Department for
Business, Energy
& Industrial Strategy

VALUATION OF ENERGY USE AND GREENHOUSE GAS

Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government

March 2017

Contents

1. Introduction and background

1.1 This document is a supplement to HM Treasury's Green Book[1], providing specific guidance on how analysts should quantify and value energy use and emissions of greenhouse gases (GHGs). It is intended to aid the assessment of proposals that have a **direct** impact on energy use and supply and those with an **indirect** impact through planning, land use change, construction or the introduction of new products that use energy. It is appropriate for undertaking options appraisal for policies, programmes and projects; for use in building business cases; and for conducting impact assessments. It can also be used to inform the evaluation of policies.

1.2 This guidance should be used in conjunction with the Green Book, and the Green Book guidance on Business Cases. Guidance on risk management is available in HMT's Orange Book[2] and on policy evaluation in HMT's Magenta Book[3]. The Better Regulation Executive (BRE)[4] publishes guidance on regulatory Impact Assessments.

1.3 The guidance has been prepared and reviewed across government through the BEIS-chaired Interdepartmental Analysts' Group (IAG) on Energy and Climate Change[5]. It is accompanied by:

1.4 an Excel-based **calculation toolkit,** to convert increases or decreases in energy consumption into changes in greenhouse gas emissions, and value these changes,

1.5 **Data tables** containing the latest published assumptions for carbon values, energy prices, long run variable energy supply costs, emission factors and air quality damage costs over the 2010-2100 period, and

1.6 a **background information document** (including explanations of the methodologies used in this guidance).

1.7 This guidance and the listed accompanying documents can be found at the Green Book supplementary guidance section of the GOV.UK website along with the toolkit.[6] This edition of the guidance was published in March 2017. Any questions should be addressed to: GHGappraisal@beis.gov.uk.

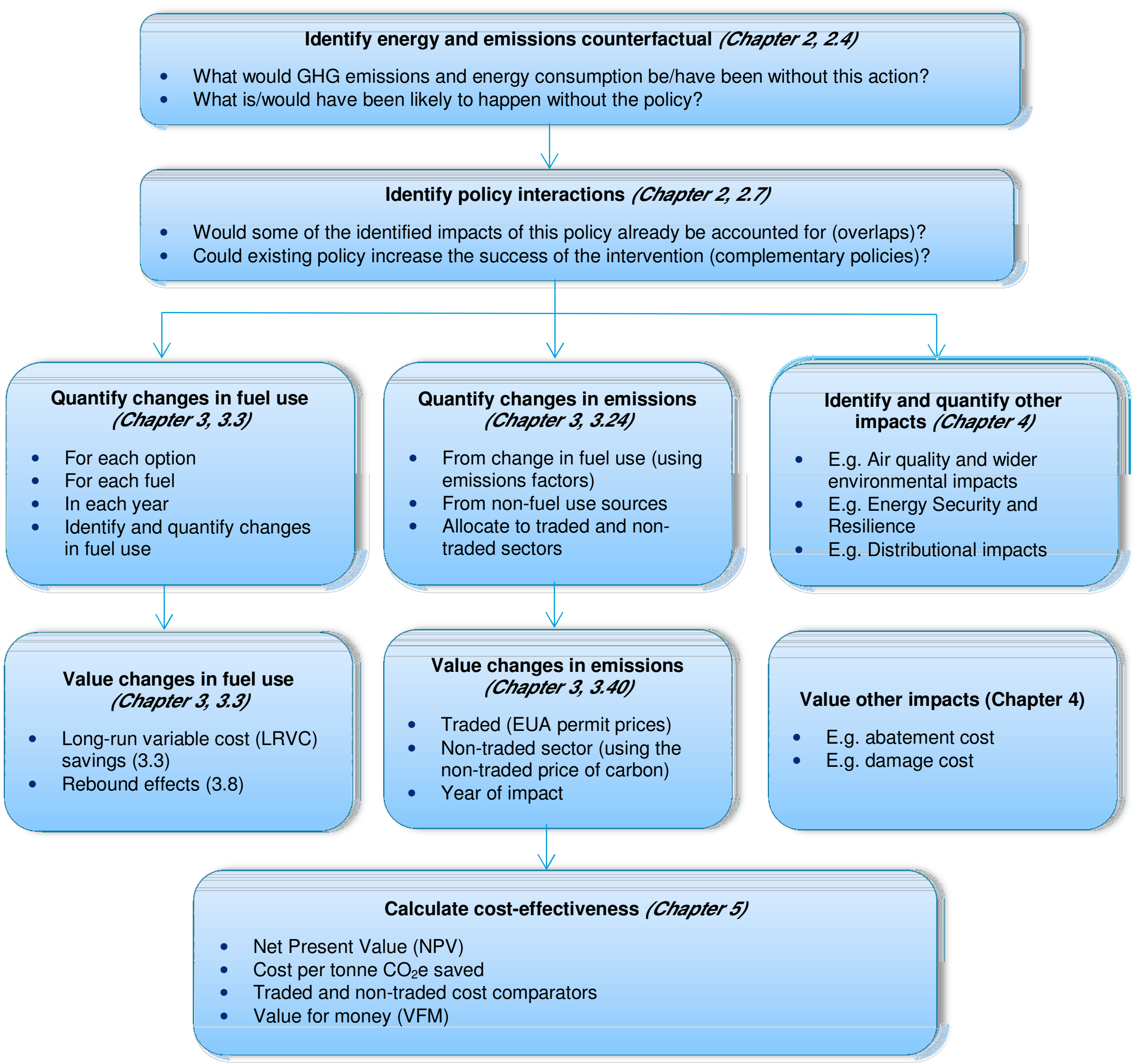
[1] The Green Book is available on: https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent
[2] The Orange Book is available on: https://www.gov.uk/government/publications/orange-book
[3] The Magenta Book is available on: https://www.gov.uk/government/publications/the-magenta-book
[4] Guidance on Impact Assessments can be found at: https://www.gov.uk/producing-impact-assessments-guidance-for-government-departments
[5] Further information on IAG can be found at: https://www.gov.uk/government/policies/using-evidence-and-analysis-to-inform-energy-and-climate-change-policies/supporting-pages/policy-appraisal
[6] Please see: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

2. How to undertake energy and GHG emissions appraisals

Introduction

2.1 Each appraisal of energy and GHG emissions presents different challenges, as well as common calculations. The diagram in Figure 2.1 shows the analytical process and calculations required when valuing energy and GHG impacts, and the relevant sections within this guidance which provide more detail.

Figure 2.1 Analytical process to appraise impacts on energy use and GHG emissions



Framing the analysis

Planning and preparation

2.2 In order to aid planning, Analysts should establish at the outset:

- the objectives of the analysis,
- what specific questions must be answered, and
- outputs required.

2.3 Chapter 6 provides further information on establishing the necessary outputs. Analysts should work backwards to determine what information is required, and how this information is going to be obtained.

Base case or counterfactual

2.4 A project, policy or other proposal will generate costs and benefits, which could differ across options. The first step to assess these impacts is to consider what would happen if the policy or project was not carried out. This default course of action is known as the "do nothing" option and provides the base case, or counterfactual. Analysts need to appraise costs and benefits of each option relative to their counterfactual (see Box 2.1 for an example).

2.5 Analysts need to carefully consider which is the most appropriate counterfactual, as it could significantly change the projected impact of a proposal. If the counterfactual is uncertain, the analyst should highlight and explain the impacts of varying the counterfactual.

2.6 The counterfactual should include all policies to which the government is already committed and which have funding. BEIS's latest Energy and Emissions Projections will therefore need to be referred to.[7]

[7] See https://www.gov.uk/government/organisations/department-of-energy-climate-change/series/energy-and-emissions-projections

Box 2.1: Example – identifying the counterfactual

Consider the case of a one-off policy, funded from general taxation that provides energy-efficient boilers to all households with existing boilers that are below a certain efficiency standard.

To understand the true costs and benefits of this policy, one must identify what would have happened had this policy not come into existence. A study reveals that ten per cent of households with boilers below this standard would naturally replace these anyway. This means that only ninety per cent of the boilers delivered would have been in addition to the base case uptake.

As a result, no additional benefit would be delivered for these boilers, and there would be a redistribution of costs from households to the exchequer.

Policy interactions

2.7 Analysts should ensure that all changes in energy use and UK GHG emissions factor in the interactions that policies and projects in one sector can have on other sectors. For instance, planning decisions may impact on transport emissions as well as emissions from buildings.

2.8 The impacts of policies or projects might also **overlap** or reinforce each other, impacting their combined effectiveness, and the analysis should account for any interaction. For example, the savings from a new efficient boiler will be lower in a house that already has cavity wall insulation.

3. Quantifying and valuing energy and GHG emissions

Introduction

3.1 This chapter is about quantifying and valuing the energy use and GHG emissions resulting from a proposed policy, programme or project. Chapter 4 covers additional impacts including air quality, energy security and wider environmental impacts.

3.2 **This guidance is applicable when there are no significant wider impacts on the energy market** such as significantly changing energy prices. In those circumstances, analysts should consider developing detailed modelling to account for these impacts.

Valuing Changes in Energy Use

3.3 Changes in energy consumption impact the use of resources in the production, transportation, and final supply and use of energy. In order to value these impacts, analysts should use the **long-run variable cost (LRVC)** of energy supply. The calculation required is demonstrated in Box 3.1 Valuing changes in energy useBox 3.1.

