Department for Energy Security & Net Zero

# Valuation of energy use and greenhouse gas emissions

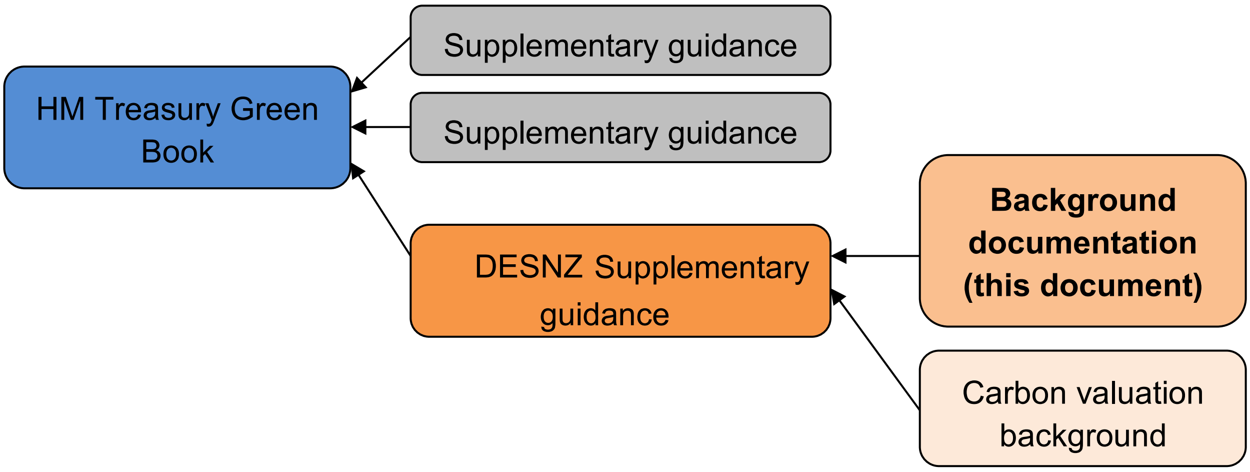
## Background documentation

October 2023

# Contents

# 1 Introduction

This background document to the HM Treasury Green Book[1] supplement, 'Valuation of Energy Use and Greenhouse Gases (GHG) Emissions for Appraisal and Evaluation'[2], contains auxiliary material aimed at providing further detail on the topics covered in the main guidance. Where the brevity of explanations in the DESNZ Treasury supplementary guidance is insufficient for whatever purpose, analysts should first refer to this background document, although any queries may also be directed to GHGappraisal@energysecurity.gov.uk For further information on HM Government's approach to carbon valuation, please consult the GOV.UK website.[3]




In the following sections the theory behind the recommended approach to valuing changes in energy use and emissions is presented, and the underlying assumptions and modelling results underpinning the methodology outlined in the main guidance document are given, including the marginal electricity grid emissions factors and the long-run variable costs of electricity supply (LRVCs). This document also covers the valuation of rebound effects, and the valuation of potential cost savings resulting from interactions with existing renewables policies. The various components of energy prices, and their contribution to quantifying LRVCs, are explained. Other issues are considered including indirect tax distortions, assumptions in behaviour change, and security of supply. Finally, details are given on the DESNZ Energy and Emissions Model, including guidance for policy analysts on how to report impacts of interventions for inclusion within the model.

Analysts appraising or evaluating policies with impacts on energy and emissions should endeavour to apply sound principles of cost-benefit analysis consistent with the HM Treasury Green Book and DESNZ guidance. Although this background document aims to provide further clarification to analysts, there will be issues unique to the analysis in question that will require further thought. Further guidance may always be sought by contacting the GHG appraisal team at DESNZ using the contact address above.

[1] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

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

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

# 2 Valuing changes in emissions

This section provides an explanation for the valuation of policies that have impacts on emissions. It will also explain the methodology behind computing emissions factors and any changes from previous versions of the guidance. Emissions factors for each energy type and each year are available in data tables 1 and 2.

## 2.1 ‘Marginal’ Policies

The guidance and its supporting data tables provide a framework for use in the valuation of ‘marginal’ policies or proposals. That is, small impacts that are delivered on top of ‘existing’ policies (i.e., those already accounted for in the modelling of the price and emissions factor assumptions published alongside this guidance). In other words, the guidance is suitable for assessing projects that change energy use or emissions by an amount that does not lead to wider changes in the market.

Some proposals are likely to produce material changes to the numbers provided in the data tables and should therefore be identified and treated as having non-marginal impacts. For example, a policy that reduces energy demand by a large amount may significantly change the long-run variable cost of marginal electricity supply or the retail electricity price. Whether the expected change is ‘significant’ is ultimately a question of judgement but may be informed through modelling.

Rather than using the numbers contained in the guidance, non-marginal policies should be appraised using bespoke analysis. Such analysis should be undertaken in consultation with the relevant experts in DESNZ and other Government departments and should use a methodology consistent with the Green Book and the DESNZ Treasury supplementary guidance.

## 2.2 Valuation Methodology

In order to value the changes in emissions associated with policies that change the consumption of energy, three steps are necessary:

1. Estimate the changes in energy/fuel use by type of energy/fuel.
2. Convert the changes in energy/fuel use into the corresponding changes in $CO_2e$ by multiplying the energy/fuel use by an energy/fuel-specific emissions factor.
3. Multiply estimated changes in $CO_2e$ by the relevant carbon price.

For most energy sources the marginal emissions factors used in the second step are those published by Defra through company reporting guidelines.[4] The emissions factors used for the purpose of the guidance are available in both $CO_2$ and $CO_2e$ terms and are defined on a gross Calorific Value (CV) basis.

[4] https://www.gov.uk/government/publications/environmental-reporting-guidelines-including-mandatory-greenhouse-gas-emissions-reporting-guidance

Marginal emissions factors for petrol, diesel gas and oil, in data table 2b, are from DfT and reflect the blending of biofuels into road fuels in accordance with the Renewable Transport Fuel Obligation.[5]

## 2.3 Emissions Factors for Electricity

Unlike other fuels, the emissions associated with a unit of grid electricity can vary greatly depending on the source of electricity generation. It is also important to distinguish between the average and (long-run) marginal electricity emissions factors. Whereas the average emissions factors should be used to account for emissions for the purposes of emissions foot printing, the marginal emissions factor should be used for analysing sustained *changes* in energy consumption for the purposes of cost-benefit analysis, including policy appraisal. Note that these are emissions factors per unit of electricity consumed (that, is they reflect the emissions from primary fuel use in order to deliver the electricity consumed), taking account of transmission and distribution losses post production.

- The average emissions factor is used for reporting emissions associated with electricity use and for calculating the emissions coverage of policies / sectors.
- The marginal emissions factor is used to estimate the change in UK electricity sector emissions associated with policies that lead to sustained marginal changes in the consumption of electricity.

### 2.3.1 Long-run Marginal Emissions Factors for Electricity

The marginal electricity emissions factor is intended to reflect the change in emissions that would result from a small but sustained change in electricity consumption. The change in electricity consumption is assumed to be constant throughout the day and year (i.e., no differentiation is made between peak and non-peak. Figures are a generation weighted average for each year).

The marginal plant(s) refers to what energy source(s) we expect to increase or decrease when there are marginal but sustained changes to energy demand or supply. The marginal emissions factor allows us to conduct policy analysis relative to a baseline which represents a Net Zero consistent power sector. Historically, Combined Cycle Gas Turbine (CCGT) plants have been the long-run marginal electricity generators and thus the marginal emissions factor in 2010 reflects that of a typical CCGT plant (0.357 $kgCO_2e/kWh$ before taking into account distribution and transmission losses). However, as the power sector changes to meet the UK's targets for National Determined Contributions (NDC) in 2030, Carbon Budget 6 (CB6) in 2033-37, and net zero in 2050, low carbon generation will increase significantly both as a proportion of total and marginal generation.

DESNZ modelling uses illustrative power sector scenarios to analyse the impact of power sector decarbonisation on average and marginal emissions factors[6]. The marginal emissions factors are calculated by the Dynamic Dispatch Model (DDM) and represent the volume weighted emissions intensity of the marginal plant in each half hour. The scenarios are indicative of what a future energy generation mix may look like rather than prescriptive forecasts. There remains much uncertainty, including for example, in the pace of

[5] https://www.gov.uk/guidance/transport-analysis-guidance-tag
[6] https://www.gov.uk/government/publications/energy-and-emissions-projections-net-zero-strategy-baseline-partial-interim-update-december-2021

innovation in the market, demand levels, the technical feasibility of some technologies, and the investment decisions of electricity generators. While they should not be considered forecasts given this uncertainty, these scenarios do illustrate the mix of properties required for a NDC, CB6 and net zero consistent power system.

In order not to draw overly precise conclusions from the modelling of an inherently uncertain future, we use a moving average of the annual MEFs to inform a profile of emissions factors between the MEF in 2010 and the MEF in 2030 as estimated by the DDM. A moving average of the results suggests broadly an increasing rate of decline in the emissions factors over this period.

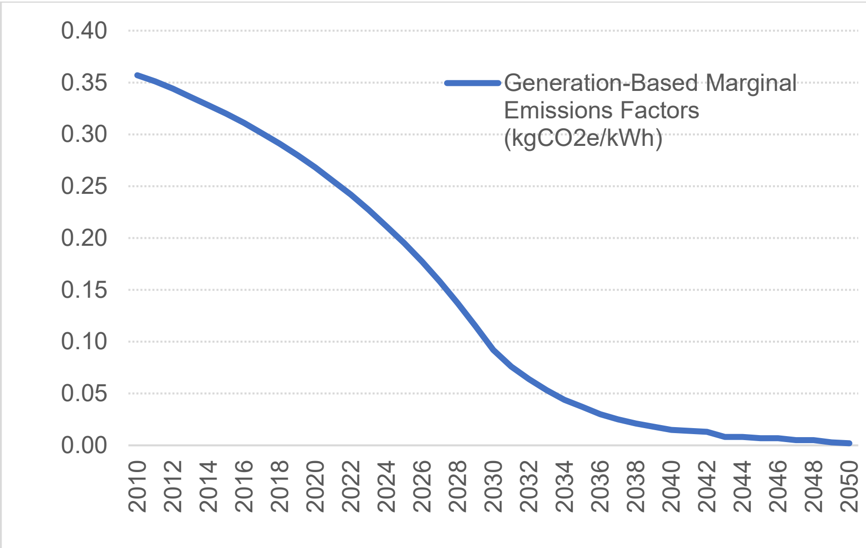
In the longer run, uncertainties increase even further. Given the high level of uncertainty around the MEFs post-2040, it is difficult to identify what the marginal impacts would be. A pragmatic approach of using the projected average grid emissions factor from 2040 onwards is taken. Between 2031 and 2040 an interpolation has been used. For modelling purposes, emissions factors are assumed to remain constant beyond 2050.

In projecting the long-run average emissions factor, historic values from DUKES have been used until 2021 and from 2022 onwards the Higher Demand Net Zero scenario from the DDM model. This predicts that by 2040, the average electricity emissions factor is 0.015kg/KWh. This then falls to 0.002kg/KWh by 2050.

**Table 2.1: Marginal electricity emissions factor estimation methodology**

| Period | Marginal Emissions Factor |
|---|---|
| 2010 | CCGT |
| 2011–2029 | Mix of technologies, found via exponential interpolation between 2010 and 2029 |
| 2030 | Modelled marginal emission factor (through the Dynamic Dispatch Model (DDM), based on 2021 Higher Demand with Hydrogen scenario. |
| 2031-2039 | Constant annual percentage change between marginal emissions factor in 2030 and average emissions factor in 2040 |
| 2040-2049 | Average emissions Factor |
| 2050 onwards | Flatlined/Constant Emissions Factor |

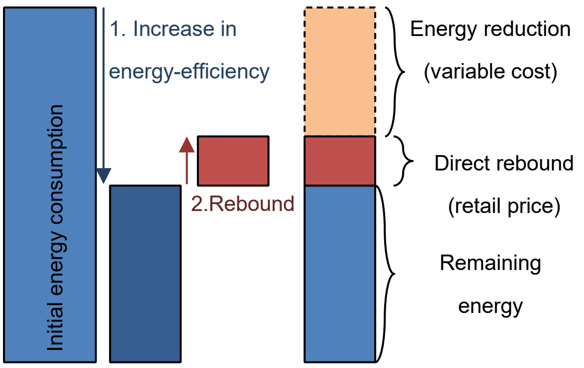
**Figure 2.1: Generation-Based Marginal Emissions Factors (kgCO2e/kWh)**



# 3 Valuing improvements in energy efficiency

This section explains the theory and rationale behind the methodology applied to valuing changes to energy efficiency. The guidance recommends that the **long run variable cost of energy supply** (LRVC) is used to value net changes in energy use, and that the **retail price of energy** is used to value the direct rebound effect (further details on the rebound effect may be found in chapter 4). Given the scale of uncertainty over LRVCs and future fossil fuel prices, in cases where fossil fuel prices are material to the conclusions of their analysis, analysts should use all the series provided for sensitivity analysis rather than just the range between scenarios B and C for gas LRVCs and central assumptions for the other series. In addition, where analysis has fiscal costing implications outside of standard DEL spending then scenario D should be used as it is closest to the latest OBR forecast. The overall approach is summarised in Figure 3.1.

