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# Verified climate calculation of contractors' design

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**Abstract**

This article proposes the use of current European standards and verification rules for environmental product declarations (EPDs) as a basis for evaluating the climate impact of contractors' alternative designs of infrastructural projects. The proposed conceptual framework for verified climate calculations is based on the Swedish-based, the International EPD® System. Several Swedish and Norwegian stakeholders were engaged in this joint project to understand driving forces and obstacles and provide key insights for the successful implementation of such verification framework for evaluation of climate impact from alternative design options. In order to perform a sharp test of some main hypothesizes about how it's possible to create verified climate calculations, four of the project participants collected data for EPD-like LCAs from infrastructural projects.


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*Keywords:* LCA, design evaluation, EPD, PCR, verification procedure, infrastructural project.

## 1. Introduction

Sweden faces major challenges in the climate field. Where the government and parliament now have taken the initiative with the goal of Sweden as a nation to be climate neutral by 2050 [1]. An active involvement of various market players is necessary to manage with the adoption of this goal to the practical work in scarp infrastructural projects. With this background the major Swedish client of infrastructure projects, the Swedish Transportation Administration, Trafikverket (STA) has established requirements for suppliers and contractors regarding energy and climate gas emissions accounting and reporting [2]. Current reporting of climate efficiency to the STA in infrastructural projects takes place after the tender documentation has been submitted and is a part of the contract

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requirements. STA uses a default calculation of the climate impact for the project, for the main building materials and construction parts, based on generic industry emission factors. The contractors and the suppliers then need to streamline this pre-determined traditional engineering solution to reach a smaller climate impact of the project.

However a key factor to achieve the climate goal is to establish a fair and standardized procedure for verification of the actual project-specific climate impact of the contractors' design in the early project phases. This verification procedure should support the establishment of a business-to-business relation between different market stakeholders to reduce the actual project-specific climate impact. It will create a great socio-economic improvement if we can match the suppliers' and the contractor' internal investments to more environmentally friendly solutions and the client's evaluation of the design options. Clients should start to demand a calculation of a project-specific actual climate emissions so the suppliers can "make business" with innovative climate-efficient solutions and products. The using a generic industry-average LCA data for the evaluation of the climate impact of contractor's competitive designs, will lead to the sub-optimization and probably to an unfair comparison.

There are some contractors in Sweden which already conduct Life Cycle Assessments (LCAs) in order to improve project's environmental performance. However LCAs can be conducted in many ways and if using different system boundaries, different assessment methods, and the way to model the entire life cycle the results will be incomparable. At present LCAs and climate calculations aren't standardized and are performed in different ways, in different commercial LCA software with different LCA methods by different players in the Swedish construction industry.

An industry-wide standardized calculation basis would make it possible to create an unbroken information flow with LCA data between material suppliers, contractors and clients. A common ground would allow the use of the same LCA calculation model for various purposes such as a company's internal monitoring of the climate performance in infrastructural projects, internal product development, purchasing of building materials, monitoring for the environmental management system, public procurement, creation of business strategies, reporting according to building assessment schemes (BREEAM, LEED, DGNB, CEEQUAL etc.) and reporting to clients.

The current lack of a reliable industry wide-used LCA calculation model and a verification procedure for project-specific LCA data is anticipated to become an important barrier to design and marketing products with improved environmental performance. At the same time, Environmental Product Declarations (EPDs) for building materials and building parts based on LCA have been increased on the Nordic market in recent years. Many manufacturers have now developed EPDs for their products in order to verify products' environmental performance. However the "middle" chain in the communication between the material manufacturers and the client, the contractor, hasn't yet started to produce verified LCAs in EPD-format for infrastructural projects. There isn't any general acceptance of EPDs as an industry-wide LCA-specification for verification of the climate impact in the construction sector.

