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Analysis on reform of Fossil Fuel Subsidies 2022

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Executive Summary

Scope, Structure and Context

This desk study report reviews the existing literature on fossil fuel subsidy removal, identifies significant subsidies in an Irish and European context and estimates specific costs and outcomes for the phase-down or phase-out of fossil fuel subsidies in Ireland. Thereafter it presents a series of specific actionable proposals for fossil fuel subsidy reform alongside recommendations for targeted compensatory measures that could be introduced to support a more just transition. The study has been commissioned by the Irish Climate Change Advisory Council.

Section one provides information on fossil fuel subsidies and relevant targets on a national and international level and elaborates on the objective and structure of this report. Section two presents the results of the literature review, delivering on the first task defined by the Council. Specifically, it examines academic literature and international examples of fossil fuel subsidy reform. Section three provides policy context for the analysis, addressing the second task defined by the Council. It offers an integrated overview of key national, European, and international objectives and proposals for fossil fuel subsidy reform. Section four reviews fossil fuel subsidies, both direct and indirect, as identified by the Central Statistics Office and the European Commission, responding to the third task defined by the Council. Further contemporary information on fossil fuel subsidies which fell outside of the defined scope is also considered here. Section five outlines the current emissions relevant in this context, addressing the fourth task defined by the Council. It outlines the existing emissions profile of Ireland in relation to the various categories of activities that are relevant or impacted by current fossil fuel subsidies. The expected environmental impacts are assessed in section six, where we also describe the methodology. This analysis uses official emission inventories to gauge activity at current prices and then, based on calculated fuel prices without subsidies, applies fuel price elasticities from the literature, to run upper and lower bound scenarios to estimate changes in activity. The impact on emissions of removing fuel subsidies is estimated through the lens of three scenarios in which the demand response to a change in fuel price is characterised as either low, moderate, or high. These ranges encapsulate much of the variability of elasticity estimates found in the literature. Section seven addresses the fifth task defined by the Council and quantifies the economic and welfare impacts of the reform of the selected significant fossil fuel subsidies. It examines and estimates the Production Tax Rate and Sales Tax Rate (the I3E policy variables in the ESRI model) channel effects on macro aggregates, household real disposable income and welfare effects. Section eight offers insight for policy design. These insights draw upon the findings of the desk research conducted for section two. Section nine offers summary conclusions and recommendations.

Key Findings

The relative scale of support that Member States provide to fossil fuels can be assessed by analysing the subsidy amounts in relation to GDP, also known as fossil fuel subsidy intensity. On average across the EU, this amounted to 0.4% of GDP in 2019. Ireland's equivalent rate is double that EU average (0.8%). The Irish fuel combustion sector contributed 68% of total GHG emissions in the year 2019 and 51% in 2020. This decrease is part explained by a drop in fuel consumption due to COVID-19 related restrictions. Within this fuel combustion sub-sector, 60% of the CO_2 emissions were attributed to activities in the transport sector (31%) and activity from the residential and commercial/institutional sector (29%) in 2020. The transport activities that contributed most to energy use for 2021 were passenger vehicles, haulage, and aviation and as such, are relevant to carbon emission abatement strategies.

The first effect analysed in this study is the change in price associated with the removal of selected subsidies - adapted from those considered by ESRI (2019). We consider diesel for road transport, residential fuels and aviation[1]. The removal of subsidies to bring convergence in the excise rates of all fuels to the rate applied to unleaded petrol, results in an average 8.85% increase in transport diesel prices for the period 2023-2040. Commercial transport also benefits from diesel rebates, which we similarly class as a subsidy. This is also removed in our subsidy removal scenarios. However, we consider VAT to be a business cost rather than a fossil fuel tax and as such this refund remains allowable. For commercial transport consumers that currently avail of diesel rebates, the subsidy removal would result in an 11.4% average increase in diesel prices over the same period. Within the residential/built environment context a similar convergence with the assumed "appropriate" tax rate applied to unleaded petrol would yield substantial price increases for those fuels used for residential and commercial purposes. The fossil fuel subsidy removal would see a sharp increase in the current base prices of residential and commercial fuels such as coal (55%), kerosene (46%), gasoil (43%), and peat (41%). Aviation demand is not impacted directly by jet kerosene price but more so by ticket price. We estimate how fuel price increases may be passed through to consumers. Under a moderate reaction scenario for aviation, we estimate an average 14% increase in air travel prices.

The second effect assessed is the impact on fossil fuel consumption and emissions that could be associated with these new prices where subsidies are removed. This has been based on fuel price elasticities from the literature that have been assigned into ranged categories of low, moderate, or high response scenarios. Each of the subsidy removal scenarios project reductions in CO_2 and NO_x emissions, with some increases projected in $PM_{2.5}$[2]. In the moderate scenario, we observe reductions in the road transport, residential and aviation sectors of 5.39% and 6.25% in CO_2 and NO_x respectively with increases of 1.43% observed in $PM_{2.5}$. In that regard the analysis is clear that fossil fuel subsidy reform could support national abatement targets. It can also reduce government expenditure through the elimination of wasteful consumption and inefficient allocation of resources. There are also preferable fuel switch opportunities that could yield further emission reductions and improve alignment with national objectives and

[1] We exclude marked diesel for consideration in the absence of viable alternatives and exclude peat power on the basis that the two main plants have since closed. Ultimately, we determine the most relevant sectors to consider as transport and residential.
[2] Coal and peat use is projected to decline as the national solid fuel regulations are introduced. As such, later in the assessment period the majority of the fuel reduced is oil which has a lower $PM_{2.5}$ emission factor than the solid fuels. This is partially replaced with electricity and also biomass which presents higher $PM_{2.5}$ emission factors.

strategies. Whilst out of scope for this specific study, there is also an opportunity here to increasingly direct displaced consumers toward preferred fuel switch options which could in turn deliver greater emission reductions. To achieve this, barriers which inhibit uptake must be identified and removed, and homes that are most likely to benefit from the fuel switch should be targeted for related incentives and supports. In the transport sector, there are also opportunities to capitalize on the higher private transport costs as part of broader efforts to deliver targeted increases in the share of active, sustainable and mass transit travel.

The broader macroeconomic impacts of subsidy removal have been assessed. Sectoral production subsidies are those aimed at decreasing the cost of production, leading to technically lower domestic prices, and improvements in the competitive situation of the country on the international markets. Commodity-related subsidies are aimed at decreasing the retail prices of energy goods through a lower excise tax burden. Regarding broader macroeconomic effects, if both commodity-related and sectoral production subsidies are gradually eliminated, macroeconomic variables are found not to be substantially affected, with only minor effects on real GDP and real investment in the long-term and slight improvements expected for net-exports-to-GDP and debt-to-GDP ratios. However, if commodity-related subsidies are removed both altogether and suddenly, it is estimated that this will have more adverse effects on real GDP and real investment as compared to sectoral production subsidies. The effect of subsidy reform on the real disposable income of rural and urban households is found to be consistent with the declines in real GDP. However, if the energy allowances to households were removed in conjunction with the removal of subsidies, this would be expected to have stronger adverse effects on the real disposable income of households.

Overall, fossil fuel subsidy reform is an action which would have a direct impact on fossil fuel prices and would be expected to noticeably reduce emissions based on this analysis. The long-term effects on real GDP are modest, and there is scope for the additional revenue to be targeted at supports and investments to mitigate effects. However, caution is advised, and the timing of action is crucial. Energy prices rose significantly in 2022 due to geopolitical tensions and that volatility looks set to continue. This creates a situation where political and public acceptability will be limited. Moreover, not all subsidies carry the same relative impact in their sector. For example, subsidies in the road transport sector will have a more modest impact on baseline prices than those in the built environment sector. Moreover, in the midst of a ‘cost of living’ crisis, triggering a substantial increase in home heating energy costs is not advised, and certainly withdrawing government transfers to households in need should not be considered. In contrast, whilst removing subsidies in the aviation sector would see an increase air travel prices this is less likely to receive a backlash as it should not impact poverty risk in any meaningful way. However, it is also estimated to yield modest national emission reductions and is a strategy that would require international cooperation and agreement.

Whatever the path, a key principle for successful reform is the efficient and visible reallocation of resources through complementary measures. In a transport context, complementary emissions abatement policies should incentivise the use of active and public transport, as well as longer term investments geared towards the shortening of distances travelled, reduction of unnecessary trips and removal of barriers to electric vehicle uptake. This will support CAP ambitions to reduce emissions in the sector and achieve 500,000 extra active and public transport journeys per day by 2030. It can also be reallocated to improving sustainable practices and behaviours in the haulage subsector, such as decarbonised last-mile delivery systems. In the residential sector, revenue generated should be reallocated to the completion of residential retrofits and the installation of air source heat pumps to mitigate energy poverty and contribute to the CAP ambition of 500,000 residential retrofits and 600,000 air source heat pumps by 2030. Ultimately, the CAP sets the official action plan for climate in Ireland, and explicitly considers the importance of a just transition in that context. As such many of the measures included within the CAP would represent appropriate initiatives that could be supported and accelerated as part of a program of fossil fuel subsidy revenue reallocation.

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Selected Glossary

Balance of Payments	BOP
Carbon Dioxide Equivalent	CO_2e
Central Statistics Office	CSO
Climate Action Plan	CAP
Economic and Social Research Institute	ESRI
Energy Taxation Directive	ETD
Gigatonnes	Gt
Greenhouse Gas Emission	GHG
International Monetary Fund	IMF
Production Tax Rate	PTR
Sales Tax Rate	STR

Disclaimer

Reference

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1. Introduction

Fossil fuel subsidies incentivise the use of fossil fuels by keeping the market prices artificially lower than they would otherwise be for consumers of those fuels. They can have a significant cost then, as they both promote the inefficient allocation of an economy's resources when interfering with those market prices, as well as supporting increased greenhouse gas (GHG) and air pollutant emissions. Worldwide fossil fuel subsidies were $5.9 trillion or 6.8% of global GDP in 2020 and the International Monetary Fund (IMF) estimates this will increase to 7.4% in 2025 as fuel consumption in emerging markets increases (IMF, 2019). The IMF further estimates that raising fuel prices to their fully efficient levels would mean that global fossil fuel CO_2 emissions would fall to 36% below baseline levels in 2025 or 32% below 2018 emissions[3] (IMF, 2019). Fossil fuel subsidies can work against global climate ambitions.

The EU target to reach net-zero GHG emissions by 2050 is aligned with the 2015 Paris Agreement, a legally binding global climate change agreement to try and limit global warming to 1.5°C and to keep it well below 2°C. The 2020 European Green Deal defines a set of policy initiatives designed to help Europe achieve these aims, and the recent 2021 Glasgow Climate Pact has specifically encouraged countries to accelerate the phase out of fossil fuel subsidies to help realise climate goals. The EU Fit for 55 package aligns with these goals and seeks to bring EU legislation in line with the 2030 goal of reducing GHG emissions by 55% and includes, for example, a proposed revision of the renewable energy directive to increase the EU target for renewable energy sources in the overall energy mix from at least 32% to at least 40% by 2030. In May 2022 the Commission published the REPowerEU plan which proposed a further increase in this target to 45% by 2030. This plan outlines a set of actions to decrease the EU's reliance on Russian fossil fuels by expediting the shift towards clean energy. As of February 2023, the Council have formally adopted an amending regulation to include REPowerEU chapters in the Recovery and Resilience Facility.

On a national scale, fossil fuel subsidies render Ireland's climate and air emission reduction goals more difficult to realise. The Climate Action Plan (CAP) 2021 sets the path for Ireland to reduce its GHG emissions to achieve a 51% reduction by 2030 relative to 2018 emission levels. The fuel combustion sector contributed 51% of total GHG emissions in the year 2020 and so it is clear then that the phasing out fossil fuels and any associated subsidies is relevant in the context of realising the ambitions set out in CAP 21/23 and wider international environmental goals.

In the Irish context, fossil fuel subsidy primarily refers to foregone tax, i.e., indirect subsidies. According to the OECD, fossil fuel supports include all direct budgetary transfers and tax expenditures that provide a benefit or preference for fossil-fuel production or consumption. The definition of support, as opposed to subsidy, is a deliberately broader one which encompasses policies that can induce changes in the relative prices of fossil fuels. Support mechanisms include tax expenditures, direct budgetary transfers, and induced transfers (or price supports or price-gaps). Tax expenditures include tax concessions that are typically provided through lower rates, exemptions, or rebates of consumption taxes on fossil fuels (mainly value-added taxes and excise taxes) or measures to reduce

[3] These IMF estimates include externalities such as air pollution and climate, not just direct subsidies, or foregone tax revenue. This is an important note of distinction relative to those that count only direct subsidy cost or foregone tax revenue.

the cost of extraction of fossil fuels. Therefore, although policies that induce changes in the relative prices of fossil fuels can be defined as supports, the Central Statistics Office (CSO) and the EU identify them as subsidies.

According to the CSO, the total budgetary cost of fossil fuel subsides in Ireland in 2019 was €2.8 billion (CSO, 2022). In the same year, the government collected a total of €430 million in carbon tax revenue (Department of Finance, 2021). The monetary value of environmentally damaging subsidies was therefore more than six and a half times higher than the carbon tax revenues. In 2020, the ratio was slightly lower as subsidies decreased by 21% to €2.2 billion, whereas the growth rate for carbon tax revenue was 15%, amounting to €494 million (CSO, 2022; Department of Finance, 2022). However, it is important to acknowledge that these figures for 2020 are distorted by the COVID-19 pandemic which resulted in a general decrease in economic and social activity, and hence fossil fuel use, and thus those 2020 figures are deemed to understate the total ongoing cost of fossil fuel subsidies in Ireland.

It is also important to note that fossil fuel subsidies can serve positive, and occasionally necessary, social purposes. For example, targeted fuel allowances to poorer households help to alleviate fuel poverty. These payments enable the purchase of fuels for home heating, which are, at present, mostly fossil fuels in Ireland. Similarly, indirect fossil fuel subsidies for transport fuels can control the cost of transport for those commuting to work and school and for whom there may be limited alternative travel options at a given point in time. Indeed, the drastic increases in fuel prices generally in 2022, and the contribution of these increases to the general cost-of-living crisis, highlight the vulnerability of lower and middle-income households to such stark fuel price volatility. As such policymakers in these markets internationally have considered an array of interventions including lump sum reliefs for energy costs, subsidised travel costs, and the capping of fossil fuel prices in the market. The phase out of fossil fuel subsidies should therefore consider how best to reduce the total cost of subsidies, but also, simultaneously, how the increased government revenue can be best redirected to areas of society and the economy to mitigate negative impacts for society and business. Increased revenues from fossil fuel subsidy removal should therefore *inter alia* be used for better targeted social spending, as well as investment in energy efficiency and alternative sustainable energy systems.

This report surveys the existing literature on fossil fuel subsidy reform internationally; identifies significant subsidies in an Irish context; estimates specific costs and outcomes for fossil fuel subsidy reform; and thereafter presents a series of specific actionable proposals for reform alongside recommendations for targeted compensatory measures that may be introduced and scaled in parallel. The report is comprised of seven sections. Section two will examine international examples of fossil fuel subsidy reform while highlighting the relative merits of each strategy, delivering on the first task defined by the Council. Section three will provide a summary of the national, EU and international requirements and commitments regarding fossil fuel subsidy reform, addressing the second task defined by the Council. Section four will review all direct and indirect fossil fuel subsidies in Ireland, as identified by the CSO and the European Commission, referring to the third task defined by the Council. Section five will identify the emissions that can be associated with each subsidy as well as the economic, social or other activities associated with those emissions, addressing the fourth task defined by the Council. Section six will explain the methodology applied in the assessment. The broad approach of which is to use existing inventories to gauge activity at current prices and then, based on estimated costs when removing the subsidies, to run upper and lower bound scenarios to estimate changes in activity based on fuel price elasticities in the literature. Section seven will analyse, and quantify where possible, the economic and welfare impacts of the reform of the selected subsidies, addressing the fifth task defined by the Council. Section eight will propose strategies for the reform, including discussion of timelines, sequences and potential use of tax revenue raised, or government expenditure avoided, delivering on the sixth task defined by the Council. Section nine will provide conclusions and recommendations.

2. Literature Review

With reference to task one, the following section reviews academic literature and international examples of fossil fuel subsidy reform to identify the strategies that worked best for reducing emissions, managing public acceptance, delivering climate justice, and understanding the economic impacts. It is important to note from the outset that the available cases of fossil fuel reform globally have occurred in many different geographical, political, and economic contexts that are quite different to the present situation in Ireland where fossil fuel subsidy reform is being explored.

Nonetheless, there is a strong consensus within the academic community that fossil fuel subsidies are fundamentally unsustainable (Nordic Council of Ministers, 2017) and that the economic, environmental, and social side effects, which include market distortions, escalating fiscal burdens, increased GHG emissions, poverty, and income inequality are severe (IMF, 2013). Reviews of past fossil fuel subsidy reforms between 2002 and 2010, show that many reforms have taken place in developing countries, with indications that the most common driver of those reforms has been the easing of mounting fiscal burdens of energy subsidies to the sitting governments (Vagliasindi, 2012). Subsidy reform to date has therefore often been an attractive fiscal rescue measure in developing countries, with the environmental and other socioeconomic objectives playing a distinctly secondary role (Vagliasindi, 2012). Outside of such contexts, it is important to understand how reform can serve not as a fiscal emergency measure, but rather as an integrated strategic element of a country's long-term climate, air and environmental policy.

Fossil fuel subsidy reform is now formally recognised internationally as an important strand of global sustainability, and accordingly corresponds to the United Nation's Sustainable Development Goals indicator 12.c.1. Under this indicator, countries are required to report on the 'number of fossil-fuel subsidies per unit of GDP (production and consumption)'. According to the OECD Inventory of Fossil Fuel Support Measures (2021) government support to fossil fuels in Ireland was estimated at €1.87 billion in 2020 and it is almost exclusively consumer-oriented, in the form of tax expenditures (€1.58 billion - accounting for 84% of the total), of which excise duties are the main component. Direct transfers then amounted to €0.29 billion. Irish Government support to fossil fuels has decreased between 2015 and 2020 (-7.6%), but this decrease was driven by a sharp reduction in tax expenditures between 2019 and 2020, explained by the drop in fuel consumption due to COVID-19 related restrictions. In contrast, direct transfers have increased by 11.5%, from €0.26 billion to €0.29 billion between 2019 and 2020. The CSO has a higher estimate for indirect subsidies than the OECD (€1.91 billion versus €1.58 billion). The reason being that the definition and estimation of fossil fuel subsidies in Ireland in 2020 provided by the OECD and the CSO differ somewhat. The different values and definitions applied by the OECD and CSO are summarised in Table 1.

Lessons for fossil fuel subsidy reform can be found in the international case literature, even allowing for the differing contexts, but the scope of considerations in that literature is quite broad. Consequently, this literature review has been organised into four categories of objectives to assist with review and interpretation of findings. Specifically, the four groups are: reducing emissions in the short and long term, managing public acceptance, delivering climate justice, and assessing the economic impacts. These are presented in sections 2.1 through to 2.4.

Table 1: Fossil Fuel Subsidies in Ireland (2020)

	Definition of Subsidies	Total Subsidies	Direct Subsidies	Indirect Subsidies
OECD	The result of a government action that confers an advantage on consumers or producers in order to supplement their income or lower their costs.	€1.87 billion	€0.29 billion (16%)	€1.58 billion (87%)
CSO	Any subsidy that directly incentivises or supports an increase in fossil fuel activities. Many transport subsidies indirectly cause an increase in fossil fuel consumption, however not all are considered fossil fuel subsidies.	€2.2 billion	€0.29 billion (13%)	€1.91 billion (87%)

2.1. Reducing Emissions in the Long and Short Term

Summary Points:

- There is robust academic literature that finds that the reduction or removal of fossil fuel subsidies can lead to a decrease in national and global CO_2 emissions. However, these benefits can be eroded in the long-term if dedicated climate policies are weak or non-existent.
- Decarbonisation in the transport sector has focused heavily on fuel technology that increases fuel efficiency and thus helps to reduce emissions. However, there is evidence of a rebound effect arising from the increases in fuel efficiency for different countries. Higher taxes through subsidy reform can counter energy savings lost from the rebound effect over time. New technology shifts (e.g., electrification) can also support lasting change.
- In a transport context, complementary abatement policies should incentivise the use of public transport and active travel, as well as the shortening of distances travelled and the reduction of unnecessary trips.
- Gradual subsidy reforms are favoured as they can reduce energy price shocks, make compensation policies more manageable, allow for more time to adapt, provide clearer signals, generate less opposition, and contribute to shifting investments.

In this section, we consider the evidence and research regarding the extent of emissions reduction in the short and long term as a result of fossil fuel subsidy removal. An important environmental consequence of fossil fuel subsidies is that they provide a relative incentive for energy, capital, and labour to stay with fossil fuels, and thus impede the low carbon transition to alternate energy systems and renewables. A 2015 study estimated that the removal of subsidies to fossil fuels (global consumer subsidies for oil, gas, coal, and electricity totalling $548 billion in 2013) (IEA, 2014a) could lead to global GHG emission reductions of between 6% and 13% by 2050 (Merrill et al., 2015). As this estimate is based only on consumer subsidies, the total effect of the removal of all fossil fuel subsides (including producer subsidies) is likely to be much higher. Additionally, it was estimated that it could unlock domestic savings to governments of between 5% and 30% of expenditure that could be reallocated towards building a low-carbon energy future (Merrill et al., 2015). A later study by the IMF (2019) found that if fuel prices had been set at fully efficient levels in 2015, estimated global CO_2 emissions would have been 28% lower, fossil fuel air pollution deaths 46% lower and government revenue would have been increased by 3.8% of GDP. Gerasimchuk et al. (2017) assessed both the first and second order impacts of fossil fuel subsidy reform at the global level and found that higher fossil fuel prices would encourage energy efficiency as well as the substitution of fossil fuels with alternative energy, thus resulting in net emission reductions between 2017 and 2050. Furthermore, Mundaca (2017) found that a reduction in subsidies to both gasoline and diesel by about 20 US cents per litre would lead to significant decreases in CO_2 emissions globally. The United States is the OECD's largest emitter of CO_2, and an increase in prices of gasoline and diesel of 20 US cents per litre of diesel and gasoline could lead, according to their estimates, to annual average reductions of CO_2 emissions for the next 16 years of about 10% and 35%, respectively. Although academic literature on the emissions reductions resulting from the removal of fossil fuel subsidies does not categorically separate effects experienced in the short term and long term, a 2014 study found that the emissions reductions benefits will be diminished in the long-term, if dedicated climate policies are weak or non-existent (Schwanitz et al., 2014). Furthermore, they found that the removal of fossil fuel subsidies, if not complemented by other policies, could slow down the global transition towards a renewable energy-based system.

A study conducted by the International Institute for Sustainable Development estimated that the complete removal of consumer fossil fuel subsidies to coal, natural gas, electricity, and oil could annually reduce GHG emissions by an average of 6.09% across 32 countries (countries that account for 77% of the global CO_2 emissions and 72% of global GDP as of 2019) between 2021 and 2030 compared to a business-as-usual scenario (Kuehl et al., 2021). More specifically, it could reduce the emissions of certain countries by over 30%. In aggregate terms, the cumulative GHG emissions that could be abated from the complete removal of fossil fuel subsidies are estimated as reaching 5.46 gigatonnes (Gt) of carbon dioxide equivalent (CO_2e) by 2030 — equivalent to the annual emissions of approximately 1,000 standard coal-fired power plants if running non-stop at full capacity[4]. The report also suggests that fossil fuel subsidy reform could deliver cumulative fiscal savings of US$2.96 trillion by 2030 across the 32 countries analysed. The study also found that if 20% of the annual subsidy savings from fossil fuel subsidies removal were invested in

[4] A standard coal-fired power plant has a capacity of 600 MW and emission intensity of one tonne CO_2e per MWh of electricity generated.

energy efficiency and 10% in renewable energy – a so-called subsidy swap[5] - there would remain cumulative subsidy reform savings of US$164 per tonne of CO_2e.

Decarbonisation in the transport sector has focused heavily on fuel technology that helps to reduce emissions. However, Schipper (2011) argued that technology alone will have a difficult time reducing emissions if the total distance driven continues to increase. Furthermore, an improvement in energy efficiency can encourage people to consume more, thereby eroding the efficiency gains – this is the 'rebound effect' (Sorrell and Dimitropoulos, 2008). A study by Stapleton et al. (2016) found a direct rebound effect between the range of 9% and 36% with a mean of 19% for Great Britain, which is consistent with the results of US studies where one fifth of the potential fuel savings from improved car fuel efficiency may have been eroded through increased driving. A meta-analysis of the direct rebound effect in road transport found that the estimates for European countries tend to be on the higher side, as compared to the US (Dimitropoulos et al., 2018). Higher fuel taxes can help to keep driving distances in check and help to counter the rebound effect. A gradual phasing out of fossil fuel subsidies can deliver a comparable effect.

In the Irish context there are two examples of contemporary studies selected as being particularly relevant to the topic of fossil fuel subsidy reform. Firstly, a study estimated that equalising the rate of excise duty on petrol and diesel, between Ireland and Northern Ireland, could reduce reported Irish carbon emissions from diesel by up to 7% (Morgenroth et al., 2018). The impact in this case being driven by reductions in potential 'fuel tourism' across the border, whereby fuel is purchased in Ireland due to a favourable price differential, but the use is largely in another jurisdiction. Whilst Ireland cannot unilaterally determine the price differential, and the implementation of any such price equalisation strategy is fraught with challenges, the study does offer some insight into the scale of potential emission abatement associated with addressing any prevailing fuel tourism.

Secondly, an earlier ESRI study evaluated the impact of the simultaneous removal by 2020 of eight fossil fuel subsidies that covered 96% of all fossil fuel subsidies in the Irish economy in 2014. The study included the following subsidies - electricity generation from peat, security of electricity supply, excise exemption on aviation fuel, diesel rebate scheme, excise exemption on auto diesel, excise exemption on auto diesel, excise exemption on fuel oil, and excise exemption on kerosene. In their scenario, the subsidies on both marked and auto-diesel were assumed to be removed simultaneously, and the sales tax rate of diesel was assumed to be increased by 62.5%. The results showed that the decline in the economy-wide CO_2 total emissions would be 20.2% lower in the year 2030 compared to the path of business-as-usual (De Bruin et al., 2017). The framework of this study is adapted in our work to understand the macroeconomic and welfare effects induced by the removal of fossil fuel subsidies in the Irish economy. It is important to note however, that the emissions outlook for 2030 has now been reduced as part of the official outlooks in line with committed climate action. Furthermore, a number of important transitions have already occurred, such as the closure of the two peat fired power plants in December 2020.

[5] The two key elements of subsidy swaps are that fossil fuel subsidies are reduced alongside an implementation of measures that increase the deployment of sustainable energy.

