Methodology for ex-ante GHG assessment of logistics investment projects

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Drafted framework for internal discussion

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Content

Terms/Glossary

Assessment period	Is the time horizon over which the GHG impact of the logistics investment project is assessed. It starts at the time of the baseline, where no project investment is in place and the contract of the investment project has not been signed. The project scenario is the end of the assessment period and represents a reasonable year of operation, where a typical operation can be expected.	Section 2.2
Baseline scenario	No project investment is in place and the contract of the investment project has not been signed.	Sections 2.2 and 4.2
Emission factor	Is used for converting the amount of fuel or material used into the GHG emissions.	
Empty trip factor	Refers to the share of empty transport: distance empty/distance loaded, i.e. km_{empty}/km_{loaded} [%].	
Leg	Is the smallest unit to further specify a route. A leg's beginning and end are defined by a change of mode, vehicle or transhipment.	Figure 11
Link	Connect point(s) of origin with point(s) of destination.	Figure 11
Load factor	Refers to the share of freight volume [tonne] per total payload capacity of the vehicle type (truck, train, and vessel). In this tool, the load factor refers to weight capacity [tonne], not to volume capacity.	
Project input	Covers the minimum of data and information necessary for calculating the GHG impact of a project.	Section 4.8
Route	Specifies a link geographically. One link may be realised by different routes. One route may consist of one or more legs.	Figure 11
Point(s) of destination	Description of the boundary at the finishing point of the transport chain, until which point the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing.	Figure 11
Point(s) of origin	Description of the boundary at the starting point of the transport chain, from which point on the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing.	Figure 11
Project scenario	Is the end of the assessment period and represents a reasonable year of operation, where a typical operation can be expected.	Sections 2.2 and 4.2

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1 Introduction

Including the carbon footprint as a factor in business decisions (alongside costs, time and reliability, etc.) is becoming of greater importance for the implementation of environmental policies e.g. as a result of actions following on from the Paris agreements. Various high-level methodological guidelines have been defined, but a detailed methodological framework allowing logistics investment projects to be assessed in a comparable and consistent way is not yet available.

This document aims to provide a framework for a methodology for ex-ante GHG emissions accounting of logistics investment projects that can be consistently applied as part of the overall project evaluation process of the EBRD. The methodology framework described here is based on a state of play analysis of EBRD projects, comparable initiatives and existing carbon footprint methodologies, which identified the starting points to be used. This theoretical framework for GHG accounting has been implemented in a tool that is accompanied by clear user guidance (manual).

1.1 Purpose and scope of the framework for the methodology

The objective of this methodology is:

To assess prior to the investment (ex-ante) to what extent logistics infrastructure investment and fleet renewal contribute to an increase or decrease of GHG emissions on a project level.

To this end, a methodological framework is developed in this report that allows users to estimate the increase or decrease of GHG emissions expected to result from the planned investment in infrastructure development or fleet renewal (for details see Section 1.2).

The emissions are determined by comparing a baseline scenario (without investment) with a project scenario (see also Figure 1). The baseline scenario takes into account expected economic growth and related transport growth, without the project. All GHG impacts caused by the project on top of the baseline, such as GHG emissions of traffic diversion, induced traffic and emissions linked to the construction of infrastructure are taken into account in the project scenario.

The methodology does not give insight into absolute emissions related to operation of the infrastructure or renewed fleet. Absolute emissions very much depend on (subjective) system boundaries and this would easily leave open room for discussion on how to calculate the emission of a project.

It should be noted that GHG emissions are based on traffic projections (ex-ante); hence the outputs cannot be used for GHG accounting for countries or companies. The applied traffic projections must be consistent with economic analysis. Furthermore, the methodology provides the impact of complete projects, not taking into account the share of individual investors in the total project investment.

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Figure 1   **Comparison of baseline and project scenario**
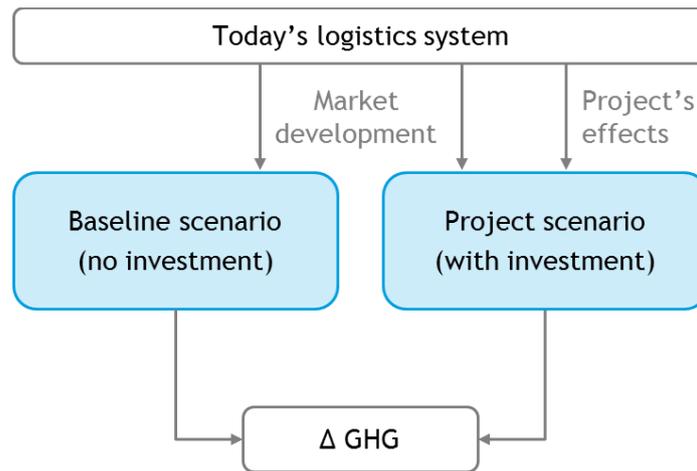
Logistics investment projects differ strongly as regards i.a. their scope, size and regional specifications. Therefore, a comparison of the GHG impact of different project types is not intended by this methodology.

The final methodological framework has been implemented in a user-friendly tool accompanied with a manual guidance to enable an ex-ante estimation of project impacts.

1.2   Types of projects covered by this methodological framework

The methodological framework covers the following types of EBRD investment projects: Investment in
−   new, or the extension of existing, terminals at seaports or intermodal terminals, as well as port infrastructure;
−   fleet renewal.

Table 1 provides examples of typical elements of such infrastructure investment projects.

Table 1   Types of logistics investment projects

Type of investment project	Description
New or the extension of existing terminals & ports	− Construction of new terminal infrastructure: new quays, storage area, buildings (administration, workshop, warehouse, etc.), fuel station, weighing station, lighting … − Construction of new hinterland connection on site: roads access, rail tracks/switches … − Construction of waterborne connection on site: dredging … − Installation of new equipment: un-/loading and handling[1], storing, cooling (e.g. reefer station). − Construction of general logistics area, buildings (administration, etc.), lighting … − Construction of flood protection. − Construction of port's energy supply: power generation, fuel station … − Renewal of existing infrastructure & equipment as described above.
Fleet renewal	− New transport technology: vehicles (truck, trailer, semitrailer, container, etc.), vessels/ferries (maritime, short sea, IWW), locomotives/wagons, airplanes.

1.3   Intended users

The methodology is intended to be used by experts involved in logistics investment decision making who have access to information requested from project applicants. Users can be EBRD staff, staff from other IFIs or contractors working on their behalf.

To facilitate its use, this methodology for GHG accounting has been implemented in a Excel-tool that is accompanied by clear user guidance (manual).

1.4   Background of the framework

Detailed comparable and consistent assessment of the GHG emissions associated with logistics investment is relatively new. Up to now, the focus of detailed assessment has mainly been on operational carbon footprinting of freight transport activities, which e.g. has resulted in the GLEC Framework (Greene & Lewis, 2016). In the beginning existing methods and initiatives were analyzed that extend the focus on operational carbon footprinting of transport towards a comprehensive assessment approach for logistics investment projects. This state of play analysis covered topics such as setting boundaries/scope of the baseline and project scenarios, data gathering on market developments and default values (to be used if, for example, no market data or existing tools for GHG accounting are available).

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[1]   i.e. Ship-to-shore crane, mobile crane, rail-mounted gantry crane, rubber-tyred gantry crane, reach stacker, straddle carrier, tractor unit, shunting train, other terminal vehicles.

The identified starting points from existing methodologies/standards for GHG assessment of logistics investment projects used to inform and develop this methodological framework are as follows:

– Operational methodological principles will be taken from the GLEC Framework (Greene & Lewis, 2016) that is a standardized approach with global support.
– Latest developments (version 2.0 of the GLEC framework (Greene & Lewis, 2016) is planned for 2018) and recommendations (e.g. as published by LEARN project (DLR, 2017)) are considered in the following tasks to ensure acceptance by the logistics sector.
– Distinction between baseline and project scenarios and their definition as described by IFI and ICAT (IFI, 2015a; IFI, 2015b; Infras ; VCS, 2017).
– Application of the ASIF model (Schipper, et al., 2000).

1.5   Reading this document

The following document covers the proposed methodological framework for ex-ante GHG emissions accounting of logistics investment projects as outlined in the introductory chapter.

It begins with general principles on GHG accounting of projects and logistics activities and overarching definitions (Chapter 2), e.g. definition of assessment period, boundary setting.

This is followed by a detailed description of the defintion of the baseline and project scenarios (Chapter 3). This covers i.a. the specification of relevant impacts of logistics investment projects.

The core element of this framework is the detailed description of the GHG accounting method for the selected types of logistics investment projects (in the following referred to as "projects") in Chapters 4.
This starts by giving an overview of the approach including a description of relevant steps of the GHG emissions assessment followed by a detailed description of each step, e.g. boundary setting, identification of relevant effects, calculation rules. In addition, all relevant input data and key variables are summarized. This is completed by a general framework for reporting the results.

Some background research and information established in the frame of the project are summarized in the Annexes.

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2 General principles

2.1 Assessment principles

The assessment principles applied are listed in Table 2 and taken from the internationally accepted GHG protocol, which many other methodologies refer to (e.g. Greene & Lewis, 2016; EIB, 2014). Those reports provide further detailed explanations.

Table 2   Assessment principles applied

Relevance
Ensure the GHG inventory appropriately reflects the GHG emissions of the project and serves the decision-making needs or reporting requirements of users **(WRI & WBCSD, 2004).**
Completeness
Account for and report on all GHG emission sources and activities within the chosen inventory boundary. Disclose and justify any specific exclusions (WRI & WBCSD, 2004, p. 7).
Consistency
Use consistent methodologies and assumptions to allow for meaningful comparisons of emissions over time. Transparently document any changes to the data, inventory boundary, methods, or any other relevant factors in the time series (basing on WRI & WBCSD, 2004, p. 7).
Transparency
Address all relevant issues in a factual and coherent manner, based on a clear audit trail. Disclose any relevant assumptions and make appropriate references to the accounting and calculation methodologies and data sources used (WRI & WBCSD, 2004, p. 7).
Accuracy
Ensure that the quantification of GHG emissions is systematically neither over nor under actual emissions, as far as can be judged, and that uncertainties are reduced as far as practicable. Chose conservative assumptions and projections. Achieve sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information (basing on WRI & WBCSD, 2004 ,p. 7).

2.2 Definition of assessment period

The assessment period is the time horizon over which the GHG impact of the logistics investment project is assessed.

It starts at the time of the baseline, where no project investment is in place and the contract of the investment project has not been signed (see also Figure 2).

Since this framework covers different types of investment projects, the implementation phase of which may differ significantly, i.e. the time for constructing new infrastructure (e.g. port, terminal) or purchasing and implementing new vehicles, trains or vessels. Therefore, no fixed time horizon is recommended. Moreover, the applicant shall take responsibility to define a reasonable year of operation, where the project investment has been finished and a typical operation can be expected.

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The GHG impact of the logistics investment project is determined by comparing the baseline emissions with the project emissions in the project year. Annual GHG emissions are calculated for the current logistics system and for the new investment. The performance of the new project is decisive. Emission impacts are calculated for the transport activity of the new project, compared to the baseline system. Emission impacts change over time during ramp up and market growth, until the maximum capacity of the project has been achieved.

Figure 2   **Definition of assessment period**
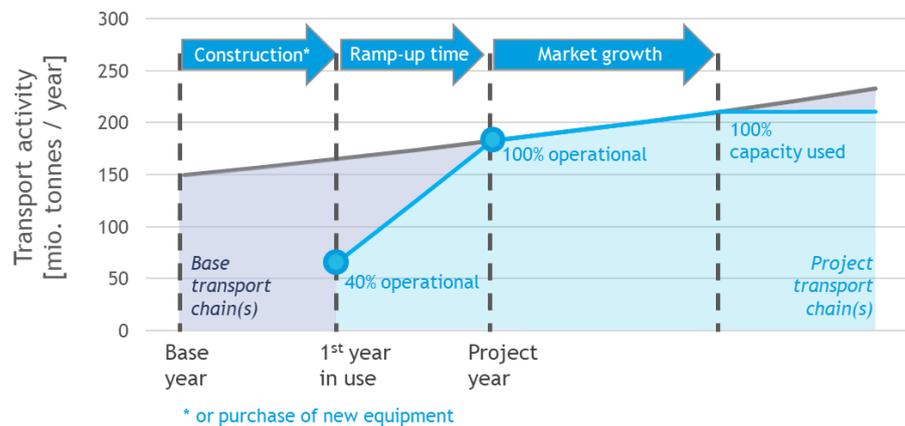
2.3   Boundary setting for the assessment

Scope 1, 2, 3

The various emission sources can in principle be structured along the GHG scopes as defined in the GHG protocol. However, a change of the viewpoint (bank or investor) leads to a change of the scopes for GHG assessment. Therefore, it was decided to develop the tool in such a way that the GHG scope can be defined on a case-by-case basis.

Geographical boundaries

The boundary of the assessment is set by the (most important) differences between the situation without (baseline/business as usual) and with the project. Since GHG emissions are a global phenomenon and logistics activities often cover international process chains, the assessment boundary should not be limited by countries' frontiers.

Process (life cycle) boundaries

Following common assessment principles, the methodology takes into account all GHG emissions that are a consequence of the project. Figure 3 shows all relevant life cycle categories for infrastructure (and equipment) on the one hand and fleet renewal on the other hand. The emission sources are categorized using a matrix distinguishing vehicle and infrastructure on the one axis and construction, activity/operation and disposal (life cycle stages) emissions on the other axis.

