Climate Rating of Transport Infrastructure Projects

Exploration of a methodology for including climate impacts in project appraisal

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CE Delft's solutions are characterised in being politically feasible, technologically sound, economically prudent and socially equitable.

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Summary

Context: ambitious targets for infrastructure networks and decarbonisation

In its recent White Paper on Transport the Commission announced ambitious plans for building a competitive transport system. At the same time, the Commission set specific objectives for greenhouse gas reduction in transport in its Roadmap for decarbonisation, which were further elaborated in the White Paper. The climate policy set out in these papers aims at a dramatic reduction of Europe's dependence on imported oil and a cut in carbon emissions in transport by 60% by 2050, compared to 1990 levels.

Climate rating as a key element in project appraisal

Infrastructure policy and climate policy interfere. Developing or upgrading transport infrastructure can have significant impacts on the decarbonisation of transport. While some types of infrastructure carry the risk to get locked-in to carbon intensive technology or transport modes, other projects may actually contribute to greenhouse gas reduction.

Until now, the impacts on greenhouse gas emissions are not well integrated in transport infrastructure project appraisal. This is not only true at a European level but also at most national and local levels. Climate rating could solve this by explicitly taking account of the effect on greenhouse gases emissions in the infrastructure project appraisal and funding decisions.

Aim of this study: the development of a methodology for climate rating

The European Commission announced that it aims at making climate rating be a part of the decision process for investments (EC, 2011). However, the Commission has not yet decided on a methodology for climate rating.
In order to achieve this interlinking of policy objectives and to feed the Commission with further developing this issue, the European Federation for Transport & Environment (T&E), together with partners asked CE Delft to develop a methodology for climate rating, which is presented in this report.

Although the study primarily focuses on TEN-T, recommendations could also be applied to other EU funds which can, directly or indirectly, influence the decarbonisation of the European transport sector.

Main elements of the climate rating methodology

The greenhouse gas impacts of new, extended or upgraded transport infrastructure consist of four main elements:

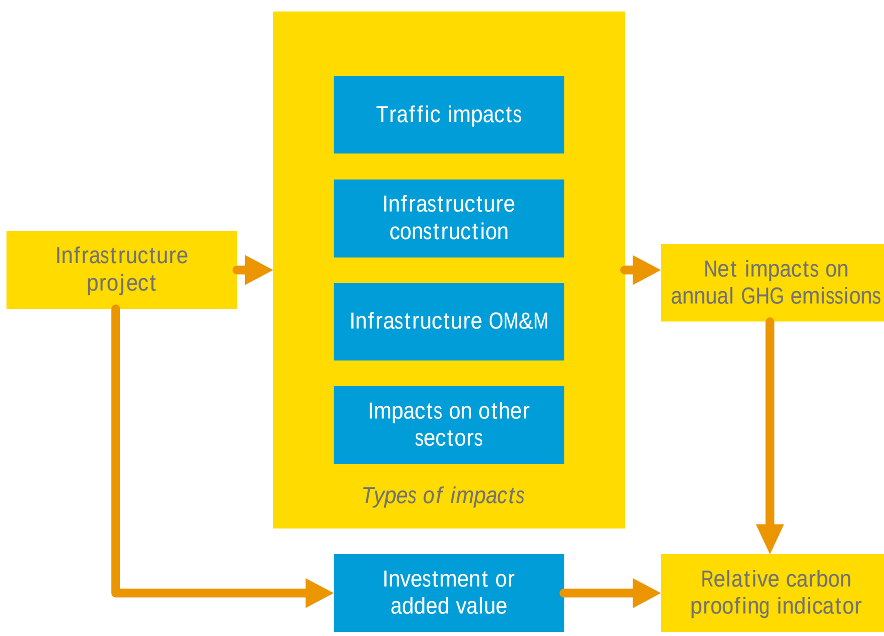
1. Changes in greenhouse gas emissions from traffic.
2. Changes in greenhouse gas emissions from infrastructure operation, maintenance and management (OMM).
3. Greenhouse gas emissions from infrastructure development and end-of-life processes.
4. Other impacts, such as indirect effects on other sectors.

This is true for all different types of infrastructure, including the development of new or upgraded road, rail or waterway infrastructure, interconnection of different transport modes, intelligent transport systems or innovative energy projects (e.g. new carbon free operation).

Traffic impacts are relevant for all types of projects. Sometime these are mainly the results form changes in transport volume or modal split, e.g. in the case of a port the upgrade of a railway line. In other cases, the changes in traffic emissions are mainly the result of changes in energy technology or vehicle efficiency, e.g. in the case of electrification projects. The greenhouse gas impacts from traffic can be calculated with the traffic volumes per mode and vehicle type and the relative emission factors per vehicle type. The traffic data can be retrieved from traffic modelling. They should be the same as the data used for the socio economic assessment of the project. The emission factors can be retrieved from national emission registration or datasets (e.g. TREMOVE). They should reflect real-life well-to-wheel emissions.

The relative importance of **emissions from developing, maintaining, managing or operating infrastructure** depends strongly on the type of project. In some cases, such as the construction of high speed railway line, these impacts can vary significantly, while in other cases they can expected to be negligible, e.g. for traffic management systems. These emissions can be estimated using either emission factors per type of material and energy used (bottom-up approach) or by using typical values, e.g. per lane or track kilometre (top-down).

For **comparing different projects**, the change in greenhouse gas emissions after project realisation compared to the reference scenario should be compared to a measure for the size or value of the project. The (EU or total) investment is the best candidate for this for the short to medium term. For the longer term, also the net contribution to economic welfare from the cost benefit analysis could be used, however, these are currently often not available. The value of the climate rating indicator could be used for deciding on the co-funding rate or for prioritisation of projects. The overall methodology as elaborated in this report is summarised below.



Conclusions and recommendations

The methodology has been applied to a few concrete examples. From this it can be concluded that climate rating is possible and can help to integrate climate and infrastructure objectives. A further development of the methodology is strongly recommended, both at the EU level (e.g. by the TEN-T Agency) as well as at national level, with support of relevant experts.

1 Introduction

1.1 Background

The European Commission stimulates economic and social development within the European Union. This is aimed at increasing welfare for all EU citizens, while taking into account environmental protection. The Commission has several instruments to stimulate the development. The Cohesion Funds and the TEN-T programme are the most important instruments where it comes to infrastructure.

The European Commission announced in its recent White Paper on Transport[1] 40 concrete initiatives for the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment. At the same time, the Commission set specific objectives for greenhouse gas (GHG) reduction in transport in its Roadmap for decarbonisation[2], which were further elaborated in the White Paper: a dramatic reduction of Europe's dependence on imported oil and a cut carbon emissions in transport by 60% by 2050 compared to 1990 levels. Other key goals for 2050 include:

- No more conventionally-fuelled cars in cities.
- 40% use of sustainable low carbon fuels in aviation; at least 40 to 50% cut in shipping emissions.
- A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport.

It is clear that the European Commission with this White Paper makes a clear statement for integrated policies on Transport, Infrastructure and Decarbonisation.

Currently the European Commission is preparing a revision of the guidelines that set the framework for the Trans-European Networks of Transport (TEN-T) policy. Since EU funding for transport investment is one of the most powerful tools to reach the Union's policy objectives, this is a good opportunity to strengthen several EU political priorities by taking these priorities into account in infrastructure investments decisions.

In the communication from the European Commission 'A budget for Europe 2020', the Commission states that the European climate objectives are to be met. Climate rating of infrastructure investments is one of the approaches for taking climate action into account. Climate rating means that the effect of a decision on the emission of CO_2 or other greenhouse gases[3] is taken into account. This rather broad definition can be further specified in various ways. The way this could be done is the main subject of this report. The Commission announced that it aims at making climate rating be a part of the decision process for investments (EC, 2011). However, the Commission has not yet decided on a methodology for climate rating.

[1] White paper - Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system SEC (2001) 359, 28 march 2011.

[2] A Roadmap for moving to a competitive low-carbon economy in 2050, SEC (2011) 289.

[3] For the definition of greenhouse gases we refer to the IPCC-work and to SEC (2011) 289, see previous footnote.

Climate rating can be used in the project appraisal process in order to select the most proper infrastructure investments from a climate point of view. So, it provides a framework for integrate climate change policies into other types of EU policy. Climate rating can thus help to align EU infrastructure spending and the EU's climate policies.

1.2 Why this study?

In order to achieve the interlinking of policy objectives, the European Federation for Transport & Environment (T&E), together with partners, wants a methodology for climate rating to be developed. This methodology must contain an indicator of the climate performance of the TEN-T projects and if possible for Cohesion Fund projects as well.

The aim of this study is to develop a methodology for climate rating of transport infrastructure projects. The underlying objective is to bring EU budget spending in line with the EU decarbonisation objective of the transport sector.

Although the study primarily focuses on TEN-T, the methodology can be used for other EU funds and even national transport infrastructure project appraisal as well.

1.3 Scope of the study

Infrastructure projects that are eligible for EU subsidies concern different transport related project categories:
- Road transport.
- Rail transport.
- IWT/short sea shipping.
- Air transport.
- Intermodal transport facilitation.
- Traffic information or guidance systems (Galileo, ERTMS).

In addition, for each transport mode, a broad variety of types of infrastructure can be supported:
- New transport infrastructure.
- Upgrade of existing transport infrastructure.
- Rehabilitation of old railways/waterways.
- Interconnection of different transport modes.
- Intelligent transport systems.
- Innovative projects; e.g. new carbon free operation.

A very broad definition of infrastructure projects is in use within the transport policy. However, in the end they all aim at increasing the transport infrastructure capacity or a more efficient use of infrastructure capacity.

This study presents a methodology that makes it possible to compare the climate change effects of the different investments. It must be seen as a first assessment. It presents a methodology and shows how it could be applied. Further development of the methodology is needed. Aspects like the exact definitions, the framework or procedures need to be further elaborated.

1.4 Reading guide

The next chapter provides an overview of TEN-T and more general of EU funding of infrastructure projects. Chapter 3 presents the overall framework of the methodology for calculating the GHG impact of an infrastructure project.

In Chapter 4 this is further elaborated with regard to the GHG effects from traffic impacts. Chapter 5 focuses on the other GHG impacts from new infrastructure related to the developments, operation, maintenance and management of the infrastructure itself and other GHG impacts from infrastructure projects.

In Chapter 6, we show how the projects could be compared on their GHG impacts and how this could be used in infrastructure project appraisal processes.

In Chapter 7 the application of the climate rating methodology is illustrated by a few cases.

Finally Chapter 8 summarises the key conclusions and recommendations of the study.

