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Research paper

The challenge of making EVs just affordable enough: Assessing the impact of subsidies on equity and emission reduction in Ireland

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ABSTRACT

Governments support the switch to electric vehicles (EVs) through subsidies and other incentives, as this is expected to help meet climate targets. This research examines the affordability of EVs for Irish households, focusing on equity implications and the impact of affordability on achieving decarbonisation goals. Affordability is estimated for eight scenarios, considering both current and reduced EV prices, and assessed across Ireland. The research finds that flat-rate subsidies do not adequately support lower-income households, impede EV adoption, and could jeopardise the achievement of emission reduction targets. Need-based subsidies would ensure more inclusive EV uptake. If current prices are considered, the target for the number of EVs on the road by 2030 can be met only with the purchase of small-sized EVs. This suggests that achieving EV targets is unlikely without promoting smaller vehicles. The current €3500 EV grant may be insufficient for many households without extended loan terms. Therefore, differentiated subsidies based on income and household size are recommended to increase EV adoption. Households in remote rural areas, where forced car ownership is high, require higher subsidies. In contrast, urban areas could receive lower subsidies to promote the use of more sustainable transport modes, such as cycling, shared mobility, and public transport.

1. Introduction

The climate emergency requires bold strategies, and the electrification of the vehicle fleet is considered one such strategy for the transport sector. This solution is expected to substantially reduce greenhouse gas (GHG) emissions in Europe and other regions. Governments are intensifying their efforts and facilitating electric vehicle (EV) uptake through strong policy measures. The climate crisis underscores the need to prioritise effective EV policies to encourage EV adoption. However, such policies also raise concerns about the potential social equity implications associated with these measures.

1.1. Incentives for EVs

Tax benefits for acquisition and ownership, purchase incentives, excise taxes on fossil fuels, and non-fiscal incentives for EVs are common policy measures among European states. These measures encourage the purchase and usage of private passenger EVs while discouraging the purchase and ownership of internal combustion engine vehicles (ICEVs). By applying penalising taxes on ICEVs to fund EV grants, Norway and Sweden have effectively closed the price gap between the two vehicle types and achieved the highest levels of EVs per capita (PBO, 2022).

In Ireland, achieving the GHG emission abatement target relies heavily on replacing privately owned ICEVs with EVs. The previous iteration of the Climate Action Plan from 2021 anticipated that private EV adoption would account for approximately 2.7 $MtCO_2eq$ of the total emission reduction target for transport, which stands at 6.1 $MtCO_2eq$ (Department of the Environment, Climate and Communications, 2021). The latest Climate Action Plan (Department of the Environment, Climate and Communications, 2023) does not specify the amount of emissions attributed to private car electrification, instead categorising it under fleet electrification with a total expected reduction of 4.74 MtCO2eq. However, the target of 845,000 private EVs needed to achieve the overall decarbonisation goal remains consistent in both documents. As of the end of 2022, there were almost 74,000 EVs on the roads, about half powered solely by electric motors (Department of Transport, 2023). These 74,000 vehicles represent approximately 9% of the 2030 target for private passenger vehicles set by the government. To reach the goal of 845,000 private passenger EVs on the roads, EV sales would need to grow rapidly, which could potentially have a significant adverse impact

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on public finances if current tax rates and subsidies remain unchanged (PBO, 2022).

The Irish government has introduced several policy incentives and disincentives to encourage the purchase and usage of EVs and reduce the presence of ICEVs on roads (PBO, 2022). In addition to the available purchase grants, prospective EV owners are offered tax benefits on acquisition and ownership, and EVs are exempt from fuel tax by default (Table 1). The government is also considering measures implemented in other countries, such as higher speed limits for EVs, access to bus lanes, parking incentives, and congestion charges linked to emissions (Department of Transport, 2021). As in other European states, battery EVs (BEVs) are treated distinctly from plug-in hybrid EVs (PHEVs), which are equipped with a rechargeable battery but can also run on petrol or diesel. BEVs are offered preferential rates and discounts over PHEVs. As of 2022, a private BEV owner can receive approximately €11, 300 in total support, compared to around €4000 available for PHEV owners (PBO, 2022). Multiple options are also available for commercial entities, and a new charging infrastructure strategy will extend the suite of grants available for home charger installation (Department of Transport, 2022).

1.2. Need for incentives and their effectiveness

Financial incentives are used to promote and accelerate the adoption of EVs across countries. Results of studies in France indicate that subsidies and registration tax exemptions are critical factors driving widespread BEV adoption (Haidar & Aguilar Rojas, 2022). That study found that a higher subsidy-to-vehicle price ratio significantly increases the likelihood of purchasing a BEV, suggesting that subsidies should be proportionate to the vehicle's price, offering greater subsidies for higher-priced BEVs. Conversely, subsidies for PHEVs do not have this effect on sales (Haidar & Aguilar Rojas, 2022). In India, simulated scenarios indicate that a purchase subsidy of approximately $1500 increased the PHEV market share by 15% in Delhi and 19% in Kolkata. A higher subsidy of $6500 led to even greater increases, with market shares rising by 109% in Kolkata and 82% in Delhi (Bera & Maitra, 2021). In Delhi, additional innovations, such as an increased electric range, more public charging infrastructure, and reduced charging time, alongside lower subsidies, could further boost PHEV adoption. However, in Kolkata, higher subsidies are crucial for significant market demand. Bera and Maitra (2021) suggest that multiple policy interventions are more effective than isolated measures. Research on HEV adoption in Japan shows that higher-income households are more likely to use subsidies for these vehicles, making current subsidy programs regressive (Wang & Matsumoto, 2022). To be effective, these programs need to benefit lower-income households. Additionally, rural households with large gasoline vehicles are unlikely to switch to HEVs unless large, long-range EVs are available (Wang & Matsumoto, 2022).

Table 1
Fiscal incentives for private passenger EVs in Ireland (PBO, 2022).

Type of incentive	Scheme/Incentive	Description
Purchase incentives	*Electric Vehicle Grant*	Purchase incentive of up to €5000 for BEVs, not available for PHEVs[a]
	Home Charger Grant	Grant of up to €600 to install home charger unit[a]
Tax benefits on acquisition	*Vehicle Registration Tax* relief or lower rate	Up to €5000 tax relief for BEVs and a lower rate of tax for PHEVs
Tax benefits on ownership	*Motor Tax* lower rate	The lowest rate of annual motor tax for BEVs and second- or third-lowest band for PHEVs
	Low Emissions Vehicle Toll Incentive Scheme	50% toll reduction for BEVs and 25% for PHEVs, up to €500 annually
	Carbon/Fuel Tax exemption	Exemption applies to the consumption of electricity

[a] Since July 1, 2023, the purchase grant amount for BEVs has been reduced to a maximum of €3500 (SEAI, 2024a), and the home charger grant to €300 (SEAI, 2024b).

Further studies highlight the importance of financial incentives in making EVs more economically viable compared to ICEVs. A study using 2012 data found that in the United States, the lifetime total cost of most EV types, when driven for 120,000 miles over 12 years, is affordable with federal tax incentives, being no more than 5% higher compared to ICEVs. Additionally, consideration of higher lifetime mileage would result in even greater overall cost savings (Tseng et al., 2013). Scorrano et al. (2020) found that purchase subsidies are crucial for making BEVs cost-competitive in Italy. Without subsidies, the cheapest BEVs are competitive with HEVs but not with diesel and petrol cars unless driven extremely long distances. With recent government subsidies, BEVs are competitive with diesel cars but not petrol cars unless driven more than 12,500 km annually. Evidence from Norway, a country with the highest rate of EV adoption in the world, shows that public sentiment regarding BEV incentives is shifting, with a growing number of people objecting to them. BEV users are less resistant to these incentives compared to ICEV users, but overall, discontent is increasing (Aasness & Odeck, 2023). This trend suggests that as the market matures, strong incentives may no longer be essential.

1.3. Equity impacts of EV incentives and other climate policies

Several studies have critically discussed the role of EVs in the transition to sustainable transport and the support that governments provide to encourage EV adoption (Sovacool et al., 2019a, Sovacool, et al., 2019b, 2019c, Kester, et al., 2019, 2019c, 2022; Barton & Schütte, 2017; Bauer et al., 2021; Hardman et al., 2021; Martiskainen et al., 2021; Mullen & Marsden, 2016; Wells, 2012). These studies have pointed out that prioritising EVs perpetuates a car-dependent system, which detrimentally impacts the biosphere and communities (Hosseini & Stefaniec, 2023). Many of these researchers have also noted the absence of affordable EV options in the market, thus positioning EVs as luxury items. There is a recognised need for quantitative analysis to estimate household purchasing power, although the existing qualitative evidence from the mentioned studies is already substantial. Bauer et al. (2021) provided a valuable basis for our analysis by comparing current household vehicle expenditure with projected costs for EVs, examining these trends through the sociodemographic characteristics of various groups within the United States of America. The affordability of EVs forms part of a broader discussion on private car ownership and its impact on household finances. Research in this area suggests that owning any car can lead to significant economic strain, especially when limited transportation alternatives force households to rely on cars (Mattioli et al., 2017, 2018). The low-income high-cost (LIHC) metric, originally developed to evaluate fuel poverty, is also useful for assessing household vulnerability to vehicle-related expenses (Hills, 2012). It is important to note that such metrics focus on the financial conditions after a purchase and do not assess the impact of the initial purchase on household finances. Our study diverges from previous work by focusing on the initial costs and purchasing power related to acquiring EVs rather than the ongoing costs of ownership, such as maintenance and travel expenses.

