Arup Netherlands

CO2 Performance ladder

Value-chain analysis for Transport & Mobility and Buildings

4.A.1 and 5.A.1, 5.A.2-1, 5.A.2-2

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1 Introduction

1.1 Objective of this report

At Arup, we constantly challenge ourselves to push the boundaries of what is possible to fulfil our mission of shaping a better world. We are committed to carry our expertise and knowledge across to our clients to achieve ‘green’ solutions. Therefore, we aims by means of this report to draw a strategy to optimise our potential influence and participation in reducing carbon emissions of our societies.

In alignment with the carbon Performance ladder, this document is a requirement starting the 4th level of certification which is intended to have certified companies more involved in managing carbon emissions along their supply-chain. This document presents an analysis of the main down-stream carbon generating activities related to our projects for which reliable information is available. In addition (future) targets are set to improve the areas of influence where the maximum profit from carbon reduction can be achieved.

1.2 Scope

As an engineering consultancy firm in the built environment, our biggest influence on carbon emissions in our value-chain is downstream. The effects of our designs surpasses by far the effects of the products and services we acquire up-stream.

In order to obtain insight in the downstream CO_2 emissions, Arup carries out a scope 3 analysis of her value chain. Scope 3 emissions include all the indirect CO_2 emissions that occur after the delivery (completion) of our services (designs).

The scope of this analysis is to identify the possibilities of implementing more sustainable design methods which can potentially lead to the reduction of carbon emissions in the final product (service/structure).

This report is also the initiative for a long term approach. We have performed a value chain analysis for a specific part of Arup activities that can have a lot of impact on CO_2 emission. A two-year period (2014-2016) is set as the time frame in which improvements will be implemented.

In 2014, we had published a first scope 3 analysis targeting ‘Road Transport’ related emissions. In the current version, the relevance of ‘Road Transport’ for our sustainability strategy is evaluated based on progress on projects and market position.

Starting 2015, the total carbon footprint of Arup b.v. has exceeded 500 ton carbon/ year. This implies that two value chain-analysis have to be carried out. The second value-chain analysis focuses on ‘Buildings’. The addition of another value-chain analysis implies also the incorporation of the results into our sustainability strategy.

1.3 Approach

The approach to define the scope 3 reduction possibilities within Arup is as follows:

1. Determine top 6 of scope 3 emissions through consultation with group leaders of most important departments (i.e. Infrastructure, Buildings & Consulting);
2. Use method described in 4.A.1 of CO_2-prestatieladder to define the size of emissions (qualitatively);

3. Based on the above analysis determine the sector/activity with the highest potential CO_2 reduction taking into account the influence of Arup within the market;
4. Prepare a value chain for the chosen activities;
5. Set targets and describe ways which will reduce the CO_2 emissions of the specific activity in the future.

1.4 Basis for scope 3 analysis

- The CO_2-prestatieladder handbook 3.0 is a reference are the reference documents for determining the top 6 activities of Arup with the most influence in CO_2 emissions. For the value-chain analysis the GHG-protocol is used as the basis.
- Arup has no significant influence on upstream scope 3 emissions so these are not included in the analysis. The downstream emissions are project related.

1.5 Boundaries downstream scope 3 analysis

Arup Netherlands uses the "operational control" approach laid down in the GHG-Protocol in the definition of its scope 3 emissions. This means that Arup is responsible for the emissions which result from office operations that Arup controls. Based on this, this document deals with the (indirect) emissions that are result from the design, engineering and consultancy work that is delivered by Arup.

The certification will cover Arup in the Netherlands registered as Arup BV. Arup BV has no authority on other Arup offices outside the Netherlands. Arup BV operates two facilities:

- Amsterdam;
- Groningen office.

Arup BV is organised internally in two main departments, 'Building & Consulting' and 'Infrastructure'. Building & Consulting is subdivided into multiple teams to deliver specialised services to different markets and clients. The teams within Building & Consulting are:

- Electrical engineering;
- Structural engineering;
- Mechanical Engineering and Plumbing;
- Acoustics;
- Computer Aided Design and Building Information Management;
- Building Physics;
- Fire engineering;
- Lighting;
- Master planning;
- Transport planning;
- Project management.

The Infrastructure department is not subdivided.

2 Relevant scope in the value-chain

2.1 Total value-chain

Arup Netherlands is an engineering consultancy firm providing a wide range of services including the design and construction of buildings and infrastructure as well as developing and advising on urban and transportation planning schemes. These services include design, technical advice and engineering for public and private clients nationally and internationally. Arup plans and undertakes projects from the policy and planning phase till the definitive design and the delivery phase . Besides that we also deliver consulting and engineering services in later stages for maintenance, renovation and disposal of existing structures. The general Arup approach per service provided to the client is generally treated in three main stages: Bid, Delivery (design/engineering) and Close-Out.

The downstream scope 3 emissions and the influence of Arup Netherlands on these emissions depend on the specific phase of the project at the moment of Arup's involvement. In Table 1 below the relevant services / products that Arup offers in each phase, the possible partners and the relevant emission category are given per activity according to GHG-protocol for downstream emissions.

Table 1 Arup services and emission categories

Phase	Products / services	Partner	Emission categories
Initiation	- Problem exploration - Inventory ambitions, desires, requirements, policies - Feasibility - Plan	Client, public or private	A B C D
Project definition	- Reports (individual studies) - Scenario analysis (design and measures of individual studies) - Program of Requirements	Client, public or private	A B C D
Design	- Preliminary design / plan (design and measures of individual studies) - Final design / plan (design and measures of individual studies) - Specifications (design and measures of individual studies)	Client, public or private Competent authority Suppliers	A B C D
Construction	- Guidance / back office (design and measures of individual studies) - Site supervision	Client, public or private, Contractor	A B C D
Operation	- Permits - Maintenance plans	Client, public or private, Contractor	A B C D
Demolition	- Demolition plan - Renovation plan - Management (possibly through exploration phase till demolition phase)	Client, public or private, Contractor	A B C D

<u>Explanation of the emission categories:</u>

A. Downstream Transportation and distribution of sold products;
B. Processing of sold products;

C. Use of sold products;
D. 'End-of-life treatment' of sold products;
E. Downstream leased assets;
F. Franchises.

2.2 Influence of Arup on the emission categories

In Table 2 the relevant influence of Arup Netherlands on the different emission categories is presented. The influence ranges from 'large' to 'negligible'.

Table 2 Downstream scope 3 emission categories and Arup influence

Emission category		**Influence ARUP**	**Large (++)**	**Medium (+)**	**Small (-)**	**Negligible (--)**
A	Downstream transportation and distribution of sold products	How we deliver our products/services for the next phases of the life of a project?		x		
B	Processing of sold products	Do we think about the processing of our products in the next phases? (e.g. maintenance)			x	
C	Use of sold products	What is the influence of our design choices in the use and maintenance of the product		x		
D	End-of-life treatment of sold products	Do we account for material disposal after the design life of the product?				x
E	Downstream leased assets	NA				
F	Franchises	NA				
G	Investments	NA				

Explanation of Table 2:

Downstream Transportation and Distribution of sold products (A)
Arup has limited influence on the way the services are delivered and handled in the next phases. The way data and information are exchanged is usually prescribed in the contract between the client and the contractor.

