

Assessing the Total Costs and Benefits of Sustainable Transport Policy in Ireland

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ABSTRACT

The objective of this paper is to assess the benefits of greenhouse gas (GHG) and air pollutant emission reductions projected by current Irish sustainable transport policy and to compare the Business as Usual (BAU) scenario and the Smarter Travel scenario, as set out in the 2009 Irish Smarter Travel document. This Smarter Travel scenario projects a 44% reduction in GHG emissions by 2020, compared with the BAU scenario. Both scenarios are quantified and monetised using the social cost of carbon (SCC) approach and penalty price approach for GHG emissions and the damage cost approach for air pollutants.

Total net cost of the policy strategy over the period 2011 to 2020 is estimated to be on average €450mn (\$640mn) per annum. Thus, using the SCC approach, the benefit-cost ratio (BCR) is 0.67:1. Using the penalty price approach, the BCR is 1.82:1. In addition, potential loss in revenue from fuel sales could be €1.3bn (\$1.85bn) in 2020, which suggests that additional compensatory tax measures may need to be considered. For example, it was estimated that total excise increases of €0.85 (\$1.20) per litre for petrol and €0.92 (\$1.30) per litre for diesel may be required to compensate for the revenue shortfall.

INTRODUCTION

The concept of sustainable transport is concerned with the movement of people and goods in a manner, which improves quality of life and ease of access for all and aims to protect the environment for future generations and enhance economic competitiveness (1). This paper focuses on cost-benefit analysis (CBA) as a tool for evaluating policy options for reducing travel demand and, in particular, the indirect benefits of reduced air pollution and GHG emissions in the transport sector as a result of more sustainable travel patterns and demand management. CBA was selected in order to evaluate the monetary benefits of reduced emissions as a result of the implementation of sustainable transport policies and to compare these benefits with the total cost of policy implementation. However, this approach focuses only on GHG and air pollutant emissions and a more holistic sustainability appraisal, including socio-economic and environmental criteria, could be considered as part of multi-criteria decision analysis (MCDA) in future work.

Policy and planning decisions often involve economic analysis to determine whether a particular option is cost-effective and which option provides the greatest overall benefits. CBA can be used to internalise the monetary value of all externalities, either positive or negative, and to help identify efficient and cost-effective policy options (2) and as a decision tool in transport policy-making (3) (4). However, one of its limitations is that it only includes impacts that can be monetised and it reduces impacts to a single reductive numeraire. This implies that impacts, which cannot be quantified and monetised, e.g. social cohesion, fairness or equity, are not internalised. In addition, all impacts are expressed using a single parameter, which does not allow for qualitative assessment or the inclusion of less tangible impacts.

While CBA has been variously adopted in transport and environmental policy appraisal, studies tend to compare direct costs and benefits as well as indirect benefits in terms of preservation of non-market ecosystem services. However, appraisal of transport policies tends not to include loss of fuel revenue as a result of land use and demand management strategies. This has implications for regional and national budgets as, in theory, sustainable transport systems could result in a dramatic reduction in fuel excise from the transport sector. Coupled with a potential loss in registration and annual circulation vehicle taxes, as consumers eschew private transport for public transport, walking and cycling, this could have serious implications for revenue-raising in the transport sector. It may result also in exorbitant tax increases on residual private car demand, which is 'locked-in' for long-term structural reasons, or general increased taxation in order to ensure revenue-neutrality. However, this could be partially mitigated by lower maintenance costs for the national road and motorway network.

The objective of this paper is to assess the benefits and costs of sustainable travel and transport and, in particular, the potential benefits of GHG and air pollutant emission reductions, as projected by the 2009 Irish Smarter Travel document (5). It aims to: (i) quantify the monetary benefits of emissions reduction; (ii) compare these with the cost of policy implementation, including both capital and current costs; (iii) evaluate the loss of fuel excise; and (iv) estimate the required increase in fuel excise to compensate for loss of revenue from fuel sales.