Figure 3   Covered life cycle emissions for infrastructure and fleet renewal investments

Infrastructure investment

	Construction	Activity/Operation	Disposal
Vehicle	Vehicle production	Vehicle use & maintenance	Vehicle scrapping/disposal
Infrastructure	Infrastructure construction	Infrastructure use & maintenance	Infrastructure dismantling

Fleet renewal

	Construction	Activity/Operation	Disposal
Vehicle	Vehicle production	Vehicle use & maintenance	Vehicle scrapping/disposal
Infrastructure	Infrastructure construction	Infrastructure use & maintenance	Infrastructure dismantling

Main impact (usually to be monitored)

Initial impact

Additional impact (usually not included)

Looking at the two categories of projects identified, the main impact caused stems from its use phase. This covers:
— vehicles, trains or ships using the infrastructure that require fuel or electricity;
— operation and maintenance of infrastructure (e.g. electricity use of terminal equipment such as cranes).

In addition, the construction phase causes relevant 'initial impact' to be considered, i.e. GHG emissions during the construction or production of the infrastructure/equipment at the beginning of the investment project.
These emissions result from the material's production (e.g. concrete, steel) as well as the energy use for the material's supply and at point of construction. The inclusion of these emissions provide a complete picture of the GHG impact of the investment project.

Another reason for including infrastructure construction emissions is the relatively high impact of construction emissions in the assessment of infrastructure investment projects, since the methodology compares project scenario emissions with a baseline scenario and only take the difference into account and not absolute emissions.

In common product life cycle analyses, those initial emissions are allocated to the overall lifetime of the product, comparable to amortization. In the area of infrastructure it is useful to use a 'calculation period', since it might be difficult to clearly define the start and/or end of the infrastructure's lifetime (Stripple & Uppenberg, 2010; Stripple et al., 2016). "The calculation period is set to a time-period close to the lifetime of the majority of the main infrastructure components (or an economic calculation period). In this way, one can receive a balanced picture for the influence of construction, maintenance and operation." (Stripple et al., 2016 p. 20). This is shown in the following figure, which is an extension of Figure 2.

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It is recommended to use a calculation period for construction emissions of 20 years[2].

Use of a calculation period for allocating initial emissions by infrastructure construction
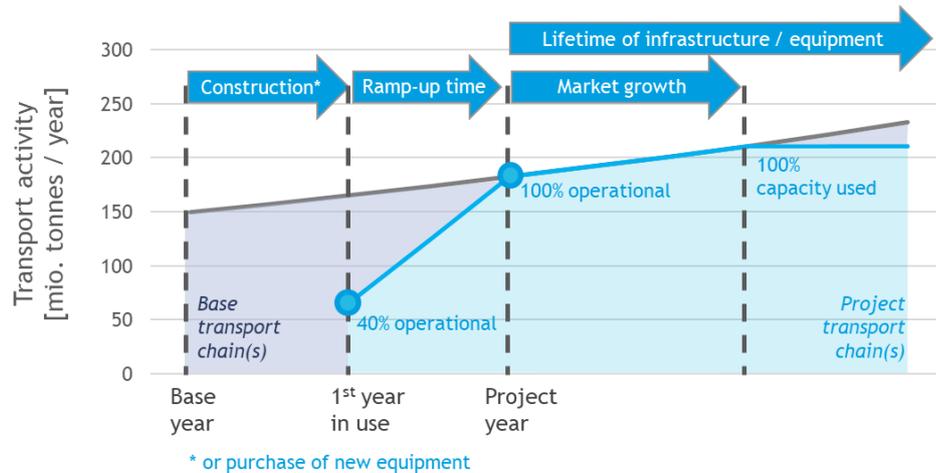
Finally, a complete life cycle approach also covers the end of life process of infrastructure and equipment, i.e. the dismantling of infrastructure or scrapping and recycling of equipment. Together with the emissions from vehicle production and disposal, these emissions are an additional impact of infrastructure investment projects, which usually are excluded from operational analysis.

The relevance of the various life cycle stages differs as does the availability of data relevant to the impacts. The vehicle use phase is by far the most important life cycle stage, as is illustrated in Annex B. Next to relevance, information about the other life cycle stages is also limited. The following decisions about the inclusion of process life cycle stages are made, with the criteria that the relevance of each process stage should be above 5% of the total:

- Infrastructure construction:
    - vehicle use;
    - infrastructure construction (conditional).
- Fleet investments:
    - vehicle use.

It is recommended to assess GHG emissions associated with construction of the investment only for larger project. No threshold for the size of the project, e.g. by means of a total investment budget, can be suggested though.
A recommended practice for inclusion is suggested to be developed in due course

The reason for not including vehicle production emissions can also be explained by the existence of vehicle production emissions in both the baseline and project scenario, as it is assumed that investment in fleets will lead to at most marginal additional demand for freight transport.

Chapter 3 further discusses the assessment scenarios.

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2   As initial value, a calculation of 20 years is provided in the tool.

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Energy life cycle

Following the common well-to-wheel (WTW) standard, both well-to-tank (WWT) and tank-to-wheel (TTW) emissions of fuel and electricity need to be included (e.g. (Greene & Lewis, 2016); (NEN, 2012)).

Figure 5 provides an overview on the well-to-wheel approach using the example of the fuel life cycle. As such, indirect emissions caused by the extraction, conversion and supply of fuels are referred to as well-to-tank (WTT) emissions and direct emissions caused by the combustion of fuels during transport as tank-to-wheel (TTW) emissions[3].

In case of electricity use (e.g. electric traction of rail transport) only indirect emissions (TTW) are relevant, i.e. by the extraction, conversion and supply via (catenary) wire.[4]

Figure 5   Fuel life cycle covering well-to-tank (WTT) and tank-to-wheel (TTW) emissions

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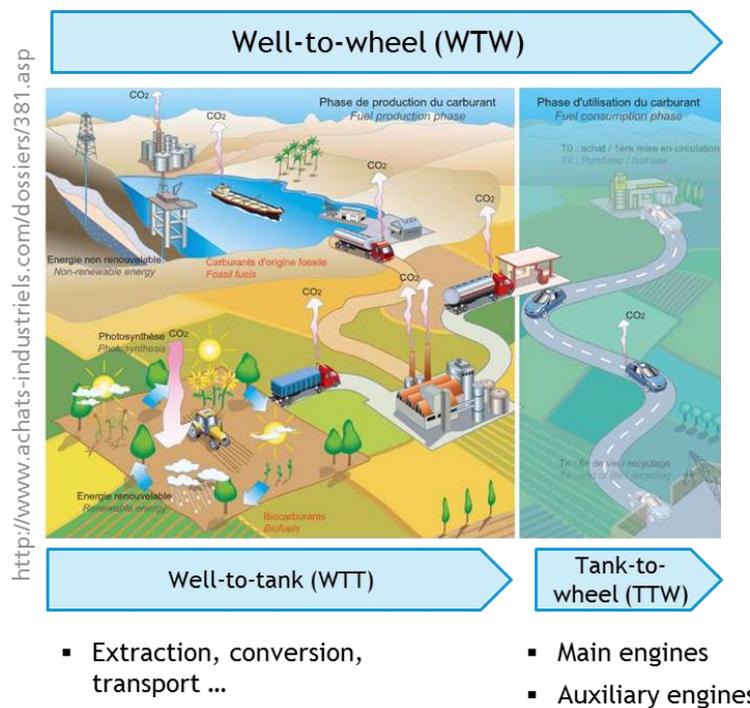
[3] In case of water transport, the use of 'propeller' instead of 'wheel' is more precise. For simplification, the framework uses consistently TTW or WTW.

[4] Again, the use of 'grid' or 'wire' instead of 'tank' is more precise. For simplification, the framework uses consistently WTT.

Greenhouse gases

Carbon dioxide (CO_2) accounts for the large majority of the total GHG emissions by logistics. Therefore, focus is on CO_2.

In case of alternative fuels and existing methane slip or losses of refrigerants, it is recommended to include all GHG emissions according IPCC, the GHG protocol (WRI & WBCSD, 2004) and the GLEC framework (Greene & Lewis, 2016).

Some general information on additional environmental impacts (i.e. air pollutants, black carbon) are given in Annex C.

3 Definition of assessment scenarios

In this chapter the methodology for assessing the GHG impacts will be described at an aggregate level.

3.1 Overall assessment framework

Figure 6 illustrates how total GHG emissions can be split into various influencing factors resulting from project implementation.

The emissions of the baseline scenario (see upper part of the figure) are influenced by the baseline transport demand. Baseline transport demand is by definition never greater than transport demand in the project scenario.

Project implementation may lead to diverted as well as induced traffic. In case of infrastructure investments construction activities are required. All these effects influence the emissions of the project scenario (see lower part of the figure).

Figure 6   GHG impacts of project implementation
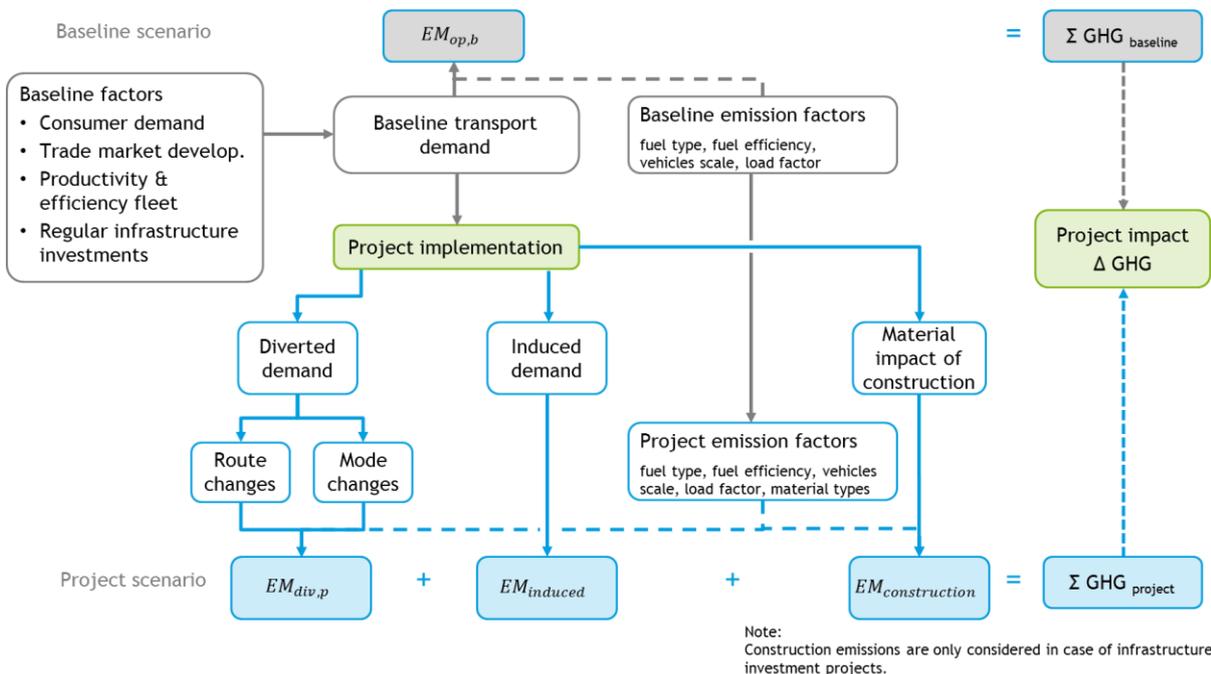
To convert transport demand of the **baseline scenario** into GHG emissions, the transport activity (tonne-km) on a route needs to be broken down into various legs and the relevant modal shares.

Multiplying the transport activity per leg (tonne-km) by the emission performance per vehicle type (kg CO_2e/tonne-km), multiplying the transhipment activity per leg (tonne) by the emission factor per modal-change (kg CO_2e/tonne) and subsequent summation over the legs will lead to the overall emissions of the baseline scenario ($EM_{op,b}$).

Equation 1

$$EM_{op,b} = \sum_i \left(W_i \times \left(D_i \times EF_{veh,i} + EF_{ts,i} \right) \right)$$

With:

$EM_{op,b}$ Operational emissions of the baseline scenario, taking into account traffic diversion only [kg CO_2e/year]

W_i Transport activity on leg i [tonne/year]

D_i Transport distance of leg i [km]

$EF_{veh,i}$ Emission factor of vehicle type (veh) used on leg i [g CO_2e/tonne-km]

$EF_{ts,i}$ Emission factor of transhipment (ts) at leg i [g CO_2e/tonne]

For the **project scenario**, the emissions caused by diverted traffic ($EM_{div,p}$) are calculated similarly (i.e. tonne-km multiplied by kg CO_2e/tonne-km).
Since transport demand is part of the baseline (see also Section 3.2), new projects mainly lead to a diversion of transport. As a function of the newly implemented project, other transport modes or routes may be used that need to be accounted for, resulting in a change in transport volume per mode (efficiency or total tonne-km).

Project implementation may lead to *induced traffic*, in cases where logistics between points of origin and destination becomes cheaper. This is the case in e.g. mode change projects and projects where economies of scale play a role (e.g. deep sea versus short sea with different ship sizes). Traffic inducement and the respective GHG impact ($EM_{induced}$) is further illustrated in Section 3.3.

Investments in infrastructure will lead to *construction activities* that require material input (concrete, steel, etc.), energy use at site and, thus, are responsible for GHG emissions. Multiplying the material input by the emissions per supplied material (kg CO_2e/tonne or m³) will lead to the overall construction emissions ($EM_{construction}$).