Knowledge and experience of using such standardized climate calculations according to the EPD-format is still very low. In Sweden, the STA starts to encourage contractors to use project-specific EPDs as a verification of project's actual climate impact since spring 2016 [2]. Product-specific EPDs are also required for public procurement in some major projects in Norway [3], by a few municipalities in Sweden and Norway and in the international building assessment schemes (LEED, BREEAM, DGNB, CEEQUAL etc.).

The EPD is in a broad sense a market-driven format for business-to-business communication of LCA-based environmental information and more recently also business-to-consumer. A key component of a LCA in an EPD-format is the method description document, referred to as Product Category Rules (PCR). A PCR defines the LCA-model, the calculation method and data requirements [4].

PCRs are available for engineering constructions (e. g. bridges, highways etc.) and construction materials and services. However each PCR is linked to a particular EPD program operator (e. g. EPD-system Norway or the International EPD® System in Sweden). EPDs from different operators aren't comparable yet. The calculation rules for e.g. carbon dioxide emissions differ between the current EPD-systems in Europe and USA, which can be misleading when comparing EPDs. However this is already addressed within the framework of the EPD/PCR and also within the ongoing work in the EU-project, Eco-Platform [5].

The contractors and material suppliers start climate optimization of their product and solution as well as optimization of the supply chain often as a part of an internal strategical work with energy and climate reduction. An innovative climate-efficient solution is often created by contractors long before the actual bidding process. Verified LCAs and climate calculations performed in an EPD-format will support contractor's internal work with the supply

chains, support internal product optimization and in the same time allow reporting to the client according to the same LCA calculation model. In this case the material suppliers and the contractors don't need to disclose the recipe for their innovative products and designs, but a third party will audit and evaluate the quality of the provided LCAs and climate calculations. If a particular vendor claims that he can build sustainable and "green" engineering constructions this should be verified by an EPD. EPDs are the only LCA-format, which is allowed to be used in procurement to evaluate and compare alternative designs according to the European standards [10].

Using climate and energy calculations in the bidding for evaluation and rewarding the best design regarding climate impact requires specifying some key parameters for the LCA calculation model. To achieve the Swedish climate reduction goal contractors should be stimulated and rewarded for using of innovative environmentally-friendly materials/solutions in the bidden process. This means that there is a need for a verification procedure to compare the actual project-specific emissions for contractors' alternative designs in a fair and easy way. This can be achieved by pre-verification of existing commercial digital LCA-tool in order to produce EPDs.

The following driving forces to use the pre-verified LCA-tools have been identified:

- Achieve multiple customer requirements, e. g. building assessment schemes' requirements, internal product development etc., with less cost
- Reduce purchasing costs (fewer suppliers with better environmental performance)
- Easier to win a bid with a well-established process for EPDs
- Trustworthy quantitative and qualitative marketing communication with the environmental product declarations (EPDs) for truly environmentally friendly products
- Identify the most environmentally sensitive components and processes in a company's product portfolio and work strategically with the internal improvements
- Improve a company's internal purchasing cost control and project's climate efficiency goal to meet the client' requirements on the environmental performance
- Be able to steer towards increasing renewable and recycled content in products/projects, which is required by EU-directives
- Be able to meet future EU-requirements with a well-established control of the environmental performance for internal processes.

## 2. Verified climate calculations

### *2.1. The joint project*

The joint project organization has been formed by several contractor companies, building material manufacturers, branch organizations and clients. Different stakeholders from some major Nordic building companies, some public clients and municipalities, industry joint organizations have participated at this joint project.

### *2.2. Goal and scope*

In this paper, EPDs are investigated as a means to overcome some current barriers for assessment of the actual project-specific climate impact from contractors' competitive designs. The contractors in this joint project decided to investigate the using of a standard verification process of LCA-results according to the European standards for EPDs and PCRs [6, 7, and 8].