2.2. Managing Public Acceptance

Summary Points:

- All stakeholders should be engaged in the fossil fuel subsidy reform process early-on in order to chart a stable path for policy acceptance and to afford time for adjustments and investments.
- Recent reforms have shown that aligning the timing of reforms with low international energy prices can minimise price shocks and public opposition. International energy prices are currently very high.
- Case studies show that the public is more receptive to reform when arguments for reform focus on the fiscal costs and macroeconomic impacts of fossil fuel subsidies as opposed to environmental impacts.
- Price smoothing and automatic pricing can be implemented to mitigate any public backlash, both during and after the fossil fuel subsidy reform.
- A comprehensive strategy, including measures to assist low-income households, displaced workers, trade-exposed firms/regions, and the use of revenues from price reform to boost the economy in an equitable way, can improve acceptability. Objective analysis to support this strategy will be important.

In this section, we consider the evidence and research regarding strategies to manage public acceptance of fossil fuel subsidy removal. Successful reform in countries including Egypt, Indonesia and Trinidad and Tobago has shown that the public is more receptive to reform when arguments focus on the fiscal costs and macroeconomic impacts of fossil fuel subsidies as opposed to their environmental impact. Reform should also engage a broad selection of stakeholders to chart a path for balanced public acceptance (Chelminski, 2018). The absence of public support for subsidy reform is due in part to a lack of confidence in the ability of governments to shift the resulting budgetary savings to programs that would compensate the lower and middle classes for the higher energy prices they face.

Price smoothing is relevant both during and after the subsidy reform. Reform experiences from Namibia, Uganda, and Brazil show that gradual subsidy reductions can reduce energy price shocks and make compensation policies more manageable (IMF 2013a, 2013c). More recent reforms in India, Indonesia, and Saudi Arabia have also shown that aligning the timing of reforms with low international energy prices can minimise price shocks and public opposition. This is particularly relevant in the current context of high energy prices resulting from the post-COVID boom and Russia's invasion of Ukraine. Examples from Malaysia and Saudi Arabia show that the establishment of automatic pricing and smoothing mechanisms can support the stabilisation of domestic energy prices and associated tax revenues by controlling the pass-through of international market fluctuations (Rentschler and Bazilian, 2017a).

In the context of the recent increase in global fuel prices, an IMF document (Ari et al., 2022) suggests that governments cannot prevent the loss in real national income arising from the negative terms-of-trade shock for fuel-importing countries due to increased global fuel prices. Lessons from this study can be adapted for policy design of the reform process. The paper argues that governments should allow the full increase in fuel costs to pass through to end-users to encourage energy saving and the switching out of fossil fuels. Policy should shift from broad-based support such as price controls, to targeted relief such as transfers to lower-income households that suffer the most from higher energy bills. For example, fully offsetting the increase in the cost of living for the bottom 20% and bottom 40% of households would cost governments 0.4% and 0.9% of GDP respectively on average for all European countries for the whole of 2022 (Ari et al., 2022). The share of the population that receives compensation would vary across countries depending on societal preferences and fiscal space. It should ideally be designed in a way that avoids "cliff effects", in other words ensuring that benefits taper off gradually at higher income levels.

An academic book entitled 'The Politics of Fossil Fuel Subsidies and their Reform' distinguishes three broad and interdependent political factors that influence the implementation of fossil fuel subsidies and their reform at a domestic level. The first factor focuses on the interests, strategies, and organisation of actors that have sought to promote reform of fossil fuel subsidies or keep them in place (Sabatier and Wiebel, 2014). Rapid changes to certain factors such as prices of oil may provide windows of opportunity for these actors since the timing of any policy change is also crucial to its chances of reform. The second factor is the organisation of actors opposed to fossil fuel subsidy reform. A key aspect of this factor is that the benefits of maintaining fossil fuel subsidies tend to be visible and concentrated on specific groups (e.g., fossil fuel producers and recipients of consumer subsidies, such as car owners), whereas the benefits of fossil fuel subsidy reform are often less tangible and more diffuse across time and space. Lastly, ideational factors, such as the knowledge, ideas, norms, and beliefs guiding different actors can have an influence on subsidy reform (Jenkins-Smith et al., 2014). For example, clearly and consistently defining what constitutes a subsidy and any new knowledge about the environmental or socio-economic effects of fossil fuel subsidies is important during government discourse. A comprehensive strategy, for example with measures to assist low-income households, displaced workers, trade-exposed firms/regions, and the use of revenues from price reform to boost the economy in an equitable way, can all improve acceptability (Clements et al., 2013).

2.3. Delivering Climate Justice

Summary Points:

- Literature shows that most fossil fuel subsidies are regressive, meaning that in absolute terms, most of the subsidy is received by the rich. However, from a climate justice perspective it should be noted that the effects of fossil fuel subsidy removal, relative to income, are likely to be greater for the poor.
- Research finds that job opportunities may be greater in clean energy industries over fossil fuel industries, but in some cases, jobs have been of a lower grade in terms of compensation, benefits, and union rights. Such differences may however represent legacy difference between established and new industries.
- To protect the vulnerable and low-income population from the adverse impacts of fossil fuel subsidy removal such as loss of employment, higher energy costs, loss of income, etc., policy should focus on the principles of just transition through targeted supports, innovative policy schemes (e.g., wage insurance scheme), reskilling affecting workers and supporting the creation of high-quality alternative jobs.

In this section, we consider research regarding the climate justice impacts of fossil fuel subsidy removal. Fossil fuel subsidy reform may result in a loss of employment in fossil fuel linked activities and sectors. The ESRI study on fossil fuel subsidy reform in Ireland found that negative impacts on the poorest household groups' disposable incomes can be reduced if the fuel allowances of households are excluded from the removal process of fossil fuel subsidies. In this case, the policy change has slightly progressive impacts on real disposable income and household welfare (De Bruin, et al., 2019).

Whilst some fossil fuel subsidies are designed to support the poor through subsidised energy supply, literature shows that most subsidies are regressive, meaning that in absolute terms, most of the subsidy is received by the rich (Rentschler and Bazilian, 2017). Universal energy-price subsidies tend to be regressive, as their benefits are conditional upon the purchase of subsidised goods, and increase with expenditure (IEA, OPEC, OECD, and World Bank, 2010). Studies reviewed by the Independent Evaluation Group of the World Bank, found that the bottom 40% of the population ranked by income distribution receives 15-20% of fuel subsidies (Chomitz, 2009). Critically, the effects of subsidy removal relative to income, are most likely greater for the poor.

The surge in international fossil fuel prices in the wake of the Russian war in Ukraine may raise European households' cost of living by close to 7% of consumption on average in 2022 (Ari et al., 2022). Household burdens vary significantly across and within countries, and as countries try to manage inflation, Ari et al. (2022) suggests that the policy emphasis should shift rapidly towards allowing price signals to operate more freely as well as to provide income relief to the vulnerable.

Proponents of the fossil fuel industry highlight employment as being one of the major benefits of fossil fuel subsidies and warn of negative employment impacts where subsidies are reduced or removed. Apart from direct employment in coal mines and at oil and gas fields, there is also indirect employment for support service workers from construction workers to welders and divers. In addition, there are also jobs processing the products of extraction in oil refineries or coal power plants and in their subsequent distribution. The latter being more relevant in the Irish context. However, change is happening and the World Energy Employment Report by the IEA found that in 2022, jobs in clean energy now account for more than 50% of all energy sector jobs. However, while global employment numbers are likely to be greater in clean energy than in fossil fuels (IEA, 2022), research in the UK also found that they have often been of lower quality in terms of compensation, benefits, or union rights (Emden and Murphy, 2019). This is partly due to the relative age of the industries and the iterative engagements of unions and negotiators around salary and benefits. A skill-gap is also likely to be one of the major challenges to address in transitioning to a cleaner economy. However, it is important to acknowledge that since Ireland doesn't have a substantial extractive or refinement industry presence (apart from peat and gas, which are in decline or being phased out), the major risks are more likely to be with secondary jobs such as transport, construction, etc.

A just transition has been defined as creating decent new jobs with fair pay, reasonable conditions, and union rights, by investing in alternative sectors; retraining transition-affected workers to help them get alternative jobs; protecting the rights and income of workers and communities throughout the transition; and democratically engaging those stakeholders in the process of transition (ITUC, 2015; Rosemberg, 2010). A study by Muttitt and Kartha (2019) identified four key questions that policymakers should ask to understand the distributional aspects of climate transition policy design.

1. How should the impacts of climate change on vulnerable people be balanced with the impacts of transition on those dependent on fossil fuels?
2. How should the negative impacts of current extraction be incorporated?
3. Who should undergo the fastest transition?
4. Who should pay the costs of transition?

Since there is a dearth of retrospective (or ex-post) literature on the reduction of fossil fuel subsidies in countries with demographics and economic structures similar to Ireland, some lessons are taken from international cases of coal transitions. We acknowledge these lessons cannot be directly translated into the Irish system of fossil fuel subsidy reform for a host of reasons, including representing a different sector in a different context, however, there are lessons from the coal-transitions in Germany and UK, that deal with the ways in which they sought support from diverse societal interests to make the transition more socially acceptable and politically feasible. In Germany, just transition was prioritised because broad stakeholder representation in the formal transition process was crucial to enhance the legitimacy of coal phase-out policies. However, some argued that just transition was prioritised in Germany only to the extent that it aligned with the incumbent interests and could help produce a legitimate and broadly supported policy outcome. In Germany, stakeholder representation in policymaking processes are deemed very important for the legitimacy and durability of comprehensive policy reforms (Gürtler et al., 2021). On the other hand, in the UK, studies (Bang et al., 2022) found that policymakers adopted market-based policy packages, which aimed to quickly phase-in renewables and phase-out coal, with a key focus on cost-effectiveness. Although the distributional effects of this coal phase-out were assessed, no specific attention was given to the need for compensation measures for the following reasons – coal had lost its market position for quite some time and voices that worried about regional and employment effects of the coal phase-out had far weaker representation in the contemporary policymaking process. In the decarbonisation process, policymakers are often faced with balancing speed, cost-effectiveness, and a just transition, and the weights ascribed to each of these is shaped by the political-economic institutional design and capacity (Bang et al., 2022).

A study concerning the welfare costs arising from the coal phase-out in Germany found that higher wages and job security in coal drives welfare costs, and unemployment is only a small factor (Haywood et al., 2021). Without any active policy intervention, they predicted a rapid reduction of the workforce due to a combination of the retirement of older workers and their assumption that no new workers are recruited. They suggest a wage insurance scheme that can promote increased labour market participation though career switches rather than retirement, especially for workers in the middle of their working life who face the highest costs of job loss. The wage insurance scheme proposes that workers who accept a new job receive an income subsidy if the income in their new job is lower than in the previous job, thereby increasing the incentive to search for a job outside the fossil fuel industry. They find that a wage insurance scheme would reduce welfare losses by 80-99% at reasonable costs (Haywood et al., 2021).

Another example that can be cited is that of Ghana, where, as part of its Structural Adjustment Programme, Ghana's government began removing petroleum subsidies from 2005, with compensating measures aimed at the poorest members of society including eliminating fees for attendance at primary and junior schools, and increased funding for healthcare, urban public transport, and rural electrification, as well as a 20% increase in the minimum wage.

Bridle et al. (2017) highlights the limitations arising from some attempted transitions which can also be used as lessons and learnings for the Irish policy design. One case study is that of the decline in coal mining in the Asturias region of Spain, where early retirement and voluntary redundancy schemes were implemented, amongst other measures, as part of a just transition. Although the generous early-retirement measures had a number of positive impacts such as the reduction of poverty, the preservation of local economies, and the predictability of the cost and the outcome, there were several disadvantages reported as well. Apart from the primary disadvantage of the overwhelming cost of the scheme, it also failed to stem outward migration and most importantly, reduced the incentive to find new employment. This led to unintended consequences such as a tendency towards substance abuse and social breakdown, without the structure and purpose provided by meaningful work. Some key learnings from this case for those affected by the transition demonstrate that early retirement plans should be a medium-term measure and should be joined by a set of additional policies to support the early retired so as to reduce the risk of emigration, social exclusion and to further incentivise alternative job creation in the medium and long term.

It is important to note that there exist further challenges to the employment aspect of just transition (Bridle et al., 2017). It is generally easier to generate new jobs in urban areas away from the communities that have faced direct job losses. On the one hand, this leads to increased opportunities and total employment for people willing and able to commute. However, on the other hand, this risks further undermining the viability of the communities in the former fossil fuel producing regions. Decision-makers must acknowledge this throughout the policy design process.

2.4. Economic Impacts

Summary Points:

- Academic literature has found that the removal of fossil fuel subsidies has led to a decrease in GDP in the range of approximately 0.14% to 1.3% in certain cases.
- Fossil fuel subsidies have direct as well as pass-through trade and competitiveness impacts. Subsidies to fossil fuels can affect the relative competitiveness of alternative energy sources such as renewables.
- In terms of trade impacts for Ireland, subsidies that incentivise greater consumption may add risk to domestic energy shortages and/or create the need for more importation of national energy needs.
- Green capital investments (for example, reinvesting fossil fuel subsidies into renewable energy projects) can have a positive green multiplier effect on the economy.

In this section, we consider existing research regarding the economic impacts of fossil fuel subsidy removal in the context of GDP, trade, and investments. Each category is discussed briefly under an individual heading. Section seven will present the impact assessment of this report in relation to each of these categories.

GDP Impact

The ESRI study on fossil fuel subsidy removal in Ireland, estimated that removing eight subsidies simultaneously would lead to a decrease of 1.3% in real GDP in 2030 as compared to the business-as-usual scenario (De Bruin et al., 2019). Park et al. (2021) studied the impact of the removal of all fossil fuel subsidies in Korea and found that it also had a negative effect on macroeconomic variables such as GDP (a decrease in real GDP of 0.14%). However, they found that when the surplus funds generated by the reform process were invested in renewable energy industries then household consumption, investment, exports, and imports are reduced to a lesser extent. Research from the IMF found that global subsidy reform and economically efficient taxation of fossil fuels could provide governments with an average revenue stream of around 2.6% of GDP (Parry et al., 2014). Broadly, the international literature and evidence is consistent that the efficient and visible reallocation of resources through complementary measures for groups most impacted is essential to the reform process. Such policies can be implemented using revenue collected prior to reforms, as well as resources saved or generated by eliminating fossil fuel subsidies. This reallocation approach will spur economic activity, support a just transition, and accelerate the shift to cleaner energy sources (Gerasimchuk et al., 2018).

Trade Impacts

Moerenhout and Irschlinger (2020) suggest that fossil fuel subsidies can have large trade impacts. There are various pathways through which these impacts can materialise, and both direct and pass-through effects are important. Direct trade impacts are found when producer subsidies affect the markets for crude energy products such as crude oil, natural gas, and coal. Direct trade impacts are also found when consumer subsidies decrease the input costs of various industries, whether they refine crude products into energy carriers (e.g., gasoline, electricity) or they use energy products to produce non-energy products (e.g., iron, steel, plastics). Pass-through trade impacts are found when upstream subsidies lead to a lower-cost product that is then used in downstream production processes, which may be more likely to be the case in Ireland, associated with lower fuels costs for commercial transport and agriculture for example.

Subsidies support inefficiencies in the oil and gas sector as well as sectors which use oil and gas as inputs, making them cheaper and more competitive in the international market while putting pressure on domestic taxpayers. Fossil fuel subsidies can also have impacts on markets for alternative products e.g., subsidies to coal could impact the different markets of renewable energy, thereby reducing the relative competitiveness of that renewable energy market. Burniaux et al., (2011) found that a reduction of global fossil fuel consumption subsidies would lead to a small increase in global trade volumes (0.1%) but a significant shift in trading patterns of particular products and sectors and a reallocation of trade flows in products of energy-intensive industries.

Subsidising fossil fuels makes them cheaper to use thus increasing demand. A part of this is that subsidised fossil fuel prices may also lead consumers to be inefficient with their fossil fuel use. This can lead to an increased reliance on imports if domestic demand surpasses domestic supply. An example often cited is Iran, where fuel was heavily subsidised before the more recent energy subsidy reform. In oil-exporting developing economies, such as Iran, oil prices tended to be highly subsidised, in order to provide financial support for emerging industries. Cheap domestic energy prices led to a rapid increase in domestic energy consumption and by 2008, as international gasoline prices were around US$2 per litre, Iran's domestic price for gasoline was US$0.10 per litre (Guillaume et al., 2011), placing substantial pressure on the exchequer. Furthermore, Iran was importing increasing amounts of gasoline to supply domestic demand, while other issues such as fuel waste and fuel smuggling to neighbouring countries arose. This situation provided an impetus for the reform of fossil fuel subsidies.

There are also productivity and thus, competitiveness implications of fossil fuel subsidy reform. (Cockburn et al., 2017) found that the productivity of energy-intensive industries and refineries in Egypt and Jordan decreased as a result of energy sector reform. This pass-through effect was also due to the increase in electricity prices, affecting electricity-intensive industries such as manufacturing. However, the study also found that a modest reinvestment of fiscal savings into cash transfers creates a win-win scenario of reduced poverty without significantly sacrificing the fiscal and growth benefits of the reform.

Investment Impacts

Fossil fuel subsidy reform makes fossil fuel investments and national energy production less profitable (relative to the international market price). This decreases the profits of the mining and energy companies. The introduction of green subsidies supports renewable energy production in the domestic economy, and therefore the green real economy, by influencing agents' investments decisions and expectations via their net present value. In the case of green capital investments, the subsidy share is more relevant than the way in which the green subsidies are financed. It stimulates green investments, which have a positive green multiplier effect on the economy, contributing to increases in the tax revenues for the government, consumption, and employment (Monasterolo and Raberto, 2019).

2.5. Fossil Fuel Subsidy Reform Insights

In this section insights for the design and implementation of fossil fuel subsidy reform are collated and synthesised. Given that fossil fuel subsidy reform effects have broad reaching sectoral and societal impacts, reform strategies require a considered 'whole economy' approach, with careful assessment of potential adverse effects. Since 2013, G20 countries have developed and implemented a methodology for voluntary, country-led peer reviews of fossil-fuel supports as a valuable means of enhanced transparency and accountability, and as an important avenue for knowledge exchange. In 2016, the US and China agreed to be the first countries to undergo such country peer reviews, followed by the pairs of Germany and Mexico, Indonesia and Italy, and Argentina and Canada. The number of attempted and successful fossil fuel subsidy reforms seems to be increasing, but the evidence is clear that such reforms remain far more common in developing countries. These include Egypt, India, Indonesia, Iran, and the Philippines, which have increased and liberalised fuel prices as well as delivering targeted subsidies to the lower-income classes. However, successful reforms have also in some cases been followed by the re-introduction of subsidies (Chelminski, 2018). Along with international literature, the lessons and guidance from the country pairing peer reviews can inform careful design of reform packages, anticipate and address roadblocks, prevent political backlash and backsliding, and support enhanced ambition and durability of fossil-fuel subsidy phase-out (OECD/IEA, 2021). This section draws on those lessons that have emerged from the voluntary peer reviews in OECD/IEA (2021), as well as other academic literature to provide insights for policy reform.

Step 1: Defining Fossil Fuel Subsidies

Governments committed to 'rationalise and phase out inefficient fossil-fuel subsidies that encourage wasteful consumption' more than a decade ago at the G20 summit in Pittsburgh (2009). A formal definition has yet to be adopted for fossil-fuel subsidies that encourage wasteful consumption, so different countries and organisations have themselves adopted different ways to define fossil fuel subsidies. The OECD and CSO definitions of fossil fuel subsidies were provided in Table 1. Germany has included direct budgetary transfers and tax expenditures in its definition (OECD, 2017a), whereas Mexico refers only to direct budgetary transfers (OECD, 2017b). Italy on the other hand, classes every subsidy to fossil-fuel production and consumption as inefficient. China and the United States have signalled their intent to phase-out specified measures benefiting fossil-fuel production, recognising that the reduction in prices resulting from these measures encourages "wasteful consumption".

Step 2: Designing the Reform Process

Assessing Support Measures

An OECD report that draws on the experience of several countries planning and implementing fossil fuel subsidy reform recommends the 'Sequential Approach' to anticipate and address possible impacts of reform (Zhongming et al., 2021a). The Sequential Approach to analysing government support measures proposes a four-step analysis with associated analytical tools, as outlined in Table 2.

Table 2: Sequential Approach with Associated Analytical Tools

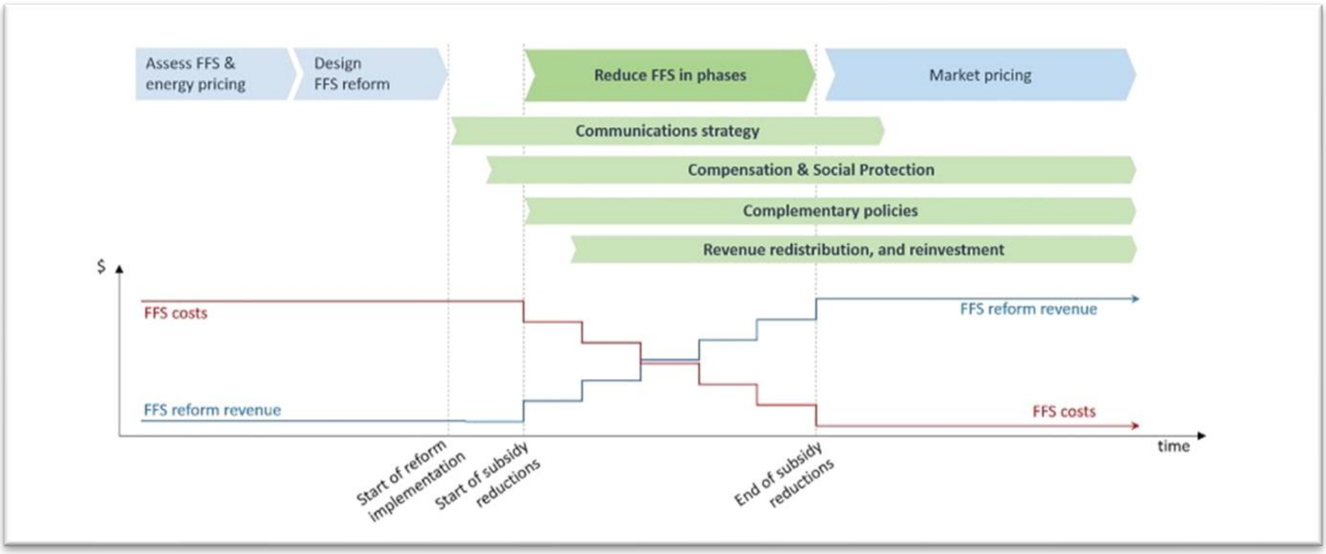
Step in Sequential Approach		Objective	Analytical Tools
1.	Identify support measures, document their objectives, and estimate budgetary cost.	Measure the cost to government of providing support for fossil fuels. Understand the objective and intended beneficiaries of the support measures.	OECD Taxonomy of support measures for fossil fuels. OECD PSE-CSE accounting framework. IEA 'price-gap' method for estimating consumer price support. G20 and APEC peer review frameworks
2.	Measure the distortedness of support measures, including their economic, social, and environmental effects.	Rank support measures by their level of distortedness on fossil fuel production	Effective average and marginal tax rates. Sectoral models (extraction models of oil and gas, a two-sector model of energy intensive and non-energy-intensive industries OECD Inventory beneficiaries' data by broad economic sector)
3.	Identify the winners and losers of fossil fuel support reform processes.	Analyse the distributional impact and other potential adverse effects of reform of support for fossil fuels.	Micro-simulation models (based on household and firm surveys). CGE models.
4.	Evaluate alternative policies with better economic, environmental, fiscal, or distributional outcomes.	Identify policies that increase the efficiency and improve the distributional impact of government intervention.	Micro-simulation models (based on household and firm surveys). CGE models.

Source: (Zhongming et al., 2021)

The analytical tools highlighted in Table 2 can help policymakers identify the most distorting government support measures as well as alternative or complementary policies that deliver the desired objectives more effectively. With regards to step one, Ireland already conducts annual reviews of spending programmes in a specific policy area and thus, support measures can be identified through spending reviews or budget evaluation. The Paris Collaborative on Green Budgeting is a related multilateral initiative to institutionalise the tracking and evaluation of public expenditure to ensure it is aligned with climate and environmental goals. Ireland commenced green budgeting practices in 2019 and has identified, tagged, and estimated climate-related expenditure for the budgets since. Climate-related expenditure undertakings can improve governments' understanding of the implications of budgetary decisions on climate and other environmental outcomes (Zhongming et al., 2021a). The OECD's Environmental Performance Review on Ireland in 2021 found that Ireland's environmental governance is deliberative, participative, and transparent, but compliance assurance needs to be strengthened further (Zhongming et al., 2021b).

Getting the timing right

As is mentioned in the prior section on managing public acceptance, any policy that increases prices has potential for political and civil backlash. Getting the timing right in such cases is essential, not just in terms of exploiting low fossil fuel prices (Beaton et al., 2013) but also in terms of making use of political windows of opportunity created by economic crises, honeymoon periods following elections (Moerenhout, 2018) or wider reforms, for instance within the energy sector. Fuel prices have been important determinants for the timing of action on fossil fuel reform. For importing countries, high oil prices increase the need for reform, thus galvanizing action, but can also aggravate the political obstacles, thus, prolonging inaction. On the other hand, low oil prices reduce political obstacles, making it easier to remove subsidies, however low oil prices also mean that the fiscal urgency for subsidy reform is reduced (Rentschler and Bazilian, 2017b). Past reform attempts have shown that political economy challenges can have a range of reasons including hardship on the poor and vulnerable, influential stakeholders (fossil fuel subsidies benefit the upper and middle classes and industry disproportionately), macroeconomic impacts (e.g., inflation), reduced competitiveness, unemployment, substitution with unsafe, inferior fuels, etc. Policymakers need to be aware of these adverse impacts and consider them when formulating related policies (World Bank, 2010). The diagram below represents a fossil fuel subsidy reform strategy, which includes not only subsidy removal, but also a range of other policy measures, that need to be timed appropriately in order to be effective.



Source: (Rentschler & Bazilian, 2017b).

Involvement of a wide range of stakeholders

There are various groups that hold a stake in fossil fuel subsidies, including fossil fuel producers, trade unions, the transport sector, and households. It may be difficult to convince some of these groups of the benefits of fossil fuel subsidy reform, but others may accept or endorse it if they feel that the subsidy reform is designed in a way that reflects their interests, with government trust playing a key role (Skovgaard and Van Asselt, 2019). Adopting a whole-of-government approach wherein a wide range of stakeholders are involved early in the process is essential.

Earmarking the revenue saved

Fossil fuel subsidy reform is a policy tool that saves government resources while simultaneously reducing GHG emissions. A report that analysed reform of fossil fuel subsidies to coal, natural gas, electricity, and oil across 32 countries found that the cumulative fiscal savings from fossil fuel subsidy reform would amount to US$2.96 trillion between 2021 and 2030 (Kuehl et al., 2021). The revenue saved from fossil fuel subsidy reform could be spent on a multitude of projects, depending on national and local priorities. For example, India placed an excise duty on gasoline and diesel and then used the revenue collected to fund their COVID-19 response. Columbia and Costa Rica used carbon tax revenues to fund forest conservation projects. In the Nordic countries, although the income from the heavy taxes imposed on oil and coal was not explicitly earmarked for renewable energy, the additional income augmented the national budget, thereby increasing the resources available for these subsidies. Furthermore, any taxes imposed on oil and coal can of course increase the relative competitiveness of renewables.

