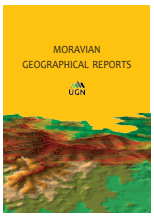
Decarbonising suburbia: Homeowners' perspectives on home retrofits and travel mode shift in Perth, Scotland



MORAVIAN GEOGRAPHICAL REPORTS

sciendo

The Czech Academy of Sciences, Institute of Geonics

journal homepage: http://www.geonika.cz/mgr.html

doi: https://doi.org/10.2478/mgr-2022-0019

Decarbonising suburbia: Homeowners' perspectives on home retrofits and travel mode shift in Perth, Scotland

Charlotte BUCKE [a], Connor SMITH [a], Dan VAN DER HORST [a]*

Abstract

Suburban neighbourhoods pose challenges to decarbonisation, due to high car-dependency and relatively large and energy inefficient homes. Home ownership dominates suburbia, thus putting responsibility on households to adopt measures to decarbonise their domestic lives and transportation. This paper examines household perspectives on the feasibility of such measures. We ran a survey and focus groups in Perth (Scotland) during the energy crisis. Whilst we found high levels of concern about climate change, energy costs, and growing engagement with cleaner technologies (e.g. heat pumps), most residents felt decarbonisation options were limited. Barriers like technologies' up-front costs, worsened with the cost of living crisis. Participants had low familiarity with sharing economy approaches like car clubs. Despite high (non-electric) bike ownership and prevalence of storage space (garages), cycling was more perceived as a leisure activity than a regular transport mode. There were shared views that the state should take a stronger role in coordinating and implementing systemic changes required for energy transition, including measures affecting residents directly, like reducing car traffic into the city centre. We conclude that despite the economic privilege of high home and car ownership in suburbia, few felt financially able to decarbonise and most seem locked into high-carbon suburban lifestyles.

Keywords: *Suburban; energy efficiency; mobility; active travel; neighbourhood; Perth*

Article history: *Received 10 October 2022, Accepted 21 November 2022, Published 31 December 2022*

1. Introduction

The Paris agreement sets out economy wide decarbonisation by 2050 (UNFCCC, 2015). Achieving these challenging targets will require radical and systemic changes to all sectors where significant amounts of energy are consumed. A quarter of the European Union's greenhouse gas (GHG) emissions are from transport, and road transport accounted for 72% of that proportion in 2019 (EEA, 2022). Buildings are responsible for 36% of the EU's GHGs (European Commission, 2020a), while residential buildings were responsible for 16.8% of total GHGs in Europe in 2014 (Gaglia et al., 2019). Yet, there is considerable scope for these sectors to reduce their carbon emissions through improved mobility services and energy efficiency in the home.

In the global north, the overwhelming majority of the population live in cities, where most of the energy consumption takes place. Literature shows that suburban areas have a greater impact on carbon footprint and GHGs per capita than larger, more densely populated areas (Dodman, 2009; Jones and Kammen, 2011; Jones and Kammen, 2014; Short and Farmer, 2021; Quinio and Rodrigues, 2021). Low- and middle-income countries exhibit higher carbon emissions per capita in urban areas (Grubler et al., 2012; York et al., 2003; Parikh and Shukla, 1995; Poumanyvong and Kaneko, 2010; Zhang et al., 2016; Moran et al., 2018; Liu et al., 2011; In: Munoz, Zwick, and Mirzabaev, 2020) while upper-middle and high-income countries exhibit lower carbon emissions per capita in urban areas (Li and Lin, 2015). Ottelin et al. (2019) analysed household carbon footprints in 25 European Union countries, finding that carbon footprints increase with urbanisation in Eastern Europe but decrease with urbanisation in Western Europe. This phenomenon is created by socio-economic variations between the economically less developed East and the rest of Europe, rather than the degree of urbanisation, which enable higher energy efficient urban areas in Western Europe.

Where suburban areas are more polluting, mobility patterns are the main culprit causing high emissions. Compared to people who reside in city centres, amenities and places of work are further from suburban residents' homes, causing longer travel distances made predominantly by private petrol/diesel cars (Macintyre, Macdonald and Ellaway, 2008; Quinio

[a] School of Geosciences, University of Edinburgh, Edinburgh, UK (*corresponding author: D. van der Horst, e-mail: *dan.vanderhorst@ed.ac.uk*)

and Rodrigues, 2021). Additionally, suburban homes tend to be larger, less energy efficient and less spatially concentrated (i.e. more stand-alone buildings, surrounded by gardens) (Quinio and Rodrigues, 2021). Therefore, there is high energy consumption for space heating, resulting in high carbon footprints per capita. Due to similar suburban sprawl patterns seen across the global north and considering the pressure of meeting global climate change mitigations target, European cities face a mutual challenge of reducing their urban and semi-urban emissions.

Research on public perceptions of and citizen engagement with low carbon energy technologies (LCETs) for homes and transport, can help to guide innovation and accelerate adoption. Conversely, negative perceptions and lack of engagement may slow the deployment of LCETs (Peterson, Stephens and Wilson, 2015). In the UK, "Energy use at the country level is largely influenced by residential energy use, and therefore, understanding household behaviour can contribute towards improving energy efficiency." (Taneja and Mandys, 2022, p. 1). The aim of this paper is to explore suburban homeowners' perceptions of home retrofitting options and sustainable mobility changes. We undertook a survey and subsequent focus group discussions in a single suburb, rather than a multi-city or national survey. This meant that participants could relate to (and hence we could study) the same place-based (as opposed to generic) challenges and opportunities associated with decarbonising existing homes. There is value in a place-based study as it puts focus on perceptions collected in one council area. Whereas, in a national study, perceptions would be collected from multiple council areas that are implementing various decarbonisation measures. Our geographical case study was the western outer suburb of the city of Perth, Scotland – an area focussing on new build projects providing low carbon living, as opposed to those for existing residents (see for examples, Perth Transport Futures, 2022; Perth West, 2021; and Public Contracts Scotland, 2021). The energy crisis, exacerbated by the Russo-Ukrainian war, has made societies more aware of and engaged with their energy use (Castanho Silva, Wäckerle and Wratil, 2022; Findlay, 2022), thus making our research (in spring 2022) particularly timely and the questions we asked, less abstract.

2. Literature review

2.1 Suburban transport: the European challenge

EU road transport emissions increased by 28% in 1990–2019 (EEA, 2022) and are projected to fall by only 35% by 2050 compared to 1990 levels (EEA, 2022). The 'Sustainable and Smart Mobility Strategy' aims to reduce transport emissions by 90% by 2050, (European Commission, 2020b). This follows the Green Deal funding for sustainable multi-modal urban mobility and clean-transport commitments in the New Leipzig Charter (European Commission, 2022). This strategy highlights actions to achieve sustainable suburban mobility; enhanced affordable high-speed rail, (via the European Rail Traffic Management System) abundant recharging and refuelling infrastructure for zero-emission vehicles, and promoting green active mobility (i.e. non-motorised) (European Commission, 2020b). This strategy acknowledges that additional guidance at local and regional levels alongside public and social acceptance is key.

66% of the European metropolitan population lives in the suburbs of Europe's 99 largest metropolitan areas (Arual Mobility Observatory, 2021). Public transport coverage is lower in European city peripherals than in city centres, with more private vehicles in suburbs (European Court of Auditors, 2020). For example, only 17% of Amsterdam's residents use private vehicles for trips within the city centre while 50% use their private vehicle to travel to and from the city (Eurocities, 2021). Ramos et al. (2019) found that the main barriers to using public transport were problems with buying tickets, low user-friendly interfaces, lateness, infrequency during off-peak hours, uncomfortable, lack of space, unsanitary WCs, poor weather, and private vehicles being more convenient. As car-sharing business models are typically designed for profitability and scalability, there is concern about the geographical scope for car-sharing as there may not be an adequate (local) mass of users (Sarasini and Langeland, 2017). In Greece, a new dockless bike-sharing scheme (DBSS) adequately serves the city centre and suburbs of Rethymno and is affordable (Bakogiannis et al., 2019). However, barriers to using the DBSS are low traffic safety, lack of cycling infrastructure, and physical exertion. In suburban Northern Poland, barriers to using e-bike-sharing schemes include the need to transport children, cost, and distance to docking stations (Bielinski et al., 2020).

2.2 Suburban transport: the UK challenge

In 2019, transport accounted for 27% of the UK's GHG emissions (Department for Transport, 2021). In 2022, Scotland's transport accounts for 36% of its total GHG emissions, 40% of that coming from cars (Green, 2022). Transport emissions are expected to increase due to new housing developments around the UK on greenfield sites on the outskirts of cities and towns which are designed for private car travel (CCC, 2019). These developments will have little or no access to public parking, few amenities, and poor or no walking and cycling routes (CCC, 2019). This is already the case for existing suburban and rural areas in the UK (Macintyre, Macdonald and Ellaway, 2008), resulting in suburban residents relying on private car use, thus increasing their emissions.

Lorenzoni, Nicholson-Cole and Whitmarsh (2007) found that, in three UK studies, many individuals perceived public transport in their area as unavailable and inaccessible. This, alongside the habitual use of private cars, is perceived by the UK public as contributing towards inadequate low-carbon transport adoption. Results from Davis and Whyte's (2020) workshop highlighted that organisational leadership across all sectors, political will, and follow-through action were required for sustainable transport change in Scotland. Additionally, the workshop revealed the need for a budget shift towards active travel, making private car use the most expensive mode of transport, highlighting availability of public transport, integrating car shares with public transport, incentivising businesses to encourage staff to car share, and, making public transport free for all. Alternative bus ownership models were favoured by the workshop with suggestions of returning bus ownership to the state. Davis and Whyte (2020) reviewed the challenges associated with making transport more environmentally sustainable in Scotland. These are: the habitual use of cars; only 3.3% of Scotland's budget for transport being allocated to active travel (i.e. walking or cycling); low availability, accessibility, and affordability of active transport; operational barriers such as slow public consultations and regulation setting; and varying socio-economic statuses. The pandemic has made the situation worse for public transport, leading to low usage and a subsequent fall in revenue (*ibid.*).

The sharing economy offers an important adoption route for LCETs for public use, like bike and electric car-sharing schemes (Gu, 2022; Ma et al., 2018). It allows residents to bypass the barriers of high up-front costs and it reduces their exposure to risks (perceived or observed) of technical problems with new technologies. However, there is evidence that bike-sharing benefits are unevenly distributed across socio-demographic groups (Ricci, 2015). Clark and Curl (2016) found that car- and bike-sharing schemes were located in areas allowing commercial advancement, resulting in most users being white, male, middle classed individuals – an unequal distribution. This suggests that there are tensions between environmental sustainability and social justice. Until economies of scale apply to both, reducing this tension will be a challenge as, ultimately, operators will consider the commercial viability of serving locations which tend to be outside suburban areas. In 2016 in the UK, car-sharing was a marginal activity due to low public awareness and varying attitudes held by policy-makers (Rodrigues, Cooper and Watkins, 2016). Rodrigues, Cooper and Watkins (2016) found that car-sharing was challenging in areas with lower population density in the UK. Kamargianni et al. (2018) found that, in London, car owners and non-car owners favour car-sharing schemes and car clubs over peer-to-peer (P2P) car rental. 20% of car-owners were willing to rent their cars via peer-to-peer (P2P) and willingness increased if they received financial benefits. Younger individuals were more willing to participate in car-sharing schemes.

2.3 Suburban retrofitting in Europe

Over 75% of European buildings are energy inefficient resulting in high energy consumption and high carbon emissions (Zhang et al., 2021). GHG emissions from buildings decreased by 29% between 2005–2019, via the EU decarbonisation strategy enacting electrification in the residential sector, decarbonising the electricity sector and improving building energy efficiency, (EEA, 2021). Despite European countries introducing residential retrofit policies, retrofit rates are still low due to implementation complexity, this is also true internationally (Zhang et al., 2021). Before the current energy crisis, 34 million Europeans could not afford to heat their homes (European Commission, 2020a). Although retrofitting can reduce energy bills and improve resident well-being, the affordability of retrofitting can be a challenge, which the EU seeks to address through policies like the 'Social Climate Fund' and 'Renewed Sustainable Finance Strategy' (European Commission, 2020a). Considering suburban homes are generally larger and less energy efficient, retrofitting is a particular challenge there.

