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Staff Working Papers

Economic Analysis of Gas Pipeline Projects

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1. Introduction

The purpose of this paper is to present a methodology to evaluate the economic viability of investments in gas pipelines. The objective is to provide the reader with practical, step-by-step guidance to prepare a cost-benefit analysis to assess the socio-economic and environmental impacts that the project would generate in the country where it is implemented. The analysis of the financial profitability of the investment, that is the expected return for the project promoter, is outside the scope of this paper.

A spreadsheet model for the economic analysis is annexed to this paper. It is meant to present a worked example and to serve as an indicative template for the appraisal of gas pipeline projects.

The paper is organised as follows: section two gives an overview of the evaluation methodology and its rationale; section three illustrates the main components and determinants of the project costs and provides some unit cost statistics; the fourth section describes the methodology to quantify the investment benefits and lists the related data requirements and sources; chapter five briefly presents the determination and interpretation of the analysis results; the concluding section deals with sensitivity and risk analysis.

2. Overview of the Methodology

The construction of a new pipeline generally increases the gas transportation capacity and makes additional volumes of gas available to the economy. In some particular situations, a new pipeline may replace an existing one. In this case, it is important that the economic analysis only considers the incremental gas amounts expected to be delivered to the market as a result of the investment. The incremental gas volumes should be determined on the basis of the differences in transported gas between the “with-the-project” and the “without-the-project” scenarios.

The costs and benefits of a gas pipeline are commonly appraised over a reference period that includes 25 years of operational phase. This time span is sufficiently long to reasonably encompass the likely medium to longer term impacts.

On the cost side, the economic analysis should consider the initial investment outlay and the pipeline operating and maintenance costs including, where relevant, the cost for the replacement of short-life equipment.

As regards the quantification of the benefits, it can be assumed that the additional volumes of gas associated with the project can substitute the consumption of alternative fuels (e.g. electricity, coal, oil products, district heating). On this basis, the benefits to society can be measured as the net savings stemming from the difference between (i) the cost for the purchase, transportation and use of alternative fuels and (ii) the cost of the additional volumes of gas that can be supplied to the market as a result of the construction of the new pipeline. Moreover, given that natural gas is a relatively clean fossil fuel, the reduction in emissions of greenhouse gases and polluting compounds from the replaceable alternative fuels are also quantified in the analysis among the project benefits.

The incremental revenues generated by the pipeline operator from gas transportation fees should not be considered. Unlike the financial analysis, the main focus of the economic appraisal is the effects of the investment on the final market for energy sources. Also, tariffs for gas transportation services are normally regulated, so the project revenue does not necessarily reflect the users’ “willingness-to-pay”.

When dealing with the transportation of natural gas, a distinction is normally made between transmission and distribution pipelines. Transmission networks are made of long, large-diameter pipes that transport gas between cities and countries. Gas distribution systems are instead typically formed by smaller-diameter and lower-pressure pipelines that are used to supply local markets. We refer here mainly to gas transmission pipelines, but a similar analysis can be equally performed for gas distribution pipelines. Also, an analogous conceptual framework can be used to appraise investments in other types of gas infrastructure, such as regasification terminals or gas storage facilities.

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1 The methodology presented in this paper is mainly based on an economic model developed by the Security of Supply Division, Energy Department, of the European Investment Bank’s Projects Directorate.
3. The Costs of Gas Pipelines

The following cost categories are typically considered in the economic analysis.

- **Investment cost**, including planning and design fees, costs of materials and equipment, transport and construction works. Some projects may also include compression stations. The length and size (i.e. the diameter) of the pipeline, the cost of steel and the type of terrain would usually be among the key determinants of the investment cost.

- **Operating and maintenance (O&M) costs**, including personnel, gas compression cost, maintenance costs and administrative and other general costs. Note that depreciation is not to be included in the analysis, as costs are only considered on a cash-flows basis.

- The costs for the replacement of short-life equipment, where relevant.