As mentioned previously, subsidy swaps can be used by governments to support national development processes in many fields such as healthcare, energy-transition, crisis recovery, education, employment, etc. Focusing on the use of subsidy swaps for the energy transition, there are four key areas – access to clean energy, energy efficiency, decarbonisation of transport, and transformation of the power sector – that countries can prioritise, based on their demographics, stage in the energy-transition, relevant Sustainable Development Goals, and climate targets (Sanchez et al., 2021). To support energy access, blanket consumption subsidies for electricity and LPG can be reformed and instead subsidies can be targeted to the population groups that need them most, while also promoting grid connections. To support energy efficiency, revenues can be reallocated from fossil fuel subsidy reform to overcome high upfront costs or de-risk energy efficiency investments, mostly in buildings. To support the decarbonisation of the transport sector, revenues can be swapped from the reform of subsidies on gasoline and diesel to incentivise private purchases of EVs or related infrastructure. To support the power sector of the future, subsidies to fossil fuels can be reformed for power generation or to support clean energy generation (Sanchez et al., 2021).

Step 3: Transparency, Reporting and Communication

Ireland, along with Italy and Germany, are among the most transparent countries when it comes to reporting on energy subsidies and Ireland has been cited as an example for 'best-practice' due to its consolidation, transparency, and consistency in reporting. This is because since 2018, the CSO has been releasing two sets of data titled, 'Environmental Subsidies and Similar Transfers' and 'Fossil Fuel Subsidies'. Clear communication to the public as well as transparency in reporting is important in regard to sharing information on the extent to which fossil fuels are subsidised and considering how the funds might be redirected for other social purposes. There is often little awareness that fossil fuel subsidies even exist and as such, drawing attention to these subsidies and their fiscal and macroeconomic impacts, rather than their environmental impact, has been noted as an important aspect of successful reform in countries including Egypt, Indonesia and Trinidad and Tobago (Chelminski et al., 2018).

Step 4: Employing Complementary and Compensatory Measures

Employing complementary measures compensating for the effects of reform is arguably the main principle of successful reform. Price increases arising from reform can create difficulties for vulnerable groups, but targeted measures can compensate those groups according to their needs. These targeted measures can take several forms, such as subsidy targeting, direct cash transfers, social safety nets, or even improvement of essential public services.

In 2014, Indonesia abandoned its gasoline subsidies, which accounted for roughly 10% of the government's total expenditure, thus saving US$15.6 billion in 2015 (Gerasimchuk et al., 2018). These savings were reallocated to major investments in social welfare and infrastructure by investing the savings in health insurance, housing for low-income groups, clean water access, increased budgets for ministries, state-owned enterprises to improve food sovereignty, economic autonomy, and security and defence, and transfers for regions and villages. For production subsidy reform, compensatory measures such as the retraining of people working in the fossil fuel extraction sector and financial support for local communities dependent on extraction have proven important for the reform of subsidies.

3. Policy Context

This section addresses the second task defined by the Council. It offers an integrated and compact overview of key national, EU and international objectives and proposals for the phase out of fossil fuel subsidies. It concludes with a note on the relevant amendments to the EU Energy Taxation Directive (ETD) under the EU Fit for 55 Package.

G20 Leaders Statement: The Pittsburgh Summit (2009) called for governments to increase investment in clean energy and to begin the phase out of inefficient fossil fuel subsidies. It was the first time the G20 stated this commitment which was then reaffirmed at subsequent summits.

The Paris Agreement (2015) was the first universal, legally binding global climate change agreement. Governments agreed to a long-term goal of maintaining global average temperatures to well below 2°C above pre-industrial levels and to try limit the increase to 1.5°C so as to significantly reduce the risks and the impacts of climate change. Individual countries were required to devise comprehensive nationally determined contributions. The reform of fossil fuel subsidies are directly relevant to realising these goals and altering international investment pathways.

The European Green Deal (2020) is a major package of European environmental actions that *inter alia* raises the EU's 2030 GHG emission target to 55% compared to 1990 levels. Key targets include at least 40% cuts in GHG emissions (from 2005 levels), at least a 32% share for renewable energy and at least a 32.5% improvement in energy efficiency. The European Green Deal also includes sector specific targets. The transport sector has targets which include a 55% reduction of emissions from cars by 2030, 50% reduction of emissions from vans by 2030 and zero emissions from new cars by 2035. The Commission further proposed removing the carbon exemption which the aviation sector previously benefited from and proposed creating an obligation for airlines to take on sustainable blended fuels for all departures from EU airports. Additionally, the new Social Climate Fund will provide €72.2 billion over 7 years of funding to renovate home and buildings, to provide access to zero and low emission mobility, and possibly income support to help EU citizens who are most affected or at risk of energy or mobility poverty.

The Climate Action Plan (2021) sets Ireland's path for climate action, and directly acknowledges the need for transparency in the phase out of fossil fuel subsidies as a part of national climate action. It specifically states that transparency in this regard will be improved by enabling the CSO to conduct ex-post assessments of fossil fuel subsidies. CAP 21 contained specific actions for fossil fuel subsidy removal in Ireland. The detailed implementation maps for actions include the development of a roadmap for review and transition away from fossil fuel tax subsidies in the Transport sector and the transformation of Irish waste measures to align with Goal 12 of the United Nations Sustainable Development Goal (Sustainable Production and Consumption) which sets out a series of targets that includes the removal of fossil fuel subsidies. The CAP also clearly recognises the importance of targeted measures to help the most vulnerable who may be affected by the decarbonisation of the Irish economy. This would include those impacted by higher fossil fuel prices and the desired shift away from fossil fuels. The importance of a just transition and targeted supports is clearly stated and as an example, the CAP notes the support to the Midlands region which was affected by the ending of peat extraction for power generation.

The Glasgow Climate Pact (2021) features an agreement between the parties to accelerate efforts to reduce coal power and phase out inefficient fossil fuel subsidies. Additional key agreements include new climate promises to help achieve the 1.5°C global warming target, a pledge to provide more climate finance for developing countries and a pledge to complete the Paris Agreement Rulebook which establishes transparency and reporting requirements for the parties who entered into the Paris Agreement.

Third G20 Finance Ministers and Central Bank Governors Meeting (2022) stressed that, to reach the goals of the United Nations Framework Convention on Climate Change and the Paris Agreement, countries needed to use all available fiscal, market and regulatory mechanisms, including carbon pricing mechanisms, to phase out and rationalise inefficient fossil fuel subsidies that encourage wasteful consumption. The G20 Communiqué additionally encouraged countries to commit to this objective and to accompany fossil fuel subsidy removal with targeted supports to the poorest and most vulnerable in line with national circumstances.

The Energy Taxation Directive (2003/96/EC) (ETD) was the EU framework for the taxation of energy products. It established structural rules for energy taxation and implemented a minimum rate of excise duty to encourage a low-carbon and energy efficient economy. The Energy Taxation Directive (ETD) has remained unchanged since its creation in 2003 and therefore does not reflect best practise or most up-to-date scientific knowledge. In this context, the EU Fit for 55 package (2021) proposed various updates to the ETD. The proposals include a new goal for emissions from the current EU Emission Trading Scheme sectors (including the extension to maritime transport) to be reduced by 61% by 2030 (relative to 2005 levels) rather than the previous 43%. As the new ETD is a revision of an existing directive, it requires acceptance from all members of the EU Council and anyone who objects will likely be asked to provide alternative solutions to help member states achieve their emissions reduction targets. The ETD remains in process at the European level and if accepted, Member States will be expected to implement changes to their domestic legislation. Features of the amended ETD are likely to include:

- Fuel taxes based on energy content and environmental performance rather than volume to ensure the environmental impact of fuels is reflected in their prices.
- A simplified categorisation process for fuel products to enable those products most harmful to the environment be taxed the most.
- Exemptions on home heating products to be phased out such that products cannot be sold below minimum rates. New measures will be introduced to support those households most vulnerable to energy poverty.
- A widened tax base to include kerosene (used by the aviation industry) and maritime industry heavy oil so as to remove the full tax exemption status which these fuels previously enjoyed as the European Commissions recognised these sectors as having a major contribution to energy consumption and pollution.
- The recognition of new energy products such as green hydrogen and to encourage their implementation.
- Minimum tax rates to be increased to reflect current pricing and will be adjusted annually.
- A five-yearly review to ensure that the ETD is up to date, adjustable and relies on the best available science.

4. Review of Fossil Fuel Subsidies

This section responds to the third task defined by the Council, and provides a review of fossil fuel subsidies, both direct and indirect, as identified by the CSO and the European Commission. Further contemporary information on fossil fuel subsidies that fell outside of the defined scope were also considered. Specifically, the 2022 State of the Energy Union report from the European Commission offered useful additional insight.

4.1. Irish Context

In an Irish context, fossil fuel subsidy primarily refers to foregone tax, i.e., indirect subsidies. According to the CSO, the total budgetary cost of fossil fuel subsides in 2019 was €2.8 billion (CSO, 2022). In the same year, the government collected a total of €430 million in carbon tax revenue (Department of Finance, 2021). Therefore, the monetary value of environmentally damaging subsidies was more than six and a half times higher than the carbon tax revenues. In 2020, the ratio was slightly lower as subsidies decreased by 21% to €2.2 billion, whereas the growth rate for carbon tax revenue was 15% equalling €494 million (CSO, 2022; Department of Finance, 2022). This decrease was partly due to the reduction in consumption of fossil fuels for transport, including aviation, due to the COVID-19 pandemic. The direct and indirect fossil fuel subsidies active in Ireland in 2020 are provided in Tables 3 and 4 respectively. Direct subsidies refer to subsidies that impact household bills, for example, fuel allowances. Whilst indirect subsidies are applied industry-wide and involve taxes not collected on certain fuels i.e., forgone tax revenue.

Table 3: Direct Fossil Fuel Subsidies in Ireland, as identified by the CSO:

Direct Fossil Fuel Subsidies	
Fossil Fuel Production	***Fossil Fuel Consumption***
Petroleum Exploration and Production Promotion and Support Programme	PSO Levy: Electricity Generation from Peat
SFI Funding to Fossil Fuel Research	Electricity, Gas or Fuel Allowance
Government Fossil Fuel R&D Funding	Other Supplements (including Heating)
	Fuel Grant for Disabled Drivers and Passengers

Source: (CSO, 2022)

Table 4: Indirect Fossil Fuel Subsidies in Ireland, as identified by the CSO:

Indirect Fossil Fuel Subsidies	**Payment**
Fossil Fuel Production	
Zero Royalties on Gas and Oil Production	Royalty
Expensing of Exploration and Development Costs	Corporation Tax
Stamp Duty Relief on Licences and leases granted under Petroleum and Other Mineral Development Act, 1960, etc.	Stamp Duty

Road Transport Fuels	
Diesel Rebate Scheme	Excise
Fuel Excise Repayment for Disabled Drivers and Passengers	Excise
Revenue Foregone: Auto diesel	Excise
Revenue Foregone: Auto LPG	Excise
Revenue Foregone: Scheduled Passenger Road Transport Services	Excise
Auto diesel VAT Refund	VAT
Air, Water, Rail Transport Fuels	
Fuel Excise Repayment for Commercial Sea Navigation	Excise
Jet Kerosene Excise Exemption	Excise
Free Allocation of Emissions Allowances to Airline Operators within EU-ETS	Cost of Allowances
Revenue Foregone: Marked Gas Oil for Rail Transport	Excise
Partial Excise Repayment on Aviation Gasoline used for Commercial Purposes	Excise
Marine Diesel Scheme	VAT
Zero VAT on Jet Kerosene for International Flights	VAT
NORA Levy Exemptions	NORA Levy
Fuels used in Industry	
Fuel Oil Excise Exemption for Manufacture of Alumina	Excise
Fuel Excise Repayment for Horticulture	Excise
Revenue Foregone: Marked Gas Oil for Agriculture, Fishing, Industry	Excise
Natural Gas Carbon Tax Exemption for Certain Industrial Uses	Carbon Tax
Solid Fuel Carbon Tax Exemption for Certain Industrial Uses	Carbon Tax

Relief for Increase in Carbon Tax on Farm Diesel	Carbon Tax
Free Allocation of Emissions Allowances to Companies within EU-ETS	Cost of Allowances
Revenue Foregone: Fuel Oil	Excise
Heating Fuels	
Revenue Foregone: Kerosene	Excise
Revenue Foregone: Other LPG	Excise
Zero Excise on Coal	Excise
Zero Excise on Peat	Excise
Zero Excise on Natural Gas	Excise
Solid Fuel Carbon Tax Exemption under Diplomatic Arrangements	Carbon Tax
Reduced VAT rate on Energy Products	VAT
Electricity	
Electricity Excise Exemption for Domestic Use	Excise
Revenue Foregone: Business Electricity Use	Excise
Relief from Taxation on Electricity used for Certain Industrial Purposes/Generated in Certain Circumstances	Excise

Source: (CSO, 2022).

On an aggregate level, fossil fuel subsidies in Ireland have increased 71% from 2000 to 2018. Direct subsidies have increased from €100 million in 2000 to €300 million in 2018 and indirect subsidies from €1.3 billion to €2.1 billion. Combined fossil fuel subsidies totalled €2.8 billion in 2019 and €2.2 billion in 2020 (CSO, 2022). It is important to recognise the impact COVID-19 lockdown restrictions have had on activity and thus subsidies in this period.

On a disaggregate level, subsidies for international aviation are an illuminating example of the extent to which certain sectors benefit from fossil fuel subsidies. As stated in Table 4, the aviation industry benefits from exemptions to Excise Duty, Carbon Tax, and the NORA Levy. Revenue foregone on jet kerosene amounted to €634 million in 2019. The fuel is exempt from excise and carbon taxes in commercial use and continues to be exempt from taxation in the EU. In 2003, an EU Directive permitted fuel to be taxed for domestic aviation, subject to bilateral agreement amongst Member States. Airlines, however, still do not have to pay tax on commercial aircraft fuel and no member states have agreed to increase taxation on kerosene since the 2003 Directive came into effect.

At the same time, lower income household subsidies have remained relatively steady and have not risen in parallel with indirect subsidies. The household electricity allowance amounted to €105 million in 2019 and the household fuel allowance amounted to €94 million. The 2022 context of higher energy costs and cost of living rises, suggests that such variation in subsidy between the aviation industry and that of home heating may merit further exploration.

4.2. EU Context

In 2020, a European Commission study on energy costs, taxes, government interventions and their impact on energy investments classified four types of subsidies: direct transfers; tax expenditures; under-pricing of goods/services; and income or price supports (European Commission, 2020). Table 5 provides the classification categories from that work, alongside their relevant subsidy instruments. This study recommended that the EU and its Member States do more to reduce fossil fuel subsidies to achieve climate neutrality by 2050.

Table 5: EU Classification of Subsidy Category and Instruments

Subsidy Category	Subsidy Instrument
Direct Transfers	Soft loans
	Grants
	Others
Tax Expenditures	Tax reduction
	Tax refund
	Tax credits
	Tax allowance
	Others
Under-pricing of goods/services	Under-pricing of government-owned resources or land
	Under-pricing of government-owned infrastructure

	Under-pricing of other government-provided goods or services
Income or price supports	Capacity payments (electricity capacity mechanisms)
	Biofuels blending mandate
	RES quotas with tradeable certificates
	Differentiated grid connect charges
	Energy efficiency obligations
	Interruptible load schemes
	Contract for Difference
	Feed-in tariffs
	Feed-in premiums
	Consumer price guarantees (cost support)
	Consumer price guarantees (price regulation)
	Producer price guarantees (price regulation)
	Others
RD&D	RD&D

Source: (European Commission, 2020).

EU Level

Between 2015 and 2019 fossil fuel subsidies in the EU increased by 4%. In the same period, on a sectoral level, fossil fuel subsidies in the energy sector fell by €1.8 billion (-10%), mainly due to decreasing subsidies on coal and lignite as a result of falling consumption in electricity generation. Subsidies for natural gas grew by €0.8 billion (+10%) representing around 16% of fossil fuel subsidies, slightly more than the share of coal and lignite (13%). Fossil fuel subsidies in the transport sector grew by €3.4 billion (+25%) and in the agricultural sector by €0.6 billion (+10%). This increase is explained by rising subsidies for petroleum products in each sector. Similarly, fossil subsidies were up by €0.3 billion (+13%) for households in the same period, principally in the form of subsidies on heating oil and natural gas consumption. In contrast, fossil fuel subsidies in industry fell by €0.5 billion (-4%) as the decrease in coal subsidies was higher than the increase in subsidies for gas (European Commission, 2020).

In 2019 fossil fuel subsidies represented 32% of subsidies by main energy carriers in the EU27. The percentage of fossil fuel subsidies distributed by instrument was as follows: direct transfers (6.25%); tax expenditures (75%); and income or price supports (18.75%). In the same year, the total tax revenues forgone by the EU reached €68bn, representing an 11% rise (+€6.5bn) on 2015. Of this €40bn were revenue waivers from excise taxes mostly on petroleum products, and €9.5bn from tax on electricity, thus totalling close to €50bn of revenue foregone (European Commission, 2020).

In 2020, fossil fuel subsidies decreased by more than 5% as a result of lower fuel consumption in transport, particularly in aviation, due to significant travel restrictions and lockdowns across the EU. In 2021, fossil fuel subsidies in the EU remained relatively stable as increases in transport and industry were compensated by decreases in fossil fuel subsidies. Specifically, subsidies on oil, coal and gas showed a slight increase, and the subsidy to fossil fuel electricity generation fell. Due to increased energy prices in the European markets, several EU Member States have introduced measures to mitigate the impact of energy bills on households and business, which in turn have resulted in larger subsidies for energy consumption (European Commission, 2022).

Member State Level

The two largest drops in fossil fuel subsidies in the energy sector on a Member State level between 2015 and 2019 were in Germany (-€1.3 billion, 27%) and Spain (-€0.5 billion, 61%). Natural gas subsidies rose by €0.5 billion in both Germany and France, whereas other countries showed a mixed picture in subsidy changes. Petroleum subsidies rose by €2.5 billion (+40%) in France and €0.6 billion (+19%) in Belgium and fell by €0.4 billion (-24%) in Sweden.

The relative scale of support that Member States provide to fossil fuels can be assessed by analysing the subsidy amounts in relation to GDP, also known as fossil fuel subsidy intensity. In 2019, Hungary had the highest rate of fossil fuel subsidy intensity at 1.2% of GDP, whereas Malta reported the lowest at 0.01%. On average across the EU, fossil fuel subsidy intensity amounted to 0.4% of the GDP. Ireland is double the EU average, having provided 0.8% of their GDP to fossil fuel subsidies in 2019 (European Commission, 2020).

5. Emissions Context

In accordance with task four, this section presents Ireland's existing emissions profile in relation to the various categories of activities that are relevant to or affected by existing fossil fuel subsidies. The main activities are categorised within two sectors, transport and residential. These areas of activity are assessed in terms of energy use by fuel type, activity, and the share of total emissions in key categories (NO_x, $PM_{2.5}$, and CO_2). From this emissions baseline we highlight the most significant sources of emissions from an activity, fuel type and key emission perspective. This will form the baseline for the analysis and method outlined in section six, as well as offering insight that will assist in targeting policy and subsidy reform towards those areas that are likely to impact on emissions.

Transport

In order to grasp the relevance of transport fossil fuel use in the broader emissions landscape we can consider the significance of the fuel combustion sector as a share of the national total GHG profile, and then the transport share of fuel combustion. Figure 1 illustrates the weight of the fuel combustion sector in the national emissions profile, it contributes 51% of total GHG emissions in the year 2020. The remaining share is split between agriculture (32%), land-use, land-use change and forestry (11%), industrial processes (4%), and waste (1%). Table 6 also summarises these key findings.

Figure 1: 2020 Sectoral Shares of Total National GHGs[6]

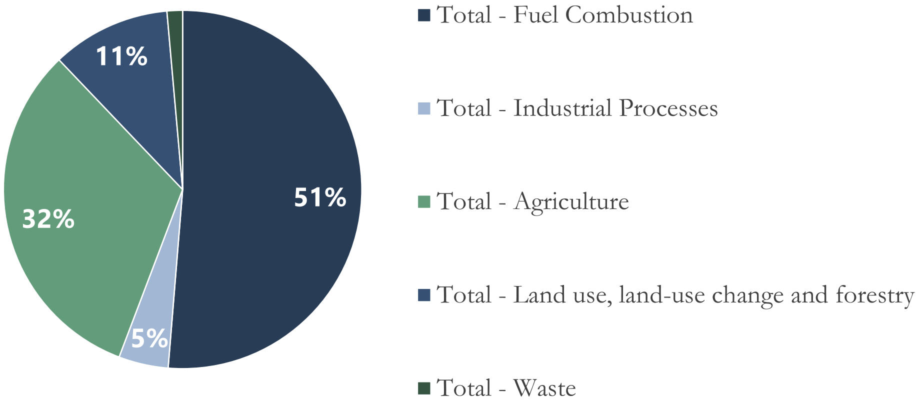
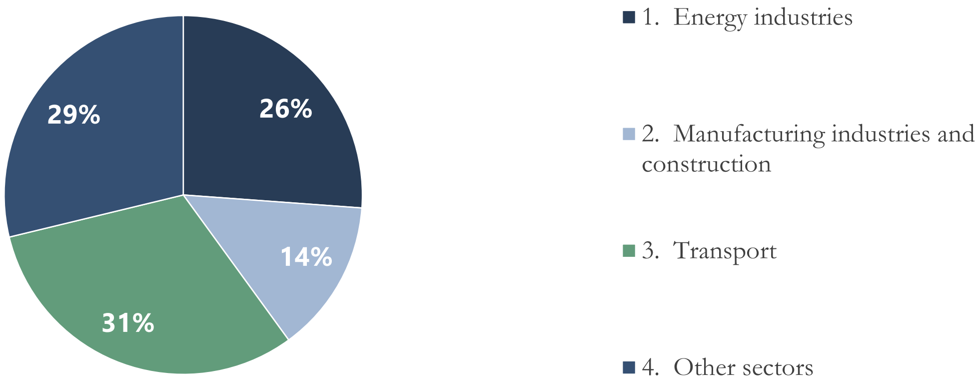


Figure 2: 2020 Share of CO_2 in the Fuel Combustion Sector by Activity[7]

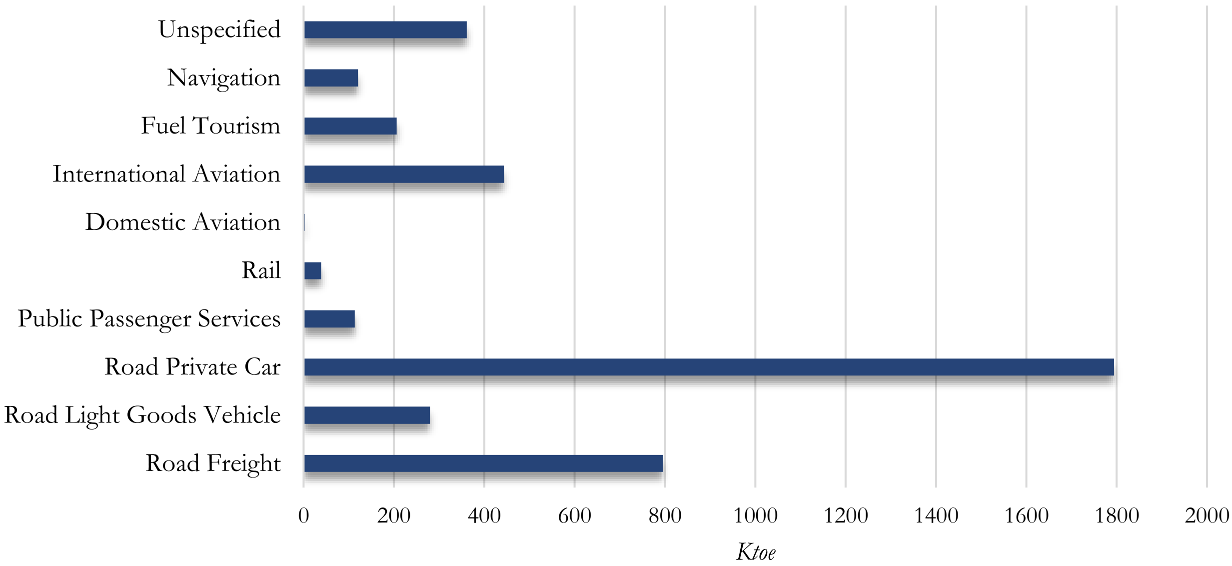


[6] Data sourced from Ireland's Final GHG emissions data, 2020, EPA.
[7] Data sourced from Ireland's Final GHG emissions data, 2020, EPA.

Figure 2 looks at the contribution of transport activity to CO_2 emissions from the fuel combustion sector and shows that in 2020 transport contributed the largest share at 31%. This was followed by other sectors[8] with 29%, energy industries with 26% and manufacturing industries and construction with 14%.

To understand the transport sector in greater detail we consider the activities which contributed most to energy use. As illustrated in Figure 3, the top three activities with the highest energy use in the transport sector for 2021 in Ireland were passenger vehicles (road private car), haulage (road freight), and international aviation. When these data are compared to results from 2018, the trend in shares are similar, with the exception of international aviation.

Figure 3: 2021 Transport Energy Use by Activity[9] (Ktoe)[10]



Aviation emissions are calculated by the energy demand of aviation based on the sales of jet kerosene apportioned into international and domestic take-off and landing cycles and distance covered. In 2018 (pre-COVID), international aviation was the second highest transport energy consuming activity making up 21% of transport energy use. In 2021, it was the third highest transport energy consuming activity making up 11% of transport energy use. Figure 4 shows that the primary transport fuel types in Ireland (2021) are oil (48%) and gasoil/diesel (35%).

In terms of air pollutant emissions, NO_x and $PM_{2.5}$ from the transport sector represent sizeable shares of national totals, with a substantial portion of their overall transport emission contribution coming from road transport. In 2020, the transport share of national NO_x emissions was 35%, with road transport representing 74% of overall

[8] Other sectors fuel combustion category covers emissions from commercial/institutional, residential and agriculture/forestry/fishing sectors. The residential sub-category is the most important source of emissions in this category.
[9] Unspecified accounts for fuel consumption with insufficient data (e.g., Motorcycles, ambulances, construction vehicles). It also accounts for discrepancy between the estimated and real-world energy demand of individual transport categories.
[10] Data sourced from 2021 National Energy Balance, SEAI

transport NO_x emissions as illustrated by Figure 5a. Similarly, in 2020 the transport sector contributed 10% of national total $PM_{2.5}$ with road transport contributing 86% of those transport emissions as illustrated by Figure 5b. 'Other' Agriculture/Forestry/Fisheries off-road vehicles and other machinery contributed 0.6%. It should be noted that the figure for aviation in these figures below represents only civil aviation (domestic landing and take-offs) and therefore is not accounting for the full international aviation contribution. This is due to differing reporting rules.

