CALCULATING EMISSIONS ALONG SUPPLY CHAINS – TOWARDS THE DEVELOPMENT OF A HARMONISED METHODOLOGY

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ABSTRACT

In order to keep climate change on a manageable level, European countries are expected to control and reduce their total greenhouse gas emissions. The growing transport sector, especially professional freight transport, is a major element in terms of greenhouse gas emissions. Several initiatives exist for the calculation of the carbon footprint freight transport chains. However, there are problems in terms of comparability, transparency and accuracy since these initiatives are based on different starting points, approaches or intentions in development. The EU-co-funded project COFRET (Carbon Footprint of Freight Transport) is making process towards a unified approach. Based on existing knowledge, COFRET will provide a harmonized methodology to calculate logistics related carbon footprint emissions along complex supply chains. The purpose of this paper is to illustrate the work that has been done during the systematic review process of COFRET's research in assessing existing knowledge, which will eventually become part of the COFRET methodology.

Keywords: carbon footprint, methodology, freight transport chains, standardization, emission calculation

INTRODUCTION

According to the International Energy Agency (IEA) the transport sector is currently accountable for 23% of the global energy related emissions (Rodrigue et al. 2009, ITF 2010), with global freight transport contributing to a significant extent. Global freight transport systems, currently relying on 95% petroleum products, therefore make a significant contribution to warming of the global climate (International Agency 2009). In order to reduce the negative environmental impact of the growing transport sector, the assessment, reporting, management and especially the reduction of greenhouse gas emission has become an important topic for more and more companies. Several actors involved in the transport of freight along supply chains, such as shippers, terminal operators or logistic service providers have defined green strategies to calculate CO2 emissions and to reduce their energy consumption. In addition, more and more end-users of products claim to be informed on the carbon footprint information by the producers of CO2.

Furthermore, international organizations, e.g. the World Energy Council, have put the topic of energy efficiency on top of their agenda. The need for efficiency improvement and the subsequent reduction of emissions is recognized all over the world and on different organizational and political levels. On a global level, organizations such as the United Nations Framework Convention on Climate Change move forward international arrangements, e.g. the Kyoto Protocol, where several countries commit to emission reduction targets. On regional level the European Union (EU) has stated that European countries are expected to reduce their annual greenhouse gas emission by at least 20% by 2020 and by 60-80% by 2050, compared to 1990 emissions level (Council of the European Union 2007). Furthermore, even from the company's point of view, additional regulations such as the requirement of calculating and publishing the carbon footprints of transport services on bids in France show the increasing importance. Other European countries may be very likely to follow with regulations.

As a consequence of these company, customer or political driven reasons for the calculation of carbon footprints, several methods and tools have been developed on the basis of individual initiatives. However, due to different starting points, intentions or approaches these developments differ and lead to incompatible results. Therefore a harmonised calculation methodology is needed to align different approaches and to result comparably. Although, initiatives to address this problem of incomparability have been established (such as CEN/TC 320/WG 10 which results in the European norm EN 16258, the GHG-protocol or ISO 14064-1:2006), they can only be regarded as a first step in a supply chain context. The EU co-funded project COFRET (Carbon Footprint of Freight Transport) is aiming at the development and test of a harmonized methodology. In order to gain a globally shared understanding and applicable format for the calculation of emissions, the project aligns different approaches and initiatives to build a next step towards an internationally applicable standard. To achieve a standard with maximum user-acceptance, the COFRET methodology is based on existing and already applied tools, standards, databases and methods. The purpose of this paper is to illustrate the systematic review process, which has been undertaken by the COFRET consortium in order to gain the existing knowledge.

SYSTEMATIC REVIEW PROCESS

The intention with the development of the COFRET methodology has from the very start been to build on existing knowledge and to take the state-of-the-art transport carbon footprinting one step further in terms of cross-modal harmonisation and coverage of the entire supply chain.
In order to access knowledge based on existing carbon footprint methodologies, calculation tools, emission factors etc. - hereafter called items - a detailed two-phase analysis has been performed.
In the first phase the entire spectrum of methods, tools and data was screened and initially reviewed in order to identify the most relevant items. Over 100 items have been categorized and 35 of them have been judged as important for the COFRET methodology development. In the second phase the items have been analysed in detail, this time with parallel work to establish cooperation with their developers. Out of these 35 items, as shown in Figure 1, 29 have been selected to eventually become part of the resulting COFRET methodology.