Box 3.1 Valuing changes in energy use

$$V_{it} = \Delta(EU)_{it} \times (VC)_{it}$$

$V_{it} = Value\ of\ change\ in\ use\ of\ fuel\ i\ in\ year\ t\ (£)$

$\Delta(EU)_{it} = Change\ in\ use\ of\ fuel\ i\ in\ year\ t\ (kWh)$

$(VC)_{it} = Year\ t\ LR\ variable\ supply\ cost\ of\ fuel\ i\ (£/kWh)$

3.4 The LRVC is used instead of the retail energy price, because energy prices include:

- fixed costs that will not change in the long run with a small sustained change in energy use,
- carbon costs, since these are valued separately, and
- taxes, margins, and other components which reflect transfers between groups in society.

3.5 Supply costs vary by fuel, category of end user, and over time because each fuel has different energy demand profiles and networks costs, which vary over time. Accordingly, the the LRVC values used in an appraisal should be fuel, sector, and time-specific.

3.6 Data tables 9-13 provide projected long-run variable supply costs that are consistent with low, central, and high fossil fuel price scenarios. Analysts should consider in the first instance the central price scenario, while high and low scenarios should be used when conducting sensitivity analysis for changes to fossil fuel prices.

3.7 For a detailed explanation of the methodology underpinning the LRVCs in these data tables, please consult the additional background documentation available alongside this guidance.[8]

Valuing Direct Rebound Effects

3.8 Proposals that improve energy efficiency (such as heating or lighting policies or projects) have the effect of reducing the overall amount of energy ud. An immediate result will be a reduction in energy bills. This frees up funds which can

[8] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

be spent on energy or other goods and services. Any resulting increase in energy use is known as the "**rebound effect**"[9].

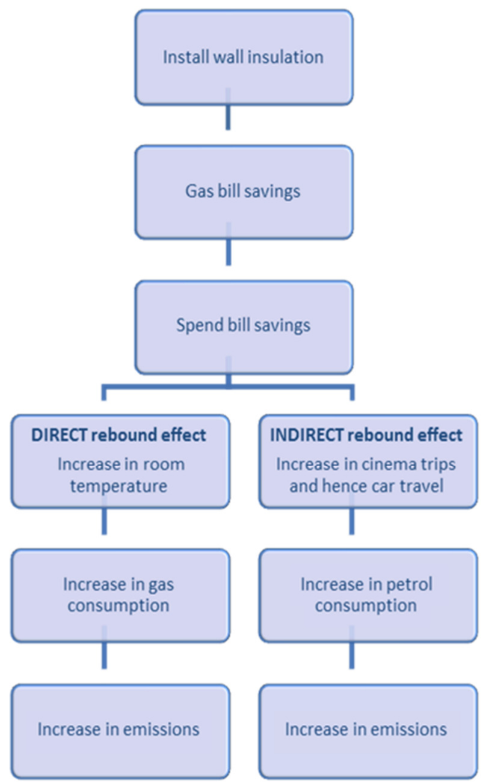
3.9 A financial saving or expenditure that changes the consumption of the same energy product is defined as a **direct rebound effect.** Conversely, a saving or expenditure that changes consumption of other energy products or other goods is defined as an **indirect rebound effect.** A more detailed explanation of rebound effects can be found in the background documentation published alongside this guidance[10].

3.10 Box 3.2 provides an example of how a proposal to install wall insulation can generate a rebound effect. High-quality wall insulation reduces the loss of heat, and generates bill savings through reduced gas consumption. However, part of the savings may also be spent on energy, offsetting some of the energy savings.

3.11 Rebound effects can apply to households, businesses, government institutions, and other economic agents. Therefore **an appraisal should consider the rebound effects for all parties impacted** by a proposal.

3.12 Analysts should value direct rebound effects in appraisals since there is a welfare benefit directly related to the policy or project. **It is not essential to value indirect rebound effects**, as this requires an analysis of changes in disposable income and expenditure that is disproportionate in most appraisals. Where appropriate, analysts should consider how the outcomes of the project would differ if there were significant indirect rebound effects.**The direct rebound effect should be valued at the retail price of the energy** as this captures the gain in welfare (the retail price acts as a proxy for the consumer's willingness-to pay). 1 summarises the rebound effects , and an example is given in Box 3.3.

Box 3.2 Rebound effect from a wall insulation



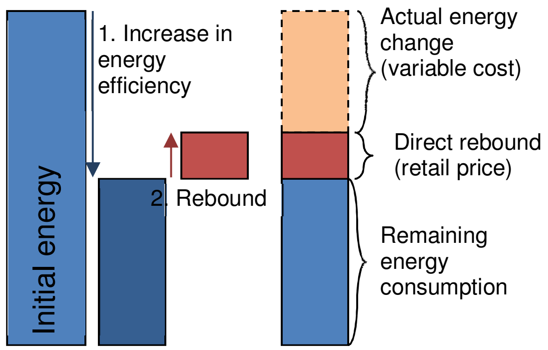
3.13 In this example, both the **actual energy change** relative to the counterfactual and the **direct rebound effect** are quantified. The net energy change is the reduction in energy consumption due to the efficiency improvement, minus the subsequent increase in energy consumption due to the

[9] On the rebound effect see also UK ERC (2007): http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/the-rebound-effect-report.html

[10] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

direct rebound effect. The net change in energy consumption should be valued using the long-run variable cost (LRVC) of energy supply as described above and should be used to calculate and value the changes in emissions.

Figure 3.1 Valuing energy changes with direct rebound effects



3.14 Figure 3.1 shows a summary of these two parts. In addition, the Excel-based toolkit available with this guidance includes a tool to value direct rebound effects. Further details on the rationale for the approach to valuing rebound effects is available in the background documentation.

Accounting for the UK's renewable energy target

3.15 On 23 June, the people of the United Kingdom voted in the EU referendum to leave the EU. Until exit negotiations are concluded, the UK remains a full member of the EU and all the rights and obligations of EU membership remain in force. During this period the Government will continue to negotiate, implement and apply EU legislation, including comply with the EU Climate and Energy Package.[11] The EU

Box 3.3: Valuing energy consumption changes and rebound effects

A new policy in 2016 drives take-up of energy-efficient household boilers. For the target group (who use 1 TWh of gas per annum with their existing boilers), the improvement in energy efficiency means the same heat can be delivered with 50% of the input fuel (500 GWh instead of 1TWh). However, following installation the households spend some of the resulting cost savings increasing by 20% the amount they heat their homes (the rebound effect: 20% of 500 GWh = 100 GWh).

The net annual energy saving is 400 GWh. The size of the rebound is 100 GWh per annum.

The energy impacts (first 2 years only) are valued as follows:

		2016	2017
Net energy savings	GWh	400	400
LRVC (gas) (table 10)	p/kWh	1.3	1.3
Value of net energy savings	**£m**	**5.4**	**5.2**
Rebound	GWh	100	100
Retail price (table 5)	p/kWh	4.3	4.0
Value of rebound effect	£m	4.3	4.0
Value of energy impacts (undiscounted)	**£m**	**9.7**	**9.2**

Note that analysts should also value the carbon impacts of the 400 GWh of energy.

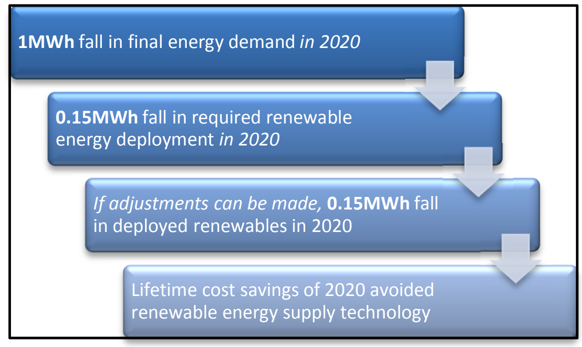
Package requires that, by 2020, 15% of the UK's capped Gross Final Energy Consumption (GFEC) comes from renewable sources.

3.16 Changes in final energy consumption in 2020 (except most changes in aviation consumption[12]) will change the amount of renewable energy supply required to meet the UK target. This is summarised in Figure 3.2. For instance, a proposal that reduces energy consumption in 2020 will also reduce the required amount of energy from renewable sources, generating a saving on the cost to deploy renewables. The same would be true if a proposal is expected to lead directly to additional renewable energy supply (as it would reduce the need to deploy renewables elsewhere).

3.17 There are also interim targets for renewable energy before 2020. However, it is not essential to consider the cost of supplying energy from renewable sources before 2020 against these interim targets for the purpose of analysis.

3.18 Whilst the 15% target is economy-wide, it is reasonable to assume that the impact of a proposal on the renewables target is limited to the same sector. For example, if there is a large reduction in the demand for heat, then there would be a more significant reduction in renewable heat deployment than in, say renewable transport fuels. This is clearly a simplifying assumption, and if there are specific circumstances that could warrant following an alternative approach then the analyst should contact GHGappraisals@beis.gov.uk.

Figure 3.2: Mechanism of avoided costs of renewables



3.19 It is not essential for analysts to value any cost savings from renewable policy adjustments in their main analysis, but if s/he wishes to, further guidance is provided below.

3.20 Changes in **grid electricity** demand are already valued at the long-run variable cost of electricity supply (LRVC) which incorporates the expected change in renewable electricity generation technologies resulting from demand changes. As such, no further valuation is necessary.