2 Scope of the EU funding

2.1 General

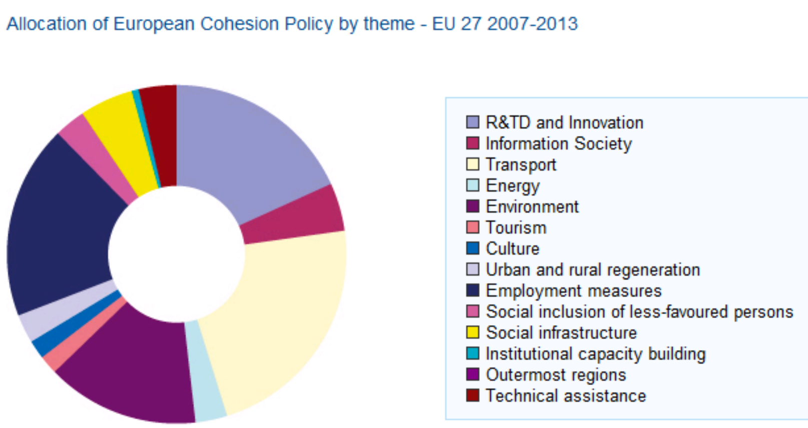
The European Commission uses different financial instruments to support TEN-T implementation:
- The TEN-T programme.
- The Cohesion Fund.
- The European Regional Development Fund.
- The European Investment Bank.

In the following sections the two most important funds for infrastructure are explained. In the last section the focus is on the environmental aspects of the current guidelines for TEN-T.

2.2 Cohesion funds

The Cohesion Funds are the second largest budget of the EU, after the Agricultural budget. Funding for regional and cohesion policy in 2007-2013 amounts to 347 billion Euro. This is 35.7% of the total EU budget, for that period, just over € 49 billion a year. All cohesion policy programs are co-financed by the member countries, bringing total available funding to almost € 700 billion. Transport gets the largest share of the Cohesion funds, using approximately 22% of the budget, almost € 11 billion a year.

Figure 1 Allocation of the Cohesion funds[4]



[4] http://ec.europa.eu/regional_policy/thefunds/funding/index_en.cfm#4 (11-07-2011).

2.3 TEN-T

The TEN-T programme 2007-2013 has an overall budget of approximately € 8 billion. This budget over the 2007-2013 funding period is primarily allocated to projects selected via calls for proposals which are launched each year by DG MOVE and, as of 2009, by the TEN-T Executive Agency on its behalf. The norm is that, each year, both a Multi-Annual Call and an Annual Call are launched.

Overall, the Multi-Annual Calls aim to give an important impetus to the implementation of the TEN-T priority projects - as defined in the TEN Guidelines - and to address some horizontal priorities.

Projects funded under the **Multi-Annual Calls** are expected to help complete the TEN-T network as approved by the European Parliament and the Council, with a target completion date of 2020. For this purpose, Community funding aims to mobilise as much public and private financing as needed to meet the challenging timetables. In general, Multi-Annual projects are of a larger size and longer duration than Annual projects. 80-85% of the TEN-T budget is allocated through Multi-Annual Calls.

Annual Calls are intended to complement the Multi-Annual Calls, thus also giving priority to projects that address key TEN-T issues such as bottlenecks or cross-border projects. However, given their annual nature, Annual Calls have a higher degree of flexibility to meet new priorities. Since a smaller portion of the TEN-T budget (15-20%) is dedicated to Annual Calls, these are not suited to cover large projects over a long period of time.

Figure 2 shows the division of the calls in 2010 by category. It is clear that road infrastructure only takes a very small part of the calls. Where shipping and rail take a large part.

Figure 3 shows that the funding of rail almost takes two third of the budget and that the supporting management systems take more than 10% of the budget.

Figure 2 TEN-T result of the annual call 2010

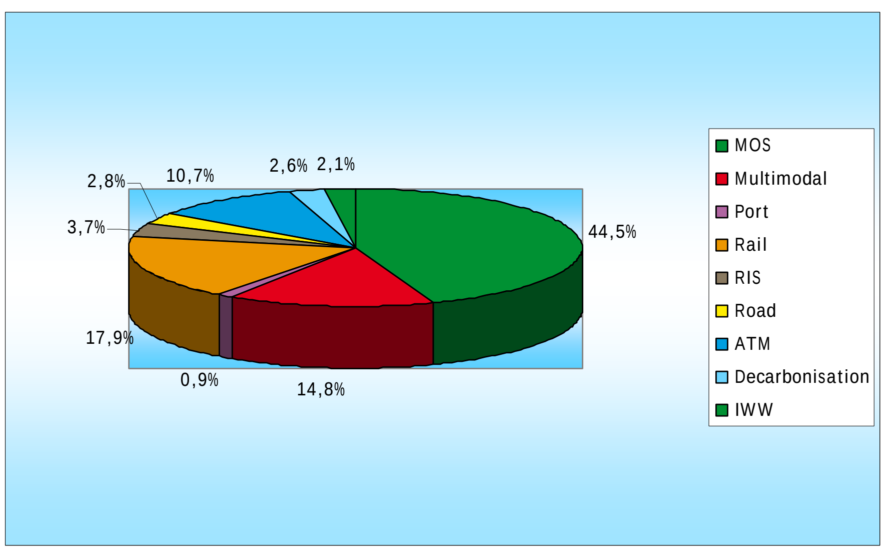
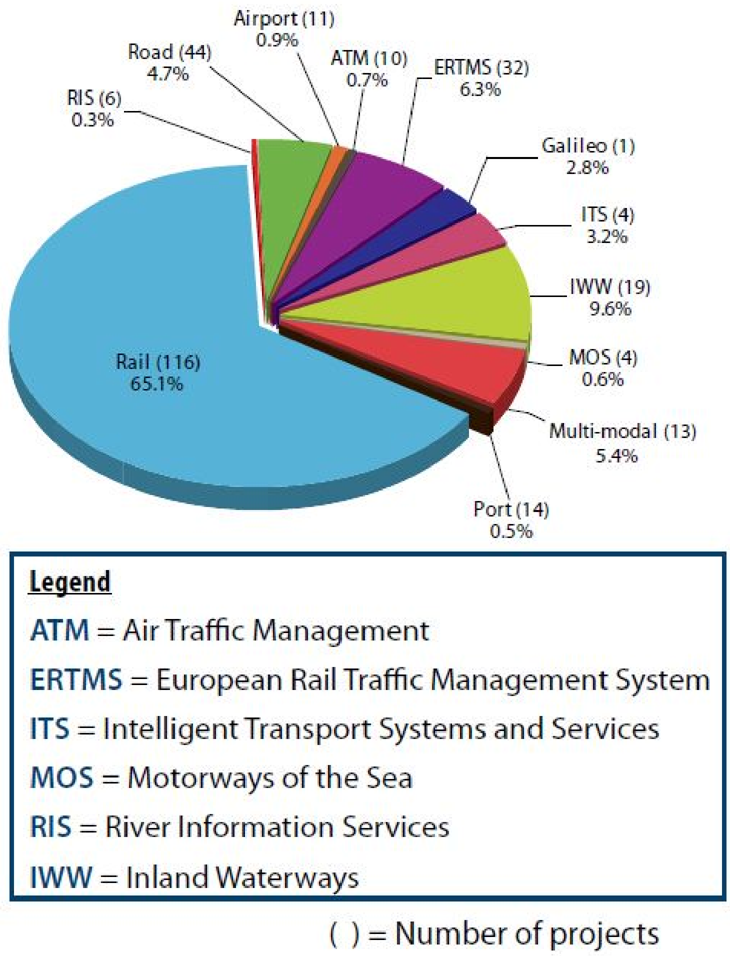


Figure 3 Funding by transport mode 2010



2.4 TEN-T Guidelines

TEN-T has guidelines on the application and granting of a fund. For the Environmental aspects Section 1, article 8 applies:

> *"Environmental protection*
> *1. When projects are planned and carried out, environmental protection must be taken into account by the Member States by carrying out, pursuant to Directive 85/337/EEC, environmental impact assessments of projects of common interest which are to be implemented and by applying Directives 92/43/EEC and 2009/147/EC. As from 21 July 2004, an environmental assessment of the plans and programmes leading to such projects, especially where they concern new routes or other important nodal infrastructure development, shall be carried out by Member States pursuant to Directive 2001/42/EC. Member States shall take the results of this environmental assessment into account in the preparation of the plans and programmes concerned, in accordance with Article 8 of Directive 2001/42/EC.*
> *2. Before 21 July 2004, the Commission shall, in agreement with Member States, develop suitable methods for implementing the*

strategic environmental impact assessment with the objective of ensuring, inter alia, appropriate coordination, avoiding duplication of effort, and achieving simplification and acceleration of planning processes for cross-border projects and corridors.
The results of this work and of the environmental assessment of the trans-European networks projects carried out by Member States pursuant to Directive 2001/42/EC shall be taken into account, as appropriate, by the Commission in its report on the guidelines and the possible accompanying legislative proposals to revise the guidelines, as provided for in Article 22 of this Decision."

This means that Member States are already obliged to assess the environmental impacts of their projects. One of these impacts is the contribution to GHG emissions, especially CO_2. However, the current guidelines do not explicitly mention GHG impacts as one of the key criteria for project evaluation and/or prioritisation.

3 Overall methodology for the impact on GHG emissions

3.1 General

The core of a climate rating methodology of transport related infrastructure projects is the approach for calculating the impact on GHG emissions. In principal the GHG impact should be available from the Environmental Impact Assessment (EIA). However, from EIAs carried out in the last few years, it becomes clear that a reliable, complete and transparent assessment of the GHG impacts is often not available from the EIA.

For a proper climate rating, a harmonized approach is imperative. Such an approach should cover all relevant GHG impacts that can be expected. The type of GHG impacts can differ widely from various types of infrastructure projects, as can be understood by the following examples. In the case of road construction projects, the impacts on road traffic volumes will usually be the main GHG impact. For the electrification of a railway link, the fuel shift from diesel to electricity will certainly be crucial, possibly complemented by some modal shift when an improvement of the rail transport quality, speed and/or capacity would also be the result. Finally for a road pricing scheme the main impacts will be related to modal shift, improvement of load factors and overall reduction of transport volume, but also changes in routing can be significant when the scheme is just implemented on certain parts of the networks (e.g. only motorways or in one country).

In this chapter we describe the overall methodology for calculating the GHG impact for all these different types of transport infrastructure projects. In the next two chapters the main elements of this methodology are further elaborated.

First, in the next section an overview is given of the main types of GHG impacts that need to be considered. Next, in Section 3.3 it is explained how various types of emission can be summed up. Section 3.4 discusses the choice of the reference year. Finally, in Section 3.5 a formula is presented that shows how the methodology can be translated to calculation rules.