Processing of sold products (B)
Arup has limited influence on the way a design will be executed after completion of the design phase. Arup is never responsible for the construction itself. In the construction phase Arup can be involved as technical advisor to the Client or as technical advisor to the contractor.

As technical advisor to the client Arup generally provides support and guidance (back office) or delivers site supervision services. The contractor is responsible for the construction. Responsibilities are recorded in service agreements between client and Arup and in construction contracts between client and contractor.

As contractor's consultant Arup provides technical advice and design services to the contractor. Responsibilities are recorded in service agreements between Contractor and Arup.

Use of Sold products (C)

The influence of Arup on the use of the product has technical and social aspects. Design choices can significantly influence the use of the end product and the resulting CO_2 emissions. So in this stage Arup has the largest influence in CO_2 emissions produced in the operational phase. In general, the actual design and construction of a product is only a fraction of the total CO2 emission taken over the lifetime of a product, in this case mostly buildings and civil structures with a lifespan of up to 100 years.

End-of-life-treatment (D)

Depending on the type of structure the design life time is about 50-100 years for new structures. In case of renovation of existing structures, the required residual life after renovation is usually 30 years. Life cycle cost analyses are based on the design life time. During design it is possible to account for the disposal of used structures and/or materials after their design life time. The influence of Arup on the "end-of-life" of a design is limited. Through a careful choice of materials the 'end-of-life-treatment' can be influenced but not significantly since we are talking about a long time-period after the design phase.

3 Analysis of influence potential downstream

In this section, the potential for improvement and maximizing our influence downstream is analysed. Based on the trends in our business, the clients and related services, the potential reduction of carbon emissions is studied.

The sustainability reviews of 2015, that were the core of the scope 3 emission related emission reduction, have revealed a number of relevant information about clients / value-chain partners and as well as a number of points have arose indicating possibilities for improvement. These improvements can either be explored together with our major partners (SKAO requirement 3.D) or as autonomous actions (SKAO requirement 5.A.2-2). The autonomous actions can be field specific but are not meant to target a single project. These are actions that help us increase our own knowledge capital to better address the environmental challenge. Our ultimate goal is increase our added value in the markets we operate in.

3.1 Business and Market trends

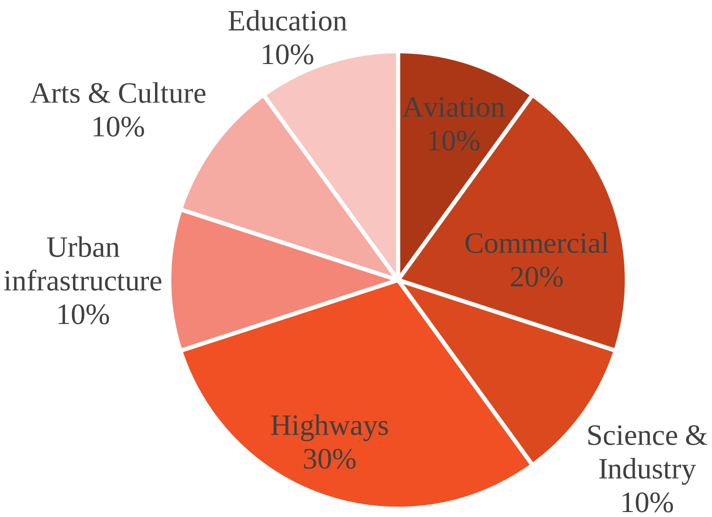


Figure 1: Proportion of different markets according to successful projects acquisition surpassing a certain fee threshold between October 2014 and May 2015.

3.2 Buildings

3.2.1 Services and Markets

The building related services in Arup Amsterdam are divers. The markets and services are listed below:

Markets

- Cultural
- Education
- Office / retail

- Residential
- Public / governmental
- Hotels

Associated services

- Sustainability consulting
- Façade design
- Installation, mechanical
- Fire engineering
- Structural engineering and structural upgrading
- Lighting
- Acoustics

3.2.2 Direct clients

The building services have often have initial sustainability criteria in their design scopes. These can arise from different motifs of the clients and applicable legal requirements related.

The different clients show interest in energy reduction of their buildings to different extends and level of ambition. Based on the sustainability sessions held internally in Arup Netherlands, different categories of clients were identified:

1- Clients with energy reduction ambitions with economic motifs, such as to reduce operational costs.

2- Clients with energy reduction ambitions driven by marketing motifs. These often require high standard certifications for their buildings (BREEAM, LEED, etc.)

3- Clients of semi-public sector such as municipalities. These are motivated by political reasons to increase the sustainability performance of their projects and/ or operational savings.

4- Clients with high ambitions because of own ethical convictions.

5- Architects and contractors, that are likely to depend on their respective clients. Contractors are most likely to focus on price and feasibility related aspects. Risk reduction is very important.

3.2.3 Indirect downstream partners

Often, Arup Building services do not specify products to be used with the exception of lighting, installations and acoustic related services. All other services are relying on material specification of the contractor. However, the manufacturing process, materials and related transport are relevant aspects to the quantification of downstream emissions.

The different requirements and regulations defined by the different Sustainable building Certification schemes and regulating bodies influence the performance and general practice and performance of downstream emissions.

The requirements and influence of end-users of office or residential buildings can also have an influence of the design choice. The suitability of solutions from an ownership point of view have been identified as relevant aspects to the criteria in the design process.

Indirect value chain partners are:

- Manufactures of lighting devices and equipment
- Manufactures of installation systems
- Building material manufactures
- Acoustic system manufacturers
- Contractors
- End-users of buildings
- Building Certification Schemes operators. (LEED, BREEAM, etc.)
- Municipalities/ authorities where the buildings are located.
- The regulating bodies
- Policy makers and politics at urban scale.

3.2.4 Relevance of carbon emissions

The building services consultancy team in Arup Netherlands has a variety of projects where energy performance is a central design topic. The relevance of the field in general relies on the fact that building use (office, residential, commercial, cultural and educational) has an important share in global carbon emissions 39 % according to the *Center for Climate and Energy Solutions.* See figure 2. The team in the Netherlands has built a considerable portfolio in Sustainability consultancy and participated in the design of a number of leading projects in the field of low-energy buildings in the Netherlands. Considering this exposure to larger scale projects and projects where innovative solutions are applicable, the team's potential influence in the market offers a good position to engage in a sector wide improvement of solutions.