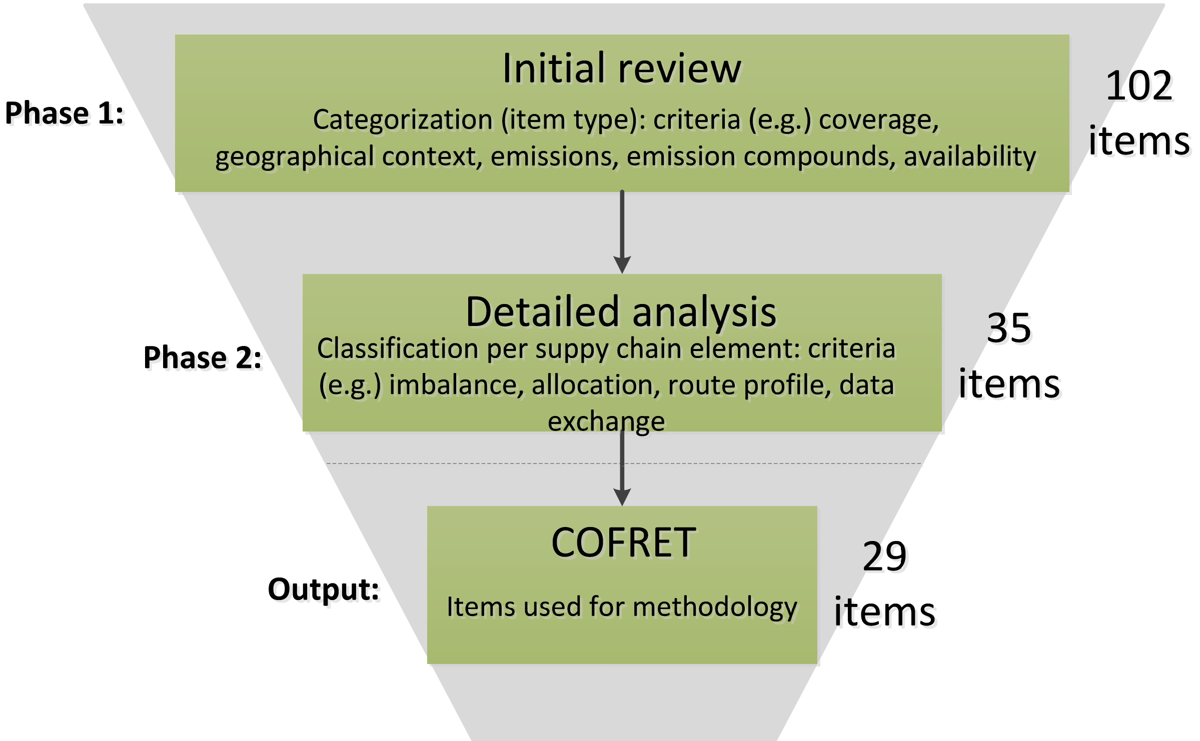

Figure 1 - Structure of systematic review process

Phase 1 - Initial screening of methods, tools and data

The first part of the review process consisted of a literature survey of existing methods, tools and databases for calculation of carbon footprint of transport and logistics. Source materials used included methodology reports, guidebooks, manuals, research reports, scientific publications, brochures, etc. In addition, the actual calculation tools and databases were examined if available, and expert interviews with developers and users of the items were used to fill in information gaps. The review and assessment process was organised using a structured review template, thus following a systematic approach to collect basic information, to analyse the coverage and to evaluate implications to the COFRET methodology development. Over 100 items were covered, and a template was filled in for each of them.

The reviewed items were classified into four categories (distribution of the items reviewed is shown in Figure 2). Each item is fixed to one category in order to avoid double counting:

1. Carbon footprint methodologies cover actual standards, standard-like guidelines, guidebooks and schemes that provide the framework for how to calculate and report carbon footprint of transport and logistics along the supply chain or some part of it.

2. Carbon footprint calculation tools encompass all tools, instruments, software, algorithms and other applications, whether public, commercial or company specific, that are used to carry out and facilitate the calculations of carbon footprint of transport and logistics along the supply chain or some part of it.

3. Emission factor databases are considered as collections of greenhouse gas emission data, either public or commercial, that are needed in order to calculate carbon footprint of transport and logistics along the supply chain or some part of it. Examples of emission factors in such databases are vehicle emissions, emissions from fuel production and emissions per transport unit.

