Transport Pricing Guidance

Guidance for assessing the greenhouse gas impacts of transport pricing policies

May 2018

How to quantify the GHG impacts

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.

Figure 7.1: Overview of steps

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 selected as the year in the assessment from which projections will be made into the future. The 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 CO₂ emissions are included; for simplification, emissions of methane (CH₄) and nitrous oxide (N₂O) 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. Choose the appropriate approach based upon data and capacity available. The same baseline scenario applies for both Approaches A and B. Section 7.2 provides the guidance for Approaches A and B. Section 7.3 provides the guidance for Approach C.

Where applying Approach C, refer to Section 7.3 for guidance on defining the baseline scenario and calculating base year emissions for an individual year.

Approaches A and B use top-down, national data to estimate base year emissions for policies implemented at the national level. In contrast to Approaches A and B, Approach C is particularly suitable for the city level where activity data is available for activities (i.e., fuels used) within the city boundary. In both cases, the baseline scenario is considered to be a continuation of the conditions that exist in the absence of the new policy. Calculate base year emissions 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, while the emission factor is related to the carbon content of the vehicle fuels utilised and is defined in tonnes of CO\textsubscript{2} per unit of fuel. In this guidance, 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 both Approaches A and B.

**Figure 7.2: Overview of steps for Approach A**

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 and may be 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.

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If transport fuel contains 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 biogenic emissions from biofuels can be assumed to be zero. It should be considered in the applied emission factor when calculating the emissions following Figure 7.3 above. 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 Chapter 11). A more comprehensive way to assess the emissions of biofuels within the ground transport system is depicted 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 calculate GHG (CO₂ 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 with diesel fuel, Approach B should be applied.

Where this is the case, follow the four steps 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.²

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, it is also necessary to 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 kgCO₂/TJ on a net calorific basis (i.e., NCVs are

² This is a conservative assumption since, by ignoring upstream emissions, emissions reductions are also excluded from the results.
applied in order 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 prior to applying the
emission factor, for example using the method provided by the IPCC.³

Data on total fuel use is 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 other similar
governmental bodies may manage these data in some cases. 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 utilised in the country. Depending upon the sources (e.g.,
national production and/or imports), data can be derived from refineries, fuel importers and/or customs
authorities. Users could also use well-designed and executed surveys of fuel distributors or fuelling
stations to build the data set. In the latter case, it is recommended to 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) country statistics.⁴

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

- **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 vary considerably. 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 back-up electricity generation at private homes using diesel
generators
  - For countries with subsidised 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 dataset 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, users can report the related uncertainty but omit the consideration from the
calculations.

³ IPCC 2006. Available at: http://www.ipcc-
nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf#page=17.

⁴ Available at: http://www.iea.org/statistics/.
Table 7.1 provides an overview of the activity data parameter for Approach A, as well as possible data sources.

**Table 7.1: Activity parameter for Approach A**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_y$</td>
<td>Total fuel used for ground transport in year $y$ (unspecified mix of gasoline, diesel and/or other transport fuels)</td>
<td>TJ</td>
<td>In order of preference:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- National energy balance or similar national energy statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Data collection process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- International sources, such as IEA</td>
</tr>
</tbody>
</table>

For Approach A, since all fuel types are aggregated in the activity data, the user should 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 (i.e., in litres or gallons), the user will need to apply fuel density values ($\rho_i$) 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 with possible data sources.

**Table 7.2: Conversion factors for activity data for Approach A**

<table>
<thead>
<tr>
<th>Conversion factor</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_i$</td>
<td>Share of fuel type $i$ in ground transport combustion, on an energy basis (i.e., expressed in units of energy TJ)</td>
<td>%</td>
<td>In order of preference:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- National statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Indicative national reports or studies, expert estimate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- A share of 50% diesel and 50% motor gasoline may be assumed in the absence of any suitable national information</td>
</tr>
</tbody>
</table>

Step 3: Compile emission factors

The emission factors ($EF_i$) represent the amount of CO$_2$ emissions expected to result from combusting a unit of fuel, and are based on the total carbon content of the fuel. In Approach A, emissions of methane (CH$_4$) or nitrous oxide (N$_2$O) are ignored for simplification. Users should take into account the different transport fuels utilised 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 of this guidance, emission factors consider only tank-to-wheel emissions and no “upstream” or well-to-tank emissions.

Table 7.3 provides an overview of the emission factor parameters for Approach A with possible data sources.

**Table 7.3: Emission factor parameters for Approach A**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Emission factor for fuel type i</td>
<td>tCO&lt;sub&gt;2&lt;/sub&gt;/TJ</td>
<td>In order of preference:</td>
</tr>
</tbody>
</table>

- National energy or environmental statistics
- National fuel providers, such as refineries and/or fuel importers, based on their measurements
- Default values. Diesel: 74.1 tCO<sub>2</sub>/TJ, Gasoline: 69.3 tCO<sub>2</sub>/TJ (both IPCC 2006, Vol. 2 Ch. 3 Table 3.2.1)

Step 4: Calculate base year emissions for the selected year

Calculate base year emissions for the selected year <i>y</i> by using the collected activity data (fuel used <i>F<sub>y</sub></i>, share of fuel type <i>S<sub>i</sub></i>) and emission factors (<i>EF<sub>i</sub></i>) as inputs to the following equation. For each fuel type <i>i</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 (<i>BE<sub>y</sub></i>).

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

Base year emissions for year <i>y</i>: 

\[ BE_y = \sum_i F_y \text{ (in TJ)} \times S_i \text{ (in %)} \times EF_i \text{ (in } \frac{tCO_2}{TJ}) \]

The results represent the GHG emissions (CO<sub>2</sub> only) from fuel consumption in ground transport for the selected year in the baseline scenario, in units of tCO<sub>2</sub> (i.e., in the absence of the policy).

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

**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 be targeted at 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, and 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 follows Step 1. *Align geographic aggregation* and determines 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 chooses to use the default values since other values are not available.

The Ministry staff determines the base year emissions by applying Step 4. Calculate base year emissions for the selected year:

Base year emissions for year $y = (782,000 \text{TJ} \times 50\% \times 74.1 \text{tCO}_2/\text{TJ}) + (782,000 \text{TJ} \times 50\% \times 69.3 \text{tCO}_2/\text{TJ}) = 28,973,100 \text{tCO}_2 + 27,096,300 \text{tCO}_2 = 56,069,400 \text{tCO}_2$

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

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 calculate GHG impacts (CO$_2$ only) where separate data are available on the annual fuel consumption of gasoline and diesel. It is appropriate to use Approach B where separate data are available on annual fuel consumption of 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 a proxy for light duty vehicles (LDV) that tend to use gasoline, and heavy duty vehicles (HDV) that tend to use diesel. LDVs are vehicles with a gross vehicle mass (GVM) up to around 3,900 kg$^5$, such as typical passenger cars with a GVM of around 1,800 kg. They are utilised mainly for personal travel.

HDVs are vehicles with a higher gross vehicle mass that 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) versus commercial vehicles (HDV). Price elasticities are often different for these two groups of vehicles,$^6$ accounting for the fact that there is not perfect congruency between each 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 described in Step 1 of 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 the national borders.$^7$

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$^6$ Dahl 2012.

$^7$ Users should note that this is a conservative assumption since, by ignoring upstream emissions, emissions reductions are also excluded from the results.
Step 2: Compile activity data

The activity data are comprised of 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, as long as disaggregated data are available. Users should obtain the 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 Section 7.1.

The third alternative is to use international sources, such as International Energy Agency country statistics.\(^8\)

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

- **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 vary considerably. 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 back-up electricity generation at private homes using diesel generators
  - For countries with subsidised 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, users can report the related uncertainty but omit the consideration from the calculations.

During the compilation of activity data, it is also necessary to 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 in order 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 prior to applying the emission factor, for example using the method provided by the IPCC.\(^9\)

Table 7.4 provides an overview of activity parameters for Approach B, as well as possible data sources.

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\(^8\) Available at: [http://www.iea.org/statistics/](http://www.iea.org/statistics/).

Table 7.4: Activity parameters for Approach B

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{G,y}$</td>
<td>Total gasoline fuel used for ground transport in year $y$</td>
<td>TJ</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy balance or similar national energy statistics</td>
</tr>
<tr>
<td>$F_{D,y}$</td>
<td>Total diesel fuel used for ground transport in year $y$</td>
<td>TJ</td>
<td>• Data collection process</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• International sources, such as IEA</td>
</tr>
</tbody>
</table>

Where activity data are expressed in volume units (i.e., in litres or gallons), the user will need to apply fuel density values ($\rho_i$) 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, including possible sources of data.

Table 7.5: Conversion factors for activity data for Approach B

<table>
<thead>
<tr>
<th>Conversion factor</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_i$</td>
<td>Density of fuel type $i$</td>
<td>kg/m$^3$</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reliable international sources$^{10}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Default values. Diesel: 835 kg/m$^3$ at 15 deg C (Directive 1998/69/EC)$^{11}$. Gasoline: 720 kg/m$^3$ at 15 deg C (NOAA)$^{12}$</td>
</tr>
<tr>
<td>$NCV_i$</td>
<td>NCV of fuel type $i$</td>
<td>TJ/Gg</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reliable international sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Default values. Diesel: 43.0 TJ/Gg, Gasoline: 44.3 TJ/Gg (both IPCC 2006, Vol. 2 Ch. 1 Table 1.2)</td>
</tr>
</tbody>
</table>

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 $F_{i,y}$).

