An Roinn Caiteachais Phoiblí
Sheachadadh PFN agus Athchóirithe
Department of Public Expenditure
NDP Delivery and Reform

Infrastructure Guidelines

Supplementary Guidance

Measuring & Valuing Changes in Greenhouse Gas Emissions in Economic Appraisal

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1. Introduction

This document provides further assistance in calculating and valuing greenhouse gas emissions when performing an economic appraisal. This guidance builds on the information currently provided in the Infrastructure Guidelines, specifically, the information in relation to monetising greenhouse gas emissions using a shadow price of carbon. While the Guidelines provide detailed values for converting greenhouse gas emissions to monetary amounts, this guidance aims to provide practical assistance to bodies seeking to calculate and value the greenhouse gas emissions associated with a policy proposal.

Economic appraisals are required to estimate the emissions from the "basket of seven" greenhouse gas emissions a project or proposal may give rise to. These emissions are then converted into CO2e (carbon dioxide equivalent) using GWP (Global Warming Potential) conversion rates – Carbon Dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Sulphur Hexafluoride (SF6), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Nitrogen Trifluoride (NF3) - where these emissions are considered relevant, significant and practicable for inclusion.

These emissions should then be monetised according to the shadow price of carbon. In any cases where emissions are not considered to be relevant, significant or practicable for inclusion, public bodies should note how this conclusion was arrived at in the economic appraisal.

2. Guidance on calculating and valuing greenhouse gas emissions in economic appraisal

This guidance is provided to measure policies with marginal impacts. In practice this means that the guidance is suitable for appraising policies that change energy use or emissions by an amount that does not lead to wider changes in the market. For example, a policy that increases demand for energy to a degree that it may influence the cost of energy is not considered to be marginal.

The following is a guide to each step that should be undertaken when calculating the value of the greenhouse gas emissions a proposed project or policy may give rise to.

Step 1. Establish a counterfactual

1. To understand the effect of a policy, it is necessary to establish a counterfactual scenario i.e. the situation that would occur if the policy or intervention was not implemented. It should be noted within the economic appraisal if the counterfactual is uncertain. The modelled impact of a policy will be largely dependent on the establishment of this base case and hence it may be necessary to consider the outcomes if certain assumptions within this case were altered.
2. Establishing the counterfactual involves using judgement. However, there are some requirements that must be taken into account. The counterfactual should take account of all policies the Government has committed to and provided funding for.
3. The base or reference case is considered to be the "do nothing" or "do minimum" scenario. The outputs and outcomes produced under this scenario are considered to be deadweight, in that they would have occurred without any intervention. An impact arising from a policy is additional if it would not have occurred in the absence of the intervention. If greenhouse gas emissions reduced by a project would have been reduced by another policy that government has committed to and provided funding for, then these reductions should not be included in the appraisal. Only the additional emissions directly attributable to the project being appraised should be captured using the shadow price of carbon.

> **Additionality**
>
> **When calculating the greenhouse gas emissions associated with a programme it is important to only include those that are considered "additional". If it is likely some of the change in greenhouse gas**

emissions would have happened anyway, these should not be included in the economic appraisal.

4. Calculations should also take account of displacement effects i.e. the number or proportion of intervention outputs accounted for by reduced outputs elsewhere in the target area should be deducted. For example, this may be the case if a new intervention is expected to target greenhouse gas emissions reductions in a sector which already has emissions reduction policies in place.

5. Appraisal should also be careful to consider the rebound effects associated with policy implementation. Policies, such as those that increase energy efficiency levels, result in lower energy costs. This results in additional funds being made available, which can be spent on energy or other goods and services. Any resulting increase in energy use is known as the "rebound effect". Rebound effects can apply to households, businesses, government institutions, and other economic agents. Rebound effects can be direct i.e. they effect consumption of the same energy good, or indirect i.e. they affect the consumption of another energy good. An economic appraisal should consider the direct rebound effects associated with a proposed project.

Rebound Effect

While energy efficiency improvements to technologies allow us to use less energy and achieve the same outcome, more efficient technologies free up resources and hence can allow individuals to increase consumption levels. When this happens some, or all, of the potential energy savings associated with the new technology are not achieved. This is known as a rebound effect.