The *project emissions factors* may differ from the *baseline emissions factors*, both in terms of the values and which factors are relevant since the modal shares, fleet technologies and sizes used may differ.

The difference between the GHG emissions of the project scenario and the baseline scenario is the GHG impact of the implemented project (Δ GHG).

Infrastructure development may also induce economic activity, but since the impacts are a topic of debate among economists and EBRD does generally not assess these impacts on project basis, GDP impacts and the consequences for GHG emissions are not included (see Annex D).

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Four sub methods

Following this approach, four sub-methods are integrated into the overall methodology for GHG accounting of infrastructure and fleet investment impacts, as shown in Figure 7. However, their readiness to be used varies: The methodology for GHG accounting of *transport operations* is in place. Here the existing and globally accepted GLEC framework can directly be transferred (green). The method for *traffic diversion* was adapted from earlier work for EBRD (yellow), while the methods to assess *induced traffic* and *infrastructure construction* have been set up from scratch (red).

Figure 7   Methods required for ex-ante GHG assessment of infrastructure investment projects
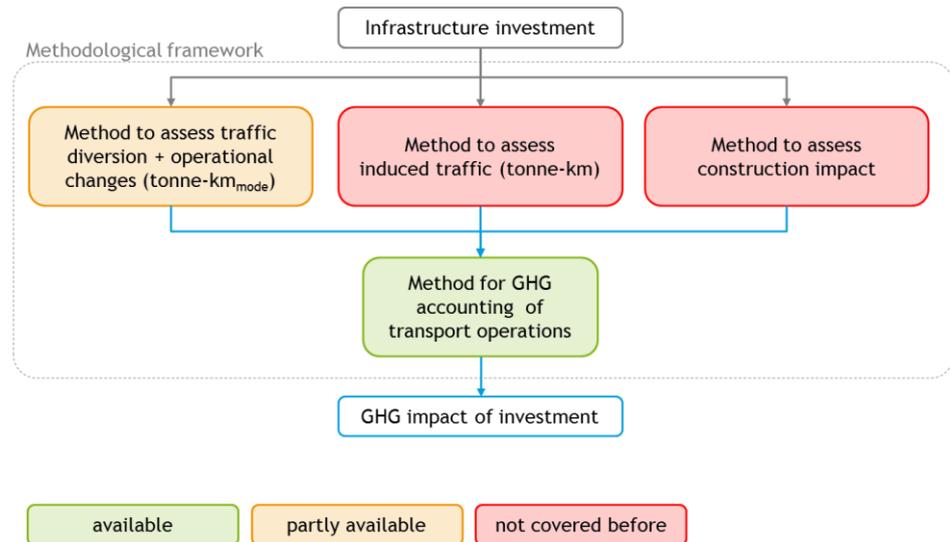
3.2   Definition of baseline scenario

The baseline for the assessment of the net GHG footprint will refer to a projection when the project is not implemented. In most cases, this baseline projection corresponds to a situation without an alternative new project, while trend investments to ensure the integrity of existing infrastructure and cater for demand, if any, will be included (IFI, 2015a).

In the baseline scenario all 'business as usual' (BAU) developments (in consistency with economic analysis) are taken into account. This includes many factors contributing to changes in transport volume and corresponding emissions, such as:

- Increases in consumer demand, through:
  - GDP growth (consumption growth/market development);
  - population growth.
- Trade market developments, such as:
  - increased outsourcing/globalization;
  - removal of trade barriers.
- Productivity and efficiency changes due to regular fleet/ equipment renewal, such as:
  - terminal automation;
  - vehicles and ship size developments;
  - fleet efficiency and environmental performance developments.

- Regular infrastructure investments, allowing for expected transport growth, such as;
  - growth of existing mainports;
  - planned improvement of existing hinterland connections.

On the one hand the baseline definition reveals what effects should and should not be addressed. For example, by construction of a new port, the region will be more directly accessible for sea ships. The region was, however, already accessible by a route via another port followed by road transport. If BAU developments indicate that normal investments will cater for future demand via the old route, the effect of the port is mainly to be found in transport diversion and not so much in transport growth.
The developments depicted may also influence both scenarios (baseline and project scenario) and the difference between both. For example:

If the project comprises a modal shift from road to rail and both modes are expected to have a 10% lower GHG emissions level in 2025, the effect of the project (the difference between baseline and project scenario) will be 90% of the calculation based on current emissions values.

According to this methodological framework, the most important BAU developments need to be considered to evaluate project impacts. All effects included shall be described in detail in the assessment report.

3.3 Definition of project scenario

The main GHG impacts expected from infrastructure or fleet investments are:
- Operational effects:
  - GHG effects of traffic diversion + GHG effects that arise from operational changes by the project.
  - GHG effects of induced traffic.
- Non-operational GHG effects of infrastructure construction.

Operational effects

The operational GHG effects can be divided into diverted traffic and induced traffic. The primary operational effect of infrastructure or fleet investments is the diversion of traffic, often accompanied by modal shift. The traffic accommodated by the new infrastructure or new equipment will mainly come from other routes benefitting from aspects such as time or cost reduction or reliability.

The operational project impacts can be identified using the well-known ASIF model[5] (Schipper, et al., 2000) that separates the factors influencing total transport emissions into the following five elements that represent the full range of options to reduce GHG emissions:
1. Amount of transport activity:
   - route changes;
   - demand changes.
2. Mode of transport.
3. Greenhouse gas intensity of fuel.
4. Vehicle fuel efficiency.

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[5] ASIF refers to Activity (tonne-km), Modal Split, Intensity (energy consumption/tonne-km) and Fuel carbon content (g CO_2e/g fuel).

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5. Amount of capacity used, load factor.

In addition, emissions arise from the transhipment of the freight volume between modes. These are influenced by freight type (e.g. bulk or containerized cargo), the associated transhipment equipment and fuels used by the equipment (e.g. diesel, electricity).

The operational impacts related to traffic diversion can vary between projects and are project specific. In Table 3, an overview of possible impacts is included, that will be accounted for when developing formulas in Chapter 4.

Table 3   Examples for expected impacts of infrastructure and fleet investment projects (diverted transport + other operational effects)

New/extended seaport terminal or inland terminal	Fleet renewal/investment
Route changes: the inbound and outbound transport legs and, thus, the transport distance will change.	Change in freight routing: new vehicles/vessels/wagons may improve (or initiate/develop) the connectivity of regions; direct effect on the distance to be travelled, e.g. change of mode from road to water.
Other modes of transport are used, resulting in a change in energy efficiency or energy carriers. − Shift to other energy carriers within one mode; this may require a different fuel station infrastructure and/or detours for refueling.	Change in share of mode: higher share of one mode with a different energy efficiency or other energy carriers. − Shift to other energy carriers within one mode; this may require a different fuel station infrastructure and/or detours for refueling.
Change in energy efficiency caused by e.g. − Other sizes of fleet, enhanced carrying capacity. − Enhanced load factor. − Higher energy efficiency of terminal infrastructure and/or equipment.	Higher energy efficiency of means of transport: − Other sizes of fleet, enhanced carrying capacity. − Enhanced load factor. − Less fuel consumption (caused by better engines, tyres, wind resistance, driver assistance, etc.).
Realization of green measures, e.g. cold ironing, high degree of electrification.	

Induced traffic

Induced (new) traffic is a secondary effect as infrastructure or equipment capacity is only one of the criteria that accommodates future growth and infrastructure is generally not a bottleneck for transport growth. Transport growth is mainly driven by consumer demand and GDP growth and business as usual infrastructure investments will cater the demand. As long as infrastructure or the equipment available is not a bottleneck to make a certain region accessible[6], it is assumed that by far the largest share of traffic accommodated by the new investments is diverted traffic.

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[6]   Availability of infrastructure may be a bottleneck in cases of severe congestion, or in case the available infrastructure is allocated by a manager (e.g. airport slots). In other cases, the availability of infrastructure is not seen as a bottleneck. Latent demand is limited to a few percent (KiM, 2014) on the relatively busy Dutch Motorway network. This illustrates that latent demand in case of freight transport (without many traffic jams) is even more limited.

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The amount of induced traffic can be assessed through the impact of lower transport costs, using a transport price elasticity. Economic theory simply teaches that if a good becomes cheaper, its consumption will increase. This is illustrated in Figure 8.

Figure 8   **Relation between unit goods' cost and demand**
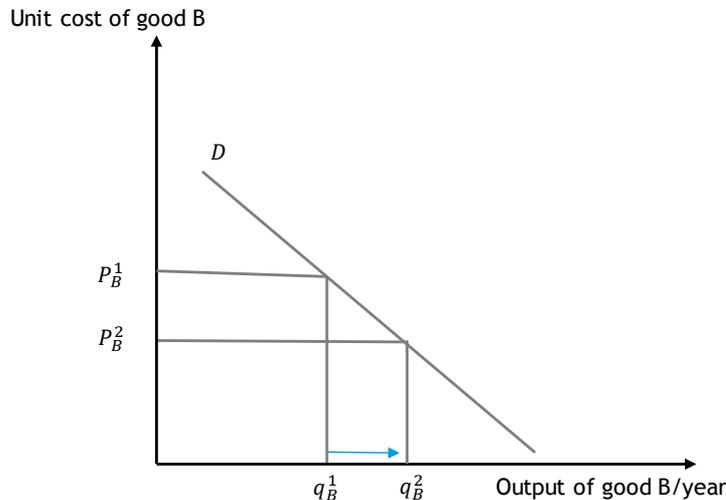
New infrastructure is only built or new advanced fleet is only bought when it is expected to increase transport efficiency and to reduce the costs as compared to existing transport links. The cost reduction might be the result of shorter origin-destination distances or scale advantages. The decrease in generalized costs (money, time, security, etc.) will to some extent attract new traffic. All these effects lead to an increase in tonne-kilometers.

> **Example of induced transport**
> The principle of induced traffic is sometimes also referred to as the rebound effect. Within logistics, the discussion on rebound effects plays a large role in context of the allowance of megatrucks (LHV) on European roads. Megatrucks offer up to 50% extra payload capacity, reducing transport costs by 20 to 30% and hence increase of demand for transport by road, partly at the cost of other modes (Doll, 2009).

The total amount of induced traffic can be assessed through the impact of lower transport costs, using a transport demand price elasticity. The typical average transport elasticity for freight transport (excluding shift to other modes) is estimated to be around -0.5 (Beuthe, et al., 2014). This implies that a project resulting in a 10% cost decrease will lead to an increase of demand of 5%, applied to volume of the project. This indicated transport elasticity of -0.5 may serve as a starting point, it is necessary to use the elasticity for the specific project though. More information on elasticities and typical values can be found in Annex A.

> **Example**
> As an example, a project with a size of 1 million tonnes and logistics chains of 1,000 km and 50 g CO_2e/tonne-km that reduces transport costs by 10% will result in emissions increase of 2,500 tonnes CO_2e per year.

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The amount of induced traffic needs to be assessed, using lowering of transport cost between origin and destination (%) between the baseline and project scenario as an input.

Further background information on induced traffic is given in Annex A.

GDP impacts

Also GDP impacts play a role in economies with have not reached a certain point of saturation, see Annex E. However, GDP impacts have been left out of scope, since EBRD analyses the wider impacts seperately.

Construction impacts (only infrastructure projects)

As described in the chapter on process life cycle boundaries (see Section 2.3), GHG emissions of infrastructure construction result from the material's production and supply (e.g. concrete, steel) as well as the energy use for material transport, construction work or maintenance.

The impact of infrastructure construction can be based on a material input analysis, as is usually done in the area of life cycle assessment. For the project types as described in the introductory chapter (see Table 1), the relevant material input is collected. Figure 9 shows exemplary areas of logistics infrastructure where construction material is required.

> **Example**
> A quay construction may consist of e.g. (Stipple et al., 2016):
> — concrete for superstructure, piles and anchors;
> — filling material, e.g. rock, rubble, excavated or dredged material;
> — steel sheet piles;
> — asphalt layer.

Figure 9   Exemplary areas of material use for assessment of construction impacts
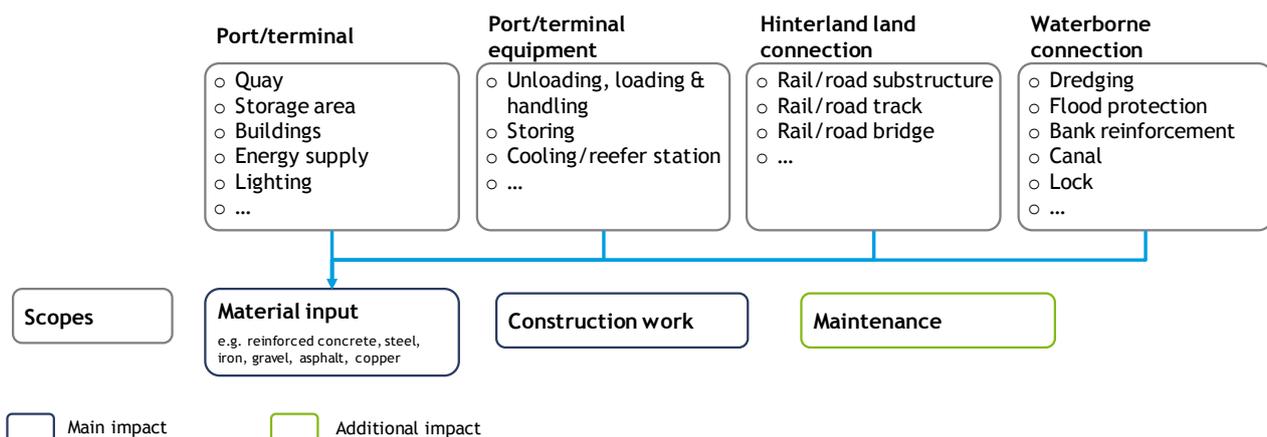
Additional GHG impact caused by fuel or electricity consumption for material transport, construction work or maintenance or by deforestation, etc. can be assessed — by means of a simplified approach — using a percentage surcharge.