**Figure 3.1: Valuation of changes in energy consumption**




Data tables 4-13 provide assumptions for the annual retail price and long-run variable supply costs for electricity, gas, coal, burning oil, gas oil, diesel, and petrol (which are split by domestic, industrial, and commercial except for diesel and petrol). These should be used for valuation of changes in energy use.

## 3.1 Summary of energy use valuation methodology

There are two valuations that need to be made: first, a valuation of the net change in energy consumption; and second, a valuation of the increase in welfare through the direct rebound effect.

To value **net changes in energy use**[7], the long run variable cost of energy supply (LRVC) is used.

The steps to calculate the costs/benefits of net changes in energy use in any given year are as follows:

- Estimate the net change in energy use by each type of energy/fuel
- Multiply the net changes in final energy use for each respective energy/fuel by their corresponding long run variable cost of energy supply (LRVC)

[7] If the change results from an improvement in energy-efficiency, then the net change will be the efficiency saving minus any rebound.

For **direct rebound effects** (including comfort-taking), the full retail price is applied to the subsequent increase in energy consumption resulting from the rebound effect, and this valuation is used for appraisal. The steps to calculate these costs or benefits are:

- Estimate the change in energy consumption that would result from the change in energy efficiency *if no rebound were to occur* (Step 1 in the diagram above).
- Estimate the difference between the net change in energy consumption and the results of step 1 (equal to step 2 in the diagram).
- Multiply this quantity of energy by the **full retail price** of the relevant fuel

For clarification, a direct rebound effect occurs when consumers use some of the financial savings they have gained from being more efficient in their use of a good or service, to purchase more of the same good or service. Expenditure of this income on other goods or services is known as the **indirect rebound** effect. **No valuation should be made of the indirect rebound effect** in the main appraisal of a policy**.**

Annex B of this document contains further details on the rebound effect.

## 3.2 Welfare impacts

Determining the overall impact on social welfare of a policy that affects energy and/or emissions requires assessing the impacts on individual societal groups, and then aggregating these[8]. Three groups are considered here: consumers (households, businesses, or any other energy consumer), energy producers and the exchequer.

The welfare effects of the net change in energy use and the rebound effect induced by an improvement in energy-efficiency may be analysed graphically, as shown in Figure 3.2. The net effect on society from an energy-efficiency improvement is a gain in welfare, comprising the two hatched areas: the red hatching (**BFIJ**) is the net societal gain from the initial direct reduction in energy consumption, while the blue hatching (**GDEI**) is the subsequent net societal gain from direct rebound effect in response to the energy-efficiency improvements.

Energy firms and the exchequer are net losers when there is an increase in energy-efficiency, with a reduction in their welfare of **AFED**. This area equates to the margins and taxation revenues that energy producers and the government lose out on from lower energy sales. Energy consumers experience a net welfare gain equal to the whole shaded area **GDABJ**. This is equal to the full financial savings from reduced energy consumption, **ABJH**, plus the addition surplus gained through the direct rebound effect, **GDH**. The individual components are presented explicitly in Table 3.1 and further detail on their derivation is given in Annex A.

[8] On the assumption that we value financial benefits in each group equally.

**Figure 3.2: Effects of an increase in energy-efficiency**

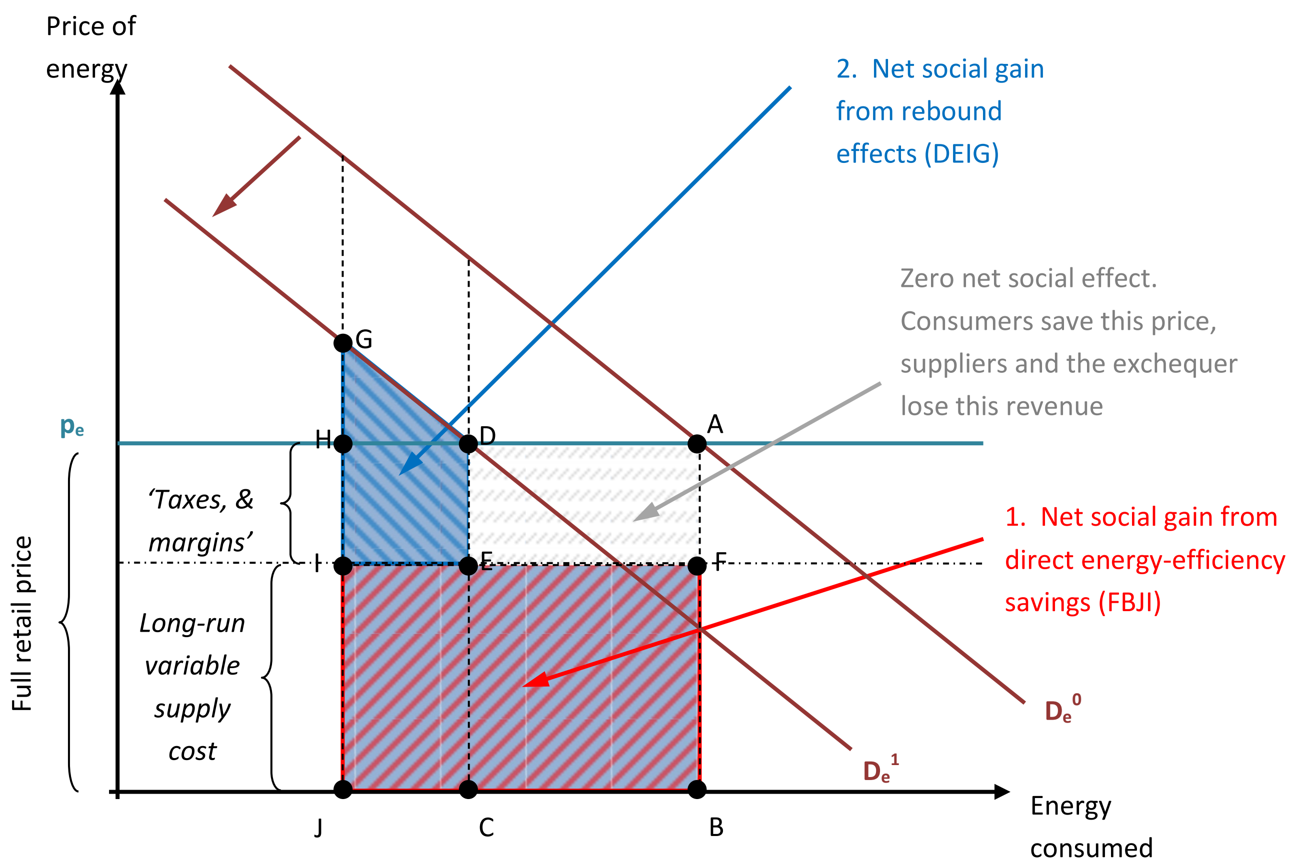



**Table 3.1 Societal gains and losses from energy-efficiency installations**

| Change in energy demand | Consumers | | Firms & Government | | Net societal effect |
|---|---|---|---|---|---|
| | Gains | Losses | Gains | Losses | |
| **Stage 1:** Lower energy demand from efficiency measure | Full retail price of energy saved = **ABJH** | | Resource costs of supplying the energy saved = **FBJI** | Full retail price of energy saved = **ABJH** | Net gain = **FBJI** (Consumers gain **ABJH**, others lose **AFIH**) |
| **Stage 2:** Direct rebound effects | Full benefit of comfort, including full retail price =**DCJH** consumer surplus =**GDH** | Full retail price paid = **DCJH** | Full retail price paid = **DCJH** | Resource costs of supplying the extra energy = **ECJI** | Net gain = **DEIG** (Consumers gain **DGH**, others gain **HDEI**) |

### Why does this not double-count some benefits?

At first glance, it is possible to view this approach as double-counting, or over-counting, welfare benefits relating to the rebound effect. It is possible to overcome this by viewing the valuation approach from another perspective.

If the consumer just installed a piece of energy-efficiency equipment to maintain their current level of energy services, this would save them **ABJH** on their bill. The reason the consumer would increase his consumption of energy in the rebound effect is to capture more utility. Therefore, by choosing greater consumption of energy through the rebound effect, this must imply the consumer yields greater or equal welfare benefits as before. Spending **DCJH** to capture **DCJG** in benefits results in a net gain of **GDH** in addition to the pre-rebound effect benefits, **ABJH**.

The exchequer and energy companies only perceive the final change in energy consumption, and do not notice the pre-and post-rebound consumption levels. Therefore, their only impacts are on this net change in energy consumption, measured at the price above the long-run variable cost of energy supply.

The above analysis considers energy-efficiency improvements on the demand side

(Improvements in how end consumers use their energy). Energy efficiency improvements may also occur on the supply-side which, although it results in different impacts, may be analysed under the same framework.

# 4 Rebound Effects

A brief discussion surrounding rebound effects is useful to explain the current valuation methodology and indicate the limitations of such an approach. For the purposes of this background documentation, an in-depth review of rebound effects and their intricacies is avoided. For more information on rebound effects the UK Energy Research Council (2007) have published a comprehensive summary of the theory and evidence on rebound effects[9]. Annex B of this document also contains a derivation of the cause of the rebound effect.

## 4.1 Direct vs. indirect rebound effects

Both the direct and indirect rebound effects affect the aggregate energy demand in an economy. These effects are not always present, but in most cases, there is likely to be some impact.

For illustration, a household may install wall insulation and receive bill savings from reduced energy consumption necessary to heat the home. How this household chooses to spend this additional money is the core question. The **direct rebound effect** relates to spending some of the money on energy to raise the temperature of the home (comfort-taking). This will be the result of two effects, the **substitution effect** (heating the home is relatively cheaper than it was before) and the **income effect** (more money is available to spend on heating).

The **indirect rebound effect** concerns changes in the energy consumption through other goods and services. For example, if the money saved is spent on foreign travel, then this would result in additional energy consumption. On the other hand, consumers may substitute some of their overall consumption, including foreign travel, into heating as the relative price of heating has fallen.

Given the lack of precedence in appraisal of real-world rebounds beyond the direct rebound effect and the difficulty in their estimation, the guidance recommends that only the direct rebound effect is quantified and valued where necessary, and that this valuation is approximated by the retail price. It is up to the analyst to estimate the size of the rebound that is likely to result from their policy. This approximation means that a small part of the welfare benefit from the direct rebound effect is excluded from the analysis (triangle **GDH** in figure 3.2). If the analyst wishes to make an estimate of this triangle, Annex B gives details on how to account for this additional welfare.

Analysts should be aware that the unaccounted *indirect* rebound effects may have implications on estimated total energy and emissions savings, and on the NPV of a policy. In general when considering improvements to energy-efficiency, the indirect rebound effect will mean that the aggregate energy and emissions savings in the economy will be reduced, but that its impact on the NPV of the policy could be positive or negative. This is due to the changes in utility derived from the additional purchased goods and services,

[9] UK Energy Research Council (UKERC) – Review of Evidence for the rebound effect https://ukerc.ac.uk/publications/ukerc-review-of-evidence-for-the-rebound-effect-technical-report-5-energy-productivity-and-economic-growth-studies/

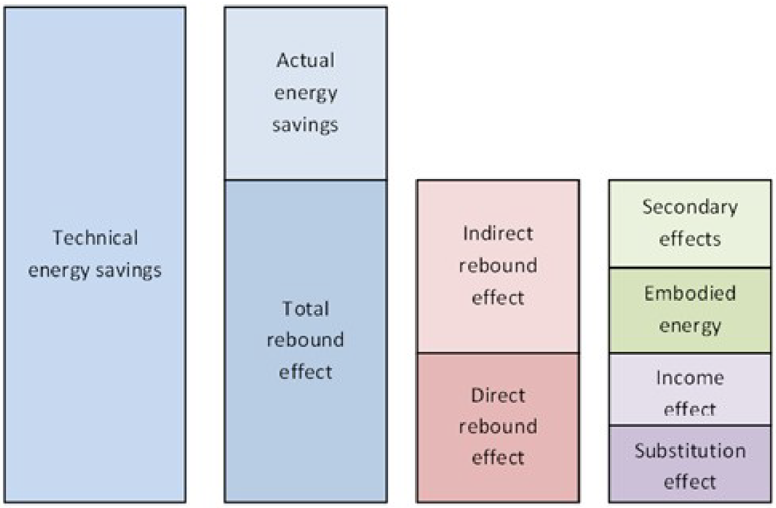
offset against any resulting externalities (such as the increase in air quality damages, for example).