Figure 4: 2021 Share of Transport Energy Use by Fuel Type[11]

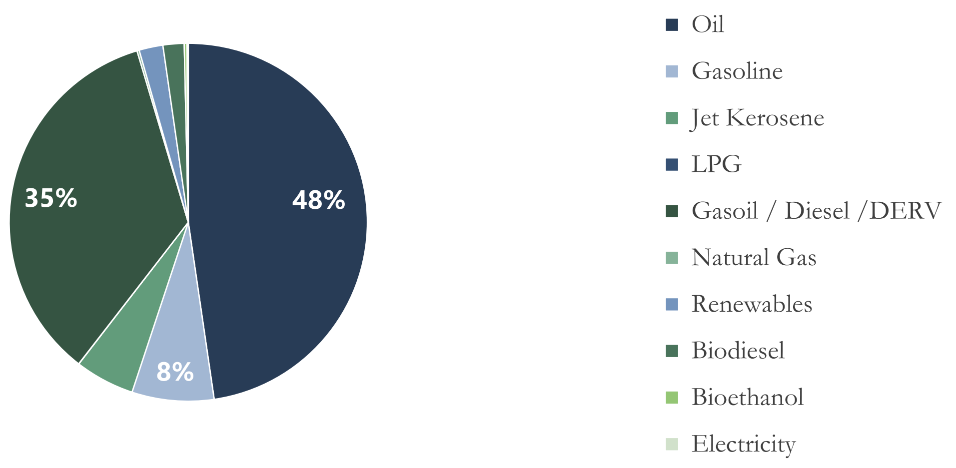
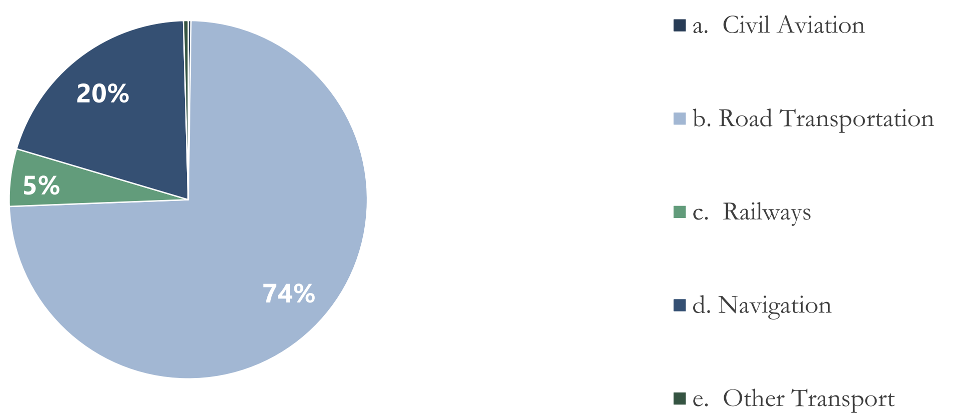
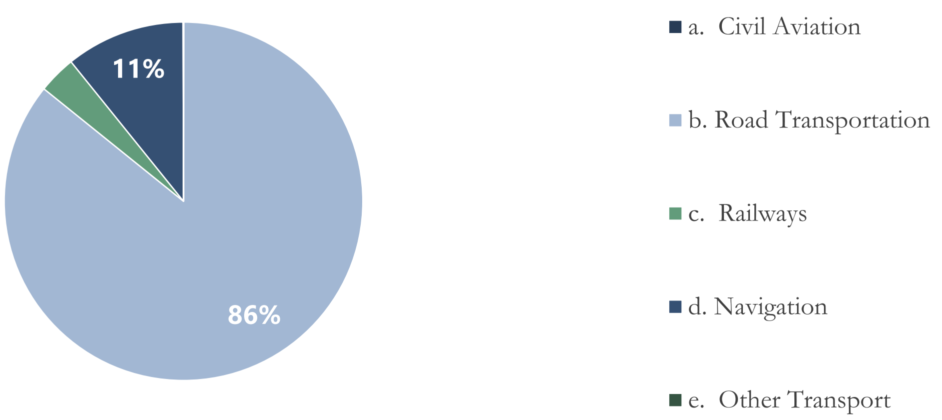


Figure 5a: 2020 Share of NO_x Transport Emissions by Activity[12]



[11] Data sourced from 2021 National Energy Balance, SEAI
[12] Data sourced from Ireland's Final GHG emissions data, 2020, EPA.

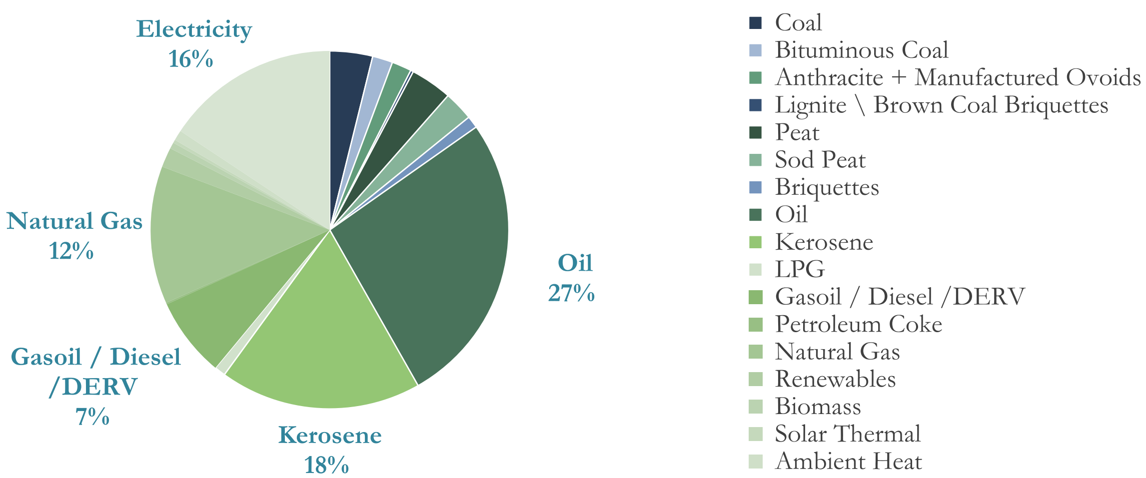
Figure 5b: 2020 Share of $PM_{2.5}$ Transport Emissions by Activity[13]



Residential

For the residential sector, energy use is dominated by four main fuel types – oil, kerosene, natural gas and electricity. This has been a stable trend with figures in 2021 similar in share and quantity to those of 2018. Figure 6 illustrates the fuel types that are present in the residential energy use data. The five fuel types with the largest shares are oil (27%), kerosene (18%), electricity (16%), natural gas (12%), and gasoil/diesel/DERV (7%).

Figure 6: 2021 Share of Residential Energy Use by Fuel Type[14]



[13] Data sourced from Ireland's Final GHG emissions data, 2020, EPA.
[14] Data sourced from 2021 National Energy Balance, SEAI

In terms of the impact of residential emissions on total CO_2 emissions as well as emissions of key air pollutants – NO_x and $PM_{2.5}$ we can see that residential emissions contribute a significant share. Figure 2 shows the share of CO_2 emissions from fuel combustion activities, the category for 'other sectors' is the second highest contributor (29% of total fuel combustion in 2020). This category covers the emissions from commercial/institutional, residential and agriculture/forestry/fishing sectors. The residential sub-category is the most important source of emissions in this category in Ireland. In relation to NO_x and $PM_{2.5}$ Table 6 highlights the shares of passenger cars, public electricity and heat production, and residential emissions as these are among the highest contributing activities or categories. In the case of $PM_{2.5}$ the bulk of those residential emissions are associated with solid fuel combustion in the sector.

Table 6: Summary of Emission by Key Categories, 2020[15]

Contribution of Key Categories to Total $PM_{2.5}$ (kt)		
Total 2020 $PM_{2.5}$	12.1	*% Share*
Passenger Cars	0.1	1%
Public Electricity & Heat	0.3	2%
Residential	6.9	57%
Contribution of Key Categories to Total NO_x (kt)		
Total 2020 NO_x (unadjusted)	93.7	*% Share*
Passenger Cars	9.8	10%
Public Electricity & Heat	5.6	6%
Residential	6.2	7%
Share of National Total GHG (kt CO_2eq)		
Total 2020 GHG Emissions	64,642	*% Share*
Fuel Combustion	33,156	51%
Agriculture	20,758	32%
Land use, land-use change and forestry	6,926	11%
Industrial Processes	2,896	4%
Contribution of Key Categories to Total CO_2 (kt)		
Total 2020 CO_2	41,049	*% Share*
Transport	10,169	25%
Other Sectors[16]	9,365	23%
Energy Industries	8,513	21%

[15] Data sourced from Ireland's Final GHG emissions data, 2020, EPA.

[16] Other sectors fuel combustion category covers emissions from commercial/institutional, residential and agriculture/forestry/fishing sectors. The residential sub-category is the most important source of emissions in this category.

6. Environmental Impact and Abatement Potential

Section 4 and 5 identified key selected fossil fuel subsidies and the emissions associated with their corresponding sectoral activities. In this section we estimate the emissions abatement potential associated with the removal of these subsidies by determining the change in price from subsidy removal and then the consequent potential impact on fuel consumption and associated emissions. ESRI (2019) identified and modelled the impact of the removal of eight subsidies, accounting for 96% of total subsidies. The ESRI defined the subsidies as: electricity generation from peat, security of electricity supply, excise exemption on aviation fuel, diesel rebate scheme, excise exemption on auto diesel, excise exemption on marked and auto diesel, excise exemption on fuel oil, and excise exemption on kerosene. Although all subsidies are considered later in the macro-economic impact assessment in Section 7, given recent changes in the peat and power industry, subsidies related to these activities are not accounted for here. Similarly we do not consider the impact of the removal of marked diesel on emissions. In their analysis of abatement potential in the Irish Agriculture sector, Teagasc (2018) did not recognise bioethanol or biodiesel as viable alternative fuel solutions. In this context, there is therefore a paucity of credible alternatives or substitute fuels for marked diesel. Removal of these subsidies was thus considered to be at odds with stated policy ambitions to support the agricultural sectors transition to a sustainable future (Government of Ireland, 2020). Instead, we focus on the subsidies relevant to road transport, aviation and home heating when assessing impacts on emissions.

In order to determine the impact of subsidy removal on activity levels, we firstly consider how current prices (e.g., diesel prices) are impacted by the removal of subsidies, which in this case would represent adjusting for tax foregone with an increase in the existing excise rates. Thereafter, we review national and international evidence to collate illustrative values and plausible ranges for the associated fuel price elasticities. We then apply these elasticities within indicative ranges to the anticipated price changes and using the EPA's activity projections, estimate revised activity levels for all affected sectors to 2040. Emissions changes are then calculated by applying emission factors defined by IPCC, SEAI[17] and from the EMEP/EEA inventories to the new projected activity level.

Definition of Price Elasticity of Demand

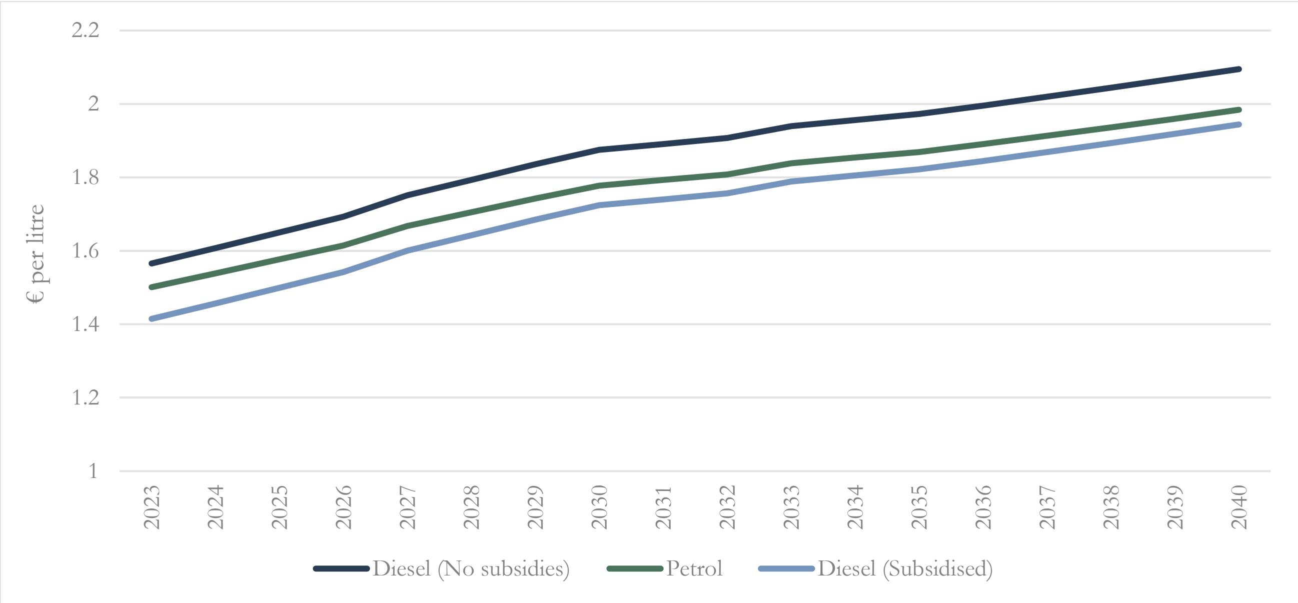
Price elasticity of demand is a measurement of the change in the consumption of a product in relation to a change in its price. Economists use price elasticity to understand how supply and demand for a product may change when its price changes. It is defined as the percentage change in quantity demanded divided by the percentage change in price. Since demand normally reduces as price increases, the price elasticity of demand is usually a negative number (OECD, 1993). Our study applies international estimates of fuel price elasticity.

[17] SEAI Conversion Factors

6.1. Impact on Fuel Prices

In estimating fuel price subsidies, akin to the approach employed by the ESRI (2019) we use the non-carbon excise rate charged on unleaded petrol as our baseline and consider all excise charged below that rate as a subsidy. In estimating prices when subsidies are removed, we assume the excise rate on unleaded petrol to be the appropriate tax rate and apply this rate to all fuels considered in the analysis. Fuel price forecasts are conducted similar to the method the EPA and SEAI would apply for their projections. We project price increases based on growth in the underlying price of oil in accordance with the UK BEIS[18] low oil price assumption. By applying this forecast to January 2020 fuel prices, less the prevailing excise rates, VAT, and additional fees, we calculate an estimated price for diesel, petrol, coal, peat, residential gasoil, residential kerosene, and jet kerosene to 2040[19]. For the baseline these fuel taxes are applied at 2020 rates for all years, however, the carbon tax element of excise is set to increase annually to 2030 and as such this is applied based on the carbon tax trajectory of €100 per tonne by 2030.

Figure 7: Estimated Road Transport Fuel Prices at Pump 2023-2040



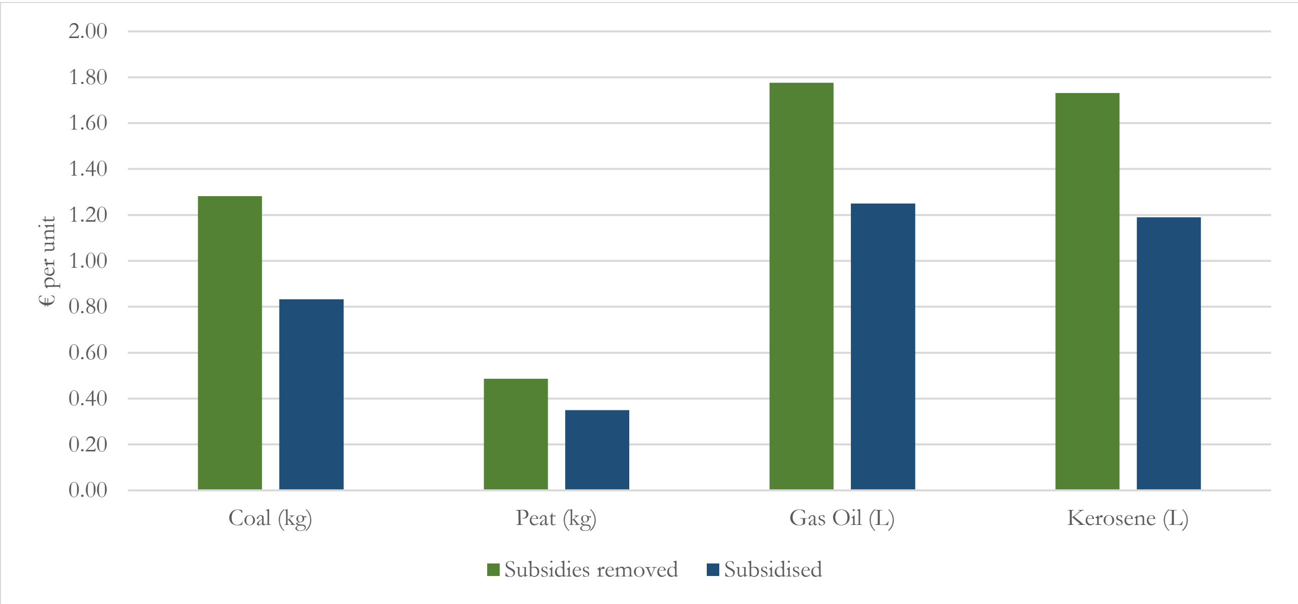
For our removal of subsidy scenarios, we calculate prices in a similar fashion with standard fuel prices calculated using non-subsidised excise rates for affected fuels. As demonstrated in Figure 7, the removal of fossil fuel subsidies results in an average 8.85% increase in transport diesel prices for the period 2023-2040 as compared with our baseline in which diesel excise is charged at a lower rate than petrol excise. In our baseline, commercial transport also benefits from diesel rebates, which we class as a subsidy. This is removed in our fossil fuel subsidy removal scenarios. We consider VAT to be a business cost as opposed to a tax on fossil fuel use and as such this refund

[18] UK BEIS Oil Price Assumption
[19] Prices are real prices for the 2020 base year.

remains allowable. For commercial transport consumers that currently avail of diesel rebates, the subsidy removal results in an 11.4% average increase in diesel prices over the same period.

Within the residential/built environment context a similar convergence with the "appropriate" tax rate applied to unleaded petrol would yield a far more substantial price increase for fuels used for residential and commercial purposes, largely due to the prevailing lower rates of excise in those contexts. Specifically, the fossil fuel subsidy removal would see a sharp increase in the current baseline prices of residential and commercial fuels of circa 55% for coal, 46% for kerosene, 43% for gasoil and 41% peat. Figure 8 details average price between 2023 and 2040 both with and without subsidies.

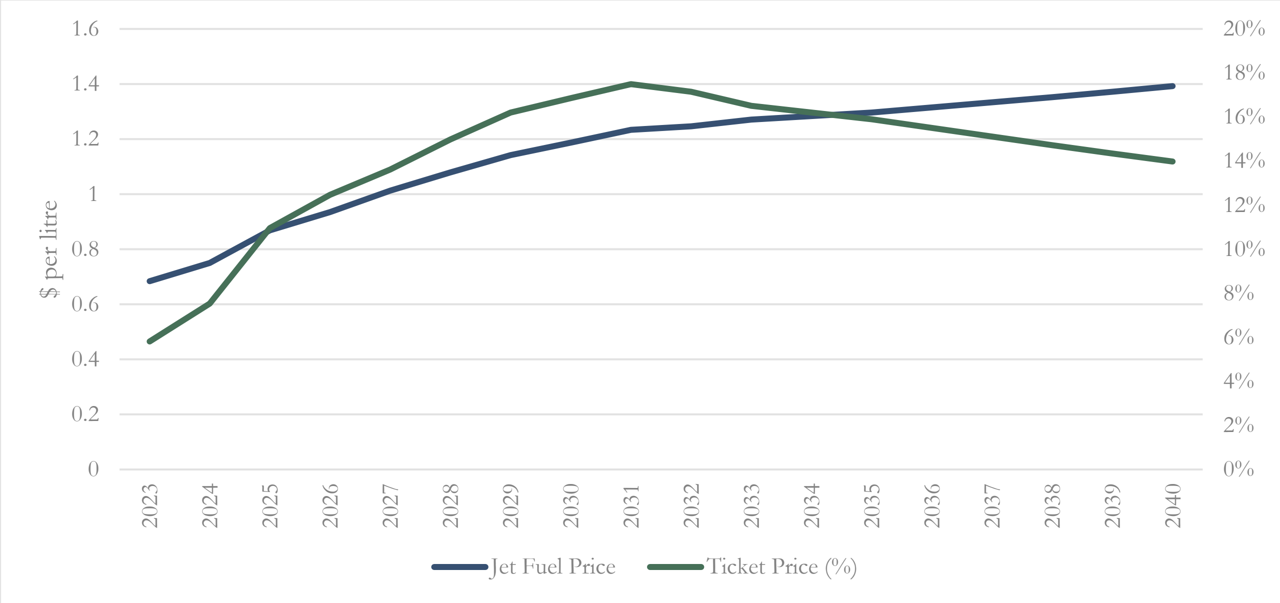
Figure 8: Comparison of Residential Fuel Prices with and without Subsidy (Average 2023-2040)



In the aviation sector the International Air Transport Association[20] demonstrate a relationship between oil prices and jet fuel which supports the use of the BEIS methodology to anticipate future jet fuel price. For our baseline, we use the International Air Transport Association gulf coast spot price per gallon (converted to litres) for January 2020[21] and estimate increases based on BEIS assumptions as with residential and road transport fuels. In contrast to the residential and road transport impacts, aviation demand is driven more so by ticket prices than by fuel prices. As such we estimate how fuel price increases might be passed through to consumers to thereby impact on demand. This is discussed further in the aviation section. Figure 9 details the average 14% increase in air travel prices we might expect under our moderate reaction scenario.

[20] IATA - Fuel Monitor
[21] IATA Gulf Coast Spot Price - Jan 2020

Figure 9: Jet Kerosene and Air Travel Prices 2023-2040



6.2. Application of Elasticities

In applying elasticities to assess impacts on demand, a number of factors should be considered. In all cases our analysis is conscious of the context surrounding demand and the dynamic nature of markets. In the literature elasticities can be represented by short run and long run figures. Elasticities are frequently lower in the short run than in the long run because developments that are not feasible in a short period of time are achievable over a longer period of time (Litman, 2004 & Litman, 2021). In the context of energy demand, we might consider the short run as the time before which the existing capital stock can change. While applications of what defines short run and long run is non-specific and open to interpretation, Litman (2004) classifies the short run as a period of less than two-years. In the context of ownership of expensive and durable capital such as road vehicles and residential boilers this may not be enough time for capital stock to change. However, it is adequate time for initial behavioural adjustments and potentially for certain investments where replacement cycles align (e.g. a boiler breakdown may result in a short-run investment / a car coming to the end of its useful life may be replaced).

In an Irish context, where car ownership is common (Rock, 2016; Carroll, 2021), the impact of fuel prices on fuel demand is assumed to be normal (Sterner, 2007). In simple terms, when the price of fuel goes up, we would expect demand and consumption to go down. This is reflected in the range of elasticities we have identified based on reviews of the literature. However, in the sections below we identify a variable range of elasticities. This variability may be attributed to a variety of factors discussed throughout the literature including *inter alia* the availability of alternatives (Yamaz-Tuzel and Ozbay, 2010), whether prevailing fuel prices are already low or high (Nowak and Savage, 2010) as well as market factors (Winebrake, 2015). Therefore, we estimate the impact of removing fuel subsidies on emissions through the lens of three scenarios in which the demand response to a change in fuel price is expected to be either low, moderate, or high. For each sector the underlying assumptions which may support an assumption of a high, low or moderate elasticity are discussed. However, the key point is that the scenario ranges are representative of elasticity ranges that are found in the literature.

6.3. Road Transport

Private Road Transport

Private road transport accounted for 43% of all transport energy demand in 2021. It is therefore a significant driver of emissions and recognised as a key pressure point for climate action (EnvEcon, 2021; Government of Ireland, 2021). Ireland is especially dependent on the private car due *inter alia* to the dispersed population around Dublin and the limited public transport connection of some of the ex-urban commuter towns built during the Celtic Tiger (Caroll et al., 2021). As of the 2016[22] census, over 60% of urban commutes and over 76% of rural commutes were in a private motor vehicle. Among the key policies targeted by the CAP to alleviate the environmental impact of this car dependence are public and active transport capacity developments (National Development Plan, 2021) and accelerated electric vehicle uptake (CAP, 2021). Similarly, Carrantini et al. (2017) indicate how effective fuel taxes can be at reducing fuel consumption and incentivising the adoption of low carbon modes of consumption. This potential is reflected in the current policy landscape in which the carbon tax trajectory is intended to serve as a price signal contributing to the CAP 21 target of 945,000 EVs by 2030, modal shift and so forth. As outlined in Table 7 road transport is a sector where there are an understandably wide range of elasticity estimates for the long-run, reflecting different perspectives on the capacity and appetite for change. The ambitious nature of the CAP would suggest that there is substantial potential for change, and that the wider policy framework will support this.

Table 7: Fuel Price Elasticity Scenarios

	Short run	Long Run
Low	-0.09	-0.31
Medium	-0.2	-0.6
High	-0.28	-0.84

Source: Graham and Glaister (2002), Dahl (2012), Havraneck (2012)

In establishing each scenario there are a variety of factors which indicate the level of expected response to a change in fuel price. Cases and considerations from the literature are described below:

- ***Low***: Havraneck (2012) suggests that demand for gasoline is more inelastic than the prevailing elasticities estimated by other meta-analysis. Elasticities should be normal (i.e., negative) and as such, results yielding

[22] CSO - Commuting in Ireland

positive elasticities are often attributed to model misspecification and thus not published. However, high negative estimates, which may also be from similar misspecification are published. Havraneck (2012) posits that this leads the literature to be biased toward stronger elasticity. In an Irish context, we might anticipate low elasticity based on our transport profile which skews toward car dependency (Caroll et al., 2021).

- ***Moderate***: Moderate elasticity values represent the central approximations of consumer behaviour in response to a fuel price change. The value used is supported by academic literature and represents a midpoint within the range established by Graham and Glaister (2002) that is consistent with the UK figure presented in that study. The argument that improvements in alternative technologies will create higher long run elasticities is tested by Labuederia (2016). While fuel and modal shifts are encompassed in these elasticity figures, they find that this effect has not become more pronounced over time as technology has improved.
- ***High***: Dahl (2012)[23] measure the consistency of elasticities across different countries and find that for higher prices of each fuel, higher elasticities are expected. Ireland's elasticity would thus be expected to reflect the fact that such fuel taxes in Ireland would render prices high in comparison to other countries. Ireland's elasticities in Dahl (2012) are comparable to the UK and Germany. In determining whether elasticities vary across countries where there are different levels of fuel price or income levels, Dahl (2012) suggests that we might consider price elasticities in Ireland to be above average relative to other countries globally and comparable with other OECD countries. Therefore, we apply the high end of the Graham and Glaister (2002) suggested range to reflect such a "High Response" scenario.