Example

An example of a rebound effect in practice is when vehicles achieve greater fuel efficiency. Motorists pay less on fuel to travel the same distance and it becomes cheaper in general to operate a car. This can encourage motorists to use their vehicle more often and to make longer journeys by car. When this change in behaviour is substantial, it leads to a greater net energy use.

Step 2. Quantify the change in Greenhouse Gas Emissions

Changes in the consumption of fossil fuels and electricity and policy changes in the agricultural sector and industry will result in changes in greenhouse gas emissions. Examples include changes in energy use, methane from landfill and agricultural livestock, nitrous oxide from fertilizer use and production and F gas emissions (HFC, PFCs and SF6). Policies can impact greenhouse gas emissions either directly or indirectly. All of these effects should be considered for each "basket of 7" greenhouse gas emissions.

Each greenhouse gas has the potential to accelerate global warming at a different rate. To reflect this, greenhouse gas emissions should be converted to a common metric using its Global Warming Potential (GWP), which is expressed in equivalent tonnes of carbon dioxide (tCO_2e). This conversion is performed according to the 100-year Direct Global Warming Potential (GWP) values from IPCC AR5 consistent with reporting under the United Nations Framework Convention on Climate Change (UNFCCC)[1].

See Global Warming Potential for total list of values.

Table 1: Sample of the 100-year Direct Global Warming Potential (GWP) values from IPCC AR5

Greenhouse Gas	Global warming potential per unit (relative to CO_2)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	28
Nitrous Oxide (N_2O)	265
HFC – 134a	1,300
HFC – 143a	4,480
Sulphur hexafluoride	23,500

[1] The conversion factors incorporate GWP values for a 100 year time horizon relevant to reporting under UNFCCC, as published by the IPCC in its Fifth Assessment Report. Although the IPCC have prepared a newer version since, the methods have not yet been officially accepted for use under the UNFCCC. As this is the basis upon which all emissions are calculated by the EPA, the Greenhouse Gas Conversion Factors used within the Infrastructure Guidelines are consistent with this.

Conversion Factors for Changes in Energy Use

In many economic appraisals, the changes in greenhouse gas emissions are a function of projected changes in energy usage. The **Sustainable Energy Authority of Ireland** produce conversion factors that make it possible to express each fuel or energy source in common units of energy. SEAI also provide emission factors that allow for the conversion of these common units to CO_2 equivalent. To give a practical example, in 2024 it is projected that each kWh usage of gas will result in CO_2 emissions of 204gCO_2/kWh, while a kWh of electricity usage will give rise to CO_2 emissions of 281.7gCO_2/kWh.

The SEAI conversion factors for fuels are available in the Appendix to this document or here: https://www.seai.ie/data-and-insights/seai-statistics/conversion-factors/

When conducting an economic appraisal, the latest values available from the SEAI conversion factors should be used **except in the case of changes to electricity usage, which must use the conversion values provided in this document (see Appendix)**.

Calculating Changes in Greenhouse Gas Emissions - Examples

Table 2: Examples of estimating changes in greenhouse gas emissions

1. Estimating changes in emissions from changes in direct fuel use (where there are no wider impacts on the energy market)
Fuel use is the largest source of greenhouse gas emissions globally. Most combustion of fuel releases CO_2 and other greenhouse gases. Therefore, changing the amount of fuel that is used changes greenhouse gas emission levels. However, different fuels emit different quantities of these gases. Changing the type of fuel used will also change greenhouse gas emission levels, thus requiring an estimation of the greenhouse gases associated with a reduction in one type of fuel and an increase in the other. • To calculate the changes in greenhouse gas emissions resulting from changes in energy use, the net changes in energy use are calculated by fuel type, taking account of any rebound effects that may occur. • These changes in energy use should then be converted to a common base using the relevant SEAI conversion factors. • The energy use, measured in kWh, is then multiplied by an emissions factor that converts it to the emissions produced (gCO_2e/kWh), measured in terms of the equivalent amount of carbon dioxide emissions (gCO_2e). Multiply this by 0.001 to get kgCO_2e, and multiply kgCO_2e by 0.001 to get tCO_2e.

- Changes in direct fuel use apply what is known as a marginal emissions factor. This is considered to be constant across different levels of supply and demand (i.e. the average and marginal emissions factors are identical), and also over time.