A rapidly expanding body of literature explores the effectiveness and social impacts of policies aiming to achieve climate targets, such as subsidies for alternative fuel vehicles (El Hachem and De Giovanni, 2019; Guo and Kontou, 2021), road pricing (Bureau and Glachant, 2008; Levinson, 2010; Ungemah, 2007), congestion-based charging (Meyer de Freitas et al., 2017), low emissions zones (De Vrij and Vanoutrive, 2022), carbon tax (Bureau, 2011; Santos and Catchesides, 2005), or a combination of policies (Axsen and Wolinetz, 2021; El Hachem and De Giovanni, 2019; Pyddoke et al., 2021). Most often, studies refer to a concept of distributional justice and research how the social and economic burdens and benefits of policies or transportation arrangements are distributed within society and across regions.

In Ireland, some efforts have been undertaken to assess the anticipated social and general impacts of policy measures to encourage EV adoption. For instance, Caulfield et al. (2022) found that an equity gap exists between income groups in EV adoption. Their findings suggest that a financial barrier may prevent less well-off households from shifting to EVs. However, no governmental mechanism has yet been designed to minimise those impacts, and no policies have yet been introduced to adequately address existing equity issues. Although the purchase grant was noted to adversely affect distributive justice, the policy is being repeatedly extended (Department of Transport, 2021). The establishment of the Zero Emission Vehicles Ireland (ZEVI) Office in 2022 (Government of Ireland, 2022) and new initiatives to promote EV uptake do not adequately address barriers to EV purchase among lower-income households. Nevertheless, new measures address some current equity concerns regarding home chargers (Department of Transport, 2022). A new scheme will be launched for dwellers of apartments and other homes (both owners and tenants) that do not have access to driveways – groups that have been previously excluded from receiving a home charger grant. Both tenants and homeowners will also be able to apply for the grant without having an EV.

1.4. Transport affordability and its impact on accessibility

Transport can both contribute to and alleviate poverty (Grieco, 2015). Affordability refers to the ability to access goods and services whenever transport is needed. This concept emphasises the relationship between household income and transport costs, such as public transport fares. When this balance is disrupted, households face substantial vulnerability in terms of mobility and accessibility (Falavigna & Hernandez, 2016). Vale (2020) measures accessibility by cost using effective speed, demonstrating that higher-income individuals benefit more across all transport modes due to their greater purchasing power. The disparity is most pronounced in car accessibility and minimal in pedestrian accessibility. The relationship between affordability and accessibility is more clearly defined and extensively researched in the context of public transport than in private mobility. Studies have explored how the cost of public transport services costs impacts residents' accessibility (Lionjanga & Venter, 2018). Van Heerden et al. (2022) discuss how travel costs impact mobility, noting that unaffordable travel modes limit households' access to opportunities ('restricted mobility options'). This issue is worsened by dispersed land use, which hinders proximity planning and forces reliance on motorised transport. Consequently, disadvantaged social groups experience both high affordability constraints due to low incomes and restricted mobility options. Venter (2011) explains that transport costs as a proportion of household expenditure vary significantly over time and location. While overall transport spending rises with income, it tends to consume a larger share of income among poorer households. This is also true for Ireland, where in 2023, households in the first quintile (with a disposable weekly income below €536.71) spent €54.49 on transport, while households in the fifth quintile (disposable weekly income of €1836.00 or more) spent more than four times that amount: €243.00 (CSO, 2024c). On average, Irish households spent €142.39 or 14.13% of their total expenditure on transport in 2022–2023 (CSO, 2024c).

1.5. Rationale of this study

This study aims to provide the grounds for evidence-based debate in policymaking regarding the equity impact of incentives supporting the uptake of EVs and their design. This is to equip scholars and decision-makers with stronger arguments to support a multilevel transition to low-carbon mobility that meets the needs of various income groups in society.

By examining the affordability of EVs across Irish households, this study concurrently provides insight into the main beneficiaries of current EV policy measures in terms of income group, which facilitates analyses of the probability of meeting emissions reduction targets by electrifying the private car fleet. Affordability is estimated by the number of households that could purchase an EV on loan without being pushed into financial poverty, which we refer to as the affordability threshold. The four scenarios designed consider two models of EVs and two loan repayment options. Knowing that EV prices are expected to fall, and savings can be used to offset the price, the study also considers price reductions in each of the four scenarios, extending the timeframe of the research to the next several years. The estimates are examined across the geographical territory of Ireland, and numbers are reported at the electoral division level (ED = 3409). This analysis is useful to understand the spatial distribution of EV affordability in light of present incentives and identifies regions that could benefit most. The results are not intended to reflect the diversity of households in each area or their specific characteristics. By incorporating median income values, our results illustrate general distribution patterns; however, they do not consider outlier households that are wealthier or worse off within a given administrative boundary. Finally, by discussing the findings, we aim to inform policymakers on how the adverse effects of EV policies can be minimised, and we offer suggestions on how support for EVs can be diversified.

This research spans climate policy and social justice to make two main scientific contributions. First, by analysing household affordability, it exposes the potential equity implications of current EV subsidy design and provides recommendations on how to mitigate the negative social impacts of this design. Second, it underscores the importance of sociodemographic factors, particularly income, in determining the feasibility of achieving EV uptake targets. The developed estimation method is applicable elsewhere if income and household type data are available, and it can also assess the affordability of various travel options or the fairness of other policies and schemes.

2. Materials and methods

This research estimates the number of households in Ireland that cannot afford a new EV under the current incentive policies and consequently cannot take advantage of EV incentives. It examines how these households are geographically distributed and discusses how the affordability of EVs among different income groups within the Irish population could affect meeting the governmental emissions reduction targets. The findings could potentially shape the design and customisation of EV subsidies to achieve higher affordability rates and help prevent the perpetuation of inequalities in access to valued opportunities due to the lack of EV adoption (Vecchio & Martens, 2021).

2.1. Study area and data

The findings related to the financial capacity of households to buy an EV are based on a case study of Ireland conducted at the electoral district (ED) level; the study covers 3409 districts. The data are derived from the 2016 Census statistics (CSO, 2016a), and the data points used for estimation are presented in Table 2.

Given that income data were not collected in the 2022 Census, but the EV prices we applied were from 2022, it was necessary to adjust the household median gross income from 2016 to reflect its equivalent value in 2022. To adjust the income from 2016 (denoted as year t_1) to 2022 (denoted as year t_2) using both wage growth and inflation, the following formula was applied:

$$Adjusted\ Income_{t_2} = Income_{t_1} \times (1+g) \times \frac{P_{t_2}}{P_{t_1}}, \quad (1)$$

Here, g represents the wage growth rate between the base year 2016 (t_1) and the target year 2022 (t_2), while P_{t_1} is the price index for the year 2016, and P_{t_2} is the price index for the year 2022. In this equation, the term $(1+g)$ accounts for wage growth over the period, and the fraction

Table 2
Data used for estimation.

Data	Unit	Definition	Data source
Household median gross income by ED, 2016	Euro	Gross household income is defined as direct income plus state transfer payments.	CSO (2016a)
Private households by type by ED, 2016	Number of households	Household types refer to the composition of persons living in one housing unit, with a distinction between adults and children (see Table 4).	Census Curator (2017a)
Permanent private households by type of occupancy by ED, 2016	Number of households	Households are divided into living in owned and rented homes. For households that live in rented homes, the rent is deducted from their disposable income.	Census Curator (2017b)
Average weekly rent by ED, 2016	Euro	The average rent paid for a rented home in each ED. Because of comparable rent and mortgage repayment values in 2017, which were €1131 and €1138 nationwide, respectively (EBS, 2017), the rent values were deducted from the income of households that own their homes on a mortgage.	CSO (2016b)

$\frac{P_{t_2}}{P_{t_1}}$ adjusts for inflation by comparing the price levels of the two years. The wage growth was calculated by comparing average total earnings between 2016 and 2022 (CSO, 2024a) and was determined to be 24.35%. The inflation rate, based on the Customer Price Index (CPI) from 2016 to 2022 (CSO, 2024b), was calculated to be 15.8%.

Further, disposable household income was calculated as gross income less income tax and social insurance deductions, also accounting for personal tax credits (CSO, 2022a). The following income tax bands for 2022 were used: for a single person without children, income up to €36,800 was taxed at 20%, while income above this threshold was taxed at 40% (Irish Revenue Commissioners, 2024a). Universal social charge rates varied between 0.5%, 2%, 4.5%, or 8%, depending on gross income level (Irish Revenue Commissioners, 2024b). Personal tax credits for a single person in 2022 remained at €1700 (Irish Revenue Commissioners, 2024a).

2.2. Determining household affordability of EVs

In this study, household EV affordability refers to the financial ability to purchase an EV while ensuring that sufficient resources remain to meet the household's basic needs. The affordability threshold is determined with reference to the poverty line, serving as a benchmark for assessing the level of affordability.

A threshold of 60% of the national median equalised residual income (A) is used to determine if the equivalised residual income of a household (RI) is below or above the threshold (Berry et al., 2016). The threshold marks the 'at risk of poverty' line defined in Ireland (CSO, 2022c), similar to practices in the EU and UK (Mattioli et al., 2018). In 2022 in Ireland, the nominal median annual disposable income per person was €26,257, and the 'at risk of poverty' threshold stood at €15, 754. It is estimated that 13.1% of the population in Ireland was below the poverty threshold that year (CSO, 2023).

The financial resources of each household, denoted as the equivalised residual income (RI), are estimated and compared with the affordability threshold (A). As shown in Equation (1), the equivalised residual income (RI) is computed by deducting housing costs (H) and car loan repayment value (L) from the equivalised disposable income (DI). This study's method of estimating affordability resembles the 'low-income' measure of the LIHC metric (Hills, 2012; Mattioli et al., 2018), but additionally deducts the projected loan cost that would be incurred if a household purchased an EV. In line with studies analysing household vulnerability (Berry et al., 2016; Mattioli et al., 2018), housing costs are subtracted from disposable income as they represent unavoidable expenses, including loans, mortgage and rent costs. Housing billing expenses were excluded due to a lack of sufficient data granularity.