It argues that transport policy appraisal should include indirect costs and benefits and, in particular, indirect costs as a result of reduced fuel sales. This is an important factor to be included as it illustrates the 'true' cost to Government of policy interventions rather than just the 'direct cost'. Therefore, it is recommended that loss of fuel revenue should be included as an indirect cost of sustainable transport policy and that consideration should be given as to how a revenue shortfall could be met, e.g. through increased direct taxation in other areas or

an increase in fuel excise for transport users, which could be hypothecated for sustainability mobility initiatives or raised as part of general taxation.

The structure of the paper is as follows. Section 2 outlines the recent trends and projections in energy consumption and emissions in the Irish transport sector. Section 3 evaluates the monetary value of the benefits of sustainable transport and compares these benefits with the total cost of sustainable transport policy in Ireland. Section 4 estimates the potential carbon levy or increased fuel excise required to ensure revenue neutrality due to the potential loss of fuel excise. Section 5 discusses the results and offers final conclusions.

TRANSPORT ENERGY AND EMISSION TRENDS

Energy Consumption

The Total Primary Energy Requirement (TPER) of the transport sector in Ireland increased by 180.5% between 1990 and 2007, with an average annual growth rate of 6.3% (6). This compares with economic growth in terms of Gross Domestic Product (GDP) of 190.4% over the same period, which indicates a slight relative decoupling. Not all this increase in energy consumption, however, is directly attributable to Irish residents and it is estimated that in 2004, 10% of petrol and 25% of diesel sold in Ireland was consumed outside the State as a result of fuel tourism (7). Recent trends show that the annual average growth rate in Total Final Consumption (TFC) in the transport sector was 6.3% between 2005 and 2007, whereas all other sectors showed a growth rate of less than 1% in the same period (6). This indicates that the transport sector has shown a strong increase compared to other economic sectors in Ireland and has proven intractable in terms of achieving absolute decoupling from economic growth.

Furthermore, the number of licensed vehicles on Irish roads increased by 138% from 1.05mn vehicles in 1990 to 2.5mn vehicles in 2008. In addition, road freight increased by 111% from 8.2bn tonne-km in 1998 to 17.3bn tonne-km in 2008, which indicates strong pressure in terms of road freight (8). Private car ownership in Ireland increased by 92% from 227 cars per 1,000 population in 1990 to 435 cars per 1,000 population in 2008, although this is still below the 2007 EU-27 average of 464 cars per 1,000 population. This suggests that there remains the potential for further growth in Ireland, as car ownership has not yet reached saturation point (6).

The TPER in the transport sector is projected to increase by 31.2% from 5,705 kilotonnes of oil equivalent (ktoe) in 2007 to 7,485ktoe in 2020 under the Baseline scenario, while TFC is projected to increase by 32.3% from 5,685ktoe in 2007 to 7,519ktoe in 2020. Its sectoral share is projected to increase from 43% in 2005 to 46% in 2020 (9). Table 1 shows the percentage change in TPER and TFC between 1990 and 2007.

TABLE 1 Total percentage change in acid rain precursor emissions (SEI (6); CSO (8))

	Percentage Change 1990-2007 (%)
Total Primary Energy Requirement (TPER)	180.5
Total Final Consumption (TFC)	181.1
Gross Domestic Product (GDP)	190.4
Number of Licensed Vehicles	131.6

Greenhouse Gas (GHG) Emissions

Greenhouse gas (GHG) emissions from the transport sector in Ireland increased by 178% from 5.17 megatonne (Mt) CO₂-equivalents in 1990 to 14.38Mt CO₂-equivalents in 2007, of which road transport accounted for 97%. The sectoral share of the transport sector increased from 9.34% in 1990 to 20.78% in 2007. This compares with total economy-wide emissions, which increased by 25% from 55.38Mt CO₂-equivalents in 1990 to 69.2Mt CO₂-equivalents in 2007 (10).

In the 2007 Irish National Climate Change Strategy (NCCS), transport emissions were projected to be 16.48Mt CO₂-equivalents in 2020, inclusive of policies defined as “existing measures”. This is 218% above the 1990 baseline estimate in accordance with Kyoto Protocol reporting requirements (7). The emissions projections for 2020 have recently been adjusted as a result of revised economic growth projections, which take account of a short-term recession between 2008 and 2009 but a recovery in the economy to where it otherwise would have been in 2020, i.e. the Credit Crunch scenario (11).

