7 Estimating the baseline scenario and emissions

Estimating the GHG impacts of a transport pricing policy requires a reference case, or baseline scenario, against which impacts are estimated. The baseline scenario represents the events or conditions that would most likely occur in the absence of the policy being assessed. Properly estimating the emissions associated with this scenario – the baseline emissions – is a critical step in estimating the achieved GHG impacts of a pricing policy.

Checklist of key recommendations

- Estimate base year emissions
- Develop a projection of baseline emissions for each year of the assessment period

7.1 Introduction to estimating base year emissions

It is a *key recommendation* to estimate base year emissions. The base year is the year in the assessment from which projections will be made into the future. Where the results of the assessment will be used in the GHG accounting of an NDC, users should consider aligning the base year for this assessment with the base year of the NDC and related targets. For this purpose, input parameters (e.g. activity data, emission factors, socioeconomic data) used to estimate baseline emissions of transport pricing policies should be aligned with similar parameters used for setting NDC targets, and relevant GHG accounting and reporting under the Paris Agreement.
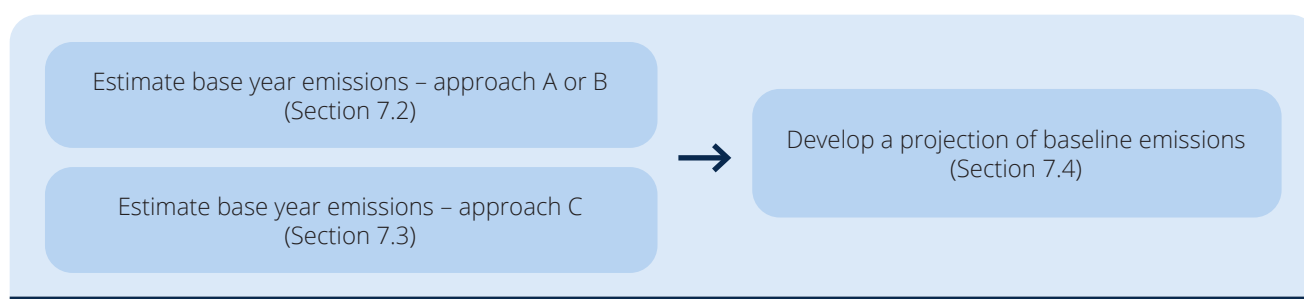
Calculation of base year emissions for an individual year uses activity data on the key drivers of emissions, primarily from fuel consumption, and emission factors for the fuels combusted nationally. Consistent with the definition of the GHG assessment boundary, only carbon dioxide (CO_2) emissions are included; for simplification, emissions of methane (CH_4) and nitrous oxide (N_2O) are excluded.

Refer to Section 4.2.2 for guidance on whether to apply approach A, B or C, or both approaches B and C, to estimate base year emissions. Users should choose the approach that is appropriate based on data and capacity available. Approaches A and B use the same baseline scenario. Section 7.2 provides guidance for approaches A and B. For approach C, Section 7.3 provides guidance on defining the baseline scenario and calculating base year emissions for an individual year.

Approaches A and B use top-down, national-level data to estimate base year emissions for policies implemented at the national level. In contrast, approach C is particularly suitable for the city level where activity data (i.e. fuels used) are available for activities within the city boundary.[20] In both

FIGURE **7.1**

Overview of steps in the chapter

Estimate base year emissions – approach A or B (Section 7.2)

Estimate base year emissions – approach C (Section 7.3)

→

Develop a projection of baseline emissions (Section 7.4)

---

[20] System boundaries can be chosen as "fuel used" or "fuel sold" within the geographical borders; see Executive Body for the Convention on Long-range Transboundary Air Pollution (2015).

cases, the baseline scenario is considered to be a continuation of the conditions that exist in the absence of the new policy.

Base year emissions are calculated for an individual year using activity data and emission factors. Activity data are related to the key driver of emissions from transport, which is primarily fuel consumption. The emission factor is related to the carbon content of the vehicle fuels used and is expressed as tonnes of CO_2 per unit of fuel. In this methodology, only gasoline and diesel are included for approaches A and B. However, the same approach can be applied to other fuels (e.g. LPG) by using analogous equations with different input data (i.e. travel activity data, emission factors and elasticity values).

7.2 Estimate base year emissions: approaches A and B

Figure 7.2 provides an overview of the steps for approaches A and B.

The basic calculation for approaches A and B multiplies activity data with an emission factor to determine base year emissions (see Figure 7.3). The activity data consist of vehicle fuel use for the year selected in the baseline scenario, expressed in units of energy, volume or mass. Available national data for the year should be used. In the simplest case, this amounts to the observed vehicle fuel use for a year in the absence of the policy.

If transport fuel includes a share of biofuels (e.g. bioethanol or biodiesel), the share of these fuels within the fuel mix should be sourced from government or distributor data. As a simplification, the GHG emissions from biofuels can be assumed to be zero. These emissions should be considered in the applied emission factor when calculating the emissions following Figure 7.3. For example, in a country that applies a biogenic share of 5% in transport fuels, the emission factor is reduced by 5%. It is important that, where biofuels are relevant, this simplification is transparently indicated for monitoring and reporting purposes (see Chapters 11 and 12). A more comprehensive way to assess the emissions of biofuels within the ground transport

FIGURE **7.2**

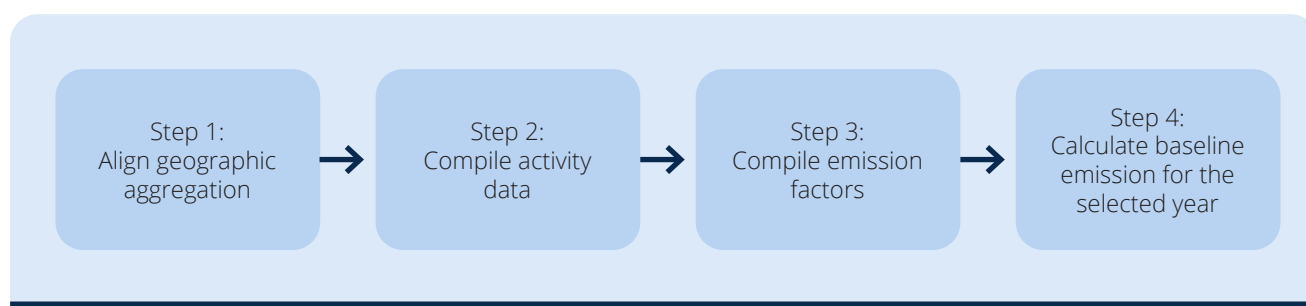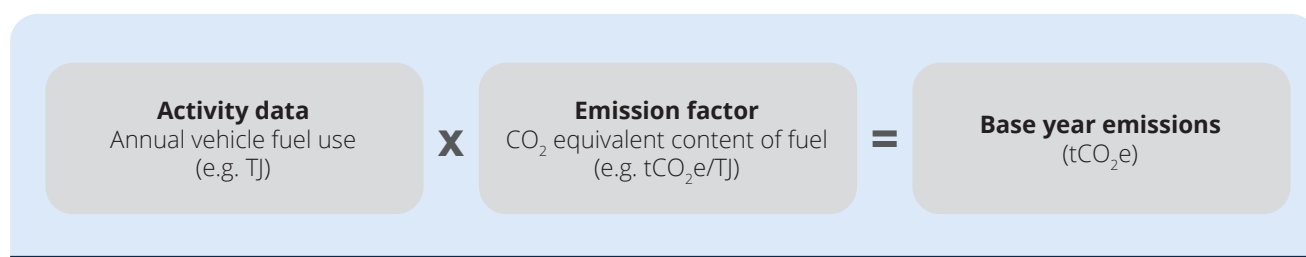**Overview of steps for approaches A and B**

Step 1:
Align geographic aggregation

Step 2:
Compile activity data

Step 3:
Compile emission factors

Step 4:
Calculate baseline emission for the selected year

FIGURE **7.3**

Base year CO$_2$ emissions calculation for approaches A and B

Activity data
Annual vehicle fuel use
(e.g. TJ)

X

Emission factor
CO_2 equivalent content of fuel
(e.g. tCO_2e/TJ)

=

Base year emissions
(tCO_2e)

system is shown in approach C (see Sections 7.3 and 8.2.3).

7.2.1 Approach A: Estimate impact of the policy on the national vehicle fleet

Approach A is a simple approach to calculating GHG (CO_2 only) impacts where only aggregated data are available. It is appropriate to use approach A where the activity data on annual fuel consumption are available as an unspecified mix of gasoline, diesel and/or other transport fuels. If it is known or assumed that freight transportation is mainly powered by diesel fuel, approach B should be applied.

The four steps for approach A are described below.

Step 1: Align geographic aggregation
Confirm that the geographic aggregation of the activity data on annual fuel consumption is the same as the geographic level at which the policy will be applied. In most cases, the geographic aggregation is the national border. The simplified approach A ignores upstream emissions from fuels, whether or not these occur within the national borders.[21]

Where activity data on fuel use are available at a smaller geographic aggregation, such as for a region or a province, the same calculation method described here can be used to calculate base year emissions for a regional or provincial policy.

Step 2: Compile activity data
The activity data are the annual fuel quantity combusted by vehicles for ground transport (F_y). In this approach, the user obtains aggregated data for all vehicle fuel types together, in energy units (TJ or similar). Users can obtain the data from (in order of priority) (1) the national energy balance or similar national energy statistics, (2) a data-collection process or (3) international sources.

During the compilation of activity data, select any conversion factors needed to convert the fuel-use data into units that are compatible for multiplication with the emission factor. The default IPCC emission factors are expressed in units of $kgCO_2$/TJ on a net calorific basis (i.e. NCVs are applied to determine the usable heat energy released through combustion), so fuel activity data should be in energy units. It is important to determine whether the energy units are

expressed on a net calorific basis. Where a different basis is used, the values should be converted before applying the emission factor (e.g. using the method provided by the IPCC[22]).

Data on total fuel use are often made available by the ministry of energy or equivalent in the national energy balance, although entities such as the ministry of transport, ministry of finance or similar governmental bodies may manage these data in some cases. National energy balances are also published by the International Renewable Energy Agency (IRENA).[23] Where using data from the national energy balance, ensure that the boundaries of the data set are clear. For example, reported diesel use may also include consumption for sources that are not related to transport (e.g. water pumps, diesel generator sets for power generation).

In the absence of a robust national data source, the alternative is to build the activity data set directly. In this case, consider the sources of transport fuel used in the country. Depending on the sources (e.g. national production and/or imports), data can be derived from refineries, fuel importers or customs authorities. Users could also use well-designed and well-executed surveys of fuel distributors or fuelling stations to build the data set. In the latter case, it is recommended that users refer to accepted guidance on survey design and execution to ensure a robust result. These two approaches for building an activity data set directly may require significant resources.

Where building an activity data set directly is too resource-intensive, users can use international sources, such as International Energy Agency (IEA) and IRENA country statistics.[24]

For all data sources, analyse the compiled fuel-use data while accounting for the following:

- **Data vintage.** Note the year that the activity data represent and not only their year of publication. The delay between data compilation, analysis and publication may be considerable. A study published in 2016 may report data for the year 2013.

---

21   This is a conservative assumption since, by ignoring upstream emissions, emissions reductions are also excluded from the results.

22   IPCC (2006). Note, the enhanced transparency framework states that "Each Party shall use the 2006 IPCC Guidelines and any subsequent version or refinement of the IPCC Guidelines agreed upon by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA)".

23   https://irena.org/Statistics

24   Available at: www.iea.org/statistics and https://irena.org/Statistics.

- **Boundaries of the data set.** Consider the likelihood of over- or under-reporting of transport fuel use within the statistics. Over-reporting may occur where there are significant non-transport uses of typical transport fuels. Situations that could generate this type of problem are

  » the presence of significant backup electricity generation at private homes using diesel generators
  » for countries with subsidized fuel, black-market export of transport fuels to neighbouring countries and/or significant fuel sales to vehicles that operate in neighbouring countries ("tank tourism").

If a data set used seems to be subject to significant over- or under-reporting, provide an estimate of the magnitude of the impact, justify the assumption, and incorporate it into the calculations. Alternatively, report the related uncertainty but omit the consideration from the calculations.

Table 7.1 provides an overview of the activity data parameter for approach A, and possible data sources.

For approach A, since all fuel types are aggregated in the activity data, estimate the share of different fuel types on an energy basis (i.e. expressed in units of energy – TJ). If there are reliable indicators on the share of gasoline versus diesel and/or other transport fuel use in the country (e.g. different taxation or subsidy, reliable data on shares in passenger and freight transport), apply these values to define the proportion (S_i). Otherwise, a default assumption can be applied.

Where activity data are expressed in volume units (e.g. in litres or gallons), the user will need to apply fuel density values (ρ_i) to convert the data to mass units. Where activity data are expressed in mass units, the NCV (NCV_i) should be applied to obtain energy units. In either case, it is preferable to use national values to make these conversions. In the absence of appropriate national data, reliable international sources or default values can be applied.

Table 7.2 provides an overview of the conversion factor for activity data for approach A, and possible data sources.

Step 3: Compile emission factors
The emission factors (EF_i) represent the amount of CO_2 emissions expected from combusting a unit of fuel, and are based on the total carbon content of the fuel. In approach A, emissions of CH_4 and N_2O are ignored for simplicity. Users should take into account the different transport fuels used in the country and determine an emission factor for each fuel type i. Emission factors can be obtained from (in order of priority) (1) national energy or environmental statistics, (2) national fuel providers or (3) default values from international sources.

For approaches A and B, emission factors consider only tank-to-wheel emissions and no "upstream" or well-to-tank emissions (i.e. emissions that stem from electricity production and distribution).

Table 7.3 provides an overview of the emission factor parameters for approach A, and possible data sources.

TABLE **7.1**

Activity parameter for approach A

Parameter	Description	Unit	Sources
F_y	Total fuel used for ground transport in year y (unspecified mix of gasoline, diesel and/or other transport fuels)	TJ	In order of preference: • national energy balance or similar national energy statistics • data-collection process • international sources, such as IEA

TABLE **7.2**

Conversion factors for activity data for approach A

Conversion factor	Description	Unit	Sources
S_i	Share of fuel type i in ground transport combustion, on an energy basis (i.e. expressed in units of energy – TJ)	%	In order of preference: • national statistics • indicative national reports or studies, or expert estimate • assumption of a share of 50% diesel and 50% motor gasoline, in the absence of any suitable national information

TABLE **7.3**

Emission factor parameters for approach A

Parameter	Description	Unit	Sources
EF_i	Emission factor for fuel type i	tCO_2/TJ	In order of preference: • national energy or environmental statistics • national fuel providers, such as refineries or fuel importers, based on their measurements • default values – diesel: 74.1 tCO_2/TJ; gasoline: 69.3 tCO_2/TJ[a]

[a] Both values are from both IPCC (2006), vol. 2, Chapter 3, Table 3.2.1.

Step 4: Calculate base year emissions for the selected year

Calculate base year emissions for the selected year y by using the collected activity data (fuel used, F_y; share of fuel type, S_i) and emission factors (EF_i) as inputs to equation 7.1. For each fuel type i, the share and emission factor are multiplied by the total fuel amount. Then the results of the multiplication for each fuel type are summed to obtain the total base year emissions for the year under consideration (BE_y).

Equation 7.1: Estimation of base year emissions from fuel use for approach A

$$BE_y = \sum_i F_y \,(\text{in TJ}) \times S_i \,(\text{in \%}) \times EF_i \,(\text{in tCO}_2/\text{TJ})$$

The results represent the GHG emissions (CO_2 only) from fuel consumption in ground transport for the selected year in the baseline scenario (i.e. in the absence of the policy), in units of tCO_2.

Box 7.1 provides an example calculation of base year emissions using approach A.

7.2.2 Approach B: Estimate impact of the policy on gasoline and diesel vehicles of the national vehicle fleet

Approach B is a simple approach to calculating GHG impacts (CO_2 only) where separate data are available on the annual fuel consumption for gasoline and diesel. It is appropriate to use approach B where separate data are available on annual fuel consumption for gasoline and diesel, but not on PKM or TKM for freight.

Approach B allows users to separately assess the impacts of the policy on vehicles using gasoline and on those using diesel as proxies for light-duty vehicles (LDVs), which tend to use gasoline, and heavy-duty vehicles (HDVs), which tend to use diesel.

BOX **7.1**

Example of calculation of base year emissions

A government plans to implement a national fuel levy on gasoline and diesel that will target LDVs in the form of a fixed sum per litre – higher for gasoline than for diesel. The national energy balance breaks down total fuel use by sector. The transport sector is a major source of demand, with an annual energy use of 782,000 TJ. The Ministry of Transport knows that this quantity comes from liquid fuels, but there is no breakdown by specific fuel type. Still, the ministry wishes to calculate the emissions reductions from implementing the fuel levy, and they start by calculating the base year emissions for one year.

The ministry staff follow step 1 (Align geographic aggregation) and determine that the data (national) align perfectly with the new levy that will be applied nationwide.

Next, they undertake step 2 (Compile activity data), and find that the data from the most recent national energy balance for the transport sector of 782,000 TJ is the value to apply. Also, since the ministry does not have a clear idea of the split in liquid fuel use in the sector, they choose to apply a share of 50% for gasoline and 50% for diesel.

Under step 3 (Compile emission factors), the ministry staff choose to use the default values, since other values are not available.

The ministry staff determine the base year emissions by applying step 4 (Calculate base year emissions for the selected year):

Base year emissions for year y = (782,000 TJ × 50% × 74.1 tCO$_2$/TJ) + (782,000 TJ × 50% × 69.3 tCO$_2$/TJ)

$$= 28,973,100 \text{ tCO}_2 + 27,096,300 \text{ tCO}_2 = 56,069,400 \text{ tCO}_2$$

Thus, the result shows that emissions in the base year are about 56 MtCO$_2$.