The following table reports some statistics for a sample of unit costs of gas pipelines that can be used as indicative benchmark for the appraisal of the project costs.2

<table>
<thead>
<tr>
<th>Unit Investment Cost</th>
<th>Levelised Cost (5 % discount rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUR/m</td>
<td>EUR/km/cm²</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Minimum</td>
<td>300</td>
</tr>
<tr>
<td>Average (DN 500 to 1000)</td>
<td>751</td>
</tr>
<tr>
<td>Median</td>
<td>894</td>
</tr>
<tr>
<td>Average</td>
<td>1,138</td>
</tr>
<tr>
<td>Maximum</td>
<td>2,694</td>
</tr>
</tbody>
</table>

Source: JASPERS calculations on a sample of 19 European gas pipelines

The project costs need to be estimated over the entire infrastructure life. Typically, 25 years of operations are considered after the investment phase. Where relevant, the investment residual value should be inputted in the last year of the time horizon. For simplicity, it can be assumed to be equal to the share of the initial investment plus possible replacement costs that are still not depreciated.

In the economic analysis, the project inputs (e.g. materials, equipment, labour) should be valued at their social opportunity costs. This is the value of a given resource in its best alternative use. In the case of pipeline projects it can be assumed that the relevant markets are sufficiently competitive so that the observed prices adequately reflect opportunity costs. A possible exception may be the opportunity cost for unskilled labour that, depending on local conditions (e.g. high unemployment), may be lower than the wages actually paid (intuitively, in some cases the project may be generating indirect benefits for the creation of jobs, particularly in the construction phase).

The European Commission’s “Guide to Cost-Benefit Analysis of Investment Projects” reports some formulas that can be used to convert observed market prices into shadow prices that better reflect opportunity costs.3 For example, in case of high unemployment in the region where the project is to be constructed, the following equation can be used to estimate the shadow wage (SW):

\[
SW = W^*(1-u)*(1-t)
\]

Where, \( W \) is the market wage, \( u \) the unemployment rate and \( t \) the rate of social security payments and relevant taxes.

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2 The sample is relatively small and also includes a few gas distribution pipelines that have higher levelised costs than transmission pipelines. Therefore, when appraising gas transmission pipelines, we advise to use the median as a reference for comparison, because it is not sensitive to the value of outliers. Alternatively, the average for the pipeline sub-sample DN 500 to 1000 can be used where relevant.

4. The Benefits of Gas Pipelines

The main benefits generated by the construction and operation of a new gas pipeline can be classified under two categories:

- **Benefits from the avoidance of costs related to the use of alternative fuels**, including:
  - Savings in fuel purchase costs, calculated as the difference between purchase costs of replaceable fuels and purchase cost of gas, valued at “border prices”.
  - Savings in fuel transportation costs, determined as the difference between transportation costs of alternative fuels and gas transportation costs.
  - Savings in capital and O&M costs of the relevant facilities. For example, gas-fired power plants typically have lower investment and operating costs than coal-fired ones.

- **Benefits from the reduction of negative environmental “externalities”** including:
  - Reductions in emissions of greenhouse gases (GHG), based on the differences in GHG emissions factors between gas and replaceable fuels.
  - Reductions in emissions of polluting compounds, such as SO₂, NOₓ and particulate matter, to be determined on the basis of the differences in emissions from natural gas and alternative fuels.

In some specific cases, a new pipeline may also contribute to improve the security of gas supplies, by reducing potential gas disruptions to interruptible industrial clients. A related project benefit can then be estimated as the avoided economic losses from the reduction of volumes of gas not supplied.

4.1. **Avoided Costs of Alternative Fuels**

A new pipeline typically generates a net increase in the volume of gas that can be delivered to the market. For simplicity, we can group all different gas uses under three main sectors: power generation, industry and residential/commercial. It can be assumed that the incremental gas transmitted by the project can potentially displace the use of other fossil fuels that are employed in those sectors. This assumption is consistent with the trend generally observed in Europe of a gradual increase in the share of natural gas in the total primary energy consumption.

The value of the additional gas availability associated with the project can be monetised as the net savings to those three economic sectors that stem from the difference between the cost for the purchase, transportation and use of alternative fuels and the cost of the additional volumes of gas that can be supplied to the market as a result of the construction of the new pipeline.