Public Road Transport

Public transport accounted for 3% of all transport energy demand in 2021 (SEAI, 2021). This means it is less relevant as a source of emissions and as a target for fossil fuel subsidy removal. Indeed, mass transit modal shifts are a defined objective of the Climate Action Plan and the CAP 21 has an ambition to realise 500,000 extra walking, cycling and public transport journeys per day by 2030. Higher private road transport fuel costs would be expected to see a rise in public transport use, and the sector may merit ongoing support for fossil fuel prices in order to curtail passenger ticket prices and improve the relative attraction of public transport over private car transport. This is not to suggest that public transport fleets should not decarbonise, only that mass transit is a mode of travel to encourage.

Therefore, the analysis for public transport takes a somewhat different approach and considers the impact of fuel price changes on transit ridership – a cross price elasticity. This is because we believe that the greater impact from fossil fuel subsidy removal would be in regard to modal shift in the context of public transport. This assessment uses cross price elasticities where the change in fuel price is assessed for the impact that it would have in terms of incentivising more people to travel by public transport. Whilst higher fuel prices may also impact upon ticket prices

[23] Dahl (2012) apply an alternative measurement approach to Graham and Glaister (2002) and as such yield lower elasticity figures across the board. As such the specific figure is not considered for this approach but the finding that higher fuel prices yield higher elasticities could indicate that Ireland should be at the higher end of any range.

for public transport, the cost would be distributed across a larger ridership, and public transport operators should already have clear longer-term motivation to decarbonise their fleets and move to more efficient powertrain systems.

Table 8: Public Transport and Fuel Cross Price Elasticities

	Short run	Long Run
Low	0	0.2
Medium	0.2	0.5
High	0.3	0.8

Source: Nowak and Savage (2013), Blanchard (2009), Holmgren (2007)

Nowak and Savage (2013) present a summary of cross price elasticities between fuel prices and transit ridership demonstrating an elasticity range between 0 and 0.8. Blanchard (2009) finds substantial variation in the cross price elasticity figure from city to city and year to year. Fuel price as Blanchard describes it is not the main influencer of transit demand, however, there is evidence that fuel prices do induce a modal shift from driving to transit. However, again there are many factors which may influence outcomes, and we describe these in our three response scenarios.

- ***Low:*** As discussed, a feature of the transport profile in Ireland is that it includes many satellite towns located outside of central business districts. This dispersed population feature lends itself to a higher car dependency (Carroll et al., 2021). As such there may be few if any transit options for consumers to switch to when fuel prices are high. Yamaz-Tuzel & Ozbay (2010) demonstrate that if the transit system does not provide enough coverage, it will not represent a viable alternative to driving and regardless of price impacts, there will be little in the way of a modal change. In this case a low elasticity is expected.
- ***Moderate:*** Although Nowak and Savage (2013) identify substantial variation in cross price elasticities between transit and fuel, they accept the Holmgren (2007) midpoint values of 0.2 in the short run and 0.5 in the long run, for countries with generally low transit market share. This may be consistent with the Irish transport profile into the future, where substantial investments are being made in alternative modes.
- ***High:*** Yanmaz-Tuzel and Ozbay (2010) describe a situation in which short term fluctuations in fuel prices do not yield tangible impacts in transit ridership, but long-term changes do encourage modal shift. The removal of fossil fuel subsidies could be classed as a long-term price change. As such, the price change associated with the removal of subsidies would signal sustained higher prices and may therefore see a greater shift toward mass transit travel over time, especially as complementary CAP policies are progressed.

Haulage

Haulage accounted for 19% of all transport energy demand in 2021 (SEAI, 2021). It is a substantial contributor to national emissions and therefore represents an important subsector for national emission abatement strategies. However, as outlined in CAP 21 the technology pathways are still developing in the (heavy) haulage sector, with activity in this context likely to remain dependent on diesel, at least in the short term. As such, the focus is largely on improving sustainable practices and behaviours to achieve abatement potential. As CAP 21 identifies, increased biodiesel blends and more fuel-efficient driving are potential actions in this context. However biofuels often do not represent cost-effective solutions to increasing diesel prices, and haulage operators are already incentivised to target efficiency as a means of improving profitability. As such there may be less suitable alternatives in the short term for the sector, and this is reflected by the elasticity ranges identified. Electrification is already a competitive reality for lighter duty vehicles, and into the future electrification will play an increasingly important role for heavier haulage.

Table 9: Elasticity Range for Haulage

	Short run	Long Run
Low	0	0
Medium	-0.1	-0.3
High	-0.15	-0.6

Source: Winebrake et al. (2015); DeJong (2010), Bailly (1999).

Despite the potential offered by such technologies, we adopted a conservative view to fuel switching in our scenarios for the haulage sector. In accordance with the CAP (2021) ambitions, we anticipated fuel reductions to come via improvements in fuel efficiency, transport efficiency as well as changes in transport volume (De Jong, 2012). Changes in fuel efficiency involves purchasing more fuel-efficient vehicles and changing the style of driving to be more fuel efficient. Changes in transport efficiency include acquiring larger vehicles and increasing shipment size, consolidating shipments originating from the same company, getting more load returns to reduce empty driving, and more efficient route planning. Changes in transport volumes including updating of production technologies (toward lighter goods) include sourcing raw materials from closer locations, using more local suppliers, and reduced demand for product. As discussed however, operators may already gain a competitive advantage from such practises. Our scenarios considered the impact of further improvements of this type, however enhanced electrification options would further enhance estimates.

- ***Low:*** Winebrake et al. (2015) suggests that rather than reducing demand through the processes described above, or passing price on to consumers, operators in a competitive market cut expenditure on other operational costs. Their analysis fails to reject the null hypothesis that haulage price elasticity of demand is inelastic. Such a response to fuel prices might be expected given Irelands location as an island state that is largely reliant on road and sea transport for imports and exports.

- ***Moderate:*** Bailey (1999) suggest a range for haulage elasticities of between -0.05 and -0.15 in the short run and -0.2 and -0.6 in the long run. DeJong (2012) confirms this range offering a recommended value in line with the midpoint values. This figure includes the aforementioned behavioural responses: changes in fuel efficiency, changes in transport efficiency and changes in road freight transport demand.
- ***High:*** In this instance we anticipate elasticities on the high end of the range offered by DeJong (2012) and Bailey (1999). These figures are still comparable to the moderate range for private transport, highlighting that haulage is more inelastic than private transport, with fewer alternative options for operators to switch to. Nonetheless there are alternative electric options expected even for heavy haulage by mid-decade.

6.4. Aviation

International aviation accounted for 1187kt of CO_2eq emissions in 2020, however the sector was heavily impacted by the COVID-19 pandemic at that time. In 2019 emissions totalled 3347kt amounting to approximately 5.6% of national emissions. Aviation is a heavily subsidised sector. As described, jet kerosene used for commercial aviation is not subject to mineral oil tax (excise) or in the case of international aviation – VAT. These subsidies for international aviation are an illuminating example of the extent to which certain sectors may benefit from fossil fuel subsidies. Revenue foregone on jet kerosene amounted to €634 million in 2019. In 2003, an EU Directive permitted fuel to be taxed for domestic aviation, subject to bilateral agreement amongst member states. Airlines, however, still do not have to pay tax on commercial aircraft fuel and no member states have agreed to increase taxation on kerosene since the 2003 Directive came into effect. Social Justice Ireland have repeatedly called for the imposition of tax on aviation fuel, arguing that the burden of the current carbon taxation system is resting on households. At the same time, lower income household subsidies have remained relatively steady and have not risen in parallel with indirect subsidies. The household electricity allowance amounted to €105 million in 2019 with household fuel allowance amounting to €94 million. The current 2022 context of higher energy costs and cost of living rises, suggests that the variation in subsidy between the aviation industry and that of home heating may merit further exploration.

Table 10: Elasticity Range for Aviation

	Elasticity	Pass-through rate
Low	-0.45	54%
Medium	-0.6	62%
High	-0.9	100%

Source: Oum (1990), Mayor and Tol (2007), IATA (2007), Ventura (2020).

When estimating price changes, the profile of aviation energy use represents a particular challenge in respect to this study. Our elasticities reflect the responsiveness of airline passengers to a change in the price of flights, rather than the responsiveness to the price of fuel (as was the case in the categories estimated above). To account for this, we estimate the impact of fuel price increases on the price of flights using estimates of pass-through rate and the share of fuel costs to the overall airline costs. In a competitive market, where airlines compete on price, we might expect for pass through rates i.e., how the burden of the tax is shared between buyers, sellers, and end users of aviation fuel to vary. There is a lack of clarity surrounding pass-through rates, however the average pass-through rate of aviation fuel tax to carriers has been estimated as approximately 54.3–62.3% (Fukui & Miyoshi, 2017). We apply the limits of this range in our low and moderate scenarios and for our high impact scenario assume full pass through. In terms of the impact of fuel cost, we apply the estimation of Selim (2018) which suggests that fuel costs account for 30% of total costs. Thus we apply a given pass through rate to 30% of the fuel price cost when exploring the impact on ticket prices.

Our end-use consumers do not have ownership of capital stock and we assume that the options for technology and efficiency improvements (i.e., reducing number of flights) on behalf of airliners is very limited in the short-term. Furthermore, many airlines hedge fuel prices over the short-term. We therefore assume perfect inelasticity in the 2-year short run period. We do recognise that COVID saw a sharper impact, however this was stimulated by regulatory changes and public health guidance. We also note that we cannot distinguish between fuel use shares for the three most common profiles of demand for flights namely, leisure, business, or haulage. However, we acknowledge that each of these demand profiles should have different elasticities.

- ***Low:*** Our low value adopts the -0.45 figure from Oum (1990) which Mayor and Tol (2007) also apply as a baseline. Ireland is an island state with limited substitutes for air travel. This could contribute to demand being more inelastic to price. Furthermore, pass-through rates for aviation fuel taxes may be low (Fukui & Miyoshi, 2017). In this context we apply that low-end of the pass-through rate range (54%).
- ***Moderate:*** Our moderate scenario relies on IATA (2007) analysis and involves applying their pan national guideline level of -0.6. This pan national figure implies that the price increase is consistent across all flights and that the only credible substitute would be modal change. As discussed, our activity data does not have the required level of disaggregation for us to provide distinct elasticities based on type of demand, however the relative inelasticity of business trip demand when compared with leisure trip demand is considered by IATA in arriving at the figure of -0.6. In this scenario, we also apply the higher range of the passthrough rate identified Fukui and Miyoshi (2017).
- ***High:*** Ventura et al (2020) find price elasticity in remote areas to be -0.9. While similarities between their analysis location and Ireland are few, this was selected as a more extreme upper range for areas with limited substitution alternatives to aviation. For this high impact scenario 100% pass through is assumed.

6.5. Home Heating

The residential sector accounted for 11.4% of GHG emissions by sector in 2021 and also represents a significant contributor to $PM_{2.5}$ and NO_x as outlined in section five. However, the former is associated with solid fuels primarily. The sector also accounted for 27.5% of energy related CO_2 in Ireland in 2021 with 72.7% of residential energy demand coming from fossil fuels. The Sectoral Emissions Ceilings (Government of Ireland, 2022) for the residential built environment sector, call for indicative reductions of ~20% by the final year of the 2021-2025 period (as compared with 2018) and a ~40% reduction in the final year of the 2026-2030 period. In aid of this target the government will support the retrofitting of 500,000 homes and installation of 680,000 renewable energy heat sources in both new and existing residential buildings. Other measures include increased targets for district heating and the public sector and strengthening building standards for all buildings (Government of Ireland, 2021). Of further relevance is also the new Solid Fuel Regulations (2021), which aims to reduce air pollution from residential heating.

Table 11: Elasticity Range for Residential

	Short run	Long Run
Low	-0.2	-0.47
Medium	-0.24	-0.75
High	-0.25	-0.8

Source: Galvin and Sunikka-Blank (2012); Labandeira (2017), Miller and Alberini (2016)

Due in part to the substitution possibilities available in the residential sector, Labandeira (2017) identify home heating fuel (specifically heating oil) as the most elastic fuel throughout their extensive analysis of fuel price elasticities. In contrast Miller and Alberini (2016) suggest there is evidence of households being locked into a specific fuel, with residential fuel use therefore remaining relatively inelastic. These perspectives are reflected in the range of elasticities presented in the literature. A figure in the region of -0.2 is commonly cited as a short run elasticity, however, the long run situation demonstrates more variability when consumers have time to react to price changes and pivot away from incumbent technologies. Our study considers the removal of subsidies on gasoil, kerosene, and coal and describes the potential rationales for selecting a low, medium or high elasticity below.

- ***Low:*** Lower fuel price elasticities such as those estimated by Galvin and Sunikka-Blank (2012), may be attributed to a number of factors. In an Irish context, a resistance to change could be associated with a higher level of cost, hassle and complexity associated with moving away from an oil heating system.
- ***Moderate:*** The values presented by Labandeira (2017) are the result of a meta-analysis of 44 studies. Their estimated elasticities offer a moderate midpoint, and showcase a far greater long-run elasticity where households engage and invest in new home heating technologies and energy efficiency.

- ***High:*** There is evidence throughout the literature of residential fuel oil being especially elastic in the long run (Labandeira, 2017). Particularly high long run elasticities (>1) are also a feature of Madlener (2011) and Lin (1987) which are noted to reflect the options available to households to fuel switch in the long term. Miller and Alberini (2016) present a range of elasticities at which -0.8 is the upper limit. We adopt this figure as our high long-run elasticity scenario.

6.6. Emission Factors

Tables 12 and 13 detail the emissions factors, informed by SEAI[24] and the EMEP/EEA inventory guidebook, and as applied by the EPA in calculating Ireland's official emissions, with noted adaptations applied as necessary. Selected bullets of information are included below the tables.

Table 12: Transport and Aviation Fuel Emission Factors

Pollutant	Unit	Petrol	Diesel	Biofuel	Jet Kerosene	Electricity (2023)
$PM_{2.5}$	kg/TJ	5.8	8.9	8.9	3.1	1.3
NO_x	kg/TJ	25.9	235.7	235.7	335.2	31.4
CO_2	Tonne/TJ	70.0	73.3	71.6	71.5	50.6

Table 13: Residential Fuel Emission Factors

Pollutant	Unit	Coal	Sod Peat	Kerosene	Gas Oil	Gas	Biomass*	Electricity*
$PM_{2.5}$	g/GJ	57	396	1.45	1.45	0.2	207.6	1.3
NO_x	g/GJ	130	82	67.92	67.92	42	80	31.4
CO_2	Tonne/GJ	98.3	104	71.4	76	56.9	112	50.6

- "Biofuels" represent a range of fuels, many of which have differing emission factors. This analysis calculates a weighted emission factor based on the 90:10 ratio of biodiesel to bioethanol used in road transport.
- "Biomass" also represents a range of fuels with differing emission factors. This analysis assumes, based on the splitting ratio employed by the 2021 EPA Air Pollution Inventory, that 44% of biomass used for residential heating is non-traded wood with the remaining 56% traded on the market. This ratio is consistent with the 2020 Energy in Ireland Report (SEAI, 2020). Of the wood available at market, the EPA inventory assumes, 64% is already of the preferred standard, which we assume for our baseline scenario.

[24] SEAI Conversion Factors

- EPA or EMEP do not offer granular detail on differences in air emissions relating to biofuels. In this instance we have applied the diesel rate emission factor for $PM_{2.5}$ and NO_x.
- Upstream electricity generation emissions are dynamic and entirely dependent on the makeup of the electricity balance. Our approach applies emission factors and projected balances from the EPA Air Emissions Inventory. The emissions factors listed in Table 12 are a snapshot of projected 2023 values.
- Appendix I details equations (1) and (2) which are used to calculate emissions from such fuel consumption in a sector and to assess the reduction of emissions when subsidies are removed and activity rates change.

6.7. Fuel Switching

Brons et al. (2002), highlight the relationship between price elasticity of demand and the availability and quality of substitutes. They indicate that this relationship is built into elasticity estimates, with a higher number of substitutes implying a higher elasticity whereas a lower number contributes to making demand more rigid. The projected reductions in demand that we forecast therefore embody a number of responses including improvements in fuel efficient driving, reduction of trips, and improvements in technology. However, for certain categories of fuel use, such as private road transport there may also be an element of fuel and mode switching. In the context of aviation, Brons et al. (2002) identify three levels of substitution relevant to the price increase anticipated from the removal of subsidies. These include destination substitution, non-travel substitution and mode substitution that may also be adopted to describe substitutions in other categories of fuel use. Using the example of road transport, diesel is the most prominent fuel used and likely to be most heavily impacted by the removal of fossil fuel subsidies. Fuel switching in this context is calculated using the method outlined in equations 3-7 in Appendix II.

To summarise the methodology described in Appendix II; the availability of road transport modal substitutes is reflected in the positive cross price elasticity of demand between transit and fuel. Increases in fuel prices result in higher volumes of people availing of transit options. A moderate Cross Price elasticity of 0.2 is applied in the short run and 0.5 in the long run, based on Nowak and Savage (2013) and Holmgren (2007). When adjusting our energy balance projections, we then move a portion of reduced diesel demand to public transport in accordance with this elasticity figure. Of the remaining diesel abated, we consider two possible switches. Active transport methods and vehicles with alternative fuel types. Applying a conservative vehicle to active ratio of 83:17 (based on 2016 census national commuting profile) the remaining reductions are assigned to car transport and active transport. Car transport fuel demand is adjusted for the relative efficiency of engine and fuel types and assigned to either petrol, biofuel, or electricity, in accordance with the shares of each fuel projected by the EPA in the WEM[25] projections.

In the residential sector, improvements in fabric efficiency of buildings are built into the baseline projections. Our estimates assume that the average level of comfort in our baseline is maintained across each household, with reductions in affected fuels manifesting in increases in biomass, natural gas, electricity, and renewable use. In

[25] EPA With Existing Measures projections (WEM) and With Additional Measures projections represent (broadly) current agreed policies and additional *planned* policies respectively.

addition to the EPA's WAM projections we estimate market and legislative changes related to the supply of solid fuels. These include the 2022 solid fuel regulation[26]. We initially project affected smoky coal and on-market peat use to transfer to low-smoke coal and biomass at a ratio consistent with their respective shares in the EPA projection.

Allowing for the fuel switch, we run our scenarios based on the elasticities and price changes identified above. Reduced demand of affected fuel is screened as a potential secondary fuel. This includes low-smoke coal and peat. The share of each of these fuels used as secondary fuel is estimated using the SEAI's anonymised BER dataset in conjunction with 2016 census data. Estimated secondary fuel use transfers exclusively to biomass as this is considered the only credible substitute to coal and peat where price is not affected by the removal of subsidies. The remaining fuel i.e., fuel used as a primary fuel, is adjusted for efficiency, and transferred from coal, peat, kerosene and gas oil to natural gas, biomass, renewables, and electricity (heat pumps) using the projected share from the EPA projections. In the case of our other monitored sectors including road haulage, fuel and mode switch options are more limited. As such in these cases, we assume that reductions occurring due to the removal of subsidies account for reduced demand of consumers at this higher price point as well as improvements in efficiency from suppliers.

6.8. Emissions Abatement

The second effect assessed in this section is the impact on fossil fuel consumption and emissions that could be associated with the removal of fossil fuel subsidies. This has been based on the price elasticities from the literature that have been assigned into ranged categories of low, moderate, or high response scenarios. Our findings, as presented in this section demonstrate that a policy of removing the identified fossil fuel subsidies can deliver reductions of CO_2 as well as impacting on NO_x and $PM_{2.5}$ emissions. Our three scenarios project notable reductions in CO_2 and NO_x emissions over the analysis period, with slight increases projected in $PM_{2.5}$. The distinctive trend line represents the switching from short-run to long-run effects after two years and allows an easy interpretation of how the scale of impact may differ where we expect either short or long run elasticity values to prevail over time.

The reasoning behind the projected increase in $PM_{2.5}$ emissions over the analysis period is as follows. Coal and peat use is projected to decline as the national solid fuel regulations are introduced, as such, later in the assessment period the majority of the fuel reduced is oil which has a lower $PM_{2.5}$ emission factor than the solid fuels. This is partially replaced with electricity, but also biomass which presents higher $PM_{2.5}$ emission factors. In the case of CO_2 (Figure 10), and NO_x (Figure 11), we see overall reductions, peaking in 2025 when we anticipate sustained long run impacts to kick in. These reductions are slightly less pronounced later in the assessment period as baseline fossil fuel use is projected to decrease independent of the removal of subsidies.

Under the moderate scenario we see reductions in the residential, road transport and aviation sectors of 5.39% of CO_2 emissions over the analysis period (2023-2040), with the most pronounced reductions in the residential sector (12.71%). Similarly, we see reductions of 6.25% of national NO_X emissions over the analysis period, with the largest

[26] Solid Fuel Regulation - Gov.ie (2022)

reductions in the residential sector (15.73%). Regarding $PM_{2.5}$ emissions, we observe reductions of 7.98% and 1.83% in the aviation and road sectors respectively, with a slight increase in the residential sector (2.81%), amounting to an increase of 1.43% across the three sectors.

Figure 10: CO_2 abated Time series 2023-2040 (Kilotonnes)

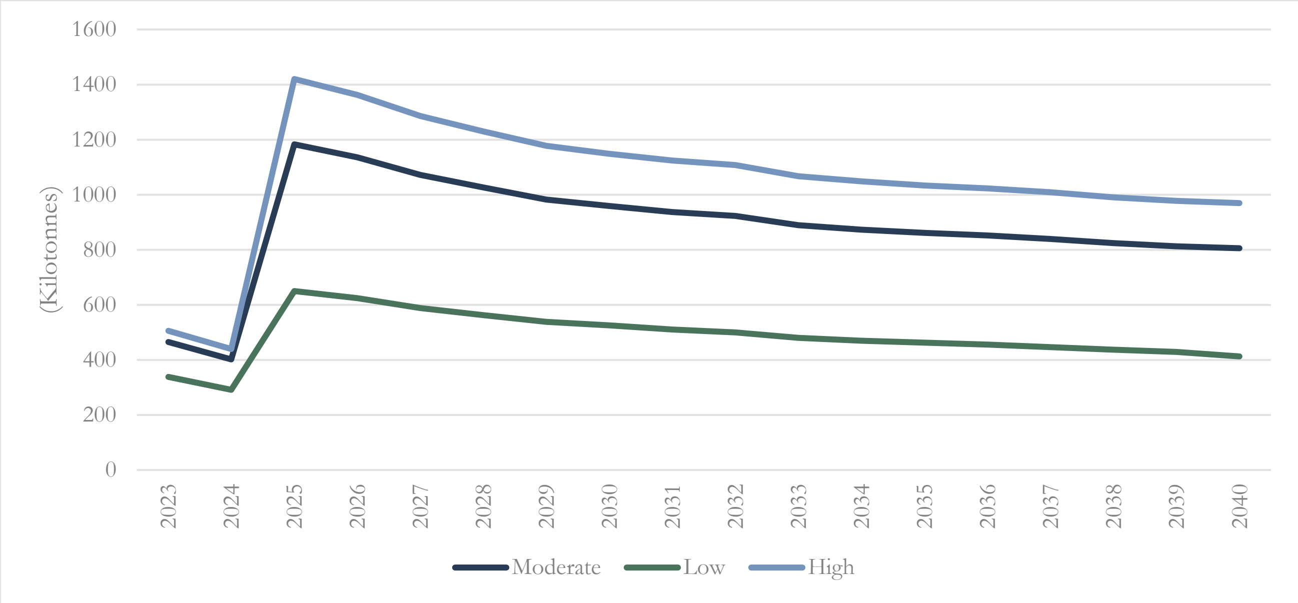


Figure 11: NO_x abated Time Series 2023-2040 (Tonnes)

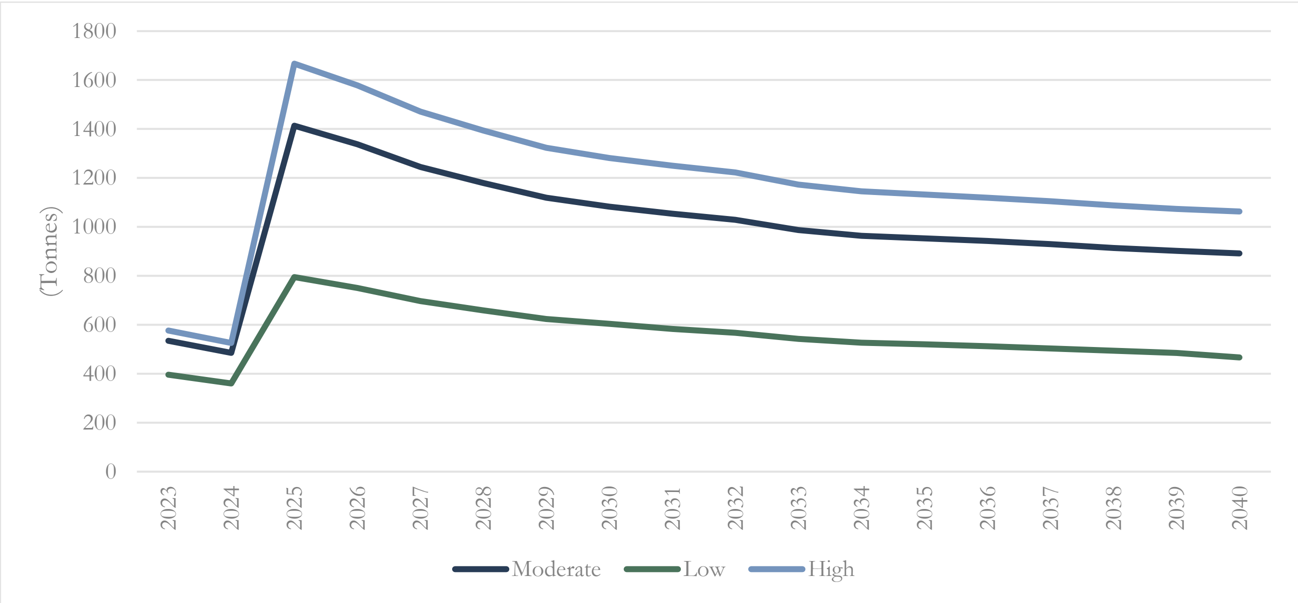
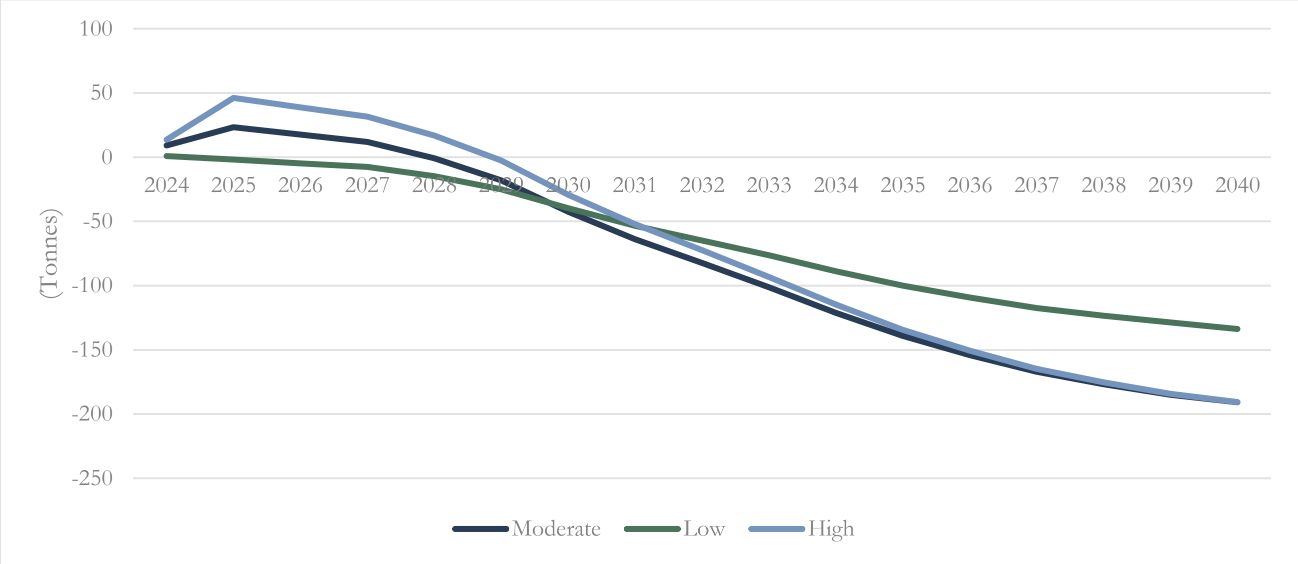


Figure 12: $PM_{2.5}$ abated time series* (Tonnes)



*** The 2023 period includes BNM peat briquettes which are to be phased out by 2024. To avoid distortion, we use a 2024 Time series.**

Tables 14, 15 and 16, showcase the reductions forecast in the road transport, aviation and residential sectors under each scenario as compared with our baseline. These highlight the substantial benefits in achieving national reduction targets that can be realized from the the removal of the identified fossil fuel subsidies. Figure 13 focuses on CO_2 emissions, providing an alternative visual representation of the data outlined in Table 14 on cumulative emission reductions across time periods and sectors. Selected notes on Figure 13 and Table 14 are as follows:

- The impact on emissions in the different periods (e.g. 2^{nd} carbon budget period) should be considered.
- The scale of reductions in aviation emissions in the high response scenario indicates how impactful the pass-through rate of the tax is. The elasticity (0.9) and pass-through rate (100%) are more extreme and thus should be interpreted with caution.
- In the road transport sector, the limited uptake of public transport in our low scenario further supports the need for complementary actions in this area such that we may align fossil fuel subsidy reform with the CAP ambition of 500,000 more active-transit and public transport trips per day.
- Despite the removal of subsidies having an impact on reducing diesel consumption, the modest road transport reductions outlined in tables reflect both the more moderate price increases in this sector, the inelasticity of demand and the assumption that projected fuel and modal switches will not maximize the abatement potential of the price induced diesel displacement. Our analysis suggests that improved uptake of active transit and low carbon fuel options will further improve outcomes in this sector.
- The residential sector has options to switch away from fossil fuels. However, care should be taken to avoid this fuel switch having an unintended negative impact on either air quality and energy poverty risk.