Barriers to residential retrofitting across Europe fall into four categories. Firstly, technical problems – lack of skilled workforce (Galvin and Sunikka-Blank (2013); Weiss, Dunkelberg and Vogelpohl, 2012), poor accessibility to skilled workers (Neuhoff et al., 2011; Sebi et al., 2019), lack of collaboration between differently skilled workers (Galvin and Sunikka-Blank, 2017); and difficulty in identifying which retrofit measures apply to individual properties (Wu et al., 2017). Secondly, financial problems – initial investments are unaffordable (Myhren et al., 2018; Ortiz, Caquero-Modrego and Salom, 2019; Tsoka et al., 2018); there is uncertainty around investment returns (Galvin, 2012), and there is a lack of financial support (Sebi et al., 2019). Thirdly, management problems – tensions can arise between landlords and tenants if the property owner is unwilling to invest in high energy-efficiency retrofits; this means tenants are unable to benefit from lower energy bills and more sustainable living (Lang et al., 2021). The rebound effect is prominent as residents who have retrofitted tend to use more energy due to financial savings, therefore the environmental benefit is not as high as it is claimed to be (Gram-Hanssen, 2014; Lopez et al., 2018). Lastly, lack of knowledge and awareness – residents have limited awareness of and knowledge about energy efficiency and retrofitting causing unwillingness to start (Caputo and Pasetti, 2015; Christensen et al., 2014; Ebrahimigharehbaghi et al., 2022). There is a lack of motivation to learn about the process and go through the upheaval of retrofit (Karytsas and Theodoropoulou, 2014).

2.4 Suburban UK retrofitting

The UK has the oldest and (thus) one of the least energy-efficient housing stocks in Europe (Bennadji et al., 2022; Paddington et al., 2020), a key causal factor of UK homes being responsible for 16% of UK GHGs (UKGBC, 2022). Researchers have examined the impact of UK policies, such as the Green Deal, on retrofitting. The general consensus is that policies are failing to deliver at the pace needed to ensure alignment with climate targets and legal obligations (e.g. the 2008 Climate Act and Carbon Budgets) (Putnam and Brown, 2021). For example, the 'Zero Carbon Homes and Code for Sustainable Homes' policy has been removed (CCC, 2019). The remarkable lack of UK government ambitions to address energy efficiency in the built environment stands in clear contrast with the efforts made by the devolved administration in Scotland (Wade et al., 2022; Webb and van der Horst, 2021), but in general, low carbon housing funding priorities seem to go towards flats, social housing, the fuel poor or towards low carbon new builds thus paying insufficient attention to the housing category of existing owner-occupied suburban homes (Alexander and Gleeson, 2018; Frantál and Dvořák, 2022).

Decarbonising the housing stock requires installing heat pumps, which requires skills (CCC, 2019). However, the instability of UK Government policies has stunted enrolment of skills development in housing design, construction, and heat pump installation (*ibid.*). Policy failure is caused by underdeveloped supply chains, due to a lack of policy support and inconsistent demand caused by retrofitting challenges (CCC, 2019; O'Keeffe, Gilmour and Simpson, 2016). Underdeveloped supply chains create a lack of trust in contractors to install LCETs (O'Keeffe, Gilmour and Simpson, 2016). This concern is accelerated by concern for LCET reliability, outcome quality, and cost-savings, even when there are motivations for retrofitting (Wilson et al., 2015). Fylan et al. (2016) argue that the lack of trust in LCETs is compounded by the existing homogeneity of policies and technologies offered by contractors who rarely consider residents' quality of life. Hansford (2015), Brown et al. (2018), and Lowe and Chiu (2020) argue that contractors and policymakers must view and incentivise houses as a whole system, eradicating the current way of viewing retrofitting; single technology replacements/ instalments. The challenge with this is the complexity of coordinating multiple contractors and technologies to minimise financial and disruption risks (Brown, 2018; Kieft, Harmsen and Hekkert, 2020). Akin to the European context, there is a lack of public awareness and knowledge of retrofitting options, due to ineffective public engagement programmes (Brown et al., 2018; CCC, 2019; Marchand Koh, and Morris, 2015). Also, financing and concerns for disruptive installation challenge retrofitting (CCC, 2019;

Rosenow and Eyre, 2016). An additional barrier is a lack of appropriate modelling tools that do not accurately convey the complexity of potential futures looking towards 2050 (Eames et al., 2014).

Literature reveals systemic challenges of retrofitting homes compound social challenges. Pelenur (2013) described retrofitting barriers similar to Europe: upfront cost; property structure; behaviour (e.g. lack of time, convenience, forgetfulness, and laziness); landlord-tenant associations; inter-occupant opposition; lack of knowledge; and institutional distrust. Pelenur (2013) also found seven motivating factors: saving money; environmental benefits; resource efficiency; comfort; aesthetic; health and safety; and convenience. Williams et al. (2013) presented challenges of retrofitting English suburbs, including the size of the suburban estate, lack of climate change adaptation awareness, lack of finance, and lack of clarity on those responsible for suburban change. Trotta (2018) found barriers to accepting household retrofit in England are credit constraints, lack of information, questioning the rationale of retrofitting, retention of the status quo, heuristic decision making and inconvenience. Trotta (2018) revealed that older individuals, women, and residents of flats are more likely to invest in retrofits than younger individuals, men, and residents of other properties. Furthermore, pro-environmental behaviour did not correlate with investment, suggesting a trade-off between environmental value and cost.

Table 1 summarises the key findings from the 11 existing empirical studies on suburban perceptions of home retrofitting and low-carbon transport that we found. Table 2 provides methodological and case study details of these studies. As these tables illustrate, our paper stands out in addressing both retrofitting and transport. It also adds to the diversity of empirical literature in terms of geography (Scotland) and the smaller case study urban area (Perth).

Authors	Key Findings
Suburban retrofitting	
Williams et al., 2013	Residents believe that comfort, cost and health should be priorities when implementing suburban adaptation measures.
	Damage to homes and degradation of greenspace must not occur.
	Adaptation options are different for different types of suburbs facing different threats; local approach required.
	Both residents and stakeholders were unfamiliar with many adaptation options. Most had basic knowledge on mitigations measures (e.g. solar PVs and insulation).
	Some residents have already implemented changes (e.g. roof insulations, triple/double glazing, and trickle vents) but motivated to do so due to cost savings, not environmental benefits.
	Unacceptable measures: External wall insulation, extended eaves, external render, flood-proof door, flood gate, air brick covers.
	Measures which have mixed perceptions: Solar panels, internal shutters, shaded outdoor space, internal thermal mass, green roof, white roof and walls, blue infrastructure, drought-resistant trees, community cool room, reconfigure street drainage.
	Measures already implemented or will be considered: Solar PVs, double/triple glazing, roof insulation, external solar shading, solar film, lock-open windows, water butt, street trees, shading in green space, energy efficient street lighting.
Mortensen et al., 2014	Energy savings do not motivate homeowners to implement home energy retrofits.
	Financial cost of energy retrofits is often why homeowners do not implement energy retrofits.
	Motivations to retrofit include home comfort and architecture.
	Knowledge of non-energy benefits and consumption increase retrofits, therefore there is a need for a strategy to improve knowledge.
Qui et al., 2014	Urban and suburban homes are less likely to have conducted energy efficiency measures.
	Households' perceived mobility as measured by the probability of moving within five years, can amplify the negative impact of risk aversion on the adoption of energy efficiency retrofitting technologies.
	High upfront cost was a common barrier for the diffusion of efficient technologies.
	There were uncertainties about the benefits an individual can receive from efficient technology adoption.
	Risk aversion has a negative influence on the diffusion of energy efficiency retrofitting.
Sunikka-Blank and Galvin, 2016	Homeowners are reluctant to compromise heritage or aesthetic components of their homes for retrofits.
Tsoka et al., 2018	Installation costs and maintenance, aesthetics, insulation efficiency and risk of wall dampness were significant factor influencing decisions to implement retrofits.
Suburban low-carbon transport	
Ogilvie et al., 2008	Active travel was associated with being younger, living in owner-occupied accommodation, not having to travel a long distance to work and not having access to a car.
	Active travel increased with close proximity to shops.
	Environmental characteristics may have limited influence on active travel in deprived urban populations characterised by a low level of car ownership, in which people may have less capacity for making discretionary travel choices.

... Tab. 1: continuing on the next page ...

Authors	Key Findings
Suburban low-carbon transport (continued)	
Barton et al., 2012	Places and communities vary to a degree which makes generalisations based on average figures potentially very misleading for any particular locality.
	New suburbs and commuter settlements are generally more car dependent than older suburbs and areas on urban edges.
	Flat areas are less car dependent, and see more walking and cycling than hilly areas.
	Areas with extremely high car use are those with cul de sac layout.
	Areas with highest levels of active travel are those with cell-type or linear layouts.
	Areas with high public transport use are those with better quality public transport services.
	Active travel was perceived as more important for health than for environmental reasons.
	Barriers to walking included high traffic and unsafe streets.
Aldred et al., 2019	The intervention programme in the suburbs have a measurable and positive early impact on active travel uptake and perceptions of the local cycling environment.
Biehl et al., 2019	A barrier to walking and cycling is fear for personal safety.
	Active travel is viewed as conduits of leisure fulfilment rather than a utilitarian activity.
	Public transport is viewed as top priority to meet utilitarian needs of the community as jobs are located outside of the neighbourhood.
	Social status is perceived as a barrier to travel behaviour change; public transport for low social status in Evanston but as utilitarian in Humboldt Park. Cyclists in Evanston are perceived to be 'looking down' on others, while in Humboldt Park, cyclists are 'scoffed' at as it is only seen as leisure. However, participants in both areas express interest in reduced car travel.
	Demonstrates the need to capture individual and neighbourhood level variation in attitudes.
Delgado Jalón et al., 2019	The underground and buses are perceived as expensive and for the 'working class', which prevents middle-upper class individuals from using them.
	The metro is preferred over busses for its speed. However, if the traveller has more time, making the trip for leisure or is elderly, the bus is preferred as it is perceived as more pleasant.
	Public transport is perceived as a healthy option for the city, money saving and time saving as there was difficulty in getting into the city by car and poor parking availability.
	Older people opt to use public transport due to lack of a car or driving licence.
Ramos et al., 2019	Public road transport was, at times, perceived as polluting, being late, and expensive.
	Some prefer private car use for several daily trips due to poor coverage of transport network.
	Perceptions of affordability of public transport vs private car were divided.
	Transit users outside Lisbon municipality mainly use "pollutant", "traffic" and "expensive" to describe road transport.
	For the trains outside Lisbon municipality, the most prominent words are "Hygiene" and "Reliable".
	Public transport usage would increase if the level of service was brought in line with users' expectations.

Tab. 1: Key findings from empirical studies of perceptions of home retrofitting and sustainable transport in suburbia Source: authors' compilation

Fig. 1: A) Case study location in Perth, Scotland. B) Map placing Perth in Scotland. Blue lines indicate Perth and Kinross Council area. Source: authors' compilation

Authors	Study Location	Research Focus	Research Methods
Suburban retrofitting			
Williams et al., 2013	Oxford, Bristol, and Stockport (England)	• To identify a range of adaptation options for different types of suburbs in England • Focusses more on retrofitting than transport • Focusses on both individual home and neighbourhood action	• 3 different models to model the effectiveness of adaptations measures • Data on neighbourhood characteristics gathered from maps, literature, on-site assessments, and home-owner questionnaires • 7 workshops with residents, professionals, and institutional stakeholders to test acceptability of adaptation measures (6–15 people in each, recruited through postal invitation)
Mortensen et al., 2014	Suburbs of Aalborg, Aarhus, Odense, and Copenhagen (Denmark)	• To determine how Danish homeowners can be motivated to conduct energy retrofits	• Questionnaires
Qui et al., 2014	Arizona and California (USA)	• To investigate the relationship between homeowner risk preferences and the decision to improve the energy efficiency of a home	• Online surveys • The multiple price list (MPL) method to elicit and measure homeowner risk preferences
Sunikka-Blank and Galvin, 2016	Cambridge (England)	• To provide new knowledge on the attitudes and motivations of UK homeowners and uncover possible resistances to thermal retrofits	• Interviews with retrofitting owners, many of whom reside in typical suburban homes
Tsoka et al., 2018	Greece, Italy and Spain	• To investigate the public and professional attitudes towards an innovative energy efficient façade refurbishment system, in suburban multi-storey buildings in Mediterranean countries	• Two multiple choice questionnaires.
Suburban low-carbon transport			
Ogilvie et al., 2008	Glasgow (Scotland)	• To examine the contribution of putative personal and environmental correlates of active travel and overall physical activity in deprived urban neighbourhoods in Glasgow, Scotland	• Postal survey
Barton et al., 2012	12 suburbs and exurbs in London, Newcastle, Cambridge and Bristol (England)	• To determine neighbourhood accessibility and active travel to local facilities	• Postal household survey • GIS to locate post code centres • Ordnance Survey Meridian dataset to determine actual trip distances • Focus groups
Aldred et al., 2019	Suburbs in Enfield, Waltham Forest, and Kingston ('mini-Holland' programme area)	• To examine whether and how proximity to active travel interventions is associated with changes in travel behaviour and attitudes	• Longitudinal survey
Biehl et al., 2019	Humboldt Park neighbourhood and suburb of Evanston (Illinois, USA)	• To uncover the local mobility culture, embedded norms and values associated with acceptance of active travel modes in different communities	• Focus groups
Delgado Jalón et al., 2019	Madrid (Spain)	• To study user's perceptions of urban and suburban transport to compare the social value of various means of transport. (Comparison of urban and suburban was not clear)	• Face-to-face survey
Ramos et al., 2019	Suburbs of Lisbon (Portugal)	• To obtain a deeper understanding of attitudes towards public transport and to explore perceptions of the public transport service	• Ethnographic interviews • Focus group discussions • Content and inductive thematic analysis

Tab. 2: Details of the empirical studies mentioned in Table 1. Source: authors' compilation

3. Methodology

3.1 Case study: Perth

Our research took place in the western (outer) suburb of the city of Perth, Scotland (Fig. 1 – see p. 292). Perth is a small but growing city, located almost entirely on the west bank of the river Tay. The city is situated in central Scotland, at a key crossroad of national motorways which separate the city's existing suburbs from planned urban extensions further to the west. With approximately 50 thousand inhabitants, Perth is the only city and largest population centre within the local authority area of Perth and Kinross Council (PKC) which has a total population of 151,910 (National Records of Scotland, 2021).