The method of computing the household's residual income, on which the affordability of purchasing an EV is based, is presented below. The residual income DI_e^s of each household for a scenario s is computed as follows:

$$RI_e^s = DI_e - \left(H_{e,o} + L^s\right), \tag{2}$$

Where DI_e is the median disposable income of a household in a given electoral district $e \in \{1, 2, \ldots, 3409\}$, $H_{e.o}$ represents housing costs for a household in a given electoral district e having a certain ownership right to their home $o \in \{\text{'owned'}, \text{'owned with mortgage'}, \text{'rented'}\}$, and L^s indicates a loan repayment value determined for each scenario $s \in \{\text{'S3'}, \text{'S5'}, \text{'M3'}, \text{'M5'}, \text{'S3r'}, \text{'S5r'}, \text{'M3r'}, \text{'M5r'}\}$, as described in Section 2.3.

Whether a household n can afford an EV in a given scenario s is determined as shown below:

$$i_n^s = \begin{cases} 0 \text{ if } DI_e^s \geq A_h \\ 1 \text{ if } DI_e^s < A_h \end{cases} \tag{3}$$

Where $i_n^s = 0$ represents that a household n in scenario s can afford an EV, while $i_n^s = 1$ indicates that a household cannot afford an EV, A_h denotes the affordability threshold determined based on the household's type $h \in \{\text{'1A'}, \text{'2A'}, \text{'2A1C'}, \text{'1A1C'}, \text{'2A1H'}, \text{'2A1C1H'}, \text{'1A1C1H'}\}$ with the income values presented in Table 3.

Then,

$$N^s = \sum_{i=1}^{N} i, \tag{4}$$

Where N^s *is* the total number of households that cannot afford an EV in a given scenario s.

Based on the household composition, the equivalised income threshold for each household type has been calculated and is expressed in weekly terms (Table 3). A weight of 1 was used for the first adult, 0.66 for the second and subsequent adults, and 0.33 for each child in the household (CSO, 2022c).

Table 3
'At risk of poverty' threshold for households by type of household, 2022

Type of household	Weekly disposable income threshold (Euro)
One-person household (1A)	302.96
Married or cohabitating couple household (2A)	502.92
Married or cohabitating couple with children household[a] (2A1C)	602.89
One-parent family with children household[a] (1A1C)	402.94
Couple and others household[b] (2A1H)	702.87
Couple with children and others household[b] (2A1C1H)	802.85
One parent family with children and others household[b] (1A1C1H)	602.89

[a] It is assumed that the household has one child only.
[b] It is assumed the 'others' in the household include one adult person.

2.3. Scenario design

The financial ability of Irish households to purchase a new EV is estimated for different scenarios. Eight scenarios are evaluated, taking into account different EV types, lengths of the loan repayment period, and a predicted decrease in the sales price of EVs (Fig. 1). We consider two models of EVs: Renault Zoe Play, a small, inexpensive vehicle classified in segment B, and the Volkswagen ID.4 Life, a medium-sized, more comfortable vehicle classified in segment C. These models were selected based on their popularity among buyers as bestselling EVs in their category (SIMI Motorstats, 2023). The current price of the former vehicle is €30,295, whereas the latter costs €48,606, both including a government purchase grant of €5000. The grant was reduced to €3500 starting as of July 1, 2023 (SEAI, 2024c). While this reduction is not factored into the current analysis, it indicates that new EVs are now slightly less affordable than previously. In comparison, the top-selling ICEVs in segments B and C in Ireland in 2023, the Ford Fiesta and Hyundai Tucson (SIMI Motorstats, 2023), are respectively priced at €22, 058 and €37,295. This makes these models approximately €10,000 more affordable than their electric counterparts. It is worth noting that in our analysis, only the price of the vehicle is included in the EV cost. We do not consider the cost of purchasing and installing a home charger, which ranges from €1200 to €1600 before a €300 grant is deducted (SEAI, 2024c). Considering the low coverage of public charging infrastructure, most households opt to install home charging points, accounting for 80% of charging sessions as of 2021 (Caulfield et al., 2022). This additional expense increases the financial burden associated with purchasing an EV.

Two sets of prices were considered: the current price and a 20% lower price due to an expected drop in the near future. Forecasts indicate that EV prices will decline over time, and in the next five years, A- and B-segment EVs, which are smaller cars, will be 23% cheaper, while C- and D-segment vehicles, which are larger cars, will be 16% cheaper (Goetzel & Hasanuzzaman, 2022). An average of these two reductions was assumed for calculations. Notably, it is anticipated that smaller EVs will not reach price parity with ICEVs even by 2030. The second-hand market for EVs is only emerging, so only buying a new EV – which is a more feasible option at present – was considered. Nonetheless, the 20% decrease in price could be interpreted as a scenario in which a used EV is purchased, though it is important to note that the purchase grant cannot be claimed for a second-hand EV.

It should be recognised that trade-ins can contribute to reducing the upfront costs of purchasing an EV. Consequently, the scenarios implicitly take this into account by assuming a 20% reduction in the price of EVs, serving as a stand-in for situations where households might trade in their current vehicles. In 2022, the average age of privately owned cars in Ireland was 9 years, showing a gradual increase from 5.8 years in 2008 (SIMI&Arup&Jim Power Economics, 2022). Selling a car after one year of use decreases its value by 15%–35%, and 50% of its original value is usually lost after three years of use. While the depreciation rate of new car slows after one year of use, the price of a several-year-old car is substantially lower than its purchase price (Carzone, 2020; Irish Revenue Commissioners, 2024c). Although we did not explicitly model the trade-in process and its varied impact across different income brackets, the assumed price reduction reflects the broader economic relief that could benefit potential EV buyers. Importantly, potential EV buyers who may require the most financial relief to purchase an EV typically own older and smaller – and therefore less expensive – vehicles. This suggests that the benefits of such a trade-in are likely less substantial for lower-income households.

For the loan duration, two time periods were considered, 3 and 5 years, with the assumption that the interest rate will not change. Using online loan calculators provided by the most popular lenders (Bank of Ireland, Allied Irish Bank, Permanent TSB, An Post, and Credit Union), the weekly repayment rates were calculated, and the average value was used for further computations (Table 4). Car dealers also offer personal contract plans for financing the purchase; however, in Ireland, these plans require a prior deposit and, as such, were not considered.

Although purchasing an EV comes with certain benefits, such as lower running and maintenance costs (Nocera & Cavallaro, 2016), the process can be financially challenging for households. When buying a new EV, households should be prepared for a long waiting time of around six months for delivery (The Irish Times, 2022). An upfront payment is necessary, and even if the payment is made by a loan provider, households must still repay the first instalments before delivery. Therefore, purchasing an EV increases the transportation expenses of

Fig. 1. Scenarios designed to estimate households' financial ability to purchase a new EV.

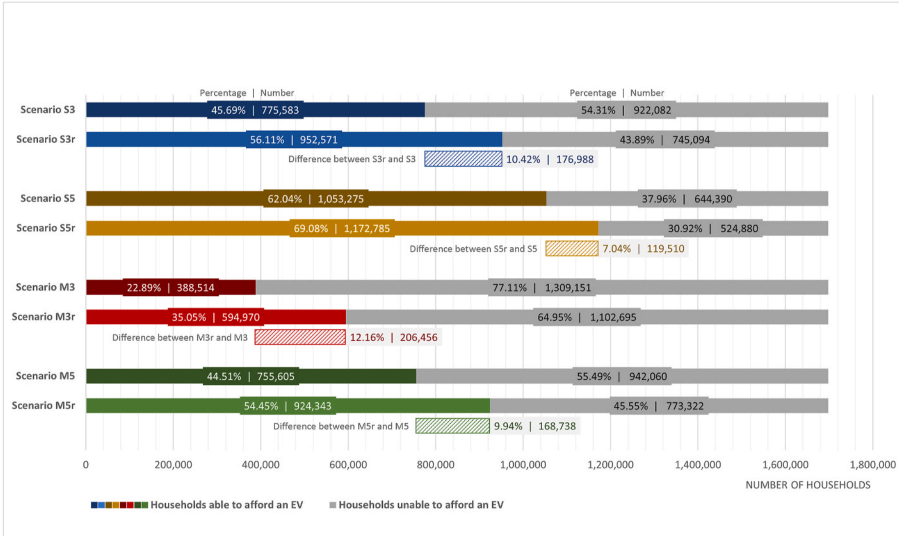

Fig. 2. Household affordability of EVs at the country level in various scenarios.

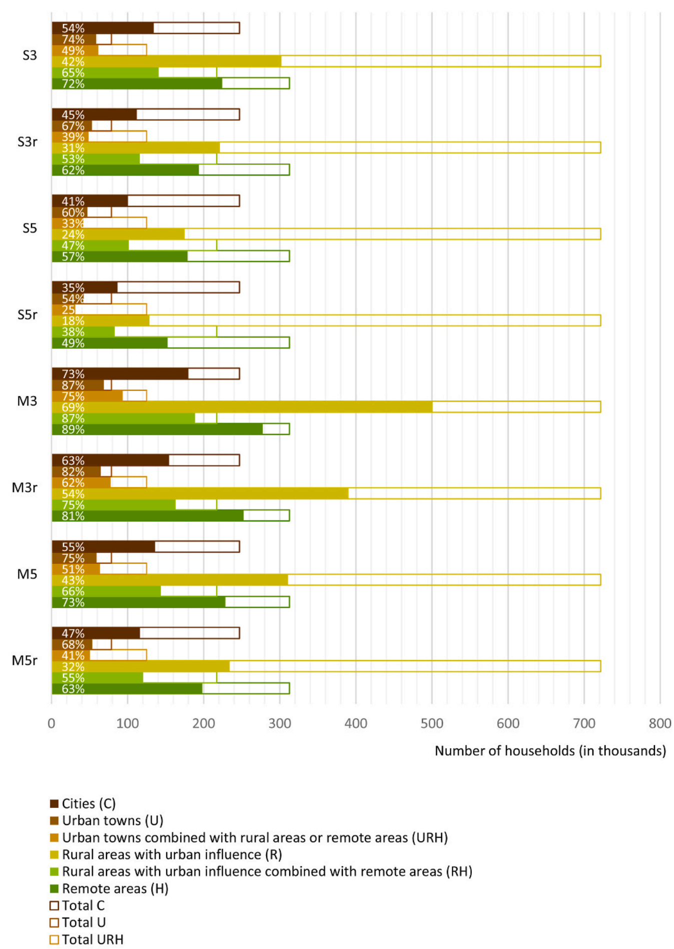

Fig. 3. Number of households below the EV affordability threshold by urbanisation level, displayed against the total number of households in each area type.

households, as they would likely continue using their current mode of transport until the purchased EV is delivered, all while making payments in advance. This means that it may not be feasible for households that

Table 4
Loan repayment values are calculated based on the EV type (B and C segments), loan repayment period (3 and 5-year periods), and price (full price and 20% price reduction).