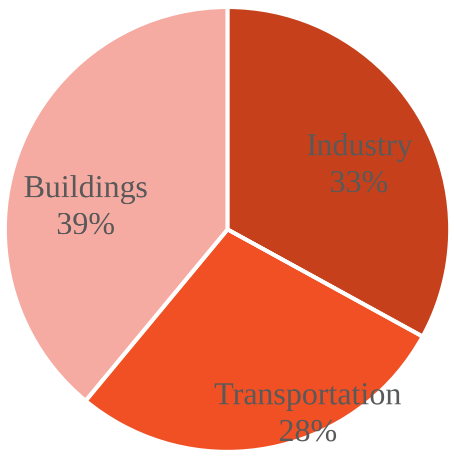


Figure 2: U.S. Department of Energy (DOE), 2008 Buildings Energy Data Book, Section 1.1.1, 2008.

3.3 Infrastructure

3.3.1 Services and Markets

The infrastructure services in Arup b.v. are concentrated around large scale bridge renovation. New build bridge and highway design are also among the services that are offered in the previous projects.

- Highways
- Renovation of steel bridges
- Urban infrastructure (pedestrian and cyclist bridge)
- Structural assessment of bridges

3.3.2 Client and direct partners

Due to the scale of infrastructure projects and their strategic role, the market is usually confined between operating/executive governmental bodies at national of regional levels. The involved regulations are well defined. Project scopes are usually limited to technical and environmental aspects concerned with acceptance and general suitability of the proposed plan. The related political concerns often concentrate on acoustic and visual aspects. The general health and carbon emissions have been slowly introduced. The applicability of these criteria is not in full implementation to date.

- Clients/ downstream partners
  - National governmental bodies (Rijkswaterstaat)
  - ProRail (future partner)
  - Contractors
  - Architects
  - Municipalities

3.3.3 Relevance of carbon emissions

To date, the carbon related criteria are incorporated in bids. The CO_2 Performance ladder tool was used to guide client and bidding party to incorporate carbon reduction goals into the scope of the projects. This has been first implanted by ProRail then followed by 'Rijkswaterstaat'. Other major public sector clients have followed. However, the real implementation and relevance of the environmental impact is not given full attention in scope definition. The typical projects are often centred around technical feasibility and price reduction. Often, material reduction is a design criteria that influence the cost of the project. However, carbon performance of design alternatives is not criteria widely used.

Nevertheless, the commitment of different EU governments to carbon reduction over the coming years gives the indication that the carbon challenge will have to be carried out by the multiple governmental bodies including those involved in infrastructure design. The current quantifications of carbon emission indicate that the greatest share of emissions is due to the use phase of infrastructure. Therefore, mobility and transport are dependent on the automotive industry rather than the performance of the physical infrastructure.

3.4 Transport planning

3.4.1 Analysis

- Clients/ downstream partners
  - Municipalities
  - Governmental bodies
  - Private- public sector partnerships (public transportation companies)
  - Investment/ development banks

- Project types
  - Transport planning projects for urban mobility
  - Bus-network optimisation
  - Traffic models for infrastructure design.
  - Vehicle choice/ selection consultancy, mainly vehicle running on alternative energy sources

3.4.2 Relevance of Carbon emissions

The transport planning field remains a major service to help cut down carbon emissions as it counts for 28 % of the global energy consumption.

The traffic route optimisation and vehicle type consultancy (using alternative energy sources) are relevant to improvement of the global performance of urban and national road networks. The team of Transport planning in Arup Netherlands is active in researching ways to improve the approach to design and modelling of different transport modes. Encouraging multi-modal transport and increasing the share of low-carbon transport modes are focus points. Our transport planning team works to improve infrastructure for pedestrians and cyclists. Despite the great share of cycling in the urban mobility in the Netherlands, little is known about the real behaviour and route choice of cyclists. In major cities, cyclist traffic jams occur frequently. The purpose of this research is to measure and quantify design parameters that are so far lacking in current models.

3.5 Masterplanning

3.5.1 Analysis

- Clients/ downstream partners
  - European Union/ European commission
  - Municipalities/ local governments of European cities (ex: Brussels, Amsterdam)
  - Dutch Ministry of Transport
  - Non-governmental bodies
  - Private sector/ large corporate companies
- Services
  - Energy planning
  - Sustainability planning
  - Development of tools for decision making support.
  - Research

3.5.2 Relevance of Carbon emissions

The Masterplanning team in the Netherlands has an exposure to interesting projects with direct relevance to climate challenges in the built environment. Often, carbon emissions are not a pure topic of study. The team is often involved in projects related to energy planning and a more holistic approach to sustainable infrastructure design. The team has an interesting cross-European project portfolio which increases chances to gather experience and knowledge higher decision making level. With the increasing role of the European union in setting carbon reduction goals for its member states, more involvement with similar decision making bodies is interesting for a larger potential influence.

As an example, our Masterplanning team continues work on the European Commission's FP7 Ecodistr-ICT project. This projects aims to develop an open-source tool to support decision making in retrofitting and renewal projects of districts and their constituent buildings. The team is also involved in a research project for the Dutch Ministry of Transport to develop a more progressive approach to infrastructure design that will take into account a broader approach to health and quality of life.

3.6 Fields of strategic carbon emission reduction

In order to qualitatively determine the activities with the highest CO_2 impact within Arup's influence in the different sectors, there were a number of discussions sessions and meetings held within Arup Netherlands. In these meetings participated managers, directors, engineers, designers and planners of all the different departments provided input based on their experience, insight and knowledge of the market and the specific carbon emission challenges. Also, the sustainability reviews carried out in 2015 as an implementation of the strategy defined in 2014 in the scope 3 emission value chain analysis ‘Road Transport’ and Energy Management Plan have serve a support for the following analysis in defining the strategic fields for Arup Netherlands concerning carbon reduction. The outcome of this wider scale analysis for our services and market exposure, is analysed in the previous sections under this chapter 3.

The outcome is shown in Table 3 on the next page, which presents a summary of the six most important Arup activities in relation to Arup’s potential influence on the CO_2 downstream scope 3 emissions. This table is reported to support the decision made upon the choice for topics of the herby presented value-chain analysis.

Table 3 Relative size of scope 3 emissions

Sectors and activities	**Description of activity that causes CO_2 emission**	**Relative importance of CO_2 loads of the sector and influence of the designs**		**Potential influence of Arup on CO_2 emission**	**Other criteria**	**Ranking**
a	b	c	d	e	f	g
Infrastructure	Construction	-	-	--	Our main clients, both public and private, support and stimulate measures for CO_2 control and reduction.	6
	Use	++	-	--		3
Buildings (incl. Structures, M&E, building physics, lighting, acoustics)	Construction	+	+	-		5
	Use	+	+	-		2
Master Planning	Use	++	+	--		3
Transport Planning	Use	++	+	--		1

<u>Explanation column b:</u>

Construction: In the design phase of a specific project some considerations are made based on the construction and execution phase (e.g. material used, connection types, possibilities for construction sequence, construction logistics.