LDVs have a gross vehicle mass (GVM) up to around 3,900 kg,[25] such as typical passenger cars (with a GVM of around 1,800 kg). They are used mainly for personal travel. HDVs have a higher GVM and are used for transport of freight and road-based public transport.

This disaggregation adds precision to the calculation of base year emissions and overall GHG impacts, since policies such as taxes are frequently applied differently to vehicles for personal travel (LDV) and commercial vehicles (HDV). Price elasticities are often different for these two groups of vehicles,[26] accounting for the fact that there is not a perfect congruency between fuel type and vehicle category.

Approach B follows the same steps as approach A, set out below.

Step 1: Align geographic aggregation
Use the same approach as in step 1 of approach A (Section 7.1) to align the geographic aggregation of the activity data and the policy. The simplified approach B also ignores upstream emissions from fuels, whether or not these occur within national borders.[27]

Step 2: Compile activity data
The activity data are the annual amount of gasoline fuel combusted by vehicles for ground transport ($F_{G,y}$) and the annual amount of diesel fuel combusted by vehicles for ground transport ($F_{D,y}$). Where other types of fuel are frequently used for ground transport, such as LPG, this approach can be applied to cover the other fuels as well, provided that disaggregated data are available. Users can obtain disaggregated annual fuel data from (in order of priority) (1) the national energy balance, or similar national energy or transport statistics, (2) a data-collection process or (3) international sources.

In the absence of a robust national source, the alternative is to build the data set directly. In this case, refer to the guidance in step 2 of approach A (Section 7.1).

---

[25]   U.S. EPA (2017). The definition of the LDV category limits varies somewhat from country to country per regulations.

[26]   Dahl (2012).

[27]   Users should note that this is a conservative assumption since, by ignoring upstream emissions, emissions reductions are also excluded from the results.

The third alternative is to use international sources, such as IEA and IRENA country statistics.[28]

For all data sources, analyse the compiled fuel-use data while accounting for the following:

- **Data vintage.** Note the year that the activity data represent and not only their year of publication. The delay between data compilation, analysis and publication may be considerable. A study published in 2016 may report data for the year 2013.

- **Boundaries of the data set.** Consider the likelihood of over- or under-reporting of transport fuel use within the statistics. Over-reporting may occur where there are significant non-transport uses of typical transport fuels. Situations that could generate this type of problem are

  » the presence of significant backup electricity generation at private homes using diesel generators
  » for countries with subsidized fuel, black-market export of transport fuels to neighbouring countries and/or significant fuel sales to vehicles that operate in neighbouring countries ("tank tourism").

If evidence exists suggesting that there is significant over- or under-reporting, provide an estimate of the magnitude of the impact, justify the assumption, and incorporate it into the calculations. Alternatively, report the related uncertainty but omit the consideration from the calculations.

During the compilation of activity data, select any conversion factors needed to convert the fuel-use data into units that are compatible for multiplication with the emission factor. The default IPCC emission factors are expressed in units of $kgCO_2/TJ$ on a net calorific basis (i.e. NCVs are applied to determine the usable heat energy released through the combustion), so fuel activity data should be in energy units. It is important to determine whether the energy units are expressed on a net calorific basis. Where a different basis is used, the values should be converted before applying the emission factor (e.g. using the method provided by the IPCC[29]).

Table 7.4 provides an overview of activity parameters for approach B, and possible data sources.

Where activity data are expressed in volume units (e.g. in litres or gallons), the user will need to apply fuel density values (ρ_i) to convert the data to mass units. Where activity data are expressed in mass units, the NCV (NCV_i) should be applied to obtain energy units. In either case, it is preferable to use national values to make these conversions. In the absence of appropriate national data, reliable international sources or default values can be applied.

Table 7.5 provides an overview of conversion factors for activity data for approach B, and possible sources of data.

TABLE **7.4**

Activity parameters for approach B

Parameter	Description	Unit	Sources
$F_{G,y}$	Total gasoline fuel used for ground transport in year y	TJ	In order of preference: • national energy balance or similar national energy statistics • data-collection process • international sources, such as IEA and IRENA
$F_{D,y}$	Total diesel fuel used for ground transport in year y	TJ	

TABLE **7.5**

Conversion factors for activity data for approach B

Conversion factor	Description	Unit	Sources
ρ_i	Density of fuel type i	kg/m³	In order of priority: • national energy statistics • reliable international sources[a] • default values – diesel: 835 kg/m³ at 15°C;[b] gasoline: 720 kg/m³ at 15°C[c]
NCV_i	NCV of fuel type i	TJ/Gg	In order of priority: • national energy statistics • reliable international sources • default values – diesel: 43.0 TJ/Gg; gasoline: 44.3 TJ/Gg[d]

[a] For more information on data collection, see the IPCC Guidelines (www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_2_Ch2_DataCollection.pdf).

[b] Directive 1998/69/EC (www.dieselnet.com/standards/eu/fuel_reference.php)

[c] NOAA (no date).

[d] Both values are from IPCC (2006), vol. 2. Chapter 1, Table 1.2.

Where activity data are compiled in volume or mass units (fuel consumption in litres or in Gg, labelled $FC_{i,y}$), use the following equations to calculate energy units (labelled $F_{i,y}$).

Equation 7.2: Estimation of gasoline and diesel use in energy units (TJ) for approach B (input: volume units in L)

$$F_{i,y} \text{ in energy units (TJ)} =$$
$$FC_{i,y} \text{ in volume units (L)} \times \rho_i \times NCV_i \div 10^9$$

Equation 7.3: Estimation of gasoline and diesel use in energy units (TJ) for approach B (input: mass units in Gg)

$$F_{i,y} \text{ in energy units (TJ)} =$$
$$FC_{i,y} \text{ in mass units (Gg)} \times NCV_i$$

Step 3: Compile emission factors

The emission factors (EF_i) represent the quantity of CO_2 emissions expected from combusting a unit of fuel, and are based on the total carbon content of the fuel. Approach B also ignores emissions of CH_4 and N_2O for simplicity. Determine an emission factor for both gasoline and diesel fuel. Emission factors can

be obtained from (in order of priority) (1) national energy or environmental statistics, (2) national fuel providers or (3) default values from international sources.

For approaches A and B, emission factors consider only tank-to-wheel emissions and no "upstream" or well-to-tank emissions.

Table 7.6 provides emission factor parameters for approach B.

Step 4: Calculate base year emissions for the selected year

Calculate base year emissions for the selected year y by using the activity data and emission factors for the different fuels as inputs to the following equations. For each fuel type i, the emission factor is multiplied by the total fuel amount to obtain the total base year emissions ($BE_{i,y}$) associated with that fuel type for the year y under consideration.

Equation 7.4: Estimation of base year emissions from gasoline and diesel use for approach B

Base year emissions from gasoline for year y:

$$BE_{gasoline,y} = F_{G,y} \text{ (in TJ)} \times EF_G \text{ (in tCO}_2/\text{TJ)}$$

Base year emissions from diesel for year y:

$$BE_{diesel,y} = F_{D,y} \text{ (in TJ)} \times EF_D \text{ (in tCO}_2/\text{TJ)}$$

The results represent the CO_2 emissions from gasoline and diesel consumption in ground transport for the selected year in the baseline scenario, in the absence of the policy.

Users wishing to consider aggregated base year emissions for the whole national vehicle fleet may sum the emissions from the two fuels.

Box 7.2 provides an example calculation of base year emissions using approach B.

TABLE **7.6**

Emission factor parameters for approach B

Parameter	Description	Unit	Sources
EF_G	Emission factor for gasoline fuel	tCO$_2$/TJ	In order of priority: • national energy or environmental statistics
EF_D	Emission factor for diesel fuel	tCO$_2$/TJ	• national fuel providers, such as refineries or fuel importers, based on their measurements • default values – gasoline: 69.3 tCO$_2$/TJ; diesel: 74.1 tCO$_2$/TJ[a]

[a] Both values are from both IPCC (2006), vol. 2, Chapter 3, Table 3.2.1.

BOX **7.2**

Example of calculation of base year emissions for approach B

A government plans to implement a national fuel levy on gasoline and diesel that will target LDVs in the form of a fixed sum per litre – higher for gasoline than for diesel. The national energy balance breaks down total fuel use by sector. The transport sector is a major source of demand, with an annual energy use of 782,000 TJ. The Ministry of Transport has further data showing that 7,860 Gg of gasoline ($FC_{G,y}$) and 8,000 Gg of diesel ($FC_{D,y}$) were used that year. The ministry wishes to calculate the emissions reductions from implementing the fuel levy, which they expect will reduce the emissions from LDVs using gasoline more than from other vehicles. They start by calculating the disaggregated base year emissions for one year.

The ministry staff follow step 1 (Align geographic aggregation) and determine that the data (national) align perfectly with the new levy that will be applied nationwide.

Next, they undertake step 2 (Compile activity data), and find that the data from the most recent national energy balance for the transport sector of 782,000 TJ is consistent with the fuel consumption data in Gg from the ministry. They decide to use the default NCVs to convert the fuel amounts to energy units.

$F_{G,y}$ = 7,860 Gg × 44.3 TJ/Gg = 348,198 TJ (equation 7.3)

$F_{D,y}$ = 8,000 Gg × 43.0 TJ/Gg = 344,000 TJ (equation 7.3)

Under step 3 (Compile emission factors), the ministry staff choose to use the default values, since other values are not available.

The ministry staff determine the base year emissions by applying step 4 (Calculate base year emissions for the selected year):

Base year emissions from gasoline for year y BE$_{gasoline,y}$ = 348,198 TJ × 69.3 tCO$_2$/TJ = 24,130,121 tCO$_2$ (see equation 7.4)

Base year emissions from diesel for year y BE$_{diesel,y}$ = 344,000 TJ × 74.1 tCO$_2$/TJ = 25,490,400 tCO$_2$ (see equation 7.4)

Thus, the result shows that emissions in the base year from the two fuels are about 50 MtCO$_2$ (49,620,521 tCO$_2$).

7.3 Estimate base year emissions: approach C

Approach C focuses on ground transport and considers the substitution of individual motorized transport by cars with public transport (and non-motorized transport). In the context of this section, private road passenger transport (i.e. on-road gasoline passenger cars only) and public transport (i.e. diesel buses and diesel or electric rail systems) are considered. This approach enables assessment of a policy's impact on both GHG emissions and on transport mode shifts by using cross-elasticities (see Section 8.1.1 for an explanation of cross-elasticities). For this purpose, data on distances travelled for the analysed transport modes (e.g. private road vehicles, bus systems, rail systems) are also collected.

This methodology only considers the use of gasoline, diesel and electricity. However, the calculation method can be applied to other fuels (e.g. LPG) by using analogous equations with different input data (i.e. travel activity data, emission factors and elasticity values).

Also, the analysis of mode shifts in the methodology is restricted to public passenger transport. The methodology can also be applied to shifts to electric mobility, CNG or non-motorized transport (if data are available), based on the equations shown for mode shifts to public transport.

In contrast to approaches A and B, which use top-down data on energy use, approach C uses both top-down energy-use data and bottom-up travel activity data to estimate base year emissions (see Section 3.2.1 for more explanation of top-down and bottom-up data). Approach C therefore is not directly comparable to approaches A and B.

There are two main differences:

- Freight transport cannot be assessed with the proposed calculation (although users can apply the approach to freight transport as well as using different input data and cross-price elasticities).

- It is necessary to adjust the system boundaries to urban regions instead of to the national level (because the proposed cross-price elasticities might not work for rural areas, and because of data availability).

As a result, approach C will only allow users to quantify a portion of the emissions reductions achieved through the policy. However, the approach provides further information regarding mode shift than approaches A and B.

The method is based on the ASIF terminology (see Appendix E in this document and Section 2 in the *Reference Document on Measurement, Reporting and Verification in the Transport Sector*). It is appropriate to use approach C where bottom-up travel activity data for passenger transport, such as PKM for different modes of passenger transport, are available separately for gasoline, diesel and electricity, with an appropriate emission factor. See Figure 7.4 for the formula for calculating base year emissions using approach C. In addition to calculating total base year emissions, the base year emissions are also divided by PKM (see Figure 7.5) to obtain a ratio that can be used to quantify the impacts of the policy in Section 8.2.

FIGURE **7.4**

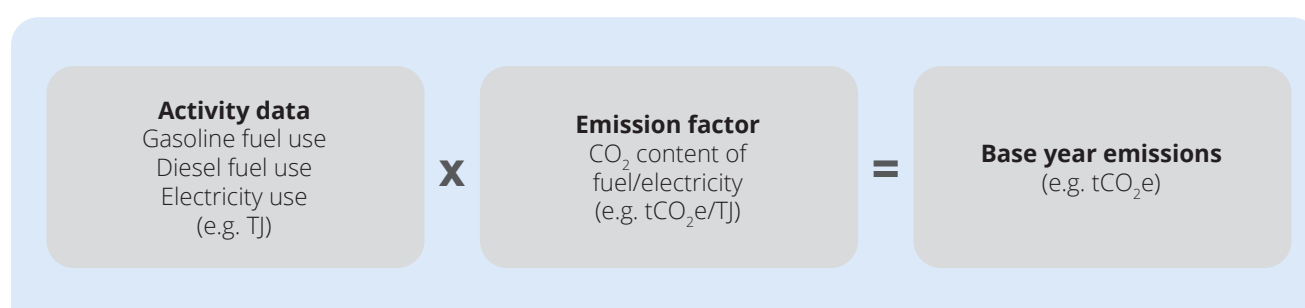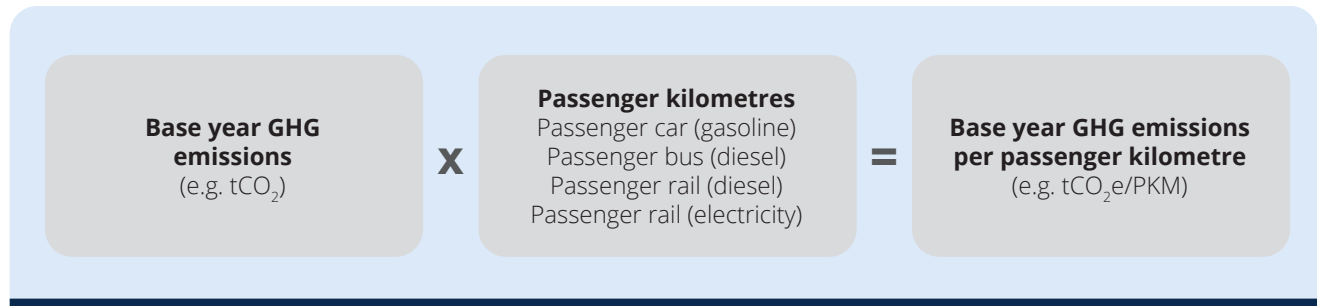**Calculation of total base year GHG emissions for approach C**

| **Activity data**
Gasoline fuel use
Diesel fuel use
Electricity use
(e.g. TJ) | **X** | **Emission factor**
CO_2 content of
fuel/electricity
(e.g. tCO_2e/TJ) | **=** | **Base year emissions**
(e.g. tCO_2e) |

FIGURE **7.5**

Calculation of base year GHG emissions per PKM

Base year GHG emissions (e.g. tCO_2)	X	Passenger kilometres Passenger car (gasoline) Passenger bus (diesel) Passenger rail (diesel) Passenger rail (electricity)	=	Base year GHG emissions per passenger kilometre (e.g. tCO_2e/PKM)

If transport fuel contains a certain share of biofuels (e.g. bioethanol or biodiesel), the share of these fuels within the fuel mix should be sourced from government or distributor data. This share may change over time. The emissions of the biofuel share and the fossil fuel share can then be calculated separately (using separate activity data and emission factors) and summed to reflect the emissions from the fuel consumed (consisting of both biofuel and fossil fuel fractions). The emissions from the biofuel can be calculated using analogous equations to the fossil fuel share. If possible, country-specific emission factors (and, where relevant, NCVs) should be used. If such country-specific data are not available, the Renewable Energy Directive[30] provides default values that can be used.

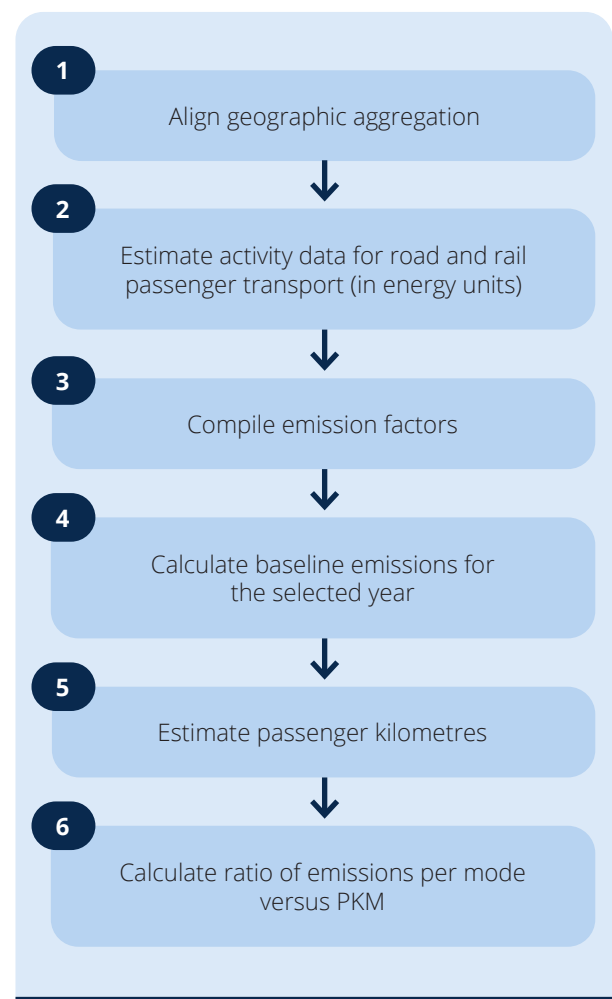To calculate base year emissions for passenger transport, follow the steps in Figure 7.6.