Category of EV	Model		Price	Repayment value (weekly)	
				3-year loan	5-year loan
Small-size (Segment B)	Renault Zoe Play	Current price	€30,295.00	€234.87	€151.45
		20% price reduction	€23,236.00	€180.12	€116.14
Medium-size (Segment C)	VW ID.4 Life	Current price	€48,606.00	€373.56	€240.82
		20% price reduction	€37,884.80	€291.15	€187.70

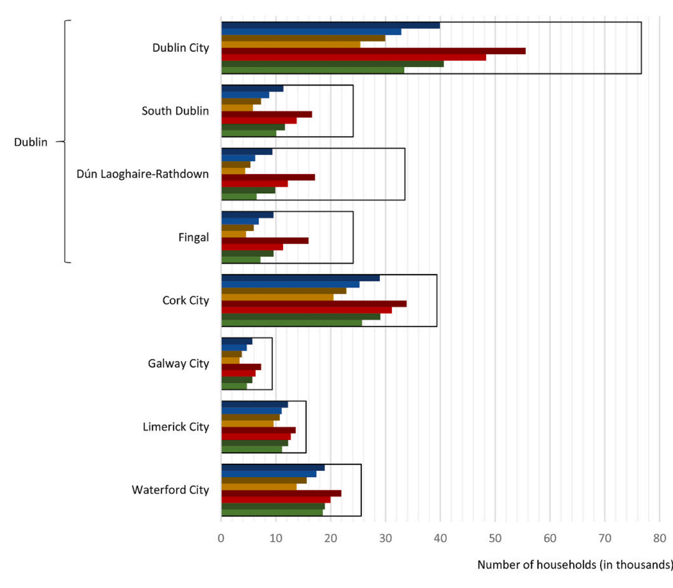

Fig. 4. Number of households **below** the EV affordability threshold in selected high-density urban areas, displayed against the total number of households in each area.

currently own an ICEV to sell their car to offset the cost. These difficulties are exacerbated in rural areas, where alternative, more sustainable transportation modes are scarce and car ownership is highest (Carroll et al., 2021). Households in Ireland saved an average of 10% of their income before the pandemic, and 19% after (CSO, 2022b). With a 20% savings rate assumed, a household earning the national median income could save €4119 annually, which could cover approximately 2.5–8 months of the loan period, depending on the scenario. In addition, less well-off households would save less, making it even harder for them to manage loan repayments compared to wealthier households.

3. Results and discussion

This section presents the results of analysing the EV affordability of households. If the disposable income of a household, after deducting the car loan repayment amount was, fell below the affordability threshold for a given household type, the household was deemed to be below the threshold. Consequently, it would not qualify to benefit from government incentives for the purchase and use of these vehicles.

3.1. Cumulative household affordability of EVs

Fig. 2 shows the estimates for each scenario in terms of the number of households and the share of these households in the total number of households nationwide. Scenario M3 is the most severe of the eight scenarios (followed by M3r), indicating that 77% of all Irish households would be unable to repay the loan within 3 years if buying a medium-size EV. Scenarios S3 and M5, along with S3r and M5r, apply repayment values that differ only by €6 and €8, respectively, and therefore yield comparable results. The first pair indicates that around 55% of households nationwide would be at risk of poverty if they purchased a small-size EV model on loan with a 3-year repayment period or a medium-size one with a 5-year period, while the second pair suggests a share of 45% if EV prices drop as expected. Comparing current-price scenarios to future-price scenarios, an insubstantial difference of between 7 and 12 percentage points can be observed. The most affordable scenarios are S5r and S5, which assume that households buy a small-size EV on a 5-year loan. However, even in these cases, around 35% (0.5–0.6 million out of all 1.7 million households) would still be at risk of experiencing serious budget loss, potentially preventing them from meeting essential financial obligations.

By the end of 2022, 74,000 EVs were registered in Ireland (Department of Transport, 2023). Considering the government's target of facilitating the purchase of 845,000 private EVs by 2030 (Department of the Environment, Climate and Communications, 2023), this means that 771,000 EVs have yet to be purchased. The total number of households in Ireland stood at 1,697,665 in 2022. To achieve the governmental private EV target, there can be no more than 926,665 households – or 54.58% of total households – below the EV affordability threshold. Fig. 2 shows that this condition is not met in scenarios M3, M3r, and M5. This suggests that if only medium-sized or larger EVs are considered for purchase, meeting the purchase targets and climate objectives will only be possible with a price reduction of over 20%, provided a leasing period of five years is available. Such a reduction could result from market price reductions, government subsidies, or trade-ins of vehicles already owned by households.

Specifically, it is estimated that to achieve the necessary minimum number of households able to afford an EV, the monthly repayment value for an EV should not exceed €236. This threshold is met in all scenarios involving small-size EVs. These findings emphasise that policies supporting the production and deployment of smaller vehicles are highly advantageous. These vehicles are not only more affordable but also generate lower environmental impacts due to their smaller size and lighter weight. As the size of a vehicle affects the resources required for its production, maintenance, and waste disposal at the end of its lifecycle, smaller vehicles offer a reduced environmental impact. Moreover, a smaller size implies lower weight, which translates into lower energy consumption and, consequently, lower emissions.

The latest Climate Action Plan (Department of the Environment, Climate and Communications, 2023) does not specify the emission savings attributed to the 845,000 private EVs. However, if the previously cited figure of 2.7 MtCO_2eq. from the earlier iteration of the document is considered, fully achieving this target would account for 44% of total emission reductions in the transport sector. This corresponds to a reduction of 3.20 ktCO_2eq. for every 1000 EVs purchased, which represents 0.12% of the electrification target for private cars. For instance, in scenario M5, the target would be missed by 1.85%, resulting in 49.26 ktCO_2eq. of unwanted emissions. To put this into perspective, it would take approximately 26,309 cars, each travelling 16,867 km at a rate of 111.0 gCO_2 per km (CSO, 2019a; SEAI, 2023), to emit an equivalent amount of these emissions in one year.

From an EV affordability perspective, the numbers suggest that subsidies higher than those currently available may not be necessary if all households opt to purchase a small-size EV. Assuming a €5000 grant is offered, the required number of households (at least 771,000) would likely be able to afford a small-size EV. Even now, with the grant reduced to €3500 (SEAI, 2024a), it is anticipated that households may still afford a small-size EV by taking out a longer-term loan. However, it is important to acknowledge that many of these households, while not being pushed into the risk of poverty by this purchase, would still find themselves at a disadvantage, with limited resources available for other necessary and discretionary expenses.

In our analysis, we do not estimate a flat rate of subsidy that would sufficiently alleviate the financial burden on low-income households, as there is no one-size-fits-all solution that addresses everyone's varying circumstances. This observation suggests that a differentiated subsidy, which accounts for income levels and household sizes, would be preferable, although the exact rates require further study. Moreover, under the M scenarios, an additional subsidy above the €5000 would be needed for 15,395 households to enable them to purchase medium-sized EVs using the maximum leasing period. With the subsidy now reduced to €3,500, this further diminishes the purchasing power of even more households.

3.2. Regional disparities

The financial capacity of households to purchase an EV varies substantially across Ireland. The estimated figures for households unable to afford an EV in each ED were aggregated by county and presented as percentages in Table 5. Residents of Dún Laoghaire-Rathdown, Kildare and Fingal – three of the seven counties in the Greater Dublin Area – exhibit the greatest potential to adopt EV technology. In the most favourable scenarios (S5 and S5r), only 12%–25% of households in these counties are unable to buy an EV. Conversely, in the least optimistic scenario (M3), the figures in these counties range from 51% to 66%. Among the three counties, households in Dún Laoghaire-Rathdown show the highest affordability for EVs. Findings from the study by Caulfield et al. (2022) also reveal that the number of home charging points in this area exceeds those found in other Dublin counties and across the country. This evidence indicates that a greater proportion of households in Dún Laoghaire-Rathdown (compared to other parts of Dublin) already own EVs and may not be motivated to purchase an additional electric car.

In contrast, Table 5 indicates that between 52 and 69% of households in Limerick City, County Donegal, Waterford City, and Cork City cannot afford a small-size EV even with a 5-year loan in the most favourable scenarios (S5r and S5). Interestingly, different patterns are observed for the county areas adjacent to the three listed cities – counties Limerick, Waterford, and Cork – which rank between 3rd to 11th in terms of affordability. This suggests that low-income households are more likely to reside within the core city boundaries, while wealthier residents prefer the suburbs. This spatial configuration is a result of decades of

Table 5
Percentage of the households **below** the affordability threshold by county for the eight scenarios.

