in their energy costs. Overall, average savings for GSHPs were estimated to be around £630 per year, with households in Archetype 5 (who typically own larger detached homes) likely to experience annual savings of over £750. Fuel bill savings from ASHPs are lower than GSHPs, with typical bill savings of around £200. However, households within some of the archetypes switching from mains gas to ASHPs did see an increase of up to £170 in their annual fuel bills.

It is worth reiterating at this point that modelling here has assumed that trends in uptake of heat pumps under the RHI will continue until 2025, based on the likelihood of public funds being allocated to supporting renewable heating post March 2021, given the imperative to decarbonise heat.

Table 11: Current and projected numbers of heat pump installations

Energy consumer archetype	Current heat pump* installations (2019)	Projected future GSHP installations (2019-2025)	Projected future ASHP installations (2019-2025)	Projected total heat pump* installations(2019-2025)	Total number of all heat pump installations (2025)
Archetype 1: Single low income renters using electricity for heating	6,110	30	3,440	3,470	9,580
Archetype 2: Urban very low income single older adults	370	0	0	0	370
Archetype 3: Switched on wealthier couples and families	570	60	1,650	1,710	2,280
Archetype 4: Families or younger couples in urban areas	570	0	500	500	1,080
Archetype 5: Wealthy rural families	1,790	840	500	1,340	3,130
Archetype 6: Older urban couples who own their homes outright	1,200	0	440	440	1,640
Archetype 7: Urban social renters with long term health problems	0	0	0	0	0
Archetype 8: Rural, less affluent older adult households	2,100	630	790	1,410	3,520
All households	**12,710**	**1,570**	**7,310**	**8,880**	**21,600**

* includes both GSHPs and ASHPs

Table 12: Distribution of current and projected heat pump installations across different energy consumer archetypes

Energy consumer archetype	Proportion of current heat pump* installations (2019) (%)	Proportion of projected future GSHP installations (%)	Estimated average bill change from GSHP (£)	Proportion of projected future ASHP installations (%)	Estimated average bill change from ASHP (£)	Proportion of all future heat pump* installations (2025)
Archetype 1: Single low income renters using electricity for heating	48%	2.2%	-£369	47.0%	-£183	44%
Archetype 2: Urban very low income single older adults	3%	0.0%	£0	0.0%	£0	2%
Archetype 3: Switched on wealthier couples and families	4%	4.0%	-£610	22.5%	-£200	11%
Archetype 4: Families or younger couples in urban areas	5%	0.0%	£0	6.9%	-£161	5%
Archetype 5: Wealthy rural families	14%	53.8%	-£547	6.8%	-£273	14%
Archetype 6: Older urban couples who own their homes outright	9%	0.0%	£0	6.0%	-£208	8%
Archetype 7: Urban social renters with long term health problems	0%	0.0%	£0	0.0%	£0	0%
Archetype 8: Rural, less affluent older adult households	17%	40.0%	-£758	10.8%	-£193	16%
All households	**100%**	**100.0%**	**-£630**	**100.0%**	**-£194**	**100.0%**

* includes both GSHPs and ASHPs

Solar PV

Table 13 and

Table 14 show summary modelling statistics from projected solar PV installations by energy consumer archetype. By 2025, approximately 20,000 dwellings inhabited by Archetype 3 (Switched on wealthier couples and families) households were to have solar PV installed. This represents around 25% of all suitable dwellings in this group, and approximately 70% of all solar PV systems installed between now and 2025, demonstrating how solar PV systems are likely to only benefit some of the wealthiest energy consumers.

The modelling also suggests that significant numbers of households who have roofs suitable for PV systems will be unable to participate. This means these households miss out on a possible benefit (e.g. reduction in electricity costs), but also that significant potential carbon emissions reductions are unlikely to be realised unless further support or mechanism are in place to enable these dwellings to have solar PV systems installed. The modelling analysis suggests that if solar PV systems continue to be predominantly installed by mostly affluent consumers then approximately 95% of dwellings suitable for solar PV but inhabited by less affluent households are likely to remain without solar PV installations.