In order to be able to monetise this benefit, the following variables need to be specified:

- **Calorific values** of gas and alternative fuels (e.g. GJ/m³ of gas, GJ/t for coal and oil products). This is needed to convert all fuel quantities into energy equivalents (e.g. GJ) in order to allow comparison and determine the amounts of potentially replaceable fuels. Calorific values of fossil fuels can vary across countries. The project promoter should normally know the calorific value of gas that is transported by the pipeline. If national data sources are not available, the energy content of other fossil fuel can be found in publications of the International Energy Agency (IEA). For example, the IEA “Electricity Information 2009” reports country specific calorific values for different types of fuels.

- **Project demand**, as gauged by the peak gas flows expected to be transmitted through the new pipeline over the project reference period (in Mm³ and GJ). Those data are typically found in the demand analysis section of the project feasibility study. If the new pipeline is replacing an existing one, only the incremental volumes expected to be made available to the market compared to the without-project scenario should be considered.

- **Gas market structure**, in the form of a breakdown of gas use in the following three sectors (to be expressed as percentage of total gas consumption): power generation, industry and residential/commercial. For simplicity, possible alternative gas uses (e.g. in transport) should be ignored or reattributed to the three sectors so that the sum of the percentages
adds up to 100 %. For example, in the annexed spreadsheet model the following initial gas market structure is assumed:

- Power generation: 14 %
- Industry: 35 %
- Residential/Commercial: 51 %

This information is used as a proxy for the destination of the additional volumes of gas transmitted by the new pipeline. The breakdown clearly depends on the specific situation of the gas market of a given country. In the absence of national statistics, the relevant data can be found in the IEA “Natural Gas Information”, which is published annually.

Under a Business-As-Usual scenario (BAU), it can be assumed that the gas market would not be affected by any significant change in energy policy or regulatory background. For simplicity, under a BAU scenario the structure of final gas consumption by sector can then be kept constant over the project reference period at the currently observed levels.

In addition to the BAU scenario, the template spreadsheet allows specifying different estimates of possible gas market developments, to test the sensitivity of the economic analysis results to two other alternative scenarios:

- Green Scenario (GRS): it assumes that the country would achieve the relevant national targets related to the EU “20-20-20” energy goals for 2020: saving 20 % of the EU’s primary energy consumption, reducing by 20 % the emissions of greenhouse gases and generating 20 % of energy from renewable sources by 2020. The impact on gas consumption will depend on the specific country situation. In principle, the gas share in power generation under the GRS should be higher than in the BAU scenario if it is expected that gas would win more market share from coal than it can lose from renewable sources (or nuclear).

- Gas Enhanced Scenario (GES): it assumes a significant increase in the consumption of natural gas, particularly in those sectors where the potential for replacing alternative fossil fuels is high (e.g. in power generation).

- **Mix of replaceable fuels** in the three sectors (in %). For simplicity it can be kept constant over the reference period. Similarly to the gas market structure, the types and shares of alternative fuels will also depend on the specific energy mix of the country in the different sectors. For example, the following assumptions are used in the template spreadsheet:
  - 75 % of gas going to power generation would replace coal, 25 % lignite
  - 75 % of gas going to industry would replace coal, the remaining 25 % heavy fuel oil
  - 60 % of gas going to the residential/commercial sector would replace coal, 40 % gas oil

The IEA’s “Energy Statistics of OECD Countries”, which are updated and published on an annual basis, can be used as a data source to determine the likely mix of alternative fuels to be considered in the economic analysis.

- **Differences in efficiencies** should also be considered when determining the amounts of replaceable energy from alternative fuels (in GJ). For instance, in its “Projected Costs of Generating Electricity” the IEA reports thermal efficiencies for a sample of power plants of OECD countries. The reported median efficiency for a combined-cycle gas turbine (CCGT) is 57 %. For (“supercritical” and “ultra-supercritical”) coal-fired plants it is 41 %. However, existing coal plant fleets can also have much lower efficiencies, e.g. ranging between 30 % and 38 % in the case of outdated “subcritical” plants. The ratio between the efficiency of gas-fired and coal-fired technology to be potentially displaced need to be taken into account. The value will depend on the specific country situation, particularly as regards the condition of the existing coal-fired plants. For example, considering the IEA median case, 1GJ of gas to power generation would replace 1*57%/41%GJ of coal for the purpose of the economic analysis. If data are available, similar adjustments may be done for the other sectors.