3.21 For changes in **transport** fuel demand, the variable cost series provided in the supporting tables do not presently incorporate the impacts on the costs of the relevant renewable policy.[13] Analysts

[12] A change in UK aviation consumption in 2020 that leaves the level of aviation consumption above 6.18% of GFEC will not have any effect on the level of the renewables target. Changes that bring the level below 6.18% would reduce the target.

[13] For transport fuels the relevant policy instrument is the Renewable Transport Fuels Obligation (RTFO). This policy mandates that a certain proportion of transport fuel supplied is from renewable sources. Therefore, changes in transport fuel consumption will mean that savings relating to the RTFO will automatically occur. These costs will be reflected in the long-

should therefore note that the effects have not been captured, but are expected to be be small.[14]

3.22 For **heat**, there would presently be no renewable policy adjustment without further intervention by policymakers. Analysts may wish to explore what the cost savings could be if further policies were to adjust, but these should not be included in the main policy appraisal.

3.23 For further information on accounting for the UK's renewable energy target, please consult the background documentation published alongside this guidance.

Quantifying and valuing GHG emissions

3.24 To appropriately quantify GHG emission, analysts should identify key drivers of emissions impacted by a policy or project proposal. Policies and projects can affect emissions of GHGs in a number of ways, either directly (for example through carbon capture and storage), or indirectly through changes in energy use (for example changing from using oil to using gas for heating a house; or using more efficient bulbs to provide light using less electricity).

3.25 Another aspect to consider is where a proposal has a significant impact on emissions produced abroad, especially in cases where they are embedded in imported materials. Specific guidance is available from paragraph 3.49 onwards.

Expressing GHG emissions in a common unit

3.26 Each GHG has a different potential to accelerate global warming. For convenience, analysts should express the potential impact of GHG emissions in common units. The standard approach is to identify the Global Warming Potential (GWP) of each GHG, which allows to express it in terms of **equivalent tonnes of carbon dioxide (tCO_2e)**. Carbon dioxide (CO_2) is used as a common unit because it is by far the most abundant GHG.[15] The factors to convert a tonne of a greenhouse gas into an equivalent quantity of CO_2 are given in Table 3.1. For example, a tonne of nitrous oxide has the equivalent global warming potential of 310 tonnes of CO_2. So if a policy increases emissions of nitrous oxide by one tonne, we would count this as an increase of $310tCO_2e$.

3.27 Fuel combustion is the UK's biggest source of GHG emissions. Most fuel combustion releases CO_2 and other GHGs. However, different fuels emit different quantities of these gases. Therefore, changing the amount of fuel that is used, or switching from using one fuel to using another, changes the amount of emissions that are produced.

run variable cost element of transport fuels blended with biofuels.

[14] Further information on the RTFO is available here: https://www.gov.uk/renewable-transport-fuels-obligation

[15] Although it has a relatively low global warming potential compared to other GHGs

Table 3.1[16]: Factors for converting greenhouse gases to their equivalent in carbon dioxide

Greenhouse Gas	Global warming potential per unit mass (relative to CO_2)
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298
HFC – 134a	1,430
HFC – 143a	4,470
Sulphur hexafluoride	22,800
Carbon Dioxide as Carbon[17]	3.67

3.28 The GHG emissions associated with the use of energy may be estimated by applying a fuel-specific emissions factor. By multiplying the energy use (measured in kWh) by an emissions factor (measured in $kgCO_2e/kWh$), one obtains the quantity of GHG emissions produced, measured in terms of the equivalent mass of carbon dioxide emissions ($kgCO_2e$).

3.29 In order to quantify changes in GHG emissions resulting from changes in energy use, net changes in energy use should first be quantified, making sure to include the impact that any rebound effect may have (see paragraph 3.8). Marginal emissions factors are then applied to these energy use changes as demonstrated in Box 3.4.

Box 3.4 Converting changes in fuel use to GHG emissions

$$\Delta \boldsymbol{C}_{it} = \Delta(\boldsymbol{EU})_{it} \times \boldsymbol{M}_{it}$$

$\Delta \boldsymbol{C}_{it}$ = *Change in emissions from fuel i in year t* ($kgCO_2e$)

$\Delta(\boldsymbol{EU})_{it}$ = *Change in use of fuel i in year t* (kWh)

$\boldsymbol{M}_{it}$ = *Year t marginal emissions factor* ($kgCO_2e/kWh$)

3.30 For estimating changes in emissions from changes in **direct fuel** use, such as burning coal or gas, analysts should use the emissions factors found in **data tables 2a and 2b**. The marginal emissions factor is assumed to be constant across different levels of supply / demand (i.e. the average and marginal emissions factors are identical), and also over time. While there are minor variations in the emissions produced from these fuels over time resulting from differences in the average chemical composition, it is reasonable to assume that this variation is insignificant for appraisal purposes.

3.31 For estimating changes in emissions from changes in **grid electricity** use, analysts should use the (long run) marginal grid electricity emissions factors in **data**

[16] The conversion factors incorporate GWP values for a 100 year time horizon relevant to reporting under UNFCCC, as published by the IPCC in its Fourth Assessment Report - Working Group Report I: The Physical Science Basis (Chapter 2) (2007, page 212). Revised GWP values have since been published by the IPCC in the Fifth Assessment Report (2013) Current UNFCCC Guidelines on Reporting and Review are that the figures in the Fourth Assessment Review should be used in the emission inventory carbon budgets and for international reporting.

[17] Prior to 2007, figures for changes in GHG emissions were presented in terms of carbon (C). Any such figures should be converted into units of CO_2e using the conventional conversion factor of 44/12 (e.g. 1 tonne of C emissions is equivalent to 1 x (44/12) = 3.67 tonnes of CO_2e).

table 1. These emission factors will vary over time as there are different types of power plant generating electricity across the day and over time, each with different emissions factors. An example of the calculation is presented in Box 3.5.

Box 3.5 Using emissions factors to convert electricity use changes into GHG emissions changes

An energy efficiency programme which reduces the use of electricity by households is being considered. Electricity consumption is predicted to be cut by 10GWh (10 million kWh) relative to the "do nothing" option in each year between 2016 and 2037. The calculations below demonstrate how this change in energy use is multiplied by the appropriate marginal emissions factor (see data table 1) to derive the change in emissions.

	Change in electricity use	**Marginal emissions factor (Table 1) - Domestic Households**		**Change in emissions**
	GWh	**$kgCO_2e$ /kWh**	**tCO_2e /GWh (see Annex B)**	**tCO_2e**
2016	-10	0.33	327	-3270
2017	-10	0.32	317	-3173
…	…	…	…	…
2035	-10	0.08	82	-824
2036	-10	0.08	75	-753
2037	-10	0.07	69	-687

3.32 There are complex mechanisms that determine the effects of sustained but marginal changes to the grid electricity supply (from either displacement with other generation or a demand reduction). A small reduction in grid electricity consumption will be met through a reduction in supply from a small subset of plant, rather than through an equal drop across all generation plant. Very temporary changes in consumption will likely only result in short run changes to generation levels, rather than changes in capacity. However, sustained changes in consumption will result in changes to generation capacity – in terms of the timing, type, and amount of generation plant built and / or retired – as well as changes in generation levels. Modelling undertaken by BEIS has estimated these longer-term dynamics, and they are reflected in the marginal emissions factors. Further information may be found in chapter 2 of the background documentation accompanying this guidance.

3.33 The grid electricity emissions factors also capture **whole system impacts** in their values as these are built into the

Dynamic Dispatch Model (DDM)[18] which informs these factors.

3.34 The emissions factors are based on constant change in electricity consumption throughout the day and year. If your policy affects specific consumption e.g. peak demand, advice should be obtained by contacting GHGappraisal@beis.gov.uk.

3.35 Where bespoke emissions factors exist they should be used instead of the supplementary guidance emissions factors.[19]

3.36 When a policy or project results in a **switch from using one fuel to another**, this may be analysed in a similar way as when only one fuel is affected. In such situations, it is necessary to consider the impact on the consumption of each fuel separately and apply the appropriate emissions factor to the change in consumption of each fuel (an increase in one, and a reduction in the other).

Measuring the emissions footprint of an entity

3.37 For some purposes we wish to know the level of GHG emissions attributable to a particular sector, organisation, or building, based on its share of fuel use in the UK, known as the **emissions footprint**.

3.38 For **fossil fuel** use, analysts should simply use the emissions factors in **data tables 2a and 2b**.

3.39 For **grid electricity** use the total mix of generation plant used will determine the average emissions factor. This will differ from the mix of plant used to calculate the marginal emissions factor and will also vary over time. The electricity emissions footprint of an entity is its share of emissions from electricity generation across the grid and analysts should use the average emissions factors in **data table 1**. An example of how to conduct an emissions footprinting is given in Box 3.6. Further explanation of marginal and average electricity emissions factors may be found in the background documentation.[20]

[18] https://www.gov.uk/government/publications/dynamic-dispatch-model-ddm

[19] For example when the change in emissions is for Gas CHP plants

[20] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Box 3.6 GHG emissions footprinting

As part of a report, an analyst may wish to present the amount of the UK's emissions resulting from the consumption of gas and electricity by one small, non-energy intensive commercial sector in 2016. They have information on the final energy consumption by the industry of both of these fuels in 2016 (500GWh for gas and 1,500GWh for electricity), and need to convert these to an emissions footprint.

In order to conduct this calculation, analysts should use **average emissions factors,** which give the amount of emissions produced through consumption of energy, expressed as the ratio of all GHG emissions and total energy consumption. In these circumstances, it would not be appropriate to use marginal emissions factors, as the analyst is not considering the emissions impact of changes in energy consumption by the industry. Instead, they wish to know what share of emissions this industry is responsible for.