4. Other activities cover all items other than methodologies, calculation tools and databases that contribute to the topic of carbon footprint of transport and logistics along the supply chain. Examples of such activities include research projects, awareness raising initiatives and different types of communication forums and channels.

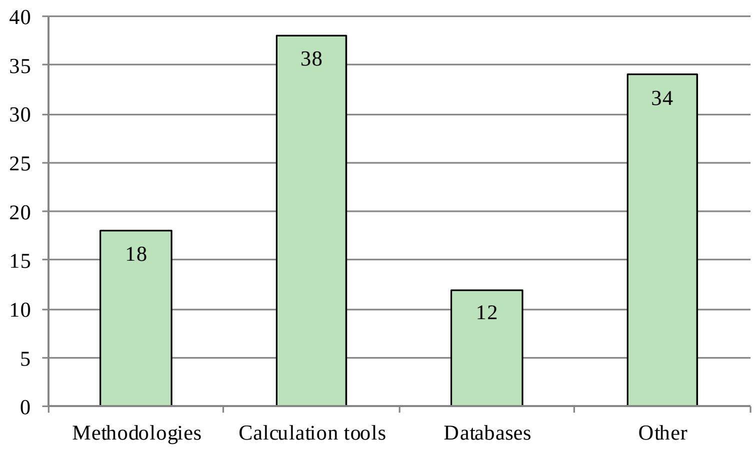

Figure 2 – Number of items by category (102 in total) in December 2011

Each item was accessed according to several evaluation criteria. Table 1 summarizes the general results per evaluation criteria.

Table 1 - Evaluation criteria and coverage or general assessment results

Evaluation criteria	Coverage / assessment
Transport modes, vehicles and equipment	The four basic transport modes and relevant vehicles are all well covered by methodologies, tools and data respectively, whereas comparability is a problem. Most detailed and advanced applications are available for road transport. Working machines (e.g. industrial vehicles and mobile machinery) are covered in lesser detail.
Logistics operations and supply chain elements	Methods, tools and data largely focus on the transport phase. Other logistics operations (e.g. loading and unloading, transshipment, storage and terminals) are rarely included, even though the need to allocate impacts of these operations to the product or transport service is acknowledged.
Phases of the life cycle (of a transport service)	Tools and data typically address the transport phase only. However, the methodological side is likely to direct them towards inclusion of upstream energy processes. Instead, life cycle phases taking e.g. transport infrastructures or vehicle manufacturing into account are not seen relevant under this scope. WTW and TTW approaches are supported.
Emission compounds	Typically the three focal greenhouse gases (CO_2, CH_4 and N_2O) are addressed. Some carbon footprint applications, however, still limit calculation to CO_2 only, based on it being the main contributor. Other greenhouse gases are rarely included. On the other hand, certain other air emissions are often provided, as environmental impacts other than climate change are often being addressed simultaneously (e.g. HC, NOx and PM emissions, relevant in air quality issues).
Methodological ambition	In general, tools (and data) refer and resort to established, widely accepted methods (programs, initiatives and standards) and use them together even though comparability remains questionable (e.g. due to variability and freedom of choice in many methodological aspects such as allocation). Methodological shortcuts and lack of transparency are significant problems.
Referenced methods and data	The methods and data referenced by other items seem to converge to a reasonable number of established, widely accepted standards, guidelines and databases.
Relevant calculation context	Methods, tools and data are available through the spectrum of the scope (e.g. shipment, company, vehicle and policy-oriented) and level of detail. Scope and level of detail relevant to the supply chain approach are available.
Geographical context	Limitation in applicability beyond national context is one of the most common weaknesses. Collaboration towards comparable systems with neighbouring countries, the whole of Europe and worldwide are needed.
Publicity and availability	Methods, tools and data are widely available free-of-charge and the commercial solutions are reasonably priced. Instead of

	financial and publicity aspects, language limitations are a bigger barrier in terms of accessibility and availability.

As a parallel activity, user needs, practices and experiences with carbon footprint methodologies, tools and data were analysed. In-depth interviews with a selection of stakeholders were followed up by an extended user need online-survey open for all. The topics of the interviews and the survey covered motivations to carbon footprinting, current practices on use of calculation tools, current shortcomings, future needs and expectations, etc. The stakeholders taking part included transport and terminal operators, logistics service providers, manufacturers, wholesalers, retailers, consumers, researchers and policy makers. As a final effort to interpret the results of the interviews and the survey, and to deepen the understanding of the user needs, a stakeholder workshop to a selection of core user group representatives was arranged. Thus the conclusions on user expectations for the COFRET methodology development could be validated and plans to carry on the cooperative involvement of the users could be established.