As shown in Figure 3, construction emissions only occur at the initial stage of a project (during construction phase) and therefore need to be allocated over the calculation period (see Figure 4). It is proposed to use a calculation period of 20 years for transport infrastructure (road, rail, fairways) and for ports/terminals (Stripple & Uppenberg, 2010; Stripple et al., 2016).

If the user chooses a varying calculation period or lifetime, this should be specified in the assessment report (see Step 6).

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4 Methodology calculating CO$_2$ emissions from investment projects

4.1 Introduction

This chapter covers the methodology for investment projects focusing on
— new, or the extension of existing, terminals at seaports or intermodal terminals, as well as port infrastructure;
— fleet renewal.
as described already in more detail in Section 1.2.

The methodology considers six steps (see Figure 10): Starting with boundary setting of the scenarios to be assessed, followed by parallel assessment steps 2-4 and ending with calculating the overall GHG impact of the investment project and reporting of the results. Each step is described in detail in the next sections.

Figure 10   Relevant steps of the GHG emissions assessment
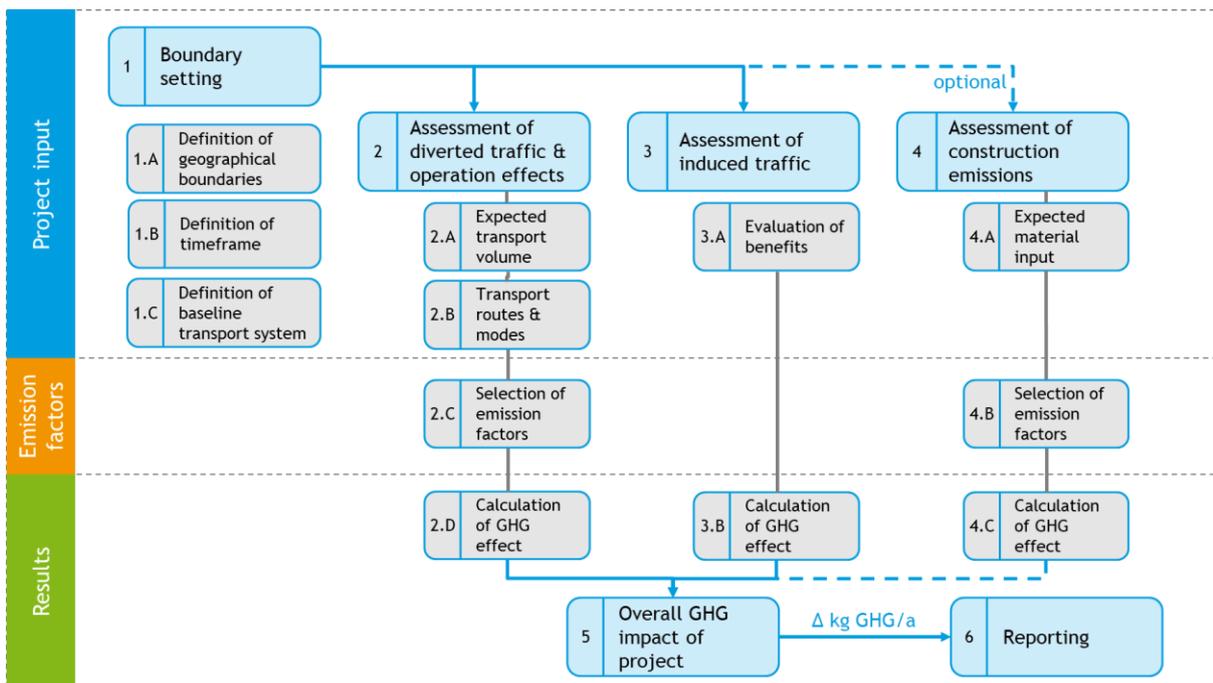
4.2 Step 1 - Boundary setting

1.A Definition of geographical boundaries of logistics chain

The emissions are determined by comparing a baseline scenario with a project scenario (see also Figure 1). Therefore, relevant transport chains within the baseline and project scenarios are described in the beginning. For this, select the most relevant routes for each scenario covering at least 80% of the transport activity. Describe those by specifying the relevant points of origin and destination (see Figure 11):

– Point(s) of origin. Description of the boundary at the starting point of the transport chain, from which point on the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing.
– Point(s) of destination. Description of the boundary at the finishing point of the transport chain, until which point the new/extended terminal/port infrastructure most likely affects the transport flows, e.g. change of mode, other routing.

The 'points' of origin/destination can be both detailed, e.g. selected cities, or less detailed, e.g. regions.

The origin - destinations relation are defined as *links*. The logistics system under study can consist of one or more links, depending on the number of point(s) of origin and destination.

For each link, various *routes* may be possible. For infrastructure investments new routes are established by e.g. the construction of a new port/terminal (see example below).

Each route can be further specified by introducing modes and relevant via-points. One route may consist of one or more *legs*, whereas a leg's beginning and end are defined by a change of mode, vehicle or transhipment.

Figure 11 Differentiation of 'link', 'route' and 'leg' within geographical boundaries of logistics chain
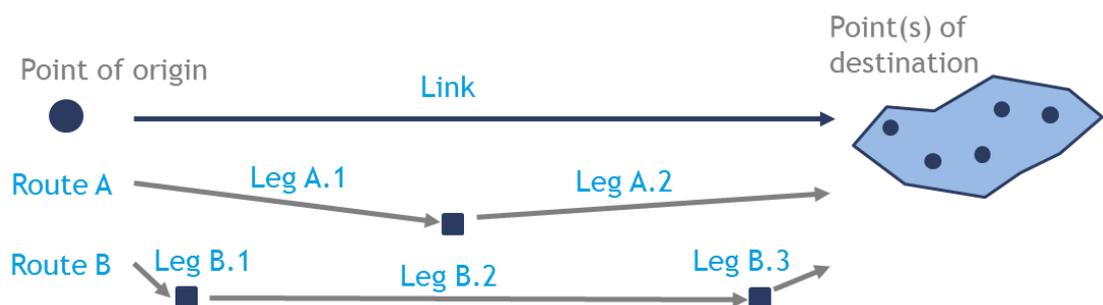
The consideration of future new points of origin/destination should only be included if this is distinctive of the project to be assessed.

Example: Infrastructure investment

The following simplified example reflects EBRD investment in DCT Gdansk expansion (Poland, EBRD project code 45805, 2014). The project covers the construction of a second deep-water container terminal at the Port of Gdansk, offering an alternative route to markets around the Baltic region and Central Europe. In the assessment report[7] the main impact of the investment project is seen in the modal shift on the main haul between a Western and Central European port. Rotterdam is identified to be the main competitor port to Gdansk and, therefore, the geographical boundaries are defined with Rotterdam as point of origin and various transit and transhipment markets in Central Europe[8] as points of destination. All other transport legs before and after are not affected by the investment and are left out of scope.

Figure 12   Geographical boundaries of example of DCT Gdansk terminal (simplified)
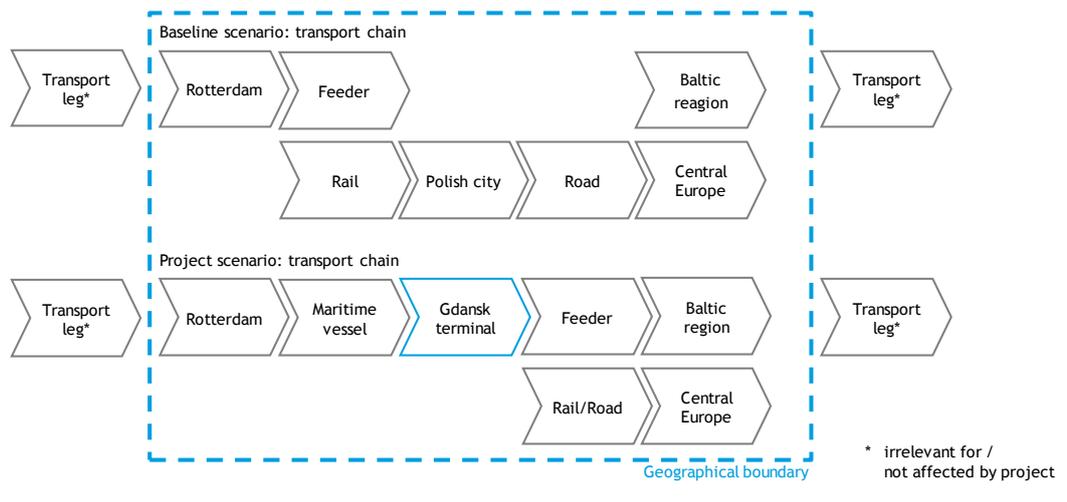
Example: Fleet investment

The following simplified example bases on the EBRD investment in a new RoRo ship (Turkey, EBRD project code 46917, 2014), with road transport in the baseline scenario. The capacity of the ship is 200 trucks and it makes one round trip per week between Turkey and Italy. The distance by road from Istanbul to Trieste is 1,800 km by road in the baseline and 50 km by road in the project scenario, followed by a sea leg of 2,200 km. Products transhipped may be produced in the Turkish or Italian hinterland, but this does not differ between the scenarios and is therefore left out of scope.

Figure 13   Geographical boundaries of example of Turkish RoRo example (simplified)

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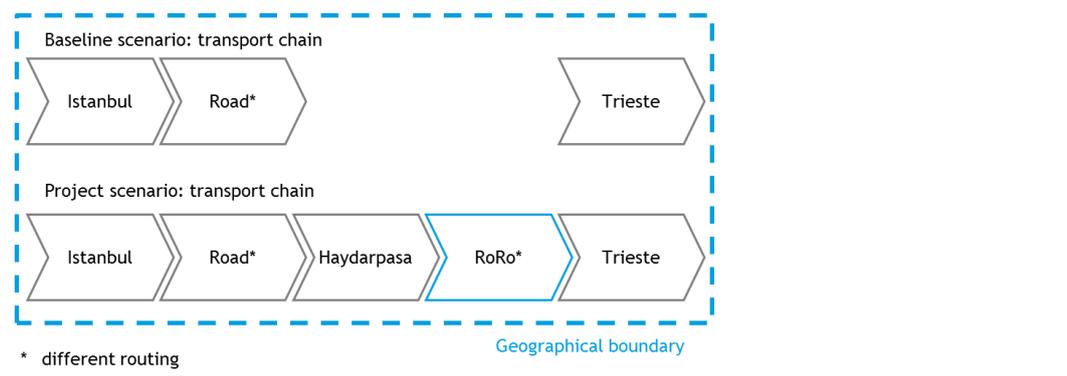
[7]   Internal EBRD document: ARUP (2014) Assessment of opportunities in DCT Gdansk. Issue 2.

[8]   Transit markets: Slovak Rep., Czech Rep., Belarus, Russia, Ukraine and Transhipment markets: Lithuania, Latvia, Estonia, Finland, Russia.

1.B Definition of base year and project year

Identify the base and project year for the assessment. The years are defined as follows:
- Base year. The base year is the most recent year for which transport data are available. It concerns transport that will be influenced by the project. In the base year no project is in place.
- Project year. The project year is the year, the investment is in place and a typical operation can be expected, i.e. no commissioning or unplanned shutdowns.

1.C Definition of transport system in the base year

The definition of the baseline transport system requires the following actions:
- Identify the total freight volume[9] (tonne) in the base year. The volume should include all the transports that will be affected by the project and, thus, may refer to less than the total infrastructure's capacity (e.g. capacity of terminal, route). Affected volume should not exceed the capacity of the project.
- Allocate the freight volume to the modes of transport and corresponding vehicle types, vehicle load factors in the base year by means of:
  - an overall share on the project level using tonne-km;
  - a detailed share on selected link and route level

4.3 Step 2 - Assessment of diverted traffic & operational effects

To determine the effect of diverted traffic, the following steps need to be followed.

2.A Expected transport volume

The freight volume in the base year (in tonnes) needs to be extrapolated to the expected volume in the project year.

Equation 2

$$W_{p;total} = (1 + GR_{total}) \times W_{by;total}$$

With:

$W_{p;total}$	Total transport activity in the project year [tonne/year]
GR_{total}	Expected overall growth rate for the project [%]
$W_{by;total}$	Total transport activity in the base year [tonne/year]

The extrapolation should preferably be based on expected market developments per link, resulting from economic and market analysis.

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[9] The transport volume used refers to tonnes. If TEU is more convenient to use for the assessment, a conversion factor as publishe by GLEC (2016) shall be used, i.e. 10 tonne/TEU.

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2.B Allocation of transport volume to routes & modes

Allocate the expected freight volume to the selected transport mode(s) for both the baseline and the project scenario. The allocation of the freight volume in the baseline scenario will follow the allocation shares of the base year, taking into account growth as covered by Equation 3. The allocation in the project scenario should follow from the project plans.

Depending on the investment project in focus (e.g. fleet renewal) and data availability this allocation may be reasonable to be based on tonne-km per mode.

However, it is recommended to use a more detailed level if data is available: As such for both baseline and project scenario, specify the relevant transport legs for each selected route and their corresponding modes of transport. Identify the relevant transport distance, vehicle types, vehicle load factor and via points (transshipments).