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$^{10}$ For more information on data collection, see the IPCC Guidelines available at: [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_2_Ch2_DataCollection.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_2_Ch2_DataCollection.pdf)


$^{12}$ NOAA. Available at: [https://cameochemicals.noaa.gov/chemical/11498](https://cameochemicals.noaa.gov/chemical/11498)
Equation 7.2: Estimation of gasoline and diesel use in energy units (TJ) for Approach B (input: volume units in L)

\[ F_{G,Y} \text{ in energy units (TJ)} = F_{C_{G,Y}} \text{ in volume units (L)} \times \rho_G \times NCV_G \times 10^9 \]

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

\[ F_{G,Y} \text{ in energy units (TJ)} = F_{C_{G,Y}} \text{ in mass units (Gg)} \times NCV_G \]

Step 3: Compile emission factors

The emission factors \((EF)\) 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 methane (CH\(_4\)) and nitrous oxide (N\(_2\)O) for simplification. 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 of this guidance, 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.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>(EF_G)</td>
<td>Emission factor for gasoline fuel</td>
<td>tCO(_2)/TJ</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy or environmental statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National fuel providers, such as refineries and/or fuel importers, based on their measurements</td>
</tr>
<tr>
<td>(EF_D)</td>
<td>Emission factor for diesel fuel</td>
<td>tCO(_2)/TJ</td>
<td>• Default values. Gasoline: 69.3 tCO(_2)/TJ, Diesel: 74.1 tCO(_2)/TJ (both IPCC 2006, Vol. 2 Ch. 3 Table 3.2.1)</td>
</tr>
</tbody>
</table>

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 \((BE_{i,y})\) associated with that fuel type \(i\) 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 \(y\): \(BE_{\text{gasoline}, y} = F_{G,Y} \text{ (in TJ)} \times EF_G \text{ (in } \frac{tCO_2}{TJ})\)

Base year emissions from diesel for year \(y\): \(BE_{\text{diesel}, y} = F_{D,Y} \text{ (in TJ)} \times EF_D \text{ (in } \frac{tCO_2}{TJ})\)

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.
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 be targeted at 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, and 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\(_{\text{G},y}\)) were used that year, and 8,000 Gg of diesel (FC\(_{\text{D},y}\)). 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 follows Step 1: Align geographic aggregation and determines 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.

\[ F_{\text{G},y} = 7,860 \text{ Gg} \times 44.3 \text{ TJJ/Gg} = 348,198 \text{ TJ} \quad \text{(Equation 7.3)} \]

\[ F_{\text{D},y} = 8,000 \text{ Gg} \times 43.0 \text{ TJJ/Gg} = 344,000 \text{ TJ} \quad \text{(Equation 7.3)} \]

Under Step 3: Compile emission factors, the Ministry staff chooses to use the default values since other values are not available.

The Ministry staff determines 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\(_{\text{gasoline},y} = 348,198 \text{ TJ} \times 69.3 \text{ tCO}_2/\text{TJ} = 24,130,121 \text{ tCO}_2 \) (see Equation 7.4)

Base year emissions from diesel for year \( y \) BE\(_{\text{diesel},y} = 344,000 \text{ TJ} \times 74.1 \text{ tCO}_2/\text{TJ} = 25,490,400 \text{ tCO}_2 \) (see Equation 7.4)

Thus, the result shows there are about 50 MtCO\(_2\) emissions in the base year from the two fuels (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 motorised transport by cars with public transport (and non-motorised 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 both the assessment of a policy’s impact on GHG emissions, and also the assessment of impacts 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 guidance 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 guidance is restricted to public passenger transport. For shifts to electric mobility, CNG or non-motorised transport, the method can be applied as well (if data is 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 utilises both top-down energy use and bottom-up travel activity data to estimate base year emissions (see Section 4.2.2 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: a) freight transport cannot be assessed with the proposed calculation (though users can apply the approach to freight transport as well using different input data and cross-price elasticities), and b) 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 emission reductions achieved through the policy. However, the approach provides further information regarding mode shift.

The method is based on the ASIF terminology (see Appendix E ASIF Terminology 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 PKMs 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 Approach C base year emissions calculation formula. In addition to calculating total base year emissions, the base year emissions are also divided by PKM (see Figure 7.5) in order to obtain a ratio which can be used to quantify the impacts of the policy in Chapter 8.2.

**Figure 7.4: Calculation of total base year GHG emissions for Approach C**

\[
\text{Activity data} \times \text{Emission factor} = \text{Base year emissions (e.g., tCO}_2\text{e)}
\]

**Figure 7.5: Calculation of base year GHG emissions per PKM**

\[
\text{Base year GHG emissions (e.g., tCO}_2\text{e)} \div \text{Passenger kilometres} = \text{Base year GHG emissions per passenger kilometre (e.g., tCO}_2\text{e/pkm)}
\]

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 (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 emission calculation for the biofuel can be conducted with the analogous equations as for the fossil fuel share. If possible, country-specific
emission factors (and where relevant NCVs) should be used. If such country-specific data is not available, the Renewable Energy Directive\footnote{Renewable energy directive from the European Commission, published in 2009. The directive is currently being revised. Available at: \url{https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive}.} (European Commission, 2009) provides default values that can be used.

For the calculation of base year emissions in passenger transport, follow the steps in Figure 7.6

*Figure 7.6: Overview of steps for Approach C*

Step 1. Align geographic aggregation

Follow the same approach as described for Approaches A and B in Step 1 of Section 7.2.1 to align the geographic aggregation of the activity data and the policy.

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.

*Table 7.7: Activity data for Approach C (in energy units)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Activity data (in energy units)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_{i,j,y}$</td>
<td>Total fuel energy $i$ (from gasoline / diesel / electricity) used per mode $j$ of passenger transport (road / rail) in year $y$</td>
<td>TJ</td>
</tr>
<tr>
<td>Example: $F_{\text{Diesel, rail, 2020}}$: Total energy used (in TJ) from diesel fuels in rail passenger transport in the year 2020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| $PKM_{i,j,y}$ | Total PKMs travelled per mode $j$ of passenger transport (road / rail) in year $y$ | TJ     |
| Example: $PKM_{\text{diesel, rail, 2020}}$: Total PKMs travelled in rail passenger transport with diesel fuel in the year 2020 |

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 in order 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. If a different basis is used, the values should be converted prior to applying the emission factor, for example using the method provided by the IPCC.\textsuperscript{14}

The estimation of the bottom-up travel activity data and the calculation of fuel energy used ($F_{x,ij,y}$) differs 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

In order to estimate the activity data for road passenger transport in mass units (TJ) as depicted in Table 7.7, follow these three steps:

1. Estimate activity data in volume units (total litres of fuel used; $FC_{ij,y}$) for each fuel type $i$, 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; $PKM_{ij,y}$) 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 ($FC_{ij,y}$) with conversion factors (e.g., NCV, density) in order to estimate the total fuel energy used (TJ; $F_{ij,y}$) for each fuel type $i$, each passenger transport mode $j$ in the respective year $y$.

Two outputs are obtained from the 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 in order 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 for 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.\textsuperscript{15}

\textbf{Table 7.8: Overview of bottom-up travel activity parameters (sources are in order of priority)}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Unit</th>
<th>Sources</th>
</tr>
</thead>
</table>
| $d_{ij,y}$ | Distance travelled (with fuel type $i$, mode $j$, in year $y$). | VKT | $d_{\text{gasoline, car},y}$: 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)  

$d_{\text{diesel, bus},y}$: diesel-powered passenger buses  
- Municipal, regional or national statistics or studies (from transit authorities) |

\textsuperscript{14} Available at: \url{http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf#page=17}.

\textsuperscript{15} For further information about parameter estimation, refer to UNFCCC 2014. Available at: \url{https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-18-v1.pdf}.
<table>
<thead>
<tr>
<th>$l_{ij,y}$</th>
<th>Load factor / Occupancy</th>
<th>Municipal, regional or national surveys (traffic counting, odometer reading, appropriate vehicle stock data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (per VKT) number of persons travelling in same vehicle (with mode $j$ in year $y$). (only needed for estimation of PKM)</td>
<td>Persons per vehicle $l_{car,y}$: passenger cars</td>
<td></td>
</tr>
<tr>
<td>$sfc_{ij,y}$</td>
<td>Average fuel consumption</td>
<td>Municipal, regional or national statistics or studies (from transit authorities)</td>
</tr>
<tr>
<td>Specific fuel consumption. Average consumption per VKT in municipal, regional or national fleet (with fuel type $i$, mode $j$, in year $y$).</td>
<td>Municipal, regional or national data collection process or surveys</td>
<td></td>
</tr>
<tr>
<td>$sfc_{gasoline, car,y}$: gasoline-powered passenger cars</td>
<td>Supra-regional default value (e.g., for continent). Else global default value: 2 persons, including the driver (UNFCCC 2014)</td>
<td></td>
</tr>
<tr>
<td>$sfc_{diesel, bus,y}$: diesel-powered passenger buses</td>
<td>Else global default value: 40% of total capacity (UNFCCC 2014)</td>
<td></td>
</tr>
</tbody>
</table>

---

16 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.

17 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 gasoline and diesel use in car and bus passenger transport for Approach C**

Total fuel consumption $\mathbf{FC}_{i,j,y}$ in volume units (litres)

$$
\mathbf{FC}_{i,j,y} = d_{i,j,y} \times s f_{i,j,y} \text{ (in litre per VKT)}
$$

Since the fuel consumption is expressed in volume units (i.e., in litres or gallons), as shown in Table 7.8, apply fuel density values ($\rho_i$) 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, apply national values 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 ($F_x_{i,j,y}$) for passenger cars and buses using Approach C, including units and possible data sources.