For **gas consumption**, the **average emissions factor** is same as the marginal emissions factor. For electricity consumption, the average emissions factor is not the same as the marginal emissions factor. Analysts should do the following calculation:

		Gas	Electricity (commercial)
Consumption	GWh	500	1500
Average emissions factor in 2016	$kgCO_2e/kWh$	0.18	0.27
	$MtCO_2e/GWh$	0.0002	0.0003
(Data tables 1 & 2a)	(see Annex B)		
GHG emissions	$MtCO_2e$	0.09	0.41

Valuing GHG emissions

3.40 Once the change in GHG emissions (measured in tCO_2e) resulting from the project or policy proposal has been quantified using the methodology above, these emissions should be given a monetary value. It is important to value both the changes in emissions from fuel use, and also the changes in emissions from other sources.

3.41 This section provides guidance on valuing impacts of carbon on society. Where analysts intend to model impacts on carbon prices, short-term carbon values should be used. More information and advice is available on the government webpages[21] or by contacting ghgappraisals@beis.gov.uk.

3.42 In valuing emissions for appraisal purposes, the UK Government adopts a target-consistent approach, based on estimates of the abatement costs that will need to be incurred in order to meet specific emissions reduction targets. For further information on the methodology for valuing

[21] https://www.gov.uk/government/collections/carbon-valuation--2

GHG emissions used here, please consult the carbon valuation section on GOV.UK.[22]

3.43 The EU Climate and Energy Package (December 2008)[23] introduced separate emissions reduction targets for the **traded sector** (that is those emissions covered by the EU Emission Trading System, EU ETS[24]), and for the **non-traded sector** (those emissions not covered by the EU ETS). The presence of separate targets in the Traded and Non-Traded sectors implies that emissions in the two sectors are essentially different commodities.

3.44 Changes in emissions which occur in the traded sector are valued at the Traded Price of Carbon (TPC), whereas changes in emissions in the non-traded sector are valued at the Non-Traded Price of Carbon (NTPC). These traded and non-traded carbon prices are different in the short-term, but are projected to converge, becoming equal in 2030 and remaining so in further years. This is based on the assumption that there will be a functioning global carbon market by 2030. An example of the calculation required is shown in Box 3.7 below.

3.45 To value GHG emissions for Official Development Assistance projects, please contact GHGemissions@beis.gov.uk.

[22] For further details on BEIS's approach to valuing GHG emissions, see: https://www.gov.uk/carbon-valuation

[23] See here for further details: http://www.europarl.europa.eu/climatechange/doc/EU_Legislation_on_climate_change.pdf

[24] Further information on the EU ETS is given here: https://www.gov.uk/guidance/eu-ets-carbon-markets

Box 3.7 Using the traded and non-traded carbon valueS

An energy efficiency programme reduces the use of gas and grid electricity by small businesses. Consumption of grid electricity (which indirectly reduces emissions in the traded sector) is cut by 15GWh while their gas consumption (producing GHG emissions in the non-traded sector) is cut by 10GWh. These are annual differences from the counterfactual "do nothing" option for each year between 2015 and 2050. The tables below show how to value the emission reductions using the new carbon values. These monetary savings can then be discounted in the usual way following Green Book guidance.

		2016	**…**	**2050**
Change in energy use (electricity)	GWh	-15	…	-15
Marginal emissions factor (electricity, Table 1)	tCO_2e/GWh	321	…	27
Total Emissions saving	tCO_2e	4815	…	407
Traded price of carbon (Table 3)	£/tCO_2e	4.2	…	221
Value of GHG savings (undiscounted)	**2016 £'000**	**20**	**….**	**90**

		2016	**…**	**2050**
Change in energy use (gas)	GWh	-10	…	-10
Emissions factor (gas, Table 2a)	tCO_2e/GWh	184	…	184
Emissions saving	tCO_2e	1840	…	1840
Non-traded price of carbon (Table 3)	£/tCO_2e	63	…	221
Annual Value of GHG savings (undiscounted)	**2016 £'000**	**115**	**….**	**407**

Mapping emissions into traded and non-traded sectors

3.46 In order to correctly value changes in emissions, the projected changes in GHG emissions resulting from a project or policy proposal must be mapped to either the traded (EU ETS) sector, or the non-traded sector.

3.47 Table 3.2 (and Table 6.1) explains which emissions should be allocated to each sector. For example, emissions from gas consumption by households for space heating should be attributed to the non-traded sector. However, emissions resulting from gas consumption by an installation that participates within the EU ETS would be counted in the traded sector.

3.48 If it is unclear whether emissions changes resulting from a proposal are attributable to the traded sector, advice should be sought by contacting GHGappraisal@beis.gov.uk.

Treatment of Emissions Embedded in Imported Materials

3.49 When analysing projects that result in a large change to the amount of imported goods, commodities or services, it is best practice to consider the emissions associated with these imports.[25]

[25] Although there is no requirement to include embedded emissions in the UK inventory, the decision making and

3.50 For appraisal purposes, the 'GHG emissions content' of all materials used to implement a proposal should be considered to inform the decision-making process. Some imports may be from countries without carbon pricing arrangements and so the material costs will not include the cost of the GHG emitted in their production. It is reasonable in these circumstances to consider adjustments to account for the value of the externality.[26]

Table 3.2 Mapping emissions to the traded and non-traded sectors

Traded sector GHG emissions
Grid electricity use by all sectors[27]
Direct fuel use and manufacturing processes by EU ETS participants (although certain GHGs are exempt)[28]
Direct fuel use in aviation[29]

Non-traded sector GHG emissions
Direct fuel use by households
Direct fuel use in non-aviation transport
Direct fuel use by private and public sector organisations from installations that do not participate within the EU ETS[30]
Emissions from land use, land use change, and forestry (LULUCF)
Emissions from landfill[31]
Emissions from agriculture

appraisal process should take into account the impact of UK policy on emissions from abroad if it is appropriate (for example, the question specifically focuses on emissions abroad), proportionate and practical. Consideration should be given to providing separate assessments for UK emission and global emissions.

[26] For example, some bio-fuels for consumption in the UK are imported from outside the UK, so domestic bio-fuel consumption will have implications for emissions in other parts of the world as a result of bio-fuel production processes. If these emissions occurred outside of a capped traded sector, then appraisal should account for the additional costs of the policy due to emissions overseas (an example can be found at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/230482/RO_Biomass_Sustainability_Govt_Response_-_Impact_Assessment_-_19-August-2013_FINAL_for_pdf.pdf. Where emissions occur in economies that have an emissions cap for the relevant sector, then the price of the relevant product will already include a cost of carbon.

[27] A proportion of grid electricity is produced by non-EU ETS participants. However, almost all of this generation is from zero-emissions rated plant, for example resulting from Feed In Tariffs (FiTs). Therefore, it is a reasonable approximation to allocate all grid electricity emissions to the traded sector.

[28] Includes power and heat generation (sites exceeding 20 MW input), and GHG-intensive industry sectors including oil refineries, steel works and production of iron, aluminium, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals.

[29] Emissions from intra-European flights are included under the EU ETS from 1 January 2013 to 31 December 2016.

[30] Note that organisations may be responsible for emissions both in and out of the EU ETS, and therefore in both the traded and non-traded sectors

[31] Note the Landfill Allowance Trading Scheme (LATS) ended following the 2012/13 trading year.

Box 3.8 Valuing non-domestic CO_2 emissions changes and embedded emissions in waste policy

A nationwide scheme that encourages households to recycle paper reduces the quantity of paper that is sent to landfill. It is estimated that during the course of the scheme (2016-2025) the reductions in paper sent to landfill result in savings 200 $ktCO_2e$ per year from sites within the UK.

In addition, the production of recycled paper within the UK significantly reduces the quantity of paper imported into the UK from countries with no applicable emissions cap. Using trade data and levels of carbon intensity attributed to the non-capped countries, it is estimated the reduction in imported paper saves 120$ktCO_2e$ per year of GHG emissions from the non-capped country through reduced production of paper. These emissions should be valued using the Traded Price of Carbon estimates reported in data table 3.

UK non-traded savings: (200tCO_2e × non-traded price of carbon)

	2016	…	2024	2025
Emission savings ($ktCO_2e$)	200	…	200	200
Non-traded price (2016 £/tCO_2e) (table 3)	63	…	71	72
Value of savings (2016 £m)	13	…	14	14

Embedded carbon savings: (120tCO_2e × Traded price of carbon)

	2016	…	2024	2025
Emission savings ($ktCO_2e$)	120	…	120	120
Traded price (2016 £/tCO_2e) (table 3)	4.2	…	34	41
Value of savings (2016 £m)	0.5	…	4.0	4.9

3.51 Where appropriate, proportionate and possible to identify the impact of the proposal on emissions overseas or that occur outside the target framework (e.g. radiative forcing from aviation), the change in emissions overseas should be valued at the **Traded Price of Carbon** over the 2010-2030 period (**data table 3**). The Traded Price of Carbon is recommended in the absence of a carbon value for countries without carbon pricing arrangements. Sensitivity analysis should be carried out to test for this uncertainty. Beyond 2030, the assumption of a fully functioning global carbon market implies that the carbon costs will already be internalised in the import price of each product. Therefore, no adjustment will be required after this date provided that the projected import costs include this cost of carbon.