7.3.1 Step 1: Align geographic aggregation

Follow the same procedure as for step 1 of approaches A and B (Section 7.2.1) to align the geographic aggregation of the activity data and the policy.

7.3.2 Step 2: Estimate activity data for road and rail passenger transport (in energy units)

Table 7.7 lists the activity data needed in mass units to calculate base year emissions.

FIGURE **7.6**

Overview of steps for approach C

1 Align geographic aggregation

2 Estimate activity data for road and rail passenger transport (in energy units)

3 Compile emission factors

4 Calculate baseline emissions for the selected year

5 Estimate passenger kilometres

6 Calculate ratio of emissions per mode versus PKM

---

30   European Commission (2009). The directive is currently being revised.

TABLE **7.7**

Activity data for approach C (in energy units)

Parameter	Activity data (in energy units)	Unit
$F_{i,j,y}$	Total fuel energy i (from gasoline, diesel and electricity) used per mode j of passenger transport (road and rail) in year y Example: $F_{diesel,rail,2020}$ = total energy used (in TJ) from diesel fuels in rail passenger transport in the year 2020	TJ
$PKM_{i,j,y}$	Total PKM travelled per mode j of passenger transport (road and rail) in year y Example: $PKM_{diesel,rail,2020}$ = total PKM travelled in rail passenger transport with diesel fuel in the year 2020	TJ

The default IPCC emission factors for fuel combustion are expressed in units of $kgCO_2/TJ$ on a net calorific basis (i.e. NCVs are applied to determine the usable heat energy released through combustion), so fuel activity data should be in energy units. It is important to determine whether the energy units are expressed on a net calorific basis. If a different basis is used, the values should be converted before applying the emission factor – for example, using the method provided by the IPCC.[31]

Estimation of the bottom-up travel activity data and calculation of the fuel energy used ($F_{x,i,y}$) differ for road and rail transport. The two modes are therefore differentiated in steps 2a and 2b.

Step 2a: Estimate bottom-up travel activity data and fuel energy use for road passenger transport
To estimate the activity data for road passenger transport in mass units (TJ), as shown in Table 7.7, follow these three steps:

1. Estimate **activity data in volume units** (total litres of fuel used; $FC_{i,j,y}$) for each fuel type i and each passenger transport mode j in the respective year y according to bottom-up travel activity parameters (e.g. distance travelled, average fuel consumption).

2. Estimate **PKM** ($PKM_{i,j,y}$) for each passenger transport mode j in the respective year y according to bottom-up travel activity

parameters (e.g. distance travelled, load factor).

3. Multiply the total litres of fuel used ($FC_{i,j,y}$) by **conversion factors** (e.g. NCV, density) to estimate the total fuel energy used (TJ; $F_{i,j,y}$) for each fuel type i and each passenger transport mode j in the respective year y.

Two outputs are obtained from these three steps. First, the total fuel energy used is obtained in energy units. This is the relevant activity data for calculating the base year emissions. Second, users estimate PKM data to estimate mode shifts and demand changes due to the impacts of the policy (based on cross-elasticities; for more information, see Section 8.1.4).

Table 7.8 gives an overview of relevant bottom-up travel activity parameters, including possible data sources for passenger cars and buses. Where possible, use data from municipal, regional or national statistics, studies or surveys. Where these data are not available, international default values or comparable data from other cities or countries can be used.[32]

---

[31] Available at: www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf#page=17.

[32] For further information about parameter estimation, refer to UNFCCC (2014).

TABLE **7.8**

Overview of bottom-up travel activity parameters

Parameter	Description	Unit	Sources[a]
$d_{i,j,y}$ Distance travelled	Vehicle kilometres travelled (with fuel type i, mode j, in year y)	VKT	$d_{gasoline,car,y}$: gasoline-powered passenger cars • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys (traffic counting, odometer reading, appropriate vehicle stock data) $d_{diesel,bus,y}$: diesel-powered passenger buses • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national surveys (traffic counting, odometer reading, appropriate vehicle stock data)
$l_{j,y}$ Load factor/ occupancy	Average (per VKT) number of persons travelling in same vehicle (with mode j in year y) (only needed for estimation of PKM)	Persons per vehicle	$l_{car,y}$: passenger cars • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys • Supra-regional default value (e.g. for continent); otherwise, global default value of 2 persons, including the driver[b] $l_{bus,y}$: passenger buses • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national surveys • Supra-regional default value (e.g. for continent); otherwise, global default value of 40% of total capacity[b,c]
$sfc_{i,j,y}$ Average fuel consumption	Specific fuel consumption Average consumption per VKT in municipal, regional or national fleet (with fuel type i, mode j, in year y)	Litres per VKT	$sfc_{gasoline,car,y}$: gasoline-powered passenger cars • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys (e.g. from manufacturers) • Supra-regional default values (e.g. for continent); otherwise, global default value for gasoline consumption of gasoline cars of 10 L per 100 km (assumption by the authors of this methodology, based on HBEFA[d]) $sfc_{diesel,bus,y}$: diesel-powered passenger buses • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys (e.g. from manufacturers) • Supra-regional default values (e.g. for continent); otherwise, global default value for diesel consumption of diesel buses of 50 L per 100 km (assumption by the authors of this methodology, based on HBEFA[d])

Abbreviation: VKT, vehicle kilometres travelled

[a] Sources are in order of priority.

[b] UNFCCC (2014).

[c] To estimate total capacity of bus transport, estimate fleet composition (i.e. categories of buses with specific capacity), multiply number of buses (category) with specific capacity (category), and sum the results of these calculations for all the categories within the fleet.

[d] HBEFA (2014).

Equation 7.5 shows the calculation of fuel consumption (in volume units) and PKM according to the bottom-up travel activity parameters listed in Table 7.8.

Equation 7.5: Estimation of litres of gasoline and diesel use in car and bus passenger transport for approach C

$$\text{Total fuel consumption } FC_{i,j,y} \text{ in volume units (L)}$$
$$= d_{i,j,y} \text{ (in VKT)} \times sfc_{i,j,y} \text{ (in L per VKT)}$$

Since the fuel consumption is expressed in volume units (i.e. litres or gallons), as shown in Table 7.8, apply fuel density values (ρ_i) to convert the data to mass units. Where activity data are expressed in mass units, apply the NCV (NCV_i) to obtain energy units. In either case, it is recommended that national values are used to make these conversions. In the absence of appropriate national data, reliable international sources or default values can be applied.

Table 7.9 gives an overview of conversion factors for the estimation of total fuel energy used ($F_{x,i,y}$) for passenger cars and buses using approach C, including units and possible data sources.

With the fuel use in volume units and the conversion parameters, the total fuel use in energy units can be calculated as shown in equation 7.6.

Equation 7.6: Estimation of fuel energy use (in TJ) in car and bus passenger transport for approach C

$$F_{i,j,y} \text{ in energy units (TJ)} = FC_{i,j,y} \text{ in volume units (L)}$$
$$\times \rho_i \times NCV_i \div 10^9$$

Step 2b: Estimate bottom-up travel activity data and fuel energy use for rail passenger transport
The rail category can include cable car, street car, tramway, metro, commuter rail, light rail and heavy rail. To estimate the activity data for rail passenger transport in mass units (TJ), as shown in Table 7.7, follow these three steps:

1. Estimate **activity data in volume units** (litres of diesel fuel and MWh of electricity; $FC_{i,rail,y}$) for each fuel type i used in rail passenger transport in the respective year y in a top-down approach (without any bottom-up travel activity parameters).

2. Estimate **PKM** ($PKM_{rail,y}$) for total rail passenger transport (both diesel and electric) in the respective year y in a top-down approach

TABLE **7.9**

Conversion factors for estimation of total fuel energy used ($F_{x,i,y}$) for passenger cars and buses for approach C

Conversion factor	Description	Unit	Sources
ρ_i	Density of fuel type i	kg/m³	In order of priority: • national energy statistics • reliable international sources • default values – diesel: 835 kg/m³ at 15°C;[a] gasoline: 720 kg/m³ at 15°C[b]
NCV_i	NCV of fuel type i	TJ/Gg	In order of priority: • national energy statistics • reliable international sources • default values – diesel: 43.0 TJ/Gg; gasoline: 44.3 TJ/Gg[c]

[a] Directive 1998/69/EC (www.dieselnet.com/standards/eu/fuel_reference.php)

[b] NOAA (no date).

[c] Both values are from IPCC (2006), vol. 2. Chapter 1, Table 1.2.

(without any bottom-up travel activity parameters).

3. Multiply the activity data in volume units ($FC_{i,rail,y}$) by **conversion factors** (e.g. NCV, density, energy conversion units) to estimate the total fuel energy used (TJ; $F_{i,rail,y}$) for each fuel type i used in passenger transport in the respective year y.

Two outputs are obtained from these three steps. First, the total fuel energy used is provided in energy units separately for diesel-powered and electricity-powered rail, which are necessary for calculating the base year emissions. Second, users estimate PKM data to estimate mode shifts and demand changes due to the impacts of the policy (based on cross-elasticities; for more information, see Section 8.1.4).

Table 7.10 provides an overview of the relevant activity data parameters, including possible data sources, for diesel and electric passenger rail transport.

As in step 2a, fuel consumption of diesel is expressed in volume units (i.e. litres or gallons). The conversion

factors from Table 7.9 should be applied again (see equation 7.7 for diesel).

Equation 7.7: Estimation of TJ diesel use in rail passenger transport for approach C

$$F_{diesel,rail,y} \text{ in energy units (TJ)} = FC_{diesel,rail,y}$$
$$\text{in volume units (L)} \times \rho_i \times NCV_i \div 10^9$$

Where energy units of electricity use for passenger rail transport have been estimated in MWh, as described in Table 7.10, a conversion to TJ should be conducted, as shown in equation 7.8.

Equation 7.8: Estimation of electricity use (in TJ) in rail passenger transport for approach C

$$F_{electricity,rail,y} \text{ in energy units (TJ)}$$
$$= FC_{electricity,rail,y} \text{ in MWh} \times 0.0036$$

Collection of more detailed activity data can improve the accuracy and reduce the uncertainty of these

TABLE **7.10**

Overview of activity data parameters

Parameter	Description	Unit	Sources[a]
$FC_{i,rail,y}$ Total fuel consumption	Total fuel and electricity use for rail passenger transport (with fuel type i in respective year y)	Litres of diesel; MWh of electricity	$FC_{diesel,rail,y}$: diesel-powered passenger rail • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys (e.g. from transit companies) $FC_{electricity,rail,y}$: electricity-powered passenger rail • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national surveys (e.g. from transit companies)
$PKM_{rail,y}$ Distance travelled	Ideally, PKM are available separately for diesel and electricity travel. Otherwise, estimate total PKM travelled in rail passenger transport (in respective year y).	PKM	$PKM_{rail,y}$: PKM rail • Municipal, regional or national statistics or studies (from transit authorities) • Municipal, regional or national data-collection process or surveys (e.g. from transit companies)

[a] Sources are in order of priority.

results. See the *Reference Document on Measurement, Reporting and Verification in the Transport Sector* for more information on how to improve activity data collection.

7.3.3 Step 3: Compile emission factors

The emission factors (EF_i) represent the amount of CO_2 emissions expected to result from (1) combusting a unit of fuel (e.g. gasoline, diesel), based on the total carbon content of the fuel, and (2) using a unit of electricity, based on the carbon intensity of the national electricity mix. Determine an emission factor separately for gasoline and diesel combustion as well as electricity use. Parameter EF is the powering type (i.e. gasoline, diesel or electricity). Approach C ignores emissions of CH_4 and N_2O for simplicity.

For approach C, emission factors for gasoline and diesel consider only tank-to-wheel emissions and no "upstream" or well-to-tank emissions. This is different for electricity, where the emission factor corresponds to the emissions for electricity production. The reason for this is that the emissions from the use phase for electricity are practically zero, and the "well-to-tank" emissions (emissions that stem from electricity production and distribution) are the main contributor to life cycle emissions. In contrast, well-to-tank emissions from combustion of gasoline or diesel are less relevant (10–20%). Table 7.11 provides an overview of emission factor parameters for approach C, including possible data sources for gasoline and diesel fuel emission factors.

7.3.4 Step 4: Calculate base year emissions for the selected year

Calculate base year emissions for the selected year *y* by using the activity data and emission factors for the different fuels as inputs to the following equations. For each fuel type, the emission factor is multiplied by the total fuel amount to obtain the total base year emissions associated with that fuel type for the year in question, as shown in equation 7.9.

Equation 7.9: Estimation of base year emissions for approach C per fuel type and transport mode

$$BE_{i,j,y} \text{ in } CO_2 \text{ emissions } (tCO_2) = FC_{i,j,y}$$
$$\text{in energy units (TJ)} \times EF_i \text{ (}tCO_2 \text{ per TJ)}$$

TABLE **7.11**

Emission factor parameters for approach C

Parameter	Description	Unit	Sources
$EF_{gasoline}$	Emission factor for gasoline fuel	tCO_2/TJ	In order of priority: • national energy or environmental statistics
EF_{diesel}	Emission factor for diesel fuel	tCO_2/TJ	• national fuel providers (e.g. refineries or fuel importers, based on their measurements) • global default values – gasoline: 69,300 $kgCO_2/TJ$; diesel: 74,100 $kgCO_2/TJ$[a]
$EF_{electricity}$	Emission factor for electricity	tCO_2/TJ	In order of priority: • national energy or environmental statistics (electricity mix) • national fuel providers (e.g. refineries or fuel importers, based on their measurements) • supra-regional default value (e.g. for continent); otherwise, global default value – mainly conventional/fossil fuel electricity production: 110,000 $kgCO_2/TJ$; at least 50% renewable share: 220,000 $kgCO_2/TJ$[b]

[a] Both values are from both IPCC (2006), vol. 2, Chapter 3, Table 3.2.1.

[b] Assumption by the authors of this methodology, based on UNFCCC (2014).

7.3.5 Step 5: Estimate PKM

For **road transport** (gasoline cars and diesel buses[33]), the estimation can be conducted as shown in equation 7.10 (for parameters, see step 2a).

For **rail transport**, PKM are ideally estimated separately for the two fuel energy types (diesel and electricity) (see Table 7.10). If this is the case, skip the calculations in equation 7.11 and continue with step 6.

If PKM data are not available for diesel and electricity separately, they can be estimated from total rail PKM (for both diesel- and electricity-powered rail). In this case, the energy efficiencies (η) of diesel and electricity need to be considered, since the operation of a train with electricity is much more efficient than with diesel.[34] They can be differentiated for the two fuel types using equation 7.11.

Equation 7.10: Estimation of PKM for car and bus passenger transport for approach C

$$PKM_{i,car,y} =$$
$$\sum_{i} d_{i,car,y} \text{ (in VKT)} \times l_{car,y} \text{ (in persons per vehicle)}$$

$$PKM_{i,bus,y} =$$
$$\sum_{i} d_{i,bus,y} \text{ (in VKT)} \times l_{bus,y} \text{ (in persons per vehicle)}$$

Equation 7.11: Estimation of PKM for diesel and electric rail transport for approach C

$$PKM_{diesel,rail,y} =$$
$$PKM_{rail,y} \times \frac{F_{diesel,rail,y} \times \eta_{diesel}}{((F_{diesel,rail,y} \times \eta_{diesel}) + (F_{electricity,rail,y} \times \eta_{electricity}))}$$

$$PKM_{electricity,rail,y} =$$
$$PKM_{rail,y} \times \frac{F_{electricity,rail,y} \times \eta_{electricity}}{((F_{diesel,rail,y} \times \eta_{diesel}) + (F_{electricity,rail,y} \times \eta_{electricity}))}$$

7.3.6 Step 6: Calculate ratio of total emissions per mode to PKM

The total base year emissions can now be divided by the PKM, using equation 7.12.

Equation 7.12: Estimation of total base year emissions per PKM for approach C

$$BEPKM_{i,j,y} \text{ in } CO_2 \text{ emissions (kgCO}_2) \text{ per passenger}$$
$$\text{kilometre} = BE_{i,j,y} \text{ (kgCO}_2) \div PKM_{i,j,y}$$

The results are the CO_2 emissions from gasoline, diesel and electricity consumption in road and rail passenger transport, for the selected year in the baseline scenario, in the absence of the policy. Furthermore, users obtain a ratio of this result per PKM.

Users who want to aggregate base year emissions estimated for approach C should sum the total emissions for each mode and for each fuel. Box 7.3 provides an example calculation of base year emissions using approach C.

---

[33]   As a simplification, the methodology is restricted to gasoline cars and diesel buses for approach C (assuming that most passenger LDV transport is powered with gasoline, whereas most passenger HDV transport is powered with diesel). However, if this assumption does not apply, the calculation method can be applied to other fuels (e.g. diesel passenger cars, LPG) by using analogous equations with different input data (i.e. travel activity data, emission factors and elasticity values).

[34]   The assumption is that the energy efficiency of a diesel engine is about 30%, whereas the energy efficiency of an electric engine is about 90% (estimation by authors of this methodology, based on expert judgment).

BOX **7.3**

Example of calculation of base year emissions (values rounded) for approach C

A government plans to implement a national fuel levy on gasoline and diesel that will target LDVs in the form of a fixed sum per litre. The ministry has two main goals. First, it wishes to calculate the emissions reductions in the passenger transport sector resulting from the fuel levy. Second, it plans to assess changes in travel demand for the passenger transport modes that are directly and indirectly affected by the fuel levy.

The ministry staff follow step 1 (Align geographic aggregation) and determines that the data do not align with the new levy that will be applied nationwide. They decide to focus the GHG impact assessment on the capital city. The system boundaries they choose for fuel consumption are restricted to fuels used within the city borders.

Next, they follow step 2 (Compile activity data).