## 4.2 Embodied energy-effects

**The Figure 4.1** presents the different classifications of the various effects of installing energy-efficiency measures. Direct rebound effects may be disaggregated as described above into income and substitution effects. Indirect effects resulting from both the income and substitution effects may be further disaggregated into secondary effects and embodied energy-effects.

The secondary effects are the increases in energy consumption resulting from the increases in consumption of all other energy-using services. However, one could take this a step further and consider the differences in energy embodied in the goods and services that are now purchased compared to those goods and services that were purchased before.

**Figure 4.1: Classification of rebound effects**




For example, if a consumer purchases a new table as a result of the savings, this table may have required a significant amount of energy to produce and deliver to the household. Furthermore, economy wide rebound effects can take place as efficiency improvements spur economic growth over the long term, taking us to third order effects and beyond. The Oxford Institute of Energy Studies (2011) go even further and identify a 'transformational effect' in which some efficiency measures may give rise to changes in preferences and the emergence of new goods and services that are more energy intensive[10].

It is not recommended that these additional impacts are included in an NPV estimate for a policy. However, where these impacts could be large, the analyst should make some consideration of them.

[10] The Oxford Institute for Energy Studies – 'Energy-efficiency – Should we take it seriously' http://www.oxfordenergy.org/wpcms/wpcontent/uploads/2011/12/SP_24.pdf

# 5 The long-run variable cost of energy supply (LRVC)

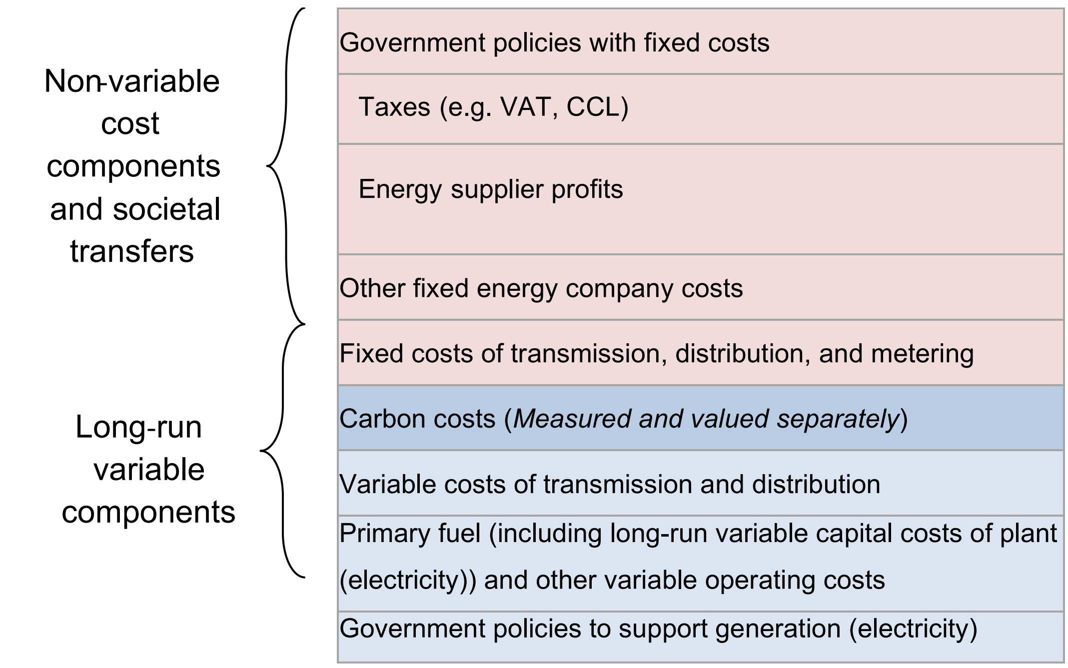
As the previous section explains, changes in energy consumption should be valued by using the long-run variable cost of energy supply. To calculate this, one must identify the parts of the retail price that represent actual costs to society that vary according to the level of consumption. Other price components are fixed or will only result in transfers between groups in society (which are of no net social benefit). The disaggregation of the price into its elements is the focus of this chapter.  What is defined as a variable cost will depend on the fuel/energy type. Therefore, the cost estimates that are provided alongside this guidance are calculated in different ways.

The following section explains the different components of retail energy prices and identifies which should be considered variable in the long-run. In section 5.2, an explanation is given on how each of the cost series published in the data tables is calculated as well as providing the underlying assumptions.

## 5.1 Components of the retail price

The retail price of energy that consumers pay is made up of a number of components relating to costs of provision, in addition to taxation and profits. These components are described below. Some components will contain both variable and non-variable elements others will only be one or the other. The components will vary depending on the fuel type being analysed.

**Figure 5.1: Components of energy prices**



## Wholesale energy cost (primary fuel)

In this context, the wholesale energy cost is the cost of energy on the wholesale market. This includes the cost of operation and raw material (fuel) inputs, and some capital costs. The wholesale cost of energy would also include any margins made by the firms involved in the supply of wholesale energy.

The wholesale price will include some non-variable costs incurred upstream in the supply chain such as the fixed costs and margins. For estimating the true cost to society, these transfers should ideally be removed from the LRVC.

## Transmission, distribution, and metering (TD & M)

Distribution charges are costs associated with the building, running and maintenance of gas pipes and power lines/wires that deliver gas and electricity to the end user and the costs of distributing petroleum and other energy products. Transmission charges are costs associated with the building, running and maintenance of high-pressure gas and high voltage transmission networks.

There will generally be a per unit cost for transmission and distribution of energy as well as a fixed cost of operating and maintaining networks.

## Other supplier costs and margins

There are additional running costs incurred by energy suppliers which relate to business activities such as sales, customer service and billing. In addition, the retail price of energy may include energy supplier profits, which will be where the price is beyond the cost of the energy sold.  Some of these margins will go to cover the fixed and sunk costs of the business, while the rest will become pure profits for the energy producer. When energy consumption changes the impact on societal welfare will depend on the variable supplier costs.

## Energy and climate change policies

Certain government policies will affect the price of energy.  Some policies will be invariant to changes in consumption levels.  Particular examples of this include Smart Metering, since the cost of smart meters is not affected by the energy consumption of users. Instead, it depends on the number of users.  Other policies may vary when consumption levels change.  An example of this would be the renewable transport fuel obligation (RTFO) which requires suppliers to source a minimum proportion of their fuels from renewables.

## Indirect taxation

Indirect taxes such as VAT[11] and road fuel duty for example, are included in the retail price but would not normally be associated with direct social costs because they are considered to be a transfer between consumers/businesses and government. Therefore, indirect taxes would not form part of the LRVC.

[11] VAT on energy bills is payable at a rate of 5% on the final energy price for residential customers.  Businesses are typically charged the standard rate of VAT on energy (20% as of March 2021).  However, those businesses that are registered for VAT may claim back any VAT that they have paid on their energy consumption.

## 5.2 Estimating the LRVC

### 5.2.1 Electricity

The variable supply cost for electricity is given by the following equation:

*LRVC $_{Electricity}$ = Wholesale prices (adjusted for demand profiles, carbon costs, balancing costs and transmission & distribution losses) + Policy support costs (RO, CfDs and Capacity Payments) + Variable distribution costs + Variable transmission costs*

Within the estimated price series, the LRVC of electricity supply is taken as being the adjusted wholesale price plus the cost of government policies that support generation costs plus variable transmission and distribution costs.

Estimated wholesale energy prices are derived from DESNZ's Dynamic Dispatch Model (DDM) and are published in DESNZ's Energy and Emission Projections.[12] The figures used are consistent with DDM's high electricity demand net zero consistent scenario. The wholesale price is adjusted to exclude the traded cost of carbon (EUAs), which is valued separately, and the exchequer revenues from the Carbon Price Support which, as a tax, is a transfer between consumers/energy firms and the government. However, Carbon Price Support costs that result in increased revenue for generators through higher wholesale prices, rather than tax revenue for the exchequer, are included as these represent a payment from consumers to generators to cover generation costs. These costs are calculated by subtracting the average emissions factor from the marginal price-setting emissions factor and multiplying by the Carbon Price Support rate.

Further adjustments are made to account for the demand profiles of different types of users, balancing costs and transmission and distribution losses. The residential electricity supply costs have been constructed by uplifting the wholesale prices discussed above to account for the additional costs of meeting the residential sector's load shape. The uplift is estimated based on the 5 year average historic difference between actual lagged wholesale prices and wholesale cost estimates consistent with those published by Ofgem as part of their Supply Market Indicators analysis.[13] This uplift will account for distribution losses, seasonal consumption profiling[14] and shaping costs. Long-run variable transmission and distribution costs have then been added.

A similar approach is used to calculate the variable costs of electricity to industry and commercial/public sectors, except that industrial customers and the commercial/public sector are assumed not to face the wider uplift on the wholesale price that the residential prices reflect. Losses on the local distribution network are also included. For the commercial/public sector, losses are assumed equal to the grid average.[15] For the

[12] See https://www.gov.uk/government/collections/energy-and-emissions-projectionsThe residential sector has its electricity costs increased because the average price (in terms of wholesale prices) of meeting the residential load shape is higher than the base-load price. Residential electricity has a higher resource cost because demand comes in peaks and troughs.

[13] Available online at: https://www.ofgem.gov.uk/energy-data-and-research/data-portal/wholesale-market-indicators

[14] For example, households tend to consume more gas in winter when it is colder and the wholesale price of gas tends to be higher.

[15] Figures are available in the electricity chapter of the Digest of UK Energy Statistics, available online at: https://www.gov.uk/government/collections/digest-of-uk-energy-statistics-dukes.

industrial sector they are assumed to be 2 percentage points lower, to reflect the fact that some demand is direct from the transmission network.

Certain assumptions are made surrounding the proportion of transmission and distribution costs that are fixed and variable. 90% of transmission costs are assumed to be variable in the long-term. By contrast, only 10% of distribution costs are assumed to be variable in the long-term. However, if a policy requires linking new users to distribution networks, 100% of distribution costs should be included in the LRVC. In these circumstances, it is the responsibility of the analyst to ensure that they make an appropriate assessment of these costs.

Although in the short-term Combined Cycle Gas Turbine (CCGT) plants typically drive the wholesale price, it is reasonable to expect in the future low carbon generators will set the wholesale price. It is therefore necessary to augment the wholesale price with estimates of Renewables Obligation (RO) support costs and Electricity Market Reform (EMR), specifically Contracts for Differences (CfDs) and Capacity Payments. Modelling of illustrative demand reduction scenarios indicates that sustained reductions in demand will result in both less low carbon capacity and less conventional generation capacity being built and operated. It is therefore necessary to reflect these costs in the estimate of the long run variable costs of energy supply.

Other supplier costs are excluded from the LRVC of electricity because most do not vary according to levels of energy consumption (although they may vary according to numbers of customers). Similarly, suppliers' margins are excluded from the LRVC of energy because these are payments between consumers and firms, and do not reflect a change in societal welfare.

### 5.2.2 Gas

The long-run variable supply cost for gas is calculated using the following equation:

$$\boldsymbol{LRVC_{Gas}} = \boldsymbol{Wholesale\ price}\ (adjusted\ for\ distribution\ losses) + Variable\ local\ \boldsymbol{distribution}\ costs + Variable\ local\ \boldsymbol{transmission}\ costs$$

The wholesale price for gas reflects the fossil fuel prices published in the supporting data. However, since the wholesale price in this context is the cost of supplying the marginal unit of gas to the transmission and local distribution networks, it is necessary to apply an uplift factor to the fossil fuel price to take account of the additional local transportation losses that result from each unit increase in gas demand. The rate of physical losses on the local gas distribution network is estimated to be 0.5%. The rate of losses on the transmission system is likely to be much smaller than in the distribution network because there are relatively few joints and vulnerable points, so in the LRVC series provided, the losses on the transmission network are ignored.

90% of the transmission costs of gas are assumed to be variable in the long-run, in contrast with only 10% of distribution costs.