For our case study, we chose an existing suburban area on the western edge of Perth, some 3–4km travel distance from the city centre. The ring road (A9) borders our case study area on the west side. On the south side our case study area is bordered by a key road running into the centre of town (A93 Glasgow road). PKC staff advised us on locally perceived neighbourhood boundaries on the northern and eastern sides and the prevalence of social versus private sector housing. We were interested in targeting the latter, as we wanted to know what homeowners consider to be relevant and appropriate measures to reduce energy use and lower their energy bills. Google street view and a site visit ensured the properties on selected streets did not vary hugely in age and architectural type; they date mostly from the 1970s and younger (NLS, 1970), and consist of bungalows and two-story houses, mostly detached. Perth and Kinross council area was among seven Scottish local authorities whose levels of extreme fuel poverty were higher than the national average (12%). 18% of Perth and Kinross' population lived in extreme fuel poverty – a result of the average EPC (Energy Performance Certificates) being quite poor, namely F or G (Scottish Government, 2021).

Surveys (summarised in Table 3) were distributed to every second or third home across the neighbourhood. Of the 480 surveys distributed, 120 were completed and sent back to us by post. In addition to the largely quantitative survey, we undertook two focus group sessions with local residents. Whilst quantitative survey data is effective in understanding what participants think about a particular topic, the qualitative nature of focus groups enables greater exploration regarding why participants think as they do (Wilkinson, 1998; Nyumba et al., 2018). Thus, we hypothesised that combining these two methodologies enables greater insight into social issues than would otherwise be possible if either were utilised in isolation.

3.2 Research Methods

In addition to quantitative survey data, qualitative data was obtained with the survey through open-ended questions and the free association method which reflects the "implicit ways of thinking about energy technologies" (Devine-Wright, 2005, p. 10) by eliciting qualitative responses that are not constrained in choice. Responses to association questions were cleaned and homogenised to create a list of semantic associations. Survey respondents' associations were subject to deductive thematic analysis as we were familiar with the data and literature, aligning with Rivas (2012) criterion for deductive analyses. This allows researchers to tailor the analysis based on previous research and theory (Braun and Clarke, 2006). The deductive thematic analysis was guided by the 6 stages of thematic analysis by Braun and Clarke (2006) and Kiger and Varpio (2020). The themes in this analysis were inspired by key external factors that influence successful implementation of cleaner energy technologies. Moreover, successful adoption and diffusion of innovations were often assumed to be merely an issue of securing the techno-economic dimension." (Valet, 2008, p. 8). However, aligned views of various stakeholders (social acceptance) are necessary for successful technology developments (*ibid.*). Additionally, stable political coalitions which are supportive of renewable energies (Van Est, 1999) and strong, early policy support have been discussed as crucial for successful renewable energy development (Krohn, 2002). Valet (2008) advocates for the inclusion of socio-economic factors when considering the deployment of renewables. Research also suggests that environmental awareness and environmental impacts of technology deployment are among the many factors that influence public perceptions of renewable energy (Tsoutsos, 2002). In short, existing literature highlights several influential factors that fall within the following themes: political (e.g. government in support of renewable energies); economic; social; technological; environmental; and legal (policy support), making up the coding framework. The coding framework was ultimately subjected to inter-rater reliability tests (see for example Belur et al. (2018), yielding a 96.2% rater agreement).

Quantitative survey data was analysed in statistical software, SPSS. Frequencies and descriptive statistics provided an overview of the survey population. Subsequently, parametric tests, such as independent t-tests and bivariate correlations, were conducted. Qualitative data was transcribed, coded and analysed. Focus group participants were recruited via a question in the survey asking respondents if they were interested in participating in further research. A total of eight residents participated, four in each group. Both sessions were conducted online via the Zoom platform and lasted approximately 90 minutes each. Thematically, discussions were split into two parts: part one focussed on how Perth can become more sustainable and living sustainably in Perth, whilst part two explored home retrofit and sustainable mobility options. After transcription and anonymisation, high-level themes were identified through thematic analysis (see Braun and Clarke, 2006). Subsequently, tables were created and populated with qualitative data relevant to each of the corresponding themes. Drawing upon this, we were able to weave together a narrative for the identified themes; what local residents think about living sustainably in Perth, home retrofit, sustainable mobility, and why.

4. Results

4.1 Properties

55% of survey respondents lived in detached houses while 26.7% lived in detached bungalows, 11.7% lived in semi-detached houses, and 5% lived in semi-detached bungalows. All survey respondents had the space to park cars on their own property; 81.7% of respondents used both a garage and driveway, and 10.8% used driveways only. 5.8% used garages only. Only one person had no car. We observed that the roads were relatively narrow and public parking spaces were rare. This would make it more challenging to create bike lanes for example.

4.2 Household energy and energy efficiency

The area is served by the national gas grid. 97.5% of survey respondents reported that they used a gas boiler with

Topic	Question
Socio-demographics	Age (eight age brackets), Gender ('male', 'female', 'non-binary', 'other' & 'prefer not to answer').
Household, property and parking type	Length of time lived in home (11-point scale, 5 years each).
	Property type ('detached house', 'detached bungalow', 'semi-detached house', 'semi-detached bungalow').
	Parking ('garage only', 'driveway only, 'on-street only', 'no parking', 'both garage and driveway', 'garage, driveway, and on-street').
	Home ownership ('I own my home', 'I rent my home', 'other').
Energy in the home	Heating system ('gas boiler & central heating', 'gas fire(s)', 'electric heating', 'wood stove', 'other').
	Using more energy during CV19 lockdown, worried about rising energy bills and cost of living crisis. For each, 4-point scale ('yes, a lot', 'somewhat', 'not really', 'not at all').
Energy efficiency and retrofitting perceptions	Satisfied with home insulation ('no', 'yes', 'if no, why not?').
	Invested in energy efficiency ('no', 'yes', 'if yes, what investment?).
	Energy Performance Certificate (EPC).
	Perception of retrofitting options – roof insulation, cavity wall insulation, double/triple glazing, air source heat pump (ASHP), ground source heat pump (GSHP), solar panel (PV), solar water heater (for each, 'I am not sure what this is', 'I have this already', 'I would consider this', 'I would not consider this', 'If you would not consider option, why not?').
	Free associations with "renewable energy for heating your home".
Transport habits and perceptions	Vehicles at household - total number and how many are electric ('car', 'motorbike/scooter', 'bicycle', 'other').
	Regular trips ('work', 'school', 'shopping/groceries', 'sport/recreation', 'other') – approximate distance (miles), frequency (no. of days per week), main and secondary mode of transport ('car', 'bus', 'bike', 'walk', 'car share', 'motorbike/scooter', 'e-bike').
	Perceptions of changes to private petrol/diesel vehicle use:
	Reducing petrol/diesel private vehicle use.
	Getting rid of petrol diesel private vehicle.
	Replacing petrol/diesel private vehicle with an electric vehicle.
	Replacing petrol/diesel private vehicle with bike/electric bike.
	Replacing petrol/diesel private vehicle with car-sharing/bike-sharing scheme.
	Specify conditions for the change.
Environmental action and concern	Partaken in neighbourhood/community environmental activities ('no', 'yes', 'if yes, please specify which activity').
	Take part in future neighbourhood/community environmental activities ('no', 'yes', 'if yes, please specify which activity').
	Concerned or unconcerned about global climate change ('very unconcerned' to 'very concerned': 5-point scale).

Tab. 3: Survey topics and questions
Source: authors' compilation

central heating, 9.2% reported that they used gas fires, 9.2% also used electric heating and 6.7% used wood stoves. The remaining 4.8% reported that they used 'other' systems: the four individuals mentioned solar panels, "solar thermal panel for hot water", an Aga cooker, and coal respectively. Given the climate, a house in Perth would have to be designed to eco-home standard (a rarity in Scotland) in order to be heated alone by roof-mounted solar panels (presumably running a heat pump) or by solar thermal (presumably with thermal storage). Using dirtier and more expensive heating options like coal fires or an Aga (which usually runs on oil) is more frequently found in rural Scotland, beyond the national gas grid.

A majority of survey respondents had used more energy during the COVID-19 lockdown, ranging from a lot (18.3%) to somewhat (42.5%) (Fig. 2). Reflecting back on the autumn of 2021, i.e. before the Russian invasion of Ukraine triggered huge energy price rises, 30% of respondents had been worried about their energy bills (7.5% 'a lot'; 22.5% 'somewhat'). At the time of the survey in spring 2022, with rising energy bills going hand in hand with high inflation and a wider cost of living crisis (COLC), this number has nearly tripled; 45% 'a lot' and 40.8% 'somewhat'. Only 3.3% reported to be 'not at all' concerned, a fivefold drop from the 17.5% in the autumn.

There was a statistically significant correlation between the number of people in households and how worried respondents were about rising energy bills and COLC, albeit weak ($r(117) = -0.214$, $p = 0.019$, two-tailed); as the number of people in the household increased, concern for rising energy bills and COLC also increased. The majority of focus group (FG) participants had already invested in energy efficiency upgrades, notably various forms of insulation and double/triple glazing windows. This aligns with our survey results which found that 65.8% of respondents had invested in energy efficiency upgrades, while 16.7% had not. 65.8%

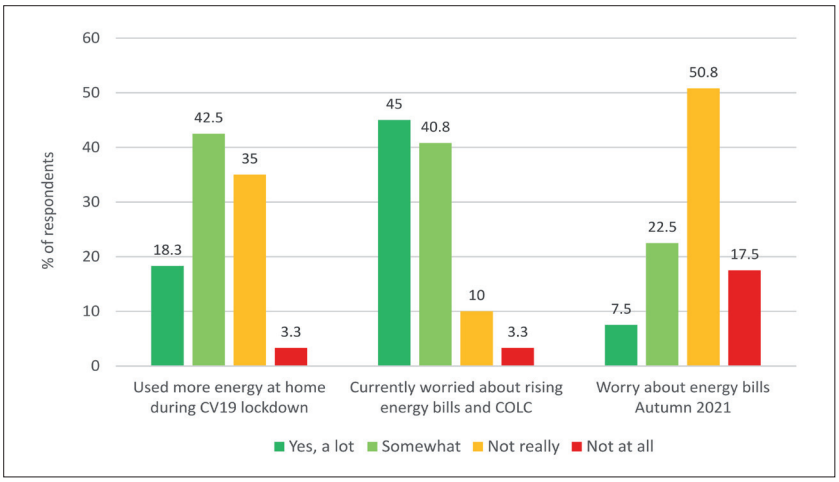


Fig. 2: Levels of concern for energy scenarios for the entire survey population
Source: author's survey

of respondents were happy with their home insulation and 31.7% were not. Table 4 lists the reasons why survey respondents were not happy with their home insulation. Table 5 lists the investments which survey respondents have made to improve their home's energy efficiency. There was no statistically significant difference in the mean level of satisfaction with home insulation between survey respondents who have and have not invested in the energy efficiency of their homes.

4.3 Environmental action and concern

As a proxy indicator of a sympathetic view towards collaborative or collective responses to decarbonisation and energy use reduction, we asked if people had participated in community activities for the common good. 91.7% of survey respondents had never partaken in community activities designed to improve their community's environmental friendliness while only 6.7% had. 65% of survey respondents would not like to partake in future community activities to help their local area become more environmentally friendly, and 27.5% would. Survey results show one focus group participant was somewhat unconcerned about climate change, one was somewhat concerned and the remaining six were very concerned. Only 53% of survey participants were concerned about climate change, a response which seemed unconnected to attitudes about collective local environmental action. A correlation between opinion on partaking in future environmental community activities and age was statistically significant ($N = 120$, $r = -0.199$, $p = 0.029$); older people were less keen. It would make sense to assume that physical fitness plays a key role here.