The With Measures scenario is based on baseline energy forecasts and the Credit Crunch scenario (12). This was revised in late 2008 to take account of the severity of the current economic downturn (13). The With Additional Measures Scenario builds on the baseline energy forecast and includes additional assumptions on measures and targets (11). An Economic Shock analysis was also carried out on the baseline energy forecast, With Measures scenario and With Additional Measures scenario (11).

Under the With Measures scenario, transport emissions are projected to increase by 26% to 18.1Mt CO₂-equivalents over the period 2007 to 2020. This is a similar projection to that made in the 2009 Irish Smarter Travel document and will be used as the BAU scenario in Section 5 (5). Under the With Additional Measures scenario, transport emissions are projected to increase by 11% over the period 2007–2020 to 16Mt CO₂-equivalents. In this scenario, it is assumed that the use of biofuels increases to 10% of all road transport fuel use by 2020. Additional policies and measures are included in this scenario, e.g. the delivery of greater public transport investment; alignment of spatial planning with infrastructural investment; an energy efficient driving campaign and changes to vehicle registration tax (VRT) and motor tax so that they are linked to CO₂ emissions (11).

Other Emissions and Environmental Impacts

The 2001 EU National Emissions Ceiling Directive, i.e. Directive 2001/81/EC, set national emission ceilings for EU Member States by 2010, including a ceiling of 42 kilotonnes for sulphur dioxide (SO₂), 65 kilotonnes for oxides of nitrogen (NO_x) and 116 kilotonnes for ammonia (NH₃) for Ireland. Emissions in Ireland in 2006 were 60 kilotonnes of SO₂ (which implies a reduction target of 30%); 122 kilotonnes of NO_x (which implies a reduction target of 47%) and 110 kilotonnes of NH₃ (14). Table 2 shows the change in acid rain precursor emissions in the transport sector in Ireland between 1998 and 2006.

TABLE 2 Total percentage change in acid rain precursor emissions in the transport sector (CSO (14))

	1998 (Tonnes)	2006 (Tonnes)	Percentage Change (%)
SO ₂	10,820	960	-91
NO _x	56,460	51,080	-9.5
NH ₃	980	2,590	+164
Total Acid Rain Precursors	51,950	41,360	-20

Although ambient air concentrations are generally within emission limit values, there is the potential for localised air pollution ‘hot spots’ to develop, which may be critical in areas of ecological sensitivity or residential areas. Emissions of both NO_x and SO₂ peaked in 1998

and have generally fallen in recent estimates, as a result of increased use of selective catalytic reduction in tailpipes and reduced sulphur content in automotive fuels.

Under the With Measures scenario, NO_x emissions are projected to fall to 24,720 tonnes by 2020; SO₂ emissions are projected to fall to 103 tonnes; NMVOC emissions are projected to fall to 7,194 tonnes and NH₃ emissions are projected to fall to 384 tonnes. The assumptions were that, under the With Measures scenario, biofuels penetration in the transport sector would reach 2% by 2008 and remain constant thereafter. Under the With Additional Measures scenario, it was assumed that biofuels penetration in the transport sector would reach 10% by 2020.

Under both scenarios, it was assumed that technology improvements are included implicitly in the With Measures emission projection and these efficiency improvements are in line with the Voluntary Agreements negotiated between the EU and the car manufacturers, which committed to a reduction to 140g CO₂/km for 2008/2009. Projections were based on uptake of Euro standards and it was assumed that sulphur-free fuels would be available from 2009.

BENEFITS OF SUSTAINABLE TRANSPORT POLICY

Methodology

The objective of this section is to estimate the monetary value of the difference between projected air pollution and GHG emissions under the BAU and Smarter Travel scenarios. The BAU scenario is based on the With Measures assumptions and projections for energy consumption in 2020 based on revised economic growth projections. The Smarter Travel scenario is based on estimated savings in GHG emissions as a result of full implementation of policies outlined in the Irish Government strategy on sustainable transport (5).