### 5.2.3 Non-transport oil products and coal

The variable supply cost is estimated by adding non-fuel variable costs and subtracting estimated average fixed costs from the wholesale price.

The equation for long-run variable supply cost for non-transport oil producers, and coal is:

$$\boldsymbol{LRVC = Wholesale\ price + Non\ fuel\ \ costs - Fixed\ costs}$$

Transmission, distribution, and metering costs are not measured for other fuels as they do not require the infrastructure assets relevant to the supply of electricity and gas. Furthermore, the wholesale prices of other fuels do not require adjustments for balancing costs and losses as is required for electricity.  As such, the calculation is less complicated.

The wholesale price is based on adjusting the underlying fossil fuel price series to reflect the costs of producing each product.

Non-fuel costs include expenses beyond those of procuring the ownership rights or production of fuel. Any costs involved in physically moving the fuel from the wholesale point of sale to the retail point of sale will come under non-fuel costs. Fixed costs relate to costs that that do not vary with respect to energy use.

Average fixed costs are estimated and subtracted from non-fuel costs to find the variable non-fuel costs. Variable non-fuel costs are assumed to vary between sectors.

### 5.2.4 Road Transport Fuels

The long-run variable supply cost is estimated using assumptions on fixed costs provided by the Department for Transport and is calculated by adding non-fuel costs and subtracting fixed costs from the wholesale price.

The equation for the variable supply cost of road transport fuel is:

$$\boldsymbol{LRVC_{Transport\ fuels} = Wholesale\ price + Non\ fuel\ costs - Fixed\ costs}$$

The fixed costs are essentially the long-term costs of refining infrastructure and capital investment. The assumptions for fixed costs are based on modelling and industry estimates.

## 5.3 Additional costs of energy supply

The analysis in the previous sections show that the LRVC should be used to value net changes in energy use. The LRVC of energy represents the opportunity cost to society of an additional unit of energy produced supplied. However, the LRVC does not include the impact on air quality, carbon costs, or any other wider impacts. Analysts should calculate the value of carbon costs and air quality impacts separately.

## 5.4 Future LRVC series to be considered

There are currently LRVC series for electricity, gas, coal, oil, and road fuel. In order to meet the Net Zero target, renewable energy sources in the UK system must also be considered in policy analysis. However, there are currently no concrete series for energy sources such as hydrogen and biomass. They are currently under development, with more detail added below.

Hydrogen

Low-carbon hydrogen has been identified as having the potential to play a significant role in decarbonising the UK energy system. The British Energy Security Strategy (published in 2022) stated the ambition to deploy up to 10GW of low-carbon hydrogen production capacity by 2030. As the role of low-carbon hydrogen in the UK energy system grows it will become necessary for analysts to have access to information on the valuation and emission factors of hydrogen. Therefore, it is the intention to include hydrogen series within this guidance in the future.

It is not currently appropriate to include low-carbon hydrogen series in this guidance due to policy changes not being marginal in this space, due to the nascent state of the hydrogen sector and minimal amount in the UK energy system. In addition, considerable uncertainty remains around many aspects of how the low-carbon hydrogen market will develop, such as the mix of production technologies and energy inputs, how any transport and storage networks will operate, and the scale of demand from different end use sectors.

In 2021, the Department for Business, Energy, and Industrial Strategy (DESNZ) published the 'Hydrogen Production Costs Report' which presented generic levelized costs of hydrogen (LCOH) for a range of production technologies. This report provides a straightforward way of consistently comparing the costs of different production technologies, focusing on the costs incurred by the producer over the lifetime of the plant. If you have specific queries about hydrogen costs and emissions factors to appraise your policy, contact hydrogenevidencebase@energysecurity.uk.

Biomass

'The word 'biomass' is an umbrella term covering a variety of fuels which derive their energy from biogenic sources. It is not possible to create a single long-run LRVC/price series for biomass due to the heterogeneity of the fuels covered by this term. Individual price series for different biomass feedstocks would have to be created for analysts appraising policies which use biomass as a fuel. Work is ongoing (the forthcoming Biomass Strategy) which looks at the long-run cost of various biomass fuels, as part of a wider assessment of how the use of biomass can best be prioritised within the UK. However, further work will be needed to transform such a high-level, strategic overview into a concrete set of time series price forecasts for biomass fuels.

Future work will need to identify which fuels are a priority for inclusion in the Green Book supplementary guidance, as well as where and how such fuels are typically used in the UK. This will require an assessment of current and planned policies which relate to the use of biomass, to understand how standardised price series data could best be used to improve the evaluation of such policies.'

# 6 Other considerations in appraisal of energy and emissions policies

## 6.1 Indirect taxation distortions

In most cases at present, government appraisals do not adjust for indirect taxation differences. However, these differences should be taken into account where option appraisal is significantly affected by different taxation regimes or in Value for Money assessments.

Different groups in society are exposed to different levels of indirect taxation. This has two implications:

- That a change in expenditure, or composition of expenditure between groups can change the government's indirect taxation revenue.

- That the quantity of goods and services that groups may purchase with a defined amount of money vary between these groups.

When comparing options or policies that have impacts on different economic groups (who are exposed to different taxation rates), there is a risk that costs and benefits may not be being assessed on an equal basis.

Annex C explains how these distortions arise, and how in principle analysis may be adjusted to remove these distortions.

If adjustments were made, an option's NPV would only be different if *all* the following are true:

- The policy delivers impacts on more than one economic group
- These economic groups are subject to different rates of indirect taxation
- There are non-financial impacts being monetised (e.g. increased comfort)

For policies where this is not the case, the NPV would remain unchanged and no adjustment would be required. If it is judged that the impacts of indirect taxation are likely to have a significant impact on the NPV estimate of a policy, further advice should be sought from GHGappraisal@energysecurity.gov.uk.

## 6.2 Behaviour Change Assumptions

Behaviour change is often a key goal for energy and climate change policies. Behaviour change is "a challenging and complex process, requiring theories, methods and evidence from many academic disciplines" (UCL Centre for Behaviour Change)[16].

Implicit in policy appraisal may be a number of assumptions about human and organisational behaviour including assumptions relating to the likely take up of new products and technologies, and effectiveness with which people put new technologies to use over time. Analysts should consider hidden or implicit assumptions about human and organisational behaviours and ensure at the minimum that all such assumptions are given consideration and clearly stated. These assumptions, in particular those that are not evidenced, can then be examined at the evaluation stage as far as possible. Attention should be given to the key evaluation questions, including those about behaviour change, at the policy design stage. The way a policy is formulated or implemented can have significant impacts on the ability to evaluate it rigorously.

The following questions and examples are used to illustrate what analysts should endeavour to consider:

| **Questions** | Examples |
|---|---|
| **Are there implicit assumptions that behaviours will change in response to policy and are these realistic?** | Where a policy involves installing solar water heating; some people do not achieve the theoretical potential energy savings because they prefer to take a power shower in the morning rather than showering in the evening when hot solar heated water is available. In this case it is not realistic to assume that behaviours have changed to deliver the full potential energy savings of the policy. |
| **Have assumptions been made that certain behaviours will not change in response to policy and are they realistic?** | As houses become draught-proofed, some consumers may respond by opening more windows.<br><br>As consumers accumulate more energy-efficient products, they may change their preferences towards energy intensive products. |
| **Are estimates of the effectiveness of technologies based upon laboratory experiments rather than pilots of how they have been used in practice? If so, did the experiments account for the role of human behaviours when assessing the potential impact of technologies, and if not, have potential limitations of the analysis been** | A policy which requires new energy-efficiency light-bulbs to be installed in buildings may not deliver carbon savings envisaged from lab experiments because consumers choose to change the lights and fittings before the technical life of the bulbs for aesthetic reasons |

[16] For an overview of behaviour change models, see: GSR (2008) Practice Guidance: An overview of behaviour change models and their used (http://webarchive.nationalarchives.gov.uk/20140305122816/http://www.civilservice.gov.uk/wp-content/uploads/2011/09/Behaviour-change_practical_guide_tcm6-9696.pdf)

| | |
|---|---|
| **clearly stated? Put another way, what is the quality of the evidence base to support the assumptions?** | |
| **Does the analysis assume for instance that consumers have read a manual or have been trained in the effective use of technologies? Or does the analysis assume that training is not necessary for the effective use of technologies?** | The policy involves fitting new heating controls to commercial buildings, but the building managers are not trained in how to use them so projected carbon savings might not transpire. |
| **Have assumptions been clearly stated about the effectiveness with which technologies are used, particularly relating to new and relatively untested technologies?** | Stating assumptions behind a policy on carbon capture and sequestration. |

When conducting subsequent evaluations, analysts should aim to *measure* the impact of human behaviours and test the assumptions made at the appraisal stage. A good starting point is to map the intervention logic. Logic mapping or logic models are a structured way of setting out the assumptions, and evidence on which they are based to describe the relationship between an intervention's inputs, activities, outputs, outcomes and impacts. They are the representation of the causal theory underlying the impact of the associated intervention. This can then be tested in the evaluation. For further details on evaluation, see HM Treasury's Magenta Book[17].

## 6.3 Energy Security and Resilience

No clear international consensus exists on how to define energy security and resilience. We understand a secure and resilient energy system to be 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.[18] Any policy that has a significant impact on the supply of or demand for energy or energy services, including by affecting the way energy markets function, could therefore affect the UK's energy security and resilience.

Quantitative evidence where possible, or a qualitative assessment where not, should be provided to assess the security and resilience impact of a proposal. Suggested approaches and factors to consider are set out below.

[17] https://www.gov.uk/government/publications/the-magenta-book

[18] 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*.

## Quantitative approach

One approach to valuing an interruption to energy supply would be to estimate the expected energy unserved. That is, the probability of an interruption multiplied by the size of the interruption; multiplied by the value of lost load[19] (the value that customers attach to the unserved energy). Conducting this analysis for each of the years of the lifetime of a project, and comparing this to the “business as usual” 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. Where such an approach is possible the recommendation is that it be undertaken. Assessing the impact that a policy may have on the probability of an interruption to supply (or on the likelihood of prices spiking) is however very complex.

## Qualitative assessment

An alternative or supplementary approach is to consider the characteristics of a secure and resilient system. Ultimately, assessing what the impact of any policy will be on energy security and resilience is about working out whether what is being proposed is likely to increase or decrease the current or future margin between likely peak demand and likely available supply – and therefore the risk of excessive price volatility or interruptions to supply (along with the costs that those can bring).

Markets in the UK are used as a key instrument for delivering energy security and resilience.  Therefore, policies which increase market participants’ exposure to (and/or ability to respond to) price signals will improve the way in which UK and international energy markets function, increase the likelihood of supply and demand balancing and be likely to increase energy security. At all times, therefore, analysts should consider how their policy impacts on the energy market.

However energy is not supplied by perfect markets. It is therefore important to consider all the ways in which a proposal may affect the ‘physical’ characteristics of the energy system (i.e. the things that affect the margin between supply and demand). Physical characteristics can be assessed under the following headings:

Factors affecting likely margins - supply side:

- Maximum potential level of 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

[19] Estimating the Value of Lost Load, London Economics, July 2011: https://londoneconomics.co.uk/blog/publication/estimating-the-value-of-lost-load-voll/#:~:text=VoLL%20represents%20the%20value%20that,level%20of%20security%20of%20supply. 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

Factors affecting likely margins - demand side:

- Unrestrained[20] level of demand
- Demand side responsiveness

Detailed guidance on the definitions of these characteristics are set out below. Table 7.1 lists the issues an analyst may wish to consider in their assessment of a policy's impact on each of the characteristics.

Various composite and/or probabilistic measures exist of likely future margins, each dealing with a subset of the characteristics set out above.

For example in the electricity sector a crucial measure of the likely imbalance between supply and demand is given by the Loss of Load Expectation (LOLE)[21]. LOLE represents the number of hours per annum in which, over the long-term, it is statistically expected that supply will not meet demand. Government has set a reliability standard of three hours LOLE per annum; the potential impact of a proposal on achieving this will need to be carefully considered[22]. Another commonly used proxy indicator for future security and resilience is the de-rated capacity margin, meaning the margin between supply and demand adjusted to take account of the reliability (but not diversity, responsiveness, etc) of supply sources. In the gas sector a common proxy measure for future security and resilience is the capacity margin (i.e. the difference between maximum potential supply and typical peak demand).

These composite indicators are useful tools for considering energy security but must be used alongside consideration of the other characteristics to ensure a complete picture is built up.