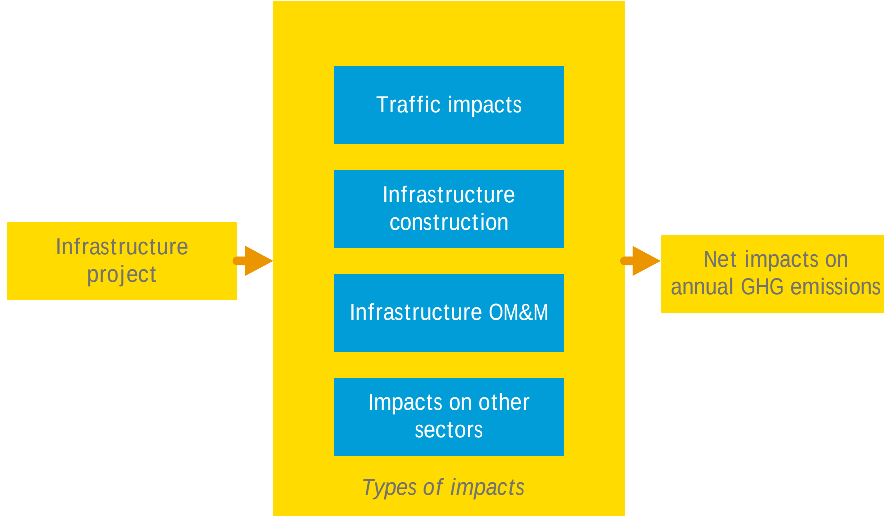
3.2 Overview of main types of GHG impacts

The GHG impacts of new, extended or upgraded transport infrastructure consist of four main elements:

1. Changes in GHG emissions from traffic.
2. Changes in GHG emissions from infrastructure operation, maintenance and management (OMM).
3. GHG emissions from infrastructure development and end-of-life processes.
4. Other impacts, such as indirect effects on other sectors.

These four types of impacts are illustrated in Figure 4.

Figure 4 **Overview of the types of GHG impacts of transport infrastructure projects**



The first type of impact includes **changes in modal split, changes in the total traffic volume and changes in relative emissions** for each transport mode. This impact is relevant for all types of projects, but the kind of impact and mechanisms behind it can be different. It can be related to changes in transport volume, modal split, load factors, emissions factors, fuel mix and the type of propulsions from innovations in vehicle or energy technology.

In the case of the construction or expanding of roads, railways, waterways or (air)ports, the changes in traffic volumes and modal split will generally be dominant. However such projects may also affect the emission factors, in those cases where new infrastructure results in new vehicle stock (with usually lower emission factors) or traffic growth in certain markets that differ from the average (e.g. the container market). Therefore also in the case of projects that build new infrastructure capacity, the impacts on emission factors can be significant.

Most other types of infrastructure projects such as, pricing systems, intelligent transport systems or security systems (e.g. ERTMS) or new energy systems (e.g. electrification of a railway or infrastructure for electric road vehicles) have a significant impacts on emissions from traffic by either changing the transport demand, modal split and/or emission factors.

The GHG impacts related to **infrastructure operation, maintenance and management (OMM) and to the infrastructure development** are of a different kind than the traffic related impacts. They are partly once only, as far as it concerns the emissions from the initial construction. All these emissions can be very significant compared to the traffic related emissions. In some specific cases they may even be larger than the traffic impacts (AEA, 2011).

Building roads, railways or inland waterways causes significant GHG emissions related to the construction materials and energy needed for the construction work. Also the GHG emissions from maintenance of infrastructure can in some cases be significant. In the case of other types of infrastructure (such as an intelligent transport, traffic management, security or pricing system), the emissions from infrastructure construction and OMM may expected to be often negligible, except for cases where such systems would have extremely high electricity use. The embedded emissions from developing new energy infrastructures can generally expected to be significant.

The fourth and final type of GHG impact from infrastructure projects is related to **impacts on other sectors**, most of which will also last for the lifetime of the project. Examples are the GHG emissions from handling and storage of goods and potential indirect impacts on the magnitude and type of economic development. We will come back to this when discussing these impacts and the methodology for quantifying them (Paragraph 5.5).

As explained above, the relative importance of the four types of greenhouse gas impacts can be different for different types of infrastructure projects. Table 1 provides an indicative overview of this.

Table 1 **Relative importance various GHG impacts per type of infrastructure project (indicative)**

Type of project	Traffic		Infrastructure development	Infrastructure OM&M	Other impacts
	Changes in volume & modal split	Changes in emission factors			
New transport infrastructure	High	Low	High	High/medium	Low
Upgrade of existing transport infrastructure	High	Low	High/medium	Medium	Low
Rehabilitation of old railways/waterways	High	Low	High	Medium	Low
Interconnection of different transport modes	High	Low	Medium	Medium	Low
Intelligent transport systems	High	Medium	Low	Low	Low
Innovative projects; e.g. new carbon free operation	Low	High	?	?	?

3.3 Adding up once only and continuous emissions

It should be noted that the timescale of GHG impacts can be very different. Some of the GHG impacts of an infrastructure project last for the entire lifetime of the infrastructure, e.g. their traffic impacts. However, other impacts occur only once, because they are related to the initial construction, development or end-of-life processes of the infrastructure.

To estimate the total GHG emissions, these different elements should be brought to the same basis for which there are two main options:
– Annual emissions for a certain year.
– Total emissions for a certain period, e.g. the lifetime of the infrastructure.

The first option means that all once only emissions from development or end-of-life processes of infrastructure need to be divided by a certain lifetime.

In the case of the second option, all emissions that occur during the lifetime of the infrastructure need to be summed up. This means that traffic forecasts and projections for the emissions from operation, maintenance and management for the entire lifetime are required. In this case it is important to note that the lifetime of various types of infrastructure can be very different. It can even be different for various parts of infrastructure. Moreover, the lifetime of infrastructure is in some cases very hard to predict.

For almost all infrastructure projects, the emissions from development and end-of-life processes will be considerably smaller than the other emissions, particularly from traffic impacts. Therefore, the sensitivity for the choice of infrastructure lifetime on the calculated impact on GHG emission will be smaller when annual emissions are compared instead of emissions over the entire lifetime. When emissions over the entire lifetime would be the basis of the comparison, the maybe arbitrary choices of the lifetime could have huge impacts on the results. This could make it difficult to compare projects on an equal basis.

In addition, also the GHG impacts of other policy measures are usually expressed in emissions per year. For these reasons, this approach is to be preferred. The choice of the infrastructure lifetime remains an important choice as part of the once only emissions. This topic is further discussed in Chapter 5.

3.4 Choice of the reference year

GHG emissions from traffic, construction and all other impacts of infrastructure change over time. The average energy efficiency of vehicles generally improves, power generation is decarbonised and the carbon impacts of fossil fuel production increases. Such developments make that the choice of a reference year is critical for a fair comparison of various projects. Therefore, the GHG impacts of projects should be compared for one and the same reference year.

The choice of a reference year can be chosen in accordance with the time schedule of the projects within a certain programme that need to be compared. The reference year should be a few (five to ten) years after the planned finalisation of the projects. As an example, the time period for the new TEN-T programme is 2014-2020. For this programme 2025 seems an appropriate reference year as all projects should be finalised by 2020. The reference year should not be chosen too close after the completion of the projects as otherwise there will not yet be the full traffic impacts of the new infrastructure.

3.5 Formula for calculating the total GHG impacts

The various elements of GHG impacts can be brought together in one formula, which can be regarded as the core framework of the climate rating methodology. The following formula can be used to calculate the total GHG impact of a project:

$$Epa_{total} = Epa_{traffic} + Epa_{OMM} + E_{embedded} / L + Epa_{other}$$

Epa_{total}	Total GHG emissions per annum.
$Epa_{traffic}$	The total GHG emissions from traffic per year (for all modes).
Epa_{OMM}	The total annual GHG emissions due to operation, management and maintenance of all modes.
$E_{embedded}$	Total GHG emission related to the development and end-of-life phase of infrastructure.
L	Technical or economic lifetime of the infrastructure.
Epa_{other}	Total of emissions in other sectors related to the project.

The impact of a project is represented by the *change* in GHG emissions. This can be calculated by subtracting the total emissions for the reference scenario (business as usual) from the total emissions of the scenario with completion of the project.

In the subsequent chapters a methodology is elaborated for each of the types of GHG impacts distinguished above. First the GHG impacts from changes in traffic are discussed in Chapter 4. Next in Chapter 5 all other GHG impacts from new infrastructure are discussed: impacts related to the development, operation, maintenance and management of the infrastructure itself and other types of GHG impacts.

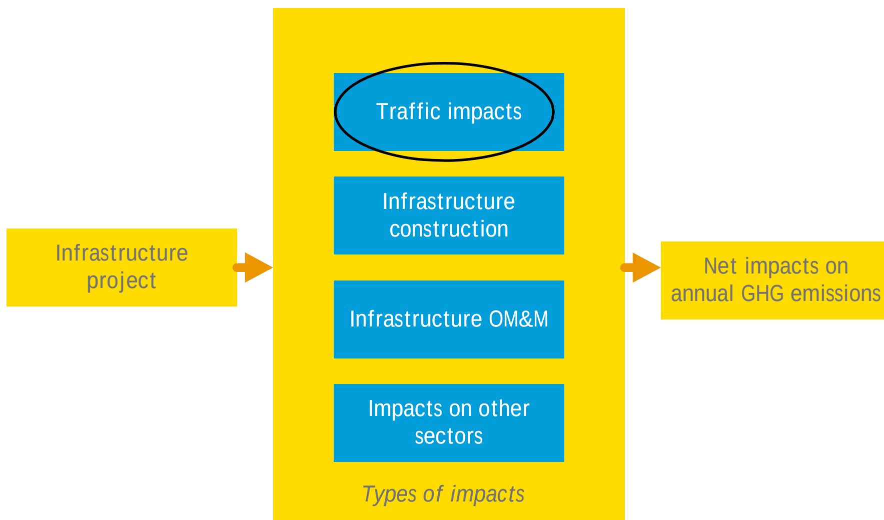
4 Methodology for changes in GHG emissions from traffic

4.1 Framework

In this section, the methodology for traffic related emissions is discussed. This is the first element from the formula presented in Paragraph 3.5, see also Figure 5:

$$Epa_{total} = Epa_{traffic} + Epa_{OMM} + E_{embedded} / L + Epa_{other}$$

Figure 5 Traffic impacts in relation to other GHG impacts of transport infrastructure projects



Basically all types of infrastructure projects affect the GHG emissions from traffic. This is obviously true for a new railway link, port or an upgraded motorway, but also for other types of infrastructure such as an electronic road charging scheme or intelligent traffic management system.

There is a broad range of changes in GHG emissions from traffic. The following effects can be distinguished:
1. Changes in traffic volumes and modal split (expressed in the total annual distance per vehicle type).
2. Changes in the average emission factors for direct vehicle emissions (tank-to-wheel) per vehicle type.
3. Changes in average emission factors for upstream emissions from production of fuels or electricity (well-to-tank) per vehicle type.