Use: The design itself may have an effect on the use of the structure/service (e.g. it should be safe, accessible for future maintenance). Specifically in case of Master and Transport Planning there is a direct relation between Arup activities (technical advice from plan to procurement) and the operational phase.

We expect transport planning projects to have the largest potential impact on carbon emissions. Therefore we will focus on this type of activities for the chain analysis in the next section.

4 Chain Analysis Transport

4.1 Activities

The Transport Planning team of Arup is involved on an early project stage from plan to procurement. These are the most critical stages with significant influence on carbon emission. In these early phases (e.g. feasibility study phase, sketch design phase, preliminary design phase) Arup provides technical advisory services (consultancy) and plays an important role in the choices of clients (e.g. real estate developers, municipalities) by presenting them with evidence to support their decision making.

Arup can also be involved in a later project stage, such as the implementation (design) stage where the infrastructure department plays a major role. In general, design choices will be made based on client's functional requirements with these choices eventually influencing the way the project is built and how the end product is used (operation phase). We assess the influence of the decisions made at this stage on the following phases of the project and evaluate the possible effects.

Arup carries out Transport Planning projects both for national and international clients. Particularly in the Netherlands, spatial planning is a rigorous exercise and transport being an important part of any spatial planning project. Our current market position in transport planning in the Netherlands is limited.

The following are standard transport planning services of Arup in the Netherlands:

- Strategic modelling (static);
- Traffic modelling / assessment (static & dynamic);
- Road design (including extensive cycling infrastructure);
- Municipal and provincial transport plans.

4.2 Chain partners per project phase of Transport Planning

At each project phase multiple parties both from the private and public sector can be involved.

4.2.1 Policy

Policies are set based on social, economic and environmental criteria. Policy definition typically involves Ministries, Provinces and City regions. At each of these levels Arup provides advice and technical support to help set the policy strategy and define the overall target. Arup can influence the choices by pointing out solutions which are most beneficial to reducing carbon emissions.

4.2.2 Strategy

At this stage both public and private parties can be involved (municipalities, public transport operators, governmental agencies like Rijkswaterstaat, financial institutions, land owners). As soon as the main goal is defined at a policy level, the ways to achieve these targets need to be determined. Arup helps develop efficient and sustainable strategies and plans for achieving those targets.

4.2.3 Implementation

At this stage strategic plans are elaborated further. It mainly involves the preliminary and final design phases but there is still some room for choices that can influence the CO_2 impact in later phases (i.e. construction, operation, demolition). Arup provides full technical support and can play a crucial role in the design choices.

Figure 3 is a visual presentation of Arup's influence during the different stages of a project and its influence on CO_2 emissions. Obviously an earlier Arup involvement in the design process signifies a bigger influence on decisions and design choices related to reduction of CO_2 emissions.

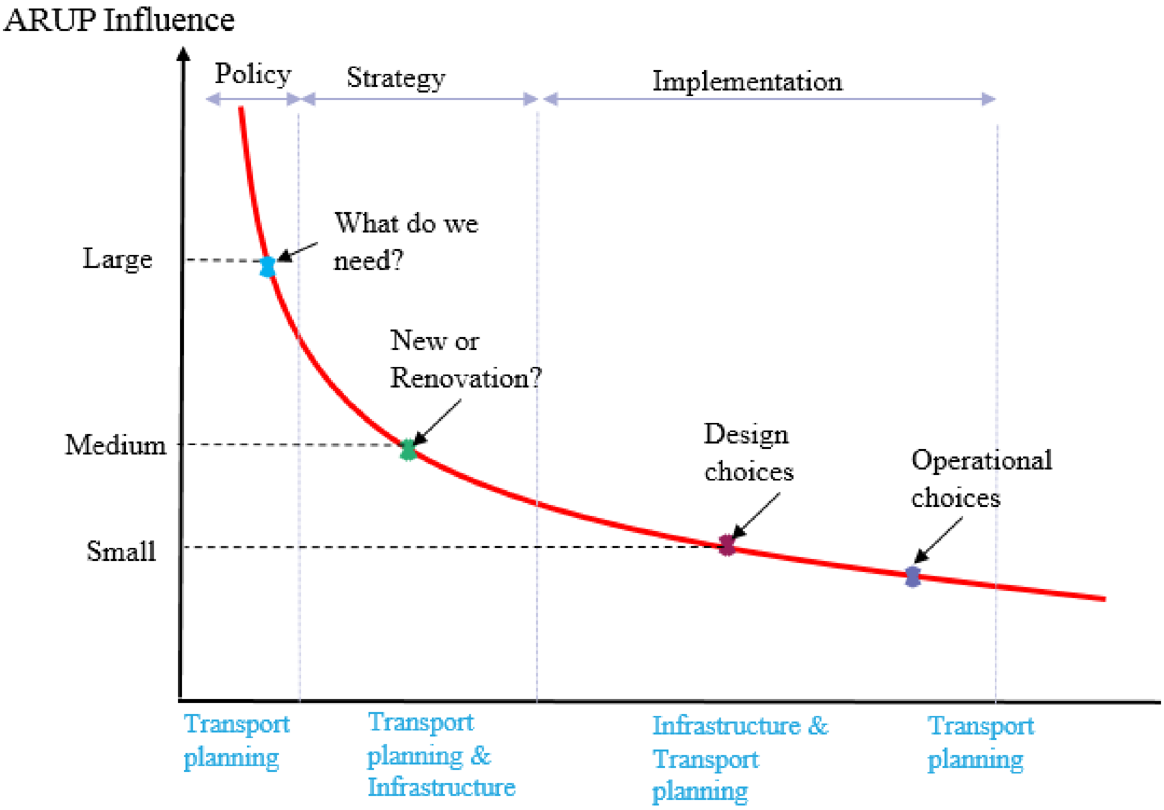


Figure 3 Arup's influence per project phase and activity

4.3 Quantification

4.3.1 Based on literature

Report "EU Transport GHG: Routes to 2050 II" [1]is taken as the basis for the quantification of the CO_2 emissions. According to this report, transport is responsible for a quarter of EU greenhouse gas emissions making it the second biggest greenhouse gas emitting sector after energy. Figure 4 presents the contribution of Transport to GHG emissions in 2009. The figures show that transport accounts for almost three-quarters of EU transport-related greenhouse gas emissions and over one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas.