## Maximum potential level of supply – both in terms of infrastructure capacity and/or commodity supply

For electricity this is the sum total of all the generation capacity available, plus the maximum potential import flows on electricity interconnectors and maximum potential flows from any storage facilities. It would also encompass the maximum capacity in transmission and distribution systems. For gas this is the sum total of maximum flows for pipelines and interconnectors entering the UK, flows from storage if full and maximum production on the UK continental shelf. For gas, commodity supply should also be considered, for example the tightness of the markets delivering gas to the UK, including European and LNG markets. For oil maximum capacity is the total amount of oil that could be imported into the UK, delivered from storage[23] and/or produced on the UK continental

[20] 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.

[21] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/267665/EMR_Summary_of_responses_and_Govern ment_response_to_the_July_2013_Consultation.pdf

[22] It is important to note that in most cases loss of load would be managed without significant impacts on consumers.

[23] Or, *in extremis*, from oil stocks. However, note that mandated oil stocks are different from gas or electricity storage in that they are not part of the normal commercial operation of the market and are only used to boost supply under certain (emergency) conditions.

shelf. Oil commodity supply should also be considered, for example the tightness of the international oil market.

## Nature, quality, or characteristics of supply – both in terms of infrastructure capacity and/or commodity supply

There are a number of factors that could be judged to affect the nature or quality of supply. Some examples are as follows:

### Reliability

The certainty with which an aspect of the supply chain will fulfil its function, whether energy supply sources, infrastructure or delivery networks. Reliability relates to the risk that an aspect of the system will fail to deliver or be unavailable when called upon. This could be technical reliability, UK and international market reliability, or the risk of geopolitical or social impacts.

### Responsiveness

For each energy market the infrastructure and supply sources available must be able to meet demand in a timely fashion. The more quickly a supply technology or market can respond to demand – in other words the more flexible it is – the less likely it is that any particular event will lead to tightness in the market or to an interruption to supply.

### Diversity

Diversity of the capacity on the market should be considered to ensure the UK is not overly exposed to the failure of one particular piece or type of infrastructure. Diversity of supply in the commodity market should be considered to ensure the UK is not overly exposed to the failure of one particular supply source.

### Resistance

Provision of adequate and proportionate protection for critical energy infrastructure, assets and networks reduces vulnerability to outside threats and therefore increases resilience.

### 'Repairability' or 'restorability' of supply

It is important to have effective preparations and plans to enable rapid recovery from disruptions, to ensure the system is back to normal as soon as possible with minimal disruption to those affected. As well as supply, this may include emergency intervention on the demand side.

## Unrestrained level of demand

The level of demand generally affects the ability of the system to deliver energy security and resilience. This is not always the case, as where demand reduction is factored in by the market (i.e. supply is adjusted to accommodate it) demand reductions may have no overall impact on energy security. However, due to time lags, market imperfections and the long lifetimes of existing infrastructure, demand reduction can in practice have positive effects on energy security, increasing the margin between potential supply and peak demand and reducing strain on existing infrastructure assets. Conversely, policies that serve to increase demand may have a negative impact on energy security for the same reasons. The impact across energy systems should also be considered, for example the widespread rollout of electric vehicles will reduce demand for oil but increase demand for electricity.

## Demand side responsiveness

The degree to which demand can adjust (over the very short term) to accommodate any changes in supply – for example as a result of price signals. The availability of demand side response indicates the ability of the system to absorb any supply shortages and is important (particularly for electricity) in the ability of the system to balance.

**Table 7.1: Issues to consider in a qualitative assessment of energy security and resilience**

| ‘Physical’ characteristic of the energy system | Issue to consider | Notes |
|---|---|---|
| **Supply side** | | |
| **Maximum potential level of supply** | **Electricity generation capacity** | The key figure is the maximum amount of potential (non-derated) electricity generation. |
| | **Network capacity** | Consider the capacity of the transmission and distribution systems or infrastructure (for electricity, gas, or oil). |
| | **Domestic production** | Particularly of oil, gas, and coal. However, where derived from non-fossil sources, domestic production of electricity or heat could be considered. |
| | **Import/ export capacity** | |
| | **Storage capacity and/ or deliverability** | For gas or electricity. Suggested measures: annual capacity (bcm / MW) and peak day deliverability (mcm/day / MW/day). |
| | **Stocks (oil)** | Consider the effect on oil or oil product stocks or oil-stocking arrangements |
| | **Refinery capacity** | Also consider, where appropriate, whether the type of petroleum products that the refinery produces are affected. |
| | **Investment incentives** | This includes incentives for investments in generation and/or infrastructure, including storage and networks. |

| | | |
|---|---|---|
| | **Investment lead times** | |
| | **Uncertainty of market participants** | This will affect their willingness to invest in additional capacity or supply. |
| | **Market functioning** | The functioning of UK, EU or international markets will impact on the level of supplies potentially available to the UK. |
| **Reliability of supply** | **Technology reliability** | Consider the impact on a particular energy technology, including transmission and distribution networks. |
| | **Fuel or power reliability** | Consider the impact on the availability of fuel or power sources. For example, the reliability of electricity supply will likely be reduced following an increase in (intermittent) wind generation. Note that in some cases the fact of supply being within the UK may increase the extent to which it is – in extremis or due to market imperfections - ultimately responsive to national needs, control or influence, making it more reliable. |
| | **Import reliability** | Import reliability could be improved, for example, through strengthening international relationships or improving the functioning of international markets. |
| **Responsiveness of supply** | **Supply responsiveness** | This is the ability of the supply side to respond (potentially rapidly) to changing demand (likely mediated by price signals in the market). |
| | **System balancing** | Consider whether the policy will impact on the system operator’s ability to balance the system. |
| **Diversity of supply** | **Nature and diversity of the generation mix** | |
| | **Diversity of sources of commodity (e.g. fuel) supply** | |
| **Supply resistance** | **Infrastructure/network exposure** | This includes exposure to physical risks (such as hazards or technical failure) or cyber/systems related risks. |

| | | |
|---|---|---|
| | **Mitigation strategies** | These are the strategies and measures in place to reduce risks being realised. |
| **’Repairability’ or ‘restorability’ of supply** | **Ability to restore supply** | This concerns the ability of the energy system to restore supply swiftly following supply disruptions or emergencies. It could be affected, for example, by encouraging emergency planning or risk assessments. |

| **Demand side** | | |
|---|---|---|
| **Unrestrained level of demand** | **Demand levels** | In particular, the average level of unrestrained demand at a given price. |
| | **Demand diversity** | This concerns the diversity of the energy sources that are demanded. Demand diversity could be increased, for example, through an increase in electric vehicles or heat pumps. |
| | **Natural variation or profile of demand** | Consider whether the policy will change the natural (e.g. daily, weekly, seasonal) shape or pattern of demand around the average, and therefore its natural peak level. [24] |
| **Demand side responsiveness** | **Responsiveness of demand to price** | |
| | **Responsiveness of demand through contractual obligations** | Policies may allow for the removal of demand from the system, for example, in response to a crisis. |
| | **Mandated removal of demand** | |
| | **Availability of substitutes** | Consider whether the policy will increase the ease with which consumers can substitute one energy source for another. For example, increased adoption of hybrid cars would increase the degree to which petrol could be substituted. |

[24] Note that we distinguish here between the ‘natural’ pattern or shape of demand over a given time period and the extent to which that demand may flex or shift in response to price or other signals (i.e. demand side responsiveness).

Further advice on a case by case basis can be sought from GHGappraisal@energysecurity.gov.uk.

## 6.4 Financing Costs

### Public sector projects

Proposals funded directly through the exchequer do not have traditional financing costs associated with them. Therefore, these costs do not form part of the decision-making process because the public spending envelope is determined independent of individual policies. In these circumstances, assessments of interest payments would therefore not typically be made for projects involving finance provided through the exchequer, when conducting appraisals or evaluations.

A separate affordability analysis should be conducted on a project's financing options if required.

### Project delivered by the private sector

Many of the policies relating to energy and climate change are capital intensive and are often delivered through private sector organisations. When capital is tied up in a specific project, alternative profitable use of such capital is ruled out. The cost of capital should reflect the best alternative return on the capital i.e. the opportunity cost, comprising two elements. Firstly, an element that is equal to a risk-free return (the social discount rate). Secondly, a risk premium should be added to express the risk-adjusted opportunity cost of capital i.e. the return foregone in the financial market on an investment with the same presumed risk profile. Where the method and terms of financing do not differ between options, it would usually make sense to include the costs of capital in an NPV discounted back to present value using the social discount rate of 3.5%[25].

Complications arise where appraisal options cover more than one financing method, or where the cost of finance varies between options. In these circumstances, the issue must be explored in more detail in order to ensure that options are appraised on a level basis. Advice on this may be sought from GHGappraisal@energysecurity.gov.uk.

To illustrate a potential difficulty in accounting for different financing costs, consider the case of a project with financing underwritten by government, with the result that the project is likely to be significantly cheaper than private cost of capital. However, this does not fully reflect the true costs and benefits to society. Government can generally borrow at lower rates than private consumers as it is perceived as being at a lower risk of default. Therefore, by funding a capital intensive project with Government finances, taxpayers absorb risks of the project.

[25] This approach is in line with the Green Book which supports adjustment of cash flows to account for risk rather than adjustment of the social discount rate.

# 7 Measuring the impact of policies on energy demand for DESNZ's energy model

## 7.1 Reporting requirement for additional policy savings inclusion in the DESNZ Energy Model

All UK energy or emissions saving policy is included within the DESNZ energy model baseline projections when it is implemented, adopted (announced government policy with secured funding) or planned. The following fuel impact information is a reporting requirement for all non-transport and non-power generation policy. Transport and power generation policy inclusions in the DESNZ energy model may require specialised information and policy analysts are asked to please contact the DESNZ modelling team directly. Fuel saved by the additional policy must be set out in the format demonstrated in the tables below: individual policy impact on energy demand (saving by fuel, year, and sector).

**Table 8.1: Total sector saving (Please complete one table for each relevant sector)**

| TWh | 2021 | 2022 | 2023 | ……… | 2045 |
|---|---|---|---|---|---|
| Electricity | | | | | |
| Gas | | | | | |
| Oil | | | | | |
| Solid Fuel | | | | | |
| Renewables | | | | | |

*Please note*: figures can be positive (indicating a reduction in fuel use) or negative (indicating an increase in fuel use) if policy includes fuel switching. For example if a policy reduces electricity use but increases gas use, the figures for the energy impact may be +3.4TWh of electricity, -2.8TWh of gas saved in year 2021.

**GHG emissions savings:** savings of greenhouse gas emissions from fuel use should also be submitted. These must be disaggregated by originating sector (Industry, Commercial, etc.), and by emissions sector:

- Traded direct (Fossil fuel combustion within scope of the UK ETS)
- Traded indirect (Electricity consumption, with emissions at generation, rather than consumption stage)
- Non-traded (All other sources).

**Table 8.2: GHG emissions changes**

| MtCO2e | Emissions sector | 2021 | 2022 | 2023 | ... | 2050 |
|---|---|---|---|---|---|---|
| **Industry** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |
| **Commercial** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |
| **Public admin** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |
| **Domestic** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |
| **Transport** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |
| **Agriculture** | Traded Direct | | | | | |
| | Traded Indirect | | | | | |
| | Non-traded | | | | | |

All figures for energy and GHGs should be provided on an annual basis for the lifetime of the policy or until 2050, whichever is the sooner.

It is also essential that policy overlaps have been accounted for, and that the methodology used by the analyst is explained clearly.

For further information on completing any of these tables (including policy overlaps), or for any clarification on the latest projections please contact the DESNZ Energy Model Team: emissionsprojections@energysecurity.gov.uk.

# Annex A: Analysis of energy-efficiency improvements

## Linkages between energy markets and demand for energy services

Consumers demand energy for the services (e.g. heating, lighting, etc) the energy can provide. An energy-efficiency measure improves the efficiency through which these services can be delivered, which in turn reduces the amount of energy needed to provide these services. This relationship is demonstrated in Figure A1 and is explained below.

While consumers of energy ultimately care only about their consumption of energy services, we cannot readily observe this consumption. Instead, it is the purchase of energy that can be observed and measured. Therefore, it is useful to link the energy services market (top-left) with the energy market (top-right) in Figure A1.

The quantity of energy services is related to the quantity of energy through the energy efficiency converter (bottom-left). The slope of this curve determines how efficiently energy can be used to provide energy services. The steeper the curve, the less efficient the conversion, and higher the energy requirement to provide energy services. Within this framework, we assume that any demand changes are small, and so they do not impact on the market price for energy. This is represented by a flat supply curve for energy and energy services. Nevertheless, it is fairly straightforward to extend this analysis to non-marginal changes in energy demand.