The main goal of this joint project was to develop a conceptual framework for calculation of climate impact from infrastructural constructions as bridges and roads in an EPD-format. The scope was to investigate difficulties and driving forces to deliver climate calculations in an EPD-format using data from currently used project planning IT-systems in some Swedish and Norwegian building companies.

### *2.3. The joint LCA-model*

The steering group in this joint project defined a need for an industry-wide LCA-model, which can support entrepreneurs and other actors to perform a rough calculation of the actual climate impact in the early project stage and gradually improve climate performance throughout the project. One challenge for that is to be able to plan for the reduction of climate impact already in the early planning stage where detailed knowledge of solutions and purchased material is missing.

To make comparison of different project alternatives, it is crucial to develop definitions and adoption of an industry joint LCA-model as a basis for comparison. The same system boundaries and data quality should be applied into such industry joint LCA-model to allow the using of different commercial LCA-software. To achieve a comparable LCA-data collection for an infrastructural project, the data should to be broken down to various building components/materials according to the EN 15978 [9]. The different input and output flows in a performed LCA should be allocated to related project' stages, e.g. the material production, the use phase etc. according to EN 15804.

There was a request from the companies involved in this joint project not to develop separate LCA-models for various contract types. A comprehensive LCA-model should fit for all contract types. Swedish municipalities have a need for a simplified climate calculation in order to procure suppliers with better environmental performance. Municipalities need to use a model, which supports climate calculation in the early planning stage and the bidding process. Municipalities would then integrate this LCA-model with their overall work on environment improvement.

Reporting according to the EPD-format includes a mix of accounting and consequence LCAs. For example, Module D of an EPD is such a "consequence LCA", where all potential missing emissions and "credits" to other product systems should be reported, se Figure 1. Even for the use phase, various potential usage scenarios far ahead in time, for example a particular source of energy, should be disclosed.

| **Upstream Module** | | **Core Module** | **Downstream Module** | | | | | **Other environmental information** |
|---|---|---|---|---|---|---|---|---|
| Construction | | | Operation | Maintenance | End-of-Life | | | |
| Raw material supply (extraction, processing, recycled material)<br>Transport to manufacturer<br>Manufacturing | Transport to construction site | Construction of the bridge | Use / application<br>Operational energy use<br>Operational water use | Maintenance<br>Repair<br>Replacement<br>Refurbishment | Deconstruction / demolition | Transport to end-of-life | Waste processing for reuse, recovery or recycling | Disposal | Benefits and loads beyond the system boundaries (BLBSB) |
| A1-A3 | A4 | A5 | B1, B6, B7 | B2-B5 | C1 | C2 | C3 | C4 | D |

Fig. 1. Modules of the whole life cycle included in the EPD-concept [6].

An important question is how to include the climate impact of the operation and maintenance in the LCAs. The supplier should get credit for using of innovative solutions and products without any maintenance alternatively with shorten the service life. It isn't enough to calculate the climate impact only from the material production (Modules A1-A3), since maintenance and operation actions (Module B1-7) are planned for the entire construction or the construction part and seldom at the material level [6]. Contractors can control this part of the construction process and can contribute with more environmentally-friendly solutions for A4-C4, e. g. by optimization of planning,

design and production processes. Using environmental assessment only for A1-A3 in the evaluation of alternative contractor' designs may lead to the sub-optimization.

The Working Group in this joint project conducted a comprehensive survey of the issues that needed to be sorted out in order to achieve the project goals. In order to perform a sharp test of some main hypothesizes about how it's possible to conduct verified climate calculations, some EPD-like calculations was performed in this project.

### *2.4. Pre-verification of a digital LCA-tool*

A pre-verification of a digital LCA-tool to produce EPDs doesn't replace the single EPD-verification, but it makes the verification procedure simpler as the tool has been pre-verified to provide selected generic data in accordance with a specified PCR. This is different from EPD Process Certification, which replaces a single EPD verification. EPD Process Certification means that the internal procedures and processes of a company to generate verified EPDs are checked yearly by an accredited certification body. There is a possibility to pre-verify and register a digital LCA-tool as an EPD-tool according to the International EPD® System, with the purpose to generate EPDs based on verified data. Alternative uses of the tool (e.g. based on forecasted data or internal improvement of products) could also be foreseen.