- In this sector it is worth noting that the most significant reduction of emissions occur in the middle of the assessment period with CO_2 emissions reductions somewhat less pronounced in the 2036-2040 period. This is reflective of the EPA's WEM projection which we use for our baseline. This forecasts reduced demand for fossil fuels in the sector by this time with increased electrification complemented by reduced upstream electricity generation emissions. This is an example of how policies which support decarbonized electricity and low-carbon solutions in the residential sector can operate in a synergistic manner.

Figure 13: Reductions in CO_2 emissions by sector 2023-2040

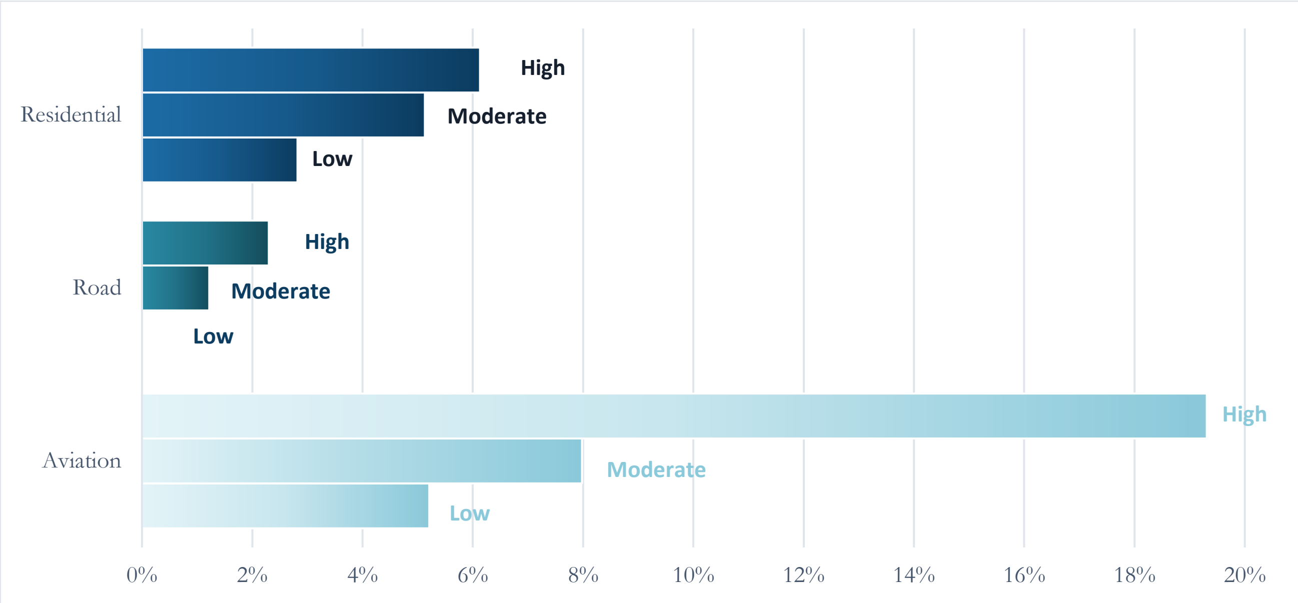


Table 14: CO_2 Emissions Reductions in Assessed Sectors Relative to Baseline[27]

	CO_2 Reductions				
	2023-2025	2026-2030	2031-3035	2036-2040	Overall
Residential					
Moderate	8.79%	15.58%	13.50%	11.86%	12.71%
Low	6.27%	9.80%	8.50%	7.46%	8.14%
High	9.27%	16.68%	14.46%	12.70%	13.59%
Road					
Moderate	0.68%	1.20%	1.35%	1.56%	1.22%

[27] It should be noted that the percentage reduction of aviation emissions are repeated across all three pollutants. This is due to the relative consistency in projecting activity in this sector as compared to others. There is no fuel or modal switching in this context and as such the percentage reductions in activity are directly proportionate to elasticities.

Low	-0.02%	0.00%	0.03%	0.07%	0.02%
High	1.25%	2.40%	2.54%	2.80%	2.30%
Aviation					
Moderate	2.29%	8.86%	10.00%	8.84%	7.98%
Low	1.50%	5.79%	6.53%	5.77%	5.21%
High	5.54%	21.44%	24.18%	21.37%	19.31%
Total					
Moderate	3.55%	6.1%	5.77%	5.6%	5.39%
Low	2.22%	3.35%	3.12%	2.95%	2.97%
High	4.10%	7.31%	6.93%	6.73%	6.43%

Table 15: NO_x Emissions Reductions in Assessed Sectors Relative to Baseline

NO_x Reductions					
	2023-2025	**2026-2030**	**2031-3035**	**2036-2040**	**Overall**
Residential					
Moderate	11.63%	18.83%	16.40%	14.67%	15.73%
Low	8.28%	11.85%	10.32%	9.23%	10.08%
High	12.27%	20.16%	17.56%	15.71%	16.81%
Road					
Moderate	0.68%	1.20%	1.35%	1.56%	1.22%
Low	-0.02%	0.00%	0.03%	0.07%	0.02%
High	1.25%	2.40%	2.54%	2.80%	2.30%
Aviation					
Moderate	2.29%	8.86%	10.00%	8.84%	7.98%
Low	1.50%	5.79%	6.53%	5.77%	5.21%
High	5.54%	21.44%	24.18%	21.37%	19.31%
Total					
Moderate	4.35%	7.09%	6.58%	6.41%	6.25%
Low	2.77%	3.97%	3.62%	3.45%	3.51%
High	4.95%	8.38%	7.82%	7.63%	7.38%

Table 16: $PM_{2.5}$ Emissions Reductions in Assessed Sectors Relative to Baseline

$PM_{2.5}$ Reductions					
	2023-2025	2026-2030	2031-3035	2036-2040	Overall
Residential					
Moderate	3.63%	-1.15%	-4.78%	-6.84%	-2.81%
Low	3.01%	-0.72%	-3.01%	-4.30%	-1.63%
High	3.75%	-1.23%	-5.12%	-7.32%	-3.04%
Road					
Moderate	1.11%	1.92%	2.00%	2.16%	1.83%
Low	0.09%	0.08%	0.10%	0.13%	0.10%
High	1.86%	3.44%	3.48%	3.68%	3.19%
Aviation					
Moderate	2.29%	8.86%	10.00%	8.84%	7.98%
Low	1.50%	5.79%	6.53%	5.77%	5.21%
High	5.54%	21.44%	24.18%	21.37%	19.31%
Total					
Moderate	2.85%	-0.16%	-2.74%	-4.5%	-1.43%
Low	2.1%	-0.46%	-2.07%	-3.16%	-1.12%
High	3.16%	0.28%	-2.52%	-4.46%	-1.18%

Table 17: Contribution to Overall CO_2 Emissions 2040

	National CO_2 Shares 2040 (kt CO_2)		
	Road Transport share of National Total CO_2		
	Road Transport	Total	% Share
2040 Baseline	7775 kt	25507 kt	30.48%
2040 Moderate	7645 kt	24851 kt	30.76%
	Residential share of National Total CO_2		
	Residential	Total	% Share
2040 Baseline	4144 kt	25507 kt	16.25%
2040 Moderate	3851 kt	24851 kt	15.10%
	Aviation share of National Total CO_2*		

	Aviation	Total	% Share
2040 Baseline	2766 kt	25507 kt	10.84%
2040 Moderate	2533 kt	24851 kt	10.19%

***International Aviation is subject to alternate reporting rules, as such shares of total emissions are indicative rather than representative of actual emissions inventories**

Figure 14: Projected Transport Fuel Switch Scenario 2040

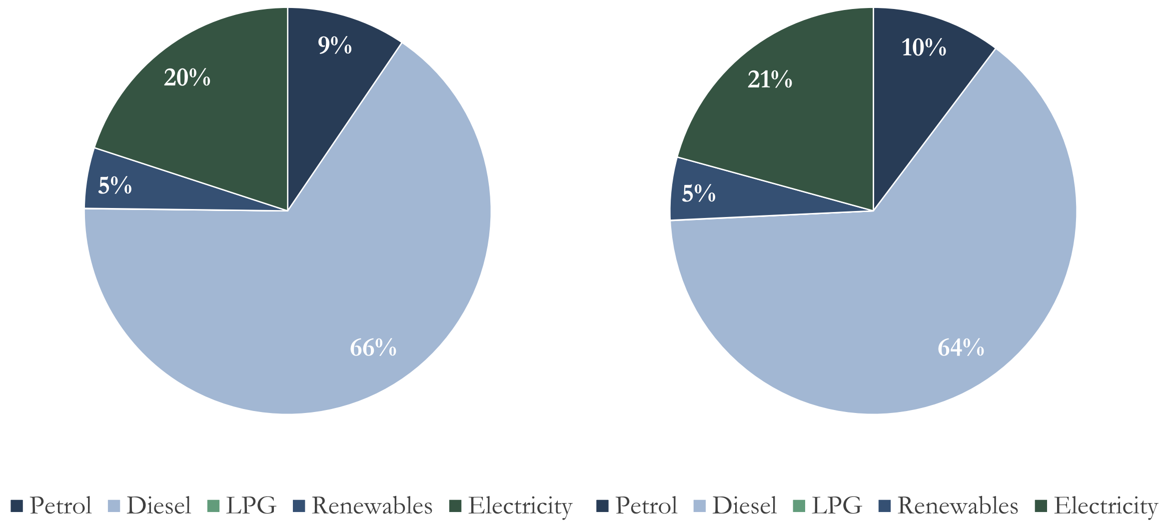
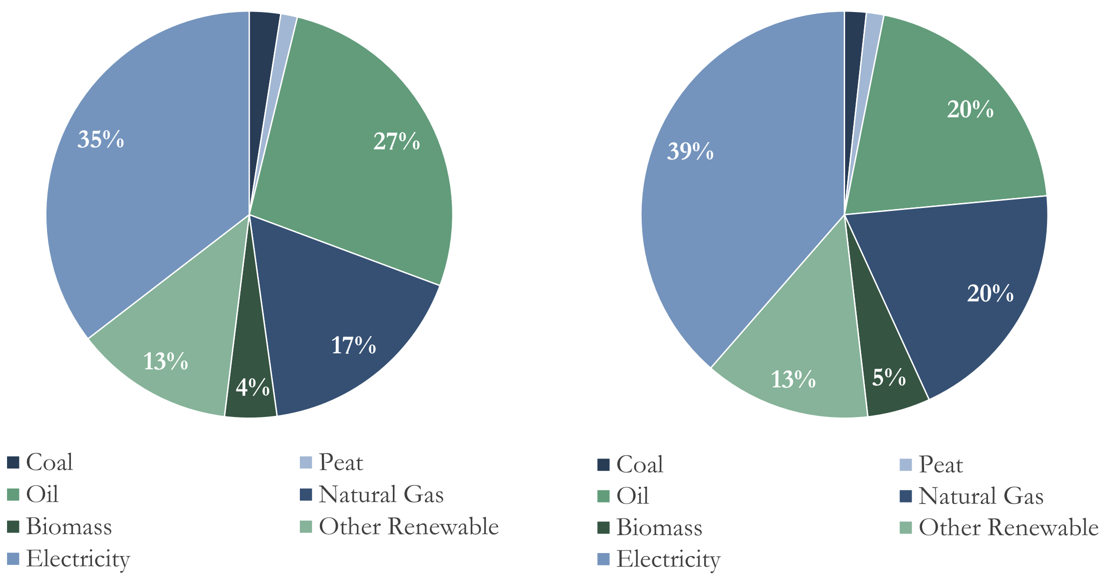


Figure 15: Projected Residential Fuel Switch 2040



In contributing to the overall reductions in the gases and pollutants outlined above, a policy of removing subsidies on fossil fuels will have a mixed impact on the contribution of sectors directly affected. Table 17 outlines the overall impact of the removal of subsidies, highlighting how such a policy would impact the three key affected sectors contribution to national CO_2 emissions. It should be noted that complementary policies (e.g. CAP actions) and spill-over effects (e.g. behavioural change) would be expected to offer synergistic outcomes to complement fossil fuel subsidy reform. Figures 14 and 15 offer added detail on the potential fuel switches between the baseline and moderate scenario to 2040.

Table 18: Total CO_2 Emissions and Reduction in GHGs (non-ETS)

	2023-2025	2026-2030	2031-2035	2036-2040	Total
Total (kilotonnes)	**-2050**	**-5174**	**-4482**	**-4133**	**-15839**
Total (reduction of GHGs)	*1.5%*	*2.4%*	*2.2%*	*2.1%*	*2.1%*
Road Transport (Kt)	**-252**	**-669**	**-663**	**-701**	**-2285**
Road Transport (%)	*0.2%*	*0.3%*	*0.3%*	*0.4%*	*0.3%*
Aviation (Kt)	**-5**	**-30**	**-31**	**-28**	**-94**
Aviation (%)	*0.0%*	*0.01%*	*0.02%*	*0.01%*	*0.01%*
Residential (Kt)	**-1793**	**-4475**	**-3788**	**-3404**	**-13460**
Residential (%)	*1.3%*	*2.1%*	*1.9%*	*1.7%*	*1.8%*

In a broader emissions context Table 18 outlines the projected impact of the policy for fossil fuel subsidy reforms on reducing non-ETS GHGs in the Non-ETS sector. The modest figures in this context are reflective of some of the factors discussed above including the inelasticity of these types of demand, the application of moderate elasticties from the ranges and suboptimal fuel switch scenarios. The direction of impacts however, highlights how the policy of removing fuel subsidies can function as a market-based complement to wider policy ambitions in the transport and residential sectors.

7. Impact Assessment

This section addresses the fifth task defined by the Council and quantifies the economic and welfare impacts of the phase-down or phase-out of the most significant fossil fuel subsidies. It examines and estimates the Production Tax Rate and Sales Tax Rate (the I3E policy variables in the ESRI model) channel effects on macro aggregates, household real disposable income and welfare effects.

7.1. The Rationale of STR and PTR

The ESRI (2019) paper applies the I3E (Ireland Economy-Environment-Energy) model to estimate the economic and environmental implications of removing the eight most significant fossil fuel subsidies, according to their monetary cost provided by CSO, that represent a considerable share of fossil fuel subsidies within the Irish economy[28]. The eight subsidies considered include: electricity generation from peat, security of electricity supply, excise exemption on aviation fuel, diesel rebate scheme, excise exemption on auto diesel, excise exemption on auto diesel, excise exemption on fuel oil, and excise exemption on kerosene. One category of subsidies refers to direct fossil fuel subsidies, which promote the usage of fossil fuels in general, while the second category refers to indirect fossil fuel subsidies, which encourage the increased consumption of environmentally harmful fossil fuels and/or underpins environmentally harmful practices.

The CSO estimate that environmentally damaging fossil fuel subsidies amounted to almost €4.2 billion in 2014, and €4.1 billion in 2016 of which €1.8 billion were direct subsidies and €2.3 billion were indirect subsides. The most recent CSO estimates indicate that total fossil fuel subsidies were €2.8 billion in 2019, decreasing to €2.2 billion in 2020 due to the COVID-19 pandemic. In the same year, total fossil fuel subsidies were estimated to be 13% in direct subsidies and 86% in indirect subsidies.

Table 19: The I3E policy variables connected to the respective removed subsidy:

I3E Policy Variable	Removed Subsidy
Production Tax Rate (PTR)	Electricity Generation from Peat, Security of Electricity Supply, Excise Exemption on Aviation Fuel, and Diesel Rebate Scheme.
Sales Tax Rate (STR)	Excise exemption on Auto Diesel, Excise Exemption on Marked & Auto Diesel, Excise Exemption on Fuel Oil, and Excise Exemption on Kerosene.

The subsidies removed in the I3E model are listed in Table 19 alongside the two policy variables which they are connected to within the I3E model, the Production Tax Rate (PTR) and the Sales Tax Rate (STR). The PTR is an activity-specific variable paid by the activity to the government over the monetary value of total production, while the STR is a commodity-specific variable that is paid by commodity to the government over the value of total domestic sales. Sectoral production subsidies decrease the cost of production, supporting lower domestic prices, and improving the competitive situation of the country in international markets. Subsidies on commodities decrease the retail prices of energy goods through a lower excise tax burden. In the I3E model, the removal of sectoral production subsidies are translated as increases in the PTR whilst the removal of commodity-related subsidies are translated as increases in the STRs of the government. Equations 8-11 in Appendix III illustrate how these two policy variables, PTR and STR are introduced into the I3E model, and how the removal of those subsidies affect

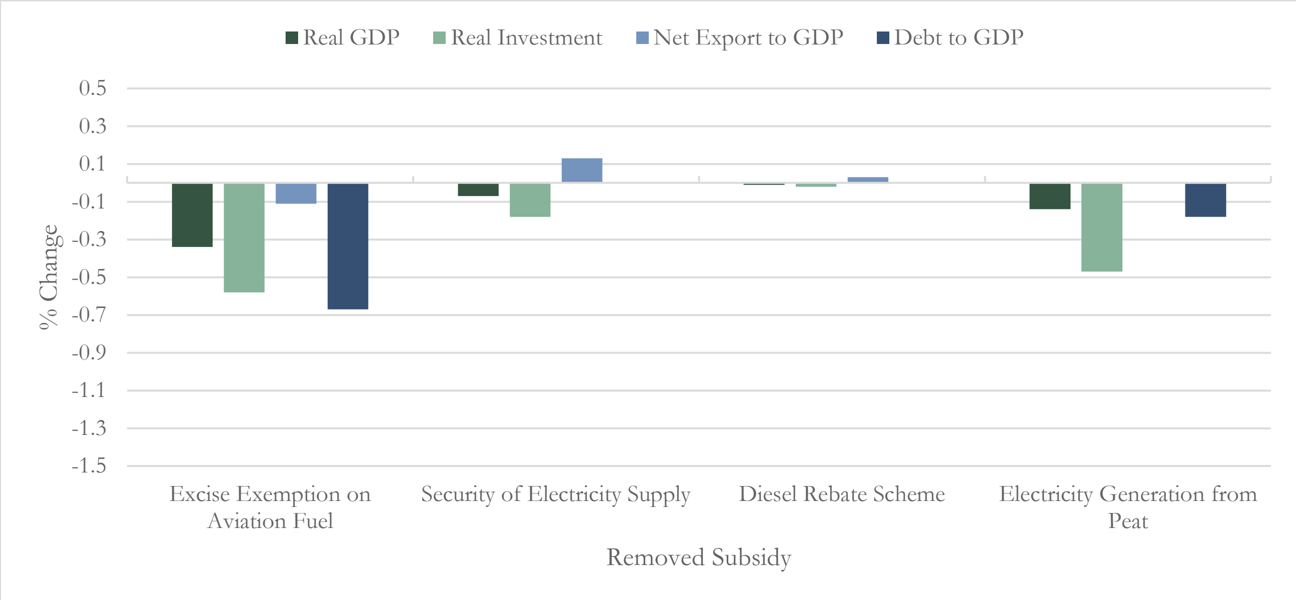
[28] The eight fossil fuel subsidies accounted for 96% in 2014.

economic activity in Ireland, through the total volume of production, in the first instance, and subsequently through government revenues.

7.2. Macro impacts

We collate and analyse data produced by ESRI (2019) concerning the macroeconomic implications of removing fossil fuel subsidies to demonstrate which set of fossil fuel subsidies, either sectoral production subsidies or commodity-related subsidies induce the most adverse, minor, or neutral consequences on macroeconomic aggregates, such as real GDP, real investment, net export-to-GDP ratio and debt-to-GDP ratio. See Appendix IV for additional detail on the methodology (Equations 12-16). Appendix V provides detailed macroeconomic results.

Figure 16: Macroeconomic impacts coming from PTR I3E policy variable



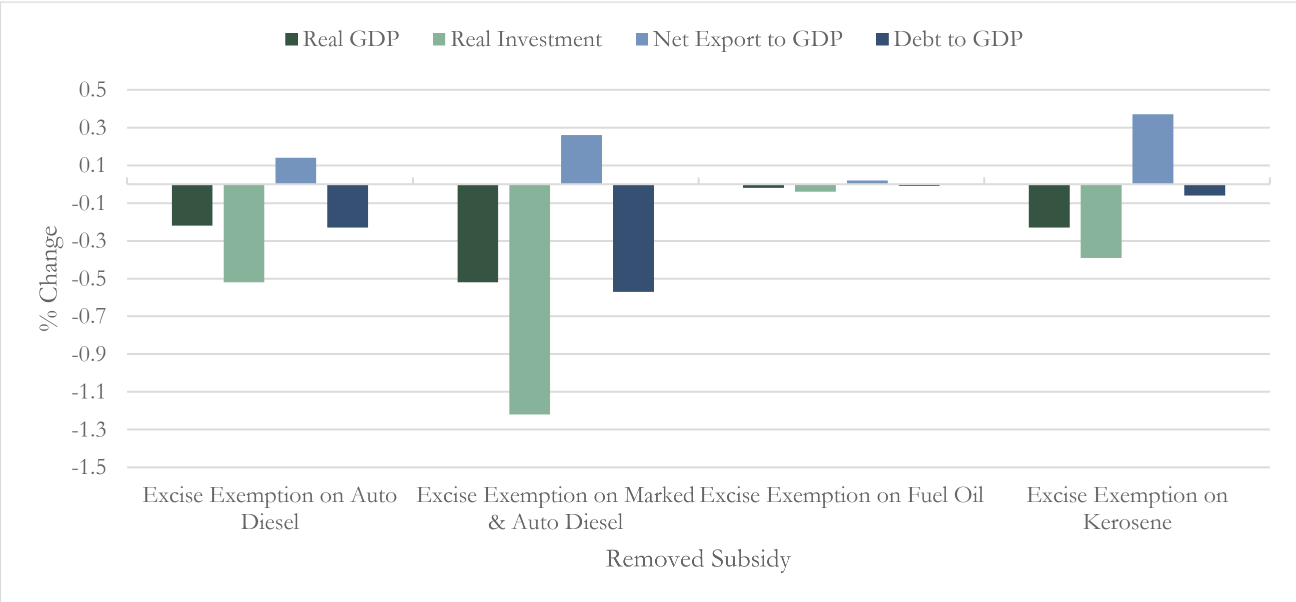
Source: ESRI (2019)

When fossil fuel subsidies are removed the economy will experience slight output declines. The driving factor of the fall in GDP is the quantity impact that compresses the price of commodities in the sector. In other words, the higher production costs squeeze the price mechanism, contributing to a deterioration of economic activity in the sector. In this context, both sectoral production subsidies and commodity-related subsidies can induce minor reductions in terms of real GDP. Comparing the aggregate effects of the two policy variables, PTR and STR, the removal of commodity-related subsidies is noted to bring on slightly higher negative effects on real GDP (-0.99%) in 2030 as compared to sectoral production subsidies (-0.56%).

As Figure 16 illustrates for the PTR, the removal of the excise exemption on aviation fuel is expected to reduce GDP by 0.34% to 2030 while the removal of electricity generation from peat is projected to also result in a slight fall in GDP (0.14%) to 2030. Figure 17 presents similar outcomes regarding the minor falls in GDP for the STR policy variable where the removal of excise exemption for kerosene leads to a minor decrease in GDP (0.23%) while the removal of the excise exemption on marked & auto diesel is results in a further decline in GDP (0.52%).