**Table 7.9: Conversion factors for the estimation of total fuel energy used ($F_x_{i,j,y}$) for passenger cars and buses for Approach C**

<table>
<thead>
<tr>
<th>Conversion factor</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_i$</td>
<td>Density of fuel type $i$</td>
<td>kg/m$^3$</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reliable international sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Default values. Diesel: 835 kg/m$^3$ at 15 deg C (Directive 1998/69/EC)$^{18}$, Gasoline: 720 kg/m$^3$ at 15 deg C (NOAA)$^{19}$</td>
</tr>
<tr>
<td>$NCV_i$</td>
<td>NCV of fuel type $i$</td>
<td>TJ/Gg</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Reliable international sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Default values. Diesel: 43.0 TJ/Gg, Gasoline: 44.3 TJ/Gg (both IPCC 2006, Vol. 2 Ch. 1 Table 1.2)</td>
</tr>
</tbody>
</table>

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 TJ fuel energy use in car and bus passenger transport for Approach C**

$\mathbf{F}_{i,j,y}$ in energy units (TJ) = $\mathbf{FC}_{i,j,y}$ in volume units (litre) $\times \rho_i \times NCV_i \div 10^9$

---


$^{19}$ NOAA. Available at: [https://cameochemicals.noaa.gov/chemical/11498](https://cameochemicals.noaa.gov/chemical/11498).
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. In order to estimate the activity data for rail passenger transport in mass units (TJ) as depicted 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 (without any bottom-up travel activity parameters).

3. Multiply the activity data in volume units \( (FC_{i,rail,y}) \) with conversion factors (e.g., NCV, density, energy conversion units) in order 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 the three steps outlined above. 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 in order 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.

Table 7.10: Overview of activity data parameters (sources are in order of priority)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
</table>
| \( FC_{i,rail,y} \) | 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)  
\( FC_{electricity, rail,y} \): electric powered passenger rail  
  - Municipal, regional or national statistics or studies (from transit authorities)  
  - Municipal, regional or national surveys (e.g., from transit companies) |
| \( PKM_{rail,y} \) | Ideally, PKMs are available separately for diesel and electricity travel.  
Else, estimate total PKMs travelled in rail passenger | PKM | \( PKM_{rail,y} \): PKMs 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) |
As in Step 2a, fuel consumption of diesel is expressed in volume units (i.e., in litres or gallons). The conversion factors from Table 7.9: Conversion factors for the estimation of total fuel energy used (Fx,i,y) for passenger cars and buses for Approach C 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**

\[ F_{\text{diesel, rail, } y} \text{ in energy units (TJ)} = F_{\text{C, diesel, rail, } y} \text{ in volume units (litre)} \times \rho_i \times NCV_i \div 10^9 \]

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 TJ electricity use in rail passenger transport for Approach C**

\[ F_{\text{electricity, rail, } y} \text{ in energy units (TJ)} = F_{\text{C, electricity, rail, } y} \text{ in MWh} \times 0.0036 \]

More detailed activity data collection can improve the accuracy and uncertainty of these results. See the Reference Document on Measurement, Reporting and Verification in the Transport Sector for more information on how to improve activity data collection.

**Step 3: Compile emission factors**

The emission factors (EF) represent the amount of CO₂ emissions expected to result from a) combusting a unit of fuel (e.g., gasoline, diesel) based on the total carbon content of the fuel and b) 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 methane (CH₄) and nitrous oxide (N₂O) for simplification.

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.

**Table 7.11: Emission factor parameters for Approach C**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Units</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF gasoline</td>
<td>Emission factor for gasoline fuel</td>
<td>tCO₂/TJ</td>
<td>In order of priority:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy or environmental statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National fuel providers; for example refineries and/or fuel importers, based on their measurements</td>
</tr>
<tr>
<td>EF diesel</td>
<td>Emission factor for diesel fuel</td>
<td>tCO₂/TJ</td>
<td>• Global default values. Gasoline: 69,300 kgCO₂/TJ,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diesel: 74,100 kgCO₂/TJ (both IPCC 2006, Vol. 2 Ch. 3 Table 3.2.1)</td>
</tr>
</tbody>
</table>
ICAT Transport Pricing Guidance, May 2018

<table>
<thead>
<tr>
<th>$EF_{\text{electricity}}$</th>
<th>Emission factor for electricity</th>
<th>kgCO$_2$/TJ</th>
<th>In order of priority:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National energy or environmental statistics (electricity mix)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• National fuel providers; for example refineries and/or fuel importers, based on their measurements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Supra-regional default value (e.g., for continent). Else global default value: mainly conventional/fossil electricity production: 110,000 kgCO$_2$/TJ; at least 50% renewable share: 220,000 kgCO$_2$/TJ (assumption by the authors of this guidance document, based on UNFCCC 2014)</td>
</tr>
</tbody>
</table>

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 with 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**

$BE_{ijy}$ in CO$_2$ emissions (t CO$_2$) = $FC_{ijy}$ in energy units (TJ) x $EF_i$ (t CO$_2$ per TJ)

Step 5: Estimate passenger kilometres

For **road transport** (gasoline cars and diesel buses$^{20}$), the estimation can be conducted as shown in Equation 7.10 (for parameters, see Step 2a):

**Equation 7.10: Estimation of PKMs for car and bus passenger transport for Approach C**

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

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

For **rail transport**, PKMs are ideally estimated for both fuel energy types (diesel and electricity) separately (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 PKMs (for both diesel- and electric-powered rail). In this case, the energy efficiencies ($\eta$) of diesel and

$^{20}$ As a simplification, the guidance is restricted to gasoline cars and diesel buses for Approach C (assuming that most of the passenger LDV transport is powered with gasoline, whereas most of the 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, or LPG) by using analogous equations with different input data (i.e. travel activity data, emission factors and elasticity values).
electricity need to be considered, since the operation of a train with electricity is much more efficient than with diesel\(^2\). They can be differentiated for the two fuel types as follows:

**Equation 7.11:** Estimation of PKMs for diesel and electric rail transport for Approach C

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

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

Step 6: Calculate ratio of total emissions per mode versus PKMs

The total base year emissions can now be divided by the PKMs:

**Equation 7.12:** Estimation of total base year emissions per PKM (PKM) for Approach C

\[
BE_{\text{PKM},ij,y} \text{ in CO}_2 \text{ emissions (kg CO}_2\text{) per passenger kilometre} = BE_{ij,y} \text{ (kg CO}_2\text{)} \div PKM_{ij,y}
\]

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

**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 be targeted at 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, the Ministry plans to assess changes in travel demand for the passenger transport modes directly and indirectly affected by the fuel levy.

The Ministry staff follows Step 1. **Align geographic aggregation** and determines that the data does not align with the new levy that will be applied nationwide. They decide to focus the GHG impact assessment only 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 estimates the total fuel energy used for road passenger transport (cars and buses; step 2a). They obtain the data on distance travelled from the national transit authorities (from a traffic counting study):

\[
d_{\text{gasoline, car,y}} = 10,900 \text{ million VKT}
\]

\[
d_{\text{diesel, bus,y}} = 980 \text{ million VKT}
\]

\(^2\) Assumption: 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 guidance document based on expert judgment.
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:

\[ l_{\text{car},y} = 2 \text{ persons, including the driver} \]
\[ l_{\text{bus},y} = 40\% \text{ of total capacity. The Ministry staff assumes that the buses have 40 seats on average.} \]
\[ \text{The average load factor equals } 40\% \times 40 \text{ seats} = 16 \text{ taken seats per VKT.} \]
\[ sfc_{\text{gasoline, car},y} = 10 \text{ litres per 100 VKT} \]
\[ sfc_{\text{diesel, bus},y} = 50 \text{ litres per 100 VKT} \]

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

\[ FC_{\text{gasoline,car},y} = 10,900,000,000 \text{ VKT} \times 0.1 \text{ litre per VKT} = 1,090 \text{ million litres of gasoline} \quad (\text{Equation 7.5}) \]
\[ FC_{\text{diesel,bus},y} = 980,000,000 \text{ VKT} \times 0.5 \text{ litre per VKT} = 490 \text{ million litres of diesel} \quad (\text{Equation 7.5}) \]

For the conversion of fuel consumption in volume units to energy units, the Ministry staff uses the default density and NCV values as depicted in Table 7.9:

\[ F_{\text{gasoline,car},y} = 1,090,000,000 \text{ L} \times 720 \text{ kg/m}^3 \times 44.3 \text{ TJ/Gg} \div 10^9 = 34,767 \text{ TJ} \quad (\text{Equation 7.6}) \]
\[ F_{\text{diesel,bus},y} = 490,000,000 \text{ L} \times 835 \text{ kg/m}^3 \times 43.0 \text{ TJ/Gg} \div 10^9 = 17,593 \text{ TJ} \quad (\text{Equation 7.6}) \]

Second, the Ministry staff estimates 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):

\[ FC_{\text{diesel,rail},y} = 300 \text{ million litres of diesel} \]
\[ FC_{\text{electricity,rail},y} = 440,000 \text{ MWh} \]

The Ministry staff uses the default density and NCV values in order to convert the fuel consumption in volume unit to as depicted in Table 7.9:

\[ F_{\text{diesel,rail},y} = 300,000,000 \text{ L} \times 835 \text{ kg/m}^3 \times 43.0 \text{ TJ/Gg} \div 10^9 = 10,772 \text{ TJ} \quad (\text{Equation 7.7}) \]
\[ F_{\text{electricity,rail},y} = 440,000 \text{ MWh} \times 0.0036 = 1,584 \text{ TJ} \quad (\text{Equation 7.8}) \]

Under Step 3. Compile emission factors, the Ministry staff chooses 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.

\[ EF_{\text{gasoline}} = 69.3 \text{ tCO}_2/\text{TJ} \]
\[ EF_{\text{diesel}} = 74.1 \text{ tCO}_2/\text{TJ} \]
\[ EF_{\text{electricity}} = 220.0 \text{ tCO}_2/\text{TJ} \]
Next, the Ministry staff determines the base year emissions by applying Step 4. Calculate base year emissions for the selected year:

\[ BE_{\text{gasoline, car, y}} = 34,767 \text{ TJ} \times 69.3 \text{ tCO}_2/\text{TJ} = 2,409,328 \text{ tCO}_2 \] (Equation 7.9)

\[ BE_{\text{diesel, bus, y}} = 17,593 \text{ TJ} \times 74.1 \text{ tCO}_2/\text{TJ} = 1,303,675 \text{ tCO}_2 \] (Equation 7.9)

\[ BE_{\text{diesel, rail, y}} = 10,772 \text{ TJ} \times 74.1 \text{ tCO}_2/\text{TJ} = 798,168 \text{ tCO}_2 \] (Equation 7.9)

\[ BE_{\text{electricity, rail, y}} = 1,584 \text{ TJ} \times 220.0 \text{ tCO}_2/\text{TJ} = 348,480 \text{ tCO}_2 \] (Equation 7.9)

The Ministry staff follows Step 5. Estimate PKMs and estimates PKMs (PKM) for all the passenger transport modes.