First, the ministry staff estimate the total fuel energy used for **road passenger transport** (cars and buses; step 2a). They obtain the data on vehicle kilometres travelled (VKT) from the national transit authorities (from a traffic counting study):

$d_{gasoline,car,y}$ = 10,900 million VKT

$d_{diesel,bus,y}$ = 980 million VKT

Since no country-specific values are available for the load factors and the average fuel consumption of vehicles, and the ministry has no capacity to conduct a study, they apply the global default factors:

$l_{car,y}$ = 2 persons, including the driver

$l_{bus,y}$ = 40% of total capacity. The ministry staff assume that the buses have 40 seats on average. The average load factor equals 40% × 40 seats = 16 taken seats per VKT.

$sfc_{gasoline,car,y}$ = 10 L per 100 VKT

$sfc_{diesel,bus,y}$ = 50 L per 100 VKT

With these data, the fuel consumption in volume units can be calculated:

$FC_{gasoline,car,y}$ = 10,900,000,000 VKT × 0.1 L per VKT = 1,090 ×10^6 L of gasoline (equation 7.5)

$FC_{diesel,bus,y}$ = 980,000,000 VKT × 0.5 L per VKT = 490 ×10^6 L of diesel (equation 7.5)

For the conversion of fuel consumption in volume units to energy units, the ministry staff use the default density and NCV values shown in Table 7.9:

$F_{gasoline,car,y}$ = 1,090,000,000 L × 720 kg/m^3 x 44.3 TJ/Gg ÷ 10^9 = 34,767 TJ (equation 7.6)

$F_{diesel,bus,y}$ = 490,000,000 L × 835 kg/m^3 × 43.0 TJ/Gg ÷ 10^9 = 17,593 TJ (equation 7.6)

Second, the ministry staff estimate the total fuel energy used for **rail passenger transport** (diesel and electric trains; step 2b). They ask the two operating rail companies in the capital city about the most recent data on diesel and electricity use. The companies report the following data (accumulated for both companies):

$FC_{diesel,rail,y}$ = 300 ×10^6 L of diesel

$FC_{electricity,rail,y}$ = 440,000 MWh

The ministry staff use the default density and NCV values to convert the fuel consumption in volume units to energy units, as shown in Table 7.9:

$F_{diesel,rail,y}$ = 300,000,000 L × 835 kg/m^3 × 43.0 TJ/Gg ÷ 10^9 = 10,772 TJ (equation 7.7)

$F_{electricity,rail,y}$ = 440,000 MWh × 0.0036 = 1,584 TJ (equation 7.8)

Under step 3 (Compile emission factors), the ministry staff choose to use the default values, since other values are not available. For the emission factor of electricity (national electricity mix), they decide to apply the factor for a conventional (i.e. fossil fuel) electricity mix, since the share of renewables is low:

$EF_{gasoline}$ = 69.3 tCO$_2$/TJ

EF_{diesel} = 74.1 tCO$_2$/TJ

$EF_{electricity}$ = 220.0 tCO$_2$/TJ

BOX 7.3, continued

Example of calculation of base year emissions (values rounded) for approach C

Next, the ministry staff determine the base year emissions by applying step 4 (Calculate base year emissions for the selected year):

$BE_{gasoline,car,y}$ = 34,767 TJ × 69.3 tCO$_2$/TJ = 2,409,328 tCO$_2$ ([equation 7.9](#))

$BE_{diesel,bus,y}$ = 17,593 TJ × 74.1 tCO$_2$/TJ = 1,303,675 tCO$_2$ ([equation 7.9](#))

$BE_{diesel,rail,y}$ = 10,772 TJ × 74.1 tCO$_2$/TJ = 798,168 tCO$_2$ ([equation 7.9](#))

$BE_{electricity,rail,y}$ = 1,584 TJ × 220.0 tCO$_2$/TJ = 348,480 tCO$_2$ ([equation 7.9](#))

The ministry staff follow step 5 (Estimate PKM) to estimate PKM for all the passenger transport modes.

For road transport, PKM can be calculated according to the bottom-up travel activity data:

$PKM_{gasoline,car,y}$ = 10,900,000,000 VKT × 2 persons = 21,800 million PKM ([equation 7.10](#))

$PKM_{diesel,bus,y}$ = 980,000,000 VKT × 16 persons = 15,680 million PKM ([equation 7.10](#))

For rail transport, PKM cannot be derived separately for diesel and electricity. The operating rail companies report the total PKM (combined):

$PKM_{rail,y}$ = 18,000 million PKM

Starting from this combined value, the ministry staff calculate the share of rail PKM for diesel and electricity:

$PKM_{diesel,rail,y}$ = 18,000 million PKM × ((10,772 TJ × 0.3) ÷ ((10,772 TJ x 0.3) + (1,584 TJ × 0.9))) = 12,490 million PKM ([equation 7.11](#))

$PKM_{electricity,rail,y}$ = 18,000 million PKM × ((1,772 TJ × 0.9) ÷ ((10,772 TJ × 0.3) + (1,584 TJ × 0.9))) = 5,510 million PKM ([equation 7.11](#))

The next step is step 6 (Calculate ratio of total emissions per mode to PKM). This calculation allows the ministry staff to compare the emission efficiencies of the different modes:

$BEPKM_{gasoline,car,y}$ = 2,409,328,000,000 gCO$_2$ ÷ 21,800,000,000 PKM = 111 gCO$_2$/PKM ([equation 7.12](#))

$BEPKM_{diesel,bus,y}$ = 1,303,675,000,000 gCO$_2$ ÷ 15,680,000,000 PKM = 83 gCO$_2$/PKM

$BEPKM_{diesel,rail,y}$ = 798,168,000,000 gCO$_2$ ÷ 12,489,902,406 PKM = 64 gCO$_2$/PKM

$BEPKM_{electricity,rail,y}$ = 348,480,000,000 gCO$_2$ ÷ 5,510,097,594 PKM = 63 gCO$_2$/PKM[35]

Thus, the result shows that there are approximately 4.86 MtCO$_2$ annual emissions in the base year with all the modes (passenger gasoline car, diesel bus, diesel train and electric train).

7.3.7 General considerations for estimating activity data for approach C

When assessing the activity data for approach C, it is important to keep in mind the assessment principles outlined in [Chapter 4](#), particularly the principle of accuracy. The assessments done using approach C produce highly uncertain results for fuel use in passenger transport as a result of the following limitations:

- Uncertainties in parameter estimations (e.g. distance travelled) are major and have a large influence on the results of approach C.

- Using default values (e.g. average fuel consumption of vehicles, load factor, conversion factors) leads to further uncertainty.

- Approach C only accounts for gasoline consumption in passenger car transport (i.e. excludes diesel consumption).

---

[35] If the electricity mix contained more than 50% of electricity from renewable sources and the other option for the emission factor could have been chosen (110,000 kgCO$_2$/TJ), $BEPKM_{electricity,rail,y}$ would be approximately 32 gCO$_2$/PKM.

7.4 Develop a projection of baseline emissions

It is a *key recommendation* to develop a projection of baseline emissions for each year of the assessment period. Most calculation parameters identified in Sections 7.1 and 7.2 need to be projected into the future. By projecting the base year emissions, users can determine baseline emissions for a time series. Figure 7.7 provides an overview of steps for projecting baseline scenarios. These steps are addressed in this section.

Where the results of the assessment will be used to meet the reporting requirements of the transparency framework, users should consider aligning the parameters used for the emissions projections of transport pricing policies with those used to develop sectoral projections to meet relevant reporting requirements. It is recommended that users align the time frame used for the emissions projections of transport pricing policies with the time frame used for sectoral projections developed to meet the reporting requirements of the transparency framework (i.e. the starting and final year of the projections developed for transport pricing policies should be the same as the starting and final year of the transport sector projections).

7.4.1 Step 1: Determine the influence of other policies in the transport sector

This step comprises two substeps: determining the influencing policies, and determining the direction and significance of effects.

Step 1a: Determine influencing policies and actions

National strategies and goals influence policies that are likely to be implemented within the assessment period. They include general development strategies, NDCs, climate strategies and dedicated sector strategies, such as energy and transport strategies.
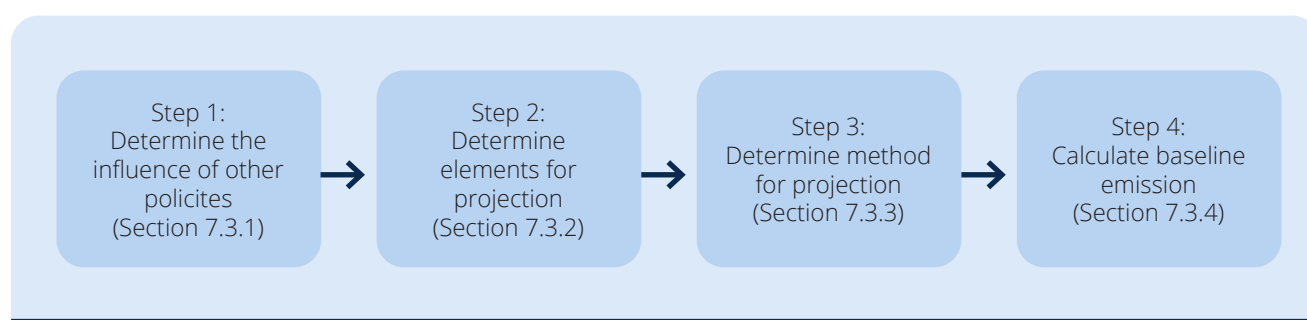
Users should assess the influence of policies (other than the one being assessed) on transport sector developments when projecting the baseline scenario. Some policies that are already implemented or under preparation will directly influence expected developments in the transport sector. This is particularly the case if they have been introduced recently and their effects have not yet had an influence on observed trends in the sector. As discussed in Section 5.2, users can decide to assess such policies together with the pricing policy as a package. In such cases, the impact of the other policies would not be considered here in determining the baseline. In all other cases, their impact should be part of the baseline.

Users who are assessing the sustainable development, transformational or other GHG impacts of a policy should use the same underlying assumptions about macroeconomic conditions, demographics and other non-policy drivers. For example, if gross domestic product (GDP) is a macroeconomic condition needed for assessing both the job impacts and the economic development impacts of a buildings policy, users should use the same assumed value for GDP over time for both assessments.

Users projecting transport sector emissions should consider several dimensions that can be influenced by existing or planned policies, but also by other

FIGURE **7.7**

Overview of steps for projecting baseline emissions

Step 1:
Determine the influence of other policites
(Section 7.3.1)

Step 2:
Determine elements for projection
(Section 7.3.2)

Step 3:
Determine method for projection
(Section 7.3.3)

Step 4:
Calculate baseline emission
(Section 7.3.4)

factors. In particular, technology innovation can be a critical factor influencing baseline developments. It is important to consider not only the most obvious policies, but also policies outside the transport sector. A few examples are provided in Table 7.12.

Step 1b: Determine direction and magnitude of effects

The more detailed the assessment method, the more detailed the analysis of the influence of other policies should be. The main question relating to the effect of other policies is whether their influence on expected developments mainly leads to a continuation of past trends or to a shift from past trends. If the general assessment is that these policies impact the trend, the next question is in which direction, by how much (magnitude) and the likelihood of influence. The magnitude and likelihood of effects will determine how appropriate a simplified and/or econometric method is for the assessment, and how much the results of such methods need to be adjusted to reflect implemented (or planned) policies (other than the one being assessed) in projecting the baseline.

The direction of effects needs to be determined based on expert knowledge and a logical chain of effects that impact relevant parameters. For lower-accuracy methods (approaches A and B), the magnitude can be determined using a rule of thumb, based on literature or experiences in other countries; this is illustrated in Table 7.13, using the

relative magnitude of effects (i.e. how a policy is likely to change observed or expected trends). For more detailed methods, effects should be determined using more elaborate methods.

An example is as follows: If car ownership per capita has increased by 2% per year in recent years, the question is whether policies can be expected to change this trend. For example, a new import regulation that aims to prevent old, inefficient and unsafe vehicles from being imported could slow this trend, because fewer people would be able to afford a car. The magnitude of impact on the vehicle fleet and resulting fuel use depends on a number of factors, including the relevance of imported vehicles targeted by the policy, price differences compared with vehicles not affected by the policy and the detailed design of the policy. Effects would be considered major if, for example, the expected impact would reduce the growth rate of vehicle ownership to 1.7% (a relative magnitude of 15%). The same principle applies in cases where trends are more rapid, such as with an annual growth rate of 70%. Here, a policy that is expected to change the trend by 0.7 percentage points to 70.7% annual growth would be considered minor (a relative magnitude of 1%), whereas a 15% change in relative magnitude to 80.5% annual growth would be considered major.

TABLE **7.12**

Examples of policies influencing transport sector developments

Dimension	Examples
Maintenance and operation, and investment in new infrastructure	• Changes in responsibilities (e.g. privatization of infrastructure or services) may result in different levels of investment. • Programmes to support economic growth in certain sectors can lead to enhanced infrastructure investment.
New technologies entering the market	• Incentive programmes (e.g. to promote electric vehicles or biofuels) may influence adoption of new technologies. • Changes in import regulation may change prices and availability.
Technology improvements	• Health and safety measures (e.g. introduction of mandatory regular vehicle inspection) can influence the age structure and thus the overall efficiency of the fleet. • National fuel efficiency standards can influence vehicle technology.
Development of customer preferences	• Awareness-raising measures and education can increase environmental concerns.

TABLE **7.13**

Assessing the relative magnitude of impacts of other policies

Relative magnitude of impacts	Description	Approximate relative magnitude (rule of thumb)
Major	The policy significantly influences one or more of the trends in transport sector development. The resulting change in relevant parameters is likely to be a significant change from current status and past trends.	>10%
Moderate	The policy influences one or more of the trends in transport sector development. The resulting change in relevant parameters could lead to significant changes from current status and past trends.	1–10%
Minor	The policy has little or no influence on the expected developments in the transport sector. The change in parameter values is insignificant.	<1%

Source: Adapted from WRI (2014).

Different policies may influence the same parameters within the transport sector. The effects can be reinforcing, overlapping or independent. The relative magnitude of effects should be determined for each policy separately. This involves identifying the parameters that are most likely to be affected and estimating the relative magnitude of the effect for each.

7.4.2 Step 2: Determine elements for projection

Population and economic growth have a large influence on the transport sector. They are considered primary factors and will in most cases directly impact the activity parameters needed for calculation. Thus, projections usually account for expected trends in population and GDP. Users should determine baseline scenario projections based on expected changes in population and GDP.

Secondary influencing factors (e.g. car ownership rates, technological development, cost, availability of transport alternatives) may be valuable additional factors for the impact assessment, provided they can be monitored.[36]

Table 7.14 provides an overview of the data categories that need to be projected and which of these are influenced by population, GDP or other factors.

For approaches A and B, fuel use is influenced by population and economic growth, whereas emission factors are independent. For approach C, population growth will likely affect the number of trips taken and potentially the distance travelled (e.g. through urban sprawl). Economic growth also influences the number of trips, distance travelled and fleet composition; thus there is a strong influence of population and/or GDP. Users should make projections based on the per capita or per GDP ratios of parameters to allow meaningful projections.

---

[36] Secondary factors can be directly influenced by primary factors – for example, car ownership is usually correlated with population and/or GDP. Monitoring and quantifying secondary factors might be difficult (e.g. the impact of technological development is difficult to measure).

TABLE **7.14**

Influence of population and GDP on data categories

Category of data	Projection necessary for simplified method (Section 7.4.3)	Projection necessary for advanced methods (Section 7.4.3)	Influenced by		
			Population	GDP	Other
Approaches A and B					
Fuel use	Yes	Yes	Major	Moderate	
Emission factors per fuel	No Constant values[a]	No Constant values			
Approach C					
Carbon content	No Constant values	No Constant values			
Fleet composition	No	Yes	No	Major	
Distances travelled (VKT)	Yes	Yes	Minor	Moderate	
Trips	No	Yes	Major	Minor	
Load factor	No	Yes	Moderate	Minor	Attractiveness, cost, availability
Fuel consumption	No	Yes	No	No	Technological development

Abbreviation: VKT, vehicle kilometres travelled

[a] Emission factors for each fuel type are mainly determined by the carbon content of the fuel.

7.4.3 Step 3: Determine method for projection

Different methods are available to project individual parameters and overall emissions. They vary in their level of complexity and in data requirements, as illustrated in Figure 7.8. The choice of method fundamentally depends on the input data available. It is preferable to build a baseline from a time series. If a time series is available, statistical methods should be used to determine trends. These trends can be adjusted to reflect the analysis of the expected influence of other policies, as discussed above. The most complex method is transport sector modelling, which integrates these effects and reflects interlinkages between different system elements.

If a time series is not available, a single data point can be used. In this case, the results produced will be less robust. If available, a multi-year average may make the results more robust. However, in many countries where only one data point is available, a less robust approach may be sufficient. In such cases, the per capita or per GDP ratio (intensity) of parameters can be used, together with assumptions about the future development of population and GDP. Alternatively, users can apply trends from comparable sources, such as neighbouring countries at a similar stage of development, or with similar transport systems and growth patterns.