- When calculating the potential savings to power generation, the differences in capital and O&M costs per unit of fuel used should also be taken into account. In general, coal-fired

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plants have higher capital and O&M costs than gas-fired plants. The latter, on the other hand, have higher fuel costs. In the lack of country-specific estimates, it can be assumed that the life-cycle capital and O&M costs of coal-fired plants exceed those of gas-fired plants by some € 0.85 per GJ of coal used.

- **Fuel purchase costs**, to be expressed at “border prices” in order to better reflect opportunity costs. This should include the cost of replaceable fuels (e.g. coal, gasoil), as well as the cost of natural gas. Fuel purchase prices will likely change over time so have to be forecast over the entire reference period. The template spreadsheet makes use of the EIB fuel price forecasts. These prices are expressed in US dollars and are converted into euros based on a constant 1.30 USD/EUR exchange rate. The model allows testing the economic analysis results under low and high fuel prices scenarios.

- **Fuel transportation/distribution costs**, to be kept constant over the project time horizon for simplicity. Transportation costs to industry and power generation can be expected to be lower than those to residential and commercial locations. The costs depend on specific local market conditions. The following table provides some examples.

<table>
<thead>
<tr>
<th>Fuel Name</th>
<th>Unit</th>
<th>Fuel Transportation Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>EUR/GJ</td>
<td>0.50 To Power Generation and Industry</td>
</tr>
<tr>
<td>Coal</td>
<td>EUR/ton</td>
<td>10</td>
</tr>
<tr>
<td>Liquid fuels</td>
<td>EUR/ton</td>
<td>60</td>
</tr>
</tbody>
</table>

Source: own calculations

Transportation costs for gas should be considered in the analysis (as a reduction of benefits) in so far as they are not already taken into account in the project capital and O&M costs. For example, in the appraisal of a gas transmission pipeline, it may be appropriate to only consider the gas distribution costs if the transmission costs can be considered to be already allowed for under the project investment and operating costs.

4.2. Reduction in CO₂ Emissions and Other Environmental Externalities

Compared to other fossil fuels, natural gas has the lowest carbon content and is a relatively cleaner source of energy. The related environmental benefit can be monetised in the economic analysis based on the differences between the value of CO₂ emissions and other externalities from gas and the replaceable fuels.

Assumptions need to be made about:

- The specific CO₂ emission factors for the different fuels. For example, the values reported in the following table can be used in the analysis.

<table>
<thead>
<tr>
<th>Fuel Name</th>
<th>Amount of Fuel</th>
<th>kg CO₂</th>
<th>kg CH₄</th>
<th>kg N₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>1TJ</td>
<td>56,100</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Coal</td>
<td>1TJ</td>
<td>94,600</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Lignite</td>
<td>1TJ</td>
<td>101,000</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Gas/Diesel oil</td>
<td>1TJ</td>
<td>74,100</td>
<td>3.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Residual fuel oil/HFO</td>
<td>1TJ</td>
<td>77,400</td>
<td>3.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Source: 2006 IPCC “Guidelines for National Greenhouse Gas Inventories”

CH₄ and N₂O need to be converted in CO₂ equivalent for the monetisation. To convert to CO₂e one has to multiply CH₄ by 21 and N₂O by 310.

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The forecast cost of CO₂ emissions over the project reference period. Based on the paper “Clean Energy for Europe: A Reinforced EIB Contribution”, the template spreadsheet makes use of estimates for carbon dioxide prices ranging from € 25 to € 45 per ton of CO₂ over the appraisal reference period. The model allows testing the sensitivity of results to low and high CO₂ prices scenarios.