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

\[ PKM_{\text{gasoline, car, y}} = 10,900,000,000 \text{ VKT} \times 2 \text{ persons} = 21,800 \text{ million PKM} \] (Equation 7.10)

\[ PKM_{\text{diesel, bus, y}} = 980,000,000 \text{ VKT} \times 16 \text{ persons} = 15,680 \text{ million PKM} \] (Equation 7.10)

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

\[ PKM_{\text{rail, y}} = 18,000 \text{ million PKM} \]

Starting from this cumulated value, the Ministry staff calculates the share of rail PKM with diesel and electricity:

\[ PKM_{\text{diesel, rail, y}} = 18,000 \text{ million PKM} \times \left( \frac{(10,772 \text{ TJ} \times 0.3)}{(10,772 \text{ TJ} \times 0.3) + (1,584 \text{ TJ} \times 0.9)} \right) = 12,490 \text{ million PKM} \] (Equation 7.11)

\[ PKM_{\text{electricity, rail, y}} = 18,000 \text{ million PKM} \times \left( \frac{(1,772 \text{ TJ} \times 0.9)}{(10,772 \text{ TJ} \times 0.3) + (1,584 \text{ TJ} \times 0.9)} \right) = 5,510 \text{ million PKM} \] (Equation 7.11)

The next step is Step 6. Calculate ratio of total emissions vs. PKMs. This calculation allows the Ministry staff to compare the different modes on their emission efficiency.

\[ BEPKM_{\text{gasoline, car, y}} = \frac{2,409,328,000,000 \text{ gCO}_2}{21,800,000,000} \text{ PKM} = 111 \text{ gCO}_2/\text{PKM} \] (Equation 7.12)

\[ BEPKM_{\text{diesel, bus, y}} = \frac{1,303,675,000,000 \text{ gCO}_2}{15,680,000,000} \text{ PKM} = 83 \text{ gCO}_2/\text{PKM} \]

\[ BEPKM_{\text{diesel, rail, y}} = \frac{798,168,000,000 \text{ gCO}_2}{12,489,902,406} \text{ PKM} = 64 \text{ gCO}_2/\text{PKM} \]

\[ BEPKM_{\text{electricity, rail, y}} = \frac{348,480,000,000 \text{ gCO}_2}{5,510,097,594} \text{ PKM} = 63 \text{ gCO}_2/\text{PKM} \]

Thus, the result shows that there are approximately 4.86 Mt CO\text{2} annual emissions in the base year with all the modes (passenger gasoline car, diesel bus, diesel train and electric train).

---

22 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\text{2}/TJ), the \( BEPKM_{\text{electricity, rail, y}} \) would be approximately 32 gCO\text{2}/PKM.
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, and in particular the principle of accuracy. The assessments done using Approach C produce highly uncertain results for fuel use in passenger transport due to the following limitations:

- Uncertainties in parameter estimations are major (e.g., distance travelled) 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)
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. It is necessary for most calculation parameters identified in Sections 7.1 and 7.2 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 Section 7.3.

Figure 7.7: Overview of steps for projecting baseline emissions

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

This step is comprised of two sub-steps: Determining the influencing policies and actions, followed by determining the direction and significance of effects.

Step 1a: Determine influencing policies and actions

National strategies and goals influence policies and actions that are likely to be implemented within the assessment period. They include general development strategies, NDCs, climate strategies or dedicated sector strategies, such as energy and transport strategies.

Users should assess the influence of policies and actions (other than the one being assessed) on transport sector developments when projecting the baseline scenario. Some policies and actions 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 and actions together with the pricing policy as a package. In such cases, their impact would not be considered here in determining the baseline. In all other cases, their impact should be part of the baseline.

Users that are assessing the sustainable development, transformational or other GHG impacts of the policy should use the same underlying assumptions about macroeconomic conditions, demographics and other non-policy drivers. For example, if GDP is a macro-economic condition needed for assessing both the job impacts and economic developments 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 and actions, but also by other factors. In particular, technology innovation can be a critical factor influencing baseline developments. Here it is important to consider not only the most obvious policies and actions, but also to consider policies outside the transport sector. A few examples are provided in Table 7.12.
Table 7.12 Examples of policies and actions influencing transport sector developments

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

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 and actions should be. The main question related to the effect of other policies and actions is whether their influence on expected developments mainly provides a continuation of past trends or constitutes a shift from previous trends. If the general assessment is that these policies and actions impact the trend, the next question is in which direction, how much (magnitude) and 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 as 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.

Table 7.13 Assessing the relative magnitude of effects

<table>
<thead>
<tr>
<th>Relative magnitude of impacts</th>
<th>Description</th>
<th>Approximate relative magnitude (rule of thumb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
<td>The policy or action significantly influences one or more of the trends in transport sector development. The resulting change in relevant parameters is</td>
<td>&gt; 10%</td>
</tr>
</tbody>
</table>
likely to be a significant change from current status and past trends.

Moderate
The policy or action 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.

Minor
The effect has little or no influence on the expected developments in the transport sector. The change in parameter values is insignificant.

Source: Adapted from WRI 2014.

Example: If car ownership per capita has increased by 2% per year in recent years, the question is whether policies or actions 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, as 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 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 percent points to 70.7% annual growth would be considered minor (a relative magnitude of 1%), while a 15% change in relative magnitude to 80.5% annual growth would be considered major.

Different policies and actions may influence the same parameters within the transport sector. They can be reinforcing, overlapping or independent. The relative magnitude of effects should be determined for each policy and action separately and should identify those parameters that are most likely affected together with the estimated relative magnitude of the effect.

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 developments 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.23

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.

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23 Secondary factors can be directly influenced by primary factors (e.g., 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

<table>
<thead>
<tr>
<th>Category of data</th>
<th>Projection necessary for simplified method (Section 7.4.3)</th>
<th>Projection necessary for advanced methods (Section 7.4.3)</th>
<th>Influenced by</th>
<th>Population</th>
<th>GDP</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approach A and B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel use</td>
<td>Yes</td>
<td>Yes</td>
<td>Major</td>
<td>Moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emission factors per fuel</td>
<td>No Constant values(^{24})</td>
<td>No Constant values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon content</td>
<td>No Constant values</td>
<td>No Constant values</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fleet composition</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Major</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distances travelled (VKT)</td>
<td>Yes</td>
<td>Yes</td>
<td>Minor</td>
<td>Moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trips</td>
<td>No</td>
<td>Yes</td>
<td>Major</td>
<td>Minor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Load factor</td>
<td>No</td>
<td>Yes</td>
<td>Moderate</td>
<td>Minor</td>
<td>Attractiveness, cost, availability</td>
<td></td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Technological development</td>
<td></td>
</tr>
</tbody>
</table>

For Approaches A and B, fuel use is influenced by population and economic growth, while emissions 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 for meaningful projections.

7.4.3 Step 3: Determine method for projection

There are different methods available to project individual parameters and overall emissions. They vary in the 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.

\(^{24}\) Emission factors for each fuel type are mainly determined by the carbon content of the fuel.
If a time series is available, use statistical methods to determine trends. These trends can also be adjusted to reflect the analysis of the expected influence of 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, it may be more robust to use a multi-year average. 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 on 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*

<table>
<thead>
<tr>
<th>Time series data available</th>
<th>Only data point available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplified</td>
<td>Using per capita or per GDP ratio</td>
</tr>
<tr>
<td>Advanced</td>
<td>Application of comparable growth rates</td>
</tr>
<tr>
<td>Trend analysis of parameters</td>
<td>Trend with adjustments</td>
</tr>
<tr>
<td>Modelling</td>
<td>Increasing complexity and data needs</td>
</tr>
</tbody>
</table>

### 7.4.4 Step 4: Calculate baseline emissions

In Step 4, calculate emissions for each year based on projected parameter values using methods set out 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 guidance on performing calculations using the 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: Simple approach to projecting parameters using population projections
Box 7.4 provides possible sources for projections of population and GDP, while Box 7.5 provides an example illustrating the simplified method to 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.

**Box 7.4: Sources for population and GDP projections**

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

**Population**
- National statistics offices or similar agencies normally provide detailed country-level projections
- The UN Department of Economic and Social Affairs Population Division regularly publishes the *World Population Prospects*. Available at: [https://esa.un.org/unpd/wpp/](https://esa.un.org/unpd/wpp/)

**GDP**
- National statistics offices, economic or development ministries or similar agencies
- The International Monetary Fund regularly publishes the World Economic Outlook, including projections on key financial indicators, such as GDP (currently until 2021). Available at: [http://www.imf.org/en/data](http://www.imf.org/en/data)

**Box 7.5: Example of simplified method for projecting scenarios for Approach A**

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

The Ministry staff starts with *Step 1: Determine elements for projection*. They decide to use the simplified method to project scenarios due to low data availability. Therefore, they keep the emission factors for fuels constant and only apply a projection to the fuel use.