Example (simplified): Infrastructure investment
DCT Gdansk expansion (Poland, EBRD project code 45805, 2014)

Figure 14 shows the routes in the baseline and project scenario on two exemplary links, i.e. from Rotterdam to (1) Finland and (2) Hungary, with relevant modes and distances for both scenarios.
The transport capacities are defined as follows: large maritime vessel (18,340 TEUs), feeder (small vessel, 4,400 TEUs), rail (28 platform train, 56 TEUs), and road (truck 40 t, 1.7 TEUs). Terminal capacity is 1.5 million TEU per year.

Figure 14   Baseline and project routes for 2 links from study of DCT Gdansk terminal (simplified)
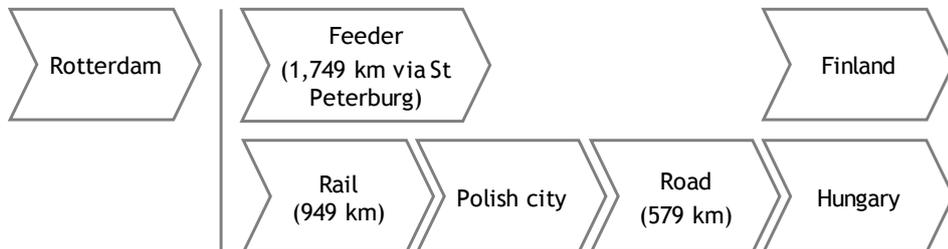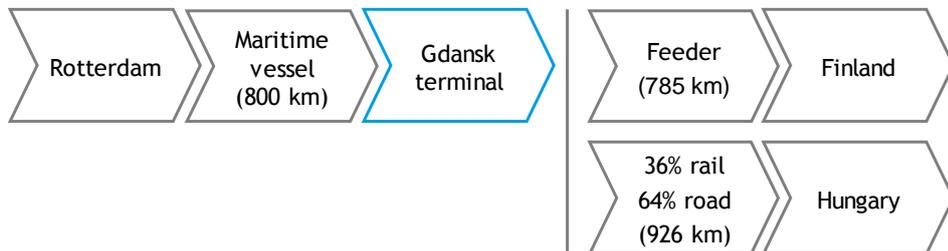
Example (simplified): Fleet investment; using a tonne-km allocation approach
RoRo ship (Turkey, EBRD project code 46917, 2014)

Figure 15   Transport flows in Turkish RoRo example (simplified)

Baseline scenario: transport chain

| Istanbul | Road* (2,000 km) | | | Trieste |

Baseline scenario:
Road: 800 million tonne-km

Project scenario: transport chain

| Istanbul | Road* (50 km) | Haydarpasa | RoRo** (2,200 km) | Trieste |

Project scenario:
Road: 20 million tonne-km
RoRo: 880 million tonne-km

*   200 trucks * 50 weeks = 10,000 trucks (40 tonne truck, 50% load in both directions)
** 1 ship * 50 weeks = 50 ships (8,000 tonne RoRo ship, 50% load in both directions)

2.C   Selection of emission factors

Look up the emission factors for all the transport modes (g/tonne-km) and vehicle/vessel types specified in Step 1.C and 2.B.

Relevant emission factors are provided in the developed tool that can be further customized by the user.

2.D   Calculation of GHG effect

The GHG effect of traffic diversion can be calculated by taking the difference between project scenario and baseline scenario.

In formulae the emission due to traffic diversion (EM$_{diverted}$) is calculated as follows:

Equation 3

$$EM_{diverted} = EM_{op,p} - EM_{op,b}$$

With:

$EM_{diverted}$ GHG effect due to traffic diversion (negative emissions in case of emission reduction) [kg CO_2e/year]

$EM_{op,p}$ Operational emissions of the project scenario, taking into account traffic diversion only [kg CO_2e/year]

$EM_{op,b}$ Operational emissions of the baseline scenario [kg CO_2e/year]

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The operational emissions of the baseline scenario EM$_{op,b}$ or the emissions of the diverted traffic in the project scenario EM$_{op,p}$ are calculated by summing over the emissions of the different links involved in the scenario:

Equation 4

$$EM_{op,b} = \sum_l EM_{op,b;l} \text{ and } EM_{op,p} = \sum_l EM_{op,p;l}$$

With:

$EM_{op,b}$ Operational emissions of the baseline scenario [kg CO$_2$e/year]

$EM_{op,b;l}$ Operational emissions of link l in baseline scenario [kg CO$_2$e/year]

$EM_{op,p}$ Operational emissions of the project scenario [kg CO$_2$e/year]

$EM_{op,p;l}$ Operational emissions of link l in project scenario [kg CO$_2$e/year]

For each link in the baseline or project scenario the GHG emissions can be determined as:

Equation 5

$$EM_{op,s;l} = \sum_r EM_{op,s;r(s)} = \sum_{r(s)} \left(W_{r(s)} \times \sum_{r(s)} \left(D_{r(s),i} \times EF_{veh,s;r(s),i} + EF_{ts,s;r(s),i} \right) \right)$$

With:

$EM_{op,s;l}$ Operational emissions of link l in scenario s [kg CO$_2$e/year] with baseline scenario (s=b) and project scenario (s=p)

$EM_{op,s;r(s)}$ Operational emissions of route r in scenario s [kg CO$_2$e/year] with baseline scenario (s=b) and project scenario (s=p)

$W_{r(s)}$ Annual transport activity on route r in baseline (s=b) or project scenario (s=b) [tonnes]

$D_{r(s),i}$ Distance of leg i on route r in baseline (s=b) or project scenario (s=b) [km]

$EF_{veh,s;r(s),i}$ Emission factor of vehicle type on leg i of route r in baseline (s=b) or project scenario (s=b) [g CO$_2$e/tonne-km]; defined by the transport mode, vehicle or vessel type, load factor of the vehicle or vessel type and fuel

$EF_{ts,s;r(s),i}$ Emissions factor of transhipment at leg i of route r in baseline (s=b) or project scenario (s=b) [g CO$_2$e/tonne]

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Example (simplified, focus on only one route): Infrastructure investment
DCT Gdansk expansion (Poland, EBRD project code 45805, 2014)

Figure 16 shows the emissions calculation for both the baseline and project scenario for a selected link between Rotterdam and Finland. Emissions caused by transhipment in Gdansk terminal have been left out of scope in this example.

Figure 16   Operational emissions for link Rotterdam-Finland of example of DCT Gdansk terminal (simplified)
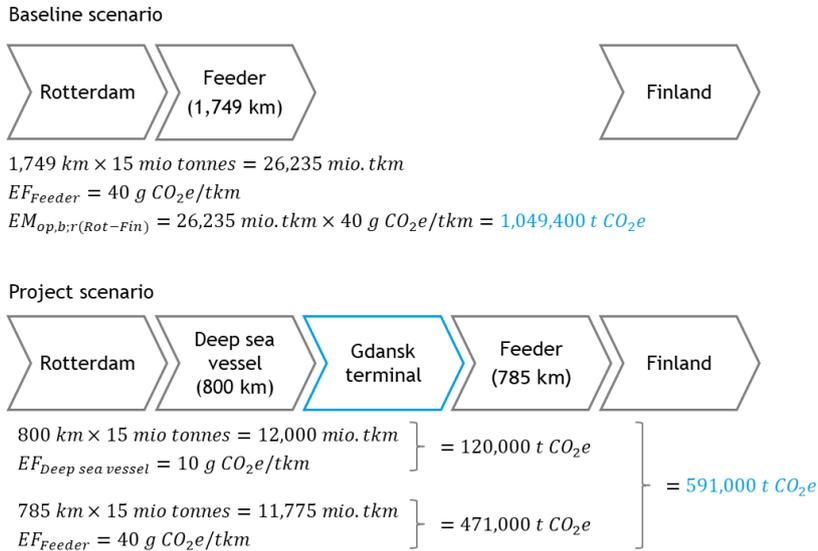
Baseline scenario

$$1,749 \; km \times 15 \; mio. tonnes = 26,235 \; mio. tkm$$
$$EF_{Feeder} = 40 \; g \; CO_2e/tkm$$
$$EM_{op,b;r(Rot-Fin)} = 26,235 \; mio. tkm \times 40 \; g \; CO_2e/tkm = 1,049,400 \; t \; CO_2e$$

Project scenario

$$800 \; km \times 15 \; mio. tonnes = 12,000 \; mio. tkm$$
$$EF_{Deep\,sea\,vessel} = 10 \; g \; CO_2e/tkm$$
$$= 120,000 \; t \; CO_2e$$

$$785 \; km \times 15 \; mio. tonnes = 11,775 \; mio. tkm$$
$$EF_{Feeder} = 40 \; g \; CO_2e/tkm$$
$$= 471,000 \; t \; CO_2e$$

$$= 591,000 \; t \; CO_2e$$

Example (simplified): Fleet investment
RoRo ship (Turkey, EBRD project code 46917, 2014)

Figure 17 shows the emissions calculation for both the baseline and project scenario for the link between Istanbul and Trieste. Emissions caused by transhipment at the RoRo-Terminal have been left out of scope in this example.

Figure 17   GHG emissions of routes in Turkish RoRo example (simplified)

Baseline scenario: transport chain

$$EF_{Road} = 100 \; g \; CO_2e/tkm$$
$$EM_{op,b;r(Istanb.-Trieste)} = 800 \; mio. tkm \times 100 \; g \; CO_2e/tkm = 80,000 \; t \; CO_2e$$

Project scenario: transport chain

$$EF_{Road} = 100 \; g \; CO_2e/tkm$$
$$EM_{op,p;i(Istanb.-Haydarpasa)} = 2,000 \; t \; CO_2e$$

$$EF_{RoRo} = 20 \; g \; CO_2e/tkm$$
$$EM_{op,p;i(Haydarpasa-Trieste)} = 17,600 \; t \; CO_2e$$

$$EM_{op,p;r(Istanb.-Trieste)} = 19,600 \; t \; CO_2e$$
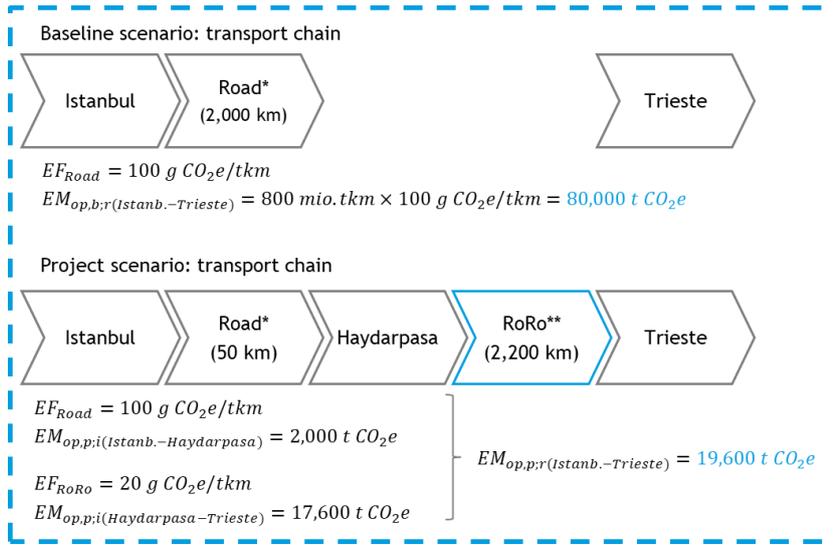
4.4 Step 3 - Assessment of induced traffic

The amount of induced traffic needs to be assessed, using lowering of the total transport cost between origin and destination (%), between the baseline and project scenario as an input.

To make the assessment, the following steps should be followed.

3.A Evaluation of benefits

Evaluate the benefits of the infrastructure for the most important routes in terms of costs. Costs that play a role in the assessment are all the carrier's costs during transport: fuel, maintenance, insurance, handling and storage costs, services directly linked to a transport, labor, capital invested in vehicles, plus all residual indirect costs like those of administrative services. Transport time impact on the inventory cost of transported goods proportional to their value, a part of the shipper's logistic cost, is also included.
These costs should be evaluated both for the baseline and the project scenario per fixed amount of goods (tonne). From the total costs in the baseline and project scenario the relative cost change (CC) can be calculated (either as an average of the project or on link-level) as follows:

Equation 6

$$CC = \frac{Cost_p - Cost_b}{Cost_b} \times 100\% \text{ or } CC_l = \frac{Cost_{p;l} - Cost_{b;l}}{Cost_{b;l}} \times 100\%$$

With

$Cost_p$	Total transport costs after project implementation [€/tonne] (of link l)
$Cost_b$	Total transport costs in the baseline scenario [€/tonne] (of link l)
CC	Relative cost change [%] (of link l)

3.B Calculation of GHG effect by induced transport

The induced transport volume cannot be allocated to specific modes.
It is therefore assumed that all modes per link, identified in the diverted traffic, grow at the same rate. The emissions of induced transport can, therefore, be calculated applying the growth factor to the emissions for the diverted traffic (see Step 2.D), again, either on project level or on link level.

As described in Section 3.3 a sensitivity of transport volume to transport costs of $\varepsilon = -0.5$ is suggested, which should be adjusted according to the investment project at hand.