2. Estimating changes in emissions from changes in grid electricity

While the carbon intensity of most fuels will not change over time, this is not true for electricity. The greenhouse gas emissions associated with the use of a unit of electricity provided from the all-island grid will change quite considerably as the composition of electricity generation changes, particularly as the electricity sector decarbonises and a greater share of our electricity is generated from renewable sources.

Different generators will be employed depending on the economics of the electricity market and hence the emissions associated with electricity consumption can vary over very short time periods. It is obviously not possible to make exact calculations of the emissions associated with a project or policy at this level of granularity.

However, as part of its 2022 National Energy Projections Modelling, SEAI has determined the likely changes to the emissions intensity of electricity generation on an annual basis over the 2022 – 2050 period that current Government policy outlined in the Climate Action Plan 2023 will give rise to.

These emissions factors are detailed in the Appendix to this report and should be used in all economic appraisals that might involve a marginal change to grid electricity usage.

Step 3. Monetising the change in Greenhouse Gas Emissions

Once the changes in emissions resulting from the proposed policy have been estimated in tonnes of CO_2e, it is necessary to monetise these values. This should be done using the guidance contained in chapter 6 of the *Infrastructure Guidelines: Central Technical References and Economic Appraisal Parameters*: available here.

Table 3: Shadow Price of Carbon 2024 – 2055

Shadow Price of Carbon €$_{2018}$tCO_2	
2024	322

2025	335
2026	349
2027	363
2028	377
2029	392
2030	408
2031	424
2032	441
2033	459
2034	477
2035	496
2036	516
2037	537
2038	558
2039	580
2040	604
2041	628
2042	653
2043	679
2044	706
2045	735
2046	764
2047	794
2048	826
2049	859
2050	890
2051	926
2052	963
2053	1001
2054	1041
2055	1083

Table 4: Methodology for Valuing Greenhouse Gas Emissions in the Infrastructure Guidelines

Methodology for Valuing Greenhouse Gas Emissions in the Infrastructure Guidelines
The Government has chosen a marginal abatement cost, also known as a target consistent approach, to valuing the greenhouse gas emissions in an economic appraisal. This method uses the estimated emissions abatement costs associated with reaching Ireland's emissions reduction targets. This methodology was applied in the 2019 review of the Shadow Price of Carbon. In carrying out the review of the Shadow Price of Carbon used in the Infrastructure Guidelines, it was deemed that this methodology is still the most appropriate, and so this approach remains unchanged. To learn more about the approach, please see the most recent Revision of the Shadow Price of Carbon paper, which can be viewed here.

2024 Revision of the Shadow Price of Carbon

The previous iteration of the supplementary guidance for Measuring & Valuing Changes in Greenhouse Gas Emissions in Economic Appraisal, published in 2019, recommended using separate schedules of shadow prices to value emissions in the traded and the non-traded sectors. This was due to the fact that the EU Climate and Energy Package established two distinct emissions reduction targets for the **traded** (those emissions covered by the EU Emission Trading System) and the **non-traded** (those emissions not covered by the EU ETS) sectors.

Up until recently, the reduction of emissions in the ETS sector has only been subject to the overall EU wide ETS emissions target, with Ireland's legally binding climate targets based on reducing emissions in the non-ETS sector. This essentially meant that emissions in the two different sectors (ETS and non-ETS) were different commodities, and thus should be valued separately.

However, certain developments since the 2019 revision of the shadow price of carbon have led us to reconsider the appropriateness of valuing ETS and non-ETS emissions differently. Ireland now has a legally-binding, economy-wide 51% emissions reduction target in 2030 and net-zero by 2050. These targets do not differentiate between emissions in the ETS and non-ETS. Marginal abatement costs should ideally be compared across the entire economy to determine the least cost pathway for Ireland to reach these targets. Therefore, as part of the recent review of the Shadow Price of Carbon used in the Infrastructure Guidelines, the decision was made to use one schedule of values for all emissions. Providing one shadow price of carbon for all emissions simplifies the calculation required for an appraisal and ensures that there is a greater level of consistency across appraisals. The new values are set out in Chapter 6 of the Infrastructure Guidelines: Central Technical References and Economic Appraisal Parameters.