### Initial equilibrium

The initial equilibrium price and quantity of energy services is $P_{es0}$ and $Q_{es0}$ respectively in Figure A1. At the initial energy-efficiency, $F_0$, this is equivalent to $Q_{e0}$ units of energy. Using the 45 degree line for energy (bottom-right), the equilibrium in the energy market can be depicted where the initial demand for energy, $D_{e0}$, intersects with the supply of energy, $S_e$. This yields the initial price and quantity for energy, $P_{e0}$ and $Q_{e0}$.

### Impact of an improvement in energy-efficiency

An improvement in energy-efficiency reduces the amount of energy required to deliver the same level of energy services. Graphically, this can be represented by a fall in the steepness of the energy-efficiency curve from $F_0$ to $F_1$. This is equivalent to a reduction in the price of energy services from $P_{es0}$ to $P_{es1}$ given by a shift in the supply of energy services from $S_{es0}$ to $S_{es1}$ (note that energy suppliers do not actually change their supply curves for energy: $S_e$ stays the same. Any increase in the equilibrium consumption of energy services stems from the energy-efficiency measure and the shift in the demand curve.

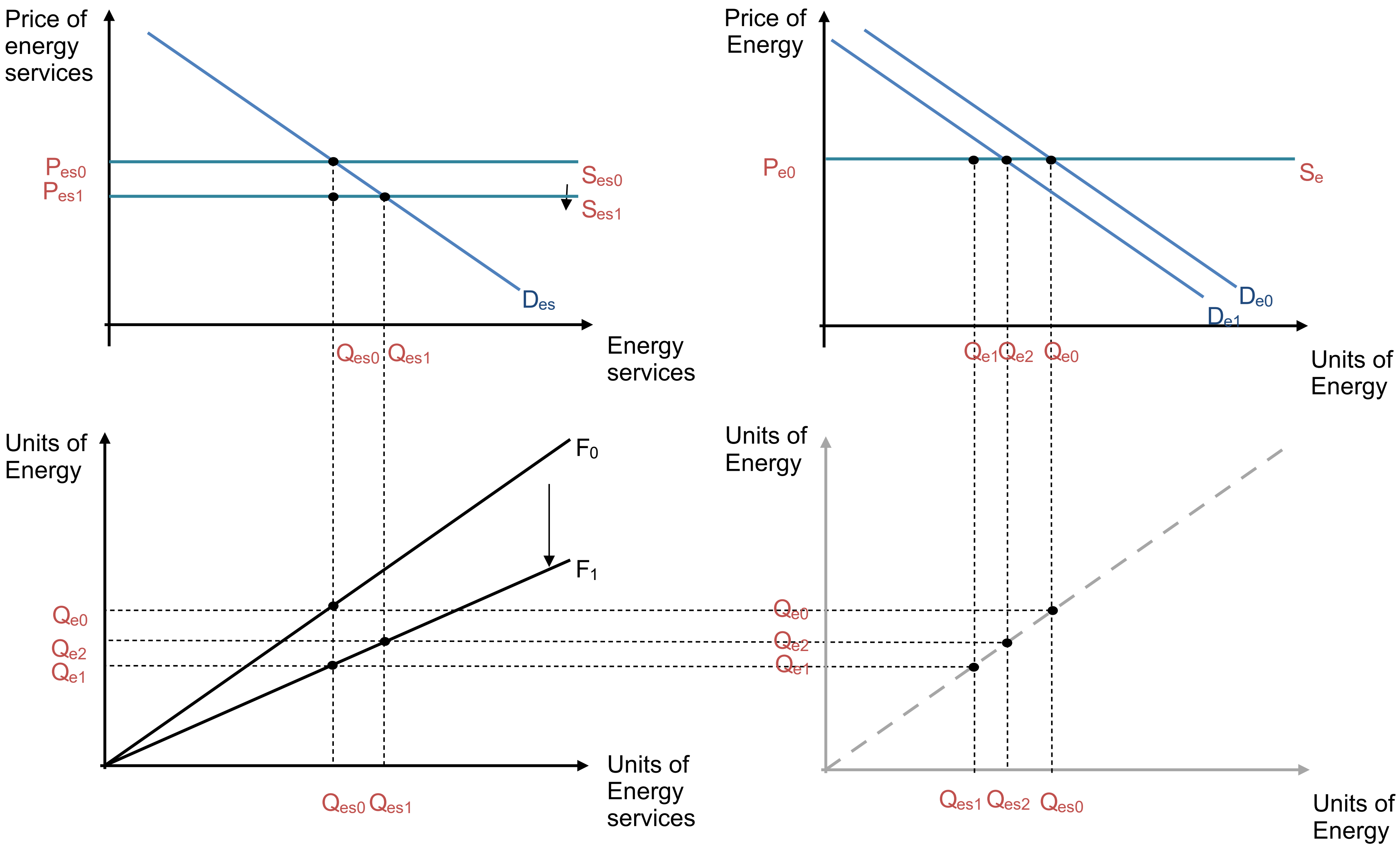



**Figure A1: Relationship between energy services and energy with a demand side energy-efficiency measure**

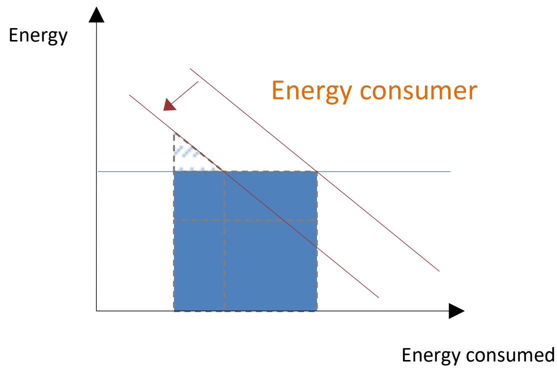
If consumers do not adjust their consumption of energy services following the improvement in energy-efficiency, thus remaining at $Q_{es0}$, they can enjoy the same level of energy services at a lower price, $P_{es1}$. Consuming at this level of energy and at this price ($Q_{e1}$, $P_{e0}$), however, is not a point on the consumer's new demand curve, $D_{e1}$.[26]

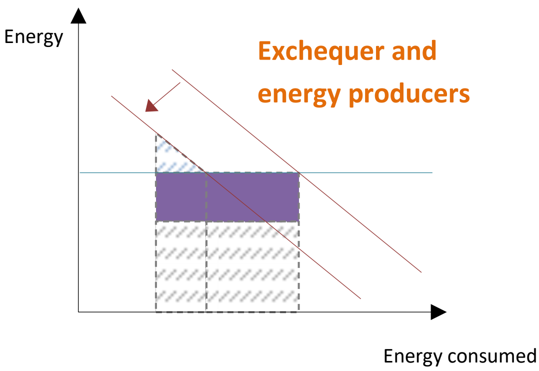
The fall in the price of energy services results in a move along the demand curve for energy services from $Q_{es0}$ to $Q_{es1}$. The final *energy* demand, post-installation of the energy-efficiency measure, can be found at $Q_{e2}$. The demand curve for energy has shifted from $D_{e0}$ to $D_{e1}$. Given the flat supply curve for energy, the price of energy, $P_e$, remains the same throughout.

# Demand-side energy efficiency improvements

## Stage 1: An increase in energy-efficiency reduces energy consumption

When a consumer installs an energy-efficiency measure, they require less energy in order to deliver the same level of energy services. As a result, immediately after the installation of the equipment the consumer's energy demand drops from **A** to **H** in Figure 3.2, since in the very short run they do not increase their consumption of energy services.[27] However, the consumer's preferences at this point in time are actually given by $D_e^1$ and so their consumption is in disequilibrium. The subsequent adjustment to this equilibrium is the direct rebound effect and is analysed in Stage 2 below.[28]

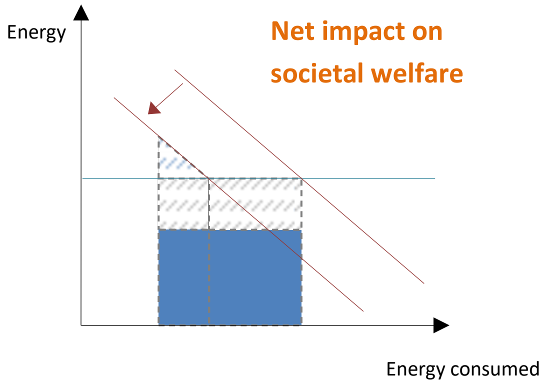



In this stage, the consumer gains **ABJH**, the full bill savings of the energy no longer required to deliver the same level of energy services as before. Those previously receiving payment for the energy supplied no longer receive this payment. The exchequer loses the taxes that were payable on the energy no longer served. Energy producers no longer receive the pre-tax retail price. Together, government and energy producers lose the full retail price in revenues (**ABJH**).

[26] There is no demand curve going through this point because it is not an optimal consumption choice for consumers. A rebound effect due to the change in price of energy services mean that consumers will choose to consume more at this price of energy. The only circumstance under which the new demand curve for energy would run through this point is if the demand for energy *services* is completely inelastic.
However, we would expect this is to be unlikely in most situations.
[27] This dynamic assumption that the consumer maintains his level of energy services before adjusting later is not crucial to the analysis of welfare changes; the final outcome will be the same. It is merely used here to illuminate the individual effects.
[28] It should be noted that the example assumes the demand curve is not perfectly inelastic. In the case of a perfectly inelastic demand curve, H is also the point through which the demand curve will run through. This mean there is no rebound effect.

However, although they lose sales revenues, energy producers avoid the cost of providing the energy that they no longer need to supply to the consumer, the long-run variable cost of energy supply. Energy producers therefore avoid these resource costs equivalent to the area **FBJI** Figure 3.2, mitigating the effects of the reduction in revenues from lower sales of energy. The result of this is that the net losses incurred by firms and government are limited to the 'taxes and margins' element, **AFIH**. For further discussion of the components of the energy price, including the resource costs and taxes and profits, see section 5.1.

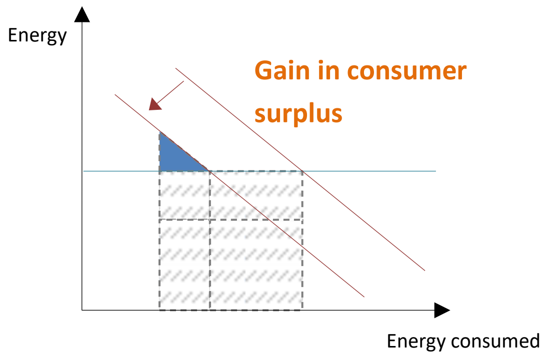



The net social welfare impact from stage one is the sum of the gains and losses from the societal groups. The consumer gains the savings from lower energy consumption, but government and energy firms lose their taxes and margins. The resulting welfare change can be interpreted as the resource cost element associated with avoided energy production. Societal welfare improves by **FBJI** by using fewer resources to maintain its original position. The taxes and margins on the energy no longer supplied do not represent a change in societal welfare, as the impact is merely a change in the amount of money transferred between the energy consumer, firms, and government.

## Stage 2: Direct rebound effect

Following stage 1 above, the energy consumer now has more disposable income (from their energy bill savings) and is also able to acquire this energy service more cheaply now than he was prior to the energy-efficiency measure being installed. The energy consumer may choose to consume more of this energy service by using a portion of their bill savings (through the **income effect**), or by substituting away from other expenditure, given these energy services are now relatively cheap (**substitution effect**). The theory of the rebound effect, including the

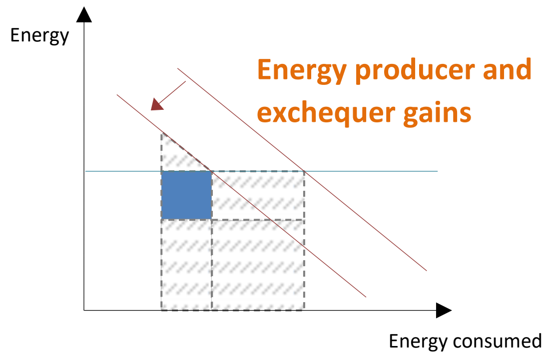
distinction between the direct and indirect rebound effect, is explained in more detail in section 4.