County	Total number of households	S3		S5		M3		M5		S3r		S5r		M3r		M5r	
		(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank	(%)	Rank
Co. Carlow	25,515	63.36	25	42.29	23	83.38	23	65.08	25	48.41	23	37.16	25	71.09	23	50.81	24
Dublin City	76,658	52.06	15	39.07	17	72.48	10	53.01	16	42.88	17	33.13	20	63.07	14	43.57	16
South Dublin	24,117	47.16	11	30.21	12	68.89	9	48.24	11	36.38	12	24.06	13	57.24	10	41.69	14
Fingal	24,109	39.59	4	24.73	4	66.21	4	39.74	3	28.48	3	18.93	6	46.82	3	29.79	3
Dún Laoghaire-Rathdown	33,550	27.94	1	16.02	2	51.07	1	29.47	1	18.56	1	13.10	2	36.31	1	19.35	1
Co. Kildare	48,119	31.74	2	15.76	1	56.50	2	32.36	2	24.27	2	11.93	1	42.38	2	25.20	2
Co. Kilkenny	44,431	41.39	5	25.58	5	66.20	3	42.25	5	31.82	6	20.56	9	52.54	5	32.94	5
Co. Laois	33,889	43.63	8	27.99	9	73.24	12	45.42	9	31.67	5	19.63	8	54.98	7	33.36	7
Co. Longford	31,971	59.04	22	40.82	21	82.69	22	59.62	21	47.34	21	30.73	18	73.03	25	48.41	19
Co. Louth	13,556	48.54	13	30.71	14	77.80	15	50.58	14	35.54	11	24.90	14	64.13	15	38.04	12
Co. Meath	43,163	42.84	7	26.03	6	68.16	5	43.32	7	33.14	8	18.55	5	56.63	9	34.40	8
Co. Offaly	48,547	55.22	17	38.28	16	80.59	20	55.78	17	42.37	16	27.82	16	68.26	18	44.96	17
Co. Westmeath	46,446	44.60	10	27.26	8	72.90	11	45.61	10	34.51	10	19.23	7	58.30	11	35.54	10
Co. Wexford	62,264	58.63	21	39.37	18	83.66	24	60.42	22	46.32	19	30.73	17	69.16	21	47.97	18
Co. Wicklow	42,910	48.17	12	30.10	11	77.37	14	49.76	12	36.62	13	22.44	10	60.26	12	40.07	13
Co. Clare	80,671	57.38	19	42.54	24	78.25	16	57.58	18	47.46	22	35.37	22	68.72	19	49.40	22
Cork City	39,381	73.50	31	58.01	31	85.95	29	73.77	31	64.16	31	52.10	31	79.09	32	65.33	31
Co. Cork	185,905	43.64	9	28.48	10	68.60	8	44.95	8	33.25	9	22.78	11	55.14	8	34.82	9
Co. Kerry	72,252	63.55	26	45.18	26	84.71	27	65.18	26	51.99	26	37.75	26	74.04	26	53.06	26
Limerick City	15,513	78.59	34	69.02	34	87.78	32	78.95	33	71.25	34	61.90	34	82.07	33	71.66	33
Co. Limerick	68,089	41.82	6	26.08	7	68.34	6	42.24	4	32.21	7	18.11	4	52.32	4	32.94	6
North Tipperary	33,112	50.01	14	30.62	13	75.50	13	50.53	13	37.31	14	22.97	12	61.16	13	38.03	11
South Tipperary	52,777	66.51	28	49.20	28	84.16	26	67.77	28	58.35	29	43.44	29	74.74	28	59.81	29
Waterford City	25,563	74.01	32	61.07	32	85.85	28	74.10	32	68.05	32	53.89	32	78.17	31	72.71	34
Co. Waterford	45,197	39.54	3	23.44	3	68.50	7	42.62	6	29.56	4	16.91	3	52.63	6	31.18	4
Galway City	9342	60.94	23	40.67	20	78.26	17	60.94	23	50.25	24	36.02	23	67.56	17	50.44	23
Co. Galway	119,728	56.96	18	41.49	22	80.03	19	59.11	20	47.15	20	33.41	21	69.22	22	48.88	21
Co. Leitrim	37,216	68.37	30	54.84	30	88.68	33	69.45	30	58.57	30	43.91	30	78.10	30	59.81	30
Co. Mayo	87,917	66.89	29	49.83	29	86.30	30	68.02	29	55.95	28	40.62	28	75.50	29	57.98	28
Co. Roscommon	47,062	61.69	24	42.81	25	83.94	25	63.13	24	51.18	25	36.92	24	72.23	24	52.95	25
Co. Sligo	37,576	57.62	20	40.40	19	81.02	21	59.02	19	45.27	18	32.27	19	68.97	20	48.61	20
Co. Cavan	40,242	52.37	16	32.13	15	79.20	18	52.81	15	40.61	15	25.59	15	64.48	16	43.05	15
Co. Donegal	67,425	78.04	33	63.27	33	90.93	34	79.60	34	68.11	33	57.14	33	85.53	34	69.44	32
Co. Monaghan	38,076	64.89	27	45.54	27	87.19	31	66.52	27	54.46	27	39.41	27	74.54	27	56.33	27
Total Ireland	1,697,665	54.31		37.96		77.11		55.49		43.89		30.92		64.95		45.55	

Note: Dublin consists of four administrative counties: Dublin City, South Dublin, Dún Laoghaire-Rathdown, and Fingal.

development on the outskirts, marked by one-off housing that has led to more scattered patterns, commonly referred to as urban sprawl (Ahrens & Lyons, 2019). Researchers agree that this settlement pattern encourages car dependence and hampers efforts to provide efficient public transportation, thereby contributing to an unsustainable transportation system throughout the country (Moriarty et al., 2023).

The spatial differences highlighted above were further explored by aggregating EDs based on the level of urbanisation (Fig. 3). The categorisation of area types follows the typology established by the CSO (2019b), which classifies Small Areas (SAs) into cities, satellite urban towns, independent urban towns, rural areas with high urban influence, rural areas with moderate urban influence, and highly rural and remote areas. However, since the units of analysis in this study are EDs, which can contain multiple SAs, the typology applied here differs from the CSO's classification, as some EDs encompass a blend of these original types.

The results in Fig. 3 show that rural areas with urban influence (R) have the lowest percentage of households below the EV affordability threshold (18%–69% across scenarios), outperforming all other area types. They are followed by urban areas combined with rural or remote areas (URH). Cities (C), characterised by high-density populations, show moderate EV affordability issues (35%–73% across scenarios) but also substantial variability, as detailed in Fig. 4. Rural areas with urban impacts blended with remote areas (RH), as well as purely remote areas (H), face greater affordability challenges, with remote areas experiencing significant issues, ranging from 49% to 89%. Households in remote areas are especially dependent on car use due to limited public transport. For example, statistics reveal that in Irish rural regions, 80% of trips are by car, and amenities are often not within walking distance (NTA, 2018).

Further, our analysis shows that urban towns (U) experience the most severe affordability issues (54%–87%), reflecting the broader trend of urban town decay and the relocation of wealthier residents towards rural areas. These findings suggest that EV subsidy policies need reevaluation, considering the varying levels of support required by households across different degrees of urbanisation. Urban towns could capitalise on their denser public transport networks, whereas rural areas that are remote (H) or partially isolated (RH), collectively accounting for over 500,000 households, would require higher subsidies than those currently available to facilitate the green transition. These households also tend to travel longer distances (NTA, 2018), making the decarbonising of their trips a potentially greater source of emissions savings.

The affordability within the area types is not uniform, and this is illustrated for high-density urban areas in Fig. 4. This figure compares major cities by showing the proportion of households below the EV affordability threshold. Each bar represents a different city or district, with segments corresponding to the scenarios. The length of each segment indicates the number of households unable to afford an EV relative to the city population living in high-density areas, denoted by a black rectangle. Dublin, including its subdivisions of Dublin City, South Dublin, Dún Laoghaire-Rathdown, and Fingal, features shorter bar segments, indicating a larger proportion of households that can afford EVs. In contrast, cities like Cork, Galway, Limerick, and Waterford exhibit larger proportions of households falling below the EV affordability threshold.

The geographical distribution of EV affordability is presented in Fig. 5 for the four scenarios based on current EV prices. The share of households below the EV affordability threshold, relative to the total number of households in each ED, was used to highlight differences between EDs. The observed spatial patterns align with the 2016 Pobal HP Deprivation Index (Pobal, 2022) and earlier research (Carroll et al., 2021), which identified clusters of transport disadvantage in Ireland. These clusters are characterised by low public transportation coverage and forced car ownership, resulting in economic stress.

The results of this study identify hotspots of low affordability in the northern, north-western and western edges of Irish territory. This includes counties Donegal, Leitrim, Cavan, Sligo, Roscommon, Mayo, West Galway and Clare, Kerry, and West Cork. Notably, the EDs in the northern and north-western parts of Ireland overlap with hotspots of potential forced car ownership identified by Carroll et al. (2021). This overlap suggests that transport conditions in these areas force many households to own a car to maintain sufficient transport accessibility. As households struggle to cover vehicle running expenses, this situation may exacerbate financial hardship.

Hence, it is clear that targeted support for EV technology would be needed most in regions with higher concentrations of financially disadvantaged households and forced car ownership due to dispersed settlement patterns. Conversely, the lighter spots on the maps designate areas where many households could afford to buy an EV, in some instances without governmental support. These areas include parts of Dublin and EDs in the metropolitan areas neighbouring Dublin, including south-east Meath, east Kildare, and north Wicklow. They are also located near the cities of Cork, Galway, Limerick, Kilkenny, and Portlaoise (but not in the cities themselves). Notable differences can be observed between scenarios in that brighter spots appear when the loan repayment value decreases (see S5 in particular).