For the pre-verification of a digital LCA-tool, based on a certain LCA-model, according to a specific PCR, e. g. for bridges or roads, following functions in the tool and outside of the tool are required by the Swedish operator for EPD-system [4]:

- Checking of few examples with input data for climate calculations (a material recipe or so-called Bill of Materials, BoM)
- Used LCA-databases must be approved, verified and structured according to EN 15804
- Verification of links between building materials, machinery etc. in the BoM and emission factors, which were used to calculate the environmental impact
- Control of the used system boundaries for the LCA-model (according to PCR and EN 15804)
- Monitoring of the final EPD-report
- The tool should be pre-verified by the EPD-operator, Environdec.

## 3. Results

### *3.1 The verification procedure*

The project has developed a draft for a verification procedure for delivering climate calculations between different players and from different digital LCA-tools. In the verification procedure were included all important ingredients according to EN 15804, EN 15978, PCRs for bridges and roads and the International EPD® System' requirements for pre-verification of a LCA-tool and EPDs.

A verified LCA-model for a standardized climate calculation should include, for example, the generic or project-specific emission factors from verified LCA-databases. The boundaries of what should be included and not in a standard climate calculation must be made very clear, as well as how to verify the accuracy of each calculation step.

The workflow for the calculation of the climate impact in an EPD-format starts with the BoM-template preparation. Next, it has to be selected or created a mapping of the BoM' items to emissions factors in a LCA-database. The LCA calculation method should be chosen as well. Then the calculation results should be presented in the pre-defined Word-template for an EPD-report. The implementation of these verification steps have been done in this joint project on some infrastructural projects. The project participants tested to perform the verified climate calculations in order to calculate the climate impact (GWP) and total primary energy use for four infrastructural projects.

### *3.2. Workflow for a pre-verified LCA-tool*

This joint project was concentrated to define some main requirements for a pre-verification process for a digital LCA-tool in order to produce the verified EPDs. The pre-verification of any digital commercial LCA-tool requires the checking of the LCA input data. In this joint project an Excel-based template for preparation of BoM with a pre-configured input structure was created. The BoM data was then collected for each infrastructural project from companies' cost estimation systems. The joint project has also developed a pre-configured Word template with a standard report layout according to the EPD-format. This Word-template was used for the final EPD-report, se Figure 2.