For projects on *physical infrastructure*[5], it is clear that all direct and indirect emissions from the traffic on the new infrastructure should be taken into account. In addition changes in traffic on existing infrastructure from the same mode and changes in traffic of other modes (modal shift) need to be included. Such a project will in any case affect the traffic volumes of one ore more transport modes. However, it can also significantly affect the emission factors, e.g. because of a shift within a certain transport mode to vehicles that have different energy efficiency, vehicle size or vehicle utilisation than the average.

For other types of infrastructure which are more ICT types of infrastructure (e.g. ITS or ERTMS), the types of impacts are principally the same. However, the relevance or magnitude of the changes in traffic volumes or emissions factors can be different. In those cases both volume and modal shift impacts can occur as well as significant changes in emission factors of vehicles or the production of energy carriers.

In the case of energy infrastructure, it is obvious that emission factors are affected. However, in this case also the traffic flows can be changed significantly because of changes in transport costs or infrastructure capacity (e.g. electrification railway can increase the capacity of railway networks because it enables the use of more advanced security systems).

For calculating the emissions from traffic, the following formula can be used:

$$Epa_{traffic} = \sum_{vehicle\_types} [(EFTTW_{vehicle\_type} + EFWTT_{vehicle\_type}) * Vpa_{vehicle\_type}]$$

$Epa_{traffic}$	The total GHG emissions from traffic per year (for all modes and vehicle types).
$EFTTW_{vehicle\_type}$	Emission factor tank-to-wheel (per vehicle type).
$EFWTT_{vehicle\_type}$	Emission factor well-to-tank (per vehicle type).
$Vpa_{vehicle\_type}$	Transport volume per year (per vehicle type).

In the next sections, the methodology for each of these elements is elaborated. In this formula, the transport volume can be defined either in vehicle-kilometres (vkm) or in passenger-kilometres (pkm) and tonne-kilometres (tkm). The choice between those two options has certain consequences. In the case of the first option (per vkm), the emission factors should be expressed in g/vkm, while in the second case they should be defined as g/tkm and g/pkm. However, the two options are not fundamentally different as they can be easily translated from one into the other by applying the average load factor per vehicle type.

A crucial choice in the calculation of traffic impacts is the vehicle types that are distinguished. This depends on the type of project. The minimum differentiation that is required is distinguishing the various transport modes. If also significant changes in the fleet can be expected (e.g. changes in fuel mix, average energy efficiency or average load), a further differentiation to the relevant parameters is required. Table 2 below summarises the minim differentiation required and also an example of further differentiations that can be relevant in some cases.

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5 We mean here with physical infrastructure projects the construction, upgrade or extension or roads, railways, waterways, (air)ports or terminals. These are to be distinguished from *non-physical* infrastructure projects such as road pricing systems, intelligent transport systems, etc.

Table 2 Overview of vehicle types to be distinguished

Type of transport	Minimum set	Additional differentiations
Passenger		
	Passenger car	Fuel types (petrol, diesel, LPG, CNG, full electric) Size or engine classes
	Bus	Fuel types (petrol, diesel, LPG, CNG, hybrid) City bus, regional bus, coach
	Tram/metro	Vehicle type: tram, metro
	Train	Electric or diesel Regional train, Intercity, High speed train
	Aircraft	Aircraft size
	Cycling/walking	
Freight		
	Van/light commercial vehicle	Fuel types (petrol, diesel, LPG, CNG, full electric) Size classes
	Truck	Size classes Type of goods (e.g. bulk, container, miscellaneous goods)
	Train	Energy type (electric or diesel) Size classes Type of goods (e.g. bulk, container, miscellaneous goods)
	Inland barge	Size classes Type of goods (e.g. bulk, container, miscellaneous goods)
	Sea ship	Size classes Type of goods (e.g. bulk, container, miscellaneous goods)
	Aircraft	Aircraft size

4.2 Traffic volume and modal split

The changes in traffic volumes of each mode are part of the broader social economic assessment of infrastructure projects. Therefore changes in traffic volume and modal split will generally be available from that assessment. These impacts are usually estimated using traffic or transport models.

A general rule should be that the climate rating builds on the same traffic impacts as used for economic assessment of the project. This is true for both the reference scenario as well as the traffic impacts of the project. This guarantees that the growth of traffic volumes, resulting from a certain project and contributing to its socio-economic benefits, is equally taken into account in the assessment of GHG impacts.

There are various critical issues regarding the assessment of traffic impacts:
- What is used as business as usual (BAU) traffic (among others related to GDP).
- Geographical scope and granularity of the network considered.
- Types of response mechanisms included.

There exist already some guidelines for traffic models within the context of infrastructure project assessment (like in HEATCO, 2006 or IMAGINE, 2006) and many member states and regions have their own traffic models. In addition there is a range of EU wide models such as the TransTools network model. It is beyond the scope of this study to discuss transport modelling in detail. However, there are a few critical issues regarding the modelling of traffic demand and modal shift impacts and how these could be taken into account in a climate rating methodology. These are briefly discussed in the next subsections.

4.2.1 Reference scenario

The choice of the reference scenario is important because this is the reference against which the project will be assessed. This is not only true for the climate rating but as well for the socio-economic assessment.

The reference scenario should be defined in a transparent way and reflect the business as usual situation without the project. Particularly attention should be paid to the following assumptions:

- GDP growth (to be based on official EU or national projections).
- Oil price development (to be based on official EU or national projections).
- Resulting traffic growth.
- Other infrastructure development: all other (infrastructure) projects that are already formally decided should be taken into account.
- In specific cases also assumptions on changes in population size and geographical distribution (e.g. changes in citizens of relevant cities because of urbanisation) can be relevant and should preferably be based on official national projections.

4.2.2 Geographical scope and granularity of the network

For all types of GHG impacts, it is important to define the geographical scope for which the impacts are calculated. In principle one could argue that the reference case and the scenario with the project should be compared *ceteris paribus* without any geographical limitation. However since all significant impacts will usually occur in a certain geographical area and for practical reasons, the assessments will be limited to a certain geographical region. The size of the region varies per project and depends on the area insignificant impacts can be expected. Generally these will be higher for infrastructure for long distance traffic such as a sea port or airport and smaller for more regionally oriented projects.

A similar reasoning applies to the granularity of the network. The granularity should be chosen in such a way that all significant impacts are included. As an example, in the case of a motorway road charging scheme also impacts on the underlying network should be considered.

It should be highlighted that in the specific case of infrastructure to (air)ports, also impacts on maritime traffic or aviation should be considered. For example, connecting an airport with a high speed rail link can in some cases mainly result in a modal shift from road to rail, while in other cases the increase in air traffic is much more important and more than compensating the effect of modal shift.

4.2.3 Response mechanisms

For assessing the traffic impacts of an infrastructure project it is important that the traffic model used, does take account of all relevant response mechanisms. In generally these are:

- **Modal shift** between transport modes (including transport to and from terminals).
- Changes in **overall transport demand** because of new (economic) activities or changes in origin and destination patterns, but also resulting from changes in average speed or (generalised) transport cost.
- Different impacts on different **market segments** (e.g. relatively high growth of container transport compared to bulk in the case of the development of a new railway).
- Changes in average **load factors and vehicle size** (e.g. changes in average load factors in the case of the upgrade of a inland waterway link).
- Potential **interaction between freight and passenger traffic**, particularly for road and rail transport (e.g. impacts on freight transport on the regular railway network in the case of the development of a new high speed railway link).

In some cases, some of the last three impacts mentioned above may be irrelevant or likely to be insignificant.

Not all transport models are capable to assess all these impacts. If the model used has some limitations here, additional assessment should be made in order to take account of the relevant responses that are not covered by the model.

4.3 Emission factors – tank-to-wheel and well-to-tank

The second element that determines the emissions impacts from traffic is the set of emission factors used. GHG emissions from transport fall apart into:

- Tailpipe emissions from the vehicles (usually referred to as *tank-to- wheel* emissions). And
- Emissions from upstream processes such as electricity generation or fuel production vehicles (usually referred to as *well-to-tank* emissions).

Both types of emissions should be taken into account.

The tank-to-wheel emission factors will generally be available from national emission registration. However, in the case of climate rating, the factors used should reflect the emission levels in the reference year e.g. 2025 (see Paragraph 3.4). This means that the autonomous development in emission factors (e.g. because of fleet renewal) as well as changes induced by policy (e.g. EU CO_2 emission regulation of cars and vans or national vehicle tax differentiation to improve the fuel efficiency of the fleet) should be taken into account.

The emission factors should reflect real-life emissions, so not refer to test cycle values (like the type approval test cycles for cars and vans).

The average emission factors, both well-to-tank and tank-to-wheel, can vary considerably across countries. Therefore, the set of emission factors should generally be country specific.

To avoid the possibility of gaming with the emission factors, a harmonized approach is to be preferred. Many member states have their own national emission registration and projections. Using those official emission factors seems an appropriate way of standardizing the emission factors. An alternative approach would be to use a single European set, such as the emission factors from Copert as available via the TREMOVE transport model. This has the advantage that:

- The set includes data for all member states.
- It covers various reference years (every year up to 2030).
- The set includes both tank-to-wheel and well-to-tank emissions.
- The emission factors reflect real-life emissions (no test cycle values).
- The values are differentiated to vehicle size category, fuel type and road type.
- The data are based on a single, EU wide and validated methodology.

The type of transport emissions that contribute to global warming are mainly CO_2 emissions. There is evidence that also black carbon (from PM emissions) may contribute to global warming. However, it currently lacks data to be able to quantify these impacts.

The main type of non-CO_2 emissions that should be taken into account are the **non-CO_2 emissions from aircraft** at high altitudes and also their contribution to cloudiness. Various studies were carried out to quantify these impacts. Usually these impacts are related to the climate impacts of the CO_2 emissions of aircraft and expressed in multiplier.
Lee et al. (2009) can be regarded as the state of the art on this. It estimates that the GWP of aviation including preliminary estimates for the effects of aircraft induced cloudiness are a, 0.9 to 1.0 the size of impacts of the CO_2 emissions; so this corresponds with a multiplier of 1.9-2.0. As noticed by Lee et al. themselves the uncertainties in this index are, although unknown, probably large. However, as this is the state of the art on this topic, we recommend this factor of 2 for estimating the non-CO_2 climate impacts of high altitude emissions from aviation.

4.3.1 Tank-to-wheel emission factors

The tank-to-wheel emission factors from TREMOVE or national datasets are not differentiated to the speed profile of the traffic (apart from the three road types considered in TREMOVE and similarly in most national data sets). Some infrastructure projects might have significant impacts on traffic speeds, e.g. by reducing congestion. That has impacts on the emission factors. If those impacts are expected to be significant, additional assessment could be carried out, e.g. by applying correction factors for the average emission factors before and after the infrastructure project. However, those corrections should take well account of the fact that congestion is usually limited to certain peak hours and only limited part of the network. Therefore the overall impact on the GHG emission factor is usually limited.
In addition, when considering the potential impact of congestion reduction on the emission factors, the demand impact of congestion reduction, due to the increase in average travel speed, is to be included as well, as this latter impact on GHG emissions is usually more significant than the first.