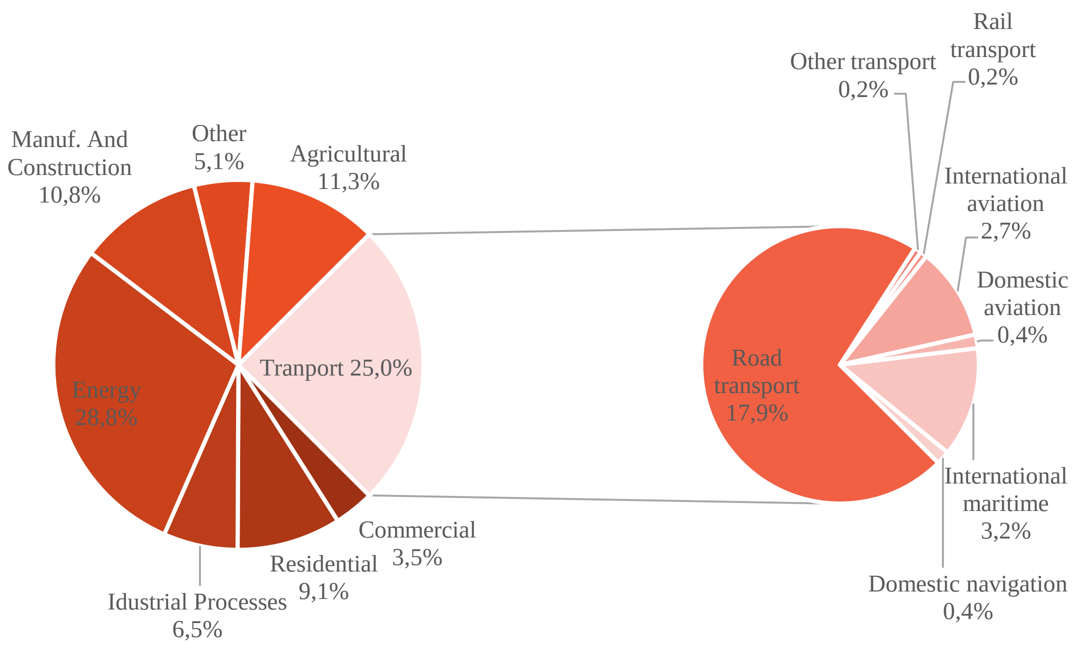


Figure 4 EU27 greenhouse gas emissions by sector and mode of transport, 2009 [1]

The report [1] emphasizes that the GHG emissions due to transport infrastructure and vehicle manufacturing and disposal are significant components of the current overall transport GHG footprint. These are likely to significantly increase in importance in the long term. Policy action should aim to minimize the degree to which future GHG emissions from these elements erode the GHG savings due to reductions in the operational energy use (and GHG intensity) of vehicles.

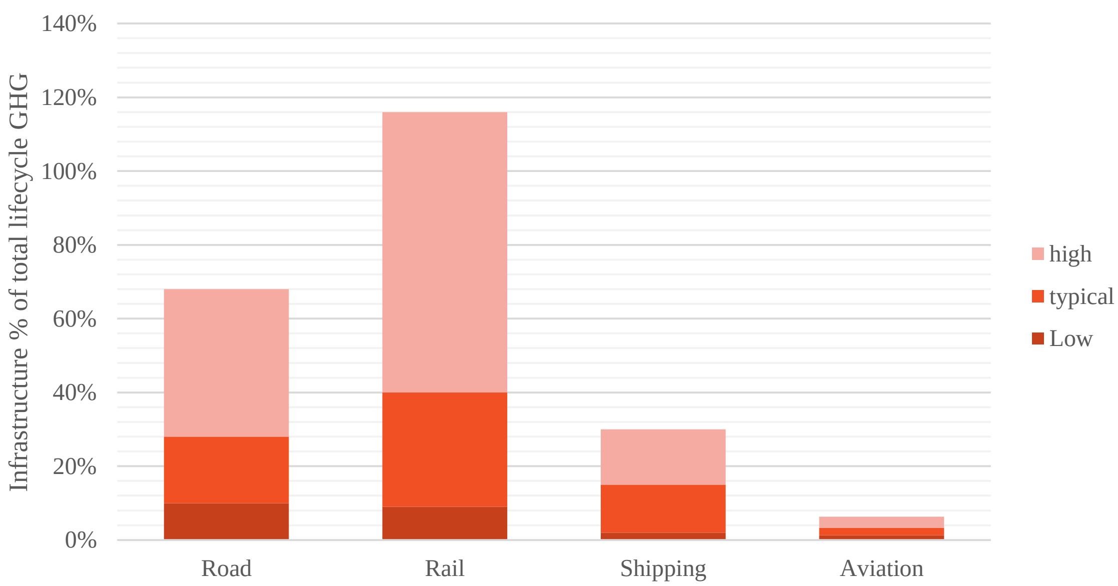


Figure 5: Comparison of the relative significance of GHG emissions from infrastructure development and operation as a proportion to overall lifecycle GHG emissions (including vehicle energy consumption). EU transport GHG: Routes to 2050 II 30 April 2012.

From the above shown figures, road transport seems to offer considerable potential for carbon emissions down-stream. Both transport planning and infrastructure design services are concerned with the outcome of this analysis. However, the two teams intervene in different stages of decision making and often deal with different design scopes. The study outcome of the one team, operating at earlier stages of design and consultancy form the grounds for the design scope presented to the later team further down along the decision making trajectory.

4.4 Chain analysis Road Transport

Within Arup Netherlands, the ‘Transport Planning’ team is the team that is closely involved in the early - and most influential - stages described above (‘Policy’ and ‘Strategy’) whereas the ‘Infrastructure’ department has a role later in the strategy phase when the question for ‘new construction’ or ‘renovation’ is raised. Additionally the ‘Infrastructure’ department plays a role in the choices made during the design phase.

Figure 6 presents the chain activities of Arup in relation to road transport CO_2 emissions. The colored boxes indicate the fields/activities where Arup has the most influence.

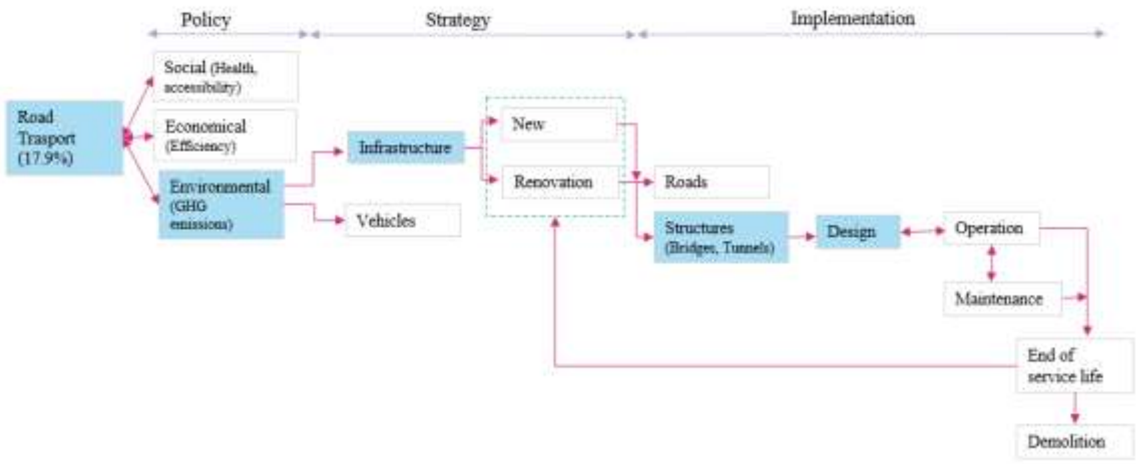


Figure 6 Chain analysis of infrastructure in relation to road transport emissions