In *Step 2: Determine method for projection*, the Ministry staff chooses 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 executes the calculations in *Step 3: Calculate baseline emissions*. From their earlier calculations (see Box 7.1) they know the fuel consumption in the current year:

$$F_y = 782,000 \text{ TJ}, \text{ of which 50\% gasoline and 50\% diesel}$$

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

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

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

The Ministry staff assumes 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 with the projected population numbers:

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

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

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Year $y$ (historic)</th>
<th>Year $y+1$ (proj.)</th>
<th>Year $y+2$ (proj.)</th>
<th>Year $y+3$ (proj.)</th>
<th>Year $y+4$ (proj.)</th>
<th>Year $y+5$ (proj.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (in millions)</td>
<td>Millions</td>
<td>50.0</td>
<td>50.8</td>
<td>51.5</td>
<td>52.3</td>
<td>53.1</td>
<td>53.9</td>
</tr>
<tr>
<td>Per capita ratio:</td>
<td>GJ per capita</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>gasoline consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per capita ratio:</td>
<td>GJ per capita</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>diesel consumption</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{gasoline,y}$ (projected)</td>
<td>TJ</td>
<td>391,000</td>
<td>396,865</td>
<td>402,818</td>
<td>408,860</td>
<td>414,993</td>
<td>421,218</td>
</tr>
<tr>
<td>$F_{diesel,y}$ (projected)</td>
<td>TJ</td>
<td>391,000</td>
<td>396,865</td>
<td>402,818</td>
<td>408,860</td>
<td>414,993</td>
<td>421,218</td>
</tr>
<tr>
<td>$BE_{gasoline,y}$ (projected)</td>
<td>ktCO$_2$</td>
<td>27,096</td>
<td>27,503</td>
<td>27,915</td>
<td>28,334</td>
<td>28,759</td>
<td>29,190</td>
</tr>
<tr>
<td>$BE_{diesel,y}$ (projected)</td>
<td>ktCO$_2$</td>
<td>28,973</td>
<td>29,408</td>
<td>29,849</td>
<td>30,297</td>
<td>30,751</td>
<td>31,212</td>
</tr>
<tr>
<td>$BE_{total,y}$ (projected)</td>
<td>ktCO$_2$</td>
<td>56,069</td>
<td>56,910</td>
<td>57,764</td>
<td>58,631</td>
<td>59,510</td>
<td>60,403</td>
</tr>
</tbody>
</table>
Option 2: Advanced methods for projecting scenarios

**Application of comparable growth rates**

Assuming constant absolute values is in most cases an over-simplification of expected real developments. Using the per capita ratio or intensities is already a means to address this, but still falls short of real world developments, particularly since it is more than one factor that 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.

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

\[
\begin{align*}
\text{Fuel use per capita in year } 2 &= \text{fuel use per capita in historic data year } x \times (1 + \text{growth rate}) \\
\text{Fuel use per capita in year } 3 &= \text{fuel use per capita in year } 2 \times (1 + \text{growth rate})
\end{align*}
\]

Using the example in figure Y and applying a growth rate of 3%, this would result in the following values:

\[
\begin{align*}
\text{Fuel use per capita in year } 2 &= 0.0001 \text{ TJ per capita} \times (1 + 0.3) = 0.000206 \text{ TJ per capita} \\
\text{Fuel use per capita in year } 3 &= 0.000206 \text{ TJ per capita} \times (1 + 0.3) = 0.000206 \text{ TJ per capita}
\end{align*}
\]

**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. As such, it 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 historic developments (trend) into the future in the form of a linear increase or decrease of parameters. This technique is often used in the extrapolation of historic efficiency development in vehicle efficiency (also called autonomous technology development). Constant growth rates lead to linear trends.

- **Non-linear trends**: Non-linear developments are usually captured by 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 period.
  - 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.

**Figure 7.10: Projecting parameters using linear and non-linear trends**

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

- **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 the 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 in a clear curve. Values change from year to year based on a wide range of influencing factors. The larger and more unpredictable these fluctuations are, the less a trend will represent likely developments. Population, for example normally has a relatively uniform development with very limited fluctuations. GDP on the other hand, shows frequent and strong fluctuations that make the determination of a trend and the projection of future GDP development challenging.

- **Expected changes in fundamental drivers**: As discussed above, policies and actions can influence the underlying drivers of individual parameters. Additionally, these can 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. While there is little we can do to capture natural and man-made catastrophes in projections, the next section discusses how to factor in some of the developments we can already foresee.
Trend with adjustments

To add another layer of analysis to the trend, the influence of policies and actions 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 which have individual dates for coming into operation. The starting point can also be the start point of the assessment, if policies or actions are already in place, but are not yet expected to be represented in the observed trend.

2. **Translate qualitative assessment into quantitative effect**: the main question is whether the effect is:
   - A one-time effect: it changes the value of the trend for the year where it occurs and then continues the trend from that new value
   - A continuous effect: effects keep influencing the parameter and lead to a complete deviation from the trend. This deviation can, as the trend itself, be linear or non-linear. The application of a learning curve, for example to reflect autonomous technology improvement, would be a classical example for a continuous, non-linear effect. The value for change should be determined based on expert judgement and, where available, experiences from other countries, regions or cities.

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

*Figure 7.11: Trend adjustment for different effects*

![Trend adjustment for different effects](image)

**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:

• **Cube.** Software for modelling and simulation of traffic and land use. Available at: [http://www.citilabs.com/software/cube/](http://www.citilabs.com/software/cube/)

• **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. Available at: [https://www.planning.dot.gov/FHWA_tool/default.aspx](https://www.planning.dot.gov/FHWA_tool/default.aspx)

• **Motor Vehicle Emission Simulator (MOVES).** Estimates emissions for mobile sources at the national, country and project level. Available at: [https://www.epa.gov/moves](https://www.epa.gov/moves)

• **TransCAD.** Provides GIS-based travel demand modelling. Available at: [http://www.caliper.com/tctraveldemand.htm](http://www.caliper.com/tctraveldemand.htm)

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

Figure 8.1: Overview of steps

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

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
- Carry out a careful interpretation of results, including an assessment of 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 to 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.

The own-price elasticity is the percentage change of a good’s demand divided by the percentage change of that good’s price. Own-price elasticities quantify how fuel demand changes when fuel prices rise, while cross-price elasticities quantify how the demand for other transport modes change when fuel prices rise (i.e., mode shift).

The own-price elasticity is used to estimate the direct impact, or the net effect of a fuel price increase on fuel demand. It is the percentage change of a good’s demand divided by the percentage change of that good’s price. 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. It is the percentage change of a good’s demand divided by the percentage change of a substitute good’s price. Box 8.1 provides an example calculation for both own-price elasticity and cross-price elasticity.
Box 8.1: Examples of own-price elasticity and cross-price elasticity

**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 fuelled vehicles
- Increased switching to different transport modes

The net impact of a fuel price change is the reduced fuel demand and subsequent emissions reductions from transport fuel use. However, a fraction of this reduction will be compensated 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 is 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 like 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. Long-run elasticity values are elasticity values from static models or long-run elasticity

---

25 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 \( \varepsilon = \frac{\Delta \ln(Q)}{\Delta \ln(P)} = \frac{(\Delta Q/\Delta P) \times (Q/P)}{(\Delta Q/Q) / (\Delta P/P)} \), which is a percent change of the demand when the price changes by one percent. (i.e., this value needs to be multiplied with the actual percent change of the price in order to determine the actual percent change of demand due to the price change determined by the pricing policy).

26 For example, a pricing policy is perceived by the public as a long-run effect on the price (the policy is considered to be persistent), which 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.
estimates from dynamic models. There is no consensus about how price elasticity estimates should be classified. In some studies, they are categorised as intermediate run, in others as long-run. However, Dahl (2012) found that more recent literature tends to interpret static elasticity estimates as long-run.

Dahl (2012) analysed over 200 references on fuel price elasticities. They form the basis for the default elasticity values presented in Sections 8.1.2, 8.1.3 and 8.1.4. These values can be used for estimating 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 ahead to Section 8.2.

It is very important to be aware that price elasticity values depend on the actual price change (i.e., the price elasticity for gasoline will not be the same for a price increase of 1% as it is for a price increase of 500%). In this guidance, the default elasticity values are based on empirical studies completed within the last five decades. Hence, these elasticities 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 in order 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 ($\varepsilon_{\text{fuel mix}}$) are provided in Table 8.1. The simple method provided in Approach A should only be used when limited data is available. Approach B should be applied in the case 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 level. Fuel price elasticities change only marginally over time and can be revised for different years using the respective development of consumer price index (CPI) and 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: Default fuel mix price elasticity values ($\epsilon_{\text{fuel mix}}$) for Approach A (national level)

<table>
<thead>
<tr>
<th>Fuel mix price (2016 US¢ per litre)</th>
<th>Income per capita (2016 USD/population)(^{27})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\leq 12,000$</td>
</tr>
<tr>
<td>$\leq 30$</td>
<td>-0.15</td>
</tr>
<tr>
<td>$30 - 80$</td>
<td>-0.22</td>
</tr>
<tr>
<td>$\geq 80$</td>
<td>-0.26</td>
</tr>
</tbody>
</table>

Source: Values adapted from Dahl 2012.

Table 8.1 shows prices and incomes per capita in US dollars for the year 2016. For every new assessment, the ranges of prices (e.g., fuel mix price $\leq 30$) and incomes per capita (e.g., income per capita $\geq 24,000$) 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 requirement:
   - Actual fuel price (annual average) in local currency for the assessment year
   - 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.\(^{28}\)
   
   Calculation:
   - Fuel price from Step 1a $\div$ PPP\(_{\text{conversion factor for the year of assessment}}\)
   - Per capita income from Step 1b $\div$ PPP\(_{\text{conversion factor for the year of assessment}}\)
   
   Results:
   - Fuel price (annual average) in USD for the assessment year, adjusted to PPP
   - Local per capita income (annual average) in USD for the assessment year, adjusted to PPP

3. Adjust the ranges of fuel price (e.g., fuel mix price $\leq 30$) and income per capita (e.g., income per capita $\geq 24,000$) in the tables above according to the change of the US consumer price index (CPI) between the year 2016 and the year of the assessment.\(^{29}\)
   
   Calculation:

---

\(^{27}\) 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. It is strongly recommended to use country-specific data if available.