In Figure 3.2 this direct rebound is demonstrated by a shift in consumption from **H** to **D**, bringing consumption to the new equilibrium. When a consumer consumes more energy services as a result of the direct rebound effect following an improvement in energy-efficiency, they will realise welfare benefits. Assuming that the welfare derived from energy services is given by their **willingness-to-pay for energy** (as a proxy for his

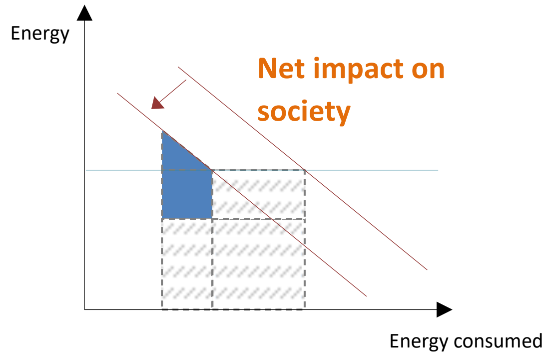
willingness-to-pay for energy services), we can measure this welfare by considering the area under their energy demand curve, **GDCJ**. However, in order to derive this increase in welfare, they must pay the full retail price $p_e$ for the additional energy they consume. They therefore incur the cost of this energy consumption, **DCJH**. The net effect to the consumer is the difference between their willingness to pay and the retail price or the gain in consumer surplus, that is, a gain of **GDH**.

The only societal welfare effects that are experienced by energy firms and the exchequer are related to the change in energy consumption. The consumer purchases more energy following the direct rebound effect, and this is purchased at the full retail price, $p_e$, which includes the resource costs and taxes and margins. Therefore, energy producers and the exchequer gain the revenues from this increased consumption, **DCJH**. However, energy producers must also pay for the resource costs associated with producing more energy, **ECJI**. Therefore, the net gains for these two groups equal **DEIH,** which includes only taxes and margins[29].




The sum of the consumer, exchequer and energy producer impacts from stage 2 gives the net impact on society of the direct rebound effect. These gains are equivalent to the consumer surplus, **GDH**, and the gain in taxes and margins for energy producers and government, **DEIH**, so society gains **GDEI.**

Resulting from the improvement in energy efficiency, society experiences a welfare change equal to the sum of the welfare impacts from the two stages. This full impact on societal welfare can be summed up from the net benefits from the two stages:

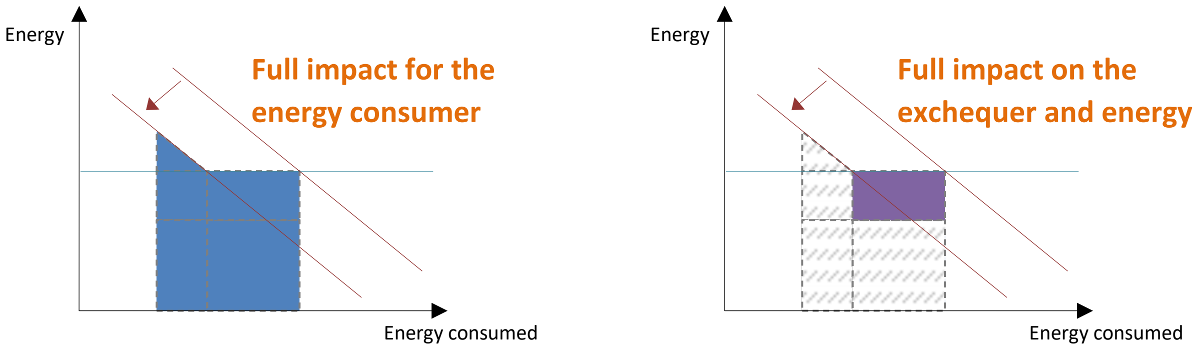



- Gains and losses from the reduction in energy required to deliver existing levels of energy services (**FBJI**)
- Gains and losses from the rebound effect (GDEI)

From the two stages, the consumer derives a benefit of the full retail price of the energy saved,

**ABCD**, plus the additional benefit (willingness-to-pay) gained from the direct rebound effect, **GDCJ**. Energy producers and government lose out only from the net change in energy consumption, and of this only lose the portion of the price that is above the long run variable supply cost of that energy. Energy producers and government only perceive a fall in energy

[29] It may appear that we giving value to a transfer here. One way to look at this dynamic is that society as a whole gains from this rebound effect at what it is worth to consumers less the resource costs of production. Taxes and Margins transfer some of the surplus, which is additional, from consumers to energy producers and government by increasing the price of energy beyond the resource costs.




consumption and do not incur any other welfare costs or benefits.[30] In total, therefore, the exchequer and energy producers jointly experience losses of **AFED**.

Aggregate benefits from demand side energy-efficiency improvements have therefore been shown to equal the blue and red hatched areas shown in Figure 3.2. One way of looking at this is to say that the value to society is the consumer's valuation of their gain from the rebound, **DCJG**, in addition to the saved costs of producing the energy that is no longer supplied, **FBCE**. The excluded area, **AFED**, represents the loss of margins and taxes incurred by firms and government, but that is offset by the benefit consumers gain from not having to pay this portion of the cost.

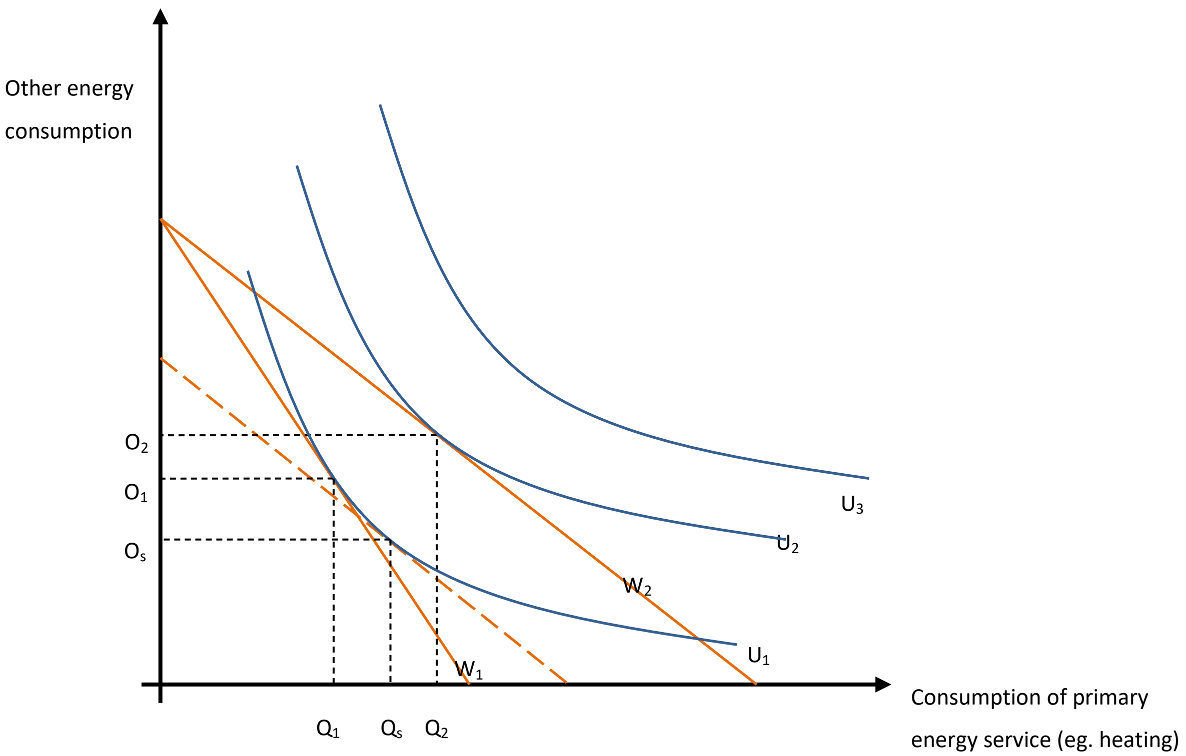
[30] Note that an energy-efficiency measure is not 'bad for business'. Although, energy producers may lose out, the overall effect on business should be positive as consumers are likely to spend more on other goods in the economy from their realised bill savings.

# Annex B: Further analysis of rebound effects

## The cause of rebound effects

Figure B1 depicts the direct and indirect rebound effects. Prior to the energy-efficiency installation being made, energy consumption is in equilibrium at ($Q_1$, $O_1$). This is the point where the relevant indifference curve[31], $U_1$, is tangential to the budget constraint $W_1$. This maximises the representative consumer's utility and is the theoretical optimal choice. Subsequent to the installation being made, two effects occur. First, there is a change in the relative prices of heating services and all other energy-consuming services. This results in a tilt to the budget constraint (the dotted line), and a subsequent substitution effect between heating services and all other energy-related services. This substitution effect is comprised of two parts: an increase in demand for heating services to $Q_s$ and a fall in demand for all other energy-related services to $O_s$.

**Figure B1: Direct and indirect rebound effects**




With the income effect from bill savings, the representative consumer's budget constraint pushes out to $W_2$. The indifference curve tangent to $W_2$ is now $U_2$, giving us a theoretical optimal choice at $Q_2$, $O_2$. The overall change in demand for other energy-related services depends on the shape of the indifference curves and the relative prices of the two energy-related services. It is possible that in some circumstances the substitution effect will

[31] At points on an **indifference curve**, the consumer is ambivalent to the different consumption bundles of goods represented by the curve.

dominate and the consumption of other energy-related services will fall. Overall, however, this is unlikely to be the case as most energy services are not obvious substitutes.

In summary, the effects represented in Figure B1 are as follows:

- **Direct rebound effect:** $Q_1$ to $Q_s$ (substitution effect) to $Q_2$ (income effect)
- **Indirect rebound effect:** $O_1$ to $O_s$ (substitution effect) to $O_2$ (income effect)

The impact of the indirect rebound effects can be viewed under the same framework as for direct rebound effects. The differences are in the drivers of the rebound and the energy/emissions intensity of the goods consumed. While the income effect will drive both types of rebound effects, the substitution effect induces both direct and indirect rebound effects, which work in opposite directions. If the energy intensity of the good that has fallen in price, which consumers substitute consumption towards, is greater than the energy intensity of the basket of goods that consumer substitutes away from, the net effect would be an increase in aggregate energy consumption. As for the income effect, the greater the elasticity of energy demand with respect to income, the greater both types of rebound effects will be, and the further to the right the resulting energy demand curve will be.

# Measuring the full impact of the direct rebound effect on consumer surplus

In practical terms, it is necessary to draw limits when assessing rebound effects. Referring to

Figure 3.2, the direct rebound effect is measured for consumers according to their willingness to pay (**GDCJ**) as approximated by the retail price of energy (**HDCJ**). By using the retail price, this excludes a valuation of the additional area **GHD**, which also represents a further improvement in consumer welfare.

To avoid over-complicating the process, the additional surplus area, **GHD**, can be treated as a triangle and approximated using the elasticity of the demand curve and the size of the rebound effect[32]. There are a number of studies that estimate the size of both of these,[33] and could be used to inform assumptions made in policy appraisal. In most circumstances however, it is unlikely to be proportionate to quantify this triangle in an appraisal.

It should be noted that direct rebound effects are not limited to only domestic consumers. For example, energy consuming firms will have a demand curve for energy that reflects the energy consumption level that maximises profit at a given energy price. By installing energy-efficiency measures, firms may produce the existing level of output using less energy. However, they may wish to expand their output to take advantage of the lower

[32] The area of the triangle may be approximated as follows: $A = \frac{1}{2} base \times height = \frac{1}{2}\Delta e \times \Delta p$. The base is equal to the size of the rebound. This may be used with the elasticity of the energy demand curve to estimate the height of the triangle, by rearranging the formula for the elasticity $n$ itself. $n = \frac{\%\Delta e}{\%\Delta p} = \frac{p\Delta e}{e\Delta p}$ (where $e$ is the energy consumption, $p$ is the prevailing energy price, $\Delta e$ represents HG in figure 3.2). Therefore, the height of the triangle may be calculated as follows: $\Delta p = n^{-1}\frac{p}{e}\Delta e$

[33] See, for example, Espey and Espey (2004); Madlener and Hauertmann (2011); and Wirl (1997).

input costs. The increase in profit that they would experience would be represented by the area underneath their energy demand curve, which would include the equivalent triangle.

# Annex C: Indirect taxation distortions

The discussion here draws on Robert Sugden's paper *The treatment of taxation in the cost-benefit appraisal of transport appraisal*[34] prepared for the Department for Transport.

HM Treasury's Green Book states the following:

*The adjustment of market prices for taxes in appraisal is appropriate where it may make a material difference to the decision. In practice, it is relatively rare that adjustments for taxation are required, because similar tax regimes usually apply to different options. It can also be difficult in practice to estimate costs net of tax. However, where the tax regimes applying to different options vary substantially, this should not be allowed to distort option choice. In such cases it is important to adjust for any differences between options in the incidence of tax arising from different contractual arrangements, such as in-house supply versus buying in, or lease versus purchase. Options attracting different VAT rates, for example, should be compared as if either the same VAT payments, or no payments were made in all cases.*

This acknowledges that there is potentially an issue. However, for the purpose of option appraisal it may be unnecessary to make an adjustment for indirect taxation, as the taxation regimes between the options are often similar. While this is not problematic for weighing up options against each other it does not ensure that the value of the impact is accurate or comparable to valuations of other policies. If an accurate assessment of the value of the impact on society is to be made, such as in making a Value for Money assessment, then indirect taxation should be considered.