Figure 16 shows that the removal of the excise exemption on aviation fuel reduces real investment by 0.58% and removing the electricity generation from peat reduces real investment by 0.47% in 2030. The aggregate effect on real investment of removing jointly all of the sectoral production subsidies covered by PTR policy variable is estimated as -1.25%. The outcomes regarding the other set of commodity-related subsidies covered by STR policy variable (Figure 17) are not very different, with the removal of the excise exemption on auto diesel expected to reduce real investment by 0.52% while the removal of the excise exemption on marked & auto diesel is projected to reduce real investment by 1.22% up to 2030. The aggregate effect of STR on real investment is estimated at -2.17% to 2030. We can conclude that the effects of the removed commodity-related subsidies covered by STR are higher compared to the aggregate effects of removed sectoral production subsidies covered by PTR in the long-run.

Figure 17: Macroeconomic Impacts Coming from I3E STR Policy Variable



Source: ESRI (2019)

As with investment effects, the fall in nominal GDP triggered by the removal of fossil fuel subsidies shrinks the net exports of the Irish economy. Notably, the trade balance worsens as the elimination of the subsidies triggers higher prices in the domestic economy. Such effects are to be expected as the domestic sectors would experience higher energy costs with the removal of the fossil fuel subsidies, which in turn lead to higher retail prices, thereby reducing the export side of the trade balance in the Irish economy to the global markets. From this perspective, competitiveness losses[29] are also likely to be recorded in the trade balance, and the scale of them depends on the subsidy's relevance in the Irish economy. For instance, if the Irish economy has a relatively high rate on fossil fuel subsidies, its economy will suffer more from the competitiveness losses of the subsidy removal.

Taking the absolute terms of nominal GDP and net exports ratio, with the growth rate of nominal GDP to be higher than the net exports, we could expect that the net export-to-GDP ratio is improved in all cases, apart from the excise exemption on aviation fuel which is expected to decrease -0.11% (Figure 16). Overall, the removal of all commodity-related subsidies will bring about a larger positive effect on net exports-to-GDP at 0.79% (Figure 17) compared to removal of sectoral production-related commodities that account for 0.05% in the net exports-to-GDP (Figure 16). The effects of removed subsidies, such as the diesel rebate scheme, electricity generation from peat, excise exemption on auto diesel, as well as excise exemption on fuel oil all have negligible repercussions on the net exports-to-GDP ratio. In relation to government foreign debt stock to GDP ratio, in all cases both sectoral production subsidies and commodity-related subsidies produce positive but minor impacts on debt to GDP by 2030. The deterioration of economic activity forces the government to reduce expenditure to the economy[30].

7.3. Household and Welfare Impacts

We assess the changes in household real disposable income changes induced by the removal of fossil fuel subsidies. However, we generally exempt targeted energy allowances to households given their importance to considerations around equity and a just transition. We examine the household impacts across two groups: urban households and rural households. As Figure 18 demonstrates, the phasing out of sectoral production subsidies covered by PTR policy variables seems to have negative but modest effects both on rural and urban household's real disposable income. Excise exemption on aviation fuel calculated for rural and urban groups at -1.08%, and -0.97%, respectively, represent the highest adverse effect in this set of fossil fuel subsidies.

The removal of commodity-related subsidies, as Figure 19 illustrates, has a slight negative impact on the real disposable income of households. The highest adverse impact here is recorded by the removal of the excise exemption on marked and auto diesel subsidy in both household's groups, -1.2% (rural), and -1.26% (urban) correspondingly and is followed by the excise exemption on kerosene and excise exemption on auto diesel. Overall, we can conclude that the adverse effects of removed fossil fuel subsidies on household's real disposable income are higher (-2.38% for rural households and -2.45% for urban households) when the government decides to remove commodity-related subsidies (Figure 19), and thus increase its STR, as compared to the effects caused by the removal of production subsidies at -1.83% for rural households, and -1.7% for urban households (Figure 18).

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[29] Competitive losses occurred due to the changes in relative prices after the removal of fossil fuel subsidies (Boqiang L., and Aijun L., 2012).

[30] There is a positive relationship between nominal GDP and government demand for goods and services. This positive relationship is presented in equation (8).

The effects are far more severe should the government eliminate all energy allowances to households. Such a policy would impact dramatically, and disproportionately against household's (specifically rural households) real disposable income. The removal of energy allowances reduces rural real disposable income by -6.37% and the corresponding urban value by -0.43%. It is important to highlight that the decrease in real disposable income of households can be explained and attributed to the fall of real GDP in the Irish economy due to the removal of fossil fuel subsidies.

Figure 18: Household impacts coming from PTR in terms of real disposable income in 2030.

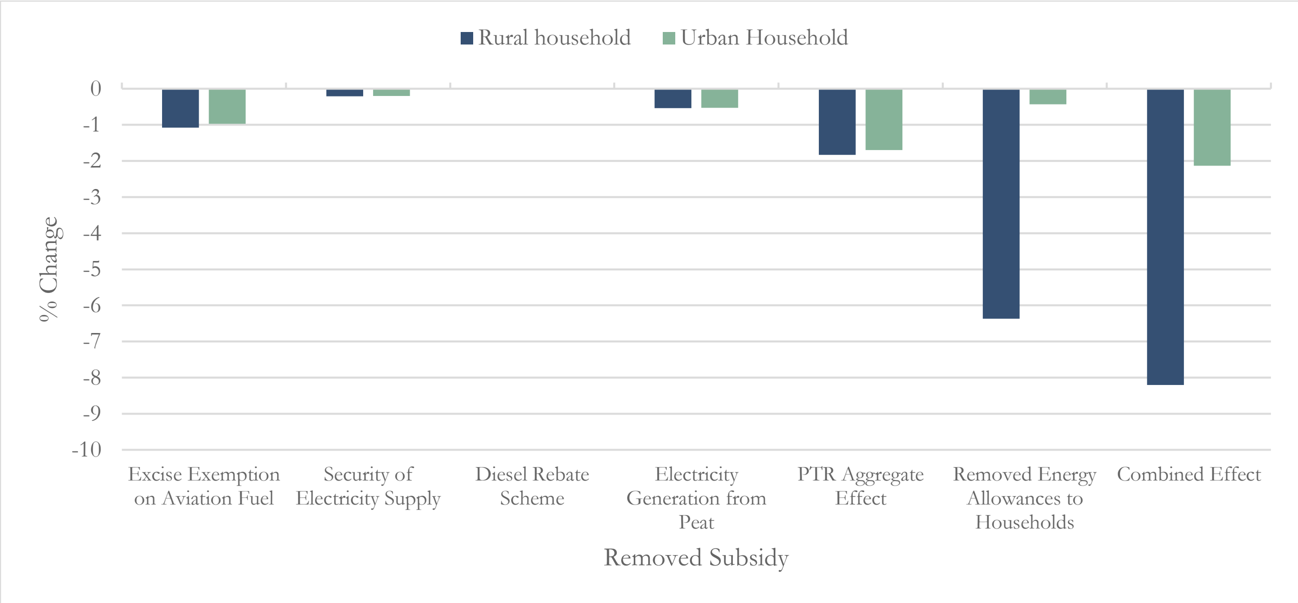
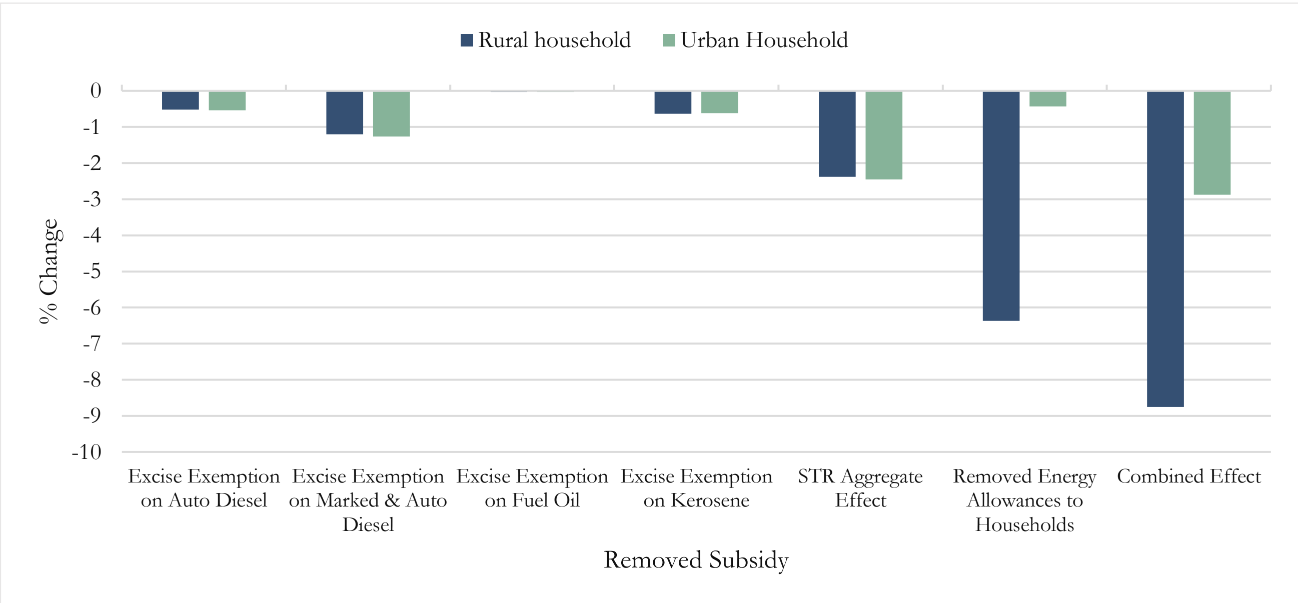


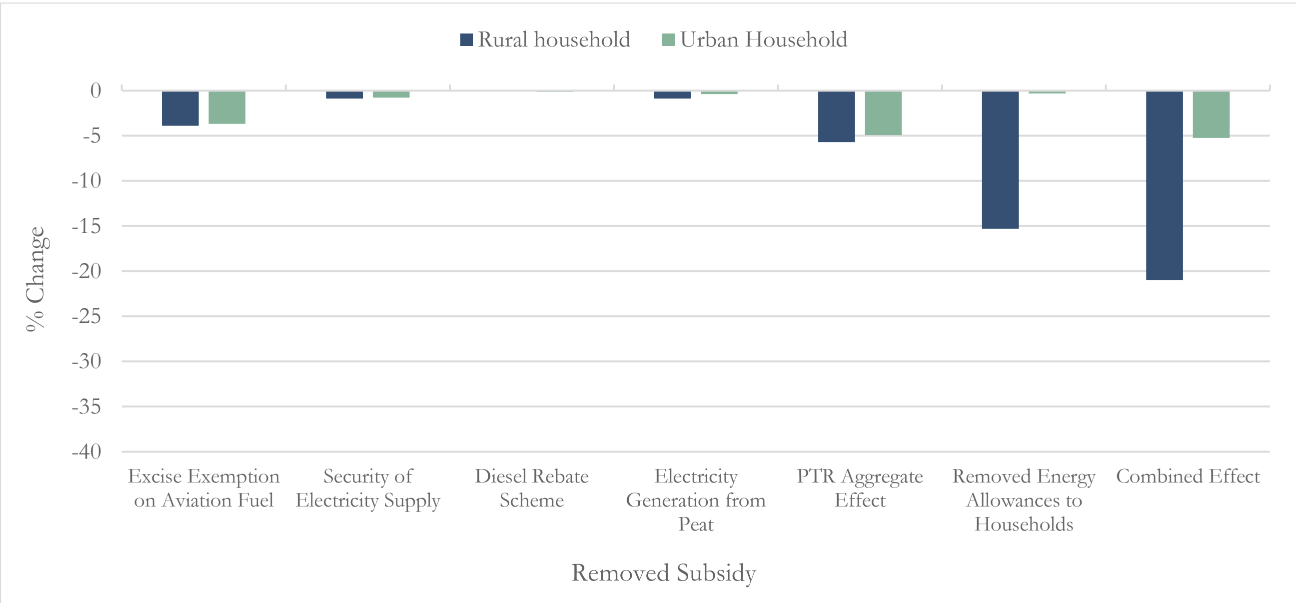
Figure 19: Household impacts coming from STR in terms of real disposable income in 2030.



Utilising the methodology of Equivalent Variation[31], ESRI (2019) estimated the repercussions of removing fossil fuel subsidies on rural and urban household's welfare. We harness these estimates to illustrate the welfare effects induced by the phasing out of sectoral production subsidies and commodity-related subsidies. In the first instance, all households are worse off in terms of welfare following the removal of fossil fuel subsidies. Sectoral production subsidies (Figure 20) outcomes show that the removal of excise exemptions for aviation fuel documented the highest adverse effect (-3.89% for rural households, and -3.68% for urban households) in comparison to other subsidies within the same set of the PTR policy variable. On the other hand, the removal of commodity-related subsidies (Figure 21) introduces more adverse and intense effects for households. For example, the removal of the excise exemption on marked and auto diesel had the highest impact on rural (-8.85%) and urban (-4.56%) households in the context of welfare impacts coming from the STR policy variable, followed by the removal of the excise exemption on kerosene at -6.76% for rural households and -3.67% for urban households.

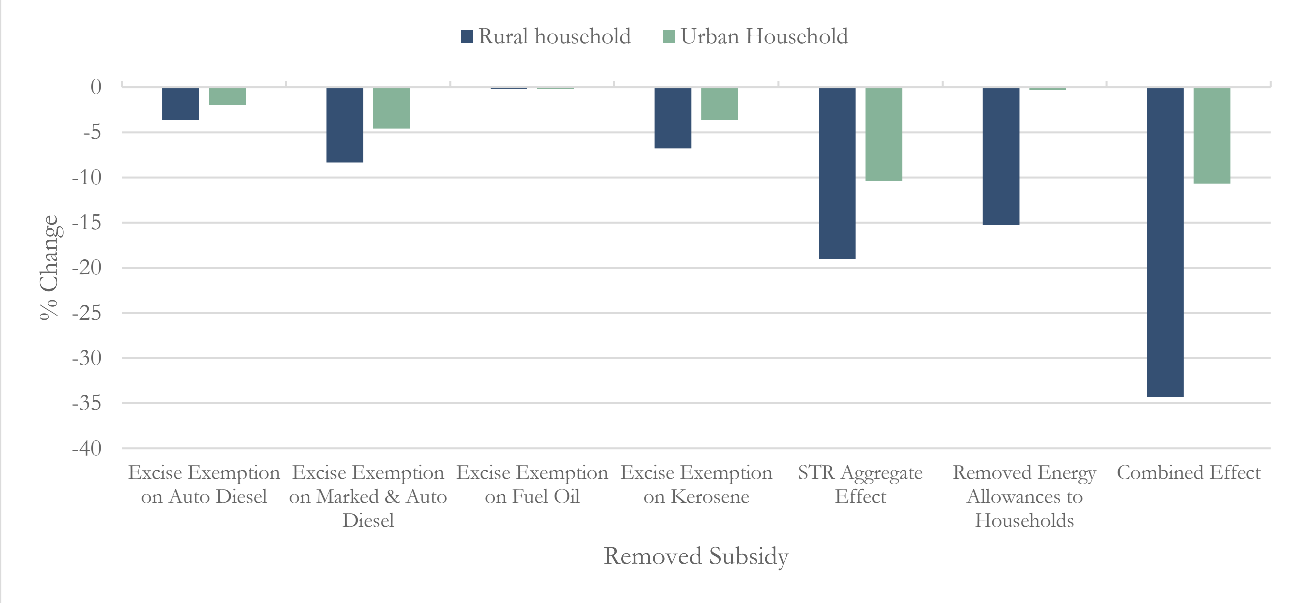
As illustrated by Figures 20 and 21 the reform of commodity-related subsidies (Figure 21) leads to more adverse and regressive effects (-19% for rural households and-10.37% for urban households) on household welfare in contrast to sectoral production subsidies (Figure 20) (-5.68% for rural households and -4.92% for urban households). If the government were to eliminate all energy allowances to households, this could heighten the adverse effects on welfare for both rural and urban households, affecting rural welfare disproportionately. This policy reduces the rural welfare by -15.3% and urban welfare by -0.31%.

Figure 20: Welfare impacts coming from PTR policy variable in 2030.



[31] Equivalent Variation is the adjustment in income that changes the consumer's utility equal to the level that would be achieved if another event had occurred.

Figure 21: Welfare impacts coming from STR policy variable in 2030.



It is worthwhile to point out some caveats about the I3E model and its methodology. Like all CGE models, the I3E methodology makes assumptions which we consider important to flag in this impact assessment section. First of all, the I3E model calculates all the intersectoral linkages and relationships among economic agents on the single-year data (base year – 2014). For this specific report that means COVID-shocks, energy balances shifts, the Russian war in Ukraine and the induced high energy prices have not been included. In general, the interpretation of the results for the economic system should be therefore recognise these constant elements.

Secondly, most CGE models assume that commodities imported and exported are imperfect substitutes of domestically produced and used commodities. The imported and domestically produced commodities are transformed into a new composite commodity under constant returns to scale. This can result in an overestimation of terms of trade effects.

Thirdly, the I3E model assumes perfect competition without any market failures and non-convexities in the production process. Nevertheless, the majority of traded commodities are exchanged under non-perfect competition. Another shortcoming of CGE models is the existence of uncertainty over parameters, the specification and the experimental design. This uncertainty may result in a range of biases.

Lastly, it is argued that the computational approach to economic policy analysis of capturing all sectors of the economy may lead to a loss of important components of sectors, overlooking critical effects in the effort to cover the aggregate picture of the economic system. However, in spite of these caveats, such systems can offer some perspective and scale to potential interactions and outcomes that are relevant to the appraisal of any related policy interventions around fossil fuel subsidy reform.

8. Policy Design

The analysis presented in section six is clear that the reform of fossil fuel subsidies could yield overall emission reductions and can thereby support national emissions abatement targets. In addition, section seven offers insights that fossil fuel subsidy reform can deliver budgetary improvements through reduced government expenditures. The analysis in section seven then highlights the estimated scale of various macroeconomic effects that may be associated with the removal of various subsidies. Building from the foundation of international evidence and strategies for the phasedown of fossil fuel subsidies - established in section two - this section now proposes strategies for the phasedown of fossil fuel subsidies in Ireland.

As outlined in section two, the G20 countries have established and implemented a framework for voluntary, country-led peer assessments of fossil-fuel subsidies as a means of increasing transparency and accountability (OECD/IEA, 2021). This section will be informed by the results of that work as well as the broader academic literature and government reports related to fossil fuel subsidy reform. All completed tasks feed into this section and inform its proposals, in particular the earlier identified four-step process for fossil fuel subsidy reform. The overall broad summary recommendations are presented at the outset in the box below.

Summary Recommendations for the Reform of Fossil Fuel Subsidies:

- It is recommended that a clear definition of fossil fuel subsidies in an Irish context be adopted. This should include tax expenditures and direct transfers.
- It is recommended that the 'Sequential Approach' be employed to guide the reform process.
- It is recommended that fossil fuel subsidies are gradually eliminated to minimise effects on macroeconomic variables.
- It is recommended that stakeholder engagement and transparent reporting be prioritised from the very beginning of the reform process and that engagement is continued throughout. This will support acceptability and allow time for revisions to strategy and appropriate investment responses.
- It is recommended that direct energy supports to households are **not** removed for the foreseeable future. The removal of such supports would impact energy poverty risk to the most vulnerable and presents substantial negative macro impacts.
- It is recommended that further complementary targeted measures are implemented to mitigate the negative effects of any reform process on groups most adversely impacted.
- Fossil fuel subsidy reform revenues should be targeted to support the transition using revenue collected prior to reforms, as well as resources saved or generated by eliminating fossil fuel subsidies.

Step 1: Define Fossil Fuel Subsidies

A formal definition has yet to be adopted for fossil-fuel subsidies and therefore countries have adopted individual definitions. As outlined in section two, definitions range from the inclusion of one or multiple categories such as direct budgetary transfers and tax expenditures, to the inclusion of all subsidies to fossil-fuel production and consumption. Government support to fossil fuels in Ireland was estimated at €1.87 billion in 2020. This was exclusively in the form of tax expenditures amounting to €1.58 billion (84%) and direct transfers amounting to €290 million (16%). Therefore, a logical definition of fossil fuel subsidies in an Irish context would include tax expenditures and direct transfers. However, the EU classification of subsidy categories may be adopted to extend this definition to include under-pricing of goods/services, income or price supports, and RD&D.

Step 2: Design the Reform Process

Assessment: The Sequential Approach (outlined initially in Table 2) is recommended by the OECD/IEA (2021) at this stage of the reform. This approach involves ranking subsidies according to their level of distortedness on fossil fuel production so the removal of the most significant subsidies can be prioritised. This four-step approach predicts possible impacts of the reform process and allows for the mitigation of issues. Table 20 discusses this approach as applied to the Irish case and provides recommendations for each stage of the assessment process.

Table 20: Applying The Sequential Approach to the Irish Case

Step in Approach	Irish Context	Recommendation
Identify support measures, document their objectives, and estimate budgetary cost	The CSO regularly release two sets of data providing information on "Environmental Subsidies and Similar Transfers" and "Fossil Fuel Subsidies".	As fossil fuel subsidies, their objectives and budgetary cost are already reported on by the CSO, these data sets can be utilised at this stage of the reform process.
Measure the distortedness of support measures, including their economic, social, and environmental effects.	The ESRI (2019) paper applies the I3E model to estimate the economic and environmental implications of removing the eight most significant fossil fuel subsidies. The results of this paper are discussed further in Section 7.	This official national CGE model should be applied to measure the distortedness of support measures at present and identify the economic, social and environmental impacts of the removal of the most significant fossil fuel subsidies.
Identify the winners and losers of fossil	Section 7 offers results and insights. Clearly, withdrawing government transfers to households poses an energy poverty risk to	EnvEcon's Home-Heating Energy Poverty Risk Index (Kelly et al., 2020) and Transport Poverty Risk Index can be employed to

fuel support reform processes.	the most vulnerable and poorer households. It would affect both rural and urban households, affecting rural welfare disproportionately. As such, it is not recommended to withdraw direct energy supports to households.	identify potential impacts from the reform process by location and can thereby support the spatial targeting of complementary measures to mitigate negative effects in those two key impact areas.
Evaluate alternative policies with better economic, environmental, fiscal, or distributional outcomes.	The main principle of successful reform is the efficient and visible reallocation of resources through complementary measures for groups most adversely impacted. Such policies can be implemented using revenue collected prior to reforms, as well as resources saved or generated by eliminating fossil fuel subsidies.	Revenue collected prior to reforms, as well as resources saved or generated by eliminating subsidies should be reallocated to a number of areas, including active and public transport and the decarbonisation of energy. Additionally, spatially targeted policy measures should be employed to mitigate home-heating energy and transport poverty risk.

Timing: Policy which increases prices always has the potential for political and civil backlash and therefore, identifying favourable timing in this context is essential. It is important to recognise the impact fuel prices can have on determinants of action and to design reform accordingly. As identified in section seven, the gradual elimination of subsidies is expected to minimise impacts on macroeconomic variables. In addition, providing a timeline for the removal of subsidies allows governments to incentivise producers to cut emissions through subsidies while providing them a means to punish producers (by removing their subsidies) if they fail to meet their goals. Such an approach would offer a clear signal on the price trajectory of affected fuels, allowing for an earlier transition to a low-carbon capital stock and reducing the relative incentive of sticking with high carbon transport or heating systems. However, again, aligning the timing of reforms with low or fluctuating international energy prices can minimise price shocks and public opposition (Rentschler & Bazilian, 2017a). For importing countries, such as Ireland, high oil prices increase the need for reform, but can also increase political barriers which can delay action. Low oil prices can reduce political obstacles, making it easier to remove subsidies, however, they may also reduce the fiscal urgency for subsidy reform (Rentschler and Bazilian, 2017b). Climate action imperatives should assist in stimulating greater urgency for action, even at times of low oil prices.

Stakeholders: To design a route for balanced public acceptability, fossil fuel subsidy reform should be accompanied by transparent and broad communication and engagement with a diverse range of stakeholders, including the general public. It is advised that stakeholder engagement is prioritised from the beginning of the reform process and should continue throughout. This will help to achieve policy acceptability and allow time for revisions and investments. There is compelling evidence that clear, transparent, and honest information surrounding the scope of subsidies, their costs and consequences, reform plans, and complementing actions is required for the successful reform of fossil fuel subsidies. Several examples show how a failure to engage and communicate with stakeholders has compromised prior reform attempts (Whitley & Van Der Burg, 2015).

Direct Supports to Households: As identified in section seven, the effect of fossil fuel subsidy reform on the real disposable income of rural and urban households is consistent with the declines in real GDP. However, where energy allowances to households are removed in conjunction with the removal of subsidies, this would be expected to have stronger adverse effects on the real disposable income of households, with worse effects for rural households. Withdrawing government transfers to households poses an energy poverty risk to the most vulnerable and poorer households. The welfare implications of removing such subsidies would be regressive, disproportionately benefiting richer households over poorer households. As such, it is not recommended to withdraw direct energy supports to households (e.g., heating allowance). Moreover, further targeted complementary measures should be introduced to mitigate the effects of fuel price increases for groups most impacted by the reform process. Such policies can be implemented using revenue collected prior to reforms, as well as resources saved or generated by eliminating fossil fuel subsidies. This will be discussed further in step four of this approach.

Step 3: Provide Transparent Reporting and Communication

Clear communication to the public as well as transparency in reporting are important to provide information on the extent to which fossil fuels are subsidised and on how the funds spent on these subsidies can be redirected for other social purposes in the event of reform. Ireland has been cited as an example of best practice regarding transparency, reporting and communication due to the annual provision of data on environmental subsidies and fossil fuel subsidies by the CSO (European Commission, 2021). It is important then that this level of communication and transparency continues through the reform process. There is often little awareness that fossil fuel subsidies, and less as to how they can be defined. Clearly explaining the approach to subsidy definition in this context and drawing attention to such subsidies and their fiscal and macroeconomic impacts is an important part of the reform process. Furthermore, efforts should be made to ensure that the communication is not overly focused on emissions, but rather also on elements such as reinvestment of resources, realisation of long-term strategies, a just transition and so forth. In addition, providing clear information on the visible reallocation of resources resulting from subsidy reform can influence public acceptance, and is recommended as a core ongoing feature of the process.

Step 4: Employ Complementary and Compensatory Measures

As was noted in section six, a policy such as this, which has direct impacts on energy demand, can complement and spill over into many other existing policies and strategies. The main principle for successful reform is the efficient and visible reallocation of resources through complementary measures for groups most adversely impacted. Such policies can be implemented using revenue collected prior to reforms, as well as resources saved or generated by eliminating fossil fuel subsidies. Although there are particular concerns for aid to sectors, industries, and enterprises, as well as to households and individuals, complementary measures should be developed and implemented in accordance with a set of basic principles based on lessons from general good policy reform practice. Selected proposals for complementary and compensatory measures are outlined below. However, it is important to note that the CAP establishes the official climate strategy for Ireland, and specifically acknowledges the significance of a just transition in that context. As such many of the measures included within the CAP would represent appropriate initiatives that could be supported and accelerated as part of a program of fossil fuel subsidy revenue reallocation.