For the calculation of the GHG effect by induced transport, the following formulae apply:

Equation 7

$$EM_{induced} = CC \times \varepsilon \times EM_{op,p} \quad \text{or} \quad EM_{induced} = \sum_l \left(CC_l \times \varepsilon \times EM_{op,p;l} \right)$$
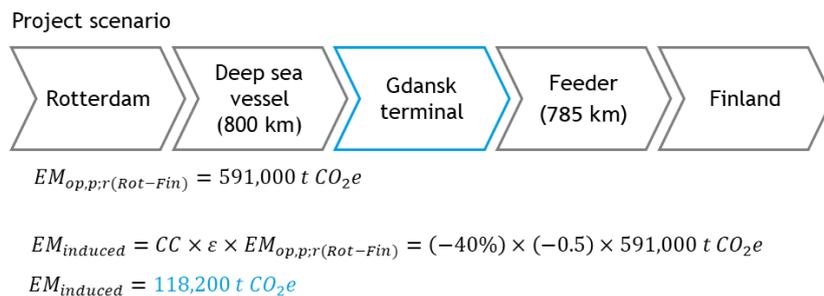
With:

$EM_{induced}$	Emissions due to induced transport [kg CO$_2$e/year]
CC or CC_l	Relative cost change in the project scenario relative as per volume [tonne] (on link l) after project implementation [%]
ε	Elasticity giving the relation of transport costs per tonne on transport demand in tonne-km [-]
$EM_{op,p}$ or $EM_{op,p;l}$	Operational emissions in project scenario (on link l) taking into account traffic diversion only [kg CO$_2$e/year]

Example (simplified, focus on only one route): Infrastructure investment
DCT Gdansk expansion (Poland, EBRD project code 45805, 2014)

The new route via the new terminal in Gdansk results in a cost reduction of 40%. The preselected transport sensitivity is used in the example. The emissions of traffic inducement can be calculated as follows.

Figure 18   Induced emissions for link Rotterdam-Finland of example of DCT Gdansk terminal (simplified)

Project scenario

$$EM_{op,p;r(Rot-Fin)} = 591,000 \ t \ CO_2 e$$

$$EM_{induced} = CC \times \varepsilon \times EM_{op,p;r(Rot-Fin)} = (-40\%) \times (-0.5) \times 591,000 \ t \ CO_2 e$$

$$EM_{induced} = 118,200 \ t \ CO_2 e$$

Example (simplified): Fleet investment
RoRo ship (Turkey, EBRD project code 46917, 2014)

Below, the emissions related to traffic inducement are calculated for the Turkisch RoRo example. The new route using a RoRo-vessel results in a cost reduction of 50%. The preselected transport sensitivity is used in the example. The emissions of traffic inducement can be calculated as follows.

Figure 19   Induced GHG emissions of project implementation (simplified)

Project scenario

$$EM_{op,p;r(Istanb.-Trieste)} = 19,600 \ t \ CO_2 e$$

$$EM_{induced} = CC \times \varepsilon \times EM_{op,p;r(Istanb.-Trieste)} = (-50\%) \times (-0.5) \times 19,600 \ t \ CO_2 e$$

$$EM_{induced} = 4,900 \ t \ CO_2 e$$

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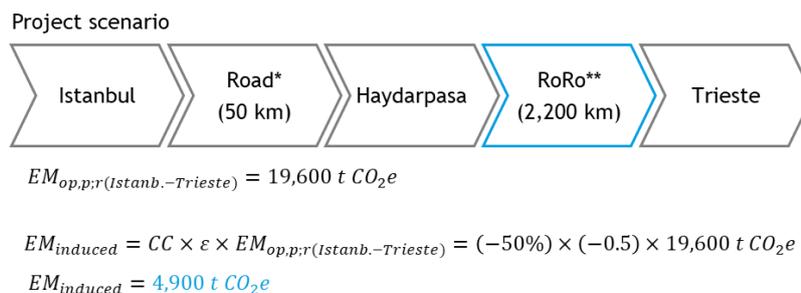
4.5   Step 4 – Assessment of construction emissions

4.A   Expected material input

The calculation of the GHG impact of infrastructure construction is recommended for large infrastructure projects (see Section 3.3). It is based on a material input and energy carrier analysis. Therefore, estimate the material input as well as energy carriers used for all relevant areas of the project investment. For your guidance, exemplary areas for material input of terminal or port infrastructure investments are given in Figure 20.

Figure 20   Exemplary areas of material use of terminal or port infrastructure investments

Port/terminal	**Port/terminal equipment**	**Hinterland land connection**	**Waterborne connection**
o Quay o Storage area o Buildings o Energy supply o Lighting o …	o Unloading, loading & handling o Storing o Cooling/reefer station o …	o Rail/road substructure o Rail/road track o Rail/road bridge o …	o Dredging o Flood protection o Bank reinforcement o Canal o Lock o …

Relevant material categories are e.g. (reinforced) concrete, (reinforced) steel, asphalt, gravel, sand, limestone, clay brick, cement, aluminum, copper, plastics such as HDPE, PVC, glass fiber reinforced plastic, synthetic rubber, wood, wood preservative, lubricating oil.

The total material input per material type is estimated as follows:

Equation 8

$$V_m = \sum_{area} V_{m,area}$$

With:

V_m Annual amount of used material m for the total project scenario p [tonne, m³ or others]

$V_{m,area}$ Total amount of used material m for the different areas of investment project [tonne, m³ or others]

Example: Infrastructure investment

The following simplified example bases on the EBRD investment in Yuzhny Grain Terminal (Ukraine, EBRD project code 47383, 2016). The investment refers to the development of a modern greenfield grain transhipment terminal in the Port of Yuzhny.

The material balance for the following selected areas are given in this example:
- quay: 440 m length; water depth of 16 m;
- ship loader: two with a capacity of 2,000 tonnes/hour;
- rail connection: rail station on berth with a capacity of 16,250 tonnes/day.

Since some detailed data is lacking, the following assumptions are used for establishing the above material input matrix:
- quay: 20 m width with 10 m^3 of concrete per m length of quay (Stripple & Uppenberg, 2010);
- ship loader: Height/length/depth loader 20 m/2 m/2 m, density steel 8 tonne/m^3;

rail connection: Length wagon 15 m; with material input for single tracks with concrete sleepers as published by Stripple & Uppenberg (2010), i.e. 60 kg steel/m rail, 250 kg concrete/sleeper, 1,7 sleeper / m rail, 10 m^3 base material/m rail.

Table 4   Exemplary material input

Core-module	Steel [tonne]	Reinforced concrete [m³]	Gravel [m³]	Asphalt [tonne]	...
Quay		4,400			
Ship loader	1,280				
Rail connection	32.4	225	5,400		
...					
Total project	**1,312.4**	**4.625**	**5,400**	...	...

4.B   Selection of emission factors

Look up the emission factors for all the material types/energy carriers specified in Step 4.A.

Relevant emission factors are provided as part of the GHG emissions calculation tool. The emission factors concern the life cycle emissions of the material/energy carrier, including mining, production transport and use.

4.D   Calculation of GHG effect by infrastructure construction

Calculate the GHG emissions by multiplying the amount of material type and energy carrier used for construction and the relevant emission factor of material type, or energy carrier respectively.

The following formulae apply:

Equation 9

$$EM_{constr-t} = \left(\sum_m (V_m \times EF_m) \right) \times (1 + MT) + EM_{surcharge}$$

With:

$EM_{constr-t}$	Total emissions due to construction of infrastructure [kg CO$_2$e]
V_m	Volume of used material or energy carriers m in project scenario [tonne, m³ or others]
EF_m	Emission factor for life cycle emissions of material or energy carrier m [g CO$_2$e/tonne or m³ or others]
MT	General surcharge of emissions for maintenance of the infrastructure [%]
$EM_{surcharge}$	Emissions for those areas, for which no material input can be estimated or a simplified assumption is reasonable (e.g. 10% for dredging, deforestation[10], others) (for total lifetime)

For comparison with annual operational emissions (see also Annex D), the total infrastructure and equipment emissions are divided by the depreciation period of the infrastructure t to convert them to annual emissions a follows:

Equation 10

$$EM_{construction} = \frac{EM_{constr-t}}{t}$$

With

$EM_{construction}$	Annual emissions due to construction of infrastructure [kg CO$_2$e/a]
$EM_{constr-t}$	Total emissions due to construction of infrastructure [kg CO$_2$e]
t	Depreciation period of the infrastructure [a]; Recommendation: $t = 20\ a$

4.6 Step 5 - Calculation of overall GHG impact of investment project

The total annual GHG impact of investment project are given by:

Equation 11

$$EM_{total} = EM_{diverted} + EM_{induced} + EM_{construction}$$

With:

EM_{total}	Total annual GHG impact of the project [kg CO$_2$e/year]
$EM_{diverted}$	Annual GHG effect of diverted traffic [kg CO$_2$e/year]
$EM_{induced}$	Annual emissions due to induced transport [kg CO$_2$e/year]
$EM_{construction}$	Annual emissions due to construction of infrastructure [kg CO$_2$e/year]

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[10] An Approach for emissions due to deforestation is published in the draft CDM methodology AM0104. Section 5.6. Leakage (UNFCCC, 2012)

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The total GHG emissions of the baseline scenario as well as the project scenario is calculated as followed.

Baseline scenario (see step 2.D):

Equation 12

$$EM_b = \sum_{r(b)} EM_{op,b;r(b)} = \sum_{r(b)} \left(W_{r(b)} \times \sum_{r(b)} \left(D_{r(b),i} \times EF_{veh,b;r(b),i} + EF_{ts,b;r(b),i} \right) \right)$$

With:

EM_b	Emissions of the baseline scenario
$EM_{op,b;r(b)}$	Operational emissions of route r in baseline scenario [kg CO_2e/year]
$W_{r(b)}$	Annual transport activity on route r of the baseline scenario [tonnes or TEUs]
$D_{r(b),i}$	Distance of leg I on route r of the baseline scenario [km]
$EF_{veh,b;r(b),i}$	Emission factor of vehicle type on leg i of route r in the baseline scenario [g CO_2e/tonne-km]; defined by the transport mode, vehicle or vessel type, load factor of the vehicle or vessel type and fuel
$EF_{ts,b;r(b),i}$	Emissions factor of transhipment at leg i of route r in baseline scenario [g CO_2e/tonne]

Project scenario (see steps 2.D, 3.B and 4.C):

Equation 13

$$EM_p = \sum_{r(p)} EM_{op,p;r(p)} + EM_{induced} + EM_{construction}$$

and

Equation 14

$$\sum_{r(p)} EM_{op,p;r(p)} = \sum_{r(p)} \left(W_{r(p)} \times \sum_{r(p)} \left(D_{r(p),i} \times EF_{veh,p;r(p),i} + EF_{ts,p;r(p),i} \right) \right)$$

With:

EM_p	Emissions of the project scenario
$EM_{op,p;r(p)}$	Operational emissions of route r in project scenario [kg CO_2e/year]
$EM_{induced}$	Emissions due to induced transport [kg CO_2e/year] (see also Equation 7)
$EM_{construction}$	Emissions due to construction of infrastructure [kg CO_2e/year] (see also Equation 9 and Equation 10)
$W_{r(p)}$	Annual transport activity on route r of the project scenario [tonnes or TEUs]
$D_{r(p),i}$	Distance of leg I on route r of the project scenario [km]

$EF_{veh,p;r(p),i}$	Emission factor of vehicle type on leg i of route r in the project scenario [g CO_2e/tonne-km]; defined by the transport mode, vehicle or vessel type, load factor of the vehicle or vessel type and fuel
$EF_{ts,p;r(p),i}$	Emissions factor of transhipment at leg i of route r in project scenario [g CO_2e/tonne]

4.7 Step 6 - Reporting of assessment results

The reporting refers to internal reporting of the assessment results and bases on the requirements as covered by the GLEC framework (Greene & Lewis, 2016).

− ensure that data reported represent a comprehensive inventory of the emissions within the selected project and transport chains;
− clearly list the source of data and emission factors, if not provided by the tool;
− use consistent methods and units throughout the calculation;
− ensure transparency by clearly listing assumptions embedded the analysis or underlying data, e.g.:
  • selected routes, legs, via points, etc.;
  • applied depreciation period;
  • …

4.8 Key variables summarizing the difference between baseline and project

The key variables that are expected to change and show the impact of the investment project are summarized as follows:

$W_{by;total}$	tonne/a	Total transport activity in the base year
GR_{total}	%	Expected overall growth rate for the project
$D_{r(s),i}$	km	Distance of leg i on route r on leg i in scenario s
$W_{r(s)}$	tonne/a	Annual transport activity on route r in scenario s
CC	%	Relative cost change
$V_{m,area}$	tonne, m³ or others	Total amount of used material m for the different areas of investment project

In addition, information on vehicle or vessel types used on the relevant links or respectively routes (i.e. $r(s), i$) of the baseline and project scenario are key to monitor the GHG impact.