FIGURE **7.8**

Overview of methods for projection
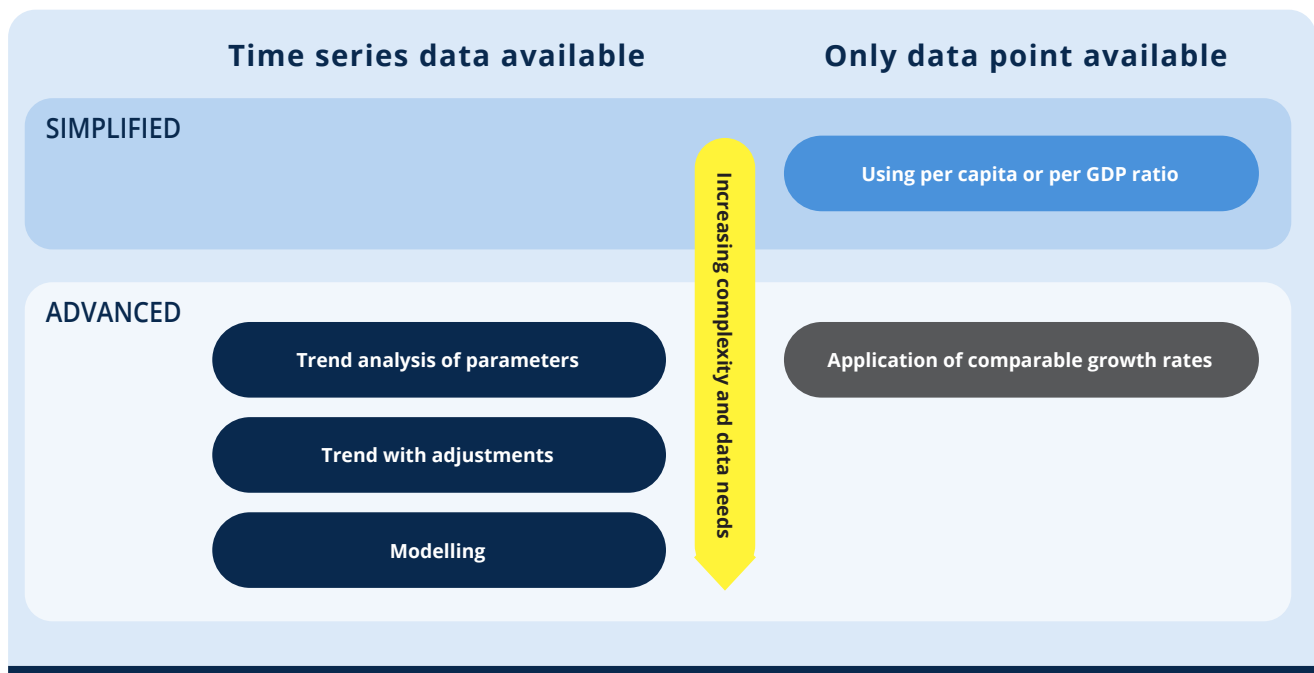
7.4.4 Step 4: Calculate baseline emissions

In step 4, calculate emissions for each year based on projected parameter values, using the methods in Sections 7.1 and 7.2 (modelling based on the factors identified in Section 7.4.1). Apply the selected method to the relevant parameters for all years of the assessment period. The next two sections provide detailed methods for performing calculations using simplified and advanced methods.

Option 1: Simplified method for projecting scenarios
Based on the strong relationship between population and/or GDP and some of the key parameters for calculating emissions, per capita values or intensities can provide a good basis for projections. In particular, this is a useful approach where data for only one year are available.

The simplest way of projecting parameter values into the future is to select the main driving factor for a parameter (e.g. population or GDP) and assume a constant development over time, as illustrated in Figure 7.9, which uses approach A and projects fuel use based on expected population development. Current fuel use per capita can be calculated using known data on fuel use and population. The simplest

assumption is that per capita fuel use will remain constant.

More sophisticated methods may include the impact of GDP on the same parameter – for example, through the use of income elasticities as a means to predict travel demand as a function of increasing income (see also section on trends with adjustments below).

FIGURE **7.9**

Simplified approach to projecting parameters using population projections
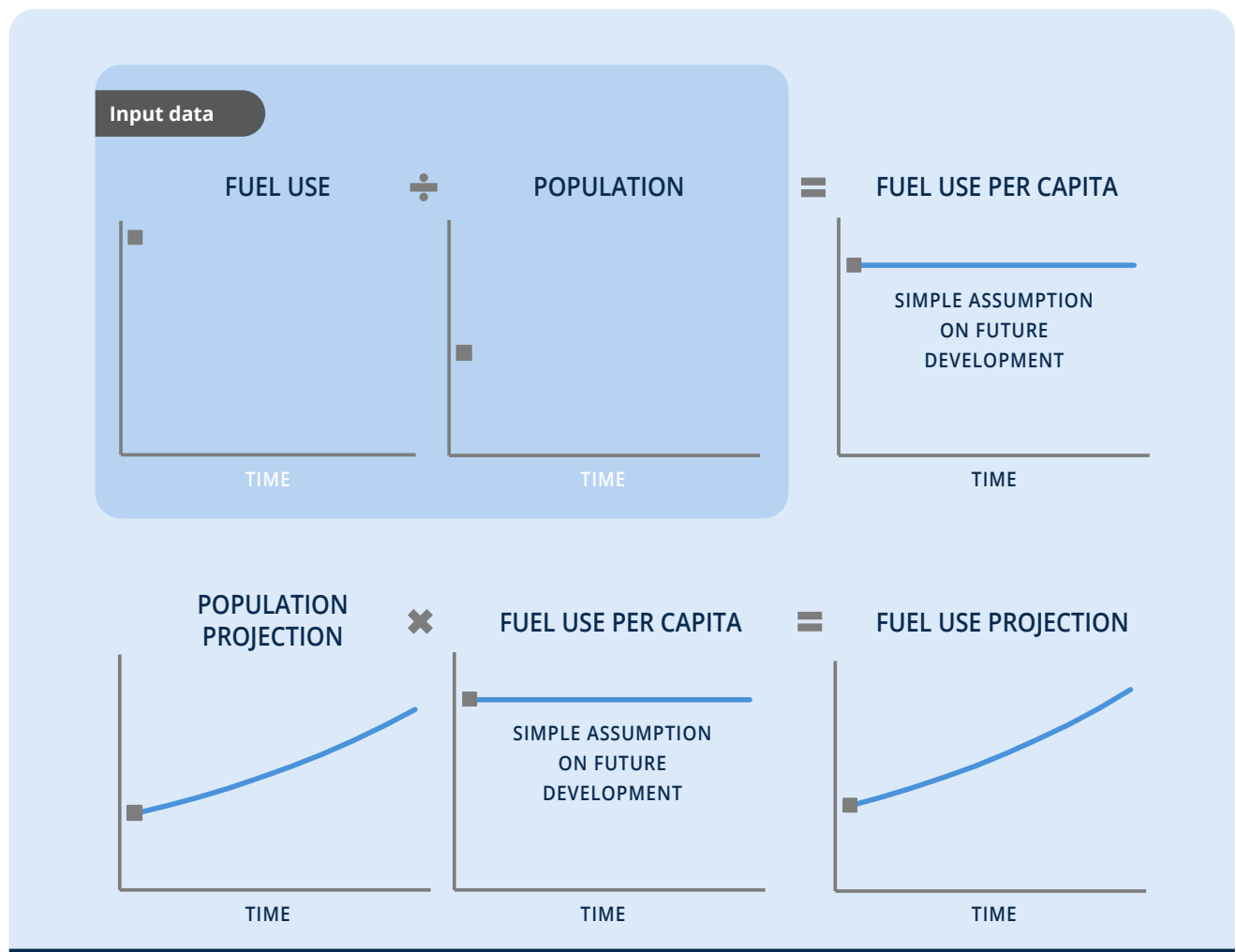
Box 7.4 provides possible sources for projections of population and GDP, and Box 7.5 provides an example illustrating the simplified method for projecting scenarios using approach A. Templates of the tables used in this example can be found in Chapter 12 (Table 12.3), where users can report on the data collected and used for calculations in this section.

Option 2: Advanced methods for projecting scenarios

Application of comparable growth rates

Assuming constant absolute values is in most cases an oversimplification of expected real developments. Using per capita values or intensities addresses this to some extent, but still falls short of real-world developments, particularly since more than one factor usually influences the parameter.

Growth rates based on relevant literature or data from comparable settings can help to incorporate some of the complexities of the different influences on a parameter in the absence of available time-series data that would deliver trends specific to the assessed situation.

BOX **7.4**

Sources for population and GDP projections

Projections for population and GDP are important elements in determining transport sector baseline scenarios. Providing methodologies for projecting these parameters is outside the scope of this methodology. Robust projections are usually available from a range of sources. The most widely used include the following.

Population

- National statistics offices or similar agencies normally provide detailed country-level projections.
- The United Nations Department of Economic and Social Affairs Population Division regularly publishes the World Population Prospects (https://population.un.org/wpp).
- The World Bank produces population estimates and projections (https://databank.worldbank.org/source/population-estimates-and-projections).

GDP

- National statistics offices, economic or development ministries, or similar agencies produce projections for GDP.
- The International Monetary Fund regularly publishes the World Economic Outlook, including projections on key financial indicators, such as GDP (currently until 2021) (www.imf.org/en/data).
- The World Bank recently published the *Global Economic Prospects* (forecasts available until 2019) (www.worldbank.org/en/publication/global-economic-prospects).

BOX **7.5**

Example of simplified method for projecting scenarios using approach A

A government plans to implement a national fuel levy on gasoline and diesel. The ministry decided to use approach A (step 1). They have already estimated the baseline emissions for the current year y (according to Section 7.2.1). As the next step, they plan to project the base year result to the years between $y + 1$ and $y + 5$.

The ministry staff start with step 2 (Determine elements for projection). They decide to use the simplified method to project scenarios, because of low data availability. Therefore, they keep the emission factors for fuels constant and only apply a projection to the fuel use.

In step 3 (Determine method for projection), the ministry staff choose a simple method. They use the per capita ratio of the fuel-use parameter to extrapolate the future fuel use according to population trends.

Finally, the ministry staff perform the calculations in step 4 (Calculate baseline emissions). From their earlier calculations (see Box 7.1), they know the fuel consumption in the current year:

F_y = 782,000 TJ, of which 50% is gasoline and 50% is diesel

In the simplified method, they keep emission factors constant for the projection (see Box 7.1):

$EF_{gasoline}$ = 74.1 tCO$_2$/TJ; EF_{diesel} = 69.3 tCO$_2$/TJ

Finally, they collect the current population data from the most recent statistics. In the year y, the country has 50 million inhabitants. Hence, the per capita ratio of the fuel consumption in year y can be calculated:

Per capita ratio gasoline consumption = (782,000 TJ × 50%) / 50,000,000 = 7.8 GJ gasoline per capita

Per capita ratio diesel consumption = (782,000 TJ × 50%) / 50,000,000 = 7.8 GJ diesel per capita

The ministry staff assume that the population will grow by 1.5% every year. Now, they have collected all the data they need for the calculation (see table below).

They find the total gasoline and diesel consumption by multiplying the per capita ratio by the projected population numbers:

For example, for year $y + 1$, $F_{gasoline,y}$ = 7.8 GJ/capita (per capita ratio) × 50.8 persons (population in year $y + 1$)

From this point, the ministry staff calculate baseline emissions ($BE_{i,y}$) by multiplying with the respective emission factor, and then summing emissions from gasoline and diesel combustion.

BOX **7.5,** continued

Example of simplified method for projecting scenarios using approach A

	Unit	Year y (historical)	Year $y + 1$	Year $y + 2$	Year $y + 3$	Year $y + 4$	Year $y + 5$
Population (in millions)	million	50.0	50.8	51.5	52.3	53.1	53.9
Per capita ratio: gasoline consumption	GJ per capita	7.8	7.8	7.8	7.8	7.8	7.8
Per capita ratio: diesel consumption	GJ per capita	7.8	7.8	7.8	7.8	7.8	7.8
$F_{gasoline,y}$ (projected)	TJ	391,000	396,865	402,818	408,860	414,993	421,218
$F_{diesel,y}$ (projected)	TJ	391,000	396,865	402,818	408,860	414,993	421,218
$BE_{gasoline,y}$ (projected)	$ktCO_2$	27,096	27,503	27,915	28,334	28,759	29,190
$BE_{diesel,y}$ (projected)	$ktCO_2$	28,973	29,408	29,849	30,297	30,751	31,212
$BE_{total,y}$ (projected)	$ktCO_2$	56,069	56,910	57,764	58,631	59,510	60,403

In the above example, historical average growth rates established for a similar country, region or city could be used to determine the projected fuel use per capita. Instead of having a constant value, this parameter would increase over time using the following equations:

Fuel use per capita in year 2 = fuel use per capita in historical data year × (1 + growth rate)

Fuel use per capita in year 3 = fuel use per capita in year 2 × (1 + growth rate)

Applying a growth rate of 3%, this would result in the following values:

Fuel use per capita in year 2 = 0.0001 TJ per capita × (1 + 0.03) = 0.000103 TJ per capita

Fuel use per capita in year 3 = 0.000103 TJ per capita × (1 + 0.03) = 0.00010609 TJ per capita

Trend analysis
A trend is a statistical method that is often used to understand past developments. Under the assumption that certain parameters are most likely to develop in the same way as in the past, the trend is often extrapolated into the future. However, the trend does not necessarily constitute the most likely scenario for all relevant variables in the determination of a baseline scenario. Trend analysis requires a time series of data for the relevant parameters. There are two types of trends:

- **Linear trends** represent the extrapolation of historical developments (trend) into the future in the form of a linear increase or decrease

in parameters. This technique is often used to extrapolate the historical development of vehicle efficiency (also called autonomous technology development). Constant growth rates lead to linear trends.

- **Non-linear trends** are usually captured using more complex models, but can also be found in simplified calculations. Typical non-linear effects include

  » learning curves, with a slow effect at the beginning, then more rapid take-up and saturation after a certain time
  » exponential growth functions
  » developments based on bottom-up data, such as detailed transport sector planning models. Here, planned impact of investments can lead to sudden changes in parameters away from previous trends.

Figure 7.10 illustrates the projection of parameters using linear and non-linear trends.

How well a trend represents likely future developments depends on a number of factors, including the following:

- **Available number of data points.** Although two or three data points can be seen to represent a time series, they do not allow a meaningful trend analysis. In principle, the more data points, the better. With older data, consistency with newer data needs to be ensured, as data-collection methods, definitions or scope may have changed over time.

- **Fluctuations in the time series.** Most parameters do not develop according to a clear curve. Values change from year to year, because they are influenced by a wide range of factors. The larger and more unpredictable these fluctuations, the less a trend will represent likely developments. For example, population normally has a relatively uniform development, with very limited fluctuations. GDP, on the other hand, shows frequent and

FIGURE **7.10**

Projecting parameters using linear and non-linear trends
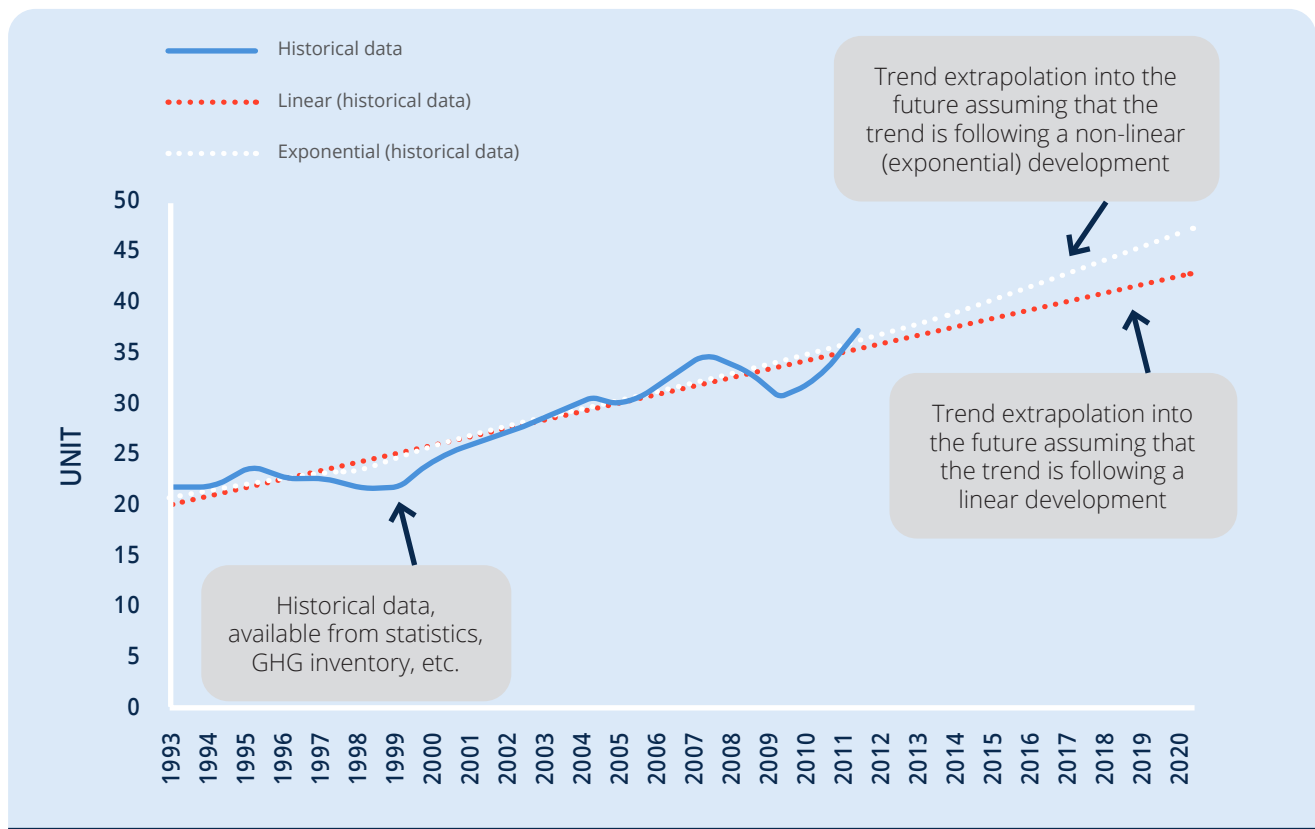
strong fluctuations that make it challenging to determine a trend and project future GDP development.

- **Expected changes in fundamental drivers.** As discussed above, policies can influence the underlying drivers of individual parameters. Policies can also be influenced by innovations or disruptive events. The invention of the car, for example, fundamentally changed mobility patterns in the early 1900s. Natural catastrophes, such as earthquakes or hurricanes, and war can significantly impact developments. Although there is little we can do to capture natural and human-caused catastrophes in projections, the next section discusses how to factor in some of the developments we can foresee.