3.52 There are important practical complications in assessing the carbon impact of imported products, so there may be circumstances where the recommended methodology above is not appropriate. Also, for many proposals, assessment of emissions from imported good could be disproportionate. Advice can be obtained by contacting GHGappraisal@beis.gov.uk

3.53 It should be noted that BEIS will not include the GHG emissions of imported materials as part of the UK's national inventory. This is because the Government has agreed to report national territorial emissions at the point of release, as recommended by the International Panel on Climate Change. In principle this means that the national inventory includes all greenhouse gas emissions generated as part of the production of goods and services within a country (e.g. the UK) regardless of where these are consumed (either in the UK or exported).[32]

[32] For more information, please consult http://www.ipcc-nggip.iges.or.jp/index.html

4. Consideration of other additional impacts

Introduction

4.1 Proposals that affect energy consumption or supply, or result in changes to GHG emissions, are also likely to have impacts that are not accounted for in either the costs of energy supply or in the carbon values described in Chapter 3. This chapter explains the most common of these additional impacts. Analysts should ensure that all significant impacts of a proposal are accounted for, and this may mean considering some, or all, of the following. For air quality and wider environmental impacts, further information and guidance should be sought from Defra's pages on the GOV.UK website in the first instance.

4.2 In addition, this chapter describes possible approaches to other analytical issues that are often present in energy and emissions-based policies and projects, including distortions from the presence of indirect taxation, and accounting for the costs of private finance.

Air Quality Impact

4.3 Air pollution can generally be defined as airborne chemicals, particulates, and biological materials that cause harm to humans or damage the environment. Under this definition, there are three key groups of impacts:

- adverse health impacts (including mortality and morbidity)
- immediate environmental impacts (such as acidification and soil eutrophication), and
- long-term environmental impacts (which include climate change).

4.4 Air quality policies typically focus on human health and immediate environmental impacts, while climate change policy focuses primarily on the long-term climate change potential. Given this definition, there are clear links between climate change mitigation policies and air quality policies. Though the majority of overlaps are mutually beneficial i.e. a policy option designed to reduce CO_2 will also reduce other air pollutants (and vice versa for air quality policies), in some cases there are trade-offs.[33]

4.5 To account for these synergies and trade-offs, and ensure they contribute appropriately to the decision-making process, policymakers should build the air quality impacts of their policy into their appraisal process, where possible, using monetary values. The Interdepartmental Group on Costs and Benefits (IGCB), a Defra-led panel of experts, has developed a number of monetisation methodologies to aid such policymakers, which should be followed and are available as Green Book supplementary guidance.[34] The approach to be taken depends on the characteristics of the project in question. In this guidance we refer to some of the most common approaches used: the Impact Pathway, the Damage Costs, and the Abatement Cost approaches.

The Impact Pathway approach

4.6 For any policy where estimated air quality impacts are above £50m NPV, analysts should undertake the "impact

[33] Information on the potential synergies and trade-offs between climate change mitigation and air quality can be found in the 2007 Air Quality Environment Group (AQEG) report "Air quality and climate change: a UK perspective". http://webarchive.nationalarchives.gov.uk/20130402151656/http://archive.defra.gov.uk/environment/quality/air/airquality/publications/airqual-climatechange/documents/fullreport.pdf

[34] Available from https://www.gov.uk/government/publications/green-book-supplementary-guidance-air-quality

pathway" approach, a bespoke air quality impact valuation.[35]

4.7 The impact pathway approach follows the source of the emission to its dispersion in the atmosphere, and the resultant exposure to estimate a range of end points (such as health impacts) that are valued. Impacts therefore vary based on a range of considerations (such as dispersion and toxicity) that arise from differences in geographical location and population exposed. At present, this approach has been used to estimate the impact of four different air pollutants: nitrous oxide (NO_x), sulphur dioxide (SO_2), ammonia (NH_3) and particulate matter (PM10).

The Damage Costs approach

4.8 For any policy where there are air quality impacts valued below £50m NPV, it is recommended to value impacts using the "damage costs" approach. An online calculator can be used to monetise the costs.[36]

4.9 "Damage costs" are based on the impact pathway approach, but have been calculated using a range of representative emissions in order to estimate an average marginal effect for each additional tonne of gas introduced into the atmosphere. These primarily value health impacts,[37] though non-health impacts are also included. Damage costs are not linked to limit values being exceeded.

4.10 It must be noted that these monetary values do not include all the likely impacts of air pollution, such as non-health impacts on acidification and soil eutrophication, and do not include the impacts on ecosystems, visibility or ozone depletion.

4.11 Changes in energy use can be used to estimate the changes in the level of pollutants emitted. **Data tables 14 and 15** provide air quality valuations for changes in the use of road transport fuels and other energy sources. Damage cost estimates are differentiated by location of fuel use to account for the fact that a policy that targets the reduction in fuel use in inner cities will reduce the damage costs of air pollution more than a policy that addresses rural fuel use (due to differences in the population exposed).

4.12 Where the change in emissions arising from the policy is known, analysts should use the Damage Costs Calculator, which applies monetary values to emissions. Where the change in emissions arising from the policy is not known, analysts should use the Activities Costs Calculator, which links a wide range of actions and technologies with the associated level of emissions, and applies monetary values to these.

The Abatement Cost approach

4.13 Air quality, as with most environmental assets, is subject to a number of major threshold and equity factors, which are protected through the

[35] https://www.gov.uk/government/publications/air-quality-impact-pathway-guidance

[36] Defra's Air Quality Guidance can be found at: https://www.gov.uk/government/publications/green-book-supplementary-guidance-air-quality
Defra's Air Quality Valuation pages can be found at: https://www.gov.uk/air-quality-economic-analysis
For further information on valuing Air Quality impacts, contact the IGCB:
igcb@defra.gsi.gov.uk

[37] Health impacts: Morbidity and mortality impacts used in the model are based on recommendations by the Committee on the Medical Effects of Air Pollution (COMEAP). Health impacts evaluated in the model are linked to incidences of respiratory or cardiac disease, but do not include others where the evidence is less robust, for example, long-term exposure effects or increased likelihood of asthma in children.

establishment of minimum standards on ambient concentrations, emissions and exposure. These standards are delivered through national and international obligations covering these areas.

4.14 Where a proposal is expected to affect compliance with these obligations[38] (whether causing, removing or altering the extent of an exceedance), then the abatement cost of restoring compliance should be factored into the appraisal. This should be undertaken through an estimation of the cost of offsetting measures (the "abatement cost" approach). Only the amount of air quality that breaches the relevant obligation should be valued using this approach – changes below the obligation should be valued using the impact pathway or the damage costs approach.

Wider Environmental Impacts

4.15 The impacts of policy and project options can go beyond GHG emissions and the air quality impacts and Treasury Green Book guidance states that policy appraisal should seek to identify all the costs and benefits including environmental. Landscape, biodiversity, noise, water quality and quantity, and flood risk all need to be considered in appraising policy options.

4.16 While impacts on the environment often do not have any market prices, it is important to try and use evidence on non-market values attached to environmental impacts where feasible, to value them on a consistent basis with other financial costs and benefits. There are different methodologies for obtaining monetary values resulting from change in the environment.[39]

4.17 Where the expected policy impact on the environment is significant, an ecosystem services framework[40] can aid comprehensive analysis of the impacts. This methodology provides a broader framework for considering all the environmental impacts of a policy and identifying the economic end points that can be valued.

4.18 Defra has produced detailed guidance on assessing wider environmental impacts.[41] This includes a checklist of questions on wider environmental impacts and a step by step guide to assessing, quantifying and valuing any environmental changes.

Energy Security & Resilience

4.19 A secure and resilient energy system is one in which supply and demand can balance at prices which are not excessively volatile. That is, physical interruptions to supply (which result in excess demand) and price spikes do not occur.[42] Any policy that has a significant impact on the supply of, or

[38] https://www.gov.uk/government/policies/protecting-and-enhancing-our-urban-and-natural-environment-to-improve-public-health-and-wellbeing/supporting-pages/international-european-and-national-standards-for-air-quality

[39] For more details on environmental valuation methods, see http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/environment/

[40] Ecosystem services are defined as services provided by the natural environment that benefit people. For more details, see "An introductory guide to valuing ecosystem services", Defra (2011): https://www.gov.uk/ecosystems-services

[41] at http://www.defra.gov.uk/environment/index.htm

[42] The *affordability* of energy over the long term (i.e. over periods running into years) is probably best thought of as a separate issue, and would likely be addressed to some extent by different policy interventions to shorter term *security and resilience*.

demand for, energy or energy services, including by affecting the way energy markets function, could therefore affect the UK's energy security and resilience.

4.20 Quantitative evidence where possible, or a qualitative assessment where not, should be provided to assess the security and resilience impact of a proposal.

Quantitative approach

4.21 One approach to valuing an interruption to energy supply would be to estimate the expected unmet energy demand. That is, the probability of an interruption multiplied by the size of the interruption; multiplied by the value of lost load[43] (the value that customers attach to the unmet energy demand).

4.22 Conducting this analysis for each of the years of the lifetime of a project, and comparing this to the 'do nothing' counterfactual case, would provide a Net Present Value of security benefits that could be compared to the costs of delivering reductions in the probability of interruptions. While this approach is recommended, assessing the impact that a policy may have on the probability of an interruption to supply (or on the likelihood of prices spiking) is very complex, and is done mainly for the power sector.

Qualitative approach

4.23 An alternative or supplementary approach to quantification is to qualitatively assess how a proposal is likely to impact the margin between future peak demand and available supply – and therefore the risk of excessive price volatility or interruptions to supply (along with the costs that those can bring).