4.5 Identified weak links and targets in 2014.

The chain analysis in figure 6 showed two main weaknesses in proposing innovative solutions to CO_2 emission reduction and sustainable designs in our projects. These two weak links were identified as follows:

- Time: the chain analysis shows a lengthy process from policy all the way down to operation. This process might take up to 30 years during which alterations to the original plans are likely. These alterations might occur because of a change in the composition of the team or change of the political environment and objectives.
- Budget: innovative ideas are usually associated with increased expenditure at both design, construction and operation stage. The return on investment is not always apparent. Both for clients (external) and Arup (internal) this could mean a lack of incentive to invest in innovative, CO_2 emission reduction ideas.

Arup Netherlands has implemented the following procedure:

- sustainability reviews for every project with a fee over € 100.000,-. The review will be carried out by our 'sustainability focus group' within a month after project inception. The group focuses on promoting sustainable design with members from our planning, infrastructure and buildings team. In the review a qualitative carbon footprint analysis will be incorporated and the 'sustainability focus group' will investigate jointly with the project team ways to reduce the carbon emissions. This will be monitored on a yearly basis. Results of the reviews will be discussed with our client.

This procedure will be implemented within the next three years (2015-2017). The first sustainability reviews carried out up to date, have not focused on specific 'Road transport' related projects. However, information was gathered about previous relevant work done internally about the question of renovation vs. new build in the infrastructure design in relation to carbon emissions.

4.6 Renovation vs. new built : Galecopper bridge

4.6.1 Introduction

The Galecopper Bridge (GCB) is a highway dual bridge near Utrecht in the Netherlands. Built in the early 1970s, it is suffering from static and fatigue problems. A renovation solution has been developed and is currently under final construction stage.

The aim of the renovation was to extend its life by 30 years. To solve the fatigue issues in the thin orthotropic steel deck the asphalt layer will be replaced by a 90mm thick High Strength Concrete (HSB) overlay on top of the steel deck. To deal with the increased weight and some static strength issues the dual bridge is strengthened using four pre-stressing steel box girders, together with few other steel strengthening measures. The renovation design allows for future widening of the motorway.

During the development of this solution a new build option was devised for comparison. The new build option consisted of two new skewed steel arch bridges. The dual bridge is designed with increased width, with two additional lanes on the parallel carriageway on each bridge.

The design team of Arup has proposed to the client an overview of the carbon implication of both solutions. A paper was produced to compare the two options in terms of sustainability. This approach considers four key objectives for a qualitative comparison:

- Energy efficiency and carbon reduction
- Materials & waste reduction
- Climate change adaption & resilience

4.6.2 Design options

Figure 7: New build option

This section compares two options for GCB in terms of sustainability. The first option involves renovating the dual bridge, with the possibility of future widening.

The second option includes replacing the superstructure with a widened arch dual bridge. Any changes to the approach roads are not taken into account.

Figure 8: Renovation option

4.6.3 Sustainability approach: 9 objectives

A sustainability assessment of a project can be divided into four main aspects: social, economic, environmental and natural resources. The Arup Sustainability Strategy lists 9 objectives specifically for infrastructure projects that incorporate these considerations and that are used to assess embedded sustainability in infrastructure projects.

The Arup Infrastructure Sustainability Objectives are listed below:

1. Energy efficiency and carbon reduction
2. Robust water supply and enhanced aquatic environment
3. Materials & waste reduction
4. Climate change adaption & resilience
5. A positive contribution to the society and environment
6. Whole-life management
7. Economic viability
8. Integrated transport and resource delivery
9. Effective land use

Differences between the two options with regard to the Arup Infrastructure Sustainability Objectives are reported below. Only objectives considered most relevant for this project have been analysed. They are:

1. Energy efficiency and carbon reduction

3. Materials & waste reduction

4. Climate change adaption & resilience

5. A positive contribution to the society and environment

The outcome of the study related to Energy efficiency and carbon reduction are further reported in this report.

4.6.4 Assessment of options against selected objectives

- Energy efficiency and carbon reduction

Embedded Carbon of the two options

EC [106*kgCO2e/kg]	Renovation option strengthening	Renovation option widening	New build option
Superstructure	5.7	6.6	15.9
Substructure	2.0	2.0	2.0
Total	7.7	8.6	17.9
%	100%	112%	232%

EC [kgCO2e/kg] = quantity of CO2 and greenhouse gasses embedded in the materials used

Table 4 Embedded carbon of the two design options

- Materials and waste

The aim of the renovation option is to eliminate waste from demolition by utilizing innovative analysis and strengthening techniques to enable re-use of the superstructure. For this option the waste is due to the removal of asphalt and bearings removal.
For the new build option the foundations will be reused but the entire superstructure will be replaced, producing 5100 tons of waste per bridge that need to be moved and deposited. Even if all the steel were to be recycled it would still produce a great amount of energy and emissions.

4.6.5 Conclusions

The lifespan of the options are different. This makes the comparison difficult because it is not a direct comparison. With regard to lifespan the new build option is more sustainable as all embodied carbon of the materials is related to a longer period of use. The absolute embodied carbon is higher, but the embodied carbon spend per year is less. However the new build option provides the same road layout as the renovation option for 30 years, while the needs may change after 30 years' time. The new build design is not very adaptable to a possible increase in the number of lanes due to the super structure above deck. Renovation option is more sustainable in terms of embedded carbon of the materials used and minimizing waste production, by upcycling most of the structure. This reflects in the costs as well. From a landscape point of view renovation option does not have a big impact, while the new option would change completely the landscape of the area. The geometry of the proposed dual bridges has a large visual impact, especially due to the skew angle and varying heights of the arches.

In terms of widening the renovation option is more flexible, but the new option has the benefit of a wider bridge in the beginning, avoiding additional construction works when widening could become necessary.

The weighting of objectives is greatly determined by the client's vision of sustainability.

In Table 5, the final scoring is reported. This is based on a system that rates carbon reduction as more important than the other objectives. Second importance has been given to the contribution to the society, leaving at the same level materials and waste together with climate change.

Comparison

Objective	Renovation	New Built
Energy efficiency and carbon reduction		
A positive contribution to society and environment		
Materials and waste		
Climate change		

Table 5: Comparison of the two options against the set criteria.