Trend with adjustments

To add another layer of analysis to the trend, the influence of policies and other factors can be incorporated. To do this, the trend is first determined and then adjusted based on the analysis of the influencing factors, as described in Section 7.4.1, using a simple method:

1. **Determine starting point of effect.** This could be the point in time when a policy is expected to enter into force or the planned end of construction for a larger infrastructure project. Effects can also be staged – for

example, if construction contains separate phases that come into operation at different times. The starting point can also be the start point of the assessment, if policies are already in place, but are not yet expected to affect the observed trend.

2. **Translate qualitative assessment into quantitative effect.** The main question is whether the effect is

   » a one-time effect – that is, it changes the value of the trend for the year when it occurs and then continues the trend from that new value
   » a continuous effect – that is, effects keep influencing the parameter and lead to a complete deviation from the trend. Like the trend itself, the deviation can be linear or non-linear. The application of a learning curve, for example, to reflect autonomous technology improvement, would be a classical example of a continuous, non-linear effect. The value for change should be determined based on expert judgment and, where available, experiences from other countries, regions or cities.

3. **Apply to trend.** Once the type of the effect is identified and its magnitude is quantified, this can be applied to the trend, as illustrated in Figure 7.11.

FIGURE **7.11**

Trend adjustment for different effects
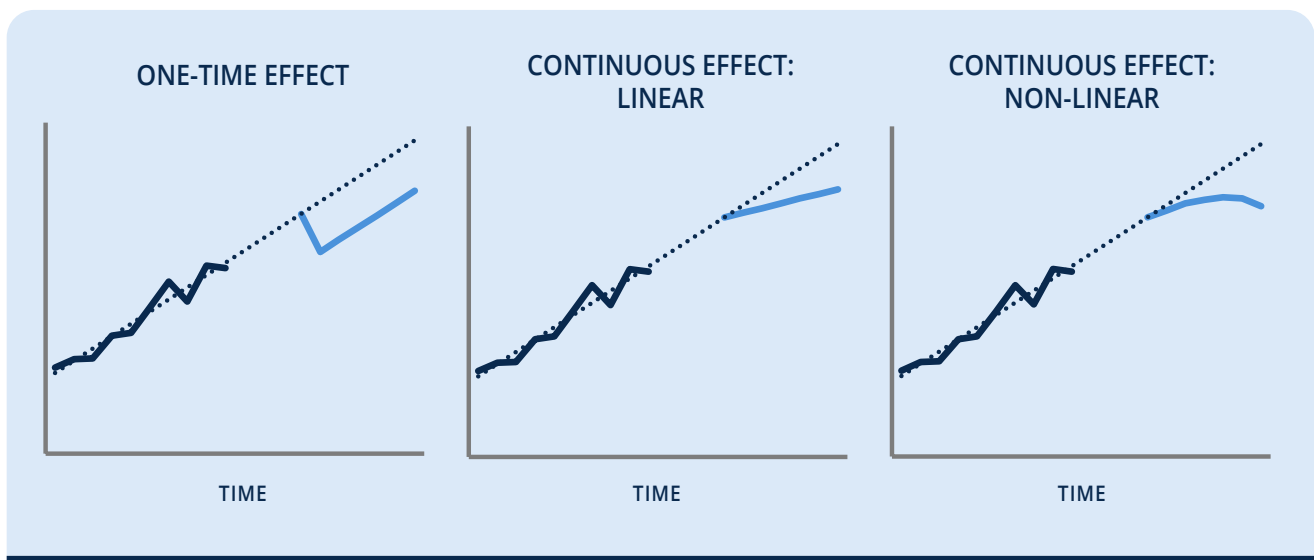
Modelling

Models apply many of the methods explained above and can in most cases also compute interrelationships between different parameters. They may be built on the actual transport infrastructure of a defined geographic area and are mostly used for transport planning. Other models represent the transport system through the parameters discussed above, in terms of fleet composition or distances travelled. Possible tools and models that can be used include:

- United Nations Environment Programme *A Toolkit for Preparation of Low Carbon Mobility Plan* – provides a detailed description of how to model transport demand based on travel characteristics[37]

- Cube – software for modelling and simulation of traffic and land use[38]

- Energy and Emissions Reduction Policy Analysis Tool – an integrated, state-level modelling system designed specifically to evaluate strategies for reducing transportation energy consumption and GHG emissions[39]

- Motor Vehicle Emission Simulator (MOVES) – estimates emissions for mobile sources at the national, country and project levels[40]

- TransCAD – provides GIS-based travel demand modelling.[41]

Models require the most detailed level of data and are only feasible to use with approach C.

---

[37] Available at: www.uncclearn.org/sites/default/files/inventory/a_toolkit_for_lcmp.pdf.

[38] Available at: www.citilabs.com/software/cube.

[39] Available at: https://cleanenergysolutions.org/es/resources/energy-emissions-reduction-policy-analysis-tool.

[40] Available at: www.epa.gov/moves.

[41] Available at: www.caliper.com/tctraveldemand.htm.

8 Estimating GHG impacts ex-ante

This chapter describes how to estimate the expected future GHG impacts of higher fuel prices. This requires an understanding of the policy scenario, which is the scenario that represents the events or conditions most likely to occur in the presence of the policy (or package of policies) being assessed. Users estimate policy scenario emissions for the GHG sources included in the GHG assessment boundary. The GHG impact of the policy is estimated by subtracting baseline emissions (as determined in Chapter 7) from policy scenario emissions. Users estimating ex-post GHG impacts only can skip this chapter and proceed to Chapter 9.

Checklist of key recommendations

- Use country-specific price elasticity data, if available, and otherwise use default price elasticity values
- Calculate the GHG impacts of the policy using appropriate parameter values and equations
- Carefully interpret the results, including assessing uncertainty and the GHG impacts of use of revenues from the policy

8.1 Choose price elasticity values

8.1.1 Introduction to price elasticities

Ex-ante impacts are assessed using specific price elasticity values to predict changes in transport demand and GHG emissions reductions compared with the projected baseline emissions obtained in Chapter 7. Pricing policies increase the fuel price, either by adding a tax or levy, or by removing an existing subsidy on the fuel (see Section 3.1). These price changes influence the demand for fuel.

The own-price elasticity is the percentage change in a good's demand divided by the percentage change in that good's price. Own-price elasticities quantify how fuel demand changes when fuel prices rise. The own-price elasticity is used to estimate the direct impact, or the net effect, of a fuel price increase on fuel demand.

The cross-price elasticity is the percentage change in a good's demand divided by the percentage change in a substitute good's price. Cross-price elasticities quantify how the demand for other transport modes changes when fuel prices rise (i.e. mode shift). The cross-price elasticity is used to estimate the indirect impact, or the gross effect, of a fuel price increase on transport demand in alternative modes.

Box 8.1 provides an example calculation for both own-price elasticity and cross-price elasticity.

FIGURE **8.1**

Overview of steps in the chapter

Choose price elasticity values (Section 8.1) → Calculate GHG impacts (Section 8.2) → Interpret the results (Section 8.3)

BOX **8.1**

Examples of own-price elasticity and cross-price elasticity[42]

> **Own-price elasticity**
>
> Price changes by +10%; demand changes by –5%; price elasticity of demand equals demand change divided by price change: –5%/+10% = –0.5.
>
> **Cross-price elasticity**
>
> Price of substitute good changes by +10%; demand changes by +20%; cross-price elasticity of demand equals demand change divided by price change: +20%/+10% = +2.

Fuel price increases due to a policy can lead to the following major impacts:

- reduced vehicle travel

- increased number of passengers per vehicle (load factor)

- increased switching to more efficient and alternative-fuel vehicles

- increased switching to other transport modes.

The net impact of a fuel price change is a reduced fuel demand and subsequent emissions reductions from transport fuel use. However, a fraction of this reduction will be compensated for by higher demand and emissions from other modes, due to mode shifts.

It is a *key recommendation* to use country-specific price elasticity data, if available, and otherwise use default price elasticity values. Sections 8.1.2, 8.1.3 and 8.1.4 provide guidance for price elasticity data for each of approaches A, B and C.

Elasticity data are generally collected using empirical methods. Empirically collected elasticity data from different sources can be analysed using statistical approaches. Patterns in the data allow users to interpolate elasticities according to specific parameters. For fuel price elasticities, such

parameters include fuel price and mean income per capita. Two types of equations are used to analyse empirically collected elasticity values:

- **Static equations** do not temporally distinguish elasticity values and only provide one estimate. The static approach does not account for temporal effects such as time lag, whereas the estimation of elasticities with a dynamic approach does account for temporal effects, and tests for time lag using lagged and non-lagged variables.

- **Dynamic equations** can distinguish between short-run and long-run elasticity effects, since they take temporal effects into account. Short-run price impacts tend to be less elastic than long-run impacts.[43] Long-run elasticity values are elasticity values from static models or long-run elasticity estimates from dynamic models. There is no consensus about how price elasticity estimates should be classified. In some studies, they are categorized as intermediate run; in others as long run. However, more recent literature tends to interpret static elasticity estimates as long run.[44]

More than 200 references on fuel price elasticities have been analysed.[45] These values form the basis for the default elasticity values presented in

---

[42] The description in the box is simplified. The exact estimation of price elasticities of demand is done with a logarithmic equation. That is, when Q is the demand and P is the price, the elasticity $\varepsilon = \Delta \ln(Q) / \Delta \ln(P) = (\Delta Q/\Delta P) \times (Q/P) = (\Delta Q/Q) / (\Delta P/P)$, which is a percentage change in the demand when the price changes by 1%. This value needs to be multiplied by the actual percentage change in the price to determine the actual percentage change in demand due to the price change determined by the pricing policy.

[43] For example, if a pricing policy is perceived by the public as a long-run effect on the price (the policy is considered to be persistent), it will lead to rather elastic reactions by consumers. If price changes are only market induced, the price change will not be considered as persistent, and reactions will be less elastic.

[44] Dahl (2012).

[45] Dahl (2012).

Sections 8.1.2, 8.1.3 and 8.1.4. They can be used to estimate the impact of a policy using approaches A, B and C. Sections 8.1.2, 8.1.3 and 8.1.4 are only relevant if no country-specific elasticity values are available. Where applicable and validated country-specific elasticity values are available, users should skip to Section 8.2.

It is very important to be aware that price elasticity values depend on the actual price change – for example, the price elasticity for gasoline will not be the same for a price increase of 1% as for a price increase of 500%. In this methodology, the default elasticity values are based on empirical studies completed within the past five decades. Hence, they take into account fuel price changes in the past (averaged for different countries and for different price increase scales). Users should follow Section 8.3 and calculate a range of possible results to take these uncertainties into account.

8.1.2 Price elasticities for approach A

The approach A default price elasticities for an unspecified fuel mix ($\varepsilon_{fuel\,mix}$) are provided in Table 8.1. The simple method provided in approach A should only be used when limited data are available. Approach B should be applied where it is known or assumed that freight transport is predominantly powered with diesel fuel.

The default price elasticity values for approach A are based on the following assumptions:

- Fuel price elasticities at the national level depend on average income per capita and fuel prices. Fuel price elasticities change only marginally over time and can be revised for different years using the consumer price index (CPI) and the purchasing power parity (PPP) index. When applying a CPI correction to fuel prices and income per capita, the values provided by Dahl (2012) are currently valid and are expected to continue to be valid in the future.

- Fuel price elasticities are expected to be similar for a broad range of price increases.

- Where fuel shares (e.g. gasoline, diesel) are unknown, gasoline price elasticity values are the best estimates for assessing impacts on the unknown fuel mix.

Table 8.1 shows prices and incomes per capita in US dollars (or cents) for the year 2016. For every new assessment, the ranges of prices (e.g. fuel mix price ≤30 cents) and incomes per capita (e.g. income per capita ≥$24,000) should be adjusted to the year of the assessment. To find the accurate elasticity values in Table 8.1, follow these three steps:

1. Collect data for actual fuel prices (annual average) and income per capita (annual average) in the local currency for the year of the assessment (most recent year with available data).
   Data requirements:

   a. Actual **fuel price** (annual average) in local currency for the assessment year

   b. Actual **per capita income** (annual average) in local currency for the assessment year

2. Convert the local fuel price (annual average) and income per capita (annual average) with PPPs. Use the PPP conversion factors (local currency unit – LCU – per international $) for the year of the assessment.[46]
   Calculation:

   a. Fuel price from step 1a ÷ $PPP_{conversion\,factor\,for\,the\,year\,of\,assessment}$

   b. Per capita income from step 1b ÷ $PPP_{conversion\,factor\,for\,the\,year\,of\,assessment}$

TABLE **8.1**

Default fuel mix price elasticity values ($\varepsilon_{fuel\,mix}$) for approach A (national level)

Fuel mix price (2016 cents per litre)	Income per capita (2016 $)[a]		
	≤12,000	12,000–24,000	≥24,000
≤30	−0.15	−0.11	−0.22
30–80	−0.22	−0.24	−0.22
≥80	−0.26	−0.32	−0.33

Source: Values adapted from Dahl (2012).

[a] The per capita income ranges are based on the best available data source for building a model of elasticities that is applicable worldwide for developing countries. Use of country-specific data, if available, is strongly recommended.

---

46   World Bank (2019a).

Results:

a. Fuel price (annual average) in US$ for the assessment year, adjusted to PPP

b. Local per capita income (annual average) in US$ for the assessment year, adjusted to PPP

3. Adjust the ranges of fuel price (e.g. fuel mix price ≤30 cents) and income per capita (e.g. income per capita ≥$24,000) in the tables above according to the US CPI between the year 2016 and the year of the assessment.[47] Calculation:

a. (US CPI $_{for\ the\ year\ of\ assessment}$ ÷ US CPI $_{2016}$) × fuel price from tables above (e.g. fuel mix price ≤30 cents)

b. (US CPI $_{for\ the\ year\ of\ assessment}$ ÷ US CPI $_{2016}$) × per capita income from tables above (e.g. income per capita ≥$24,000)

The results of these three steps are new ranges of fuel prices and per capita incomes for the tables. The elasticity values do not change, but they are now valid for the adjusted ranges of prices and incomes. Users can now apply the PPPs of the local fuel price and income per capita to the adjusted price elasticity tables to find the accurate default price elasticities.

Box 8.2 provides an example illustrating the choice of default price elasticities for approach A.

8.1.3 Price elasticities for approach B

The approach B default price elasticities for gasoline ($\varepsilon_{gasoline}$) and diesel (ε_{diesel}) fuel consumption are shown in Tables 8.2 and 8.3, respectively.

The default price elasticity values for approach B are based on the following assumptions:

• Gasoline and diesel price elasticities at the national level depend on average income per capita and fuel prices.

• Fuel price elasticities change only marginally over time and can be revised for different years using the respective CPI. When applying a CPI correction to fuel prices and income per capita, the values provided by Dahl (2012) are currently valid and are expected to continue to be valid in the future.

• Fuel price elasticities are similar for a broad range of price increases.

TABLE **8.2**

Default gasoline price elasticity ($\varepsilon_{gasoline}$) values for approach B (national level)

Gasoline price (2016 US cents per litre)	Income per capita (2016 $)		
	≤12,000	12,000–24,000	≥24,000
≤30	−0.15	−0.11	−0.22
30–80	−0.22	−0.24	−0.22
≥80	−0.26	−0.32	−0.33

Source: Values adapted from Dahl (2012).

BOX **8.2**

Example of choosing default price elasticities for approach A

A country decides to apply the default elasticity values, since no domestic studies are available and there is insufficient capacity to conduct a study. The country has a mean average income of $13,000 per capita and an annual mean fuel price of $0.50 per litre in 2016.

The default price elasticity value is $\varepsilon_{fuel\ mix}$ = −0.24.

---

[47] World Bank (2019b).

TABLE **8.3**

Default diesel price elasticity (ε_{diesel}) values for approach B (national level)

Diesel price (2016 US cents per litre)	Income per capita (2016 $)	
	≤18,000	≥24,000
≤ 80	−0.22	−0.13
≥ 80	−0.38	−0.27

Source: Values adapted from Dahl (2012).

The tables above reflect prices and incomes per capita in US dollars (or cents) for the year 2016. For every new assessment, the ranges of prices (e.g. diesel price ≥80 cents) and incomes per capita (e.g. income per capita ≥$18,000) should be adjusted to the year of the assessment. To find the accurate elasticity values in the above tables, follow these three steps:

1. Collect data for actual fuel prices (annual average) and income per capita (annual average) in the local currency for the year of the assessment (most recent year with available data).
   Data requirements:

   a. Actual **fuel price** (annual average) in local currency for the assessment year

   b. Actual **per capita income** (annual average) in local currency for the assessment year

2. Convert the local fuel price (annual average) and income per capita (annual average) with PPPs. Use the PPP conversion factors (LCU per international $) for the year of the assessment.[48]
   Calculation:

   a. Fuel price from step 1a ÷ PPP$_{\text{conversion factor for the year of assessment}}$

   b. Per capita income from step 1b ÷ PPP$_{\text{conversion factor for the year of assessment}}$

Results:

   a. Fuel price (annual average) in US$ for the assessment year, adjusted to PPP

   b. Local per capita income (annual average) in US$ for the assessment year, adjusted to PPP

3. Adjust the ranges of fuel price (e.g. diesel price ≥80 cents) and income per capita (e.g. income per capita ≥$18,000) in the tables above according to the US CPI between the year 2016 and the year of the assessment.[49]
   Calculation:

   a. (US CPI $_{\text{for the year of assessment}}$ ÷ US CPI $_{2016}$) × fuel price from tables above (e.g. diesel price ≥80 cents)

   b. (US CPI $_{\text{for the year of assessment}}$ ÷ US CPI $_{2016}$) × per capita income from tables above (e.g. income per capita ≥$18,000)

The results of these three steps are new ranges of fuel prices and per capita incomes for the tables. The elasticity values do not change, but they are now valid for the adjusted ranges of prices and incomes. Users can now apply the PPPs of the local fuel price and income per capita to the adjusted price elasticity tables to find the accurate default price elasticities.

Box 8.3 provides an example illustrating the choice of default price elasticities for approach B.