3.3. Limitations and robustness of results

The estimation process used in this study has several limitations. First, the data on income were only available as a median for each ED, requiring all households in a given ED to be treated as having the same budget. As a result, extreme income values were excluded. Second, since the 2022 Census did not collect income data, income estimates was adjusted using the 2016 Census data, applying wage growth and inflation rates. Third, this study does not consider household savings in

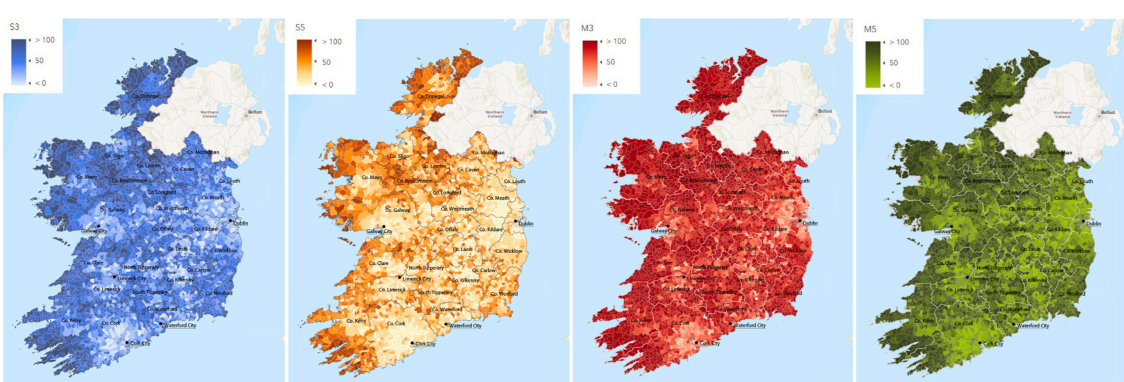

Fig. 5. Percentage of the households below the EV affordability threshold by electoral districts for scenarios S3, S5, M3, and M5. Note: Dublin consists of four administrative counties: Dublin City, South Dublin, Dún Laoghaire-Rathdown, and Fingal.

financial or property assets, nor does it account for support that a household may receive from relatives, friends, or institutional sources. Such resources could substantially reduce the cost of buying an EV. Fourth, the household composition types do not specify the number of children or persons in households considered under the category ‘others’. To address this, we assumed each household with children to have only one child and ‘others’ to consist of only one adult. This approach may have led to some households with more than one child or more than one adult in shared households being identified as able to afford an EV, while in reality, they might fall below the affordability threshold. Fifth, we do not account for personal preferences regarding owning an EV or a car of any kind.

To assess the robustness of the analysis, a business-as-usual scenario was introduced, and its results were compared to available data on household deprivation (CSO, 2023). The business-as-usual scenario represents a situation where households do not take a loan to purchase an EV but instead maintain their housing expenses. In this scenario, the number of households at risk of poverty was calculated to be 207,327 in 2022, accounting for 12.21% of all households. This estimation is slightly below the figure provided by the CSO, which reported that 13.1% of Irish households were at risk of poverty in 2022 (CSO, 2023). However, it is important to note that our analysis excludes certain factors, such as billing expenses for housing and considers only the first child in cases of large families or households. Accounting for these factors would likely increase the approximated number of deprived households in this study. To summarise, this analysis of the business-as-usual scenario results confirms the robustness of our main finding that the high percentage of deprived households makes Ireland’s EV policy success unlikely. In fact, this robustness test indicates that the estimated percentage could be several percent higher than shown in this study.

4. Conclusion and policy implications

This study estimated how affordable EVs are for Irish households and how subsidies affect or would affect this estimate. This analysis was used to assess the feasibility of meeting governmental emissions reduction targets through private EV purchase subsidies. The EV affordability threshold was defined using equivalised residual income, which adjusts income levels for household size and estimates the remaining income after deducting rent and mortgage costs (if applicable).

Under the assumption that households purchase an EV on loan, the loan repayment value was deducted from household income, and the remaining amount was compared to the ‘at risk of poverty’ threshold. This approach allowed for the identification and quantification of households below the affordability threshold, as well as their distribution across Ireland at the ED level.

Four scenarios were developed to account for two types of EVs – small and medium-sized – and two loan repayment periods of three and five years. These scenarios were labelled S3, S5, M3, and M5, where the letter indicates the EV type (small or medium-sized) and the digit denotes the loan period. Additional scenarios, S3r, S5r, M3r, and M5r, were designed to reflect reduced vehicle prices due to anticipated price decrease, potential offsets from household savings or selling an existing vehicle, or the option to purchase a second-hand vehicle at a lower price.

4.1. EV affordability and its impact on achieving emission reduction targets

Under the current policy framework, the findings indicate that EV subsidies lead to a disproportionate allocation of resources towards wealthier segments of society. This type of incentive, particularly when paired with other regressive tax policies, could place additional strain on the broader population, underscoring the need for carefully designed climate policies (Axsen & Wolinetz, 2021). Approximately 38% of Irish households – or 31% if EV prices drop – could not afford even a small-size EV on a loan with the longest available repayment period of five years.

The government aims to have 845,000 EVs on the roads by 2030. However, by the end of 2022, only 74,000 EVs were registered in Ireland, leaving a substantial gap of 771,000 EVs yet to be purchased. To achieve the target, no more than 926,665 households (or 54.85% of all households) can fall below the affordability threshold for purchasing an EV. Results from scenarios M3, M3r, and M5 indicate that this condition is not met, suggesting that without substantial price reductions or increased subsidies, meeting the target with medium-sized or larger EVs will remain unlikely.

For small-size EVs, however, the condition of a monthly repayment value not exceeding €236 is met across all scenarios, making them more viable for a larger portion of the population. These findings support policies that encourage the production and deployment of smaller EVs, which are not only more affordable but also more environmentally friendly, as they require fewer resources for production, generate less waste, and, due to their lighter weight, produce fewer emissions.

While a €5000 grant would enable the necessary number of households to afford small-size EVs, the current grant reduction to €3500 limits affordability, requiring households to take out longer-term loans. This reduction disadvantage households by restricting their resources for other essential expenses. The analysis suggests that a differentiated subsidy scheme tailored to income levels and household sizes would be more effective in alleviating the financial burden, although further analysis is needed to determine the exact rates.

Disparities in EV affordability are evident across different types of areas. Urban towns face the most significant challenges, with 54%–87% of households unable to afford an EV across the studied scenarios. Similarly, remote rural areas are heavily impacted, with 49%–89% of households below the EV affordability threshold. In these regions, where 80% of trips rely on cars, travel distances are long, and public transport accessibility is low, higher subsidies are needed to support households in transitioning to EVs. Cities with high-density populations show moderate EV affordability challenges (35%–73% across scenarios), though there is considerable variability, including within Dublin itself. These findings underscore the need for tailored EV subsidy policies that effectively address the specific needs of over 500,000 households in remote rural areas. Such targeted support could potentially yield greater emissions savings facilitating the decarbonisation of their trips.

4.2. Differentiation of EV subsidy

The results underscore a need for diversified EV subsidies. Reforming the current EV policy by incorporating a more targeted approach can help Ireland meet its transport carbon reduction targets by improving EV affordability for lower-income households. The wide variability in household EV affordability demonstrates that a flat-rate subsidy is likely to be ineffective. Instead, a differentiated subsidy which considers income levels, household sizes, and the urbanisation level of the area could provide a way to ensure the broader adoption of EVs necessary to achieve the ambitious carbon reduction targets set by the government.

First, subsidies could be scaled based on household income levels, with higher financial support provided to lower-income households that are less able to manage the upfront costs of EVs, while gradually reducing the subsidy amount as household income increases, recognising that higher-income households are more likely to afford EVs without significant assistance. Second, adjusting subsidies based on geographic criteria can address specific local needs, offering higher subsidies in rural or remote areas where transport options are limited and dependence on personal vehicles is greater. Conversely, providing lower subsidies in urban areas with better public transport networks could encourage the use of alternative transport modes. Third, the type of EV purchased should determine the subsidy amount. Smaller, more efficient EVs could receive higher subsidies, encouraging more sustainable choices, while luxury or larger EV models might receive lower subsidies, given that their buyers likely have greater financial flexibility. Finally, considering household size in subsidy calculations could ensure that larger households, which typically have greater transportation needs, receive adequate support. This would help align subsidy distribution with actual usage and needs. The above recommendations are likely to enable EV subsidies to be distributed more equitably but also strategically, promoting the most effective impact on EV adoption while not impeding Ireland's overall transition to more sustainable transport options.

The effects of diversified subsidies warrant further investigation to determine how financing adjustments could influence EV adoption rates. Modelling the impacts of differentiated subsidy scenarios on EV affordability and understanding the sensitivity of adoption rates to these changes would be a valuable direction for future research. In terms of flat-rate subsidies, their sensitivity was examined in the context of a 20% price reduction, equating to an additional subsidy of approximately €7000 for small-sized EVs and €10,700 for medium-sized EVs. It was found that these changes would enable 7–10% more households to afford a small-sized EV and 10–12% more to afford a medium-sized EV.

However, the findings suggest that despite the substantial cost of increasing subsidy rates, affordability does not increase proportionally, reinforcing the view that flat-rate subsidies are not optimally effective. Conversely, it is worth noting that means-adjusted subsidies also present challenges. They may slow the rollout of government support by increasing the complexity of the application process, creating bureaucratic hurdles that reduce accessibility. In addition, they are expensive and complex to implement, requiring a more robust, labour-intensive administrative process. Therefore, balancing both approaches is crucial when designing an effective subsidy mechanism.

4.3. Wider equity and climate policy context

Considering the broader implications of this research, we do not propose that all households must be made able to purchase an EV. Instead, Ireland requires transport policies that ensure a sufficient level of accessibility to key activity opportunities (Vecchio & Martens, 2021). This study suggests that current EV incentive policies fall short of comprehensively contributing to such a goal.