Phase 2 - Detailed analysis on selected items

After the first phase of the review, the number of possibly relevant carbon footprint methods, calculation tools and emission factor databases was reduced to 35. These items were judged the most relevant from the COFRET objectives point of view. In the first phase of the review it was indicated which transport modes and supply chain elements are included in each item and the review template was filled out for the item in general. In this phase relevant supply chain elements were classified into links, containing all processes that transport goods from A to B; nodes, containing transhipment and storage processes; and other relevant processes in the logistics part of a supply chain. A detailed multi-criteria evaluation framework was applied to assess how different supply chain elements covering all modes of transport and logistics operations were present in each item. The framework was filled out separately for each supply chain element in the item. The assessment criteria were the same as in the first phase but taken into a more detailed level. Besides a more thorough look at written sources, contacts with the developers of the items were established in most cases, and integration and cooperation opportunities with the items and the COFRET methodology development were enquired.

After filling in these templates, a summarizing matrix was filled out by two partners simultaneously, to indicate for each supply chain element considered in the item whether the following criteria are included. In order to assess the supply chain elements the criteria were divided into two classes: (1) methodological elements, reviewing what elements of the emissions are taken into account or allocation principles and (2) data elements.

Table 2 - Evaluation criteria in phase two

Methodological elements	Determining total vehicle emissions	Well-to-tank (WTT) emissions
		Tank-to-wheel (TTW) emissions
		Well-to-wheel (WTW) emissions
	Vehicle to loading unit	Allocation to shipments/partial load
		Imbalance
Data elements	Upstream energy	WTT emissions
		TTW emissions
		WTW emissions
	Route information	Vehicle utilisation
		Route profile
	Emissions coverage	Energy consumption
		CO2e
		CO2
		Other

All templates were checked by a third partner to ensure consistency; any differences between these templates have been resolved. The final selection of items to be used as parts of the COFRET methodology development was made on this basis.

The interactive, parallel task of the second phase was to arrange a workshop for the developers of carbon footprint items. In this event the methodological challenges and areas for current and future development in the topic of carbon footprint of transport and logistics were discussed. Cooperation opportunities and aligned efforts were explored and cross-European and global views were exchanged.

Outcomes of the review

After the second phase of the review, the 35 items were categorized in three different groups: important, relevant as background information only, or not relevant to the construction of the methodology. Out of these items 15 are very important to the COFRET methodology and 14 are used as background information, whereas six items are no longer considered in the COFRET approach.

Regarding the methodology items, the forthcoming European CEN standard (CEN 2012) is the most important one. It defines basic rules and guidelines that are essential for COFRET. The methodology is rather complete on transport links and COFRET has the overall tendency to comply with this item as much as possible. The DSLV guidance (Schmied, Knörr 2011) is based on the CEN standard and goes beyond by filling gaps of the nodes. The IPCC (IPCC 1996, 2006) is a very complete and an widely accepted guidebook. The DEFRA guideline (DEFRA 2010, 2011) offers different allocation strategies and also links to relevant sources of data. Table 3 summarizes the categorization of the methodology items.

Table 3 - Methodology items

Carbon footprint methodology	Important	Background
EN 16258 (CEN 2012)	X	
IPCC (IPCC 1996, 2006)		X
DSLV (Schmied, Knörr 2011)		X
DEFRA (DEFRA 2010, 2011)		X

Carbon footprint calculation tools can be in general divided into two main groups. On the one hand there are publicly accessible tools that usually cover all modes of transport and offer the possibility to adjust several parameters, such as load factor or empty trips. Due to its very detailed and accurate database with worldwide coverage EcoTransIT World (IFEU 2010) is considered as one of the most important items. On the other hand there are company internal used or commercial developed tools, for example Carbon Footprint for Metro Group Logistics (Winkler 2010), Go Green CO2-calculator of DHL (DHL 2011) or Kuehne&Nagel's carbon tool (K&N 2011). Since there is not much information publicly available, COFRET keeps close with the developers of these items. Important aspects of these tools are how they can be integrated to information systems and how large amounts of data can be handled. Table 4 illustrates the 16 calculation tools rated as important or background.