\(^{28}\) World Bank, PPP conversion factor, GDP (LCU per international $\). Available at: http://data.worldbank.org/indicator/PA.NUS.PPP.

\(^{29}\) World Bank, Consumer price index (selected country = United States). Available at: http://data.worldbank.org/indicator/FP.CPI.TOTL?locations=US.
a. \((\text{US CPI for the year of assessment} \div \text{US CPI 2016}) \times \text{fuel price from tables above (e.g., fuel mix price } \leq 30)\)

b. \((\text{US CPI for the year of assessment} \div \text{US CPI 2016}) \times \text{per capita income from tables above (e.g., income per capita } \geq 24,000)\)

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 apply the PPPs of the local fuel price and income per capita to the adjusted price elasticity tables in order to find the accurate default price elasticities. Box 8.2 provides an example illustrating the choice of default price elasticities for Approach A.

**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 USD 13,000 per capita and an (annual mean) average fuel price of USD 0.50 per litre in the year 2016.

The default price elasticity value is \(\epsilon_{\text{fuel mix}} = -0.24\).

### 8.1.3 Price elasticities for Approach B

The Approach B default price elasticities for gasoline \((\epsilon_{\text{gasoline}})\) and diesel \((\epsilon_{\text{diesel}})\) fuel consumption are depicted in Table 8.2 and Table 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 consumer price index development. When applying a consumer price index 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 \((\epsilon_{\text{gasoline}})\) values for Approach B (national level)**

<table>
<thead>
<tr>
<th>Gasoline price (2016 US ¢ per litre)</th>
<th>Income per capita (2016 USD/population)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\leq 12,000)</td>
</tr>
<tr>
<td>(\leq 30)</td>
<td>-0.15</td>
</tr>
<tr>
<td>30-80</td>
<td>-0.22</td>
</tr>
<tr>
<td>(\geq 80)</td>
<td>-0.26</td>
</tr>
</tbody>
</table>

*Source: Values adapted from Dahl 2012.*
Table 8.3 Default diesel price elasticity ($\epsilon_{\text{diesel}}$) values for Approach B (national level)

<table>
<thead>
<tr>
<th>Diesel price (2016 US ¢ per litre)</th>
<th>Income per capita (2016 USD/population)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤ 18,000</td>
</tr>
<tr>
<td>≤ 80</td>
<td>-0.22</td>
</tr>
<tr>
<td>≥ 80</td>
<td>-0.38</td>
</tr>
</tbody>
</table>

Source: Values adapted from Dahl 2012.

The tables above reflect prices and incomes per capita in US dollars of the year 2016. For every new assessment, the ranges of prices (e.g., diesel price ≥ 80) 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 requirement:
   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 purchasing power parities (PPP). Use the PPP conversion factors (LCU per international $) for the year of the assessment.\(^{30}\)
   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 USD for the assessment year, adjusted to PPP
   b. Local per capita income (annual average) in USD for the assessment year, adjusted to PPP.

3. Adjust the ranges of fuel price (e.g., diesel price ≥ 80) and income per capita (e.g., income per capita ≥ 18,000) in the tables above according to the change of the US consumer price index (CPI) between the year 2016 and the year of the assessment.\(^{31}\)
   Calculation:
   a. (US CPI\(_{\text{for the year of assessment}}\) ÷ US CPI\(_{2016}\)) x fuel price from tables above (e.g., diesel price ≥ 80)
   b. (US CPI\(_{\text{for the year of assessment}}\) ÷ US CPI\(_{2016}\)) x per capita income from tables above (e.g., income per capita ≥ 18,000)

\(^{30}\) Available at: http://data.worldbank.org/indicator/PA.NUS.PPP.

\(^{31}\) Available at: http://data.worldbank.org/indicator/FP.CPI.TOTL?locations=US.
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. Now you can apply the purchasing power parities of your local fuel price and income per capita to the adjusted price elasticity tables in order to find the accurate default price elasticities.

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

**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 USD 13,000 per capita and a (annual mean) fuel price of 50 US ¢ per litre in the year 2016.

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

The default diesel price elasticity value is $\varepsilon_{\text{diesel}} = -0.22$.

### 8.1.4 Price elasticities for Approach C

In contrast to Approaches A and B, Approach C includes not only fuel own-price elasticities ($\varepsilon_{\text{gasoline}}$), but also cross-price elasticities ($\varepsilon_{\text{cross},j}$) that address the demand of 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 Approach 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.
- Gasoline price elasticities change only marginally over time and can be revised for different years using the respective consumer price index development. When applying a consumer price index 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 as own-price elasticities. That is, if the gasoline demand gets 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 with increasing income per capita. Therefore, the scaling of price elasticities described in Table 8.2 and Table 8.3 can also be used as a proxy for cross elasticities.

The own-price gasoline elasticities shown in Table 8.4 are adopted from the study by Dahl (2012). The cross-price gasoline elasticities for shifts to bus and rail passenger transport are shown in Table 8.5.

For bus and rail, this guidance focuses on public transport vehicles. Buses are restricted to large, diesel-powered vehicles (average seats: 40). Rail systems can include both diesel and electric powered trains, and the analyses can include cable cars, street cars, tramways, metro, commuter rail, light rail and heavy rail.
For the estimation of those cross-price elasticities, values from the United States (APTA 2011) were used as a baseline. Starting from the baseline, the elasticities for different levels of 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 represented in Dahl (2012). See Appendix F for detailed information on the method for estimating the cross-price elasticities.

**Table 8.4 Default gasoline own-price elasticity ($\epsilon_{gasoline}$) values for Approach C (national/city level)**

| Gasoline price (2016 US ¢ per litre) | Income per capita (2016 USD/population) | | | |
| --- | --- | --- | --- |
| | $\leq 12,000$ | $12,000 - 24,000$ | $\geq 24,000$ |
| $\leq 30$ | -0.15 | -0.11 | -0.22 |
| 30-80 | -0.22 | -0.24 | -0.22 |
| $\geq 80$ | -0.26 | -0.32 | -0.33 |

*Source: Values adapted from Dahl 2012.*

**Table 8.5 Default gasoline cross-price elasticities ($\epsilon_{cross,j}$) for Approach C (city level)**

| Gasoline price (2016 US ¢ per litre) | Income per capita (2016 USD/population) | | | |
| --- | --- | --- | --- |
| | $< 12,000$ | $12,000 - 24,000$ | $> 24,000$ |
| $< 30$ | 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.*

The table above reflects prices and incomes per capita in US dollars of the year 2016. For each new assessment, the ranges of prices (e.g., gasoline price $\leq 30$) and incomes per capita (e.g., income per capita $\geq 24,000$) 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 your local currency for the year of the assessment (most recent year with available data).
2. **Data requirement:**
   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 purchasing power parities (PPP). Use the PPP conversion factors (LCU per international $) for the year of the assessment.\textsuperscript{32}

Calculation:

\begin{itemize}
  \item[a.] Fuel price from step 1a \div \text{PPP conversion factor for the year of assessment}
  \item[b.] Per capita income from step 1b \div \text{PPP conversion factor for the year of assessment}
\end{itemize}

Results:

\begin{itemize}
  \item[a.] Fuel price (annual average) in USD for the assessment year, adjusted to PPP
  \item[b.] Local per capita income (annual average) in USD for the assessment year, adjusted to PPP
\end{itemize}

3 Adjust the ranges of fuel price (e.g., gasoline price ≤ 30) and income per capita (e.g., income per capita ≥ 24,000) in the tables above according to the change of the US consumer price index (CPI) between the year 2016 and the year of the assessment.\textsuperscript{33}

Calculation:

\begin{itemize}
  \item[a.] \((\text{US CPI for the year of assessment} \div \text{US CPI 2016}) \times \text{fuel price from tables above (e.g., gasoline price ≤ 30)}
  \item[b.] \((\text{US CPI for the year of assessment} \div \text{US CPI 2016}) \times \text{per capita income from tables above (e.g., income per capita ≥ 24,000)}
\end{itemize}

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 apply the PPPs of the local fuel price and income per capita to the adjusted price elasticity tables in order 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\textsuperscript{34}, they should use country-specific cross-price elasticity values. Box 8.4 provides an example for choosing default own- and cross-price elasticities for Approach C.

\textit{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 USD 13,000 per capita and an (annual mean) fuel price of USD 0.50 US per litre in the year 2016.

The resulting default \textbf{gasoline own-price} elasticity value is -0.24.

\textsuperscript{32} Available at: \url{http://data.worldbank.org/indicator/PA.NUS.PPP}.

\textsuperscript{33} Available at: \url{http://data.worldbank.org/indicator/FP.CPI.TOTL?locations=US}.

\textsuperscript{34} Special situations might include, for example, an extremely expensive or exclusive public transport system, a particularly dense and easily accessible public transport system.
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: \( \varepsilon_{\text{cross, bus}} = 0.15 \).
- Cross-price elasticity with respect to gasoline price, for rail (average): \( \varepsilon_{\text{cross, rail}} = 0.24 \).

### 8.2 Calculate GHG impacts

In order 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 guidance on calculating impacts using price elasticity values for Approaches A, B and C.