4.4 Retrofitting

Table 6 shows survey respondents' top 10 associations with "renewable energy for heating your home". This shows that the top 10 associations are dominated by negative economic factors, neutral technological statements, and positive environmental associations. Survey respondents were asked if they would consider various retrofitting options if money was not a barrier (Fig. 3).

One respondent expressed that underfloor insulation would be an additional retrofitting option to consider and one respondent expressed that they would consider wall cladding Respondents were least sure about ASHPs and GSHPs. The retrofit option that was already implemented the most was double/triple glazing. The option which respondents

Reason	No of respondents who expressed reason
Require roof insulation	6
Would like underfloor insulation	5
Would like better insulation	5
Home is cold (despite energy efficiency measures)	5
Require cavity wall insulation	3
Home is still draughty despite energy efficiency measures	3
Require new windows	2
Would like cavity wall insulation but it is not possible	2
Over insulated loft	2
Windows too large	1
Require new doors	1
Lose heat	1
Areas hard to insulate	1

Tab. 4:Reasons why respondents were not happy with their home insulation
Source: authors' survey

Investment	N of respondents who made investment
Loft/roof insulation	41
Double/Triple glazing (upgraded windows)	38
Installed new boiler	21
Installed cavity wall insulation	14
Underfloor insulation	6
Upgraded doors	6
Installed more insulation	3
LED bulbs	3
Smart radiator valves	2
Draught excluders	2
New heating system	1
Installed new radiators	1
Installed solar panels	1
Installed energy efficient lighting	1
Smart meter	1
Smart thermostat	1

Tab. 5: Investments respondents made to improve their home's energy efficiency. Source: authors' survey

Association	N of respondents who expressed same association
Cost/Price	20
Expensive/too expensive/costly	16
Solar/Panels/Solar panels	13
Wind/Turbine/Windfarm	11
Environment/Environmental	9
Cheap/Cheaper	7
Clean/Cleaner	7
Sustainable/Sustainability	6
Eco/Eco-friendly	6
Efficiency	6

Tab. 6: Respondents' associations with "renewable energy for heating your home". Source: authors' survey

would consider the most suitable was solar PVs. The option respondents considered the least suitable for their home was cavity wall insulation. There were several reasons given for why respondents would not consider different retrofit options (Tab. 7). Survey respondents' opinions on different retrofit options were organised based on their property type (see Tab. 8 and Appendix 1). We tested for a correlation between concern for global climate change and consideration of retrofitting options but found nothing significant. Nor were there statistically significant independent t-tests showing differences in the mean level of concern for global climate change among those who would and would not consider each retrofit option.

Focus group (FG) participants' survey responses can be seen in Appendix 2. FG participants mentioned some barriers to replacing their gas boiler central heating system with an ASHP or GSHP, in some cases complimented with a wood stove or gas fire. These included the upfront cost and disruptive installation of heat pump technologies. This aligns with our survey findings (Fig. 3); only 42.5% would consider ASHPs and 39.2% would consider GSHPs. FGs revealed that several residents had recently considered and researched the possibility of replacing gas boilers with heat pumps, only to find out that unaffordable or inappropriate for their property. Another challenge for (FG) participants was getting a qualified engineer out to visit their property in Perth.

Additional concerns regarding heat pumps included: the aesthetics of the equipment in gardens; and noise emitted by heat pumps which could be problematic when installed close to neighbours' bedrooms. One FG participant expressed that heat pump barriers would be significantly diminished if they were already installed and included in the overall price of new build properties. This chimes with the overall consensus of FGs suggesting that the transition to low-carbon heat in homes should be led and enabled by local and national governments. In other words, the idea of relying on individual adoption of cleaner technologies and more sustainable behaviour was challenged; people (who tried to make their individual contributions too) thought that there were structural and infrastructural issues that really had to be addressed at a higher level, with more urgency and vision. Consistent failure by 'the Government' was mentioned by many while trying to avoid political discussions. This is an example of FGs providing additional insight beyond survey responses.

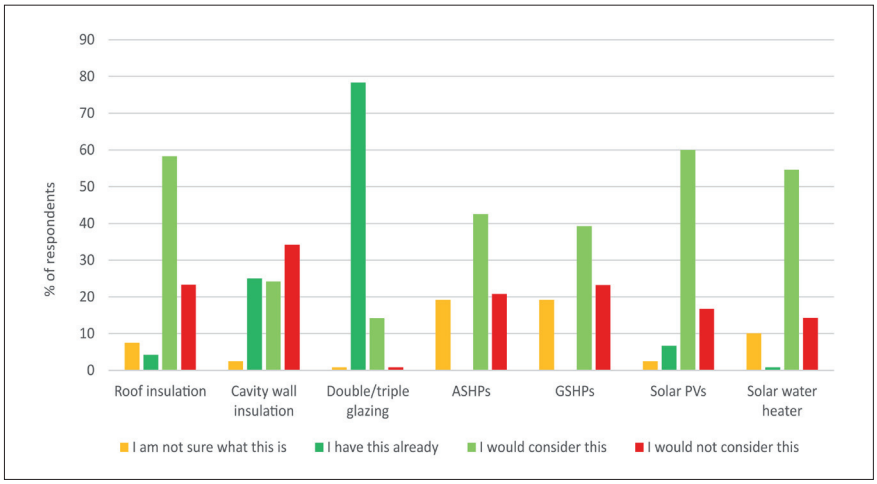


Fig. 3: Percentage of respondents who expressed each opinion about different retrofit options if money was not a barrier Source: authors' survey

Roof insulation	Cavity wall insulation	Double/triple glazing	ASHP	GSHP	Solar PV	Solar water heater
• Cost (1)	• House not suitable (20)	• No reasons given	• Cost (8)	• Cost (7)	• Cost (5)	• Cost (5)
• Not worth the hassle (1)	• Cavity is there for a reason (2)		• Recent new boiler (2)	• Not enough ground space (5)	• If problem with roof, may be a barrier (2)	• Too much change and hassle at my age (1)
	• Cost (1)		• Insufficient knowledge (1)	• Too much hassle at my age (1)	• Too much change and hassle at my age (1)	• Wrong climate (1)
	• No benefit to my house (1)		• Yet to be convinced (1)	• Concern regarding the longevity (1)	• Wrong climate (1)	
	• Not worth the hassle (1)		• Too noisy (1)	• Don't understand system (1)	• No south facing roof (1)	
	• Concerned about damp bridging (1)		• Not suitable to make home really warm (1)	• Not suitable to make home really warm (1)	• Ugly on roofs (1)	
	• Bad reviews about it (1)			• House not suitable (1)	• Not effective (1)	

Tab. 7: Reasons why retrofit options were not considered (N of respondents who said reason)
Source: authors' survey

Retrofit option	Property type least knowledgeable on retrofit option	Property type which owns the most of retrofit option	Property type which would consider retrofit option the most	Property type which would least consider retrofit option
Roof insulation	Detached bungalows	Detached bungalows	Semi-detached bungalows	Detached houses
Cavity wall insulation	Detached bungalows	Semi-detached houses	Detached houses	Semi-detached bungalows
Double / triple glazing	Detached bungalows	Detached bungalows	Semi-detached bungalows	Detached houses
ASHP	Semi-detached houses & detached houses	No respondents own	Detached houses	Semi-detached bungalows
GSHP	Detached houses	No respondents own	Detached houses	Detached bungalows
Solar PV	Semi-detached bungalows	Semi-detached houses	Detached houses	Semi-detached bungalows
Solar water heater	Detached bungalows	Detached houses	Detached houses	Semi-detached bungalows

Tab. 8: Property types which are the least knowledgeable of retrofit options, own the most of each retrofit option, would consider and would not consider each retrofit option the most
Source: authors' survey

FG participants were more technologically knowledgeable than we anticipated; many knew about heat pumps and had clearly researched them prior to the FG. In subsequent FG discussions, we confirmed that, currently, heat pumps are significantly more expensive to purchase, install, and operate than gas boilers. Perceptions of these negatives, unsurprisingly, outweighed the positive perceptions, i.e. carbon emission reductions. Despite having some technological knowledge, residents were unaware of organisations that provide free information regarding grants and interest-free loans (e.g. Energy Saving Trust). Finally, FG participants indicated an interest in Peer-to-Peer energy trading (e.g. by selling or gifting energy generated through Solar PV/Battery Energy Storage Systems (BESS) to neighbours), which could be an avenue for further research.

4.5 Vehicles Owned

As expected in suburbia, car ownership was ubiquitous. 51.7% of households had one car, 33.3% had two cars and 5.9% had more. Only 7.3% of cars were electric. To compare, 3.3% of cars in the UK were electric, including plug-in hybrids, in 2020 (Pickett et al., 2021). Three survey participants had camper vans and two participants had a scooter or motorbike. In addition, bike ownership turned out to be fairly common; a third of households had multiple bikes and a further 10% had a single bike. 9.6% of bikes were electric.

4.6 Regular Trips

To gather data on the survey respondents' use of transport, we asked them about regular trips made by each member of their household (Tab. 9). The trip made most among the 249 individuals living in the 120 respondent households was for shopping/food groceries. Overall, the mean distance travelled for regular trips made by the 249 individuals was 18.7 miles (30.01 km), the median was 4 miles (6.4 km), and the mode was 2 miles (3.2 km). The mean number of days per week travelled for all regular trips was 2.7 days, the median was 2 days, and the mode was 1 day. The modal average primary mode of transport for all regular trips was private car. The modal average secondary mode of transport was the bus. Table 9 shows dependence on private cars for all trips, aligning with UK and European literature on suburban mobility.

See Table 10 for the distance travelled to work in PKC, according to the 2011 census data (National Records of Scotland, 2011). In Perth and Kinross, 26.2% of journeys to work and place of study were less than 2 km, of these, 66.6% of journeys involve active travel methods. 45.6% of journeys to work or place of study were less than 5 km, of these, 41.7% were taken by car or van (PKC, 2018). 21% of the Perth and Kinross population do not have access to a car or van (PKC, 2018).

4.7 Petrol/Diesel private vehicle use change

See Figure 4 for the percentage of survey respondents who would consider different changes in their private petrol/diesel vehicle use. Survey respondents had the opportunity to share any conditions required for them to consider the changes. The conditions mentioned, followed by the number of respondents who mentioned them, are: conditions regarding the cost and affordability of EVs and EV charging (21), conditions regarding EV charging infrastructure accessibility (8); conditions regarding the technology of EVs (6); and conditions regarding convenience (i.e. more bus routes required around Perth not in and out of Perth, current car not needing to be replaced) (6). Respondents also shared comments/opinions related to changing their private petrol/diesel vehicle use, which give further insight into public perception of transport changes. There were six comments related to lifestyle convenience, for

Purpose of trip made	N (%) of individuals who made this trip	Mean distance travelled for this trip (miles)	Mean N of days per week travelled	Dominant (modal average) primary mode of transport	Dominant (modal average) secondary mode of transport
Shopping/Groceries	109 (43.8%)	4.18	2	Private car	Bus
Sport/Recreation	101 (40.6%)	17.1	2.4	Private car	Bus
Work	62 (24.9%)	48.05	1.5	Private car	Private car
School	22 (8.8%)	1.5	4	On foot	On foot
Caring duties	9 (3.6%)	58.4	2.7	Private car	N/A
Unknown activities	4 (1.6%)	19.5	1.5	Private car	N/A
Church	2 (0.8%)	6	1.5	Private car and bus	On foot and private car
Family visits	2 (0.8%)	17.5	1.5	Private car	N/A
Volunteering	2 (0.8%)	45	3	Private car	Bicycle
Doctor/Dentist	1 (0.4%)	2	1	Bus	Private car
Miscellaneous activities	1 (0.4%)	6	1	Private car	bus

Tab. 9: Regular trips made by respondents and individuals they lived with
Source: authors' survey

	Work from home	Distance [km]							
		0–2	2–5	5–10	10–20	20–30	30–40	40–60	>60	Other
% of PKC employed population	14.5	19.6	15.2	9.5	11	9.3	4	3.3	2.8	10.8

Tab. 10: Distance travelled to work in Perth and Kinross council area
Source: National Records of Scotland (2011)

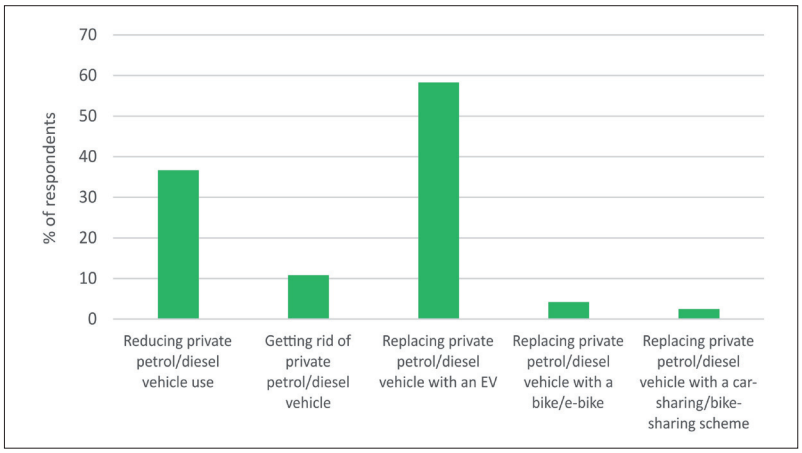


Fig. 4: Percentage of respondents who would consider reducing or ending their use of a private petrol/diesel car
Source: authors' survey

example, "this is my last car" and "rail network inadequate". There were also three comments related to cost, for example, "public transport is too expensive" and "would like to buy an EV but can't afford" (see Appendix 3 for full list of conditions and comments).