8.1.4 Price elasticities for approach C

In contrast to approaches A and B, approach C includes not only fuel own-price elasticities ($\varepsilon_{gasoline}$), but also cross-price elasticities ($\varepsilon_{cross,j}$) that address the demand for other transport modes *j*. Approach C is specifically restricted to passenger transport on road and rail, including passenger cars, passenger buses and passenger rail. Therefore, approach C does not replace approaches A or B, but can be conducted in addition for a more detailed analysis.

The default own- and cross-price elasticity values for approach C are based on the following assumptions:

   • Gasoline price elasticities at the national level depend on average income per capita and fuel prices.

---

48   World Bank (2019a).

49   World Bank (2019b).

BOX **8.3**

Example of choosing default price elasticities for approach B

A country decides to apply the default elasticity values, since no domestic studies are available and there is no capacity to conduct a study. The country has a mean average income of $13,000 per capita and an annual mean fuel price of $0.50 per litre in 2016.

The default gasoline price elasticity value is $\varepsilon_{gasoline}$ = −0.24.

The default diesel price elasticity value is ε_{diesel} = −0.22.

- Gasoline price elasticities change only marginally over time and can be revised for different years using the respective CPI. When applying a CPI correction to fuel prices and income per capita, the values provided by Dahl (2012) are currently valid and are expected to continue to be valid in the future.

- Gasoline price elasticities are similar for a broad range of price increases.

- In terms of transport demand, cross-price elasticities show similar patterns to own-price elasticities. That is, if the gasoline demand becomes more elastic (i.e. higher own-price elasticity) with increasing income per capita, demand for other passenger transport modes also becomes more elastic, thereby increasing the frequency of mode shifts. Therefore, the scaling of price elasticities described in Tables 8.2 and 8.3 can also be used as a proxy for cross-elasticities.

The own-price gasoline elasticities are shown in Table 8.4. The cross-price gasoline elasticities for shifts to bus and rail passenger transport are shown in Table 8.5.

For bus and rail, this methodology focuses on public transport vehicles. Buses are restricted to large, diesel-powered vehicles (average of 40 seats). Rail systems can include both diesel- and electricity-powered trains, and the analyses can include cable cars, street cars, tramways, metro, commuter rail, light rail and heavy rail.

For the estimation of cross-price elasticities, values from the United States[50] were used as a baseline. Starting from the baseline, the elasticities for

different gasoline prices and per capita incomes were estimated using the same patterns between the elasticity values, the gasoline price and the income per capita as in Dahl (2012). See Appendix F for detailed information on the method for estimating the cross-price elasticities.

Table 8.5 reflects prices and incomes per capita in US dollars for the year 2016. For each new assessment, the ranges of prices (e.g. gasoline price ≤30 cents) and incomes per capita (e.g. income per capita ≥$24,000) should be adjusted to the year of the assessment. To find the accurate elasticity values in the above tables, follow these three steps:

1. Collect data for actual fuel prices (annual average) and income per capita (annual average) in the local currency for the year of the assessment (most recent year with available data).

TABLE **8.4**

Default gasoline own-price elasticity ($\varepsilon_{gasoline}$) values for approach C (national/city level)

Gasoline price (2016 US cents per litre)	Income per capita (2016 $)		
	≤12,000	12,000–24,000	≥24,000
≤30	−0.15	−0.11	−0.22
30–80	−0.22	−0.24	−0.22
≥80	−0.26	−0.32	−0.33

Source: Values adapted from Dahl (2012).

---

50   APTA (2011).

TABLE **8.5**

Default gasoline cross-price elasticities ($\varepsilon_{cross,j}$) for approach C (city level)

Gasoline price (2016 US cents per litre)	Income per capita (2016 $)		
	≤12,000	12,000–24,000	≥24,000
≤30	Bus 0.09	Bus 0.07	Bus 0.14
	Rail 0.15	Rail 0.11	Rail 0.22
30–80	Bus 0.14	Bus 0.15	Bus 0.14
	Rail 0.22	Rail 0.24	Rail 0.22
≥80	Bus 0.16	Bus 0.20	Bus 0.21
	Rail 0.25	Rail 0.31	Rail 0.32

Source: Values were calculated based on data from APTA (2011) and Dahl (2012). The values are based on US cross-price elasticities (APTA 2011), which are weighted with the respective gasoline price and per capita income (Dahl 2012). See Appendix A for further information.

Data requirements:

a. Actual **fuel price** (annual average) in local currency for the assessment year

b. Actual **per capita income** (annual average) in local currency for the assessment year

2. Convert the local fuel price (annual average) and income per capita (annual average) with PPPs. Use the PPP conversion factors (LCU per international $) for the year of the assessment.[51]
    Calculation:

a. Fuel price from step 1a ÷
    $PPP_{\text{conversion factor for the year of assessment}}$

b. Per capita income from step 1b ÷
    $PPP_{\text{conversion factor for the year of assessment}}$

Results:

a. Fuel price (annual average) in US$ for the assessment year, adjusted to PPP

b. Local per capita income (annual average) in US$ for the assessment year, adjusted to PPP

3. Adjust the ranges of fuel price (e.g. gasoline price ≤30 cents) and income per capita (e.g. income per capita ≥$24,000) in the tables above according to the US CPI between the year 2016 and the year of the assessment.[52]
    Calculation:

a. (US CPI $_{\text{for the year of assessment}}$ ÷ US CPI $_{2016}$) × fuel price from tables above (e.g. gasoline price ≤30 cents)

b. (US CPI $_{\text{for the year of assessment}}$ ÷ US CPI $_{2016}$) × per capita income from tables above (e.g. income per capita ≥$24,000)

The results of these three steps are new ranges of fuel prices and per capita incomes for the tables. The elasticity values do not change, but they are now valid for the adjusted ranges of prices and incomes. Users can now apply the PPPs of the local fuel price and income per capita to the adjusted price elasticity tables to find the accurate default price elasticities.

Important factors that influence cross-price elasticities of fuels are security of the public transport system and the ease of mode shift (i.e. ease of use of transport modes, density of public transport network and access to stations). The default cross-price elasticity values shown in Table 8.5 do not consider these two factors. Where users determine that bus and rail passenger transport in their country or in a city reflects a special situation,[53] they should use country-specific cross-price elasticity values.

Box 8.4 provides an example illustrating the choice of default own- and cross-price elasticities for approach C.

---

[51] World Bank (2019a).

[52] World Bank (2019b).

[53] Special situations might include, for example, an extremely expensive or exclusive public transport system, or a particularly dense and easily accessible public transport system.

BOX **8.4**

Example of choosing default own- and cross-price elasticities for approach C

A country decides to apply the default elasticity values, since no national studies are available and there is no capacity to conduct a study. The country has a mean average income of $13,000 per capita and an annual mean fuel price of $0.50 per litre in 2016.

The resulting default **gasoline own-price** elasticity value is –0.24.

The resulting default **gasoline cross-price** elasticities for the respective passenger transport modes are:

- cross-price elasticity with respect to gasoline price, for motor bus: $\varepsilon_{cross,bus}$ = 0.15
- cross-price elasticity with respect to gasoline price, for rail (average): $\varepsilon_{cross,rail}$ = 0.24.

8.2 Calculate GHG impacts

To calculate the GHG impacts of the policy, both the baseline emissions estimate from Chapter 7 and the price elasticity estimate obtained in Section 8.1 are needed. It is a *key recommendation* to calculate the GHG impacts of the policy using appropriate parameter values and equations. The following sections provide methods for calculating impacts using price elasticity values for approaches A, B and C.

Where the results of the assessment will be used to inform GHG accounting and reporting of progress made towards implementation and achievement of NDCs, and meet the reporting requirements of the transparency framework, users should consider aligning the input parameters (e.g. activity data, emission factors, socioeconomic data) used for the calculation of GHG impacts of transport pricing policies with similar parameters used for GHG accounting and reporting under the Paris Agreement. Some parameters used for the projection of GHG impacts of transport pricing policies can also be used as key indicators for projections developed to meet the reporting requirements of the transparency framework.

Guidance for the interpretation of the results and information about uncertainties are provided in Section 8.3.

8.2.1 GHG impact calculation for approach A

The impact of the policy on the fuel demand for transport is reflected by the price elasticity. With an increase in fuel prices, the fuel price elasticity is negative, indicating a decreasing demand for fuel and a subsequent reduction in GHG emissions.

The following input data are needed for the GHG impact calculation using approach A (see Sections 7.2 and 8.1 for methods for calculating these inputs):

- baseline fuel use from gasoline and diesel fuel mix for each year y (F_y)

- baseline GHG emissions from gasoline and diesel fuel mix for each year y ($BE_{fuel\ mix,y}$)

- fuel mix price elasticity ($\varepsilon_{fuel\ mix}$)

- relative (%) fuel mix price increase (price change due to policy).

Table 8.6 shows the calculation of GHG impacts using approach A. Data in rows A–C are input values taken from Sections 7.2.1 and 8.1, and rows D–G show the output results and the respective equations.

The equations in the column "Data collection/ calculation" refer to the respective labelling in the column "Label". For example, the calculation of the anticipated fuel use (row E) for a specific year multiplies the values of rows C and D (elasticity value in the specific year, relative fuel mix price increase), adds 1 to the result, and then multiplies this by the value of row A (baseline fuel use in the specific year. See Box 8.5 for a full calculation example. The numbers in the box match the examples in Sections 7.2 and 8.1.

TABLE **8.6**

GHG impact calculation using approach A

Label	Parameter	Unit	Data collection/calculation	Example year
A	Baseline fuel use (F_y)	TJ	Input value: from Sections 7.2.1 and 7.4	782,000
B	Baseline emissions ($BE_{fuel\ mix,y}$)	tCO_2	Input value: from Sections 7.2.1 and 7.4	56,069,400
C	Fuel mix own-price elasticity ($\varepsilon_{fuel\ mix}$)	-	Input value: from Section 8.1.2	−0.24
D	Relative fuel mix price increase	%	Input value: according to planned policy	4.5
E	Anticipated fuel use	TJ	= ((C × D) + 1) × A	773,550
F	Anticipated GHG emissions	tCO_2	= ((C × D) + 1) × B	55,463,850
G	Anticipated GHG impact (emissions reductions)	tCO_2	= F − B	−605,650
H	Anticipated relative impact	%	= G ÷ B	−1.1

Abbreviation: -, not applicable

BOX **8.5**

Example of GHG impact calculation for approach A

A government plans to implement a national fuel levy on gasoline and diesel that will target LDVs in the form of a fixed sum per litre – higher for gasoline than for diesel. The fuel levy will increase gasoline prices by 5% and diesel prices by 4%. Gasoline and diesel both have a share of 50% of total fuel use, which means that the **overall fuel price increase amounts to 4.5%.** The ministry has already estimated the baseline scenario and the fuel price elasticities for the example year:

   Baseline fuel use: F_y = 782,000 TJ, 50% gasoline and 50% diesel (see row A of Table 8.6)

   Baseline emissions: $BE_{fuel\ mix,y}$ = 56,069,400 tCO_2 (see row B)

   Elasticity estimate for fuel mix = −0.24 (see row C)

   Relative fuel mix price increase = 4.5% (see row D)

The ministry staff now calculate the anticipated fuel use, emissions and GHG impacts according to the equations in Table 8.6:

   Anticipated fuel use = ((−0.24 × 4.5%) + 1) × 782,000 TJ = 773,550 TJ (see row E of Table 8.6)

   Anticipated GHG emissions = ((−0.24 × 4.5%) + 1) × 56,069,400 tCO_2 = 55,463,850 tCO_2 (see row F)

   Anticipated GHG impact = 55,463,850 tCO_2 − 56,069,400 tCO_2 = −605,650 tCO_2 (see row G)

Thus, the GHG reduction in year *y* equals −605,550 tCO_2 or −1.1% compared with the baseline scenario (see row H of Table 8.6).

8.2.2 GHG impact calculation for approach B

The following input data are needed for the GHG impact calculation using approach B (see Sections 7.2 and 8.1):

- baseline fuel use from gasoline and diesel for each year y ($F_{i,y}$)

- baseline GHG emissions from gasoline and diesel for each year y ($BE_{i,y}$)

- gasoline and diesel price elasticities (ε_i)

- relative (%) gasoline and diesel price increases (price change due to policy).

Table 8.7 shows the calculation of GHG impacts using approach B. Data in rows A–F are input values taken from Sections 7.2.2 and 8.1, and rows G–M show the output results and the respective equations.

TABLE **8.7**

GHG impact calculation using approach B

Label	Parameter	Unit	Data collection/calculation	Example year (see Box 8.6)
A	Baseline gasoline use ($F_{gasoline,y}$)	TJ	Input value: from Sections 7.2.2 and 7.4	348,198
B	Baseline diesel use ($F_{diesel,y}$)	TJ	Input value: from Sections 7.2.2 and 7.4	344,000
C	Baseline gasoline emissions ($BE_{gasoline,y}$)	tCO_2	Input value: from Sections 7.2.2 and 7.4	24,130,121
D	Baseline diesel emissions ($BE_{diesel,y}$)	tCO_2	Input value: from Sections 7.2.2 and 7.4	25,490,400
E	Gasoline own-price elasticity ($\varepsilon_{gasoline}$)	-	Input value: from Section 8.1.3	−0.24
F	Relative gasoline price increase	%	Input value: according to planned policy	5
G	Diesel own-price elasticity (ε_{diesel})	-	Input value: from Section 8.1.3	−0.22
H	Relative diesel price increase	%	Input value: according to planned policy	4
I	Anticipated gasoline use	TJ	= ((E x F) + 1) × A	344,020
J	Anticipated diesel use	TJ	= ((G x H) + 1) × B	340,973
K	Anticipated gasoline emissions	tCO_2	= ((E x F) + 1) × C	23,840,560
L	Anticipated diesel emissions	tCO_2	= ((G x H) + 1) × D	25,266,084
M	Anticipated emissions total	tCO_2	= K + L	49,106,644
N	Anticipated total GHG impact (emissions reductions)	tCO_2	= M − (C + D)	−513,877
O	Anticipated relative impact	%	= N ÷ (C + D)	−1.0

Abbreviation: -, not applicable

The equations in the column "Data collection/ calculation" refer to the respective labelling in the column "Label". For example, the calculation of the anticipated gasoline use (row I) for a specific year multiplies the values of rows E and F (elasticity value in the specific year, relative gasoline price increase), adds 1 to the result, and then multiplies this by the value of row A (baseline gasoline use in the specific year). See Box 8.6 for a full calculation example. The numbers match the examples in Sections 7.2 and 8.1.

8.2.3 GHG impact calculation for approach C

Approach C uses cross-price elasticities of a gasoline price increase, and thereby includes mode shifts in the analyses. Own-price elasticities are negative and indicate a decreasing demand for the fuels. In contrast, cross-price elasticities due to the fuel price increase are positive, indicating an increasing demand for alternative transport modes. This means that the number of PKM is reduced for private gasoline cars by the magnitude of the own-price elasticity. The number of PKM in public transport increases by the magnitude of the respective cross-price elasticity. GHG emissions from private gasoline cars decrease, coinciding with the decrease in private gasoline car PKM.

In this methodology and in the example below, it is assumed that the fuel levy on diesel consumption in public transport (bus and rail) is much lower (possibly even non-existent), since it is for private road transport. Most urban bus and rail transport is usually publicly owned. Also, private companies contributing to public transport may be exempt from the levy. Therefore, no own-price elasticity for diesel used in passenger bus and rail transport is included in the analysis.

Note, as mentioned, approach C has different assessment boundaries from approaches A and B, and is therefore not directly comparable with those two approaches.

BOX **8.6**

Example of GHG impact calculation for approach B for an example year

A government plans to implement a national fuel levy on gasoline and diesel that will target vehicles in the form of a fixed sum per litre – higher for gasoline than for diesel. The fuel levy will increase gasoline prices by 5% and diesel prices by 4%. The ministry has already estimated the baseline emissions and the fuel price elasticities for both fuels (gasoline and diesel) in the example year:

   Baseline gasoline fuel use: $F_{gasoline,y}$ = 348,198 TJ (see row A of Table 8.7)

   Baseline diesel fuel use: $F_{diesel,y}$ = 344,000 TJ (see row B)

   Baseline gasoline emissions: $BE_{gasoline,y}$ = 24,130,121 tCO_2 (see row C)

   Baseline diesel emissions: $BE_{diesel,y}$ = 25,490,400 tCO_2 (see row D)

   Elasticity estimate for gasoline = –0.24 (see row E)

   Relative gasoline price increase = 5% (see row F)

   Elasticity estimate for diesel = –0.22 (see row G)

   Relative diesel price increase = 4% (see row H)

The ministry staff now calculate the anticipated fuel use, GHG emissions and GHG impacts according to the equations in Table 8.7:

   Anticipated gasoline fuel use = ((–0.24 × 5%) + 1) × 348,198 TJ = 344,020 TJ (see row I, Table 8.7)

   Anticipated diesel fuel use = ((–0.22 × 4%) + 1) × 344,000 TJ = 340,973 TJ (see row J)

   Anticipated gasoline emissions = ((–0.24 × 5%) + 1) × 24,130,121 tCO_2 = 23,840,560 tCO_2 (see row K)

   Anticipated diesel emissions = ((–0.22 × 4%) + 1) × 25,490,400 tCO_2 = 25,266,084 tCO_2 (see row L)

   Anticipated emissions total = 23,840,560 tCO2 + 25,266,084 tCO_2 = 49,106,644 tCO_2 (see row M)

   Anticipated total GHG impact = 49,106,644 tCO_2 – (24,130,121 tCO_2 + 25,490,400 tCO_2) = –513,877 tCO_2 (see row N)

Thus, the GHG reduction in year y equals –513,877 tCO_2 or –1.0% compared with the baseline scenario (see row O of Table 8.7).