The proposed policies set out in this strategy include (5):

- (i) Aligning spatial planning with transport infrastructural investment;
- (ii) Aligning employment policy with transport planning;
- (iii) Mobility management, including travel plans, car clubs and car sharing;
- (iv) Better logistics and efficient freight transport;
- (v) Fiscal measures to influence travel behaviour;
- (vi) Improvements in public transport;
- (vii) Promoting and incentivising cycling and walking;
- (viii) Integration of modes of transport;
- (ix) Promoting sustainable aviation and maritime;
- (x) Increasing the contribution of renewable energy and alternative technologies in the transport sector;
- (xi) Encouraging more efficient driving behaviour;
- (xii) Coordination at national level;
- (xiii) Institutional arrangements at local and regional level;
- (xiv) Demonstration projects; and
- (xv) Improved network and demand management planning.

The emissions that are included in these scenarios are GHG emissions in terms of CO₂-equivalents (based on an aggregate of CO₂, N₂O and CH₄) and air pollutants, including NO_x, SO₂ and NMVOCs. These emissions are included as projections are available for 2020 and monetary values can be imputed. However, this does not account for the full impact of transport policies or the benefits of sustainable transport policies and future work could evaluate total benefits as well as direct and indirect costs.

Greenhouse Gas Emissions

Both the social cost of carbon (SCC) and penalty price approach are used in this analysis to estimate the potential costs associated with GHG emissions. The SCC includes the economic costs to society from climate change and is usually estimated as the net present value (NPV) of climate change impacts over a 100 year period as a result of one additional tonne of carbon emitted to the atmosphere. The penalty price is the likely penalty that will be incurred if GHG emissions exceed the national targets, as set for Ireland under the Kyoto protocol and, more specifically, under the EU Burden-sharing Agreement. The penalty price was assumed to be €100/tonne in this analysis¹.

There are a range of estimates of SCC based on different approaches, which differ in terms of accounting for the physical impacts of climate change, discontinuities, consideration of major risks, discount rate and time horizon, including Capros and Mantzos (15); Schreyer et al. (16); Watkiss (17); Tol (18); Bickel and Friedrich (19) and Stern (20). A meta-analysis of the external costs of climate change estimates a central value of €40/tonne CO₂ (\$57/tonne)² for 2020; €55/tonne CO₂ (\$78.3/tonne) for 2030; €70/tonne CO₂ (\$100/tonne) for 2040 and €85/tonne CO₂ (\$121/tonne) for 2050 (21). The value of €40/tonne CO₂ (\$57/tonne) was used to estimate external costs in this analysis.

Air Pollution

Air pollution costs are caused by the emission of air pollutants such as particulate matter (PM₁₀ and PM_{2.5}), NO_x, SO₂, O₃ and NMVOCs. A key factor for air pollution costs is whether emissions are generated close to population clusters. For road transport, the most important factors are the emission standards of the vehicle, vehicle speed, fuel type, combustion technology, load factor, vehicle size, driving pattern and the geographical location of the road (21). There are various estimates for Ireland on damage costs of air pollution, including *inter alia* (i) the Clean Air for Europe (CAFE) Report; (ii) the Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO) Report, which includes aggregate air pollution costs for road, rail and waterways; and (iii) the 2008 Guidelines on a Common Appraisal Framework for Transport Projects, Programmes, and Strategies that were developed for the Irish Department of Transport and contain estimates for emissions of for rural areas, urban areas and highways (21)(22).

The HEATCO estimates were used in this analysis as they are aggregate estimates and do not disaggregate between road type, urban and rural area or type of transport mode. The HEATCO report estimates factor costs for Ireland for aggregate air pollution costs for road, rail and waterways, including €1,800/tonne (\$2,568/tonne) for NO_x, €400/tonne (\$571/tonne) for NMVOCs and €1,400/tonne (\$1,997/tonne) for SO₂ (21). Particulate matter (PM₁₀ and PM_{2.5}) was not included in this analysis as there are no projections for 2020.

The methodology used in this paper takes the following steps:

Step One: Projects potential GHG emissions from the BAU and Smarter Travel scenarios;

Step Two: Uses the percentage difference between the 2 scenarios to estimate air pollution under the Smarter Travel scenario;

Step Three: Uses a meta-analysis of SCC and penalty price estimates to project the monetary cost of GHG emissions for both scenarios;

Step Four: Uses a meta-analysis of damage cost estimates to project the monetary cost of air pollutant emissions for both scenarios;

Step Five: Estimates the total cost of the scenarios and;

Step Six: Estimates the difference between the scenarios.