The most preferential mobility change among FG participants was the replacement of their petrol/diesel private vehicle with an EV. However, for many, obtaining an EV was financially prohibitive. This demonstrates that openness to transition is influenced by on-the-ground contexts. Nevertheless, several FG participants suggested that they would make the transition to EV ownership if and when prices come down. These findings align with our survey findings. It should be noted that two FG participants owned EVs, one of whom was considering reverting back to a petrol/diesel vehicle due to a change in circumstances related to his parking habits in Edinburgh or Glasgow, and commuting habits to the Far North and West Highlands where charging availability is scare.

The general consensus in both FG discussions was that the steep local landscape made cycling locally not ideal. Upon the researchers asking if e-bikes would lessen this challenge, participants were sceptical. However, many were intrigued by the experience of a fellow participant who owned an e-bike finding it greatly helpful in navigating the steep local landscape.

Several FG participants suggested that cycling into Perth's centre was dangerous and undesirable. One participant noted a painful accident that he was recently involved in whilst cycling that route. FG participants suggested that the city centre was not conducive to cycling and that the Scottish weather was also prohibitive. It became clear that FG participants desired a retrofit of Perth's cycling system to improve the safety and desirability of cycling. However, they expressed that this could increase congestion which they feel is bad enough.

One FG participant expressed that cycling safety issues are national, rather than solely local issues. At this point of the FG, an international comparison was drawn between the UK, where few people cycle and where the onus is on cyclists to make themselves more visible (hi-vis clothing) and protect themselves (helmets) *vis-à-vis* countries where cycling is far more common and popular, benefitting from an integrated cycling infrastructure that physically separates cycle lanes from the road space used by cars. This could be a contributing factor leading to the FG participants' perceptions of cycling being primarily a leisure activity, as opposed to a mobility option.

Car clubs were presented to FG participants hypothetically as this provision is currently unavailable in Perth (to the best of our knowledge and that of FG participants). Participants were interested but concerned about the extent to which they would actually use such a service; for example, one resident cited care duties which mean that they need access to a vehicle at all times. In addition, this line of investigation may have been somewhat hampered by the fact that only 25% of the FG participants owned a second car: in the research design, we hypothesised that the replacement of a second private petrol/diesel vehicle with car club membership may be an attractive, sustainable, and relatively affordable change to mobility habits (survey results found that 39.2% of respondents had more than one private car at their household). Nevertheless, and notwithstanding the above concerns, the level of initial interest shown by residents suggests that this could constitute a topic worthy of additional investigation.

Most of the FG participants perceived public transport as unattractive due to it being not great value for money, elongated routes, not enough routes (especially to parts of the wider city), and infrequent services, similar to findings from European studies in the literature review. COVID-19 was suggested as a contributing factor to this perception, not the root cause. For one FG participant, improved public transport was a must; the displacement of combustion engine vehicles with EVs was perceived negatively due to the fact that it will not get cars off the road. Survey responses also suggested that public transport provision is not currently attractive enough to residents, referring to costs, and to the convenience of car use. FG discussions revealed that the one bus route through the neighbourhood had changed during the pandemic and it now took much longer to get into the city centre.

Regarding active travel, several FG participants indicated that they walk regularly and that this can sometimes be just as quick as the bus. However, walking, like other forms of active travel (e.g. bicycle; e-bike), was deemed inappropriate for many situations and is therefore unlikely to constitute a full replacement of private vehicle use. For example, one FG participant stated that she is always carrying bags and that walking or cycling everywhere is therefore unfeasible; this point was also highlighted as an additional comment in a survey response.

5. Discussion

The focus groups were demographically and responsively very similar. Focus group and survey results were very well aligned, despite FG participants having the advantage over survey respondents of in-depth discussions amongst themselves. Our findings generally confirmed that suburban homeowners by and large engage with energy concerns and have improved their homes' energy efficiency, but that they do not feel they can take that much further due to lack of finance. Results suggest this is largely because they are worried about the cost of living crisis and energy bills.

Many people also report that they would be interested in switching to EVs and there is evidence to suggest that they appreciate that the energy transition is likely to imply systemic challenges that may affect them. The example of reducing car traffic in the centre of Perth suggests that residents are not selfish individuals but that they recognise and value efforts to revitalise their city centre. From the FG discussions emerged a clear recognition that the state should lead and do more to help unlock further action by residents.

Our findings are broadly consistent with pre-existing literature regarding various barriers to decarbonisation and to reducing energy use in everyday life, including the barrier of up-front cost, concerns about household disruptions which may limit retrofit options, and the convenience factor of private cars. Adoption of technologies is predicated on a conducive context and is different to a willingness to transition in principle. Therefore, upfront cost being expressed by FG participants as a barrier to replacing gas boilers with ASHPs and GSHPs, for example, could be interpreted as suggesting a lack of "willingness to pay", or rather, an inability to afford such technologies, suggesting the need for policy mechanisms. Some findings were perhaps slightly more surprising, like the relatively low levels of climate change concern (just over half our respondents – versus national surveys which tend to show that 75–80% of the population is concerned about climate change (Boyes et al., 2014; Office for National Statistics, 2021) and the relatively high ownership of bikes. Since we cannot assume that Perth West residents are in all respects representative of suburban residents across Scotland, and given the likelihood of selection bias in survey respondents, we cannot draw broader conclusions from such potential anomalies. However, our data is novel to the area and Scotland, thus providing meaningful contextual understanding for implementing decarbonisation policies in suburban Perth. Our study also seems to be the first that addresses suburban home retrofitting and mobility simultaneously. It is also worth noting that in the current economic and political context, a reported low concern about climate change (or the environment more broadly) can still go hand in hand with strong support for renewables, as these are domestically produced (energy security) and cheaper than oil and gas at the time of writing. However, both the specific timing of the research, i.e. the current energy crisis and cost of living crisis, and the specific setting in suburbia, open up some avenues for further discussion.

It is clear that residents were more concerned about energy costs at the time of study than they were before. It was noticeable that people were not only concerned but arguably also more knowledgeable about some of the material investment options available to them than anticipated, including for example the price of EVs and the suitability of heat pumps. This focus on the costs of energy and interest in low-carbon technologies should make it easier for government to engage citizens in the future and provide new policy support to reduce energy waste and adopt lower-carbon behaviours and technologies.

We also observed some areas where the knowledge of residents was less clear, or largely absent. Knowledge of the exact current state of their home's insulation provides an example of the former. Examples of the latter include a lack of experience with e-bikes and lack of knowledge of more collective approaches to adopting cleaner technologies (EV car clubs; peer-to-peer energy trading). This potentially limits resident interest and subsequent uptake. Again, there are policy lessons to be gleaned from this; where more collective decarbonisation approaches make engineering and/or business sense, there will be a need to increase awareness amongst members of the public, before a more proactive and dynamic engagement could take place to locally tailor and implement such approaches. Dual concern for home energy bills and cost and convenience of sustainable mobility suggest a need for policies which address both simultaneously.

Recommendations to avoid carbon lock-in and leaving behind suburban residents in the energy transition include allocation of regulation and responsibility. For example, issues concerning distributional justice could be alleviated by each nation and member state having a regulatory and governing body responsible for climate change mitigation and adaptation in suburban areas which address low-income households. Such pro-justice policy monitoring frameworks would prioritise schemes, such as bike-/e-bike-sharing, car-sharing, and high-quality public transport, located not only in wealthier areas. Incentives and discounts could be applied; discounts for EVs, bikes/e-bikes, rail, and bus passes if one invests in retrofitting (and vice versa to varying degrees) or discount off one retrofit if you invest in another. Additionally, councils, policy-makers, industry experts, and educators could collectively host community engagement, education, and experience-sharing programmes/events (in town halls, available online). Such programmes could combat industry distrust and increase awareness of the effectiveness of retrofitting and sustainable mobility.

We recognise that in practice, the implementation of local collective approaches is complicated by the dire financial state of local authorities in the UK, as well as by the need for adoption at scale. It can be argued that such approaches should be much easier to design and implement in newly built neighbourhoods than retrofitted into existing neighbourhoods where the physical infrastructure will need to be adapted and where enough existing residents would have to adopt such measures. If and when these measures are well established (demonstrated to the public that they are) and successfully operating in a new housing development, they could be gradually scaled up (and retrofitted) into adjacent, older neighbourhoods. It is of vital environmental and social importance that low carbon greenfield developments are not designed and managed in geographical isolation, but that they act as catalysts and enablers for adjacent older neighbourhoods to decarbonise in a just manner.

Regarding existing physical infrastructure, our case study neighbourhood represents a typical suburban mix of older streets with straight rows of bungalows, and newer developments of houses clustered around short and bendy dead-end roads (cul de sacs). Most homes have sizable gardens on the sides and (especially) the back, and a lot of the privately owned space is dedicated to the car; large paved-up forecourts and garages, most of which are not actually used for parking the car these days. In principle, there would seem

to be plenty of space for homeowners to accommodate PV panels, heat pumps, EV charging points, EV bike storage etc. However, FG participants having difficulty to get a qualified engineer to visit their property suggests a need to develop local supply and maintenance chains if significant roll-out of heat pumps is to occur. This aligns with the literature review on weak UK policies and supply chains. Additionally, as cycling safety issues were expressed, there is an opportunity to improve cycle routes to be used by both incoming and existing residents. It is feasible that improved cycle routes would improve perceptions of cycling as a regular suburban and urban transport mode. Moreover, improved connectivity to the town centre could alleviate fears that new retail developments on the outskirts of town will displace the (already struggling) high street. However, the public roads seem to be too narrow for retrofitting bike lanes, or for making space for bus lanes and bays or for public parking places with EV charging points. It may require some clever engineering, physically and politically, to 'free up' a mixture of public and private space to retrofit a more sustainable infrastructure for active, public or shared transport.

Finally, in terms of transitions, it is important to recognise that demography matters. Within the survey, we were unable to account for the full extent to which answers were 'coloured' by people's life phase. The FG discussions made it clear that some options are not suited for people who have children they have to taxi around, or who are carers, or who are facing age-related health concerns themselves, or are living on a pension and expect their purchasing power to diminish over time. Many elderly people are property-rich but cash poor. They are emotionally attached to their home and thus reluctant to sell their house (Kerbler, Sendi and Filipovičhrast, 2017; Pani-Harreman et al., 2020) that often becomes too expensive to heat (Longhurst and Hargreaves, 2019; Xin, 2021). Even if they can finance it, they may not think it worthwhile to have disruptive retrofits or to accept long payback times. As everywhere in the global north, ageing (and 'ageing well') presents an immense societal challenge, and our study illustrates some of the ways in which it intersects with the challenges of low carbon transitions. There is clearly scope for additional research and innovation with respect to this nexus.

6. Conclusions

In terms of reducing energy use in daily life, people living in more densely populated urban areas in Europe have the benefit of access to well-developed public transport networks and short travel distances which enable active travel. These people are also more likely to live in flats, which require less energy to heat, and are easier to retrofit at scale. At the other end of the spectrum, living in rural areas will often come with higher energy footprints due to transport needs, but for domestic energy use and increasingly for (electric) mobility, there is often scope for developing and utilising local renewables. By comparison, decarbonising suburban areas can be particularly challenging because larger privately owned, individual homes predominate and for transport needs, residents are highly dependent on their cars.

The findings from our work suggest that many suburban residents are very concerned about energy costs. They are engaged with their energy use but feel that their individual options are rather limited to reduce their energy use and carbon emissions in a feasible way. First, they observe that some material interventions are not suitable for their current travel needs or for their home (e.g. property structure unsuitable for cavity wall insulation), and that other options are currently not affordable due to the high up-front cost or cannot be utilised due to or lack wider infrastructure (for example EV charging). It is very clear that decarbonising suburbs cannot be realistically portrayed as a job that is best left to individual households, acting as proactive and autonomous agents of change. We did not find evidence to suggest that local suburb residents are resistant to state interventions for the common good. Despite their somewhat privileged socio-economic position as homeowners and vehicle owners, residents of suburbia can also be seen as being trapped by their own material possessions with the package deal of suburban house and car, acting to lock people into a higher carbon lifestyle, with spiralling costs during this energy crisis.