4.24 In the UK markets are used as a key instrument for delivering energy security and resilience, and so they should be an integral part of any appraisal of energy security and resilience.

4.25 As energy markets work imperfectly, a qualitative appraisal must also assess the impacts on the 'physical' characteristics of the energy system (i.e. the things that affect the margin between supply and demand). Table 4.1 outlines the key factors assessing margins on the supply and demand side.

Table 4.1 Factors affecting margins between peak demand and available supplies

Factors affecting likely margins - supply side:
Maximum potential level supply – both in terms of infrastructure capacity and/or commodity supply
Nature, quality or characteristics of supply – both in terms of infrastructure capacity and/or commodity supply, including for example: • Reliability • Responsiveness • Diversity • Resistance • 'Repairability' or 'restorability' of supply
Factors affecting likely margins -

[43] Estimating the Value of Lost Load, London Economics, July 2011: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf and The Value of Lost Load (VoLL) for Electricity in Great Britain, London Economics, July 2013: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf

demand side
• Unrestrained[44] level of demand • Demand side responsiveness

4.26 Detailed guidance on the definitions of these characteristics and issues to consider when assessing a policy's impact on each of them are set out in the background documentation.[45] Advice can be obtained by contacting GHGappraisal@beis.gov.uk.

Accounting for differences in taxation

4.27 Rates of taxation that vary between options, or that vary between affected parties can have distorting implications for analysis.

4.28 In most situations, it is unlikely that the size of these distortions will be significant enough to warrant special treatment. However, there are certain circumstances where extra care must be taken and adjustments may be advisable, such as by applying an **indirect taxation correction factor**. Two of the more common situations are:

- Where impacts on societal groups are being presented separately (eg. firms and consumers) and these groups are exposed to different rates of indirect taxation (e.g. VAT); or
- Where there are non-financial impacts (such as improvements in comfort) on more than one group and these groups have different indirect taxation rates applicable to them. It does not matter whether the impacts are aggregated or presented separately.

4.29 Details on how to account for these effects are beyond the scope of this guidance. However, if it is expected that the impacts are significant enough to affect the choice of option, then the analyst is encouraged to refer to Chapter 7.1 in the background documentation and make the necessary adjustments.

Costs of finance

4.30 How a project is to be financed poses challenges within social cost-benefit analysis. There are no definitive rules set out within this guidance. However, it is recommended that analysts consider a set of general principles:

- The **methods of funding** a proposal should be identified and the implications assessed,
- **Earmarked government spending** would not normally have an opportunity cost (interest) applied because the public spending envelope is determined independent of individual policies, and
- The **costs of private financing** would generally be considered to be a real social cost which affects private sector allocation decisions (opportunity cost). The cost of capital, amongst other things, represents compensation for risk and uncertainty. Where the method and terms of the financing do not differ

44 This is defined for purposes here as the level of demand that would occur without demand responsive initiatives. Overall demand is the resulting demand level following response initiatives.
45 https://www.gov.uk/government/publications/green-book-supplementary-guidance-air-quality

between options, it would usually make sense to include these (socially discounted) costs in an NPV.

4.36 **Where different financing methods exist between options, care must be taken to avoid introducing bias** to the decision-making as a result of these differences. For example, one option may target the general population with a government-guaranteed low interest rate. It would not make sense to compare this directly with the costs of an option targeted at low-income high-credit-risk individuals with very high interest rates and no government backing because the government finance option includes unvalued contingent liabilities borne by the taxpayer. As such, when comparing policies within a portfolio, care must be taken to ensure that they are appraised on the same basis.

4.38 Further information may be found in the background documentation accompanying this guidance. For analyses with significant capital requirements, please contact GHGappraisal@beis.gov.uk for further advice.

5. Cost-effectiveness

Introduction

5.1 In an appraisal, choosing the best option for a proposal is ultimately up to the decision-maker. To help inform this decision, he or she will usually consider whether the policy or project is expected to deliver its objectives cost-effectively.

5.2 There are different ways of assessing cost-effectiveness which depend on the specific objective in mind. The first and most straightforward way of assessing whether a project is good value-for-money is to consider the **Net Present Value (NPV)**. This is the sum of all monetised costs and benefits, discounted to the base year chosen. Within this NPV will be a valuation of the changes in traded and non-traded GHG emissions resulting from the proposal.

5.3 If the NPV is positive, the policy is estimated to provide a net monetised benefit, and conversely if the NPV is negative, then the policy is estimated to result in an overall monetised cost to society.

Cost Effectiveness Indicator

5.4 For energy and climate change policy, it is to be expected that a primary objective is to reduce GHG emissions. In this case, it would be appropriate to consider cost-effectiveness in terms of the **average cost of saving each tonne of carbon dioxide (equivalent)**. The focus of this chapter is on how to make these calculations of the cost-effectiveness of reducing GHG emissions.

5.5 Since GHG emissions may be in the traded or non-traded sectors, this naturally leads to two measures of cost-effectiveness. If the objective of the proposal is to reduce GHG emissions in the non-traded sector, then calculating the **non-traded emissions cost-effectiveness** indicator would be appropriate, and similarly the **traded sector emissions cost-effectiveness** indicator would be used for calculating the cost of reducing UK traded sector emissions (noting that these are capped at the EU-wide level).

5.6 The indicators of cost-effectiveness should be calculated as described in Box 5.1.[46] These indicators are calculated as (the negative of) the NPV excluding the value of the emissions saved in the sector of interest, divided by the carbon equivalent saved in this sector.

Box 5.1 The cost-effectiveness indicator of GHG emissions savings

$$\boldsymbol{CE_s} = -\frac{NPV \; - PVC_s}{\boldsymbol{\beta_t C_s}}$$

$\boldsymbol{CE_s}$ = Cost−effectiveness in sector s (T or NT)

$\boldsymbol{NPV}$ = Net present value of option (£)

$\boldsymbol{PVC_s}$ = PV of change in GHG emissions (T or NT)(£)

$\boldsymbol{C_s}$ = GHG emissions in sector s (T or NT) $((t[\![CO]\!]\_2\ e)$

$\boldsymbol{\beta_t}$ = Discount factor in year t

[46] It is important to note the sign convention. A positive number of the indicator represents a net cost per tonne of CO_2, whilst a negative number is a net benefit per tonne of CO_2e.

Weighted Average Cost Comparator

5.7 To determine whether emissions savings are being delivered cost-effectively the cost-effectiveness indicator must be compared against a benchmark. This is given by the traded or non-traded sector **weighted average cost comparator.**

5.8 The weighted average cost comparator represents the maximum amount that is desirable to spend to abate the average tonne of emissions. For emissions in the traded sector this will be the (weighted) average (discounted) price of traded carbon over the period of the policy under consideration. For emissions in the non-traded sector this will be the (weighted) average (discounted) price of non-traded carbon over the period of the policy under consideration.[47]

5.9 If the cost-effectiveness indicator is lower than the relevant comparator then the emissions are, on average, being abated in a cost-effective way. Otherwise, the emissions are not being abated cost-effectively.

5.10 To identify the appropriate cost comparator to use, analysts should follow the steps described here, which use the Traded Cost Comparator as an example. A worked example is demonstrated in Table 5.1.

Step 1) Identify the change in traded sector emissions in each year that there are impacts

Step 2) Obtain the emissions weightings by year (in-year change in traded sector emissions as a proportion of lifetime savings);

Step 3) Identify the Traded Price of Carbon (TPC) schedule for the lifetime of the policy;

Step 4) Discount the TPC schedule to calculate present values (based on the Green Book discount rates)

Step 5) Multiply the annual values from steps 2 and 4 (weight x discounted TPC price)

Step 6) Sum all the years in step 5 to give the Traded Cost Comparator.

5.11 The traded cost comparator (TCC) is summarised in Box 5.2.

Box 5.2 The traded cost comparator

$$\boldsymbol{TCC} = \sum_{t=1}^{t=Y} \boldsymbol{\beta_t TPC_t}\left(\frac{\boldsymbol{C_{T,t}}}{\boldsymbol{C_T}}\right)$$

$\boldsymbol{TCC}$ = Traded Cost Comparator for this project (lasting Y years)

$\boldsymbol{\beta_t}$ = discount factor in year t

$\boldsymbol{TPC_t}$ = Traded Price of Carbon in year t $(£/tCO_2e)$

$\boldsymbol{C_{T,t}}$ = Traded GHG emissions in year t (tCO_2e)

$\boldsymbol{C_T}$ = Lifetime traded GHG emissions (tCO_2e)

5.12 The **Non-traded Cost Comparator** is calculated in the same way except the change in non-traded emissions and the non-traded price of carbon (NTPC) price schedule should be used.

5.13 It is easier to understand the approach by considering the a worked example. Box 5.3 gives an example with savings in both sectors and over a number of years.

[47] For information on carbon prices, please see: https://www.gov.uk/carbon-valuation

Table 5.1 Example of Traded Cost Comparator calculation

Year	**2016**	**2017**	**2018**	**Total**
mtCO_2e (net)	0.6	0.7	0.4	1.7
Weighting (in-year emissions/ lifetime emissions)	0.35	0.41	0.24	1
Traded price of carbon (TPC) (£/tCO_2e) (table 3)	4.2	4.2	4.3	
Discounted TPC (2016 base) (£/tCO2e)	4.2	4.1	4.0	
Weight x discounted TPC (£/tCO2e)	1.5	1.7	0.9	
Traded cost comparator (£/tCO2e) =				4.1

Ranking policies and projects

5.14 It is not appropriate to rank policies using the cost-effectiveness indicator where their emissions savings have different profiles over time. Since the value of carbon is non-constant over time comparing the policies in terms of abating GHG emissions would therefore be misleading.