As shown in

Table 14, almost 70% of future solar PV installations were predicted to be installed in the dwellings of Archetype 3, providing them energy bills savings of around £200 annually via reduced demand for electricity from the mains grid. The loss of the FiT is likely to result in a significant reduction in the rate of those on lower incomes having solar PV systems installed on their homes, partially as a result of this no longer being a financial viable option for social landlords. The data from the SHCS suggests that 20% of Archetype 8 have had solar PV installation installed on their dwellings over the duration of the FiT. The modelling results suggested that only a further 2.4% of this group are likely to install solar PV systems between now and 2025.

Table 13: Current and projected numbers of solar PV installations

Energy consumer archetype	Current solar PV installations	Projected future solar PV installations (2019-2025)	Projected total number of installations (by 2025)	Number of dwellings suitable for solar PV
Archetype 1: Single low income renters using electricity for heating	2,540	460	3,000	61,700
Archetype 2: Urban very low income single older adults	1,980	390	2,370	61,300
Archetype 3: Switched on wealthier couples and families	8,470	21,370	29,840	140,700
Archetype 4: Families or younger couples in urban areas	1,940	1,890	3,830	100,200
Archetype 5: Wealthy rural families	2,440	2,420	4,860	29,500
Archetype 6: Older urban couples who own their homes outright	7,750	2,880	10,640	73,900
Archetype 7: Urban social renters with long term health problems	1,120	670	1,790	66,700
Archetype 8: Rural, less affluent older adult households	6,580	350	6,920	60,700
All households	**32,820**	**30,430**	**63,250**	**594,700**

Table 14: Distribution of current and projected solar PV installations across different energy consumer archetypes

Energy consumer archetype	Proportion of current solar PV installations (%)	Proportion of projected future solar PV installations in 2025 (%)	Estimated average bill change from future solar PV installations (£)
Archetype 1: Single low income renters using electricity for heating	7.7%	0.0%	£0
Archetype 2: Urban very low income single older adults	6.0%	0.0%	£0
Archetype 3: Switched on wealthier couples and families	25.8%	68.4%	-£215
Archetype 4: Families or younger couples in urban areas	5.9%	10.2%	-£192
Archetype 5: Wealthy rural families	7.4%	7.0%	-£208
Archetype 6: Older urban couples who own their homes outright	23.6%	8.5%	-£204
Archetype 7: Urban social renters with long term health problems	3.4%	3.5%	-£196
Archetype 8: Rural, less affluent older adult households	20.0%	2.4%	-£212
All households	**100.0%**	**100.0%**	**-£210**

Conclusions and Recommendations

Observations from distributional impacts modelling

This study has analysed the distributional impacts from modelling scenarios which consider a future changing energy landscape and how different Scottish energy consumers could engage with and switch to smart TOU tariffs, EVs, or install heat pumps or solar PV systems.

Evidence suggests that those most likely to switch to ToU tariffs in the near-term future are likely to be more affluent, middle-aged or older, employed and own their own home and be less risk-averse. As a result, those most likely to benefit from TOU tariffs are typically found in the more affluent archetypes, where households typically own their own homes, are more engaged in the energy market, such as Archetype 3: Switched on wealthier couples and families, Archetype 5: Wealthy rural families and Archetype 6: Older urban couples who own their homes outright.

Although it was anticipated that fewer households would purchase EVs or install low carbon energy systems in their homes than would switch to ToU tariffs, similar trends evolved from the projected uptake of these technologies. For instance Archetype 3 (Switched on wealthier couples and families) accounted for nearly half of EV owners by 2025 and two thirds of those installing solar PV systems between now and 2025. Archetype 5 (Wealthy rural families) was also expected to be the main energy consumer type that installed GSHPs by 2025.