Whilst there is a growing interest in, and literature about, living off-grid, developing community energy and embracing energy democracy, this does not reflect the daily reality of the majority of the population who live in and around cities. Engaging with suburban citizens in Perth has illustrated, yet again, that there is a key role for (national and local) government to play in facilitating and coordinating interventions that can unlock a more proactive role of citizens; individually and collectively. The cost of living crisis, energy crisis, the unprecedented calls to cut gas demand this coming winter by 15% (European Council, 2022), and the big current state interventions to help people pay their energy bills, altogether conspire to create a uniquely powerful need and opportunity for the state to step up and provide leadership. As we have seen with the pandemic (Eurostat, 2022), there is a risk of returning to business as usual if and when Russian gas supplies to Europe are restored. The challenge for researchers is to determine and advise government and other key stakeholders on how responses to the energy crisis can be designed and implemented in such a way that they deliver deep and permanent cuts to the use of fossil fuels. If we do this well, it will almost certainly also bring substantive and systemic changes to suburbia as we knew it. We also conclude that there is value in discussing home retrofitting and personal transport in conjunction as they are the highest emitters in civil society and regard the affordability of two key components of life – living comfortably in your home and commuting to nearby places and people. Our contribution, therefore, opens lines of a joint inquiry into transport and retrofitting in the suburban context which could help various stakeholders, especially policymakers and residents, to better understand how suburbia and their situated lives can be decarbonised in a socially just manner.

Acknowledgements

We would like to thank the residents of Perth for their participation. This study was funded by UK Research and Innovation through the Centre for Research into Energy Demand Solutions (CREDS, grant ref. no. EP/R 035288/1) and an EPSRC Impact Acceleration Account held at the University of Edinburgh.

References:

ALDRED, R., CROFT, J., GOODMAN, A. (2019): Impacts of an active travel intervention with a cycling focus in a suburban context: One-year findings from an evaluation of London's in-progress mini-Hollands programme. Transportation research part A: policy and practice, 123: 147–169.

ALEXANDER, S., GLEESON, B. (2019): Unlearning Abundance: Suburban Practices of Energy Descent. Degrowth in the Suburbs, pp. 113–143.

ARUAL MOBILITY OBSERVATORY (2021): Mobility in the Suburbs: Trends and Challenges in Europe [online]. [cit. 04.10.2022]. Arual Mobility Observatory website Available at: https://mobility-observatory.arval.com/mobility-in-the-suburbs-trends-and-challenges-in-europe

BAKOGIANNIS, E., SITI, M., TSIGDINOS, S., VASSI, A., NIKITAS, A. (2019): Monitoring the first dockless bike sharing scheme in Greece: Understanding user perceptions, usage patterns and adoption barriers. Research in Transportations Business & Management, (33): 1–12.

BARTON, H., HORSWELL, M., MILLAR, P. (2012): Neighbourhood accessibility and active travel. Planning Practice and Research, 27(2): 177–201.

BELUR, J., THOMPSON, L., THORNTON, A., SIMON M. (2018): Interrater Reliability in Systematic Review Methodology: Exploring Variation in Coder Decision-Making. Sociological Methods & Research, 50(2): 837–865.

BENNADJI, A., SEDDIKI, M., ALABID, J., LAING, R., GRAY, D. (2022): Predicting Energy Savings of the UK Housing Stock under a Step-by-Step Energy Retrofit Scenario towards Net-Zero. Energies, 15(9): 3082.

BIEHL, A., CHEN, Y., SANABRIA-VÉAZ, K., UTTAL, D., STATHOPOULOS, A. (2019): Where does active travel fit within local community narratives of mobility space and place? Transportation research part A: policy and practice, 123: 269–287.

BIELINSKI, T., DOPIERALA, L., TARKOWSKI, M., WAZNA, A. (2020): Lessons from Implementing a Metropolitan Electric Bike Sharing System. Energies, 13: 1–21.

BOYES, E., STANISSTREET, M., SKAMP, K., RODRIGUEZ, M., MALANDRAKIS, G., FORTNER, R. W., KILINC, A., TAYLOR, N., CHHOKAR, K., DUA, S., AMBUSAIDI, A. (2014): An international study of the propensity of students to limit their use of private transport in light of their understanding of the causes of global warming. International Research in Geographical and Environmental Education, 23(2): 42–165.

BRAUN, V., CLARKE, V. (2006): Using thematic analysis in psychology. Qualitative research in psychology, 3(2): 77–101.

BROWN, D. (2018): Business models for residential retrofit in the UK: a critical assessment of five key archetypes. Energy Efficiency, 11(6): 1497–1517.

BROWN, D., KIVIMAA, P., ROSENOW, J., MARTISKAINEN, M. (2018): Chapter 7 Overcoming the systemic challenges of retrofitting residential buildings in the United Kingdom. A Heruclean task? In: Eyre, N., Brown, M.: Transitions in Energy Efficiency and Demand: The Emergence, Diffusion and Impact of Low-Carbon Innovation (pp. 110–130). London/New York, Routledge Taylor Francis Group.

CASTANHO SILVA, B., WÄCKERLE, J., WRATIL, C. (2022): Determinants of public opinion support for a full embargo on Russian energy in Germany (No. 170). ECONtribute Discussion Paper.

CAPUTO, P. PASETTI, G. (2015): Overcoming the inertia of building energy retrofit at municipal level: The Italian challenge. Sustainable Cities and Society, 15: 120–134.

CHRISTENSEN, T. H., GRAM-HANSSEN, K., DE BEST-WALDHOBER, M., ADJEI, A. (2014): Energy retrofits of Danish homes: is the Energy Performance Certificate useful?. Building Research & Information, 42(4): 489–500.

CLARK, J., CURL, A. (2016): Bicycle and car share schemes as inclusive modes of travel? A socio-spatial analysis in Glasgow. Social Inclusion, 4(3): 83–99.

COMMITTEE ON CLIMATE CHANGE (CCC) (2019): UK housing: Fit for the future?: pp. 1–134.

DAVIS, A., WHYTE, B. (2022): Making the shift to sustainable transport in Scotland. Cities & Health, 6(2): 267–274.

DELGADO JALÓN, M. L., GÓMEZ ORTEGA, A., DE ESTEBAN CURIEL, J. (2019): The social perception of urban transport in the city of Madrid: the application of the Servicescape Model to the bus and underground services. European Transport Research Review, 11(1): 1–11.

DEPARTMENT FOR TRANSPORT (2021): Statistical Release: Transport and Environment Statistics 2021 Annual report: 1–11.

DEVINE-WRIGHT, P. (2005): Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. Wind Energy: An International Journal for Progress and Applications in Wind Power Conversion Technology, 8(2): 125–139.

DEVINE-WRIGHT, P. (2007): Reconsidering public attitudes and public acceptance of renewable energy technologies: a critical review. University of Manchester, Manchester. Available at: http://geography.exeter.ac.uk/beyond_nimbyism/deliverables/bn_wp1_4.pdf

DODMAN, D. (2009): Blaming cities for climate changes? An analysis of urban greenhouse gas emissions inventories. Environment & Urbanization 21(1): 185–201.

EAMES, M., DIXON, T., LANNON, S., HUNT, M., DE LAURENTIS, C., MARVIN, S., HODSON, M., GUTHRIE, P., GEORGIADOU, M. C. (2014): Retrofit 2050: Critical Challenges for Urban Transitions. Wales, Cardiff University: p. 1–11.

EBRAHIMIGHAREHBAGHI, S., QIAN, Q. K., VISSCHER, H. J. (2022): Municipal governance and energy retrofitting of owner-occupied homes in the Netherlands. Energy and Buildings: 112423.

ESSAYEH, C., FRIEDRICH, D., MORSTYN, T., BUCKE, C., SMITH, C., BOUREL, L., VAN DER HORST, D. (2022): Perth West as a Case Study for the Value of Greenfield Smart Local Energy Systems: pp. 1–85.

EUROCITIES (2021): Bringing urban mobility to the next level: Eurocities recommendations on the Efficient and Green Mobility Package [online]. [cit. 03.10.2022]. Eurocities website Available at: https://eurocities.eu/wp-content/uploads/2021/11/Bringing-Urban-Mobility-to-the-Next-Level-Eurocities-policy-paper-on-the-Efficient-and-Green-Mobility-package-1-1.pdf

EUROPEAN COMMISSION (2020a): Communication from the commission to the European Parliament, the council, the European Economic and Social Committee and the Committee of the Regions: A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives. COM/2020/662 final. Document 522020DC0662.

EUROPEAN COMMISSION (2020b): Communication from the Commission to the European Parliament, The Council,

The European Economic and Social Committee and the Committee of the Regions Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM/2020/789 final. Document 52020DC0789.

EUROPEAN COMMISSION (2021): Buildings Factsheet: Making our homes and buildings fit for a greener future [online]. [cit. 05.10.2022]. Europena Commission websit. Available at: https://ec.europa.eu/commission/presscorner/detail/en/fs_21_3673

EUROPEAN COMMISSION (2022): New mobility services drive healthier cities [online]. [cit. 03.10.2022]. European Commission website: Newsroom Available at: https://ec.europa.eu/regional_policy/en/newsroom/panorama/2022/01/01-12-2022-new-mobility-services-drive-healthier-cities#:~:text=The%20EU%E2%80%99s%20Smart%20and%20Sustainable%20Mobility%20Strategy%20aims,dramatically%20reduce%20private%20car%20use%20and%20air%20pollution

EUROPEAN COUNCIL (2022): Press release: Council adopts regulation on reducing gas demand by 15% this winter [online]. [cit. 14.10.2022]. European Council of the European Union website. Available at: https://www.consilium.europa.eu/en/press/press-releases/2022/08/05/council-adopts-regulation-on-reducing-gas-demand-by-15-this-winter/#:~:text=Member%20states%20agreed%20to%20reduce,measures%20of%20their%20own%20choice

EUROPEAN COURT OF AUDITORS (2018): Landscape Review – Towards a successful transport sector in the EU: challenges to be addressed.

EUROPEAN ENERGY AGENCY (EEA) (2021): Indicator Assessment: Greenhouse gas emissions from energy use in buildings in Europe [online]. [cit. 05.10.2022]. EEA website. Available at: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emissions-from-energy/assessment

EUROPEAN ENVIRONMENT AGENCY (EEA) (2022): Transport and environment report 2021: Decarbonising road transport – the role of vehicles, fuels and transport demand. Luxembourg: Publications Office of the European Union. EEA Report No. 02/2022.

EUROSTAT (2022): EU economy greenhouse gases above pre-pandemic levels [online]. [cit.14.10.2022]. Eurostat website. Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220516-1#:~:text=In%20the%20fourth%20quarter%20of,the%20fourth%20quarter%20of%202019

FINDLAY, A. (2022): Fighting climate change. Nature Climate Change, 12: 619

FRANTÁL, B., DVOŘÁK, P. (2022): Reducing energy poverty in deprived regions or supporting new developments in metropolitan suburbs? Regional differences in the use of subsidies for home energy efficiency renovations. Energy Policy, 171: 113250.

FYLAN, F., GLEW, D., SMITH, M., JOHNSTON, D., BROOKE-PEAT, M., MILES-SHENTON, D., FLETCHER, M., ALOISE-YOUNG, P., GORSE, C. (2016): Reflections on retrofits: Overcoming barriers to energy efficiency among the fuel poor in the United Kingdom. Energy Research & Social Science, 21: 190–198.

GAGLIA, A. G., DIALYNAS, E. N., ARGIRIOU, A. A., KOSTOPOULOU, E., TSIAMITROS, D., STIMONIARIS, D., LASKOS, K. M. (2019): Energy performance of European residential buildings: Energy use, technical and environmental characteristics of the Greek residential sector–energy conservation and CO_2 reduction. Energy and Buildings, 183: 86–104.

GALVIN, R. (2012): German Federal policy on thermal renovation of existing homes: a policy evaluation. Sustainable Cities and Society, 4: 58–66.

GALVIN, R., SUNIKKA-BLANK, M. (2013): Economic viability in thermal retrofit policies: Learning from ten years of experience in Germany. Energy Policy, 54: 343–351.

GALVIN, R., SUNIKKA-BLANK, M. (2017): Ten questions concerning sustainable domestic thermal retrofit policy research. Building and Environment, 118: 377–388.

GRAM-HANSSEN, K. (2014): Retrofitting owner-occupied housing: remember the people. Building Research & Information, 42(4): 393–397.