Active Transport: An ideal fuel switch from an emissions abatement point of view is from fossil fuels to active travel. Policies which increase the uptake of active transport should be implemented using revenue saved or generated due to the removal of fossil fuel subsidies. It is recommended that revenue be reallocated to the development of pedestrian and cycle infrastructure and the upgrading of existing infrastructure in both urban and rural areas. This investment would support the CAP 23 target to deliver a 50% increase in daily active travel journeys and a 25% reduction in daily car journeys by 2030. Provision of convenient, safe, and connected walking and cycling infrastructure is at the core of promoting active travel. A key purpose of such infrastructure should be to protect pedestrians and bicyclists from cars. Other factors which service both active and public transport include shelters for weather protection and changing and toilet facilities. Policies that improve public transport can also boost active travel as an access mode to transit, while policies that make car use less attractive will increase the competitiveness of active travel modes. The pathfinder projects for the transport sector in the CAP will offer multiple policy and investment ideas for related localised actions that could be supported by reallocated revenue.

Public Transport: Public transport use has a positive cross price elasticity with fuel prices. A portion of revenue saved or generated by the phase-out of fossil fuel subsidies could be reallocated to public transport in two forms. Firstly, subsidy swaps, identified in the literature review, have been used as measures in some countries to encourage green recovery. To alleviate the financial burden of removing fossil fuel subsidies on citizens and encourage the switch from private car transport to public transport, it is recommended that revenue be reallocated to further subsiding public transport for users[32]. Subsidies should be set such that estimated carbon reductions are cost effective and consistent with CAP 23 ambitions to reduce emissions in the transport sector. Secondly, revenue should be further invested in the public transport system in Ireland – as the current stock of public transport refreshes, replacements for bus and commuter rail vehicles and carriages should be low or zero carbon. Actions such as this as well as the increased rollout of rural public transport through 'Connecting Ireland' (Government of Ireland, 2021) will deliver progress on CAP 23 public transport ridership targets and can benefit from additional resources.

[32] Public transport fares in Ireland received a 20% reduction in 2022 with additional provisions for young those aged 19-23 receiving a 50% reduction in fares on all subsidised public transport.

Spatially Targeted Policy Measures: According to an IMF report (Ari et al., 2022), governments of fuel importing countries cannot avert the loss of real national revenue caused by a negative terms-of-trade shock due to an increase in global fuel costs. Governments should therefore allow the full rise in fuel costs to be passed on to end-users in order to encourage energy efficiency and the transition away from fossil fuels. It is recommended that targeted policy measures should be developed to mitigate negative impacts on the lower-income households that are disproportionately affected by rising energy costs. Spatially referenced data analysis can be utilised to identify areas most affected by the reform process and to thereby support policymakers in targeting supports and interventions to mitigate home-heating energy poverty and transport energy poverty. The Home-Heating Energy Poverty Risk Index (Kelly et al., 2020) and Transport Energy Poverty Risk Index are composite indicators, designed by EnvEcon, which can produce a spatially refined analysis of energy poverty risk in the two key sectors of residential and transport. The application of each methodology is not limited to understanding how changes in certain parameters will influence energy poverty in the sector but can also demonstrate how policy may design or modify interventions to manage changes (e.g., increases in fuel prices).

Decarbonisation of Energy: The removal of fossil fuel subsidies will incentivise a fuel switch in both the transport and residential energy sectors. It is therefore pertinent to ensure that barriers preventing the uptake of preferred technologies such as electric vehicles and air source heat pumps are identified and removed. It is recommended that revenue generated from the removal of subsidies should be reallocated to facilitate this by reducing transaction costs, providing information or adjusting fiscal supports. For example, all grants should be well advertised and a nationwide education campaign should be introduced to teach consumers about topics such as active travel benefits, full costs of different modes of travel, EVs and vehicle total cost of ownership, how to use public charging infrastructure and other basic information regarding the technology. Such an approach would further align fossil fuel reform with CAP targets and national ambitions pertaining to uptake of such technologies.

9. Conclusion

International evidence shows that fossil fuel subsidy reform can serve as an important and impactful strategic element of long-term climate and air policy. In direct terms, the reduction or removal of fossil fuel subsidies will increase the price of those fossil fuels, and thus in a similar manner to a carbon tax, can lead to a decrease in national and global CO_2 emissions. However, a shift in fossil fuel prices will also impact upon a far broader set of factors than simply emissions, given the ubiquitous use of fossil fuels in many key sectors of the global economy.

Gradual subsidy reductions are generally preferred as they can mitigate energy price shocks, make compensation policies more manageable, provide clear signals to consumers and businesses, incentivise the requisite investments in energy efficiency and low-carbon energy production, and allow more time for adaptation. Thereby gradual reductions have also been found to generate less opposition. There is also ample literature and evidence recommending that stakeholders must be engaged in the reform process early-on to chart a stable path for policy acceptance, and to afford the necessary time for policy adjustments and responsive investments. Empirical case studies also reveal that the public is often more receptive to such reform when the arguments for those reforms focus on the fiscal costs and macroeconomic impacts of existing fossil fuel subsidies as opposed to purely the environmental merits of reform. This view may shift in time, but merits consideration in terms of the design of a fossil fuel subsidy reform communication strategy. Certainly, it is not difficult to accept that citizens and businesses will take an interest in the proposed redistribution and reinvestment of revenues that had been directed towards fossil fuels. Information on the plans for such reinvestment and redistribution can build enthusiasm and support.

Research also shows that most fossil fuel subsidies are regressive, meaning that the relatively wealthier tend to benefit more from their presence. However, the effects of fossil fuel subsidy removal, relative to income, are likely to be greater for the poor. Furthermore, while new job opportunities are likely to be greater in number for clean energy than fossil fuels, there is some evidence of lower quality in terms of compensation, benefits, or union rights found in other jurisdictions for clean energy jobs that may warrant consideration. Price smoothing and automatic pricing are fiscal tools that may also be implemented to further mitigate public backlash through the process of fossil fuel subsidy reform. Ultimately, a comprehensive strategy, with measures to assist low-income households, displaced workers, trade-exposed firms/regions, and the use of revenues from price reform to boost the economy in an equitable way, are all key elements of policy strategy that can improve acceptability of the subsidy reforms.

Our case study analysis highlights the particularly strong link between subsidised sectoral fuels and emissions in the transport and residential sectors in Ireland. In 2021, the transport and residential sectors contributed 17.7% and 11.4% of national GHG emissions respectively. The activities that contributed most to transport emissions for 2021 were passenger vehicles, haulage, and international aviation. Within transport energy use the primary fuel types are oil and gasoil/diesel with 83% of transport energy use in 2021 attributed to these two fuel types. The primary fuel types within residential energy use in 2021 are oil (27%) and kerosene (18%).

Our case study analysis projected the environmental impact and abatement potential associated with the removal of subsidies in residential fuel, road transport and aviation by assessing the change in price and the consequent potential impact on fuel consumption and associated emissions. This has been based on price elasticities from the literature that have been assigned into ranged categories of low, moderate or high response scenarios. Under a moderate impact scenario the removal of subsidies could deliver emissions reductions in these sectors of 5.39% for CO_2 and 6.25% for NO_x with a moderate increase of 1.43% for $PM_{2.5}$. In addition, we estimate the impact of the removal of these subsidies on overall (Non-ETS) GHGs to be 2.1% in the same period, of which 1.8% comes from reductions in the residential sector. This is all relative to the emissions under a baseline 2040 scenario as noted. Alternative scenarios for short and long run impacts and low to strong elasticities in the literature are also presented alongside sectoral breakdowns. Whilst our assumptions are conservative in the 'moderate' scenario, expectations for substantial emissions savings associated with say adjusting diesel excise to that of petrol, should be tempered.

Much fossil fuel subsidy reform to date has been as part of fiscal rescue strategies in developing nations. For Ireland, an environmentally motivated pathway for fossil fuel subsidy reform in the transport sector could be pursued – with an initial focus on road transport and aviation. The latter would require aligned international cooperation and this may frustrate efforts to act in that regard. The ETD may influence change in this area in the near future, and so Ireland should remain attentive to opportunities to support international action in regard to aviation emissions.

In terms of unilateral action, the removal of fossil fuel subsidies in the transport sector is recommended above other fossil fuel subsidy reforms. However, identifying favourable timing in this context is essential, and that time is not likely the present. Policy literature acknowledges the need to be cognisant of current energy prices as part of fossil fuel subsidy reform and it is clear that as of early 2023 energy prices have been high in a historical context, and well beyond what subsidy removal might achieve. That volatility looks set to continue. This creates a situation where political and public acceptability will be limited, and as such we would recommend deferring action at this point.

Macroeconomic modelling suggests that the gradual elimination of subsidies is always recommended where broader subsidy action is considered, as while macroeconomic variables are not substantially affected by the reform, there are more adverse effects on real GDP and real investment when commodity related subsidies are removed all at once. Subsidy swaps are also important in this context as a mechanism to channel resources in support of a climate action to mitigate some of the potentially harsher negative impacts of fossil fuel subsidy reform. They can support the energy transition in four key areas – access to clean energy, energy efficiency, decarbonisation of sectors, and transformation of the power sector. In addition, spatially referenced data analysis will have an important role in identifying areas most affected by the reform process and can support policymakers in targeting supports and interventions to mitigate, for example, transport and home-heating energy poverty risk (Kelly et al., 2020).

The effect of fossil fuel subsidy reform on the real disposable income of rural and urban households is consistent with the declines in real GDP. However, where the defunding of energy allowances to households are removed in conjunction with the removal of subsidies, this is predicted to have far more pronounced adverse effects on the real disposable income of households, with worsened effects for rural households. Subsidy removal in terms of excise on household energy use would have a far more substantial impact on prices, and the removal of targeted supports, would have strong negative impacts on welfare outcomes. Simply put, withdrawing government transfers to households would, unsurprisingly, be expected to exacerbate home-heating energy poverty risk for the most vulnerable and poorer households, alongside what would also be substantial increases in residential energy prices where excise rates are adjusted upwards. When the national systems for targeting and delivering 500,000 residential retrofits and installing 680,000 air source heat pumps by 2030 are clearly in evidence then it may be a more appropriate time to more carefully explore a strategy for removal of subsidies to fossil fuels in the built environment.

In summary, no action is recommended in respect of subsidy reform in the built environment sector at this point. Aviation subsidy reform should be discussed with other member states and foregone tax revenue subsidy reform for road transport can be considered as prices moderate, and revenue should be earmarked for climate action.

Table 21 offers a set of summary recommendations.

Table 21: Summary of Findings and Recommendations

Sector	National Energy/CO_2 Contribution (2021) [33]	Scale of Subsidy Impact on Price	Capacity to Adjust	Recommendation
Transport Sector	34% of Energy Related CO_2 95.5% of transport energy demand coming from fossil fuels	Average 8.85% increase in passenger car transport diesel prices for the period 2023-2040 and 11.4% for commercial diesel vehicles	Relatively good capacity to adjust. Impacts on transport poverty risk can be mitigated with complementary measures. Impact on price is more modest than other sectors. Should be paired with clear investments in sustainable transport actions.	Gradual elimination of subsidies is possible. Timing in this context is essential. Process should wait until the current increases in transport fuel prices ease.
Private Road Transport	Accounts for 43% of all transport energy demand			
Public Road Transport	Accounts for 3% of all transport energy demand			
Haulage	Accounts for 19% of all transport energy demand			
International Aviation	Accounts for 11% of all transport energy demand	14% increase in air travel prices under our moderate reaction scenario	International cooperation on the issue is required. However, there is likely less political and public resistance to change.	Communicate intentions with other states at international climate and aviation conferences.
Residential Sector	27.5% of Energy Related CO_2 72.7% of residential energy demand coming from fossil fuels	Average increase in fuel price (2023-2040) for coal (55%), kerosene (46%), gasoil (43%), peat (41%)	The scale of impact on household poverty risk is deemed too great at this time to recommend 'foregone tax' subsidy reform in this sector.	No reform yet and no removal of direct energy supports to households. No short-term action on residential fuels. Revisit in the future.

[33] SEAI Energy Balance (2021)

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11. Appendices

This section provides the detail of specific equations and processes that are mentioned in the main body of the report. They have been removed to this section on request to limit the level of technical detail in the main report.

Appendix I

To calculate emissions, these emissions factors are applied to the EPA 2021 Air Pollution Inventory projections of activity associated with subsidised fuels. Emissions from such fuel consumption sector are then calculated using Equation 1:

$$E_{ij} = C_{ij}F_j \qquad (1)$$

E is the total emissions; C represents energy consumption and F represents the emission factors. Index i denotes the energy use category (i.e., aviation, road transport, residential) and j represents fuel type. When subsidies are removed, the reduction of emissions R is estimated as the difference between baseline emissions forecast T=0 and scenario emissions forecast T=1:

$$R_{i0,1} = E_{i0} - E_{i1} \qquad (2)$$

Appendix II

Fuel switching is calculated using the method outlined in equations 3-7.

$$B_j = R_j - I_{k1} \qquad (3)$$

Equation 3 calculates the balance in Diesel reductions I to be assigned to other fuels (B) where I is the increase in an alternative fuel (k1) from the reduced fuel (j).

$$A_{j,k3} = B_j . S_{k2,k3} \qquad (4)$$

Equation 4 calculates (A) which is the share (S) of B available for fuel switching for each mode where k2 are active travel alternatives to j and k3 are fuel switch alternatives.

$$F_{j,k} = A_j . S_k \qquad (5)$$

Equation 5 calculates how much of A is apportioned to each fuel type by multiplying the share of alternative (S_k) by A to calculate F.

$$X = \frac{Y_j}{Y_k} Z_{j,k} \qquad (6)$$

F cannot be directly attributed to alternative fuel types without converting for efficiency first. As diesel, petrol, biofuel, and EVs all have distinct system and fuel efficiencies we must adjust for this with Equation 7. Using this approach, we calculate the same level of transport output as in F. Here X is the efficiency conversion where Y is system efficiency for fuels j and k, and Z is the fuel conversion factor from j to k.

$$I_k = F_{j,k} . X_{j,k} \qquad (7)$$

The Increase (I) in alternative fuel k is calculated by multiplying the fuel switch (F) by the conversion factor in Equation 6.

Appendix III

The following equations illustrate how these two policy variables, PTR and STR are introduced into the I3E model, and how the removal of those subsidies affect economic activity in Ireland, through the total volume of production, in the first instance, and subsequently through government revenues. First, regarding the PTR, the total value of production is comprised of the value added, production taxes paid to the government and the total cost of intermediate inputs as described below:

$$PX_{a,t}QX_{a,t} = PVA_{a,t}VA_{a,t} + PRODTAXS_{a,t} + PCIN_{a,t}CCIN_{a,t} \qquad (8)$$

where $QX_{a,t}$ defines activity's total production, $VA_{a,t}$ is the real value added, $CCIN_{a,t}$ stands as a composite intermediate input demand, the values such as $PX_{a,t}$, $PVA_{a,t}$, and $PCIN_{a,t}$ are the prices of them and $PRODTAXS_{a,t}$ describes the value of the production tax. In other words, $PRODTAXS_{a,t}$ captures all the taxes on production payments by activities in terms of the total production, and it could be depicted as follows:

$$PRODTAXS_{a,t} = prodtax_a PX_{a,t}QX_{a,t} \qquad (9)$$

The parameter $prodtax_a$ encompasses the first set of removed subsidies which are linked to the PTR policy variable and represents an ad-valorem tax rate on a certain economic activity a. Since the production activity receives the subsidy, the removal of fossil fuel subsidies impacts on the level of the PTR, increasing substantially the amount of the PTRs collected by the government. The above effect can be depicted in Equation 10 which shows all components of government revenue. The increase of PTR will result in higher revenues after the removal of subsidies.

$$GovRev_t = \sum_a PRODTAXS_{a,t} + CETS_{a,t}0.5) + \sum_l WTAXS_{l,t} + CORPTAXS_t$$

$$\sum_c (SALTAX_{c,t} + CTAXS_{c,t} + EXPTAXS_{c,t} \qquad (10)$$

where $WTAXS_{l,t}$ defines the wage income tax payments, $CTAXS_{c,t}$ is the value of carbon tax revenues, $EXPTAXS_{c,t}$ is defined as export tax of the commodity c, $CORPTAXS_t$ is the corporate tax payments, and $SALTAX_{c,t}$ describes the value of sales tax revenues.

The ESRI estimates that the removal of the electricity generation from peat subsidy raised the PTR of the sector by 2,245.3% when compared to the 2014 value of €119 million. In parallel, the entire removal of excise exemption on aviation fuel increased the PTR of the sector by 212.07% compared to 2014 value (€425.9 million).

In parallel, sales taxes on a commodity c are implemented on total domestic supply of the commodity which means it is equal to import and export production as follows:

$$SALTAX_{c,t} = stax_c(PM_{c,t}\, QM_{c,t} + PD_{c,t}QD_{c,t}) \quad (11)$$

where $stax_c$ represents an ad-valorem STR on commodity c. $PM_{c,t}$ is defined as the price of import commodity c in domestic currency, $QM_{c,t}$ depicts the total import demand of commodity c, $PD_{c,t}$ describes the producer price of domestic supply of commodity c, and $QD_{c,t}$ represents the total domestic supply of commodity c. The parameter $stax_c$ includes the second set of the removed subsidies (commodity-related subsidies) connected with the policy variable STR. In this case, the commodity receives the subsidy, hence the removal of the subsidy influences the level of the STR of this certain commodity, leading to an increase in government revenues as illustrated in Equation 11. For example, the commodity of fuel oil recieves the subsidy for consumers to enjoy a lower price. However, the removal of this specific subsidy is projected to surge the STR by 3,096.19% when compared to the reference value of 2014 (€30.9 million). Additionally, the removal of the entire subsidy of excise exemption on marked & auto diesel is expected to increase the STR by 65.18% in contrast to the 2014 value of 793.6 million according to the ESRI.

To sum up, we have described how the removal of two categories of fossil fuel subsidies are linked to the I3E model, through the $prodtax_a$and $stax_c$ parameters, as well as the implications of removed subsidies on government revenues. Government revenues are substantially higher once fossil fuel subsidies have been phased out, demonstrating that fossil fuel subsidies are a strain on public budgets of governments, draining resources that could be allocated to other activities. Furthermore, when the government decides to remove a sectoral production subsidy, it provokes an upward trend in the production costs of the firms, impeding the supply of goods and services in that sector and driving the level of prices higher than they were prior to the reform.

In parallel, when a government chooses to eliminate commodity-related subsidies, it induces an increase in its STRs, and the price mechanism is expected to respond with a higher level of commodity prices in the sector. The main impacts induced by the removal of subsidies come from the price mechanism, as the introduction of subsidies distorts costs and prices in the economy. These distorting effects can reverse the effects of fossil fuel subsidy introduction by increasing prices and costs, eradicating the incentive for households to consume more fossil fuels, reducing both the wasteful consumption and inefficient allocation of resources in the economy and enhancing the public finances and budgetary resources of the government (IEA, 2010).

Appendix IV

The I3E model depicts a small open economy comprising of several firms, heterogeneous representative household groups, multiple commodities, government, enterprises, and the rest of the world. All the markets in the I3E model operate under the assumption of perfect competition which means all economic agents cannot influence the prices in equilibrium. Thereby, both households and firms are price-takers in the Irish economy. Furthermore, the methodology for the estimation of macroeconomic effects assumes that all international energy prices are constant at their 2018 levels until 2030, the level of carbon tax per tonne equivalent of CO_2 is kept constant at €20, and all other policy variables remain unchanged for the examined time-horizon (2014 to 2030).

Regarding economic activity, utilising the value-added approach the total value of the gross domestic product (GDP_t) is equivalent to the aggregation of the value added in each sector and indirect taxes on production activities, sales of commodities and international trade. The GDP_t equation is formed as follows:

$$GDP_t = \sum_a \left(PVA_{a,t} VA_{a,t} + PRODTAXS_{a,t}\right) + \sum_c \left(SALTAX_{c,t} + CTAXS_{c,t} + EXPTAXS_{c,t}\right) \qquad (12)$$

We use the GDP_t equation of I3E model to document the connection of GDP_t between $PRODTAXS_{a,t}$ and $SALTAX_{c,t}$ that include the relevant parameters that represent the removed fossil fuel subsidies.

The I3E model divides the investment expenditures of firms and sectors into dividend and non-dividend maximisers. We keep the first case where investment decisions are taken by considering a dividend maximisation problem in which each firm maximises the present discounted value of its dividend flow, $DIV_{dm,t}$, where $V_{dm,t}$ defines the present value of firm, by selecting both the level of physical investment, and their production factors ($K_{dm,t}$ *as capital, and* ${LD^{hh}}_{dm,t}$ *as labour*). The level of investment expenditure is determined as follows:

$$INV_{dm,t} = PPSI_t PSI_{dm,t} + PVA_{dm,t} ADJ_{dm,t} \qquad (13)$$

where $PPSI_t$ describes the price of investment, $PSI_{dm,t}$ defines the level of physical capital we mentioned above, $PVA_{dm,t}$ is derived as the price of a sectoral value added, and $ADJ_{dm,t}$ is the adjustment cost. According to estimates, the level of real investment is projected to follow the same downward trend with real GDP, as the decline in nominal GDP drives down the investment expenditures, in all cases of removed subsidies, either coming from PTR or STR policy variable, presenting slightly higher effects than those in real GDP.

On behalf of the trade balance, the I3E model defines the level of exports (Equation 14) and the level of imports (Equation 15). As we get the level of exports and imports in quantities, the trade balance is the difference in monetary values between exports and imports. Thereby, the level of exports are described as follows:

$$Q_{E_{c,t}}|_{(ce_c)} = \left[\frac{PE_{c,t}\gamma^{qxcd_{c,t}}}{PD_{c,t}(1-\gamma^{qxcd_{c,t}})}\right]\sigma^{qxcd_{c,t}}QD_c \qquad (14)$$

where $Q_{E_{c,t}}$ is defined as the total export of the commodity c, $PE_{c,t}$ is the export price of the commodity c in domestic currency, $PD_{c,t}$ describes the producer price of domestic supply of commodity c, QD_c defines the total domestic supply of the commodity c, as well as parameter γ stands as a share parameter. On the other hand, Equation 15 describes the level of imports in the Irish economy, as follows:

$$QS_{c,t}\{cpn_c \; and \; cmn_c\} = QM_{c,t} + QD_{c,t} \qquad (15)$$

where $QS_{c,t}$ is defined as the composite supply of c, $QM_{c,t}$ is total import demand of c, as well as $QD_{c,t}$ is devised as total domestic supply of c.

Equation 16 demonstrates that a reduction in the overall economic activity decreases the level of government's demand for commodities ($GOVCON_t$) in the Irish economy, as follows:

$$GOVCON_t = GOVCONA_t + mpsGDP_t \quad (16)$$

where $GOVCONA_t$ declares a fixed part of government consumption for commodities, mps is devised as government marginal propensity to spend with value 0.05. According to the results, the excise exemption on aviation fuel is projected to have an impact on debt to GDP reaching -0.67% than the rest of removed subsidies. In total, both policy variables seem to induce nearly equivalent and negligible implications on the debt-to GDP ratio.

Appendix V

Table 22: Macroeconomic impacts of PTR policy variable in 2030

Macroeconomic Impacts of PTR policy variable in 2030, percentage change				
Removed subsidy	**Real GDP**	**Real Investment**	**Net Export to GDP**	**Debt to GDP**
Excise Exemption on Aviation Fuel	-0,34	-0,58	-0,11	-0,67
Security of Electricity Supply	-0,07	-0,18	0,13	0
Diesel Rebate Scheme	-0,01	-0,02	0,03	0
Electricity Generation from Peat	-0,14	-0,47	0	-0,18
PTR Aggregate effect	**-0,56**	**-1,25**	**0,05**	**-0,85**

Table 23: Macroeconomic impacts of STR policy variable in 2030.

Macroeconomic Impacts of STR policy variable in 2030, percentage change				
Removed subsidy	**Real GDP**	**Real Investment**	**Net Export to GDP**	**Debt to GDP**
Excise Exemption on Auto Diesel	-0,22	-0,52	0,14	-0,23
Excise Exemption on Marked & Auto Diesel	-0,52	-1,22	0,26	-0,57
Excise Exemption on Fuel Oil	-0,02	-0,04	0,02	-0,01
Excise Exemption on Kerosene	-0,23	-0,39	0,37	-0,06
STR Aggregate effect	**-0,99**	**-2,17**	**0,79**	**-0,87**

Table 24: Household impacts coming from PTR in terms of real disposable income in 2030

Household impacts coming from PTR in terms of real disposable income in 2030, percentage change		
Removed subsidy	**Rural household**	**Urban Household**
Excise Exemption on Aviation Fuel	-1,08	-0,97
Security of Electricity Supply	-0,21	-0,2
Diesel Rebate Scheme	0	0
Electricity Generation from Peat	-0,54	-0,53
PTR Aggregate Effect	**-1,83**	**-1,7**
Removed Energy Allowances to Households	-6,37	-0,43
Combined Effect	**-8,2**	**-2,13**

Table 25: Household impacts coming from STR in terms of real disposable income in 2030

Household impacts coming from STR in terms of real disposable income in 2030, percentage change		
Removed subsidy	**Rural household**	**Urban household**
Excise Exemption on Auto Diesel	-0,52	-0,54
Excise Exemption on Marked & Auto Diesel	-1,2	-1,26
Excise Exemption on Fuel Oil	-0,03	-0,03
Excise Exemption on Kerosene	-0,63	-0,62
STR Aggregate Effect	**-2,38**	**-2,45**
Removed Energy Allowances to Households	-6,37	-0,43
Combined Effect	**-8,75**	**-2,88**

Table 26: Welfare impacts coming from PTR policy variable in 2030.

Welfare impacts coming from PTR policy variable in 2030, percentage change		
Removed subsidy	**Rural household**	**Urban household**
Excise Exemption on Aviation Fuel	-3,89	-3,68
Security of Electricity Supply	-0,86	-0,75
Diesel Rebate Scheme	-0,04	-0,13
Electricity Generation from Peat	-0,89	-0,36
PTR Aggregate Effect	**-5,68**	**-4,92**
Removed Energy Allowances to Households	-15,3	-0,31
Combined Effect	**-20,98**	**-5,23**

Table 27: Welfare impacts coming from STR policy variable in 2030

Welfare impacts coming from STR policy variable in 2030, percentage change		
Removed subsidy	**Rural household**	**Urban household**
Excise Exemption on Auto Diesel	-3,66	-1,95
Excise Exemption on Marked & Auto Diesel	-8,35	-4,56
Excise Exemption on Fuel Oil	-0,23	-0,19
Excise Exemption on Kerosene	-6,76	-3,67
STR Aggregate Effect	**-19**	**-10,37**
Removed Energy Allowances to Households	-15,3	-0,31
Combined Effect	**-34,3**	**-10,68**

Notes regarding the assumptions of the I3E model for removing fossil fuel subsidies:

1. All international energy prices are assumed to be constant at their levels of 2018 until 2030.
2. The level of carbon tax per tonne equivalent of CO_2 is kept constant at 20 euro.
3. All other policy variables remain unchanged for the examined time-horizon.