5 Conclusions

For the chain analysis of downstream scope 3 CO_2 emissions Arup identified activities in the transport sector as having the largest impact. A chain analysis was made and resented for our activities related to road transport. The main services involved in this sector are :

- Infrastructure
    - Infrastructure team in involved in the design of the physical infrastructure. The construction and operation of this last accounts for a typical value of 33 % of the total GHG emissions related to road transport.

    - The design criteria to cut down these emissions are not clearly defined by the concerned sector partners. The carbon emissions and sustainability are still not formulated as design criteria and therefore are difficult to implement in the project scope.
    - The sector of infrastructure design and operation should be more aware of its impact and implement clear guidelines and procedures to facilitate carbon reduction.
- Transport planning :
    - As stated before, the transport planning discipline can intervene at more influential project and decision making stages.
    - The encouragement of shifting to low-carbon transport modes is essential to carbon reduction.

These conclusions are further discussed in section Carbon reduction strategies of this report.

6 Value-chain analysis for Buildings

6.1 Activities

The activities of the Arup Buildings department in Amsterdam consist of engineering consultancy in the areas of structures, building physics, mechanical engineering and plumbing, lighting and acoustics. Arup can advise the client in any of these areas throughout the various building phases.

6.1.1 Design

In the design stage, Arup can be involved in activities ranging from feasibility studies to detailed designs. The influence of Arup is greatest in this stage, but it is of course dependent on the scope of the specific activity: decisions that can be made in a preliminary design are of greater influence than those in a detailed design. In most cases, the architect is leading and Arup plays an advisory role. Based on the clients wishes, Arup can make important design decisions that will greatly impact the way that the building is constructed, and to a lesser extent, how it is used. Arup can design energy efficient buildings and accommodate for carbon reducing behaviour.

Through a tender, a contract is created to perform the construction works, which are carried out by a contractor. Arup can be involved with the contractor in the process of submitting a tender, providing technical advice. In the review of tenders, extra points or fictional cost reduction may be awarded to those tenders meeting sustainability targets. The CO2 Performance Ladder is a tool that is used in this context. Arup can help win a tender by giving advice aimed at meeting these targets.

6.1.2 Construction

When a contractor is selected based on the tender, construction can start. Arup can have a supervisory role during construction, but has no influence on how the construction itself is carried out at this stage.

6.1.3 Use

Arup has no direct influence on the way the building will be used in the future, or how its occupants will behave. During the time the building is in-use, maintenance may be carried out. Arup can give advice on how to make a building more energy efficient, reducing GHG emissions.

6.1.4 Demolition

Arup is not involved with the demolition, but can influence emissions in the demolition phase in the design, for example when the client asks for a cradle to cradle concept.

6.2 Chain Partners

The partners in the building chain are described below. For each type of partner, a few examples from actual projects are named.

- Client

  The client can be both a public and a private party, for example a local government or a real estate developer. Arup may also be asked to provide services to an architect or a contractor.
  As a service provider, Arup is dependent on the wishes of the client. Because of that, Arup will have to adapt its sustainability strategy to the client being served. Sometimes, the client will set high sustainability targets. In these cases, Arup can directly focus on these targets and work with the client to meet hem.
  When the client is not primarily interested in sustainability targets, Arup can use tools such as LCC in order to convince the client of the added value of a sustainable design, which reduces both GHG emissions and costs. The Breda courthouse project has set an example for the implementation of such a tool.
  Example: Rijksvastgoed bedrijf, Volker Wessels, Municipality of Tilburg, G&S Vastgoed
- Architect

  Architects often take a leading role in the conceptual design of a building. By working closely together with architects, and giving them advice on how to reduce emissions, sustainability targets set by the client can be met.
  Example: OMA, IAA, Paul de Ruiter

- Contractor

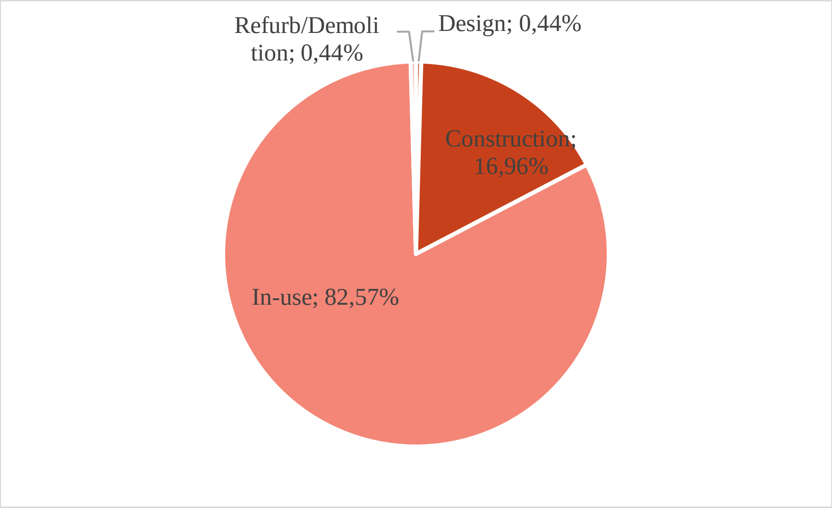
  The contractor is responsible for carrying out the construction works defined in a contract with the client, usually as a result of a tender. Arup can take an advisory or supervisory role.
  Example: Volker Wessels, BAM, Heijmans

- End users

  Through their behavior, people who will make use of the building have the biggest impact on GHG emissions. Arup's ability to steer their behavior is very limited.

6.3 Quantification

Buildings are the greatest source of CO2 emissions in the Netherlands, accounting for over a third of the total emissions. Over the life-time of a building, most CO2 is produced when the building is in use. A significant proportion, however, is also embedded into the manufacture. The diagram below shows the relative percentages of CO2 emissions that the construction industry can influence, according to a study by the Department for Business Innovation & Skills. Note that these are based on the UK market.



6.4 In-use

6.4.1 Chain analysis

The CO2 that is emitted in the in use stage of the building depends on many different things, including the type of usage, the climate it is situated in, and the access to energy resources. Therefore, the measures to reduce CO2 emissions will differ from project to project, but some of the main CO2 contributors are heating, air conditioning, ventilation, lighting and telecommunications (UNEP 2009, p.10). The chain analysis below shows that lighting and heating are the greatest contributors to the energy demand of an in-use office building.