¹ <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002D0358:EN:HTML>

² 1 EUR = 1.428 USD

RESULTS

BAU or baseline GHG emissions for 2020 are projected to be 18Mt CO₂-equivalents (5). This projection is based on a number of assumptions, including: (i) a recession in 2008 (-1.3% GDP growth) and 2009 (-0.7% GDP growth), (ii) gradual return to an average growth rate of 3.5% per annum by 2012, (iii) transport emissions to remain coupled to GDP, (iv) technology improvement in light vehicles in line with fleet average of 140g/km by 2020, (v) population to reach 4.8mn in Ireland by 2020, and (vi) car ownership to reach almost 2.5mn by 2020. The Irish Government policy on sustainable transport set out a number of policies and measures, which could ensure that the transport system in Ireland evolves along a more sustainable trajectory (5).

It was estimated that the total aggregate of these savings could range from between 6.3 to 10.3Mt CO₂-equivalents, assuming absolute reductions, as can be seen in Table 3. These estimates are based on bottom-up analysis of the potential impact of policies based on international examples of similar policy interventions. Table 3 illustrates the potential saving from these measures. The range for the fiscal measure is based on four scenarios, which include a carbon levy or tax of €20/tonne (\$28.5/tonne), €30/tonne (\$42.8/tonne), €100 (\$143/tonne) and €200 (\$285/tonne). It is estimated that a €20/tonne (\$28.5/tonne) levy would reduce GHG emissions from the transport sector (inclusive of both domestic demand and fuel tourism) by 1Mt CO₂-equivalents, a €30/tonne (\$42.8/tonne) levy by 1.4Mt CO₂-equivalents, a €100/tonne (\$143/tonne) levy by 4.1Mt CO₂-equivalents and a €200/tonne (\$285/tonne) levy by 5Mt CO₂-equivalents.

TABLE 3 Emissions reduction projections in 2020 (Mt CO₂-equivalents) (DoT (5))

Policy Measure	Projected Emission Reduction (Mt CO ₂ -equivalents)
Fiscal Measure (€20-200/tonne CO ₂ -equivalent)	1-5
10% Renewable Energy in Transport	1.62
Spatial Planning	0.86
Efficient Driving	0.76
Improved Fuel Economy	0.56
Speed Limits	0.5
10% Electric Vehicles	0.4
Mobility Management and Travel Plans	0.4
Green Labelling	0.07
Flexible Working	0.056
More Sustainable Public Transport Fleets	0.033
Congestion Charge in Greater Dublin Area (GDA)	0.033
Total	6.3-10.3

Adjusting for double-counting and cumulative impact of savings, it is estimated that emissions reductions could range from 5 to 8Mt CO₂-equivalents in 2020 by first discounting demand management measures and then fuel substitution and renewable technology. It is assumed that the full savings are realised and emissions in 2020 under this scenario are projected to be 10Mt CO₂-equivalents, i.e. a 44% reduction. This percent reduction is used to estimate emissions of pollutants other than GHGs in 2020. Although a 44% reduction is significant, further decarbonisation will be required to ensure that long-term targets of up to 80% reduction in GHG emissions will be met by 2020.

It is expected that this will have to be met largely through more innovative technologies, such as greater penetration of plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), hydrogen or fuel cells and greater fuel economy. Furthermore, the potential for land-use planning and more compact urban settlements may be constrained as a

result of the legacy of low-density residential development in Ireland and the difficulty in retrofitting sustainable transport solutions.

A number of similar studies were evaluated to determine how the policies and results outlined in this paper compared with comparative international case-studies. For example, the Moving Cooler Report suggests a number of strategies that contribute most to GHG reductions, including (i) pricing and taxes; (ii) land use and smart growth; (iii) strategies encouraging walking and cycling; (iv) public transportation improvements; (v) ride-sharing and car-sharing; (vi) regulatory strategies that moderate vehicle travel or reduce speeds; (vii) operational and ITS strategies; (viii) capacity expansion and bottleneck relief; and (ix) multi-modal freight sector strategies. It also examines the level of GHG reduction, implementation costs, change in vehicle costs and equity effects and estimates that average annual savings in direct vehicle costs exceed estimated implementation costs under most scenarios (23).