The following **input data** are required for the GHG impact calculation for approach C (see Sections 7.3 and 8.1):

- baseline travel demand in PKM for each transport mode j (car, bus, rail) and each year y ($PKM_{i,j,y}$)

- own-price elasticities for fuel types diesel and gasoline ($\varepsilon_{gasoline}$, ε_{diesel})

- relative (%) gasoline price increase (price change due to policy)

- cross-price elasticities for transport modes bus and rail ($\varepsilon_{cross,bus}$, $\varepsilon_{cross,rail}$)

- baseline GHG emissions for each fuel type i (gasoline, diesel, electricity), transport mode j (car, bus, rail) and year y ($BEPKM_{i,j,y}$).

Table 8.8 shows the calculation of GHG impacts using approach C. Data in rows A–D, G–I and L–P are input values taken from Chapter 7 and Section 8.1, and rows E–F, J–K and Q–T show the output results and the respective equations. The overall results are calculated in rows U–Z.

TABLE **8.8**

GHG impact calculation using approach C

Label	Parameter	Unit	Data collection/ calculation	Example year	Year y (projected)
Passenger car (gasoline)					
A	Baseline PKM with car ($PKM_{car,gasoline,y}$)	PKM	Input value: from Sections 7.3 and 7.4	21,800,000,000	…
B	Gasoline own-price elasticity ($\varepsilon_{gasoline}$)	-	Input value: from Section 8.2.3	–0.24	…
C	Relative gasoline price increase	%	Input value: according to planned policy	5	…
D	Baseline car gasoline emissions per PKM ($BEPKM_{car,gasoline,y}$)	gCO$_2$/ PKM	Input value: from Sections 7.3 and 7.4	111	…
E	Anticipated PKM with cars	PKM	= ((B × C) + 1) × A	21,538,400,000	…
F	Anticipated gasoline emissions (car)	tCO$_2$	= D × E ÷ 10^6	2,390,762	…
Passenger bus (diesel)					
G	Baseline PKM with bus ($PKM_{bus,diesel,y}$)	PKM	Input value: from Sections 7.3 and 7.4	15,700,000,000	…
H	Bus cross-price elasticity ($\varepsilon_{cross,bus}$)	-	Input value: from Sections 8.2.3	0.15	…
I	Baseline bus diesel emissions per PKM ($BEPKM_{bus,diesel,y}$)	gCO$_2$/ PKM	Input value: from Sections 7.3 and 7.4	83	…
J	Anticipated PKM with bus	PKM	= ((H × C) + 1) × G	15,817,750,000	…
K	Anticipated diesel emissions (bus)	tCO$_2$	= I × J ÷ 10^6	1,312,873	…

TABLE 8.8, continued

GHG impact calculation using Approach C

Label	Parameter	Unit	Data collection/ calculation	Example year	Year y (projected)
Passenger rail (diesel and electricity)					
L	Baseline PKM with diesel rail ($PKM_{rail,diesel,y}$)	PKM	Input value: from Sections 7.3 and 7.4	12,400,000,000	…
M	Baseline PKM with electric rail ($PKM_{rail,electricity,y}$)	PKM	Input value: from Sections 7.3 and 7.4	5,600,000,000	…
N	Rail cross-price elasticity ($\varepsilon_{cross,rail}$)	-	Input value: from Section 8.2.3	0.24	…
O	Baseline rail diesel emissions per PKM ($BEPKM_{rail,diesel,y}$)	gCO_2/ PKM	Input value: from Sections 7.3 and 7.4	64	…
P	Baseline rail electricity emissions per PKM ($BEPKM_{rail,electricity,y}$)	gCO_2/ PKM	Input value: from Sections 7.3 and 7.4	63	…
Q	Anticipated PKM with diesel rail	PKM	= ((N × C) + 1) × L	12,548,800,000	…
R	Anticipated PKM with electric rail	PKM	= ((N × C) + 1) × M	5,667,200,000	…
S	Anticipated diesel emissions (rail)	tCO_2	= O × Q ÷ 10^6	803,123	…
T	Anticipated electricity emissions (rail)	tCO_2	= P × R ÷ 10^6	357,034	…
Overall results					
U	Reference emissions total	tCO_2	= ((A × D) + (G × I) + (L × O) + (M × P)) ÷ 10^6	4,869,300	…
V	Anticipated emissions total	tCO_2	= F + K + S + T	4,863,792	…
W	Anticipated total GHG impact (emissions reduction)	tCO_2	= V – U	–5,508	…
X	Anticipated relative impact	%	= W ÷ U	–0.1	…
Y	Increased capacity requirement of bus system	%	= ((Q + R) ÷ (L + M)) – 1	+1.2	…
Z	Increased capacity requirement of rail system	%	= J ÷ G – 1	+0.8	…

Abbreviation: -, not applicable

The equations in the column "Data collection/ calculation" refer to the respective labelling in the column "Label". For example, the calculation of the anticipated PKM by car with gasoline use (row E) for a specific year multiplies the values of rows C and D (elasticity value in the specific year, relative gasoline price increase), adds 1 to the result, and then multiplies this by the value of row A (baseline PKM with car in the specific year). See Box 8.7 for a full calculation example. The numbers match the examples in Sections 7.3 and 8.1.

8.3 Interpret the results

The calculations in this methodology are subject to large uncertainties. It is a *key recommendation* to carefully interpret the results, including assessing uncertainty and the GHG impacts of use of revenues from the policy. Users should interpret the results of the calculations following these steps:

1. Check conditions of applicability for the assessments. Applicability is limited when

   » a country has special circumstances (e.g. very low or high fuel prices or income per capita)
   » the fuel price increase is very high or very low
   » fuel is a luxury good that is only accessible to a small, wealthy part of the population
   » there are other political or legal processes or conditions interfering with the policy.

2. Be transparent about high uncertainties in the following data-collection and calculation processes

   » activity data estimation
   » baseline activity data estimation
   » emission factors and other conversion factors
   » projection of baseline scenarios
   » price elasticity value estimation.

3. Indicate a range of the results rather than single values to account for the uncertainty (e.g. a range from 50% to 100% of the single result value).

4. Undertake a plausibility check of the results

   » Consult further literature and data sources (see Appendix B).

   » Compare results with similar assessments from other countries or cities (i.e. conduct a benchmarking exercise).
   » Conduct a stakeholder consultation process.

5. Undertake a top-down and bottom-up consistency check when applying approaches B or C

   » Compare $F_{gasoline,car,y}$ with total gasoline fuel used for private passenger road transport from the national energy balance or similar national energy statistics.
   » Be transparent when reporting differences in results from bottom-up and top-down estimations.

6. Qualitatively assess and discuss use of revenues from the fuel tax or levy

   » If the revenues are invested in activities that tend to increase emissions – such as general government spending, or building or extension of roadways – the net emissions reductions from the policy may be considerably reduced or the policy may lead to higher overall emissions.
   » If the revenues are invested in activities that tend to decrease emissions – such as investments in public transport or schemes to promote low-emission vehicles – the emissions reductions may be increased as a result of easier and more convenient mode shift.

7. Conduct the ex-post assessment presented in Chapter 9.

Studies on fuel price elasticities yield very broad and diverse results (see Appendix B for an overview). Therefore, the default values presented in this methodology have very high uncertainties, estimated by the authors of this methodology to be between 50% and 100%; they may be higher for specific cases.

Elasticities depend on the transport alternatives that are available and thus on the specific situation in the country. Care should be taken to implement the appropriate increase in fuel price based on an estimate of elasticity, to avoid adverse effects, such as decreased mobility for the poorest populations. The assumptions made to choose elasticity values are important, given that these values do not remain the same under continuous price increases.

BOX **8.7**

Example of GHG impact calculation for approach C

A government plans to implement a national fuel levy on gasoline that will target vehicles in the form of a fixed sum per litre. The fuel levy will increase gasoline prices by 5%. It is decided that public transport is not subject to the levy (i.e. diesel used in passenger bus and rail transport).

The ministry staff start by analysing private road passenger transport. They retrieve the following data from the baseline emissions estimates they conducted before (see Section 7.3) and from the choice of price elasticities (see Section 8.1):

$PKM_{gasoline,car,y}$ = 21,800 million PKM (see row A of Table 8.8)

$\varepsilon_{gasoline}$ = –0.24 (see row B)

Relative gasoline price increase = 5% (see row C)

$BEPKM_{gasoline,car,y}$ = 111 gCO_2/PKM (see row D)

With these data, they calculate PKM and emissions from private passenger cars:

Anticipated PKM with cars = ((–0.24 x 5%) + 1) × 21,800,000,000 PKM = 21,538,400,000 PKM (see row E)

Anticipated gasoline emissions (car) = 111 gCO_2/PKM × 21,538,400,000 PKM ÷ 10^6 = 2,390,762 tCO_2 (see row F)

In a second step, the ministry staff analyse passenger bus transport. The following data inputs are given from their earlier analyses (no diesel own-price elasticity is required, since public transport is not subject to the levy):

$PKM_{diesel,bus,y}$ = 15,700 million PKM (see row G)

$\varepsilon_{cross,bus}$ = 0.15 (see row H)

$BEPKM_{diesel,bus,y}$ = 83 gCO_2/PKM (see row I)

With these data, they calculate PKM and emissions from passenger buses:

Anticipated PKM with bus = ((5% × 0.15) + 1) × 15,700,000,000 PKM = 15,817,750,000 PKM (see row J)

Anticipated diesel emissions (bus) = 15,817,750,000 PKM × 83 gCO_2/PKM / 1,000,000 = 1,312,873 tCO_2 (see row K)

In a third step, the ministry staff analyse passenger rail transport with diesel and electricity. The following data inputs are given from their earlier analyses (no diesel own-price elasticity is required, since public transport is not subject to the levy):

$PKM_{diesel,rail,y}$ = 12,400 million PKM (see row L)

$PKM_{electricity,rail,y}$ = 5,600 million PKM (see row M)

$\varepsilon_{cross,rail}$ = 0.24 (see row N)

$BEPKM_{diesel,rail,y}$ = 64 gCO_2/PKM (see row O)

$BEPKM_{electricity,rail,y}$ = 63 gCO_2/PKM (see row P)

With these data, they calculate PKM and emissions from diesel and electric rail:

Anticipated PKM with diesel rail = ((5% × 0.24) + 1) × 12,400,000,000 PKM = 12,548,800,000 PKM (see row Q)

Anticipated PKM with electric rail = ((5% × 0.24) + 1) × 5,600,000,000 PKM = 5,667,200,000 PKM (see row R)

Anticipated diesel emissions (rail) = 12,548,800,000 PKM × 64 gCO_2/PKM / 1,000,000 = 803,123 tCO_2 (see row S)

Anticipated electricity emissions (rail) = 5,667,200,000 PKM × 63 gCO_2/PKM / 1,000,000 = 357,034 tCO_2 (see row T)

Finally, the ministry staff can calculate the overall GHG impacts:

Reference emissions total = ((21,800 million PKM × 111 gCO_2/PKM) + (15,700 million PKM × 83 gCO_2/PKM) + 12,400 million PKM × 64 gCO_2/PKM) + (5,600 million PKM × 63 gCO_2/PKM)) = 4,869,300 tCO_2 (see row U)

Anticipated emissions total = 2,390,762 tCO_2 + 1,312,873 tCO_2 + 803,123 tCO_2 + 357,034 tCO_2 = 4,863,792 tCO_2 (see row V)

Anticipated total GHG impact = 4,863,792 tCO2 – 4,869,300 tCO2 = –5,508 tCO_2 (see row W)

Anticipated relative impact = –5,508 tCO_2 / 4,869,300 tCO_2 = –0.1% (see row X)

Thus, the GHG reduction in year *y* equals 5,395 tCO_2 or 0.1% compared with the baseline scenario (see row W of Table 8.8).

Note: Users can estimate the extent of mode shifts towards public transport:

Increased capacity requirement of bus system = 1.2% (see row Y)

Increased capacity requirement of rail system = 0.8% (see row Z)

9 Estimating GHG impacts ex-post

Ex-post impact assessment is a backward-looking assessment of the GHG impacts achieved by a policy to date. The GHG impacts can be assessed during the policy implementation period or in the years after implementation. In contrast to ex-ante assessment, which is based on forecasted values, ex-post assessment involves monitored data collected during the policy implementation period. An ex-post assessment is important to check the plausibility of the estimated emissions reductions from the ex-ante estimation. Users who are estimating ex-ante GHG impacts only can skip this chapter.

Checklist of key recommendations

- Estimate or update baseline emissions using observed values for parameters that are not affected by the policy and estimated values for parameters that are affected by the policy
- Estimate the GHG impacts of the policy over the assessment period, for each GHG source included in the GHG assessment boundary

9.1 Estimate or update baseline emissions (if relevant)

It is a *key recommendation* to estimate or update baseline emissions using observed values for parameters that are not affected by the policy and estimated values for parameters that are affected by the policy. The baseline scenario can be estimated following the method in Chapter 7. Further guidance on monitoring parameters is provided in Chapter 11.

Where the baseline scenario was determined and baseline emissions were estimated in a previous ex-ante impact assessment, this should be updated by replacing estimated values with observed data.
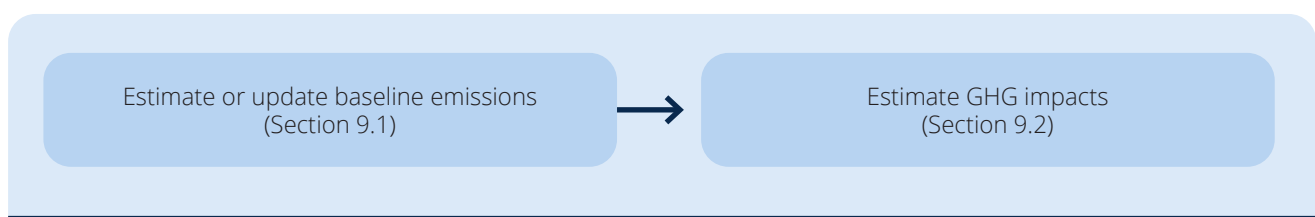
9.2 Estimate GHG impacts

The performance of the policy should be evaluated to ascertain whether it has been implemented as envisaged and to estimate its actual GHG impacts. It is a *key recommendation* to estimate the GHG impacts of the policy over the assessment period, for each GHG source included in the GHG assessment boundary.

To estimate the GHG impacts for a policy that has not been assessed ex-ante, follow the steps for ex-ante impact assessment (see Chapter 8). If an ex-ante impact assessment was done previously, that impact assessment should be updated using observed values.

FIGURE **9.1**

Overview of steps in the chapter

Estimate or update baseline emissions (Section 9.1) → Estimate GHG impacts (Section 9.2)

Table 9.1 provides the key indicators and parameters that may need to be monitored or updated when conducting an ex-post assessment. With these updated indicator and parameter values, a more accurate estimation for the GHG impacts of the policy is calculated, using the methods in Chapters 7 and 8.

If an ex-ante impact assessment was not done previously, follow the methods in Chapters 7 and 8 using current values for all relevant monitored indicators and parameters.

Box 9.1 provides a case study of an ex-post assessment of a policy involving reduction of subsidies for fossil fuels in Indonesia.

TABLE **9.1**

Indicators and parameters to consider when undertaking or updating the assessment of the policy

Indicator/ parameter	Description	Potential data sources	Related section in ex-ante assessment
Coverage of policies	The policy that is actually implemented may differ from the design of the policy at the time of the ex-ante assessment. Therefore, the type of fuels (or consumers) covered by the policy may change (e.g. exemptions for certain consumer groups may be implemented that change the impact).	Law or regulation for implementation of the policy	Changes in coverage of policy impact system boundaries for GHG sources considered in Chapter 7
Level of pricing	During the process of designing the policy, the level of the pricing or the implementation time and speed may change.	Law or regulation for implementation of the policy	Used for updating pricing signal in Section 8.2
Approach	Better data on fuel consumption (or price elasticities) may be available that allow users to use a higher-level approach (i.e. B or C) or provide a better basis for determining fuel price elasticities.	National data sources	Used for updating choice in Section 4.2.2, and calculations in Chapter 7 and Section 8.1
Baseline data	More recent data may be available on fuel consumption, for determining baseline emissions (e.g. for the last year before the implementation of the policy), or on transport emissions projections.

In general, only activity data from before the policy was implemented can be used to update the baseline, because, after that point, the impact of the policy has already led to a deviation of emissions from the baseline scenario. | See all parameters in Chapter 7 | Used for updating calculations in Chapter 7 |

BOX **9.1**

Ex-post assessment of subsidy removal in Indonesia

In 2014, the Government of Indonesia reduced subsidies on fossil fuels. For gasoline, this led to a price increase of around 25%. There were multiple reasons for this pricing policy – the main reasons were government budget limitations, high international fuel prices (combined with limited fuel production capacities in Indonesia and thus higher dependency on imports) and the realization that the subsidies were not suitable to resolving the poverty problem in Indonesia.

The subsidy removal in Indonesia was assessed ex-post using approach B of the ICAT *Transport Pricing Methodology*. A local team from the Trisakti School of Transportation Management,[54] based in Jakarta, conducted the assessment, as follows:

- country – Indonesia
- base year – 2013; assessment year – 2016
- fuels – gasoline (RON 88) and diesel: ex-post data from the Indonesian Ministry of Environment and Forestry
- price elasticities – default values from the *Transport Pricing Methodology*
- emission factors – country-specific data from the Ministry of Environment and Forestry.

The assessment showed that the subsidy removal on RON 88 gasoline and thereby the increase in the price led to a decrease in RON 88 consumption of around 6%. The case is different for diesel, where the price increase was less significant; after correcting for inflation in the assessment year, the impact of the pricing policy on diesel consumption was negligible.

The local team considered the *Transport Pricing Methodology* very helpful for conducting the pricing policy assessment, and for understanding changes in fuel prices and impacts of these changes on fuel demand. In particular, the step-by-step guidance and illustrative examples helped them when they encountered problems or questions throughout the process. The report of the Trisakti School of Transportation Management, with detailed information about the assessments conducted in Indonesia, will be published on the ICAT website.[55]

---

[54] Institut Transportasi & Logistik (ITL) Trisakti, https://itltrisakti.ac.id.

[55] Sinaga et al. (forthcoming).