A comparison of the three approaches, information about uncertainties and possible interpretations of the results 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. Due to the increase in fuel prices, the fuel price elasticity is negative, indicating a decreasing demand for the 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 and 8.1 for guidance on 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 \( y \) (\( BE_{\text{fuel mix,y}} \))
- Fuel mix price elasticity (\( \varepsilon_{\text{fuel mix}} \))
- 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 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), sums the result with 1 and then multiplies this with 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 depicted in Sections 7 and 8.1.

**Table 8.6: GHG impact calculation using Approach A**

<table>
<thead>
<tr>
<th>Label</th>
<th>Approach A</th>
<th>unit</th>
<th>Data collection/calculation</th>
<th>Example year</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Baseline fuel use (( F_y ))</td>
<td>TJ</td>
<td>Input value: from Section 7.2.1 and 7.4</td>
<td>782,000</td>
</tr>
<tr>
<td>B</td>
<td>Baseline emissions (( BE_{\text{fuel mix,y}} ))</td>
<td>tCO₂</td>
<td>Input value: from Section 7.2.1 and 7.4</td>
<td>56,069,400</td>
</tr>
</tbody>
</table>
### 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 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 calculates the anticipated fuel use, emissions and GHG impacts according to the equations in Table 8.6:

- **Anticipated fuel use** = $((-0.24 \times 4.5\%) + 1) \times 782,000 \, TJ = 773,550 \, TJ$ (see row E of Table 8.6)
- **Anticipated GHG emissions** = $((-0.24 \times 4.5\%) + 1) \times 56,069,400 \, tCO_2 = 55,463,850 \, tCO_2$ (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 to the baseline scenario (see row H of Table 8.6).

### 8.2.2 GHG impact calculation for Approach B

The following input data is needed for the GHG impact calculation using Approach B (see Sections 7 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 ($\varepsilon_i$)
- 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 and 8.1, whereas rows G-M show the output results and the respective equations.

**Table 8.7: GHG impact calculation using Approach B**

<table>
<thead>
<tr>
<th>Label</th>
<th>Approach B</th>
<th>Unit</th>
<th>Data collection/calculation</th>
<th>Example year (see Box 8.6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Baseline gasoline use ($F_{\text{gasoline},y}$)</td>
<td>TJ</td>
<td>Input value: from Sections 7.2.2 and 7.4</td>
<td>348,198</td>
</tr>
<tr>
<td>B</td>
<td>Baseline diesel use ($F_{\text{diesel},y}$)</td>
<td>TJ</td>
<td>Input value: from Sections 7.2.2 and 7.4</td>
<td>344,000</td>
</tr>
<tr>
<td>C</td>
<td>Baseline gasoline emissions ($BE_{\text{gasoline},y}$)</td>
<td>tCO₂</td>
<td>Input value: from Sections 7.2.2 and 7.4</td>
<td>24,130,121</td>
</tr>
<tr>
<td>D</td>
<td>Baseline diesel emissions ($BE_{\text{diesel},y}$)</td>
<td>tCO₂</td>
<td>Input value: from Sections 7.2.2 and 7.4</td>
<td>25,490,400</td>
</tr>
<tr>
<td>E</td>
<td>Gasoline own-price elasticity ($\varepsilon_{\text{gasoline}}$)</td>
<td>-</td>
<td>Input value: from Section 8.1.3</td>
<td>-0.24</td>
</tr>
<tr>
<td>F</td>
<td>Relative gasoline price increase</td>
<td>%</td>
<td>Input value: according to planned policy</td>
<td>5%</td>
</tr>
<tr>
<td>G</td>
<td>Diesel own-price elasticity ($\varepsilon_{\text{diesel}}$)</td>
<td>-</td>
<td>Input value: from Section 8.1.3</td>
<td>-0.22</td>
</tr>
<tr>
<td>H</td>
<td>Relative diesel price increase</td>
<td>%</td>
<td>Input value: according to planned policy</td>
<td>4%</td>
</tr>
<tr>
<td>I</td>
<td>Anticipated gasoline use</td>
<td>TJ</td>
<td>$(E \times F) + 1 \times A$</td>
<td>344,020</td>
</tr>
<tr>
<td>J</td>
<td>Anticipated diesel use</td>
<td>TJ</td>
<td>$(G \times H) + 1 \times B$</td>
<td>340,973</td>
</tr>
<tr>
<td>K</td>
<td>Anticipated gasoline emissions</td>
<td>tCO₂</td>
<td>$(E \times F) + 1 \times C$</td>
<td>23,840,560</td>
</tr>
<tr>
<td>L</td>
<td>Anticipated diesel emissions</td>
<td>tCO₂</td>
<td>$(G \times H) + 1 \times D$</td>
<td>25,266,084</td>
</tr>
<tr>
<td>M</td>
<td>Anticipated emission total</td>
<td>tCO₂</td>
<td>$K + L$</td>
<td>49,106,644</td>
</tr>
<tr>
<td>N</td>
<td>Anticipated total GHG impact (emission reduction)</td>
<td>tCO₂</td>
<td>$M - (C + D)$</td>
<td>-513,877</td>
</tr>
<tr>
<td>O</td>
<td>Anticipated relative impact</td>
<td>%</td>
<td>$N \div (C + D)$</td>
<td>-1.0%</td>
</tr>
</tbody>
</table>

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), sums the result with 1 and then multiplies this with 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 depicted in Sections 7 and 8.1.
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:** $F_{\text{gasoline},y} = 348,198$ TJ (see row A of Table 8.6)
- **Baseline diesel fuel use:** $F_{\text{diesel},y} = 344,000$ TJ (see row B)
- **Baseline gasoline emissions:** $BE_{\text{gasoline},y} = 24,130,121$ tCO$_2$ (see row C)
- **Baseline diesel emissions:** $BE_{\text{diesel},y} = 25,490,400$ 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 calculates the anticipated fuel use, GHG emissions and GHG impacts according to the equations in Table 8.7:

- **Anticipated gasoline fuel use:** $((-0.24 \times 5\%) + 1) \times 348,198$ TJ = 344,020 TJ (see row I, Table 8.7)
- **Anticipated diesel fuel use:** $((-0.22 \times 4\%) + 1) \times 344,000$ TJ = 340,973 TJ (see row J)
- **Anticipated gasoline emissions:** $((0.24 \times 5\%) + 1) \times 24,130,121$ tCO$_2$ = 23,840,560 tCO$_2$ (row K)
- **Anticipated diesel emissions:** $((0.22 \times 4\%) + 1) \times 25,490,400$ tCO$_2$ = 25,266,084 tCO$_2$ (see row L)
- **Anticipated emission total:** $23,840,560$ tCO$_2$ + $25,266,084$ 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 to the baseline scenario (see row O of Table 8.7).

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 to this, cross-price elasticities are positive due to the fuel price increase, 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 of private gasoline car PKM.

In this guidance and in the example below, it is assumed that the fuel levy on diesel consumption in public transport (bus and rail) is much lower since it is for private road transport (or possibly even non-existent). 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 than Approaches A and B, and is therefore not directly comparable to those two approaches.

The following input data is required for the GHG impact calculation for Approach C (see Sections 7.2 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 ($\varepsilon_{\text{gasoline}}, \varepsilon_{\text{diesel}}$)
- Relative (%) gasoline price increase (price change due to policy)
- Cross-price elasticities for transport modes bus and rail ($\varepsilon_{\text{cross, bus}}, \varepsilon_{\text{cross, rail}}$)
- Baseline GHG emissions for each fuel type $i$ (gasoline, diesel, electricity), transport mode $j$ (car, bus, rail) and year $y$ ($\text{BEPKM}_{i,j,y}$)

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, whereas 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>
<thead>
<tr>
<th>Label</th>
<th>Approach C</th>
<th>Unit</th>
<th>Data collection/calculation</th>
<th>Example year</th>
<th>Year y (proj.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Baseline PKMs with car ($PKM_{\text{car, gasoline, y}}$)</td>
<td>PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>21,800,000,000</td>
<td>...</td>
</tr>
<tr>
<td>B</td>
<td>Gasoline own-price elasticity ($\varepsilon_{\text{gasoline}}$)</td>
<td>-</td>
<td>Input value: from Section 8.2.3</td>
<td>-0.24</td>
<td>...</td>
</tr>
<tr>
<td>C</td>
<td>Relative gasoline price increase</td>
<td>%</td>
<td>Input value: according to planned policy</td>
<td>5%</td>
<td>...</td>
</tr>
<tr>
<td>D</td>
<td>Baseline car gasoline emissions per PKM ($\text{BEPKM}_{\text{car, gasoline, y}}$)</td>
<td>g CO$_2$ / PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>111</td>
<td>...</td>
</tr>
<tr>
<td>E</td>
<td>Anticipated PKMs with cars</td>
<td>PKM</td>
<td>$=(B \times C) + 1\times A$</td>
<td>21,538,400,000</td>
<td>...</td>
</tr>
<tr>
<td>F</td>
<td>Anticipated gasoline emissions (car)</td>
<td>tCO$_2$</td>
<td>$= D \times E \div 10^6$</td>
<td>2,390,762</td>
<td>...</td>
</tr>
</tbody>
</table>
### Passenger bus (diesel)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>PKM</th>
<th>Value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Baseline PKMs with bus</td>
<td>PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>15,700,000,000</td>
</tr>
<tr>
<td>H</td>
<td>Bus cross-price elasticity</td>
<td>-</td>
<td>Input value: from Sections 8.2.3</td>
<td>0.15</td>
</tr>
<tr>
<td>I</td>
<td>Baseline bus diesel emissions per PKM</td>
<td>g CO₂/ PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>83</td>
</tr>
<tr>
<td>J</td>
<td>Anticipated PKMs with bus</td>
<td>PKM</td>
<td>= ((H x C) + 1) x G</td>
<td>15,817,750,000</td>
</tr>
<tr>
<td>K</td>
<td>Anticipated diesel emissions (bus)</td>
<td>tCO₂</td>
<td>= I x J ÷ 10^6</td>
<td>1,312,873</td>
</tr>
</tbody>
</table>