4.3.2 Well-to-tank emission factors

For the well-to-tank emission factors, we can distinguish:

- Emissions from fuel production.
- Emissions from power generation.
- Calculating the emissions of biofuels.

The upstream emissions from **fuel production** can best be treated with by applying a mark-up to the tank-to-wheel factor. According to TREMOVE (Version 3.3) the well-to-tank emissions of diesel production are 13.0% of the well-to-wheel emissions from burning the fuel; for petrol this percentage is 13.7%. These factors are the same for all vehicles and countries and within TREMOVE assumed to be constant over the next decades.

For the emissions from **electricity production**, a similar dataset can be used as for the tank-to-wheel emission factors. Again, a (preferably EU wide) harmonized, data set with country-specific values for future year is required. The same options are available as for the tank-to-wheel emission factors: official national datasets or an EU wide dataset such as TREMOVE.

It can be argued that the electricity mix from rail transport operators can be quite different from national averages. The EcoTransit emission tool contains data for all main European railway companies. However, these data refer to the current situation and not 2020, 2025 or 2030. Therefore, these data seem less suitable and data official national projections or from an EU-wide dataset like TREMOVE more appropriate.

Another issue to be discussed is the fact that power production is included in European ETS. The extra electricity use may therefore not have a direct impact on emissions, because the emission cap is fixed and the emissions will be offset elsewhere. However, also under the ETS activities still result in GHG emissions, which should also be included in the assessment.

A third type of upstream emissions is related to **biofuels**. Biofuel production can have various impacts on GHG emissions. First the growth of the crops used for biofuels has negative GHG emissions as during the growth CO_2 is taken from the air. However, biofuels can not be considered to be carbon neutral, as sometimes claimed, for various reasons. First, the production of biomass itself requires energy for machine and processing the biomass to fuel. In addition it requires fertilizers with often relatively high GHG effects. Last but not least biofuel production can have significant impacts on land use (so called indirect land use changes), often largely off-setting the GHG reduction from production. For some types of biofuels, net GHG reductions can occur, but this depends heavily on the type of fuel, source, production method, etc.

For each mode, the share of biofuels in transport fuels is still low (less than 10%). Therefore and for the reasons mentioned above, we recommend for the short to medium term to make no corrections for the use of biofuels in climate rating of infrastructure projects.

5 Methodology for other GHG impacts

5.1 Introduction

In this chapter all impacts of infrastructure that are not directly resulting from the traffic are discussed. First, we generally discuss the GHG impacts from the development and end-of-life processes of new infrastructure as well as the impacts from operation, maintenance and management of the infrastructure (Paragraph 5.2). Next we discuss in more detail how these could be quantified in the specific case of physical infrastructure (Paragraph 5.3). Finally we discuss other GHG impacts from infrastructure projects, particularly related to impacts on other economic sectors (Paragraph 5.5).

5.2 GHG emissions related to the infrastructure itself

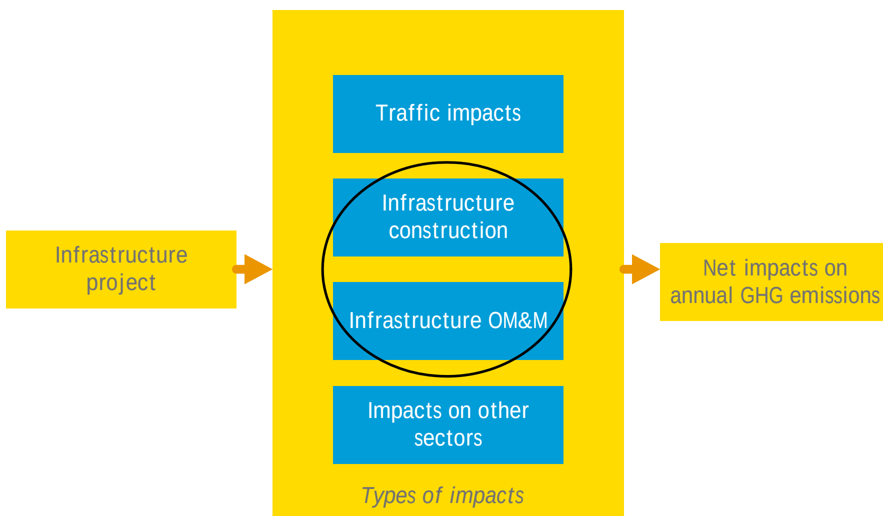
5.2.1 Overview

As explained in Chapter 3, the GHG emissions related to the infrastructure itself consist of:
- GHG emission related to the development and end-of-life phase of infrastructure.
- GHG emissions due to operation, management and maintenance.

These are the second and third element from the formula presented in Paragraph 3.5, see also Figure 6:

$$Epa_{total} = Epa_{traffic} + Epa_{OMM} + E_{embedded} / L + Epa_{other}$$

Figure 6 Impacts from infrastructure development, operation and maintenance in relation to other GHG impacts of transport infrastructure projects



This is true for all kinds of infrastructure, so not just physical infrastructure such as new or extended roads, railways, waterways, (air)ports, terminals, etc., but also for all other types of infrastructure like traffic managements systems, intelligent transport systems or road pricing infrastructure.

In the case of physical infrastructure there is quite some data available on their embedded GHG emissions (these are further discussed in the next section). For the other types of infrastructure this is not a subject on which much information is available. Although in the latter the relative share of embedded emissions can in general be expected to be relatively low, they might in specific case still be significant, e.g. in the case of electronic devices in large numbers of vehicles.

5.2.2 Formulas for calculating infrastructure emissions

In general the GHG impacts from the embedded emissions from **infrastructure development** and end-of-life processes can be calculated with the following formula:

$$E_{embedded} = E_{constr} + E_{eol}$$

Where

$$E_{constr} = E_{energy} + E_{materials} + E_{land\ \ use}$$

E_{eol} is the energy related to the end-of-life phase of the infrastructure. It consists of energy use for demolition, transport and recycling or disposal.

E_{energy} reflects the energy that is used for developing and building the infrastructure. Carbon contents for various energy carriers (like diesel, natural gas, electricity) are either default values or in the case of electricity available from national data sources or EU wide datasets such as TREMOVE (see also Paragraph 4.3.2).

$E_{materials}$ is the GHG emission related to the materials used. This value can be calculated using the GER[6] values for all materials used. For physical infrastructures this usually includes sand, rock and concrete, asphalts, steel and copper. For non-physical infrastructure these emissions will usually be low.

$E_{land\text{-}use}$ represents the GHG emissions related to the direct and indirect land-use change due to the construction of the infrastructure. An example of direct land-use change is the turnover from woods or agricultural land to road infrastructure.

6 GER = Gross Energy Requirement, the energy use of producing the material (including mining, extraction, etc.).

The GHG emissions related to the **operation, maintenance and management** of the infrastructure usually consists of E_{energy} and $E_{material}$. The can be calculated in a similar way as the, with the difference that these emission are not once only, but rather annual (see Paragraph 3.3). In addition, infrastructure projects may in some cases have impacts on the OOM emissions of multiple modes. Therefore the formula for these emissions is as follows:

$$Epa_{OMM} = \sum_{modes}[Epa_{mat} + Epa_{energy}]$$

With:

Epa_{mat}	Annual emissions from materials used for OMM processes.
Epa_{energy}	Annual emissions from energy used for OMM processes.

For physical infrastructure, particularly the maintenance of for example the tracks and road surface are relevant and tome some extent also those from lighting along motorways (AEA, 2011). Studies quantifying these impacts usually also cover emissions from infrastructure construction. The impacts of development and OMM processes of physical infrastructure are further discussed together in Paragraph 5.3. For other types of infrastructure (non-physical) these are discussed in Paragraph 5.4.

5.3 Methodology for physical infrastructure

Before describing a methodology for estimating the emissions related to physical infrastructure, it is useful to have an indication of the relative share of these emissions. This can be retrieved from a draft report of an ongoing study by AEA (2011).

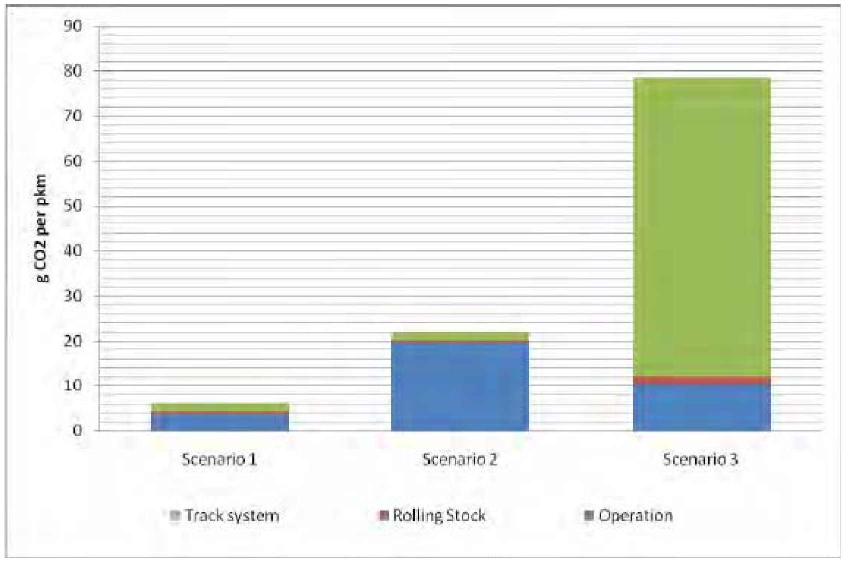
This report included a kind of meta-analysis on the GHG impacts from infrastructure development, maintenance, operation and management. The study covers all main transport modes, but just what we call here the 'physical infrastructure'.

It shows that in the case of road, the share of the infrastructure development, operation, maintenance and end-of-life processes may range from just a few per cent to over 10% of total road transport lifecycle emissions. In very few estimates the shares are higher, reaching up to over 40%.

For rail, the same study concluded that the share of infrastructure is generally higher than for road and differs considerably according to various parameters. A study for UIC (2009) developed a carbon footprint of high speed rail infrastructure. As part of this study, the energy used and emissions associated with infrastructure were analysed in the context of emissions from the operation of high speed rail, the construction of the rolling stock, and the construction of the infrastructure itself. Three scenarios were considered:
- Scenario 1: Electricity mix with low carbon footprint, average share of tunnels and bridges, high traffic on rail network, high load factor.
- Scenario 2: Electricity mix with high carbon footprint, average share of tunnels and bridges, high traffic on rail network, high load factor.
- Scenario 3: Electricity mix with high carbon footprint, high share of tunnels and bridges, low traffic on rail network, low load factor.