Table 4 - Calculation tool items

Carbon footprint calculation tools	Important	Background
EcoTransIT World (IFEU 2010)	X	
Map & Guide (PTV 2010)		X
Spin-Alp (SPIN_ALP 2009)		X
TREMOVE (de Ceuster et. al. 2007)		X
GHG Protocol (WRI 2008, 2011)		X
GREET Fleet (Wang 2007, Burnham 2009)		X
TREMOD (Knörr et. al. 2010)		X
Carbon Footprint for Metro Group Logistics (Winkler 2010)	X	
Go Green CO2-Calculator of DHL (DHL 2011)	X	
Versit+ (Ligterink 2009)		X
Zicht op CO2 stappenplan & Emissiescan Logistiek (Connekt 2010)		X
Kuehne&Nagel's carbon tool (K&N 2011)		X
Fleet Carbon Reduction Guidance (Cenex 2010)	X	
Bilan Carbone (ADEME 2010)	X	
SmartWay (EC 2008)		X
COPERT (Gkatzoflias et. al. 2007)	X	

Emission factor databases include factors for engines or vehicle types and are typically universally applicable. Differences appear according to the coverage of supply chain elements as wells as the geographical coverage. For examples the supply chain elements of sea and rail transport in LIPASTO (Mäkelä, Auvinen 2010) are valid for Finland only, whereas the very comprehensive database of HBEFA (Keller, de Haan 2004) covers only road transport. Also important for the COFRET approach is NTM (NTM 2010), which covers all logistic operations along supply chains. Table 5 shows the items classified as emission factor databases.

Table 5 - Emission factor databases

Emission factor databases	Important	Background
LIPASTO (Mäkelä, Auvinen 2010)	X	
NTM (NTM 2010)	X	
HBEFA (Keller, de Haan 2004)	X	
JEC Well-to-wheels analyses (WTW) (JRC 2007, 2008)	X	
EMEP/EEA (CORINAIR) (EEA 2009)		X

Other important initiatives are the Clean Cargo Working Group (BSR CCWG 2012) that provides important data on sea transport and the World Ports Climate Initiative (WPCI 2010) which also supplies data on short sea, deep sea or terminal activities. The Green Freight Europe (GFE) initiative is also very relevant for the COFRET project and has recently developed a calculation tool for its members, although at the moment of reviewing this had not been done and so has not been included in the list of Table 6.

Table 6 - Other activities

Other activities	Important	Background
Clean Cargo Working Group (BSR CCWG 2012)	X	
ARTEMIS (Boulter, McCrae 2007)	X	
Smartrans - Grønngodstransport (Norvik et. al 2011)	X	
World Ports Climate Initiative (WPCI 2010)	X	

To sum up the review of existing items, suitable elements for the calculation of the carbon footprint of transport and logistics along the supply chain exist even though a harmonised framework with comprehensive coverage of all supply chain elements is missing. Furthermore, the parallel interactive work with the user needs analysis validated that such an approach is needed, so that all transport modes as well as logistics nodes are acknowledged. Existing methodologies were judged rather consistent and to support life cycle thinking. However, the guidance given was rather loose, leaving plenty of room for interpretation or providing numerous alternatives to choose from, for example regarding allocation of emissions in mixed transport environments. Such shortcomings currently lead to confusion and lack of comparability. Existing tools and databases showed wide variation in quality, coverage and originality, but fairly advanced solutions for all transport modes were available. Regarding nodes, most importantly transport terminals, data coverage was not as good. Further research and development needs for nodes both on data and tools, as well as methodological issues, were identified.

Linking existing knowledge to the COFRET methodology

The COFRET methodology with its calculation scheme offers a standardized way of calculating emissions along supply chains. Since the focus of this paper is the systematic review process and the methodology itself has not been finally defined by the time of writing this paper, this chapter gives an overview of the important classified items in order to show the integration of existing knowledge into the supply chain elements.
Being in line with the forthcoming European CEN standard, which will be published at the end of 2012, the COFRET methodology divides a door-to-door supply chain into several elements. In order to calculate the emissions of a specific shipment all supply chain elements have to be identified first. For the links of the supply chains, six elements have been defined primarily for the different modes of transport. Many valuable items are available for road and sea activities. Figure 3 illustrates important rated items for transport links.