### Passenger rail (diesel and electricity)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>PKM</th>
<th>Value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Baseline PKMs with diesel rail</td>
<td>PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>12,400,000,000</td>
</tr>
<tr>
<td>M</td>
<td>Baseline PKMs with electric rail</td>
<td>PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>5,600,000,000</td>
</tr>
<tr>
<td>N</td>
<td>Rail cross-price elasticity</td>
<td>-</td>
<td>Input value: from Section 8.2.3</td>
<td>0.24</td>
</tr>
<tr>
<td>O</td>
<td>Baseline rail diesel emissions per PKM</td>
<td>g CO₂/ PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>64</td>
</tr>
<tr>
<td>P</td>
<td>Baseline rail electricity emissions per PKM</td>
<td>g CO₂/ PKM</td>
<td>Input value: from Sections 7.3 and 7.4</td>
<td>63</td>
</tr>
<tr>
<td>Q</td>
<td>Anticipated PKMs with diesel rail</td>
<td>PKM</td>
<td>= ((N x C) + 1) x L</td>
<td>12,548,800,000</td>
</tr>
<tr>
<td>R</td>
<td>Anticipated PKMs with electric rail</td>
<td>PKM</td>
<td>= ((N x C) + 1) x M</td>
<td>5,667,200,000</td>
</tr>
<tr>
<td>S</td>
<td>Anticipated diesel emissions (rail)</td>
<td>tCO₂</td>
<td>= O x Q ÷ 10^6</td>
<td>803,123</td>
</tr>
<tr>
<td>T</td>
<td>Anticipated electricity emissions (rail)</td>
<td>tCO₂</td>
<td>= P x R ÷ 10^6</td>
<td>357,034</td>
</tr>
</tbody>
</table>

### Overall results

...
<table>
<thead>
<tr>
<th>Column</th>
<th>Description</th>
<th>Formula</th>
<th>Value</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>Reference emission total</td>
<td>$tCO_2 = \frac{(A \times D) + (G \times I) + (L \times O) + (M \times P)}{10^6}$</td>
<td>4,869,300</td>
<td>...</td>
</tr>
<tr>
<td>V</td>
<td>Anticipated emission total</td>
<td>$tCO_2 = F + K + S + T$</td>
<td>4,863,792</td>
<td>...</td>
</tr>
<tr>
<td>W</td>
<td>Anticipated total GHG impact (emission reduction)</td>
<td>$tCO_2 = V - U$</td>
<td>-5,508</td>
<td>...</td>
</tr>
<tr>
<td>X</td>
<td>Anticipated relative impact</td>
<td>$% = \frac{W}{U}$</td>
<td>-0.1%</td>
<td>...</td>
</tr>
<tr>
<td>Y</td>
<td>Increased capacity requirement of bus system</td>
<td>$% = \frac{(Q + R)}{(L + M)} - 1$</td>
<td>+1.2%</td>
<td>...</td>
</tr>
<tr>
<td>Z</td>
<td>Increased capacity requirement of rail system</td>
<td>$% = \frac{J}{G} - 1$</td>
<td>+0.8%</td>
<td>...</td>
</tr>
</tbody>
</table>

The equations in the column Data collection, calculation refer to the respective labelling in the column Label. For example, the calculation of the anticipated PKMs 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), sums the result with 1 and then multiplies this with the value of row A (baseline PKMs with car in the specific year). See Box 8.7 for a full calculation example. The numbers match the examples depicted in Sections 7.2 and 8.1.

**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 starts by analysing private road passenger transport and retrieves 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)
- $BE\text{PKM}_{gasoline, car, y} = 111$ gCO$_2$/PKM (see row D)

With this data, they calculate PKMs and emissions from private passenger cars:

- Anticipated PKMs with cars =
  $((-0.24 \times 5\%) + 1) \times 21,800,000,000$ PKM = $21,538,400,000$ PKM
- Anticipated gasoline emissions (car) =
  $111$ gCO$_2$/PKM $\times 21,538,400,000$ PKM $\div 10^6$ = $2,390,762$ tCO$_2$
In a second step, the Ministry staff analyses 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):

- \( PKM_{\text{diesel, bus, y}} = 15,700 \text{ Million PKM (see row G)} \)
- \( \varepsilon_{\text{cross, bus}} = 0.15 \) (see row H)
- \( BEPKM_{\text{diesel, bus, y}} = 83 \text{ gCO}_2/\text{PKM (see row I)} \)

With this data, they calculate PKMs and emissions from passenger buses:

- Anticipated PKMs with bus = ((5% x 0.15) + 1) x 15,700,000,000 PKM = 15,817,750,000 PKM
- Anticipated diesel emissions (bus) = 15,817,750,000 PKM x 83 gCO\(_2\)/PKM / 1,000,000 = 1,312,873 tCO\(_2\)

In a third step, the Ministry staff analyses 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):

- \( PKM_{\text{diesel, rail, y}} = 12,400 \text{ Million PKM (see row L)} \)
- \( PKM_{\text{electricity, rail, y}} = 5,600 \text{ Million PKM (see row M)} \)
- \( \varepsilon_{\text{cross, rail}} = 0.24 \) (see row N)
- \( BEPKM_{\text{diesel, rail, y}} = 64 \text{ gCO}_2/\text{PKM (see row O)} \)
- \( BEPKM_{\text{electricity, rail, y}} = 63 \text{ gCO}_2/\text{PKM (see row P)} \)

With this data, they calculate PKMs and emissions from diesel and electric rail:

- Anticipated PKMs with diesel rail = ((5% x 0.24) + 1) x 12,400,000,000 PKM = 12,548,800,000 PKM
- Anticipated PKMs with electric rail = ((5% x 0.24) + 1) x 5,600,000,000 PKM = 5,667,200,000 PKM
- Anticipated diesel emissions (rail) = 12,548,800,000 PKM x 64 gCO\(_2\)/PKM / 1,000,000 = 803,123 tCO\(_2\)
- Anticipated electricity emissions (rail) = 5,667,200,000 PKM x 63 gCO\(_2\)/PKM / 1,000,000 = 357,034 tCO\(_2\)

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

- Reference emission total = (21,800 Million PKM x 111 gCO2/PMK) + (15,700 Million PKM x 83 gCO2/PMK) + 12,400 Million PKM x 64 gCO2/PMK) + (5,600 Million PKM x 63 gCO2/PMK)) = 4,869,300 tCO\(_2\)
- Anticipated emission total = 2,390,762 tCO\(_2\) + 1,312,873 tCO\(_2\) + 803,123 tCO\(_2\) + 357,034 tCO\(_2\) = 4,863,792 tCO\(_2\)
- Anticipated total GHG impact = 4,863,792 tCO\(_2\) - 4,869,300 tCO\(_2\) = -5,508 tCO\(_2\)
- Anticipated relative impact = -5,508 tCO\(_2\) / 4,869,300 tCO\(_2\) = -0.1%
Thus, the GHG reduction in year y equals 5,395 tCO$_2$ or 0.1% compared to 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%
- Increased capacity requirement of rail system = 0.8%

8.3 Interpret the results

The calculations depicted in this guidance are subject to large uncertainties. It is a key recommendation to carry out a careful interpretation of results, including an assessment of uncertainty and the GHG impacts of use of revenues from the policy. 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, 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% up 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 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, 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 emissions vehicles, the emissions reductions may be increased due to 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 guidance have very high uncertainties, estimated by the authors of this guidance document to be between 50-100%, which may also 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 in order to avoid adverse effects, such as decreased mobility for the poorest populations. The assumptions made to choose elasticities values are important given that these values do not remain the same under continuous price increases.
9. **ESTIMATING 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 emission reductions from the ex-ante estimation. Users that are estimating ex-ante GHG impacts only can skip this chapter.

*Figure 9.1: Overview of steps in the 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 guidance in Chapter 7. Further guidance on monitoring parameters is provided in Chapter 10.

Where the baseline scenario was determined and baseline emissions 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.

In order to estimate the GHG impacts for a policy which 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.
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 following the guidance provided in Chapters 7 and 8.

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

Table 9.1: Indicators and parameters to consider when undertaking or updating the assessment of the policy

<table>
<thead>
<tr>
<th>Indicator/parameter</th>
<th>Description</th>
<th>Potential data sources</th>
<th>Related section in ex-ante assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage of policies</td>
<td>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)</td>
<td>Law or regulation for the implementation of the policy</td>
<td>Changes in coverage of policy impact system boundaries for GHG sources considered in Section 7</td>
</tr>
<tr>
<td>Level of pricing</td>
<td>The level of subsidy reduction or fee on transport fuel may change alongside the political process of the design of the policy. Or, the speed at which policies are increased may slow down</td>
<td>Law or regulation for the implementation of the policy</td>
<td>Used for updating pricing signal in Section 8.2</td>
</tr>
<tr>
<td>Approach</td>
<td>Better data on fuel consumption (or price elasticities) may be available that allows users to use a higher level approach (i.e., B or C) or that provides a better basis for determining fuel price elasticities</td>
<td>National data sources</td>
<td>Used for updating choice in Section 4.2.2 and calculations in Sections 7 and 8.1</td>
</tr>
<tr>
<td>Baseline data</td>
<td>There may be more recent data on fuel consumption and other data for determining the baseline emissions (e.g., for the last year before the implementation of the policy) that can be taken into account, or more recent data on transport emission projections. In general, only activity data from before the implementation of the policy can be used for updating the baseline, as after that point the impact of the policy has already led to a deviation of emissions from the baseline scenario.</td>
<td>See all parameters in Section 7</td>
<td>Used for updating calculations in Section 7</td>
</tr>
</tbody>
</table>