The share of embedded emissions related to the infrastructure varies from 9 to 83%. The results of these studies as presented in AEA (2011) are provided below.

Figure 7 Carbon footprint of High Speed Rail for three scenarios (adapted from UIC, 2009)



Source: AEA, 2011.

These examples make clear that in the case of physical infrastructure such as new or extended road, rail or inland waterway infrastructure, the share of embedded emissions may be considerable. Particularly some specific elements such as bridges or tunnels can have relatively high GHG impacts.

For these reasons, it is concluded that the embedded emissions of physical infrastructure are often significant and need to be assessed on a case by case basis. However, since in the assessment phase of a project, not all details are known regarding construction, materials used, etc., some default values for estimating these emissions are useful. Such values could be provided at various levels of aggregation:

– The average emission for each type of material and energy used (bottom-up approach).
– Per infrastructural part per unit (e.g. lane-kilometre for rail or track-kilometre for road), plus additional emissions fro specific elements such as tunnels, bridges, etc. (top-down approach).

In case of the **bottom-up approach**, calculating the GHG impact requires an estimate of amount of materials and energy used for construction. For physical infrastructures this usually includes sand, rock, concrete, asphalts, steel and copper. The GHG emission can then be calculated by combining this with the GER values for all materials used. Default values for this are available from the Eco-invent database.

In the case of the **top-down approach**, default values can be used per type of infrastructure element. Such values for road and rail infrastructure are given in AEA (2011).

The data required for both approaches are available. This makes clear that both approaches are feasible. In a further development of climate rating, it is recommended that the data to be used are standardised.

An important choice to be made is whether also various reference years should be considered. It should be noted that most lifecycle analysis studies only consider the GHG emission impacts of embedded energy and GHG emissions as a result of *present day* GHG intensities of material production. However, in the future it is to be expected that the production of many of the materials used today will be decarbonised as part of the general economy-wide drive to significantly reduce EU (and indeed global) greenhouse gas emissions through to 2050. This is expected to be particularly significant for those materials that are (a) significant (industrial) sources of GHG emissions in the economy, and/or (b) are significantly influenced by the GHG intensity of energy supplies (particularly electricity).

However as infrastructure projects that are currently considered for funding are likely to be realised within a decade the errors with using today's values are likely to be relatively limited.

Another is issue is the choice of the lifetime of infrastructure. One default value (e.g. 30 or 40 years; see Fraunhofer-ISI & CE, 2008) is the easiest and most transparent approach. An alternative would be to use a differentiated set, per type of infrastructure element, taking account of the different lifetimes of various types of infrastructure. The choice between those two options is left as subject for further study.

Specific attention should also be given to the way recycling of materials is used (see text box).

Specific choices related to recycling of materials

In assessing the embedded emissions (or related environmental lifecycle assessment) of transport infrastructure, it is important to account correctly and consistently (as far as possible) for the method/impacts of recycling. There are broadly three types of methods that can be adopted:

1. Recycled content approach (100:0 method).
2. Substitution method (also known as closed loop system expansion, or 0:100 method).
3. 50:50 method (50:50).

There are advantages and disadvantages of each approach and it is important to consider the boundaries of a study (e.g. cradle to gate, cradle to grave) to ensure the selection of an appropriate method. Most studies calculate with the use of recycled materials in the production/construction phase and therefore apply emissions of recycled materials within the initial calculations. As a consequence, these studies allocate recycling energy/emissions benefits to the recycled products. Other studies use the substitution method and calculate with virgin materials energy/emissions factors and apply a recycling stage in the end, with allocation of recycling credits at this point. In reality the true impacts are likely somewhere in-between and the 50:50 method is based on a (relatively arbitrary) mid-point between the two extremes.

Source: AEA, 2011.

5.4 Methodology for non-physical infrastructure

For non-physical infrastructure the emissions from operation, maintenance and management are mainly related to emissions from data centres, electronic devices (in vehicles or along physical infrastructure), etc. The direct energy use of those devices (often mainly electricity) is likely to be the most relevant here, but in most cases still relatively low. Emissions related to material use will generally be even more limited. Also the emissions from infrastructure development will generally be very low for these types of infrastructure. Overall we expect that all infrastructure-related emissions of non-physical infrastructure will often be negligible compared to those from their traffic effects.

The approach for quantifying these emissions could therefore be as follows:

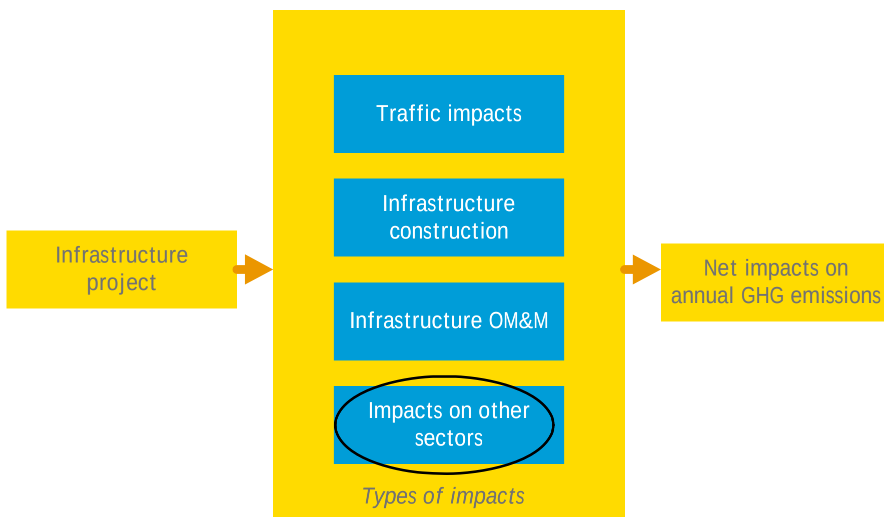
- Estimate of the order of magnitude of infrastructure development and OMM emissions, based on electricity use and material use.
- Comparison with GHG emissions from traffic impacts.
- If infrastructure related emissions are significant (e.g. more than 5% of the traffic emission impact) a more detailed tailor-made assessment could be required.

5.5 Contributions from impacts on other sectors

In this Paragraph, the methodology for other emissions is discussed. This is the fourth element from the formula presented in Paragraph 3.5, see also Figure 8:

$$Epa_{total} = Epa_{traffic} + Epa_{OMM} + E_{embedded} / L + Epa_{other}$$

Figure 8 Impacts on other sectors in relation to other GHG impacts of transport infrastructure projects



Besides the impacts GHG emissions from changes in traffic, infrastructure development and infrastructure operation, management and maintenance there may be other impacts from transport infrastructure, e.g.:

- Emissions from handling and storage of goods.
- Emissions related to changes in industrial activity.
- Impacts related to changes in water management (in case of waterway projects).
- Potential impacts on other economic sectors.

For most of the effects listed above it is not possible or useful to define a general methodology. These other type of impacts will only occur in specific cases or are very hard to quantify.

Emissions from handling and storage of goods are an exception as these are relevant for many projects. Transhipment of goods is relevant for any project that has a significant impact on the freight modal split. However the relative contribution of transhipment to the total GHG emissions of freight transport is very small (according to CE, 2011).

6 Climate rating in the context of project assessment

6.1 Introduction

The previous three chapters described a methodology for estimating the GHG impacts of transport infrastructure projects. In this chapter, it is discussed how all this can be used for the assessment of infrastructure projects.

First we discuss how the different projects could be compared on their GHG impacts (Section 6.2). Next we discuss how the result of such a comparison could be used within the project appraisal process (Section 6.3).

6.2 Criteria for climate rating of infrastructure

Before discussing the way infrastructure projects could be compared on their climate performance, we first discuss the main criteria that such an approach should meet.

First of all, climate rating should reveal the overall GHG impacts of a project. In the previous chapters it was discussed how this could be done.
However, climate rating should also be an easy and clear method for taking the GHG emissions into account in decision making. Therefore the overall approach should be:

- **Accountable**
  This means that a quantitative approach is required and that all required data should be available for all types of projects.
- **Reliable**
  This means that the methodology is well described and can be applied in a similar way for different project. It also requires the possibility to check the data basis that is for assessing a certain project.
- **Understandable**
  It should be clear what a climate rating indicator means and it should preferably be understandable for non-experts.
- **Uniform**
  The approach should be applicable to all transport modes, Member states, types of infrastructure projects (aimed at increasing capacity and/or better use of capacity). It should also be suitable for comparing projects of very different size on their GHG impacts.

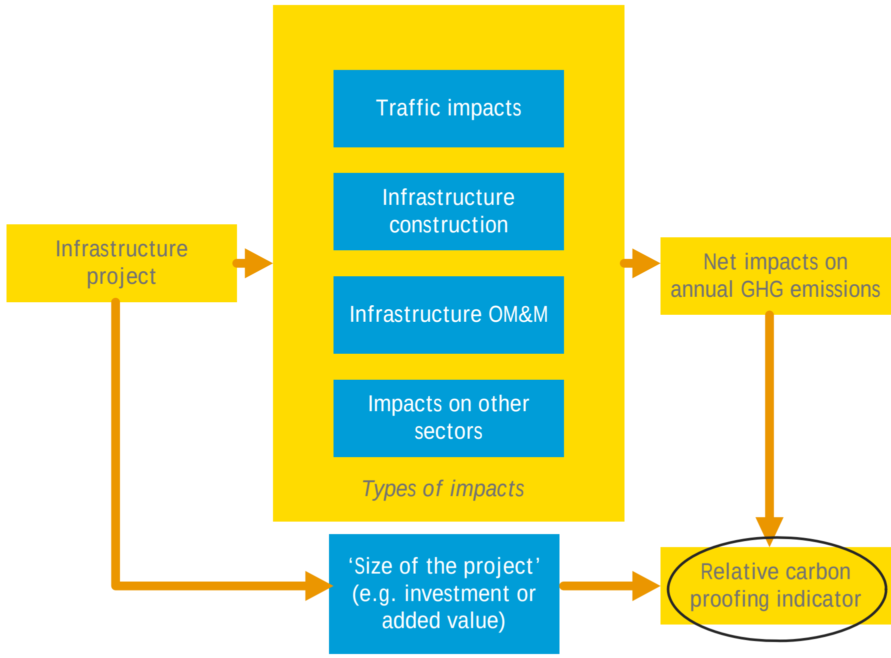
6.3 Comparing projects on their GHG impacts

The net GHG impact as such is not an appropriate indicator for comparing projects. The reason is that project may have very different 'sizes', in terms of their financial, economic, geographic and environmental impacts. Comparing projects on their absolute GHG impacts would benefit small projects for all projects that result in a net increase of GHG emissions and large projects that result in net GHG reduction.