Road	Road freight transport	-EN 16258 -EcoTransIT World -Carbon Footprint for Metro Group Logistics -Cenex -Bilan Carbone	-COPERT -LIPASTO -NTM -HBEFA -JEC Well-to-wheels analyses (WTW)	-ARTEMIS -Smartrans - Grønn godstransport (Green Freight Transport)
Rail	Rail freight transport	-EN 16258 -EcoTransIT World -Carbon Footprint for Metro Group Logistics	-Bilan Carbone -LIPASTO -NTM -ARTEMIS	-Smartrans - Grønn godstransport (Green Freight Transport)
Inland Waterways	IWW freight transport	-EN 16258 -EcoTransIT World	-Bilan Carbone -NTM	-ARTEMIS
Sea	Sea freight transport	-EN 16258 -EcoTransIT World -Carbon Footprint for Metro Group Logistics -Bilan Carbone	-LIPASTO -NTM -Clean Cargo Working Group (CCWG) -ARTEMIS	-Smartrans - Grønn godstransport (Green Freight Transport) -World Ports Climate Initiative (WPCI)
Ferry	Ferry transport	-EN 16258 -EcoTransIT World -Carbon Footprint for	Metro Group Logistics -Bilan Carbone -LIPASTO	-NTM -ARTEMIS
Air	Air freight transport	-EN 16258 -EcoTransIT World -Carbon Footprint for	Metro Group Logistics -Bilan Carbone -LIPASTO	-NTM

Figure 3 - Overview of supply chain elements (links) with important classified items

Regarding the nodes two main groups (terminal, warehouse) are integrated into the approach. These supply chain elements, including the items that are classified as important, are shown in Figure 4. There is only very limited information available for nodes and especially for warehouse. The same holds for other supply chain elements, such as reefer container, idling, order pickup or order delivery.

Terminal	Manoeuvring	-Carbon Footprint for Metro Group Logistics -World Ports Climate Initiative (WPCI)	-EcoTransIT World -Cenex
	Transhipment	-Carbon Footprint for Metro Group Logistics -World Ports Climate Initiative (WPCI) -Clean Cargo Working Group (CCWG)	-EcoTransIT World -LIPASTO
	Internal transport	-Carbon Footprint for Metro Group Logistics -World Ports Climate Initiative (WPCI)	-EcoTransIT World -Cenex
	Shuffle, sort	-Carbon Footprint for Metro Group Logistics -World Ports Climate Initiative (WPCI)	-EcoTransIT World - -LIPASTO
Warehouses	Unload	-Carbon Footprint for Metro Group Logistics	-LIPASTO
	Sort	-Carbon Footprint for Metro Group Logistics	
	Unconditioned storage	-Carbon Footprint for Metro Group Logistics	
	Cooled storage	-Carbon Footprint for Metro Group Logistics	
	Deep freeze storage	-Carbon Footprint for Metro Group Logistics	
	Order picking	-Carbon Footprint for Metro Group Logistics	
	Preparing for dispatch	-Carbon Footprint for Metro Group Logistics	
	(Re)packaging	-Carbon Footprint for Metro Group Logistics	
	Load	-Carbon Footprint for Metro Group Logistics	-LIPASTO
Other	Reefer container	-Carbon Footprint for Metro Group Logistics -Clean Cargo Working Group (CCWG)	
	Idling	-Carbon Footprint for Metro Group Logistics -Clean Cargo Working Group (CCWG) -Cenex	
	Order pickup	-Carbon Footprint for Metro Group Logistics	
	Order delivery	-Carbon Footprint for Metro Group Logistics	

Figure 4 - The important items and which supply chain elements they cover - Nodes & Other

CONCLUSION & OUTLOOK

This paper illustrates the systematic review process of the EU-co-funded project COFRET (Carbon Footprint of Freight Transport). Over 100 items, related to the calculation of carbon footprint, have been accessed in a two stage review process. Finally 29 items have been selected as relevant for the COFRET methodology development. The analysis shows that transport nodes and especially road elements are well covered with information on methodology and data, whereas on nodes there is far less information available and further research is needed.

Once the COFRET methodology is defined, the next step will be the implementation into a software prototype. With the help of the systematic review process and the integration of user needs the implementation will be tested and validated in several real world company scenarios.

ACKNOWLEDGEMENTS

The research is based on the work of the extended COFRET project consortium and its Advisory Board. The COFRET project is co-financed by the European Commission Directorate General for Research & Innovation as part of the 7th Framework Program. The authors express their gratitude for the continuous support received by these partners.

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