Monetising Non-Greenhouse Gas Emissions

Based on recommendations provided by the Department of Environment, Climate and Communications (DECC), economic appraisals should also monetise other non-greenhouse gas emissions, where these may be relevant to air quality or noise. Recommended values are provided in the Central Technical References and Economic Appraisal Parameters document for the cost of Particulate Matter with a diameter of less than 2.5 micrometers (PM2.5), Nitrogen Oxide (NOx), Non-Methane Volatile Organic Compounds (NMVOCs) and Sulphur Oxide (SOx). These values have been updated since the last revision of the Shadow Price of Carbon, which can be found in Table 6 below. The infrastructure guidelines do not provide central values to monetise noise. Departments and public bodies should use values considered applicable in their own sectors where noise is considered relevant, significant and practicable for inclusion.

Table 6: Estimated damage costs of non-greenhouse gas pollutants in Transport

Valuations for estimated damage costs of non-greenhouse gas pollutants in Transport (€$_{2016}$/tonne)							
PM 2.5			**PM10**	**NOx**		**NMVOCs**	**SOx**
Rural	**Suburban**	**Urban**[2]		**Rural**	**Urban**		
68,000	183,000	568,000	12,200	10,100	17,600	1,700	11,800

Source: EU Commission

For advice regarding sector-specific estimates of damage cost values for non-greenhouse gas pollutants for sectors other than transport, please contact the Air Quality Unit in the Department of the Environment, Climate and Communications.

Relevant base years for monetising values in different sectors:

- The shadow price of carbon values are based on UCC modelling and are priced in **€2018/tCO_2**
- The damage costs for the non-greenhouse gas emissions are valued in **€2016 per tonne**

Analysts should note that the monetary values for greenhouse gas emissions are measured using different base years. When applying monetary values to impacts over a long appraisal period in CBA, it is important to remove the effects of

[2] In accordance with the Commission's guidelines, Urban only applies to cities larger than 0.5 million inhabitants.

> inflation. Failing to remove the effects of inflation would distort the results by placing too much weight on future impacts, where values would be higher simply because of inflation. As such, values assessed should be in constant prices, so that the effects of inflation are removed. Care should be taken to ensure values are measured in a common base year, consistent with the other values being measured in the economic appraisal. The latest CSO values on consumer price inflation should be used to convert these values to the relevant base year. These values are available here: https://visual.cso.ie/?body=entity/cpicalculator .

Step 4. Discounting

The final step in valuing the greenhouse gas emissions changes in economic appraisal is to discount the annual monetary values identified in the previous step using the discount rate referenced in the Central Technical References and Economic Appraisal Parameters.

The current discount rate is 4% per annum. Further guidance on how to apply the discount rate can be found in the Central Technical References and Economic Appraisal Parameters document.

3. Applying the Shadow Price of Carbon to Emissions in Economic Appraisal

Example

A new investment programme is being considered by the Sustainable Energy Authority of Ireland (SEAI) in 2024. This programme is expected to reduce household electricity demand and demand for heating in the form of gas consumption.

Step 1. Establish a Counterfactual

A baseline “do nothing” case is established that includes a reference rate for the level of investment that would proceed independently of any SEAI programme. This provides baseline values for electricity and heating demand.

Step 2. Quantify the change in Greenhouse Gas Emissions

SEAI projects that annual electricity demand reductions of 15GWh and annual gas heating demand reductions of 10GWh will be achieved. These projections are additional to the baseline “do nothing” intervention that includes a reference rate for the level of investment that would proceed independently of any SEAI programme.

The economically useful lifespan of the assets that SEAI is investing in is considered to be fifteen years. This means that the projected electricity demand and gas demand reductions will lead to less greenhouse gas emissions over the period 2024 – 2038.

When valuing the changes to greenhouse gas emissions attributable to the reduced electricity demand, SEAI should develop a time series. This time series should detail the annual changes to electricity consumption attributable to the programme versus the baseline.

The projected annual reductions in electricity usage should then be multiplied by the relevant emission factor that will apply to electricity generation in each year of time series over the period 2024 – 2038 (remember that since the electricity sector will be decarbonising over, the emissions attributable to changes in electricity generation will also fall over time).

- *Annual electricity emissions saving = Change in electricity demand (15GWh) x Marginal Emissions Factor for relevant year*
- *Annual gas emissions saving: Change gas demand (10GWh) x Marginal Emissions Factor (204.0 tCO_2e/GWh)*

Step 3. Monetising the change in Greenhouse Gas Emissions

The resulting CO_2 emissions savings should then be monetised, also on an annual basis, using the values set out for the Shadow Price of Carbon over the period 2024 – 2038.