The Department for Transport recognises this issue in its appraisal guidance[35] and recommends making an adjustment that is similar to the approach described and recommended below. This takes the form of an adjustment factor, based on the average indirect taxation rate, which is applied to the costs and benefits encountered by one or more groups.

## An analogy

When we undertake policy appraisal we use real prices, picking a specific base year and maintaining this throughout the analysis. This is so that costs and benefits may be compared accurately. If we were to choose a different base year for different parts of the analysis, or were to use nominal prices, then this would distort the welfare impact.

This relates closely to variations in indirect taxation. Society values the goods and services

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34 http://webarchive.nationalarchives.gov.uk/20090507122314/http://www.dft.gov.uk/pgr/economics/rdg/thetreatmentoftaxation inthec3128

35 See the Department for Transport's WebTAG https://www.gov.uk/guidance/transport-analysis-guidance-tag

that money purchases, rather than the money itself. We use money as a way of accounting for the costs and benefits of goods and services, and it is important that everything is measured on the same basis. When indirect taxation varies from group to group, if this is not accounted for then this distorts the valuation of the tangible assets. For example, we want to value an apple equally no matter who has custody of it. If one person must pay more for this apple due to having to pay a higher rate of VAT it does not mean that the apple is worth more when this individual has possession of it.

An appraisal of impacts over time based on nominal prices, rather than real prices, would distort the outcome in the same way that an appraisal of impacts would based on retail prices including varying levels of taxation. To provide a consistent analysis in the first case, we would use real prices fixed in a particular base year. In the second case, we would specify the indirect tax rates that have been applied in the analysis (if any) and adjust everything so that it is measured on this basis.

# Framework

Assume an average indirect taxation rate experienced by consumers when purchasing their goods and services, equal to $\bar{t}$.

There are two price bases that could be used for accounting for the impacts of a policy, the factor cost (net of indirect taxation), or retail price (gross of indirect taxation). Therefore, goods which are valued at £1 at factor cost prices are valued at $£(1 + \bar{t})$ at retail prices.

Of the retail price, firms receive the factor cost, £1, and the exchequer receives $£\bar{t}$ in indirect taxation revenue (VAT). Therefore, as a proportion of the retail price, government receives $\frac{\bar{t}}{1+\bar{t}}$, and firms receive $\frac{1}{1+\bar{t}}$.

Consumers perceive the value of goods according to the retail price, which includes all taxes, charges, and levies. Because most businesses do not pay VAT, these businesses are able to acquire more goods and services than a consumer would with the same nominal amount of money. While this may appear to imply for cost-benefit analysis purposes that money is worth more to businesses than it is to consumers, the balancing comes in the form of exchequer revenues.[36]

## Example 1 - New government project costing £1m

Consider the case of government taking forward a new project that will cost the exchequer

£1 million Let’s assume that the government balances its budget and covers this spending through increases in direct taxation (note that these are not critical assumptions to the conclusion).

The government must raise £1 million through direct taxation of consumers. However, by raising direct taxation, consumers’ disposable income is reduced. The result of this is that indirect taxation (i.e. VAT) revenue is reduced, and that in order to achieve the £1 million required, direct taxation must be raised by *more* than £1m.

[36] In this framework we value all costs and benefits to any group or individual equally.

For each £1 raised through direct taxation, disposable income is also reduced by £1. This disposable income would be been used to purchase goods and services, which on average would have an associated indirect tax rate of $\bar{t}$. Of final consumer spending, a proportion $\frac{1}{1+\bar{t}}$ is received by the firm, and $\frac{\bar{t}}{1+\bar{t}}$ is taken as indirect taxation revenue. Therefore, £1 taken through direct taxation reduces indirect taxation by £$£\left(\frac{\bar{t}}{1+\bar{t}}\right)$, so the net change in taxation revenue is $£\left(1-\frac{\bar{t}}{1+\bar{t}}\right) = £\left(\frac{1+\bar{t}-\bar{t}}{1+\bar{t}}\right) = £\left(\frac{1}{1+\bar{t}}\right)$. Therefore, to obtain a net increase in taxation revenue of £1 million, direct taxation must be raised by $£(1+\bar{t})\ \mathrm{m}$ million.

If we were to value these by the observed retail price, consumers would lose $£(1+\bar{t})\ \mathrm{m}$ million and government would gain £1 million. This implies that there is a net cost to society of $£\bar{t}$ million when in fact all that is occurring is a transfer. The reason for this inconsistency is that we are not considering the spending power of this money.

We wish to value a particular asset the same, regardless of who has possession of it. Whether this is valued gross or net of VAT is irrelevant, but consistency is essential. £1 million spent by government would purchase the same amount of goods and services as $£(1+\bar{t})\ \mathrm{m}$ million would if spent by consumers. This is because government effectively does not have to pay VAT, in that they recoup the VAT element of the price of the goods and services purchased. Therefore, £1 million of exchequer money has the spending power of $£(1+\bar{t})\ \mathrm{m}$ million of consumers' money. If each group spent all their money, the quantity of goods and services obtained would be equal for the two groups, despite appearing as though different amounts of money were held at the start.

Therefore, if we are viewing the funding of the £1 million project from a consumer's purchasing perspective, or in retail price terms, we would apply an uplift factor of $(1+\bar{t})$ to the nominal value of exchequer costs. If we are considering the increased cost to the consumer through higher taxes, but wanted to view it from a government's purchasing, or in factor cost terms, we would divide the nominal value of $£(1+\bar{t})\mathrm{m}$ million in additional taxes to the consumer by $(1+\bar{t})$. In either case we would arrive at a net zero societal impact from the change in direct taxation policy. Since the direct impacts of a change in taxation will be limited to a transfer between different groups in society, we would expect no net change in societal welfare. The tables below show the costs and benefits to consumers and the exchequer in both units of account; factor cost and retail price, and how different units of account are manipulated to establish consistency in this example.

Without correcting for different units of account, we would be evaluating the intervention using the retail prices for the loss of disposable income, but the factor cost for the exchequer revenues. This leads to a net cost on society despite there being only a transfer of resources.

### *Consumers*

| **Component** | **Amount (consumer prices/retail prices)** | **Amount (factor cost)** |
|---|---|---|
| Loss of disposable income through increase in direct taxation | $\boldsymbol{£(1+\bar{t})m}$ | $£(1+\bar{t})m \div (1+\bar{t}) = \boldsymbol{£1m}$ |

### *Government exchequer*

| **Component** | **Amount (consumer prices/retail prices)** | **Amount (factor cost)** |
|---|---|---|
| Gain in direct taxation | $£(1+\bar{t})m \times (1+\bar{t})$ | $£(1+\bar{t})m$ |
| Loss of indirect taxation | $-£\bar{t}m \times (1+\bar{t})$ | $-£\bar{t}m$ |
| Net impact on taxation revenue | $£1m \times (1+\bar{t}) = \boldsymbol{£(1+\bar{t})m}$ | $\boldsymbol{£1m}$ |

### *Net Impact*

| **Component** | **Amount (consumer prices/retail prices)** | **Amount (factor cost)** |
|---|---|---|
| Net Impact | $£(1+\bar{t})m - £(1+\bar{t})m = \mathbf{0}$ | $£1m - £1m = \mathbf{0}$ |

## Example 2 - Consumers transfer £100 to a business

Consider the appraisal of a potential government policy which would require consumers to immediately transfer £100 to a nominated business that is registered for VAT (and therefore can claim back any VAT payments it makes on intermediate goods required in the production process).

The intention of this example is to demonstrate that £1 should not be viewed as being more valuable to businesses, but rather that we need to account for the costs and benefits of the transfer in a consistent manner.

It is clear that the net societal impact of making this transfer is zero. However, it is also clear that if a business has £100 available in its bank account it is able to purchase more goods and services with this money than a consumer could purchase with £100 in his or her bank account. This is because consumers will have to, on average, pay VAT on top of the factor cost price of the goods, whereas the business will be able to reclaim VAT and spend it on additional goods.

The missing link here lies in the net changes on the exchequer, which serves to fill the gap in identifying the net social impact.

As in the previous example, the costs and benefits for the various societal groups are presented below in both retail and factor cost prices. Because a firm's money has greater spending power than the equivalent money held by a consumer, we apply an uplift factor to obtain the value of this money in retail price terms. The exchequer loses revenue because the firm does not pay VAT on its intermediate goods, whereas consumers do pay VAT. This means that the transfer results in a loss of revenues to the exchequer. The nominal amount of these revenues is given by identifying the proportion of the retail price that is indirect taxation. As explained in the previous example, this money has greater spending power than the equivalent money held by a consumer, and therefore requires an uplift factor to be quantified on a consumer price basis.

As can be seen, if we account for the impacts consistently through either retail prices or factor cost prices for all groups, the net societal impact is zero as expected.

### *Consumers*

| Component | Amount (consumer prices/retail prices) | Amount (factor cost) |
|---|---|---|
| Loss in disposable income | $£\mathbf{100}$ | $£\frac{\mathbf{100}}{\mathbf{1}+\bar{\boldsymbol{t}}}$ |

### *Firms*

| Component | Amount (consumer prices/retail prices) | Amount (factor cost) |
|---|---|---|
| Gain in financial balances | $£100 \times (1+\bar{t}) = £\mathbf{100} + £\mathbf{100}\bar{\boldsymbol{t}}$ | $£\mathbf{100}$ |

### *Exchequer*

| Component | Amount (consumer prices/retail prices) | Amount (factor cost) |
|---|---|---|
| Loss of indirect taxation revenue | $£\left(100 \times \frac{\bar{t}}{1+\bar{t}}\right) \times (1+\bar{t}) = £\mathbf{100}\bar{\boldsymbol{t}}$ | $£\left(100 \times \frac{\bar{t}}{1+\bar{t}}\right) = £\left(\frac{100\bar{t}}{1+\bar{t}}\right)$ |

***Net Impact***

| Component | Amount (consumer prices/retail prices) | Amount (factor cost) |
|---|---|---|
| Net Impact | $£100 + £100\bar{t} - £100 - £100\bar{t} = \mathbf{0}$ | $£100 - £\left(\frac{100}{1+\bar{t}}\right) - \left(\frac{100\bar{t}}{1+\bar{t}}\right)$ $= £100 - £\left(\frac{100 + 100\bar{t}}{1+\bar{t}}\right)$ $= £100 - £\left(\frac{100}{1+\bar{t}}\right)(1+\bar{t})$ $= \mathbf{0}$ |

## Principles of Indirect Tax Correction Factors

It is generally not recommended that an adjustment is made for variations in indirect taxation between societal groups. However, in situations where it is deemed necessary to establish consistency with indirect tax correction factors, the following principles should be applied:

- Impacts on indirect taxation received by the exchequer should be factored in.
- The approach is particularly relevant where there is more than one group affected
- Costs and benefits must be assessed on a consistent basis throughout an appraisal, through the application of a correction factor where appropriate. The unit of account, whether it is the retail price or factor cost, is not important. However, this unit of account must be consistent for each group in the analysis.
- That this approach extends to non-financial benefits such as comfort and air quality. This is because if a consumer attaches a value to this benefit, then this will be according to their perceptions of market prices, including the indirect tax component.
- There would be different adjustment factors for energy, because VAT on energy is 5%, rather than 20%[37]

## Impact of Applying Correction Factors

It is likely that these changes would have an impact on the NPV of a policy, however this is not always the case. There will be no impact on the NPV in these circumstances:

- If the policy has impacts for only one societal group
- For financial transfers: In the example above where consumers transfer to firms, this would be accounted for as a loss to consumers of £100, and a gain to firms of £100 (with an NPV of zero), when no correction factor is applied. Applying correction factors mean consumers lose £100, but the aggregate net gains of firms and government totals £100, although the distribution of impacts is different to when no correction factor is applied.

[37] For more information, please contact the appraisal guidance team at GHGappraisal@energysecurity.gov.uk

In example 2 above, where there is a straight transfer from consumers to firms, the NPV would remain unchanged at zero.  However, with the use of indirect taxation factors, the distribution of impacts would be different.  Benefits to business would be greater under the new measurement, but this would be offset by a cost to government from reductions in indirect taxation revenues.