Strategies that involve development and land use patterns and improved transit and transportation options take a longer time to implement. The notable reductions for these strategies are realized in 2030 and beyond, but achieve meaningful reductions of between 9 and 15% by 2050. It was concluded that implementing various “bundles” of transportation efficiency strategies could achieve annual GHG emission reductions of up to 24% less than expected baseline levels in 2050, by changing current transportation systems and operations, travel behaviour, land use patterns, and public policy and regulations. In particular, land use changes combined with expanded transit services achieve stronger GHG reductions than when only one option is implemented (23). Other similar sustainable transport strategies that were evaluated include the 2007 UK Report Towards a Sustainable Transport System (24). This suggests that the strategy outlined in the 2009 Irish Smarter Travel document is highly ambitious and will require a firm commitment to the policies outlined therein.

The Full Cost Investigation Project in Canada focussed on the total capital and operating infrastructure costs, opportunity cost and social costs of transport, including congestion, accidents and environmental costs. This project monetarily valued externalities and ranked social costs according to magnitude, including accidents, air pollution, congestion, GHG emissions and noise. It also ranked costs according to mode, with road accounting for 85% of costs, followed by air, rail and marine transportation. It was concluded that including social costs in total cost may alter the ranking of a particular option, compared with financial costs alone. However, it did not include the benefits associated with transportation (25).

Other relevant studies include the McKinsey Marginal Abatement Cost Curves (MACCs), which evaluate the cost-effectiveness of abatement policies and technology policy options in different sectors, for example the US (26) and Ireland (27). No evidence was found that similar sustainable transport strategies attempted to estimate the indirect cost of such policies, in terms of lost revenues from fuel excise.

Emission factors that were used in this analysis include €40/tonne (\$57/tonne) CO₂; €1,800/tonne (\$2,568/tonne) for NO_x, €400/tonne (\$571/tonne) for NMVOCs and €1,400/tonne (\$1,998/tonne) for SO₂ (21). Table 4 illustrates the differences in estimation of costs between the two scenarios.

TABLE 4 Estimate of damage costs in 2020

	BAU Scenario Emissions (Tonnes)	BAU Costs (€mn/\$mn)	Smarter Travel Scenario Emissions (Tonnes)	Smarter Travel Costs (€mn/\$mn)
GHGs	18,000,000	720 (1,028)	10,000,000	400 (571.2)
NO _x	24,720	44.5 (63.5)	13,843	24.92 (35.59)
SO ₂	103	0.14 (0.2)	58	0.81 (1.16)
NMVOCs	7,194	2.88 (4.11)	4,029	1.61 (2.3)
Total	18,032,017	767.52 (1,096)	10,017,930	426.61 (609)

Therefore, the pecuniary difference or difference in total costs between the two scenarios in 2020 is approximately €341mn (\$487mn). Another approach might be to estimate the difference between GHG projections and targets and multiply by the penalty price. Transport emissions in 2005 were 13Mt CO₂-equivalents (11). Based on a 20% reduction below 2005 levels, in accordance with the 2008 EU Energy and Climate Change Package, this suggests a target of 10.4Mt CO₂-equivalents. Therefore, the Smarter Travel Scenario is likely to achieve this arbitrary target for the transport sector, although individual sectoral targets have not been set.

Assuming a penalty price of €100 (\$143) per tonne and a difference of 8Mt CO₂-equivalents in GHG emissions between the two scenarios, this implies a potential penalty of €800mn (\$1,141mn). The total cost of the air pollutant emissions was estimated to be €47.5mn (\$67.8mn) for the BAU scenario and €26.6mn (\$38mn) for the Smarter Travel Scenario, which implies a difference in damage costs of almost €21mn (\$30mn). Thus, total difference in costs between the 2 scenarios is €821mn (\$1,171mn).

Total additional net cost to the Government Exchequer over the period 2011-2020 is estimated to be €4.5bn (\$6.4bn), including both capital (63%) and current expenditure (37%). This implies a total average cost of €450mn (\$640mn) per annum. Thus, using the SCC approach, the benefit-cost ratio (BCR) is 0.76:1. Using the penalty price approach, the BCR is 1.82:1. This is assuming that the total costs are linearly spread out over the 10-year period. However, in reality, the majority of the costs are likely to be realised in the middle of the period.