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Abbreviations

ASIF	Activity, modal split, intensity, fuel carbon content
BAU	Business as usual
BC	Black carbon
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalents
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
GDP	Gross domestic product
GEF	Global Environmental Facility
GHG	Greenhouse gases
GLEC	Global Logistics Emissions Council
GWP_{100}	Global warming potential with time horizon of 100 years, updated by IPCC
HFCs	Hydrofluorocarbons
ICAT	Initiative for Climate Action Transparency
IFI	International Financial Institution
IPCC	Intergovernmental Panel on Climate Change
IWW	Inland water way
TEU	Twenty foot equivalent unit
TSC	Transport Service Category, according to GLEC
TTW	Tank-to-wheel
WBCSD	World Business Council for Sustainable Development
WP	Work package
WRI	World Resource Institute
WTT	Well-to-tank
WTW	Well-to-wheel

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List of parameters & variables

Indices:

b	Baseline scenario	op	Operational
by	Base year	r	Transport route
$constr - t$	Lifetime of infrastructure	s	Scenario
i	Transport leg	ts	Transhipment
l	Transport link	veh	Vehicle type
m	Material type		

$Cost$	€/tonne	Total costs
CC	%	Relative cost change in the project scenario relative as per volume (tonne)
D	km	Transport distance
ε	-	Elasticity giving the relation of transport costs per tonne on transport demand in tonne-km
EF	g CO_2e/tonne-km g CO_2e/tonne or m³	Emission factor for transport, construction material
EM	kg CO_2e/a	Annual emissions
GR	[%]	Growth rate of transport activity
MT	[%]	General surcharge of emissions for maintenance of infrastructure
V	tonne, m³ or others	Amount of construction material or energy carriers used during construction
W	tonne/a	Transport activity
t	a	Depreciation period of the infrastructure

List of units

a	year
€	Euro
g	gram
kg	kilogram
km	kilometer
kWh	kilowatt hour
m^2	square meter
m^3	cubic meter
t	tonne (metric)
TEU	twenty foot equivalent unit
tkm	tonne-kilometer

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Annex A Induced freight transport demand (background info)

Introduction

Infrastructure development or fleet investment may reduce the (total) cost of transport, compared to a baseline scenario. Lower prices of transport lead to new and more transport movements, resulting from the price-demand curve (see Figure 8 p. 20). Development of infrastructure could thus increase the volume of transport. This effect is known as induced demand and is part of the overall effect of infrastructure development.

The main goal of this Annex is to answer the question: how large is the effect of infrastructure investment on new demand for transport? This question will be answered by a literature review on induced demand and transport elasticities which measure the % change of transport due to % increase in the price of transport. Attention will be paid to differentiations of elasticities for countries, modes and type of goods among others. The section will conclude with an overview of elasticities that could be used in line with the scope of this project.

Explaining the concept of induced demand

Induced demand is a term that is often mentioned as consequence of transport infrastructure development. The term 'induced' refers to a particular condition that is indirectly caused by another condition (Douglas, 2002). Induced demand is defined as the traffic which would be present if an expansion of road capacity occurred, which would not be there without the expansion (Goodwin & Noland, 2003). The increase of traffic could be due to multiple reasons. As explained by Cervero (2003) increased traffic can be in the form of:
– newly generated trips;
– longer journeys;
– changes in modal splits;
– route diversions;
– time-of-day shifts.

In macro-economic research, the relationship between price and demand is expressed by so-called demand elasticities. The transport price-elasticity is the change in % of transport demand for mode i induced by a 1% change in the price of mode i, i being a particular transport mode.

It is useful to differentiate between short and long run effects. Short run elasticity is generally lower than long run elasticity as in the long run there are more opportunities to respond to price changes. Increases in port capacity lead to lower transport costs, this increases transport demand in the short term through new routes and higher volumes. In the long run there is additional growth possible by improved hinterland connections through for example highway connections. In practice demand increases along a continuum path but conceptually and for modelling it is useful to distinguish two discrete states.

Although price elasticities for demand are primarily used for application in macro-economic research, they are used in this context to estimate the reaction to price changes in individual project cases. Hereby we assume that both price changes as a result of technological improvement or scale advantages and price advantages due to shorter routes can be evaluated equally.

Many elasticities but limited evidence

Many different aspects can be measured with transport elasticities. Lee (2002a,b) explains that in general elasticities of transport tend to fall in a -0.5 and -1.0 range in the short run, while in the long run the elasticities range between -1.0 and -2.0. These elasticities incorporate a large variety of countries as well as transport types including passenger, freight and public transport.

Overview of freight elasticities

Multiple sources have investigated freight transport elasticities. Most studies investigate the change in demand due to a price change of a specific mode, for example how much trucking demand decreases if truck tkm price increases with 1%. Significance & CE Delft (2010) present an overview of literature and recommend a value of -1.0[11], of which -0.4 is due to changes to other modes. In general many elasticities focus on a single transport mode, or cross-mode elasticities which measure the % change of mode *i* due to a 1% price increase of mode *j*. There are however other factors that differ between elasticities. Significance & CE Delft (2010) discuss due to what factors freight elasticities can be different:
- they measure different market segments;
- they measure different components of total costs (e.g. toll cost, fuel cost);
- price increases or decreases, decision makers react more strongly to losses;
- price changes of different magnitude;
- different definitions of transport modes and network.

Elasticities can be very different depending on the base situation where modes have different market shares. Absence of close competitors leads to less substation possibilities and less elastics demand. It should therefore be noted that elasticities are always quantified in a certain context. At the end of this Annex, an extract from Beuthe et al. (2014) is depicted, showing the variance between studies resulting from the variety in context.

Can we quantify the effect (elasticities) that we are interested in?

For the purpose of this methodology it makes sense to look at elasticities that apply in general situation and not at elasticities that are context specific. A literature review by De Jong et al. (2010) shows that very little studies have identified similar values. The best guess of De Jong et al. (2010) is an elasticity of -1.0, which means that a 1% increase in tkm prices of road transport leads to a 1% decrease in demand. For rail transport these values are higher. For water transport the values are comparable to road transport.

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[11] This indisates that a 1% increase in price leads to a 1% decrease in demand (=-1.0/1).

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These values are, however, context specific for the European situation and could differ between situation based on the available substitutions. The infrastructure investment will lead to lower costs for all transport movements in the wider region.

In the decrease in demand, part of the decrease can be explained by a shift between modes, which is something we are not interested in for this methodology. We are rather looking for an elasticity that expresses the increase or decrease in demand and that applies to generic freight transport.

High value goods are less elastic to transport costs

Significance & CE Delft (2010) discuss the difference in elasticity between commodities, they note: "*However, price elasticities of freight transport depend on the type of goods transported. For example, one can expect transport price elasticities of valuable goods, like cars or televisions, to be low since minimizing storage costs of these goods is more important than minimizing transportation costs. The contrary holds for less valuable goods, so that these goods could be expected to be more sensitive to changes in transport prices.*" Several authors (Jovicic, 1998; De Jong, 2003; PBL, 2010) have shown that long distance transport of high value goods is less elastic than low value goods.

Beuthe et al. (2001) shows that bulk elasticities are larger than higher value goods. De Jong (2003) shows values differ slightly between modes where in general rail transport is more elastic. This is confirmed by Beuthe et al. (2014), with the notion that this is situation specific.

Another finding is that within commodity groups there are also very large differences in elasticities. These differences depend largely on the availability of substitutes (e.g. local production) and not on the type of goods transported. Overall, it can be argued that there are differences in elasticities between product types. It is, however, not possible to see this without looking at the specific situation (e.g. availability of rail infrastructure or its market share).

Therefore we cannot differentiate elasticities for commodity types.

Countries

Fouquet (2012) finds indication that transport elasticities are higher in developing countries compared to developed countries based on historical analysis in the UK. He argues that this is due a saturation effect; as countries become richer the portion of money spend on transport is decreasing. The smaller cost of transport (compared to total cost) lead to smaller elasticities. Small & van Dender (2007) have performed a similar exercise for the US and show that price elasticity of transport has decreased over time. Based on a literature review, Goodwin & Noland (2003) find evidence that income elasticity of transport has declined. It is however very difficult to indicate at what level of income transport demand becomes less effected by price changes. And whether similar factors apply for passenger and freight transport. There is indication that elasticities are lower in developed countries but there is not sufficient evidence to include this in our estimates.

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Conclusion and quantification of induced demand effect

It is likely that the infrastructure development projects (and fleet replacement to a lesser extent) where the ERBD invests in are leading to induced demand for transport. The improvement of the transport infrastructure or services offered will be included in the price of transport which in turn can be used to estimate the increase in demand, using price elasticities.

Several studies have investigated price elasticities of freight transport, however, since many studies only measure the price elasticity of a single mode within a specific context, it is not possible to conclude on the difference between modes on an aggregate level. Context specific deviations are as large as deviations between modes. Significance & CE Delft (2010) support this statement by concluding *"elasticities are strongly context specific and cannot be easily compared with one another"*.

Furthermore, only a limited number of studies differentiate between the effect on inducement and the effect on shifts to other transport modes.

The review study by Significance & CE Delft (2010) estimate an elasticity of -1.0, of which -0.4 is due to modal shifts, meaning that total road demand decreases with -0.6 due to a 1% increase in road transport price. This is in line with Beuthe et al. (2014) who show an elasticity of around -0.5 for long distance transport which is comparable between modes. This means that a 1% price reduction leads to an increase of transport with 0.5%. Based on both review studies, we propose to use -0.5 as an elasticity to model the induced effect.

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Figure 21   Illustration from the review study by Beuthe et al., 2014

Table 2. Multi-modes own price/cost elasticities and their range across commodities[a]

On aggregate cross-section data	Rail	Truck	Waterways	Others
Levin (1978)				
Aggregate logit model (all commodities together)	−0.25 to −0.35	–	–	–
Three 'modes': rail boxcar, piggyback and truck. Rail average revenue, and truck average cost Range of approximation				
Oum (1979b)				
Derived demand model (eight commodities)				
Ordinary price elasticity	−0.46 to −1.20	−0.41 to −1.07	–	–
Compensated price elasticity	−0.39 to −1.18	−0.33 to −1.04	–	–
Friedlaender and Spady				
Aggregate trans-log cost model				
1980: Price (8 commodities)	−1.68 to −3.55	−1.00 to −1.55	–	–
(5 regions and 8 commodities)	−1.45 to −4.01	−0.14 to −1.72	–	–
1981: Price (3 regions and 4 commodities)	−0.37 to −1.16	−0.83 to −1.81	–	–
Cross-section + time series (1968–1972)				
Kim (1987)				
Aggregate derived demand model				
Cost: (12 commodities)	−0.47 to −1.23	−0.24 to −0.98	–	–
(182 regions, 12 commodities)	−0.12 to −1.73	−0.10 to −1.24	–	–
Oum (1989)				
Aggregate derived demand (all commodities)				
Ordinary price elasticity	−0.60	−0.69	–	–
Compensated price elasticity	−0.54	−0.65	–	–
de Jong (2003)				
Aggregate EU countries models (cost, t-km)	−1.40 to −3.87	−0.4 to −1.01	–	–
Meta model	–	−0.4 to −0.7	–	–
Rich et al. (2011)				
Aggregate GIS-based logit model, Ton-weighted elasticities (13 commodities)				(combined transport)
Cost (tons)	−0.10 to −0.40	−0.01 to −0.13	–	−0.08 to −0.41
Cost (t-km)	−0.10 to −0.40	−0.06 to −0.28	–	−0.09 to −0.43
Beuthe et al. (2001)				
GIS-based cost minimizing, weighted elasticities				
Generalized total cost (tons)	0.06 to −4.42	0.00 to −3.61	−0.04 to −10.5	–
in aggregate (tons)	−1.77	−0.59	−2.13	–
Generalized total cost (t-km)	−0.09 to −2.87	−0.52 to −4.50	−0.29 to −11.7	–
in aggregate (t-km)	−1.21	−1.25	−1.72	–

[a]All compensated elasticities unless indicated; all cross-section data unless indicated.

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Annex B Relevance of the various process life cycle stages

To understand the relevance of single life cycle phases of logistics infrastructure (i.e. construction, operation, maintenance, disposal), existing life cycle assessment studies and reports on comparable research have been analysed and summarized in the following.[12] Although the different approaches of the studies vary and the published data, therefore, is not comparable between the studies, a recommendation is still possible.

Studies show that in the area of road freight transport non-operational energy consumption accounts for about 20 to 40% of the overal life cycle. Its exact share depends on the road traffic system (i.e. truck size) but the published figures outlines that it is of relevance. (Spielmann et al. 2004) published an overview of different environmental impact categories over the life cycle of a 40 t truck. According to these findings, the construction and maintenance of road infrastructure accounts for 10% of CO_2 life cycle emissions of Swiss road freight transport.

Spielmann et al. (2004) assessed other transport modes with the same focus: In the area of transport on inland waterways about 15% of the CO_2 life cycle emissions are caused by infrastructure, within air freight transport their share is negligibly low. As regards rail freight transport the respective regional mix of rail power has a mayor impact. For example, in Switzerland rail power is generated from 100% water power whereas a mix of diesel and electric traction is used on the European level (the latter with other electricity mix than Switzerland). Therefore, the share of infrastructre is accounted for ca. 18% (EU) to 43% (CH) of the total CO_2 life cycle emissions.

The following figure summarizes GHG emissions per tonne-km of freight transport systems in Germany (2008). One can see that the use of vehicles on road causes decisively more emissions per tonne-km compared to rail or barge transport (78.6 g CO_2e/tkm compared to 25.4 or 29.8 g CO_2e/tkm). According to that, rail transport causes 15% less emissions than barge transport.

However, the consideration of additional emissions by construction of vehicles as well as by the respective infrastructure reduces the advantage of rail to onyly 6% compared to barge transport (36.0 compared to 38.3 g CO_2e/tkm).

Although the absoulte and relative (dis)advantages between modes varies between countries and regions, this example shows, that the consideration of both the operation and construction/maintenance of vehicles and infrastructure provides a complete picture for discussing GHG impacts of different logistics systems. Therefore, it is recommended to assess the impact the construction and maintenance of logistics infrastructure as well.

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[12] e.g. Facanha und Horvath 2007; Frischknecht et al. 2011; Lampatzer et al. 2000; Milachowski et al. o.J.; Milford und Allwood 2010; Spielmann et al. 2004; Spielmann und Scholz 2005; VCÖ-Forschungsinstitut 2011.