In order to be able to compare projects of different size and focus, a relative measure is required. This means weighting the GHG impacts with some type of measure for the size or value of a project.

Figure 9 provides an overview of how this relates to the other elements of the overall climate rating methodology.

Figure 9 The relative climate rating indicator in the relation to other elements of the methodology



This raises the question what would be a useful measure for the size or value of the project. There are various options for this:
- Amount of additional transport facilitated.
- Overall investment.
- EC contribution to the project investment.
- Contribution to GDP.
- Total economic benefits.
- Net added value from SCBA (total benefits minus total social costs).

The amount of additional transport is not a good option since projects might have an objective to facilitate change in transport modes, less congestion, etc.

The overall investment and the EC contribution are good indications of the size and value of a project.

The funding schemes from the EU, both TEN-T and Cohesion funds, aim at the development, and therefore the contribution to GDP could be regarded as a suitable option. However, also other welfare effects (congestion, environmental impacts, etc.) play an important role in case of infrastructure development and should be taken into account.

Also the total economic benefits of a project give an indication of the importance of the project, but they do not take account of costs (e.g. investment costs, maintenance, external costs, etc.). The net added value as it is calculated in a Social Costs and Benefit Analysis (SCBA) reflects the real value of the project to society and takes account of all benefits and costs. However, it has the disadvantage that for many projects no propose SCBA is carried out. In addition, GHG emissions are already part of the net added value calculated in an SCBA. However, in cost benefits analysis of infrastructure projects, the relative value of climate impacts is usually very small, so in practice this risk of 'double counting' is generally limited.

From a macro-economic point of view, the net GHG impact per unit of welfare growth, seems the most appropriate indicator for comparing projects. However, given the fact that SCBAs are not yet commonly applied in project appraisal, the GHG impact per Euro of EU funding (or eventually of project investment) seems more practical and feasible, particularly at the short term.

6.3.1 Indicator for the short term

The indicator that seems most appropriate for comparing infrastructure projects on their carbon impacts is the following:

$$Efficiency\ of\ investment = \frac{\Delta GHG}{(EU)\, project\ investment}$$

The lower the value of this indicator, the better the project scores regarding its climate impacts.

When the indicator is used to decide on EU funding, it seems more logical to use the EU contribution. However, when the indicator is rather interpreted as a measure of guaranteeing that public expenditures are well in line with the overall climate policy objectives, also the total of public spending on the project or even the total investment might be considered.

This indicator does not account for operation, maintenance and management costs of the infrastructure. For infrastructure for which this is a relatively high share in the infrastructure cost, this might be problematic. This might be solved by including the net present value of the OMM cost over a certain period (e.g. 40 years). However, this has the disadvantage that it makes the indicator more complicated.

6.3.2 Indicator for the long term

In the case of welfare impact, projects would be compared on their scoring on the following indicator:

$$Efficiency\ of\ investment = \frac{\Delta GHG}{welfare\ growth}$$

This indicator show which infrastructure projects result in most welfare growth against the lowest GHG emissions. It can be regarded as a kind of climate efficiency of infrastructure project, similar to the cost effectiveness of climate policy. It should be noted that this latter indicator is only suitable for comparing projects with a net social benefit and resulting in an increase in overall GHG emissions, as explained in the text box below.

Using the indicator for projects with net GHG reduction
The indicator is best suitable for comparing projects with an increase in overall GHG emissions. The reason is that projects with a net reduction in GHG emissions would result in a negative value of the indicator, where the magnitude depends on the ratio between overall added value and GHG reduction. One cannot say that projects with a lower (more negative) value are to be preferred. When two project have the same GHG reduction, but one of the two has higher net social benefits, this would score worse than the other, which is not rational. From a climate point of view all projects that contribute to both welfare and GHG reduction are favourable and cannot be compared reasonable on the ratio between the two benefits.

Therefore this indicator should be part of a two-step methodology where the first step is to assess whether a project contributes to a net increase or decrease of GHG emissions. If it results in a net decrease it can be ranked as best in terms of climate rating. If it results in a net increase in emissions, which will often be the case, the indicator can be used to compare various projects, where projects with a higher score on the indicator score worse than project with a lower score.

Regarding projects with net social cost, the following can be noted. Decisions under the framework of the cohesion funds or the TEN-T programme aim at economic and social growth, in other words growth of welfare. Therefore it is assumed that a project that does not contribute to growth of welfare effects does not contribute to the overall objectives of infrastructure development and should therefore not be supported by EU funding.

6.4 How to use the results of climate rating?

Once an indicator has been defined, projects can be compared on their climate impacts. The next question is how the results of such an assessment can be used in the process of infrastructure project appraisal.

The following options can be distinguished:
- As a selection criteria for EU funding.
- For prioritisation of projects for EU funding.
- For determining the maximum share EU funding.

The first option would mean that projects that score too badly on the climate rating indicator are not eligible for EU funding. This would require a certain threshold, a minimum score that a project should have to be eligible for EU funding.

The second option means that the climate rating score is used for prioritising projects, e.g. by granting extra points in an overall appraisal procedure.

The third option would require a matrix with maximum shares of EU funding for various scorings of the climate rating indicator.
The feasibility, pros and cons and consequences of these various options are subject for further study. Also combinations of these options might be considered.

In all three cases, the climate rating would also incentivise adapting already planned projects or extending them with additional measures to reduce emissions. For example, a project for the construction of a new road might be adapted to the upgrade of a current route or extended with adding a toll, multiple-occupancy lane, bus-only lane, urban freight consolidation centre, inter-modal hub, etc. (assuming that these would lower greenhouse gas impact of the project).

7 Examples of application of the indicator

7.1 Introduction

In this chapter the methodology presented in this report is applied to three types of infrastructure projects. The aim of this is to show how the methodology is applicable to various types of infrastructure. Very different types of projects have been chosen:

1. Electrification of railways.
2. New road infrastructure.
3. Road pricing scheme.

In the following section, application of climate rating to each of these cases is described. We want to emphasize that the cases are included for illustrative purposes and the numbers used may in some cases not be fully realistic.

7.2 Electrification of railways

Electrification of railways will result in a decline of the use of diesel engine trains. The direct GHG emissions will be reduced, but the GHG emissions from electric power production will rise[7].

Another effect of electrification is the increase of capacity on the railway. Electric trains can operate with higher frequency due to the possibility of automated safety systems. This can result in modal shift effects.

In the example we start with a railway track of 100 km, without electrification. Per day in 2010, 40 diesel freight trains with containers run on the track. Each train has an average load of 70 TEU (735 tonnes per train). In 2025 this amount will have risen to 60 trains per day. This is considered to be the BAU reference scenario.

The project considered is electrification of this railway line. In the subsequent subsection we discuss the various impacts.

Impacts on GHG emissions from traffic

When the electrification is ready, it is expected that 98% of all traffic on the line will use electric traction; the other 2% still runs on diesel. In addition it is expected that the capacity of the railway increases. This will result in a shift from road to rail as well as some induced traffic.

We assume that in this example, 20 additional trains will run on the track every day and that half of this is from modal shift from road (equal to a reduction of 330 trucks per day), while the other half from overall transport increase (induced traffic). The latter results in some road transport to and from the railway terminals (20 km per trip).

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[7] Not considering ETS effects, see discussion on this in Paragraph 4.3.2.

The total impact on the GHG emissions from traffic in this case is then calculated with the emission factors shown in Table 3.

Table 3 **Case Electrification railway track - impacts on GHG emissions fro traffic**

	TEU/day	Emission factor (WTW) g/tkm[8]	Annual CO_2 emissions kton/year
BAU (2025)			
Diesel trains (distance 100 km)	4,200	31	50
After electrification (2025)			
Diesel trains (distance 100 km)	84	31	25
Electric trains (distance 100 km)	5,516	12	1
Reduction in trucks (modal shift; distance 100 km)	700	69	-/-19
Additional truck (to/from railway terminal; distance 20 km)	700	69	7
Total impact of the project on GHG emissions from traffic			-/- 35

So, in this example the net impact on the annual GHG emissions from traffic is a reduction of 35 ktonne of CO_2.

Impacts from infrastructure development, OMM and other impacts

The electrification of the railway track is estimated to require the following amounts of materials, see Table 4.

Table 4 **Material use for electrification**

Material (main materials used)	Amount kg per km per yr	Amount in kg per yr	Emission factor in kg CO_2/kg material	Annual CO_2 emissions kton/year
Steel	100,000	10,000,000	1.3	13
Copper	2,200	220,000	2.7	0.6
Concrete	800	80,000	0.16	0.01
Gravel	400,000	40,000,000	0.08	3.2
				16.8

The calculations have been made with an estimated lifetime of 40 years. In this illustrative example, the figures are derived from the SimaPro model. The total annual GHG emissions from construction of the electrification of the railway are about 17 ktonne CO_2 per year.

In this example it is assumed that the OMM effects and other impacts are negligible.

8 For this illustrative example, emission factors have been used from STREAM, CE (2011).

Total GHG impact
The total GHG impact of this project can now be estimated as follows:

Indicator	Value
Traffic impacts:	-/- 35 ktonnne per year
Infrastructure development:	+ 17 ktonne per year
Net GHG impact:	**-/- 18 ktonne per year**
Investment	90 million €
Net result of the CBA	million €/year
Climate rating indicator relative to investment	**-/- 0.2 kg/€**
Climate rating indicator relative to welfare impact	**-/- 3.6 kg/€**

7.3 New road infrastructure

New roads give the traffic opportunities to move. This will result in a higher use of the infrastructure and thereby to higher GHG emissions. In addition there are impacts from road construction and OMM to be considered.

As an example we take a traffic network around a large city. The network consists of about 260 km of motorways, main regional and main city roads. The BAU scenario is built from a starting year 2004 and ends in 2025.

There are two alternatives for coping with the existing and expected traffic demands. The new infrastructure in this example consists of 20 km highway in alternative 1 and 25 km of highway in alternative 2. They reduce congestion and so result in lower GHG emissions.

Impacts on GHG emissions from traffic
Traffic modelling shows the changes in traffic volume for both the BAU scenario and the two alternatives. The figures are given for trucks and cars. They are presented as total annual vehicle kilometres for all relevant roads within the network. The GHG emissions are calculated using hypothetical WTW average emission factors for the traffic in this city. We assume that they will be reduced because of congestion reduction in peak hours for part of the traffic on the network. To make it not too complicated, other traffic and modal shift effects are not included in this illustrative example.

Table 5 Case new motorway - impacts on GHG emissions from traffic

Scenario	Volume trucks in million vkm/yr	Volume passenger cars in million vkm/yr	WTW emission factor Trucks (g/vkm)	WTW emission factor Passenger cars (g/vkm)	GHG emissions ktonne/year
Situation in 2004	500	3,200	500	250	383
BAU (2025)	750	4,600	450	181	427
New motorway – alternative 1	780	4,800	442	178	438
New motorway – alternative 2	800	4,900	438	177	444

So alternative 1 results in 11 ktonne additional emissions per year, while for alternative 2, these are 17 ktonne per year.