FUEL EXCISE AND CARBON LEVY/TAX OPTIONS FOR SCENARIOS

Baseline final energy demand or TFC in the transport sector is projected to increase by 32.3% from 5,685ktoe in 2007 to 7,519ktoe in 2020 and average annual growth rates are projected to be 2.2% on average between 2005 and 2020 (6). Therefore, it is projected that the fuel split would be 2,643 megalitres of petrol (35% of total) and 3,512 megalitres of diesel (46.5%), based on the current fuel split of TFC and BAU forecasts.

Prior to Budget 2009 in Ireland, excise was €442.68 (\$631.28) per 1,000 litres unleaded petrol and €368.05 (\$524.85) per 1,000 litres of auto-diesel. After the announcement in Budget 2009 to raise petrol prices by 8 cent per litre, current excise rates are now €522.68 (\$745.3) per 1,000 litres unleaded petrol with diesel remaining at €368.05 (\$524.85) per 1,000 litres. Assuming that fuel sales are 44% lower under the Smarter Travel scenario, this implies that prospective fuel sales could be 1,480 megalitres of petrol and 1,967 megalitres of diesel. Table 5 shows the difference in projected revenue between the two scenarios.

TABLE 5 Projected revenue from fuel sales in 2020

	Petrol Consumption (Kilolitres)	Petrol Sales Revenue	Diesel Sales Revenue	Diesel Consumption (Kilolitres)	Total Sales Revenue	Total Consumption (Kilolitres)
Projected Business as Usual (BAU) Scenario	2,643,212	€1.38bn (\$1.97bn)	€1.29bn (\$1.84bn)	3,511,695	€2.67bn (\$3.81bn)	6,154,907
Smarter Travel Scenario	1,480,199	€655.3mn (\$933.6mn)	€723.8mn (\$1.03bn)	1,966,549	€1.38bn (\$1.96bn)	3,446,748

Thus, potential loss of fuel sales revenue could be €1.29bn (\$1.85bn) in 2020 and total costs, including capital and operating costs of policy implementation, in 2020 could be €1.75bn (\$2.49bn). This suggests a BCR of 0.195:1 if the SCC approach is taken and 0.47:1 if the penalty price approach is taken. Therefore, unless revenue is raised elsewhere, e.g. through increased fuel excise or other fiscal measures, the proposed policy measures could result in a net loss to the Exchequer as well as a BCR less than 1.

Total potential fuel sales in 2020 under the Smarter Travel scenario could be 3,447 megalitres, which implies an additional fuel excise of €0.38 (\$0.54) per litre on total fuel sales to compensate for the revenue shortfall. It should be noted that this is in addition to a €200/tonne (\$285/tonne) carbon levy on fuel sales in 2020, which is the upper end of the fiscal measure assumption. Assuming a €200/tonne (\$285/tonne) levy, revenue excise would increase by €0.47 (\$0.67) per litre for petrol and €0.54 (0.77) per litre for diesel. Thus, revenue excise would increase to €912.68 (\$1,299.72) per 1,000 litres for unleaded petrol and €908.05 (\$1,293.12) per 1,000 litres for diesel. Therefore, total excise increases could be €0.85 (\$1.21) per litre for petrol and €0.92 (\$1.31) per litre for diesel. It is probable that this increase in fuel excise as well as the €200/tonne (\$285/tonne) carbon levy will have a further dampening effect on transport demand, although this was not accounted for here.

DISCUSSION AND CONCLUSIONS

The aim of this paper was to compare the estimated costs of implementation of a national sustainable transport policy, including both capital and current costs, and to evaluate these costs against the reduction in negative externalities or benefits associated with a reduction in GHGs and air pollutants from the transport sector in Ireland. It is important that transport policy holistically considers the full range of benefits of transport networks, including accessibility, agglomeration economies for urban areas, connectivity, provision of a greater array of goods and services, increased leisure, housing and employment opportunities, autonomy and security. These can be estimated by using techniques such as willingness to pay (WTP) or indicator checklists and invariably involve both qualitative and quantitative assessment. Positive benefits should also be considered in relation to a reduction in negative externalities and sustainable transport policy should seek to maximise external and private benefits and minimise the externalities or external costs to society.