Step 4. Discounting

The resulting annual monetary values are then discounted back to the baseline year of the economic appraisal, using the discount rate highlighted in the Central Technical references and Economic Appraisal Parameters. The current discount rate is 4% per annum.

Table 8. Valuing changes in electricity emissions

	Units	**2024**	**…**	**2038**
Change in Energy Use (Electricity)	GWh	15		15
Marginal Emissions Factor	gCO_2e/kWh tCO_2e/GWh	281.7 281.7		69.5 69.5
Emissions Saving	tCO_2e	4225.5 (15GWh x 281.7)		1042.5 (15GWh x 69.5)
Shadow Price of Carbon	$€_{2018}/tCO_2e$	322		558
Value of Greenhouse Gas Emissions Savings (undiscounted)	$_{2018}$ €'000	1360.611 (4225.5 x 322)		581.715 (1042.5 x 558)
Discount Rate	%	4%		4%

The procedures SEAI should engage in to value the changes associated with reduced gas demand are identical to those outlined above. The differences are that, at this point, a single value for the greenhouse gas emissions intensity of gas over time may be used. However, it is important that public bodies refer to the latest SEAI values on emissions factors when calculating the greenhouse gas emissions associated with gas usage as, over time, the progressive integration of non-fossil fuel based gases (biomethane, hydrogen etc) in the gas supply may lead to reductions in the greenhouse gas emissions associated with gas usage.

Table 9. Valuing changes in gas emissions

	Units	**2024**	**…**	**2038**
Change in Energy Use (Gas)	GWh	10		10
Marginal Emissions Factor	gCO_2e/kWh tCO_2e/GWh	204.0 204.0		204.0 204.0
Emissions Saving	tCO_2e	2040		2040

		(10GWh x 204.0)		(10GWh x 204.0)
Shadow Price of Carbon	$€_{2018}$/ tCO_2e	322		558
Value of Greenhouse Gas Emissions Savings (undiscounted)	$_{2018}$ €'000	656.88 (2040 x 322)		1138.32 (2040 x 558)
Discount Rate	%	4%		4%

As this investment programmes results in a reduction in carbon emissions these values are considered to be benefits in an economic appraisal.

Appendix

Electricity Emissions Factors

Table 10. Marginal Electricity Emissions Factors								
Scenario	**Units**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
WAM	gCO_2/kWh	281.7	226.3	216.3	190.5	164.4	122.5	92.9

Marginal Electricity Emissions Factors										
Units	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**
gCO_2/kWh	90.8	76.2	73.8	76.2	80.8	70.4	64.5	69.5	63.2	51.7

Marginal Electricity Emissions Factors										
Units	**2041**	**2042**	**2043**	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**
gCO_2/kWh	49.0	47.5	51.2	46.9	54.5	42.0	42.4	38.9	40.8	40.9

SEAI Emission Factors

Available at: https://www.seai.ie/data-and-insights/seai-statistics/conversion-factors/

Table 11. ***SEAI Emission Factors***		
Fuel	**tCO_2/TJ (NCV(net calorific value))**	**gCO_2/kWh (NCV)**
Liquid Fuels		
Gasoline / Petrol	70.0	251.9
Kerosene	71.4	257.0
Jet Kerosene	71.4	257.0
Gasoil / Diesel	73.3	263.9
Residual Oil / Fuel Oil	76.0	273.6
LPG	63.7	229.3
Naphta	73.3	264.0
Petroleum Coke 2022	95.84	345.0
Solid Fuels and Derivatives		
Coal	94.6	340.6
Milled Peat 2022	132.12	475.6
Sod Peat	104.0	374.4
Peat Briquettes	98.9	355.9
Natural Gas 2022 (NCV)	56.66	204.0

Conversion Table

This table can be used for converting different quantities into a standard measurement.

Table 12		Symbol	Number	Standard form
Abbreviation	Kilo	k	1,000	10^{3}
	Mega	M	1,000,000	10^{6}
	Giga	G	1,000,000,000	10^{9}
	Tera	T	1,000,000,000,000	10^{12}
	Peta	P	1,000,000,000,000,000	10^{15}