Alongside current or differentiated EV subsidies, there is a simultaneous need for transformative policies that reduce overall car dependence and support more sustainable mobility options such as walking, cycling, shared mobility, and public transport. Sustainable mobility options often do not require high upfront private investment, making them more inclusive in achieving a basic level of accessibility. Similarly, using shared or public transport is typically less costly for users than owning a personal vehicle, particularly in urban areas where public transport is frequent, well-integrated, and supported by infrastructure, and car use incurs additional congestion and parking costs (Hörcher & Tirachini, 2021).

Another recurring concern relates to the pressing issue of climate-effective policies and their implications for achieving the state's social goals. Specifically, to what extent can the goal of GHG emission reduction justify the immediate disadvantage faced by certain social groups in pursuit of future betterment of the society as a whole? A classic example here would be a carbon tax that burdens less wealthy individuals or households who own older, more polluting ICEVs, yet aligns with climate policy objectives. While such measures may ultimately serve the long-term well-being of these and other social groups, they can be considered unfair.

In the case of support for EVs, however, the issue is not disincentives that disproportionately harm deprived groups. Instead, the concern lies in policies that disproportionately incentivise advantaged groups, providing greater benefits to wealthier individuals already in a privileged position with better access to opportunities. This study highlights that policies intended to benefit everyone actually tend to favour wealthier households, leaving less-advantaged groups – especially those in remote areas – without sufficient support for alternatives to the private car ownership. Focusing on financially better-off households fails to enhance equality of accessibility in Irish society and, therefore, cannot be considered a socially progressive climate policy.

CRediT authorship contribution statement

Agnieszka Stefaniec: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Robert Egan:** Writing – review & editing, Writing – original draft, Visualization, Software, Investigation, Formal analysis, Data curation, Conceptualization. **Keyvan Hosseini:** Writing – review & editing, Writing – original draft, Validation, Methodology, Conceptualization. **Brian Caulfield:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Investigation, Funding acquisition, Conceptualization.

Classification codes

D Microeconomics (D1 Household Behavior and Family Economics); H Public Economics (H2 Taxation, Subsidies, and Revenue); I Health, Education, and Welfare (I3 Welfare, Well-Being, and Poverty); R Urban, Rural, Regional, Real Estate, and Transportation Economics (R2 Household Analysis, R4 Transportation Economics)

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

References

Aasness, M. A., & Odeck, J. (2023). Road users' attitudes towards electric vehicle incentives: Empirical evidence from Oslo in 2014–2020. *Research in Transportation Economics, 97*, Article 101262. https://doi.org/10.1016/j.retrec.2023.101262

Ahrens, A., & Lyons, S. (2019). Changes in land cover and urban sprawl in Ireland from a comparative perspective over 1990–2012. *Land, 8*(1), 16. https://doi.org/10.3390/land8010016

Axsen, J., & Wolinetz, M. (2021). Taxes, tolls and ZEV zones for climate: Synthesizing insights on effectiveness, efficiency, equity, acceptability and implementation. *Energy Policy, 156*, Article 112457. https://doi.org/10.1016/j.enpol.2021.112457

Barton, B., & Schütte, P. (2017). Electric vehicle law and policy: A comparative analysis. *Journal of Energy and Natural Resources Law, 35*(2), 147–170. https://doi.org/10.1080/02646811.2017.1262087

Bauer, G., Hsu, C.-W., & Lutsey, N. (2021). When might lower-income drivers benefit from electric vehicles? *Quantifying the economic equity implications of electric vehicle adoption, 21*.

Bera, R., & Maitra, B. (2021). Assessing consumer preferences for plug-in hybrid electric vehicle (PHEV): An Indian perspective. *Research in Transportation Economics, 90*, Article 101161. https://doi.org/10.1016/j.retrec.2021.101161

Berry, A., Jouffe, Y., Coulombel, N., & Guivarch, C. (2016). Investigating fuel poverty in the transport sector: Toward a composite indicator of vulnerability. *Energy Research & Social Science, 18*, 7–20. https://doi.org/10.1016/j.erss.2016.02.001

Bureau, B. (2011). Distributional effects of a carbon tax on car fuels in France. *Energy Economics, 33*(1), 121–130. https://doi.org/10.1016/j.eneco.2010.07.011

Bureau, B., & Glachant, M. (2008). Distributional effects of road pricing: Assessment of nine scenarios for Paris. *Transportation Research Part A: Policy and Practice, 42*(7), 994–1007. https://doi.org/10.1016/j.tra.2008.02.001

Carroll, P., Benevenuto, R., & Caulfield, B. (2021). Identifying hotspots of transport disadvantage and car dependency in rural Ireland. *Transport Policy, 101*, 46–56. https://doi.org/10.1016/j.tranpol.2020.11.004

Carzone. (2020). Car depreciation: All You need to Know. Www.Carzone.Ie. https://www.carzone.ie/motoring-advice/car-depreciation-all-you-need-to-know/2347.

Caulfield, B., Furszyfer, D., Stefaniec, A., & Foley, A. (2022). Measuring the equity impacts of government subsidies for electric vehicles. *Energy, 248*, Article 123588. https://doi.org/10.1016/j.energy.2022.123588

Census Curator. (2017a). Permanent private households by type of Occupancy, electoral division, Census 2016, Theme 6.3, Ireland, 2016, CSO & OSi. https://census2016.geohive.ie/datasets/geohive::permanent-private-households-by-type-of-occupancy-electoral-division-census-2016-theme-6-3-ireland-2016-cso-osi/about.

Census Curator. (2017b). Private households by type, electoral division, Census 2016, Theme 5.1, Ireland, 2016, CSO & OSi. https://census2016.geohive.ie/datasets/geohive::private-households-by-type-electoral-division-census-2016-theme-5-1-ireland-2016-cso-osi/about.

CSO. (2016a). *Census 2016: Small area population statistics*. CSO. https://www.cso.ie/en/census/census2016reports/census2016smallareapopulationstatistics/.

CSO. (2016b). Percentage change in average weekly rent by electoral division, 2011-2016. https://cso.maps.arcgis.com/apps/webappviewer/index.html?id=d892c63afffe47acba8716beb4eda55c.

CSO. (2019a). *Transport Omnibus 2019: Road traffic volumes*. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-tranom/transportomnibus2019/roadtrafficvolumes/.

CSO. (2019b). *Urban and rural Life in Ireland*. CSO. https://www.cso.ie/en/statistics/othercsopublications/urbanandrurallifeinireland/.

CSO. (2022a). *Household budget Survey 2015-2016: Appendix 1 concepts and Definitions*. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-hbs/hbs20152016/app1/.

CSO. (2022b). *Household saving Q3 2022*. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-hs/householdsavingq32022/.

CSO. (2022c). Poverty indicators explained. https://www.cso.ie/en/media/csoie/releasespublications/documents/ep/surveyonincomeandlivingconditions/2020/factsheets/At_Risk_of_Poverty_Explained.pdf.

CSO. (2023). *Survey on income and living conditions (SILC) 2022*. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-silc/surveyonincomeandlivingconditionssilc2022/.

CSO. (2024a). *Average annual earnings and other labour costs [dataset]*. https://data.cso.ie/table/EHA05.

CSO. (2024b). *Consumer price index [dataset]*. https://data.cso.ie/table/CPA04.

CSO. (2024c). *Household budget Survey 2022-2023: Results and analysis*. CSO. https://www.cso.ie/en/releasesandpublications/ep/p-hbs/householdbudgetsurvey2022-2023/resultsandanalysis/.

De Vrij, E., & Vanoutrive, T. (2022). 'No-one visits me anymore': Low Emission Zones and social exclusion via sustainable transport policy. *Journal of Environmental Policy and Planning*, 1–13. https://doi.org/10.1080/1523908X.2021.2022465

Department of the Environment, Climate and Communications. (2021). *Climate action plan 2021: Securing our future*.

Department of the Environment, Climate and Communications. (2023). *Climate action plan 2023 (CAP23): Changing Ireland for better*. https://www.gov.ie/en/publication/7bd8c-climate-action-plan-2023/.

Department of Transport. (2021). *Electric vehicle policy Pathway*. Working Group Report 2021.

Department of Transport. (2022). *Electric vehicle charging infrastructure strategy 2022-2025*.

Department of Transport. (2023). *Changes to grants for privately purchased electric vehicles*. Press Release. https://www.gov.ie/en/press-release/e0766-changes-to-grants-for-privately-purchased-electric-vehicles/.

EBS. (2017). EBS DKM Irish housing affordability index. https://www.ebs.ie/content/dam/ebs/pdfs/affordability-index/ebs-mortgage-affordability-report-2017.pdf.

El Hachem, W., & De Giovanni, P. (2019). Accelerating the transition to alternative fuel vehicles through a Distributive Justice perspective. *Transportation Research Part D: Transport and Environment, 75*, 72–86. https://doi.org/10.1016/j.trd.2019.08.020

Falavigna, C., & Hernandez, D. (2016). Assessing inequalities on public transport affordability in two Latin American cities: Montevideo (Uruguay) and Córdoba (Argentina). *Transport Policy, 45*, 145–155. https://doi.org/10.1016/j.tranpol.2015.09.011

Goetzel, N., & Hasanuzzaman, M. (2022). An empirical analysis of electric vehicle cost trends: A case study in Germany. *Research in Transportation Business & Management, 43*, Article 100825. https://doi.org/10.1016/j.rtbm.2022.100825

Government of Ireland. (2022). Zero emission vehicles Ireland. https://www.gov.ie/ga/feachtais/18b95-zero-emission-vehicles-ireland/.