This paper did not aim to include all positive and negative externalities but focussed on air pollutant and GHG emissions, which are correlated with fuel consumption. Stochastic or location-specific impacts, which are indirectly related to travel frequency, for example accidents, fatalities and noise were not included. Future work could look at a wider range of impacts and seek to determine the relationship between travel frequency and impacts.

This paper estimated the monetary difference between the projected air pollution and GHG emissions associated with the BAU and Smarter Travel scenarios in order to estimate the potential impact of the proposed actions contained in the Irish Government's strategy on

sustainable transport (5). The Smarter Travel scenario is based on estimated savings in GHG emissions and air pollutants as a result of full implementation of policies outlined in that strategy. The emissions that were included in these scenarios include GHG emissions in terms of CO₂-equivalents (based on an aggregate of CO₂, N₂O and CH₄), NO_x, SO₂ and NMVOCs.

The BAU scenario projects GHG emissions in 2020 to be 18Mt CO₂-equivalents, while the Smarter Travel scenario estimates that emissions reductions could range from 5 to 8Mt CO₂-equivalents in 2020, adjusting for double-counting and cumulative impact of savings. It was assumed that the full savings are realised and emissions in 2020 under this scenario are projected to be 10Mt CO₂-equivalents, i.e. a 44% reduction. This percent reduction was used to estimate emissions of pollutants other than GHGs in 2020 and it was found that the monetary difference between the two scenarios in 2020 is approximately €341mn (\$485mn) using the SCC approach.

Another approach might be to estimate the difference between GHG projections and targets and multiply by the penalty price. Assuming a penalty price of €100 (\$142) per tonne and a difference of 8Mt in GHG emissions between the 2 scenarios, this implies a potential penalty of €800mn (\$1,138mn). The total value of the air pollutant emissions savings was estimated to be approximately €21mn (\$30mn). Thus, total difference in costs between the two scenarios is €821mn (\$1,168mn).

In addition, the total additional net cost of the plan, in terms of Government investment, was estimated to be €4.5bn (\$6.4bn) over the period 2011-2020, which implies a total average cost of €450mn (\$640mn) per annum. Thus, using the SCC approach, the BCR was found to be 0.76:1. Using the penalty price approach, the BCR was estimated to be 1.82:1. If loss of revenue from fuel sales is included, total costs in 2020 could be €1.75bn (\$2.49bn). This suggests a BCR of 0.195:1 if the SCC approach is taken and 0.47:1 if the penalty price approach is taken.

It was estimated that potential revenue loss could be €1.29bn (\$1.85bn) in 2020, which implies an additional fuel excise of €0.38 (\$0.54) per litre on petrol and diesel sales to compensate for the revenue shortfall in addition to a €200/tonne (\$284.5/tonne) carbon levy on fuel sales in 2020. Assuming a €200/tonne (\$284.5/tonne) levy, total excise increases could be €0.85 (\$1.21) per litre for petrol and €0.92 (\$1.31) per litre for diesel. Therefore, any measures to change transport behaviour, e.g. demand management measures, will have significant implications for Government revenue and policymakers should consider how a potential shortfall could be met, e.g. increased fuel excise, carbon levies or general taxation in other areas. Policymakers should also consider how revenue should be raised from more innovative technologies and alternatives such as PHEVs or BEVs and how a transition can be made from subsidies or excise relief to taxation in order to ensure a reasonably constant revenue stream.

In conclusion, it is suggested that all national transport policies should consider the indirect costs in terms of fuel sales revenue as well as direct costs of policy implementation. This can be undertaken to give a more complete picture of total costs and benefits. The analysis in this paper suggests that total costs could exceed benefits under these scenarios, if loss of revenue from fuel sales is included, unless there is a further increase in fuel excise in addition to the €200/tonne carbon levy. However, this does not account for benefits as a result of sustainable transport policy or the total socio-economic benefits and costs of both scenarios. Future work could evaluate the total benefits and costs over the period to 2020 as well as the benefits and indirect costs thereafter.

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