Figure 22   GHG emissions of freight transport in Germany (2008) (basing on UBA, 2013)
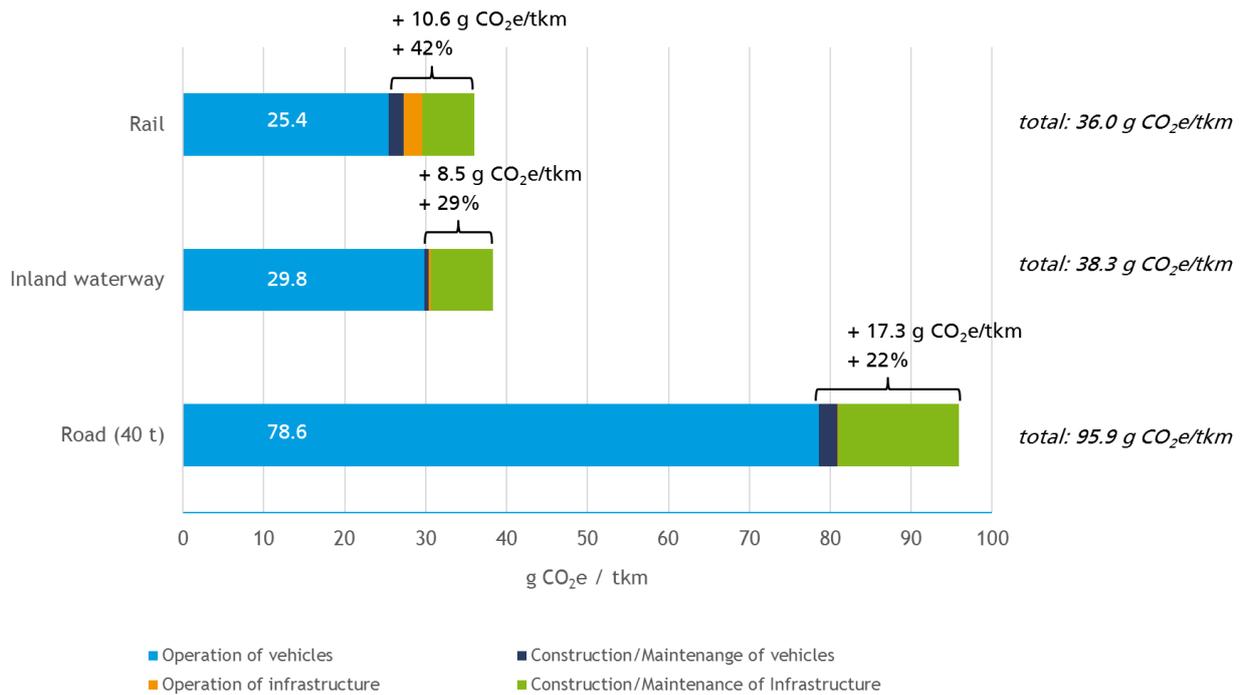
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Annex C Additional environmental impacts

Air quality impacts

In addition to greenhouse gases, the investment projects may have a positive impact on local air quality, triggering the use of low emission technologies and modes.

Air quality is a major problem in developing as well as developed regions, specifically in and around ports and areas with concentrated freight transport and handling activities. This topic is even higher on the agenda in case of proximity to urban areas (e.g. urban ports).

The assessment of air quality impacts, however, cannot be based on fuel use as it is done for greenhouse gas emissions. Air quality is a more complex issue. Along with air pollutants emitted (depending on i.a. technology used), it needs to be linked to weather conditions, local topography as well as the concentration of pollutant from other sources. Therefore, the methodological approaches for the assessment of air quality are far more complex than GHG emissions accounting and cannot be generalized in terms of impact resulting from a given action.

Hence, air quality is not addressed in this framework. However, the methodology may be extended at a later stage.
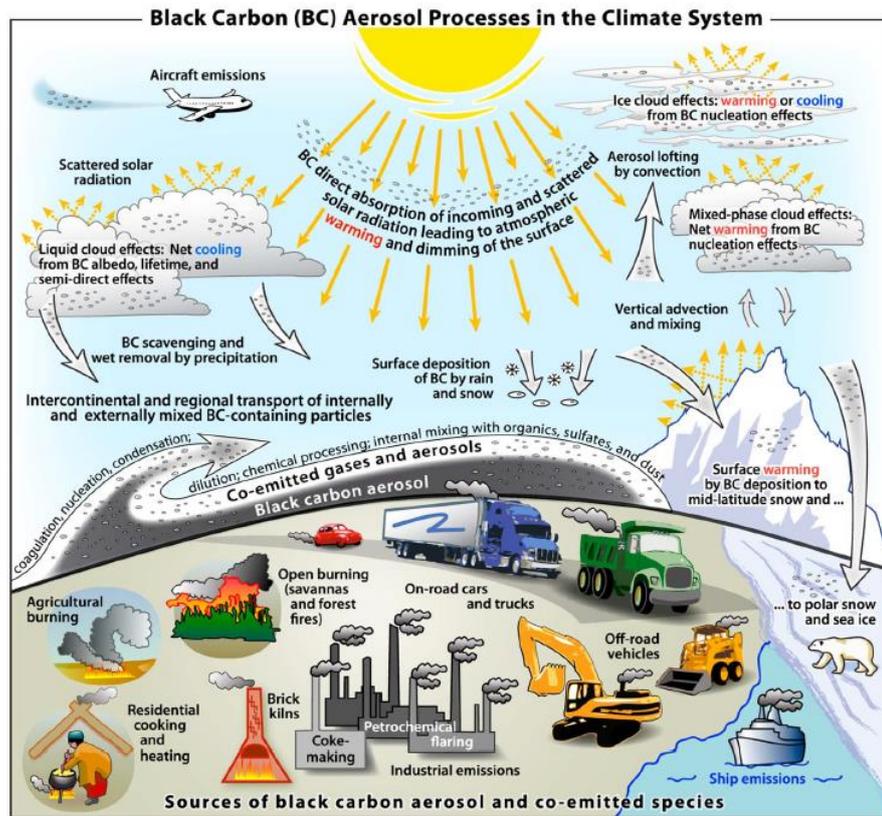
Black Carbon

In 2017, Smart Freight Centre published a "Black Carbon Methodology for the Logistics Sector" (SFC, 2017) on behalf of the Climate and Clean Air Coalition. In this document, black carbon is defined as "small, dark particles produced from the incomplete combustion of biomass and fossil fuels" (SFC, 2017 p. 7). In addition, black carbon "can also come from non-exhaust sources, such as wheel and brake wears as well as road abrasion" (SFC, 2017 p. 7).

The assessment approach by SFC (2017) is based on comparable input data as it is relevant for GHG emissions accounting, i.e. energy consumption and efficiency. Therefore, the methodology for investment projects incorporates black carbon emissions accounting as suggested by SFC (2017) (for further details see ibidem). The result on calculated black carbon emissions are expressed as mass of black carbon (e.g. in grams, tonnes or equivalent) and are, for the time being, not transferred to carbon dioxide equivalents.

In addition to its health impact, black carbon emissions affects climate change. According to Bond et al. (2013), carbon dioxide, methane and black carbon are the largest warming agents. However, high uncertainty still exists when discussing carbon metrics of black carbon. "The 100 year global-warming-potential (GWP) value for black carbon is 900 (120 to 1,800 range) with all forcing mechanisms included. The large range derives from the uncertainties in the climate forcings for black carbon effects." (Bond et al., 2013 p. 5387). The authors summarise the complexity of black carbon's role in the climate system as shown in the following figure.

Figure 23   Schematic overview of the primary black-carbon emission sources and the processes that control the distribution of black carbon in the atmosphere and determine its role in the climate system (Bond et al., 2013, p. 5390)

The black carbon methodology (SFC, 2017) is a simplified approach that presents the prospect of further development and adaption depending on e.g. data availability. Some relevant assumptions and simplification are listed in the following (for further details, see SFC, 2017):
− elemental carbon is considered to be the same as black carbon;
− consideration of black carbon emissions only related to fuel combustion that can be controlled using tailpipe exhaust emission standards;
− consideration of tank-to-wheel emissions, no well-to-tank emissions.

Literature (Annex C)

Bond et al., 2013
Bond, T.C., Doherty, S.J., Fahey, D.W., et al., Bounding the role of black carbon in the climate system: A scientific assessment. *Journal of geophysical research atmospheres*, Vol. 118, pp. 5380–5552

SFC, 2017
Black Carbon Methodology for the Logistics Sector. Global Green Freight Project, Smart Freight Centre (SFC), Amsterdam

Annex D Depreciation period of GHG emissions of infrastructure and equipment

To compare the GHG emissions of infrastructure and equipment with the annual operational emissions, it is proposed to depreciate the GHG emissions over the typical lifetime of the infrastructure to generate annual construction and equipment emissions. The depreciation period chosen, however, is not a fixed fact that has a detailed scientific development.

Moreover, four lines of thinking have been discussed for the depreciation period of the CO_2e emissions:

1. Follow the technical depreciation period of the infrastructure or equipment (see Table 4).
2. Follow the economic depreciation period of the infrastructure or equipment (see economic analysis of the investment project).
3. It has been agreed in the Paris agreement to limit warming to 1.5°C above pre-industrial levels. For the EU, GHG targets are focused on 80-95% GHG reduction by 2050. Following these goals it makes sense to not allow for depreciation times that go beyond 2050.
4. It is difficult to predict the value of the investment beyond e.g. 10 years. In 10 years there can have been developments that would favor other solutions for GHG reduction than offered by the investment. It can therefore be argued that the CO_2e emissions of infrastructure and equipment should be evaluated against a shorter period, e.g.10-20 years (as proposed).

Alternatively, total construction emissions might be reported separately from the annual operational emissions.

Table 4   Proposed calculation period and lifetime of infrastructure and equipment

Infrastructure & equipment	Calculation period/lifetime	Source
Transport infrastructure (road, rail, fairways) and ports/terminals	60 years	Stripple et al., 2016; Stripple & Uppenberg, 2010; UBA, 2013
Ship-to-shore cranes, rail mounted gantry cranes, rubber tyres gantry cranes	30 years	Stripple et al., 2016
Port cassettes	25 years	Stripple et al., 2016
Straddle carriers, reach stackers, port tractors, port translifters, forklifts	10 years	Stripple et al., 2016

Literature (Annex D)

Stripple & Uppenberg, 2010
Stripple, H. and Uppenberg, S. (2010) Life cycle assessment of railways and rail transport systems: Application in environmental product declaration (EPDs) for the Bothnia Line, Swedish Environmental Research Institute IVL [Online]
Available at:
http://www.ivl.se/download/18.343dc99d14e8bb0f58b75d4/1445517456715/B1943.pdf
[Accessed 2018]

Stripple et al., 2016
Stripple, H., Fridell, E. and Winnes, H. (2016) Port Infrastructures in a System Perspective : A Part of the Project Environmental Calculations for Transport Infrastructure [Online]
Available at:
http://www.ivl.se/download/18.7e136029152c7d48c202c36/1466685708209/C128.pdf
[Accessed 2018]

UBA, 2013
Mottschall, M. and Bergmann, T. (2013) Treibhausgas-Emissionen durch Infrastruktur und Fahrzeuge des Straßen-, Schienen- und Luftverkehrs sowie der Binnenschifffahrt in Deutschland, Umweltbundesamt [Online]
Available at: https://www.umweltbundesamt.de/publikationen/treibhausgas-emissionen-durch-infrastruktur
[Accessed 2018]

Annex E GDP impacts

Infrastructure may also lead to indirect effects by the formation of companies servicing the infrastructure and operations, resulting in additional GDP (jobs and profits). This is generally expressed as the multiplier effect for infrastructure investments.

The relationship between infrastructure development and productivity (new businesses) has been the subject of an ongoing debate during the last two decades (o.a. EIB, 2013). Frequently quoted review research by De la Fuente, (2010) says:

"On the whole, my reading of the evidence is that there are sufficient indications that public infrastructure investment contributes significantly to productivity growth, at least for countries where a saturation point has not been reached. The returns to such investment are probably quite high in early stages, when infrastructures are scarce and basic networks have not been completed, but fall sharply thereafter."

EBRD countries fit well within this definition, and the article also explains why GDP impacts of infrastructure construction are generally not taken into account in case of freight infrastructure investments in developed countries. Also EIB is critical about assessing wider economic benefits.

The GDP impact is generally expressed as the multiplier effect of infrastructure investments, estimated to be around 0.06 (Melo et al., 2013). This implies that an infrastructure project has a payback time of 17 years in terms of additional GDP. For EBRD countries, this period could be much shorter.

The GDP increase needs to be translated into GHG emissions, using the per unit of GDP GHG emissions.

Literature (Annex E)

EIB, 2013
The Economic Appraisal of Investment Projects at the EIB, European Investment Bank, EIB Projects Directorate [Online]
Available at:
http://www.eib.org/attachments/thematic/economic_appraisal_of_investment_projects_en.pdf
[Accessed 2018]

De la Fuente, 2010
Infrastructures and productivity : an updated survey
Instituto de Análisis Económico, CSIC, Revised, June 2010 [Online]
Available at: https://core.ac.uk/download/pdf/6507397.pdf
[Accessed 2018]

Melo et al., 2013
Patricia C. Melo, Daniel J. Graham, Ruben Brage-Ardao
The productivity of transport infrastructure investment : A meta-analysis of empirical evidence. *Regional Science and Urban Economics,* 43 (5) pp 695-706

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