Impacts from infrastructure development, OMM and other impacts

Estimates for the material used for these news roads are shown in Table 6.

Table 6 Materials for new roads

Material (main materials used)	Amount kg per km per yr	Emission factor in kg CO_2/kg material	GHG emissions in alternative 1 (ktonne)	GHG emissions in alternative 2 (ktonne)
Gravel	4,240,000	0.079	6.7	8.4
Bitumen	129,600	0.49	1.3	1.6
Steel	53,000	1.46	1.5	1.9
Concrete	450,000	0.11	1.0	1.2
Total			10.5	13.1
Total/year			0.26	0.33

If we combine these data with estimates for the operation, maintenance and management of the road (hypothetical estimates) then the total impacts are as follows.

Table 7 Overview of GHG impacts from infrastructure development and OMM processes

Material (main materials used)	GHG emissions in alternative 1 (ktonne)	GHG emissions in alternative 2 (ktonne/yr)
Total CO_2 emissions from materials used for construction	0.26	0.33
Total CO_2 emissions from energy used for construction	0.12	0.15
Infrastructure OMM emissions	0.22	0.27
Total emissions from construction and OMM	0.60	0.75

Total GHG impact

The total GHG impact of this project can now be estimated as follows:

	Indicator	Value
Alternative 1:	Traffic impacts:	11 ktonne per year
	Infrastructure development and OMM:	0.6 ktonne per year
	Total impact:	**12 ktonne per year**
	Investment	20 million €
	Net result of the CBA	12 million €/year
	Climate rating indicator relative to investment (in ton CO_2/Euro):	**0.6 kg/€**
	Climate rating indicator relative to welfare impact	**1.0 kg/€**

	Indicator	Value
Alternative 2:	Traffic impacts	17 ktonnne per year
	Infrastructure development and OMM	0.8 ktonne per year
	Total impact	**18 ktonnne per year**
	Investment	25 million €
	Net result of the CBA	16 million €/year
	Climate rating indicator relative to investment	**0.7 kg/€**
	Climate rating indicator relative to welfare impact	**0.9 kg/€**

7.4 Road pricing system

Road pricing effects the traffic due to higher prices for transport. This will influence the amount of traffic (at certain time frames), modal shift, but it can also reduce congestion. In addition, it could also affect the type of transport, e.g. environmental friendly types could be favoured by the price. In the end it will result in a different transport volumes, modal split and emission factors.

If we take the example from Paragraph 7.3 and instead of planning new infrastructure we start with a system of road pricing, changes in traffic volume will occur. These changes can be calculated by traffic modelling and assumptions on the effect of road pricing.

In this case we compare the BAU scenario with road pricing. We assume that traffic modelling indicates that in the case of road pricing the traffic volume as presented in the example of Paragraph 7.3 declines with 8% for passenger cars and 4% for trucks.
Again, the GHG emissions are calculated using hypothetical WTW average emission factors for the traffic in this city and other traffic and modal shift effects are not included in this illustrative example. We assume that the GHG emissions for both cars and trucks decline at a somewhat higher rate than the traffic, as we assume that the same congestion reduction is achieved as in Alternative 2 from the pervious case. The traffic impacts are summarized below.

Table 8 Road pricing – impacts on GHG emissions from traffic

Scenario	Volume Trucks in million vkm/yr	Volume passenger cars in million vkm/yr	WTW emission factor Trucks (g/vkm)	WTW emission factor Passenger cars (g/vkm)	GHG emissions ktonne/year
Situation in 2004	500	3,200	500	250	383
BAU (2025)	750	4,600	450	181	427
Road pricing	720	4,232	438	177	389

So, in this case the impact on GHG emission from traffic is a 38 ktonne reduction.

Impacts from infrastructure development, OMM and other impacts

To make road pricing possible changes in infrastructure are necessary. These changes are presumed to consist of: electronic detection equipment on the road entrances, electronic devices in cars to make detection possible, data centres for handling the information and finances.

For these equipment LCA data are available, for this case we presume an average GHG emission factor of 2.26 kg/kg equipment.

Table 9 **Electronic equipment**

Material	Amount kg per kg	Emission factor kg per kg	GHG emission kg per kg
Steel	0.46	1.3	0.6
Copper cables	0.32	2.7	0.86
Plastic	0.08	2.5	0.2
Printed board	0.14	4.3	0.6
Total			2.26

If we assume that 200,000 on-board units are needed, each weighting 3 kg and with an average lifetime of 7 year, the total impact of these would be 1.4 ktonne of CO_2 per year. If we assume that from additional assessments it would be concluded that another 1.6 ktonne per year would be needed for energy use and building in the units and another 2 ktonne per year for the other parts of the road pricing scheme, the total impact from the road pricing infrastructure development and OMM would be about 5 ktonne.

However, it can also be expected that the reduction in road traffic results in some reduction of emissions from OMM processes; in this case assumed to be 1 ktonne per year, making the net impact of infrastructure development and OMM at 4 ktonne per year.

Total GHG impact

The total GHG impact of this project can now be estimated as follows:

Indicator	Value
Traffic impacts	-/-38 ktonnne per year
Infrastructure development and OMM	4 ktonne per year
Total impact	**-/-34 ktonne per year**
Investment	40 million €
Net result of the CBA	70 million €
Climate rating indicator relative to investment	**-/- 0.9 kg/€**
Climate rating indicator relative to welfare impact	**-/- 0.5 kg/€**

8 Conclusions & recommendations

8.1 Conclusions

Infrastructure policy and climate policy interfere. Developing or upgrading transport infrastructure can have significant impacts on the decarbonisation of transport. While some types of infrastructure carry the risk to get locked-in to carbon intensive technology or transport modes, other projects may actually contribute to GHG reduction.

Until now, the impacts on greenhouse gas emissions are not well integrated in transport infrastructure project appraisal. This is not only true at a European level but also at most national and local levels. Climate rating could solve this by explicitly taking account of the effect on greenhouse gases emissions in the infrastructure project appraisal and funding decisions. The climate rating methodology developed in this report is a suitable basis for this.

The methodology is applicable to all type of infrastructure projects. It is relatively straightforward and all data required for making the calculations are available from either the socio-economic assessment of the project or from additional data sources. The most important additional data and their data sources are:
- Emission factors per mode of transport and vehicle type: from standard data sets such as TREMOVE or from national emission inventories.
- Emission factors per material and energy used for developing, maintaining, managing or operating the infrastructure (available from various studies and models like Simapro or the Ecoinvent database).

This study identified a number of critical choices in calculating the impact of infrastructure projects on greenhouse gas emissions. The most critical issues in the climate rating methodology are:

- **Impact of GHG emissions from traffic impacts**
  - The choice of the reference scenario (related to GDP).
  - Emission factors that reflect real-life well-to-wheel emissions.
  - The quality of the traffic modelling, taking account of all major response mechanisms and choosing a sufficient large geographical scope and granularity of the network.
  - A guiding principle should be that for the calculation of greenhouse impacts from changes in traffic, the most important guideline is that the same traffic changes should be used as for the socio economic assessment of the project.

- **Impacts from infrastructure development, operation, management and maintenance:**
  - First check of the order of magnitude of these emissions, to assess whether they are significant.
  - Lifetime of infrastructure used.
  - Choice between a bottom-up (average emission for each type of material and energy used) or top-down approach (average emission per unit of infrastructure, e.g. lane-kilometre, track-kilometre, bridge, tunnel).

- The assumptions on relative emissions per unit of material (Gross Energy requirement, GER), energy and/or infrastructure element.

– **Other impacts:**
  - These are expected to be often insignificant. They are to be assessed on a case by case basis.

The main data requirements and data sources that can be used for the climate rating methodology are listed in Table 10.

Table 10 Overview of main data requirements and data sources for climate rating

Type of impact	Data requirements	Data sources
Changes in traffic	- Traffic volumes and modal split (differentiated to vehicle and fuel types) - GHG emission factors (well-to-wheel, differentiated to vehicle and fuel types)	- Traffic model results from socio-economic assessment - Emissions factors from national emissions inventory or European dataset, e.g. TREMOVE
Infrastructure development and infrastructure Operation Management and Maintenance	*Bottom-up approach* - Energy use for construction and end-of-life processes. - GHG emission factors (well-to-wheel) per energy source - Materials for construction and end-of-life processes - GER (Gross Energy Requirement) values - Lifetime of infrastructure *Top-down approach* - Units of infrastructure (lane-kms, track-kms, km of bridge, tunnel, etc.) - Emission factor per unit of infrastructure	*Bottom-up approach* - Estimates in project work plan - Default values, e.g. from emissions inventory or or European dataset, e.g. TREMOVE - Estimates in project work plan - Default values, e.g. from Simapro or the Ecoinvent database - Default value(s) (e.g. 30 years or differentiated to type of infrastructure element) - Estimates in project work plan - Default set to be developed, e.g. based on AEA (2011)
Impacts on other sectors (e.g. handling of goods, storage, industrial activity, etc.)	Case by case	Case by case

For comparing different projects, the impact of a project on greenhouse gas emissions should be compared to a measure for the size or value of the project. The (EU or total) investment is the best candidate for this, for the short to medium term. For the longer term the net contribution to economic welfare from the cost benefit analysis could be an alternative. However for many projects no proper cost benefit analysis is available yet. The value of the climate rating indicator could be used for deciding on the co-funding rate or for prioritisation of projects.

8.2 Recommendations

The main recommendations from this study are regarding climate rating of transport infrastructure are:

- To further develop a climate rating methodology for transport infrastructure projects. This could be done by the TEN-T agency with input from a range of experts. Particularly the following issues deserve further attention (see also the previous section, 8.1):
  - Requirements regarding traffic modelling.
  - Standardised set of emission factors (national or a EU-wide harmonised set).
  - Elaboration of the precise definitions and default parameters for emissions from infrastructure development, operation, management and maintenance.
  - Climate impacts of black carbon.
  - To build this on the main structure defined in this study.

In addition there are a number of additional recommendations regarding transport infrastructure project appraisal in general that were identified during this study:

- To require for all major transport infrastructure projects a proper social cost benefit analysis to be carried out.
- To develop a mechanism for a quality check on all traffic modelling used for infrastructure project appraisal. This check should ensure that the geographical scope, granularity of the network and the type of response mechanisms covered by the model match well with main impacts that can be expected from the infrastructure project.
- To require to be fully transparent on the relevant data and assumptions behind the Environmental Impact Assessment and Social Cost Benefit Analysis of a project.
- To develop a mechanism that ensures impartial project assessment.
  The interests in the infrastructure project of the parties that are directly involved and making the assessments are sometimes high. The requirement of an independent external review may help to further improve the quality and fairness of project appraisal.

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