5.15 Technically, the only time when policies can be ranked using the cost-effectiveness indicator is when they have the same emissions savings profile and therefore weighted average cost comparator.

5.16 However, in practice policies will rarely have the same emissions savings profile and weighted average cost comparator. Whilst it may be acceptable for an analyst to compare policies with similar emissions savings profiles and comparators, care must be exercised.

Box 5.3 Example of non-traded cost comparator

Consider a policy that drives the uptake of ground source heat pumps by households, beginning in 2016 and lasting 10 years (2016-2025). It results in annual emissions reductions in the non-traded sector of around 10,000 tCO_2e from avoided gas consumption (or 100,000 tCO_2e of cumulative non-traded emissions savings), and an *increase* in emissions in the traded sector of around 1,000 tCO_2e in each year from increased electricity consumption.

The primary objective of the policy is to reduce non-traded carbon emissions cost-effectively, so one needs to **calculate the non-traded cost-effectiveness indicator** and **compare with the non-traded cost comparator (NTCC)**

The NPV of the policy is £1.5m, which is broken down as follows:

	NPV £m (base year 2016)
Capital costs	-7.9
Cost of Traded emissions (Electricity)	-0.1
Saving of Non-traded emissions (Gas)	5.8
Savings from energy consumption (Elec & gas)	3.7
Total	**1.5**

Savings from energy Consumption refers to the benefit to society of not having to pay for the energy saved.

The weighted average Non-Traded Cost Comparator (NTCC) is £67 per tCO_2e, calculated using the methodology described in Table 5.1.

Looking at the cost-effectiveness in the non-traded sector,

$$CE_{NT} = -\frac{NPV - PVC_{NT}}{C_{NT}} = -\frac{£1.5m - £5.8m}{100{,}000\ tCO_2e}$$ = £43 per tCO_{2e} in the non-traded sector

The policy delivers each tonne of non-traded carbon savings at a cost of **£43** per tCO_2e. This is lower than the NTCC of **£67** per tCO_2e, therefore the policy is **cost-effective**.

6. Presenting findings

Introduction

6.1 Communicating analysis clearly is essential. This chapter explains the reporting requirements for impact assessments, and also for Carbon Budgets.

Impact Assessments

6.2 Analysts are provided with a template for reporting emissions savings.[48] GHG savings in both the traded and non-traded sectors should normally be provided in the template.

6.3 For policies that have a significant impact on GHG emissions, and for policies which are specifically targeting GHG emissions, it is best practice to present further information within the supporting evidence base section. This additional information will include, where relevant:

- the emissions **counterfactual**;
- the **interactions and correlations** with other energy and GHG policies;
- **time profiles of emissions savings**, in both the traded and non-traded sectors, and the economic sector (domestic, industrial, power generation etc.);
- how impacts are felt between **different affected groups** (e.g. low- and high-income households, the exchequer, energy suppliers, etc.)
- the valuation of the annual **carbon savings**;
- the valuation of the annual **energy savings**;
- the **cost-effectiveness** of the carbon savings;
- **air quality** impacts; and
- impact on achieving **fuel poverty** objectives (if appropriate).

6.4 Analysts are also required, when completing an impact assessment, to appraise the policy against the 'One-In-Three-Out' (OI3O) framework.[49] It is highly recommended that analysts in government liaise with their department's Better Regulation Unit to establish what should and should not be included on a case-specific basis.

Reporting for Carbon Budgets

6.5 Under the Climate Change Act (2008) the Government is committed to legally binding carbon budgets. These are five year period targets for the UK's GHG emissions set fifteen years ahead. The first four Carbon Budget periods have been legislated for: 2008-12; 2013-17; 2018-22 and 2023-2027.

6.6 Given the legal requirements to meet these budgets, monitoring progress is of great importance. Consequently, when appraising policy it is worth bearing in mind the requirements for carbon budget accounting and reporting, which go beyond the minimum required for impact

[48] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

[49] https://www.gov.uk/government/policies/reducing-the-impact-of-regulation-on-business/supporting-pages/operating-a-one-in-two-out-rule-for-business-regulation

assessments. This involves reporting on the following:

- **The annual change in UK territorial GHG emissions in $MtCO_2e$** (relative to the "do nothing" counterfactual option and accounting for policy overlaps), broken-down by sector (Power Generation, Transport, Workplaces and Industry, Homes, Waste, Agriculture and Public) and by incidence in the EU Emissions Trading System (ETS) or non-ETS sector. See chapters 2 and 3 above for details on how to calculate these changes.

- **A headline figure of the total emission impact** of the policy (in $MtCO_2e$) broken-down by the **ETS** and the non-ETS sectors

- The **forecast**, if applicable, of the **purchase of offset credits by** UK organisations that a policy may incentivise or require for compliance.

- **Annual figures for the net change in energy use converted into MtC02e** broken down by fuel, user and sector (relative to the "do nothing" counterfactual option and accounting for policy overlaps).

- **Cost-effectiveness** should also be reported as described in Chapter 5.

6.7 Figure 6.1 below shows a suggested template for presenting these figures in Impact Assessments, which is also available on the Green Book supplementary guidance section of the GOV.UK webpage.

6.9 The table should report the total change in GHG emissions owing to the policy, whether the policy leads to greater GHG emissions or GHG emissions savings.

6.8 To report total GHG emission impacts, both the CO_2 and non-CO_2 (converted to CO_2e) must be included by using the conversion factors in Table 3.1. This means that, as well as identifying the change in emissions from a change in energy fuel use, the impact on major greenhouse gases must be reported and converted into the carbon dioxide equivalent. This includes methane from landfill and agricultural livestock, nitrous oxide from fertilizer use and production and F gas emissions (HFC, PFCs and SF6).

6.9 To allocate the emissions changes to the correct sectors for the purpose of Carbon Budgets reporting, Table 6.1 below provides the general rules for allocation. For emissions that are not covered within this table and where it is not clear on how they should be allocated, please contact GHGappraisal@beis.gov.uk.

6.10 Cost-effectiveness should be reported if the carbon savings from the policy meet either of the two following criteria:

- if the policy lifetime is less than 20 years and the stream of CO_2e savings exceeds 0.1 $MtCO_2e$ on average per year; or

- if the policy lifetime is more than 20 years and the stream of CO_2e savings exceeds 2.0 $MtCO_2e$ over the policy's lifetime and exceeds an average per year of 0.05 $MtCO_2e$.

6.11 Government Departments are required to report a measure of the proportion of carbon savings the costs of which falls below the carbon price.

6.12 In most cases, checking whether the policy results in a positive NPV is sufficient to determine the predicted cost-effectiveness of your policy. If the NPV is positive, 100% of the emissions are treated as cost-effective for the purpose of reporting. Conversely, if the NPV is negative, 0% of the emissions are treated as being abated cost-effectively. However, this binary indicator fails to account for the fact that a policy could contain a mix of abatement technologies, some of which are cost-effective and some of which are not.

6.13 Analysts are therefore encouraged to disaggregate their policy package if possible and assess the cost-effectiveness of the resultant components.

6.14 For policies that can be disaggregated into the traded and non-traded sectors, testing for cost-effectiveness can be done using the methodology described in detail in Chapter 5. Analysts should use this sectoral cost-comparator approach in these circumstances.

Figure 6.1: Template for Carbon Budgets reporting

Version of GHG guidance used:	e.g. September 2014

Sector		Emission Changes* (MtCO2e) - By Budget Period				Emission Savings (MtCO2e) - Annual Projections											
		CB I; 2008-2012	CB II; 2013-2017	CB III; 2018-2022	CB IV; 2023-2027	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Power sector	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Transport	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Workplaces & Industry	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Homes	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Waste	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Agriculture	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Public	Traded	0	0	0	0												
	Non-traded	0	0	0	0												
Total	Traded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Non-traded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cost effectiveness	% of lifetime emissions below traded cost comparator																
	% of lifetime emissions below non-traded cost comparator																

*** Important note: Please enter net emission savings as positive numbers and net emission increases as negative numbers.**

Table 6.1 Allocation of emissions changes to the correct sector

Step 1 Identify source of emissions change	Step 2 Allocate to Traded or Non-traded sector		Step 3 Allocate to appropriate economic sector
Emissions from energy use			
Electricity	Traded	Supplied through the grid from major power producers	Power sector – policies affecting carbon intensity of supply. Transport, workplaces, homes, agriculture, waste, public sector – Policies affecting the consumption of electricity
	Non-traded	On-site electricity generation from small non-ETS operators	Analysts should attribute these emissions to the sector generating the electricity (Transport, workplaces, homes, agriculture, waste, public sector)
Gas	Traded	When used by ETS operators	Power sector - major power producers Workplaces - Heavy industry in EU ETS
	Non-traded	Otherwise	Transport, workplaces, homes, agriculture, waste, public sector
Fuel oil/heating oil	Non-traded		Transport, workplaces, homes, agriculture, waste, public sector
Coal	Traded	When used by ETS operators	Power sector - major power producers Workplaces - Heavy industry in EU ETS
	Non-traded	Otherwise	Transport, workplaces, homes, agriculture, waste, public sector
Biofuels	Non-traded		Transport, workplaces, homes, agriculture, waste, public sector
Aviation fuel from intra-European flights	Traded	From 2013-2016	Transport
	Non-traded	Before 2013	Transport
Emissions from non-energy use			
Methane from landfill	Non-traded		Waste
Methane from agricultural livestock	Non-traded		Agriculture
Methane from industry	Non-traded		Workplaces
Nitrous Oxide fertiliser use on farms	Non-traded		Agriculture
Nitrous Oxide fertiliser production	Non-traded		Workplaces
F-gas-related emissions	Non-traded		Workplaces