Other externalities such as emissions of particular matters, nitrogen and sulphur oxides can also be included in the analysis. For example, emission factors for different fuels and technologies can be found in the “MethodEx” study, together with the associated country-specific monetary damage values. The following table reports average EU damage values calculated on the basis of MethodEx data.

<table>
<thead>
<tr>
<th>Fuel Name</th>
<th>Amount of fuel</th>
<th>Damage from SO₂, NOₓ and PM₂.₅ emissions (EUR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>1GJ</td>
<td>0.25</td>
</tr>
<tr>
<td>Coal</td>
<td>1GJ</td>
<td>2.08</td>
</tr>
<tr>
<td>Lignite</td>
<td>1GJ</td>
<td>3.82</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>1GJ</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Source: JASPERS’ calculations on ExternE and CAFE/WHO data as reported in MethodEx

4.3. Improved Security of Supply

Poor conditions of gas transmission infrastructure or inadequate diversification of supply sources may occasionally result in disruptions of gas supply. In some cases, a new pipeline may improve the reliability and security of gas services, therefore decreasing the quantity of energy not supplied. This benefit can be monetised as the expected socio-economic damage that can be avoided as a result of the implementation of the project. For example, in the case of industrial gas users this may be quantified on the basis of the Gross Value Added per unit of energy input.

However, the viability of the project should generally be already supported by the avoided costs of alternative fuels and the environmental benefits. For simplicity and to avoid possible double-counting of benefits for cases where the security of supply aspect is not relevant, this benefit is not included in the template spreadsheet.

5. The Economic Analysis Results

Once costs and benefits have been specified over the project reference period, the analysis results are determined on the basis of the discounted cash-flow methodology. For the appraisal of projects in EU countries that are eligible for Cohesion Fund assistance, the European Commission recommends using a social discount rate equal to 5.5 % (in real terms).

Project costs and benefits can either be expressed at current or constant prices, i.e. fixed at a given year price level. The template spreadsheet model reports estimates in constant prices and therefore uses a discount rate in real terms. It should be noted that, in case current prices are used, the discount rate would then have to be expressed in nominal terms.

The following indicators of economic profitability can be calculated:

- Economic net present value (ENPV)
- Economic rate of return (ERR)
- Benefit-cost ratio (B/C)

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6 [http://www.eib.org/attachments/clean_energy_for_europe.pdf](http://www.eib.org/attachments/clean_energy_for_europe.pdf)

7 "Methods and data on environmental and health externalities: harmonising and sharing of operational estimates" is a project of the EU Sixth Framework Programme for Research and Technological Development.

8 See the Commission’s CBA guide, Annex B: The choice of the discount rate.

9 The nominal discount rate is roughly equal to the discount rate in real terms plus the expected inflation rate.
A project is desirable from an economic point of view when its ENPV is greater than zero, the ERR is higher than the discount rate and the B/C ratio is greater than one.10

6. Sensitivity and Risk Analysis

Given the uncertainty that is normally associated with the estimation of economic values over a long time horizon, a sensitivity analysis should be performed on the CBA results. For example, the template spreadsheet allows checking the impact on the project performance indicators of different fuel prices, CO₂ costs and gas market structures. Also, possible variability ranges (e.g. 75 % to 150 % of the base-case estimate) can be specified for the investment cost, the operating costs and the aggregate value of project benefits. On the basis of the assumed intervals of potential variability, a Monte Carlo simulation generates a probability distribution for the ENPV, with the related descriptive statistics (e.g. mean, median, standard deviation) and the simulated probability that the ENPV is greater than zero.11

10 See the Commission’s CBA guide - Annex C: Project performance indicators - for more details on the calculation method and interpretation of the three indicators.
11 For a more in-depth presentation of sensitivity and risk-analysis methods, see the Commission’s CBA guide, § 2.6 and Annex H on risk assessment.
ANNEX I

Spreadsheet Model for the Economic Analysis of Gas Pipeline Projects

The purpose of the spreadsheet model attached to this paper (“Gas pipeline CBA with risk analysis.xls”) is to present a worked example and to serve as an indicative template for the economic appraisal of gas pipeline projects.