GREEN, A. K. N. G. (2022): Exploring Participatory Approaches to Policy Development for Decarbonising Transport to and within Loch Lomond and the Trossachs National Park: SEFARI Fellowship Report.

GRUBLER, A., BAI, X., BUETTNER, T., DHAKAL, S. et al. (2012): In: Grubler, A., Bai, X., Buettner, T., Dhakal, S. et al.: Global Energy Assessment (GEA): Urban Energy Systems (pp. 1307–1400). Cambridge, Cambridge University Press.

GU, J. (2022): Sharing economy, technological innovation and carbon emissions: evidence from Chinese cities. Journal of Innovation & Knowledge, 7(3): 100228.

HANSFORD, P. (2015): Solid Wall Insulation Unlocking Demand and Driving up Standards: A report to the Green Construction Board and Government by the Chief Construction Advisor.

JONES, C. M., KAMMEN, D. M. (2011): Quantifying carbon footprint reduction opportunities for US households and communities. Environmental Science & Technology, 45(9): 4088–4095.

JONES, C. M., KAMMEN, D. M. (2014). Spatial distribution of U.S. household carbon footprints reveals suburbanization undermines greenhouse gas benefits of urban population density. Environmental Science & Technology, 48(2): 895–902.

KAMARGIANNI, M., MATYAS, M., LI, W., MUSCAT, J. (2018): Londoners' attitudes towards car-ownership and Mobility-as-a-Service: Impact assessment and opportunities that lie ahead. MaaSLab – UCL Energy Institute Report, Prepared for Transport London, pp. 1–51.

KARYTSAS, S. THEODOROPOULOU, H. (2014): Public awareness and willingness to adopt ground source heat pumps for domestic heating and cooling. Renewable and Sustainable Energy Reviews, 34: 49–57.

KERBLER, B., SENDI, R., FILIPOVIČHRAST, M. (2017): The Relationship of the elderly towards their home and living environment. Ubani Izziv, 28(2): 96–109.

KIEFT, A., HARMSEN, R., HEKKERT, M. P. (2020): Problems, solutions, and institutional logics: Insights from Dutch domestic energy-efficiency retrofits. Energy Research & Social Science, 60: 101315.

KIGER, M. E., VARPIO, L. (2020): Thematic analysis of qualitative data: AMEE Guide No. 131. Medical teacher, 42(8): 846–854.

KROHN, S. (2002): Danish Wind Turbines: An Industrial Success Story. Copenhagen: Danish Wind Industry Association.

LANG, M., LANE, R., ZHAO, K., THAM, S., WOOLFE, K., RAVEN, R. (2021): Systematic review: Landlords' willingness to retrofit energy efficiency improvements. Journal of Cleaner Production, 303: 127041.

LI, K., LIN, B. (2015): Impacts of urbanization and industrialization on energy consumption/CO_2 emissions: does the level of development matter? Renewable and Sustainable Energy Reviews, 52: 1107–1122.

LIU, L. C., WU, G., WANG, J. N., WEI, Y. M. (2011): China's carbon emissions from urban and rural households during 1992–2007. Journal of Cleaner Production, 19(15): 1754–1762.

LONGHURST, N., HARGREAVES, T. (2019): Emotions and fuel poverty: The lived experience of social housing tenants in the United Kingdom. Energy Research & Social Science, 56: 101207.

LOPEZ, E., SCHLOMANN, B., REUTER, M., EICHHAMMER, W. (2018): Energy Efficiency Trends and Policies in Germany – An Analysis Based on the ODYSSEE and MURE Databases. Karlsruhe, (Germany), Fraunhofer Institute for Systems and Innovation Research ISI.

LORENZONI, I., NICHOLSON-COLE, S., WHITMARSH, L. (2007): Barriers perceived to engaging with climate change among the UK public and their policy implications. Global Environmental Change, 17(3–4): 445–459.

LOWE, R., CHIU, L. F. (2020): Innovation in deep housing retrofit in the United Kingdom: The role of situated creativity in transforming practice. Energy Research & Social Science, 63: 101391.

MA, Y., LAN, J., THORNTON, T., MANGALAGIU, D., ZHU, D. (2018): Challenges of collaborative governance in the sharing economy: The case of free-floating bike sharing in Shanghai. Journal of cleaner production, 197: 356–365.

MACINTYRE, S., MACDONALD, L., ELLAWAY, A. (2008): Do poorer people have poorer access to local resources and facilities? The distribution of local resources by area deprivation in Glasgow, Scotland. Social Science & Medicine, 67(6): 900–914.

MARCHAND, R. D., KOH, S. L., MORRIS, J. C. (2015): Delivering energy efficiency and carbon reduction schemes in England: Lessons from Green Deal Pioneer Places. Energy Policy, 84: 96–106.

MORAN, D., KANEMOTO, K., JIBORN, M., WOOD, R., TÖBBEN, J., SETO, K. C. (2018): Carbon footprints of 13,000 cities. Environmental Research Letters, 13(6): 064041.

MORTENSEN, A., HEISELBERG, P., KNUDSTRUP, M. (2014): Economy controls energy retrofits of Danish single-family houses. Comfort, indoor environment and architecture increase the budget. Energy and buildings, 72: 465–475.

MUNOZ, P., ZWICK, S., MIRZABAEV, A. (2020): The impact of urbanization on Austria's carbon footprint. Journal of Cleaner Production, 263(1): 121326.

MYHREN, J. A., HEIER, J., HUGOSSON, M., ZHANG, X. (2020): The perception of Swedish housing owner's on the strategies to increase the rate of energy efficient refurbishment of multi-family buildings. Intelligent Buildings International, 12(3): 153–168.

NATIONAL RECORDS OF SCOTLAND (2011): Scotland's Census 2011 – Table QS703SC – Distance travelled to work: All people aged 16 to 74 in employment the week before the census (excluding full-time students). Scotland's Census website [online]. [cit.05.09.2022]. Available at: https://www.scotlandscensus.gov.uk/search-the-census#/topics/location/CA?title=Local%20authority

NATIONAL RECORDS OF SCOTLAND (2021): Perth and Kinross Council Area Profile [online]. [cit. 01.09.2022]. National Records of Scotland website Available at: https://www.nrscotland.gov.uk/files/statistics/council-area-data-sheets/perth-and-kinross-council-profile.html#table_house_proj_type

NEUHOFF, K., AMECKE, H., NOVIKOVA, A., STELMAKH, K. (2011): Thermal efficiency retrofit of residential buildings: The German experience. CPI Report. Berlin, Climate Policy Initiative.

NLS (1970): National Library of Scotland (NLS) (This provides an online repository of maps). Map 'NO02SE – A', dated 1970, shows that the first houses are appearing within our case study suburban neighbourhood. NLS website. [cit. 06.01.2022]. Available at: https://maps.nls.uk/view/188140500

NYUMBA, T., WILSON, K., DERRICK, C. J., MUKHERJEE, N. (2018): 'The use of focus group discussion methodology: Insights from two decades of application in conservation'. Methods in Ecology and Evolution, 9(1): 20–32.

OFFICE FOR NATIONAL STATISTICS (ONS) (2021): Opinions and Lifestyle Survey: Data on public attitudes to the environment and the impact of climate change, Great Britain (Table 2: Worry about climate change) [online]. [cit. 13.10.2022]. ONS website.

OGILVIE, D., MITCHELL, R., MUTRIE, N., PETTICREW, M., PLATT, S. (2008): Personal and environmental correlates of active travel and physical activity in a deprived urban population. International Journal of Behavioral Nutrition and Physical Activity, 5(1): 1–12.

O'KEEFFE, J. M., GILMOUR, D., SIMPSON, E. (2016): A network approach to overcoming barriers to market engagement for SMEs in energy efficiency initiatives such as the Green Deal. Energy Policy, 97: 582–590.

ORTIZ, J., CASQUERO-MODREGO, N., SALOM, J. (2019): Health and related economic effects of residential energy retrofitting in Spain. Energy Policy, 130: 375–388.

OTTELIN, J., HEINONEN, J., NÄSSÉN, J., JUNNILA, S. (2019): Household carbon footprint patterns by the degree of urbanisation in Europe. Environmental Research Letters, 14(11): 114016.

PADDINGTON, J., NICOL, S., GARRETT, H., CUSTARD, M. (2020): The Housing Stock of the United Kingdom (pp. 1–44). Watford, UK, BRE Trust.

PANI-HARREMAN, K. E., BOURS, G. J. J. W., ZANDER, I., KEMPEN, G. I. J. M., VAN DUREN, J. M. A. (2020): Definitions, key themes and aspects of 'ageing in place': a scoping review.

PARIKH, J., SHUKLA, V. (1995): Urbanization, energy use and greenhouse effects in economic development: Results from a cross-national study of developing countries. Global Environmental Change, 5(2): 87–103.

PERTH AND KINROSS COUNCIL (PKC) (2018): Active Strategy for Perth and Kinross Council.

PERTH AND KINROSS COUNCIL (PKC) (2022a): About [online]. [cit. 05.09.2022]. PKC website. Available at: https://www.pkclimateaction.co.uk/about

PELENUR, M. (2013): Retrofitting the domestic built environment: investigating household perspectives towards energy efficiency technologies and behaviour. PhD thesis. Cambridge, University of Cambridge, Queens' College.

PETERSON, T. R., STEPHENS, J. C., WILSON, E. J. (2015): Public perception of and engagement with emerging low-carbon energy technologies: A literature review. MRS Energy & Sustainability: A Review Journal, 2, E11: 1–14.

PICKETT, L., WINNETT, J., CARER, D., BOLTON, P. (2021): Electric vehicles and infrastructure. House of Commons Library: 1–76.

POUMANYVONG, P., KANEKO, S. (2010): Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. Ecological Economics, 70(2): 434–444.

PUTNAM, T., BROWN, D. (2021): Grassroots retrofit: Community governance and residential energy transitions in the United Kingdom. Energy Research & Social Science, 78: 102102.

QIU, Y., COLSON, G., GREBITUS, C. (2014): Risk preferences and purchase of energy-efficient technologies in the residential sector. Ecological Economics, 107: 216–229.

QUINIO, V., RODRIGUES, G. (2021): Net zero: decarbonising the city. London, Centre for Cities.

RAMOS, S., VICENTE, P., PASSOS, A. M., COSTA, P., REIS, E. (2019): Perceptions of the Public Transport Service as a Barrier to the Adoption of Public Transport: A Qualitative Study. Social Sciences, 8(5): 1–16.

RICCI, M. (2015): Bike sharing: A review of evidence on impacts and processes of implementation and operation. Research in Transportation and Business Management, 15: 28–38.

RIVAS, C. (2012): Chapter 12 Coding and Analysing Qualitative Data. In: Seale, C.: Researching Society and Culture (pp. 366–392). London, SAGE Publications Ltd.

RODRIGUES, A., COOPER, T., WATKINS, M. (2016): Systemic barriers to upscaling car sharing in the UK. CIE-MAP Research Centre, Nottingham Trent University.

ROSENOW, J., EYRE, N. (2016): A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. Energy Research & Social Science, 21: 141–144.

SARASINI, S., LANGELAND, O. (2017): Business model innovation for car sharing and sustainable urban mobility. Nordic Energy Research, 5: 1–28.

SCOTTISH GOVERNMENT (2021): Scottish House Condition Survey: Local Authority Analysis 2017–2019 [online]. [cit. 14.09.2022]. Scottish Government website. Available at: https://www.gov.scot/publications/scottish-house-condition-survey-local-authority-analysis-2017-2019/pages/7/

SEBI, C., NADEL, S., SCHLOMANN, B., STEINBACH, J. (2019): Policy strategies for achieving large long-term savings from retrofitting existing buildings. Energy Efficiency, 12(1): 89–105.

SHORT, J. S., FARMER, A. (2021): Cities and Climate Change. Earth. 2(4): 1038–1045.

SUNIKKA-BLANK, M., GALVIN, R. (2016): Irrational homeowners? How aesthetics and heritage values influence thermal retrofit decisions in the United Kingdom. Energy Research & Social Science, 11: 97–108.

TANEJA, S., MANDYS, F. (2022): Drivers of UK household energy expenditure: Promoting efficiency and curbing emissions. Energy Policy, 167: 113042.

TROTTA, G. (2018): Factors affecting energy-saving behaviours and energy efficiency investments in British households. Energy Policy, 114: 529–539.

TSOKA, S., TSIKALOUDAKI, K., THEODOSIOU, T., DUGUE, A. (2018): Rethinking user based innovation: Assessing public and professional perceptions of energy efficient building facades in Greece, Italy and Spain. Energy Research & Social Science, 38: 165–177.

TSOUTSOS, T. D. (2002): Marketing solar thermal technologies: strategies in Europe, experience in Greece. Renewable Energy, 26: 33–46.