Conversely, those least likely to be benefitting (and potentially losing out through increase energy costs) are those on lower incomes, more loss averse and renting their own homes such as Archetype 1 (Single low income renters using electricity for heating), Archetype 2 (Urban very low income single older adults) and Archetype 7 (Urban social renters with long term health problems). Neither Archetype 2 or Archetype 7 households were expected to install heat pumps by 2025, nor were any consumers in Archetype 1 or Archetype 2 likely to be able to afford the upfront costs of solar PV systems. The end of the FiT was also likely to see rates of installations of solar PV reduce for certain energy consumers and this was most noticeable for Archetype 8 (Rural, less affluent older adult households).

The modelling also suggests that there are likely to be geographical distributional impacts. For example, those in the Highlands and Islands are likely to be the least engaged in the transition to the smart TOU tariff market.

Overall, the modelling shows that having financial resources and being less risk-averse are likely to be significant driving factors in determining whether energy consumers will participate in the evolving smart energy market and adopt newer energy technologies. As a result, benefits from new technologies and energy market solutions are likely to be stacked upon those with higher incomes. The energy consumers most likely to benefit from the future energy market are those identified as Switched on wealthier couples and families (Archetype 3) and Wealthier rural families (Archetype 5).

Meanwhile, in is anticipated that there is likely to be a premium paid by those who are unable or unwilling to engage in future energy market changes. In particular, it is likely that as ToU tariffs become more common and households switching to these are able to shift energy usage to reduce costs, those left on standard tariffs could see their bills rise to cover losses in energy supplier revenues. In addition, all consumers are likely to see electricity bills increase to cover the costs of reinforcing the electricity network in order to handle increasing demands of EV charging, while only the most affluent are likely to be EV owners.

In summary, the modelling results presented here illustrate that as the energy market evolves over the next decade, there is likely to be a significant imbalance between the levels of engagement, the benefits received and the costs burdened by different energy consumer types. It should be welcomed that some wealthier energy consumers will help to promote the use of low carbon technologies and demand side management to help reduce carbon emissions and reduce the strain on the electricity grid. However, it should also be recognised that as things currently stand, significant numbers of lower income households (as well as households in other vulnerable situations or with additional needs) are likely to be both left behind as the energy market evolves, whilst at the same time financially contributing, through energy bills, to schemes that benefit less-vulnerable consumers.

Recommendations

This research has identified certain types of consumers that are likely to be ‘left behind’ by some of the changes occurring as part of the ongoing energy system transition. Those most disadvantaged by the current transition fall broadly into two categories: those who are left behind *and* as a result of this are detrimentally affected, and those who are unable to keep up with ongoing changes happening in the energy system and markets. (In many, but not all cases households will fall into both groups.) Mitigating the disadvantages faced by each of these groups of households requires two different but related approaches. Firstly, efforts are needed to minimise the extent to which these households are being left behind, including paying for, but not benefiting from, subsidised technologies. Secondly – as energy system transition continues to develop and evolve – considerations need to ensure consumers have the capacity to keep up with these changes and given equal access to new developments.

The ideas outlined below provide some possible examples to meet these demands. These aren’t necessarily intended to be directly applied by the Scottish Government, but are included here as food for thought and because the majority of these would benefit from political support. Furthermore, an overarching principle, ‘no one left behind’, has been previously articulated elsewhere (albeit with particular reference to energy network operators).[24] It is recommended that a similar principle is adopted by the Scottish Government, particularly when considering policy development that seeks to ensure the least

[24] Making ‘No one left behind’ meaningful in our future energy system: https://www.cse.org.uk/news/view/2281

capable and most vulnerable are protected from undue disadvantages as the energy system transition continues.