The model has three main worksheets: (i) CBA Inputs; (ii) CBA Results; (iii) Sensitivity.

1. CBA Inputs: all the necessary project information and assumptions need to be inputted into the light blue coloured cells. Cost, demand and technical data are grouped in the following boxes:
   - Calorific values of fuels
   - Transportation costs of fuels: different costs can be specified for delivery to industry/power or to residential/commercial sector
   - Emission factors of fuels: input data are already provided, based on the IPCC “Guidelines for National Greenhouse Gas Inventories”.
   - Other externalities (SO2, NOx and PM2.5): a drop-down list allows selecting the country where the project is implemented. The related value of externalities will be displayed based on the data provided in the MethodEx study.
   - Economic parameters: USD/EUR exchange rate and discount rate should be specified here.
   - Power generation: to specify efficiency of coal and gas plants and the differences in capital and operating costs.
   - Costs and gas volumes: the project economic costs (i.e. investment cost, O&M costs replacement costs and residual value) and the estimated volumes of incremental gas to be transported by the pipeline needs to be inputted here over the entire time horizon.
   - Gas market structure: the model allows specifying and selecting three different scenarios (Business-As-Usual (BAU), Green and Gas Enhanced scenario – see § 4.1 above for details). At least the BAU scenario needs to be specified. This can be done by inputting in the E41:E43 range the currently observed gas consumption in the power, industry and residential/commercial sectors.
   - Market share of alternative fuels: to be specified for the power, industry and residential/commercial sectors.
   - Fuel and CO2 price scenarios: input data are already provided. The analyst has the possibility to choose between base-case, low and high price scenarios.

2. CBA Results: no data have to be inputted here. The economic benefits are calculated on the basis of the assumptions provided in “CBA Inputs”, following the methodology presented in this paper. The box “Economic Analysis Results” reports the estimated ENPV, ERR and B/C ratio.

3. Sensitivity: this sheet presents the following output in relation to possible variability of the assumptions reported in “CBA Inputs”:
   - Elasticity of ENPV with respect to (i) Investment Cost; (ii) O&M Costs; (iii) Incremental Gas Flows; (iv) CO2 Price; (v) Fuel Purchase Costs. The reported elasticity values indicate the percentage change in the estimated ENPV that would follow a +1 % change in the related variable.
   - “Switching values”, for the same five variables for which the ENPV elasticity is reported. This is a change in a variable expressed as a percentage of the base-case value used in the CBA that would make the ENPV equal to zero. For example: a switching value for the investment cost equal to 150 % indicates that a cost overrun exceeding 50 % of the initial budget would jeopardise the project economic viability as the ENPV would become negative; a 75 % switching value for the “incremental gas flow” variable means that if demand decreases by 25 % compared to the levels assumed in “CBA Inputs” the ENPV would drop to zero.
- “Spider charts” plotting the ENPV and ERR estimates against potential changes in variables between 50 % and 150 % of the base-case values. The steeper the lines, the more sensitive CBA results are to changes to a given variable.

The “Sensitivity” sheet also allows specifying variability ranges for the main project variables in order to estimate a probability distribution for the ENPV based on a *Monte Carlo* simulation. For each variable a minimum and a maximum value, expressed as a percentage of the base-case value, can be inputted in the box “Assumptions for Monte Carlo Simulation”. A VBA macro simulates CBA results assuming that the specified variability ranges follow a "triangular probability distribution".

The box “Results of Monte Carlo Simulation” includes charts of the simulated ENPV probability distribution and the related descriptive statistics: mean (expected value), median, minimum, maximum, standard deviation and probability that the ENPV is positive (on the basis of the variability ranges assumed for the CBA variables).

In addition to the three worksheets described above, there are three supplementary sheets that contain auxiliary data for the calculation of the economic benefits: (i) Fuel and CO₂ Costs; (ii) MethodEx Emissions; (iii) MethodEx Emission Values. Those sheets provide the basis for the monetisation of fuel costs and environmental "externalities". No specific project information is or needs to be included here.