UKGBC (UK Green Building Council) (2022): Press Release: UKGBC study reveals significant carbon reduction can be achieved across residential developments at little cost [online]. [cit. 11.11.2022].UKGBC website. Available at: https://www.ukgbc.org/news/masterplan-report/

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC) (2015): Adoption of the Paris Agreement, 21st Conference of the Parties, Paris, United Nations

VALET, R. (2008): Factors influencing the societal acceptance of new energy technologies: Meta-analysis of recent European projects. Deliverable 3.1, 3.2 and 4 for the Create Acceptance project on 'Cultural influences of Renewable Energy Acceptance and Tools for the development of communication strategies to promote acceptance among key actor groups', pp. 1–202.

VAN EST, R. (1999): Winds of Change: A Comparative Study on the Politics of Wind Energy Innovation in California and Denmark. Utrecht, International Books.

WADE, F., WEBB, J., CREAMER, E. (2022): Local government capacities to support net zero: Developing comprehensive heat and energy efficiency strategies in Scotland. Energy Research & Social Science, 89: 102544.

WEBB, J., VAN DER HORST, D. (2021): Understanding policy divergence after United Kingdom devolution: Strategic action fields in Scottish energy efficiency policy. Energy Research & Social Science, 78: 102121.

WEISS, J., DUNKELBERG, E., VOGELPOHL, T. (2012): Improving policy instruments to better tap into homeowner refurbishment potential: Lessons learned from a case study in Germany. Energy Policy, 44: 406–415.

WILKINSON, S. (1998): 'Focus group methodology: A review', International Journal of Social Research Methodology, 1(3): 181–203.

WILLIAMS, K., GUPTA, R., HOPKINS, D., GREGG, M., PAYNE, C., JOYNT, J.L., SMITH, I., BATES-BRKLJAC, N.

(2013): Retrofitting England's suburbs to adapt to climate change. Building Research & Information, 41(5): 517–531.

WILSON, C., CRANE, L., CHRYSSOCHOIDIS, G. (2015): Why do homeowners renovate energy efficiently? Contrasting perspectives and implications for policy. Energy Research & Social Science, 7: 12–22.

WU, R., MAVROMATIDIS, G., OREHOUNIG, K., CARMELIET, J. (2017): Multiobjective optimisation of energy systems and building envelope retrofit in a residential community. Applied Energy, 190: 634–649.

XIN, H. (2021): Environmental sustainability and the residential environment of the elderly: A literature review. Building and Environment: 206: 108337.

YORK, R., ROSA, E. A., DIETZ, T. (2003): Footprints on the earth: The environmental consequences of modernity. American Sociological Review, 68(2): 279–300.

ZHANG, C., CAO, X., RAMASWAMI, A. (2016): A novel analysis of consumption-based carbon footprints in China: Unpacking the effects of urban settlement and rural-to-urban migration. Global Environmental Change, 39: 285–293.

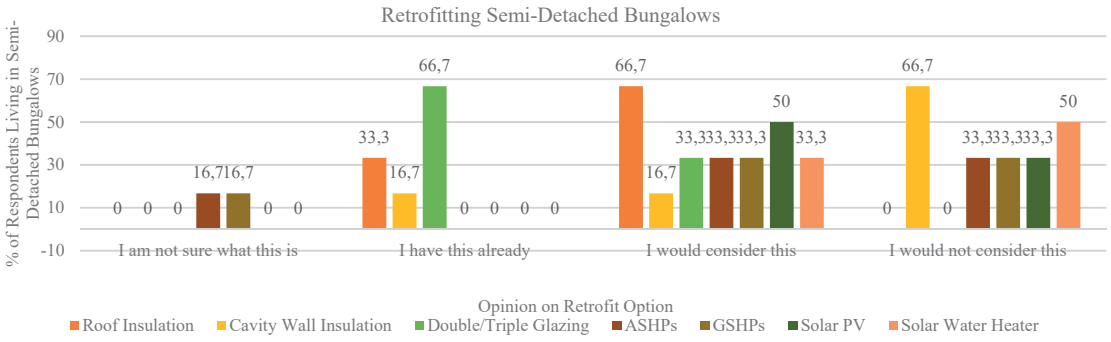
ZHANG, H., HEWAGE, K., KARUNATHILAKE, H., FENG, H., REHAN, S. (2021): Research on policy strategies for implementing energy retrofits in the residential buildings. Journal of Building Engineering, 43: 103161.

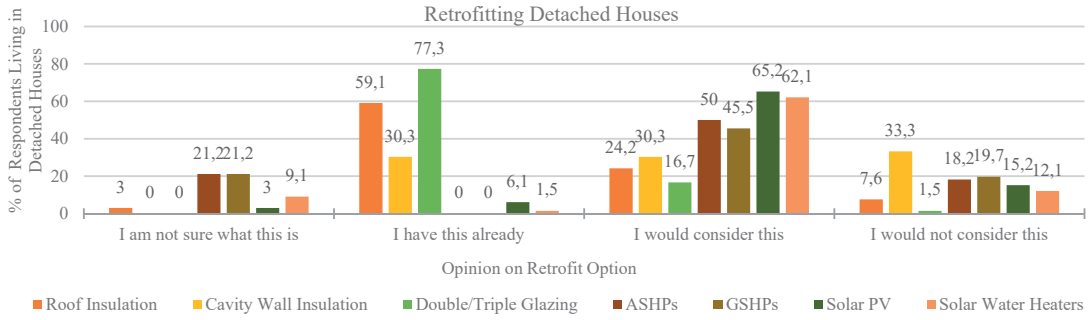
Please cite this article as:

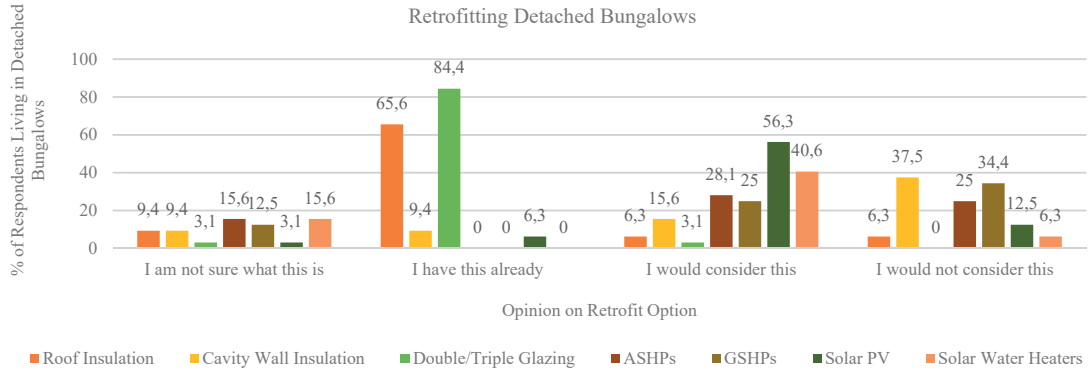
BUCKE, C., SMITH, C., VAN DER HORST, D. (2022): Decarbonising suburbia: Homeowners' perspectives on home retrofits and travel mode shift in Perth, Scotland. Moravian Geographical Reports, 30(4): 288–310. doi: https://doi.org/10.2478/mgr-2022-0019

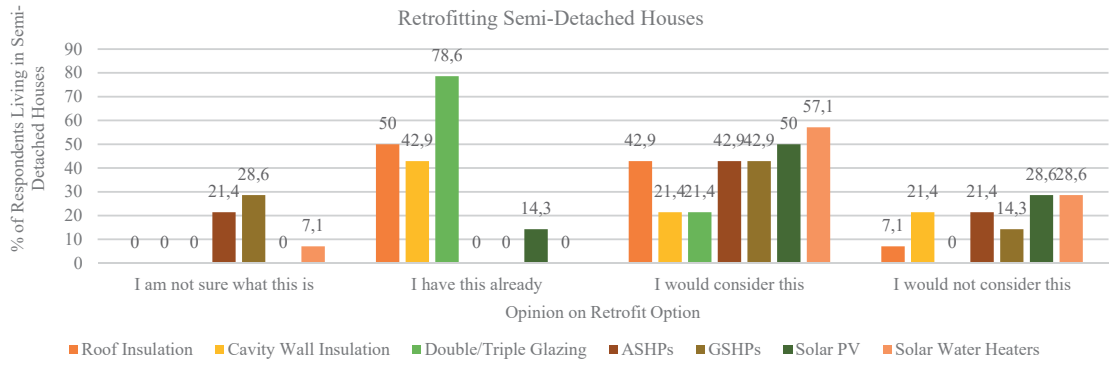
Appendices

Appendix 1 – Property types which are the least knowledgeable of retrofit options, own the most of each retrofit option, and would consider and would not consider each retrofit option









Appendix 2: Focus group participants' key survey responses

Focus Group Participant	No. of residents in home	Heating system	Worried about cost of living crisis	Satisfied with insulation	Energy efficiency investments	RE heat (would consider)	Type of vehicle	Number of drivers	Cut down vehicle use?	CC concern
FOCUS GROUP 1										
1	2	Gas Boiler & Central Heating	Yes, a lot	Yes	roof insulation; double glazing	ASHP, Solar PV, Solar WH	1 x EV	1	n/a, has EV	Somewhat unconcerned
2	2	Gas Boiler & Central Heating	Not really	Yes	loft insulation; double/ triple glazing	ASHP, Solar PV, Solar WH	2 x cars 5 x bicycles	2	Would consider getting rid for public transport	Somewhat concerned
3	2	Gas Boiler & Central Heating Wood Stove	Yes, a lot	No, attic insulation difficult to implement	Cavity wall; double/ triple glazing	Roof insulation; ASHP, Solar PV, Solar WH	1 x car 3 x bicycles	2	Would consider reducing & getting rid (but needs to tow caravan?)	Very concerned
4	2	Gas Boiler & Central Heating	Yes, a lot	Yes	loft insulation; double/ triple glazing	Cavity wall; ASHP; GSHP; Solar PV; Solar WH	1 x car	2	Would consider replacing with EV	Very concerned
FOCUS GROUP 2										
1	1	Gas boiler/ central heating	Not really	Yes	Draught excluders, double/ triple glazing	ASHP; GSHP; Solar PV; Solar WH	2 x bicycle	1	n/a	Very concerned
2	2	Gas boiler/ central heating; gas fire	Yes, a lot	No	Loft insulation, double glazing, energy efficient lights	ASHP; GSHP; Solar PV; Solar WH; Cavity wall	2 x cars 2 x bicycles	n/a	"Reducing petrol/ diesel vehicle use; Replacing with EV; Getting rid altogether"	Very concerned
3	4	Gas boiler/ central heating; Wood stove	Yes, a lot	No	Double glazing, new (more efficient boiler), loft insulation	ASHP; GSHP; Solar PV; Solar WH	"1 x car 1 x camper van"	2	"Reducing petrol/ diesel vehicle use; Replacing with EV; Replacing with EB"	Very concerned
4	4	Gas boiler/ central heating; Wood stove	Yes, a lot	Yes	Roof insulation + rigid insulation underfloor	ASHP; GSHP; Solar PV; Solar WH	"1x car 4x bicycle"	2	"Reducing petrol/ diesel vehicle use; Replacing with EV"	Very concerned

Appendix 3: List of examples of conditions and comments respondents expressed related to changing the use of their petrol/diesel private vehicle.

Conditions for Vehicle Use Change Expressed by Survey Participants		
Theme	**Example of Conditions**	**Count**
Cost & Affordability	"Cost"	21
	"Cost neutral"	
	"Trade in and running costs"	
	"Cost of charging facilities"	
	"Make them more affordable"	
	"At present changed to hybrid but not consider electric again until cheaper to buy"	
	"Money to buy electric car"	
	"Electric car prices need to reduce significantly"	
	"As and when price of an electric care compares with that of a petrol/diesel car"	
	"price would have to reduce"	
	"Lower cost of electric vehicles",	
Technology of Vehicle	Improve range, e.g., "Will not consider electric car until they can cover 600 miles"	8
	"Better technology/lifespan"	
	"Be able to tow caravan"	
Charging Infrastructure	"More public charging points"	6
Convenience	"When current car needs replaced (Not routine 3 yearly replacement)"	6
	Convenience	
	"I would not consider giving up private vehicle if I could use public transport"	
	"More bus routes around Perth, not in and out of Perth"	

Comments on Vehicle Use Expressed by Survey Participants		
Theme	**Comments**	**Count**
Cost	"Would like an electric car but can't afford, too expensive"	3
	"Providing it makes economic sense"	
	"Public transport expensive"	
Convenience	"Because of my age private vehicle use is necessary and helpful"	6
	"I currently need a vehicle available at all times due to caring duties"	
	"My car is very rarely out (11-year-old Honda) this is my last car"	
	"Rail network inadequate"	
	"None applicable to me at 77 years old"	
	"Our car usage is already minimal"	