Grieco, M. (2015). Poverty mapping and sustainable transport: A neglected dimension. *Research in Transportation Economics, 51*, 3–9. https://doi.org/10.1016/j.retrec.2015.07.002

Guo, S., & Kontou, E. (2021). Disparities and equity issues in electric vehicles rebate allocation. *Energy Policy, 154*, Article 112291. https://doi.org/10.1016/j.enpol.2021.112291

Haidar, B., & Aguilar Rojas, M. T. (2022). The relationship between public charging infrastructure deployment and other socio-economic factors and electric vehicle adoption in France. *Research in Transportation Economics, 95*, Article 101208. https://doi.org/10.1016/j.retrec.2022.101208

Hardman, S., Fleming, K., Kare, E., & Ramadan, M. (2021). A perspective on equity in the transition to electricvehicle. *MIT Science Policy Review*, 46–54. https://doi.org/10.38105/spr.e10rdoaoup

Hills, J. (2012). *Getting the measure of fuel poverty: Final Report of the fuel poverty review (CASE Report 72 CASE report 72)*. Department of Energy and Climate Change. https://sticerd.lse.ac.uk/dps/case/cr/casereport72.pdf.

Hörcher, D., & Tirachini, A. (2021). A review of public transport economics. *Economics of transportation, 25*, Article 100196. https://doi.org/10.1016/j.ecotra.2021.100196

Hosseini, K., & Stefaniec, A. (2023). A wolf in sheep's clothing: Exposing the structural violence of private electric automobility. *Energy Research & Social Science, 99*, Article 103052. https://doi.org/10.1016/j.erss.2023.103052

Irish Revenue Commissioners. (2024a). Tax rates, bands and reliefs. https://www.revenue.ie/en/personal-tax-credits-reliefs-and-exemptions/tax-relief-charts/index.aspx.

Irish Revenue Commissioners. (2024b). Universal social charge (USC). https://www.revenue.ie/en/jobs-and-pensions/usc/standard-rates-thresholds.aspx.

Irish Revenue Commissioners. (2024c). Vehicle registration tax: VRT Manual section 08—Valuation system for new and used vehicles. https://www.revenue.ie/en/tax-professionals/tdm/vehicle-registration-tax/index.aspx.

Levinson, D. (2010). Equity effects of road pricing: A review. *Transport Reviews, 30*(1), 33–57. https://doi.org/10.1080/01441640903189304

Lionjanga, N., & Venter, C. (2018). Does public transport accessibility enhance subjective well-being? A study of the city of Johannesburg. *Research in Transportation Economics, 69*, 523–535. https://doi.org/10.1016/j.retrec.2018.07.011

Martiskainen, M., Sovacool, B. K., & Hook, A. (2021). Temporality, consumption, and conflict: Exploring user-based injustices in European low-carbon transitions. *Technology Analysis & Strategic Management, 33*(7), 770–782. https://doi.org/10.1080/09537325.2020.1841895

Mattioli, G., Wadud, Z., & Lucas, K. (2017). Developing a Novel approach for assessing the transport vulnerability to fuel price rises at the household level. *Transportation Research Procedia, 17*.

Mattioli, G., Wadud, Z., & Lucas, K. (2018). Vulnerability to fuel price increases in the UK: A household level analysis. *Transportation Research Part A: Policy and Practice, 113*, 227–242. https://doi.org/10.1016/j.tra.2018.04.002

Meyer de Freitas, L., Schuemperlin, O., Balac, M., & Ciari, F. (2017). Equity effects of congestion charges: An Exploratory analysis with MATSim. *Transportation Research Record: Journal of the Transportation Research Board, 2670*(1), 75–82. https://doi.org/10.3141/2670-10

Moriarty, R., O'Mahony, T., Stefaniec, A., Boucher, J. L., Caulfield, B., Daly, H., & Torney, D. (2023). Ireland's climate change Assessment. In *Realising the benefits of transition and transformation* (Vol. 4). https://www.epa.ie/publications/monitoring–assessment/climate-change/ICCA_Volume-4.pdf.

Mullen, C., & Marsden, G. (2016). Mobility justice in low carbon energy transitions. *Energy Research & Social Science, 18*, 109–117. https://doi.org/10.1016/j.erss.2016.03.026

Nocera, S., & Cavallaro, F. (2016). The competitiveness of alternative transport fuels for CO2 emissions. *Transport Policy, 50*, 1–14. https://doi.org/10.1016/j.tranpol.2016.05.013

NTA. (2018). National household travel Survey 2017. https://www.nationaltransport.ie/wp-content/uploads/2020/09/National_Household_Travel_Survey_2017_Report_-_December_2018.pdf.

PBO. (2022). *An overview of Ireland's electric vehicle incentives and a comparison with international peers* (p. 70). Parliamentary Budget Office. https://data.oireachtas.ie/ie/oireachtas/parliamentaryBudgetOffice/2022/2022-06-02_an-overview-of-ireland-s-electric-vehicle-incentives-and-a-comparison-with-international-peers_en.pdf.

Pobal. (2022). Deprivation Indices: 2016—by ED. https://maps.pobal.ie/WebApps/DeprivationIndices/index.html.

Pyddoke, R., Swärdh, J.-E., Algers, S., Habibi, S., & Sedehi Zadeh, N. (2021). Distributional effects from policies for reduced CO2-emissions from car use in 2030. *Transportation Research Part D: Transport and Environment, 101*, Article 103077. https://doi.org/10.1016/j.trd.2021.103077

Santos, G., & Catchesides, T. (2005). Distributional Consequences of gasoline Taxation in the United Kingdom. *Transportation Research Record, 1924*(1), 103–111. https://doi.org/10.1177/0361198105192400113

Scorrano, M., Danielis, R., & Giansoldati, M. (2020). Dissecting the total cost of ownership of fully electric cars in Italy: The impact of annual distance travelled, home charging and urban driving. *Research in Transportation Economics, 80*, Article 100799. https://doi.org/10.1016/j.retrec.2019.100799

SEAI. (2023). *Key statistics: Transport*. Sustainable Energy Authority Of Ireland. https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/transport/.

SEAI. (2024a). Electric vehicle grant values. *Sustainable Energy Authority Of Ireland*. https://www.seai.ie/grants/electric-vehicle-grants/grant-amounts/index.xml.

SEAI. (2024b). Electric vehicle home charger grant. Sustainable energy Authority of Ireland. https://www.seai.ie/grants/electric-vehicle-grants/electric-vehicle-home-charger-grant/.

SEAI. (2024c). Electric vehicle charging essentials—Part 1. Sustainable energy Authority of Ireland | SEAI. https://www.seai.ie/blog/ev-charging-at-home/.

SIMI Motorstats. (2023). *The official statistics for the Irish Motor Industry*. https://stats.beepbeep.ie/.

SIMI&Arup&Jim Power Economics. (2022). Reducing light fleet carbon emissions to achieve Government targets. https://www.simi.ie/en/news/independent-report-highlights-the-huge-challenge-towards-the-decarbonisation-of-ireland-s-vehicle-fleet.

Sovacool, B. K., Kester, J., Noel, L., & de Rubens, G. Z. (2019a). Energy Injustice and Nordic electric mobility: Inequality, Elitism, and Externalities in the electrification of vehicle-to-Grid (V2G) transport. *Ecological Economics, 157*, 205–217. https://doi.org/10.1016/j.ecolecon.2018.11.013

Sovacool, B. K., Lipson, M. M., & Chard, R. (2019b). Temporality, vulnerability, and energy justice in household low carbon innovations. *Energy Policy, 128*, 495–504. https://doi.org/10.1016/j.enpol.2019.01.010

Sovacool, B. K., Martiskainen, M., Hook, A., & Baker, L. (2019c). Decarbonization and its discontents: A critical energy justice perspective on four low-carbon transitions. *Climatic Change, 155*(4), 581–619. https://doi.org/10.1007/s10584-019-02521-7

Sovacool, B. K., Newell, P., Carley, S., & Fanzo, J. (2022). Equity, technological innovation and sustainable behaviour in a low-carbon future. *Nature Human Behaviour*. https://doi.org/10.1038/s41562-021-01257-8

The Irish Times. (2022). New car buyers in slow lane as delivery delays stretch into 2023. https://www.irishtimes.com/life-and-style/motors/new-car-buyers-in-slow-lane-as-delivery-delays-stretch-into-2023-1.4810216.

Tseng, H.-K., Wu, J. S., & Liu, X. (2013). Affordability of electric vehicles for a sustainable transport system: An economic and environmental analysis. *Energy Policy, 61*, 441–447. https://doi.org/10.1016/j.enpol.2013.06.026

Ungemah, D. (2007). This land is your land, this land is my land: Addressing equity and fairness in Tolling and pricing. *Transportation Research Record: Journal of the Transportation Research Board, 2013*(1), 13–20. https://doi.org/10.3141/2013–03

Vale, D. (2020). Effective accessibility: Using effective speed to measure accessibility by cost. *Transportation Research Part D: Transport and Environment, 80*, Article 102263. https://doi.org/10.1016/j.trd.2020.102263

van Heerden, Q., Karsten, C., Holloway, J., Petzer, E., Burger, P., & Mans, G. (2022). Accessibility, affordability, and equity in long-term spatial planning: Perspectives from a developing country. *Transport Policy, 120*, 104–119. https://doi.org/10.1016/j.tranpol.2022.03.007

Vecchio, G., & Martens, K. (2021). Accessibility and the Capabilities approach: A review of the literature and proposal for conceptual advancements. *Transport Reviews, 41*(6), 833–854. https://doi.org/10.1080/01441647.2021.1931551

Venter, C. (2011). Transport expenditure and affordability: The cost of being mobile. *Development Southern Africa, 28*(1), 121–140. https://doi.org/10.1080/0376835X.2011.545174

Wang, J., & Matsumoto, S. (2022). Can subsidy programs lead consumers to select "greener" products?: Evidence from the Eco-car program in Japan. *Research in Transportation Economics, 91*, Article 101066. https://doi.org/10.1016/j.retrec.2021.101066

Wells, P. (2012). Converging transport policy, industrial policy and environmental policy: The implications for localities and social equity. *Local Economy: The Journal of the Local Economy Policy Unit, 27*(7), 749–763. https://doi.org/10.1177/0269094212455018