Ensuring households are 'less left behind'

Currently, left behind consumers are set to continue to financially contribute towards system changes that are likely to disproportionately benefit more engaged households on higher incomes. In essence, measures are needed to counter the broadly regressive nature of the energy system – and reduce the risks of detriment to lower income households – by ensuring that the costs of the energy transition are fairly passed on to consumers. As an example, consumers living in areas with low EV vehicle uptake shouldn't be expected to be contribute (through increased fuel bills) to network costs that arise from upgrades that are predominantly focused on ensuring those on higher incomes can charge their EVs at home whenever they need to.

Furthermore, EV ownership looks set to be concentrated in more urban areas (the modelling results suggest that over 80% of future EV owners will live in urban locations). Technical limitations regarding the location of existing charging infrastructure and range per charge are legitimate reasons why EV vehicles are currently more suitable for more densely populated areas. However, this disparity between rural and urban EV ownership is likely to continue unless increased investment in charging infrastructure is targeted at more rural areas in places where consumers such as Archetype 5 (Wealthy rural families) are found in higher numbers. Of course, some rural areas are likely to be less suitable for investment in network infrastructure due to low car ownership or because they are areas of with high proportions of lower income households who are unlikely to purchase private EVs. However, there are other options to ensure these communities have access to low carbon transport services. This is discussed in more detail below.

For the emerging ToU tariff market, obligations or duties should to be placed on suppliers that require them to identify the most suitable households who could benefit from a switch to ToU tariffs without the need to shift demand. This includes pensioners or stay-at-home parents who will see bills reduce because a significant amount of their energy consumption does not occur during peak times (or because they are able to switch away from peak demand without any significant change in daily routines). Conversely, suppliers also need to identify and be aware of those on the lowest incomes but who are the least flexible in terms of changing their energy consumption behaviour. These households are likely to see fuel costs rise if they are inadvertently switched to ToU tariffs without realising or being ill-informed of the consequences of more expensive electricity prices at peak times and when they most need to use electricity. More broadly, there is a more general need to raise awareness and educate consumers of the benefits and shortfalls presented by these new generation of tariffs as they become more commonplace.

Ensure households 'keep up' with ongoing changes and developments

Ultimately, mechanisms are required that focus on ensuring that more households who do not have financial, technical and educational advantages are able to participate in ongoing energy market innovations and achieve higher rates of ownership of emerging technologies. These mechanisms could include policies or grant funded programmes that provide financial support or zero or low cost loans to low income households, and thereby reducing the financial barriers associated with owning EVs or installing low carbon heating technologies. These programmes should highlight the reduced fuel and/or transport costs (as well as other indirect but related benefits) these technologies are likely to bring to these consumers.

Encouraging households to switch to ToU tariffs (where it has been identified that these households are likely to benefit from such as switch) should be implemented alongside other initiatives to ensure that these consumers maximise the benefits of these tariffs. For instance, some households will be able to easily navigate a world of smart appliances and gadgets (i.e. the internet of things) and have the financial ability to purchase additional kit to automate appliance and other energy use to maximise their consumption during the lowest tariff times. For others, adjusting energy consumption behaviour is likely to be a much more 'manual' process. Support and education to access and use additional smart kit and appliances that maximise the benefits of cheaper electricity at certain times of the day may help some, but not all, consumers, to adapt. As well as providing financial support to encourage ownership of these instruments, this could also involve promotion of leasing services for certain appliances, smart kit and gadgets to help with wider inclusion. Associated with this, however, is a need to consider whether any additional consumer policy protections are necessary to cover households leasing and using loaned equipment.

Finally, it is also worth considering increased EV ownership in a wider context of opening up access to a broader range of sustainable and low carbon transport infrastructure. While grants may help some households dependent on cars to access EVs they couldn't otherwise afford, other subsidies may help support a reliable low carbon public transport in other parts of the country, such as areas with low car ownership but high dependency on public transport. In this way, decarbonising local public transport for those currently without cars – and who are unlikely to want or be able to access a private vehicle – can be seen as a part of a wider low carbon transport initiative that helps a broader group of households participate and benefit from a range of low carbon transport options.