Note that N20 and PFCs emitted by EU ETS installation will be covered under the ETS in Phase 3 commencing 2013 and will therefore become traded sector emissions

7. Annex A: Checklist for analysts

1. Have you considered possible overlaps or synergies with other policies?
2. Have you valued changes in GHG emissions in the non-ETS sectors using the Non-Traded Price of Carbon (NTPC)? Have you valued changes in GHG emissions in the ETS sectors using the Traded Price of Carbon (TPC)?
3. Have you specified the change in energy consumption?
4. Have you considered the existence of rebound effects?
5. Have you used the long-run variable cost of energy supply (LRVC) when valuing the costs and benefits to the UK of changes in energy use?
6. Have you used the full retail price, including tax, of energy when working out sub-sectoral distributional impacts and the value of any direct rebound effects (e.g. comfort taking)?
7. Have you valued the air quality impacts of changes in energy use?
8. Has sensitivity analysis been conducted for the range of the key input variables?
9. Have you considered optimism bias?
10. Have you ensured that all the numbers in the summary page are clearly referenced in the supporting evidence and that their derivation is explained in detail?
11. Have you made explicit any assumptions about behaviours in the analysis?
    - Are the assumptions based on evidence and is this clearly set out?
    - Where evidence is lacking has this been made clear?
    - Is the outcome of the policy dependant on assumptions of how people use technology?
12. Have you involved your Better Regulation Unit on regulatory measures as early as possible and discussed One-in Two-Out status?
13. Have you set out the compliance costs (red tape) of the policy?
14. Have you reported administrative costs using the standard cost model? (contact your Better Regulation Unit for further advice if required)
15. For an Impact Assessment, have you used the official template for the evidence base section, thereby presenting the reader with a familiar format? (contact your Better Regulation Unit for a copy if required)
16. Have you considered the need to evaluate your policy post-implementation and made preparations for such evaluation?

8. Annex B: Unit conversion factors

ENERGY

1 tonne of oil equivalent (toe)	= 107 kilocalories
	= 396.83 therms
	= 41.868 GJ
	= 11,630 kWh
100,000 British thermal units (Btu)	= 1 therm

WEIGHT

1 kilogramme (kg)	= 2.2046 pounds (lb)
1 pound (lb)	= 0.4536 kg
1 tonne (t)	= 1,000kg
	= 0.9842 long ton
	= 1.102 short ton (sh tn)
1 Statute or long ton	= 2,240 lb
	= 1.016 t
	= 1.120 sh tn

VOLUME

1 cubic metre (cu m)	= 35.31 cu ft
1 cubic foot (cu ft)	= 0.02832 cu m
1 litre	= 0.22 Imperial gallons (UK gal)
1 UK gallon	= 8 UK pints
	= 1.201 US gallons (US gal)
	= 4.54609 litres
1 barrel	= 159.0 litres
	= 34.97 UK gal
	= 42 US gal

PREFIXES

UK statistical practice uses the following prefixes for multiples of Joules, Watts and Watt hours:

kilo (k)	= 1,000	or 10^3
mega (M)	= 1,000,000	or 10^6
giga (G)	= 1,000,000,000	or 10^9
tera (T)	= 1,000,000,000,000	or 10^{12}
peta (P)	= 1,000,000,000,000,000	or 10^{15}

9. Annex C: Glossary

BRE	Better Regulation Executive: A unit of the Department for Business, Innovation and Skills which works to reduce and simplify regulations affecting the public, private and voluntary sectors[50]
Carbon Budgets	A set of legally-binding caps on the level of the UK's territorial GHG emissions, with each budget covering 5 years. The caps for the first four budgets have been set and cover the years 2008-12; 2013-17; 2018-22; and 2023-27.[51]
Climate Change Act 2008	UK legislation establishing a legally-binding framework to tackle the dangers of climate change[52]
Cost-effectiveness (carbon)	The extent to which it is beneficial for a society to deliver GHG emissions savings. Usually expressed as a monetary value per tonne of CO_2e (see chapter 5 for details on calculating the cost-effectiveness of a policy)
Counterfactual	The scenario comprising the developments that would occur in the absence of the policy option being appraised. This is required to identify the expected net impacts of a policy option.
Damage costs	A simple monetisation approach to assessing the reduction in societal welfare from emissions of pollutants (see Chapter 4)
DDM	Dynamic Dispatch Model[53]
BEIS	Department for Business Energy and Industrial Strategy
Embedded/embodied emissions	GHG emissions from all factors used in the production of a good or service, including those from abroad. (See Chapter 3)
EU ETS	European Union Emissions Trading Scheme[54]
EUA	EU Allowances: Permits that must be obtained (either through allocation or trading) and submitted for any GHG emissions qualifying under the EU ETS
Final Energy Demand	All energy supplied to the final consumer for all energy uses.
GHG	Greenhouse Gas. A major contributing factor to global warming.
Global Warming	The extent to which a GHG has the potential to contribute to global

[50] See https://www.gov.uk/government/policies/reducing-the-impact-of-regulation-on-business
[51] See https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050/supporting-pages/carbon-budgets
[52] http://www.legislation.gov.uk/ukpga/2008/27/contents
[53] For further information, please see https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48383/5425-decc-dynamic-dispatch-model-ddm.pdf
[54] See https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050/supporting-pages/eu-emissions-trading-system-eu-ets for further details

Potential	warming. Usually expressed as a multiple of the global warming potential of carbon dioxide. (See Chapter 3)
Green Book	Guidance published by HM Treasury setting out the principles for appraisal and evaluation of Government Policies[55]
HMT	HM Treasury: The UK's finance ministry
IAG	Interdepartmental Analysts' Group: A BEIS-chaired cross-Government peer review forum[56]
IPCC	Intergovernmental Panel on Climate Change[57]
LRVC	Long Run Variable Cost (of energy supply). This should be used to value the change in social welfare from changes in final energy consumption. (see section 3)
LULUCF	Land Use, Land Use Change, and Forestry
Magenta Book	Guidance published by HM Treasury on conducting evaluation of Government Policies[58]
Non-traded sector	GHG emissions that fall outside the scope of the EU Emissions Trading Scheme (or future scheme)
NPV	Net Present Value (The sum of all annual costs and benefits discounted to a base year)
OI3O	One-In-Three-Out policy framework[59]
Optimism bias	The demonstrated, systematic, tendency for project appraisers to be overly optimistic (see the Green Book for further information).
Policy overlaps	Where the combined GHG emissions impact of the set of Government policies is different to the sum of the impacts of the individual policies if they were to act alone.
Post Implementation Review (PIR)	Post-implementation review (PIR) refers to the review of regulatory policy that complements the ex-ante appraisal contained in the impact assessment.
Primary Energy Demand	Direct use at the source, or supply to users without transformation, of crude energy. In other words, energy that has not been subjected to any conversion or transformation process.
Rebound effect	Direct: The change in consumption of an energy service (and hence GHG emissions) resulting from a change in the efficiency with which it may be delivered. Indirect: The corresponding change in consumption of other energy services (and hence GHG emissions) resulting from this change,

[55] Available here https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent
[56] https://www.gov.uk/government/policies/using-evidence-and-analysis-to-inform-energy-and-climate-change-policies/supporting-pages/policy-appraisal
[57] http://www.ipcc.ch/
[58] Available here: https://www.gov.uk/government/publications/the-magenta-book
[59] See https://www.gov.uk/government/policies/reducing-the-impact-of-regulation-on-business/supporting-pages/operating-a-one-in-two-out-rule-for-business-regulation for further details

	comprising a change in disposable income and a change in relative prices of goods and services (see Chapter 3)
Impact Assessment (IA)	An appraisal of a regulatory policy, to help identify which proposals will achieve government's policy objectives, while minimising costs and administrative burdens.[60]
RES	Renewable Energy Strategy[61]
RPC	Regulatory Policy Committee[62]
RTFO	Renewable Transport Fuel Obligation[63]
Security of energy supply	The ability for consumers to have access to the energy services they need (physical security) at prices that avoid excessive volatility (price security). (See section 6.3 of the background documentation)
tCO_2e	Tonnes of Carbon Dioxide Equivalent. An amount of GHGs with the equivalent global warming potential of one tonne of Carbon Dioxide.
TPC/NTPC	Traded Price of Carbon/Non-Traded Price of Carbon. These should be used to value any changes in GHG emissions. (see Chapter 3)
Traded sector emissions	GHG emissions that qualify under the EU Emissions Trading Scheme EU ETS (or future scheme) and for which EU Allowances (EUAs) must be obtained [REF]
UNFCCC	United Nations Framework Convention on Climate Change[64]

[60] See http://www.bis.gov.uk/ia for further guidance
[61] http://www.official-documents.gov.uk/document/cm76/7686/7686.pdf
[62] See http://regulatorypolicycommittee.independent.gov.uk/ for further details
[63] See https://www.gov.uk/renewable-transport-fuels-obligation for further details
[64] http://unfccc.int/2860.php