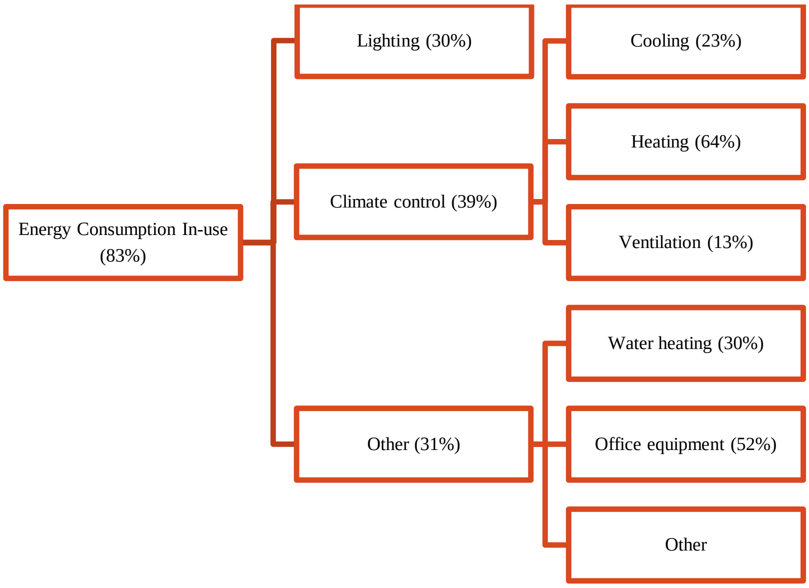


Figure 1: Relative energy consumption office building, based on bouwen met staal (2015)

6.4.2 Improvement of chain analysis

The chain analysis can be improved on the following aspects.

- Update the analysis for a typical Arup office building.
- Consider performing an analysis on various buildings designed by Arup. An office is only one building type, while the buildings department designs many different types of buildings with different uses.

6.4.3 Goals

Arup is aiming to reduce GHG emissions in the building chain. The focus will be on designing buildings that minimize the energy needed for heating, cooling and lighting. One can think of measures such as insulating the building, or positioning windows to regulate incoming heat from solar radiation. Furthermore, natural lighting will be encouraged, and the choice for sustainable lighting options promoted. The in-house lighting and acoustics department can make a valuable contribution to reduction of emissions associated with lighting.
The main goal will be to investigate the effect of these measures on the CO2 performance of a building by performing SPeAR analyses, LCAs and LCCs on actual Arup projects.

6.5 Manufacture

6.5.1 Chain Analysis

The CO2 emitted in the construction stage is subdivided into three categories. Of these categories, the actual manufacture accounts for the greatest emissions, and it is most directly influenced by Arup design. Concrete, stone and metal products are the greatest carbon producers.

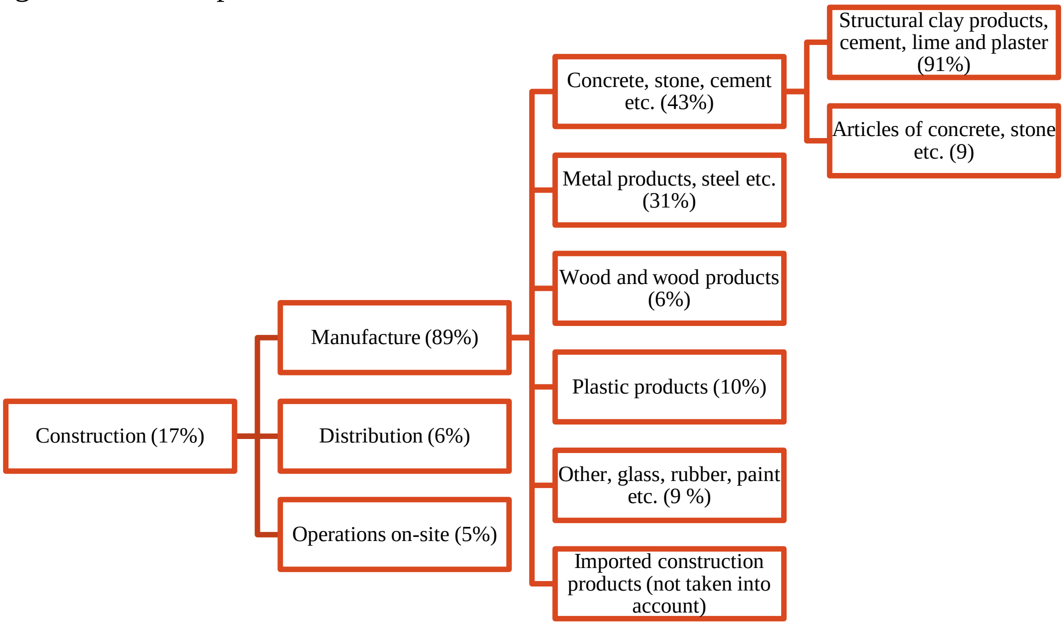


Figure 2: Relative emissions as a result of building construction, based on BIS data (2009)

6.5.2 Improvement of chain analysis

- Currently, the chain analysis is based on data from the UK market. Since the Dutch building practice, the main working area of the Arup buildings department, is expected to be different from the UK, Dutch market specific analyses should be carried out.

- Imported construction products are in this case not taken into account. The various percentages shown are only based on the internal market. It is desirable to get insight into the emissions from these products.

6.5.3 Goals

The greatest influence of Arup in the manufacturing stage is on building materials. In future projects, Arup will investigate whether measures to mitigate building material associated emissions are effective and add value to a project. This can be done using in-house tools such as SPeAR, or widely known tools LCA and LCC. Areas of interest include:

- Minimizing material usage in the design stage. This will also reduce emissions associated with material transport.
- Applying materials that can be sourced locally.
- Choosing sustainable materials. Consider alternative materials, such as timber instead of concrete or steel. Additionally, the use of fly ash to (partially) replace cement or the application of recycled or higher strength steels will improve the carbon performance.

7 Carbon reduction strategies

7.1 Implemented actions

As stated before in this report, our transport planning team has already started to measure and quantify design parameters that are so far lacking in current models for cyclist route choice. The purpose of this research is to offer better solutions in related projects and participate in building relevant infrastructure that best accommodates the demands of the user and therefore is optimally used.

7.2 Possible actions

- Assess the added value of building certification schemes and the overall performance of the resulting design conform to these schemes. Adapt design processes such as the optimal result is possible despite the specific requirements of the certification schemes that can be sometimes restrictive.
- Research thermal mass parameters of building materials. This parameter is unknown and might have an impact of the climate quality of the building.
- Investigate more on possible future ‘sustainability’ criteria related to Infrastructure design. Market analysis/ experience indicated that carbon/ sustainability criteria are expected to gain importance in the perspective our major clients.
- Gather data about relevant products in our design specifications and the associated carbon emissions throughout the life-cycle. (requirement SKAO 5.A.3)

References

[1] EU Transport GHG: Routes to 2050 II, 29 July 2012

[2] www.ghgprotocol.org

[3] www.wbcsd.org

[4] A SUSTAINABILITY COMPARISON BETWEEN RENOVATION AND NEW BUILD OPTION FOR THE GALECOPPER BRIDGE . Alessandra Villa, Sander den Blanken, Edwin Thie , Arup, London, UK, Arup, Amsterdam, the Netherlands