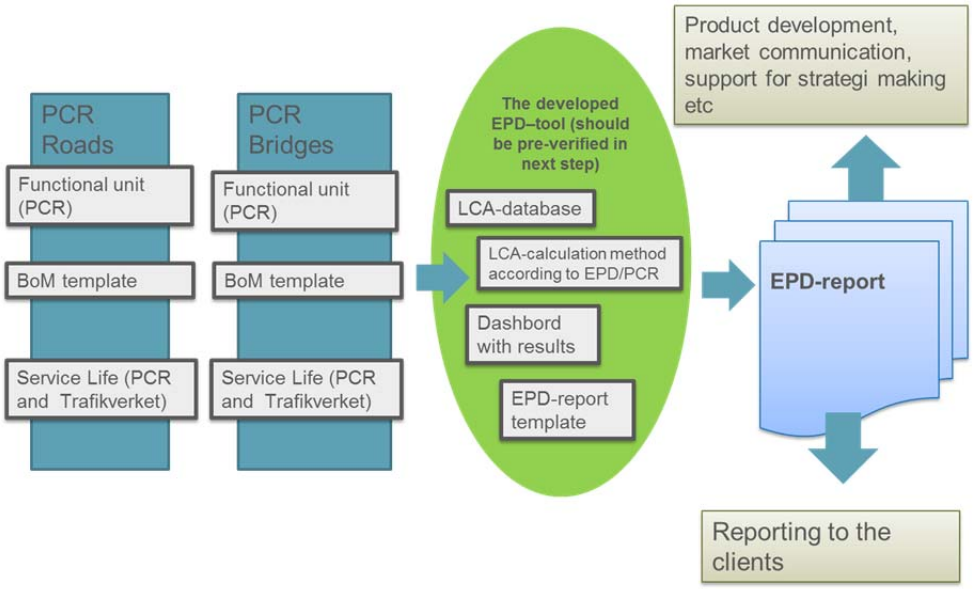


Fig. 2. The conceptual workflow in a pre-verified LCA-tool, which can produce EPDs for infrastructural constructions (e.g. bridges and roads in this joint project).

### *3.3. System boundaries*

The infrastructures considered for this pilot project are bridges and roads. Four of the group members participated actively with project examples in order to test the LCA data collection for a verified EPD. Each participant chose one or two infrastructure examples in order to collect project-specific data. Each participant collected life cycle inventory data for the selected infrastructure in the pre-defined Excel-based template (BoM template). The functional unit for the pilot project was one piece of infrastructure. For this reason, the collected data has to be entered in the corresponding BoM for one piece of infrastructure (either one bridge or one road). All life cycle phases (materials preparation, construction, operation/maintenance and end-of-life) can be covered in this BoM template depending on what is specified in the infrastructural project's BoM. The system boundaries considered as default in the delivered BoM template are described in the following Figure 3.

| **Upstream Module** | **Core Module** | **Downstream Module** | | | **Other environmental information** |
|---|---|---|---|---|---|
| Construction | | Operation | Maintenance | End-of-Life | |

| Raw material supply (extraction, processing, recycled material)<br>Transport to manufacturer<br>Manufacturing | Transport to construction site | Construction of the bridge | Use / application<br>Operational energy use<br>Operational water use | Maintenance, Repair<br>Replacement<br>Refurbishment | Deconstruction / demolition | Transport to end-of-life | Waste processing for reuse<br>Recovery or recycling | Disposal | Benefits and loads beyond the system boundaries (BLBSB) |
|---|---|---|---|---|---|---|---|---|---|
| A1-A3 | A4 | A5 | B1, B6, B7 | B2-B5 | C1 | C2 | C3 | C4 | D |
| X | X | X | MND | X | MND | X | X | X | X |

Fig. 3. System boundaries of the BoM template for the tested infrastructural projects (X = declared module; MND = module not declared).

Participants provided information and data collection about the construction stage of their infrastructural projects (including materials, transport to construction site and construction site works). Even the material and energy flows for the operation and the maintenance were added in the BoM template. The material flows have been collected for A1-A3 and the energy and the operating materials' flows for B2 according to the PCR' requirements for bridges. Since no specific information about the allocation of materials in the maintenance phase is given in the PCR for roads, the same approach as for bridges was used. Energy carriers and water use are allocated to B2.

It was made some general assumptions on the end-of-life scenarios, e. g. the amount of material to landfill, incineration and recycling. Module C1 (demolition, deconstruction) wasn't considered in the used BoM template, since no detailed data (e.g. energy, water, etc.) was available.

The main intention with the Excel-based BoM template for data collection was that each user can modify this BoM according to their needs following some guidelines and can adapt it for the different project phases. For example if the user wants to analyze a project in the tender phase, the BoM template will have to be adapted accordingly. This means that not all life cycle stages and/ or material positions will be covered or given a value. For example, the construction site and therefore the groundworks might not be known yet in the tender phase and will not be included in the BoM for an early stage (e.g. soil and gravel volumes will be set to zero). It is therefore very important to describe exactly which project phase is being analyzed and what is covered in the BoM. The completed BoM template can then be used in a pre-verified LCA-tool. All calculations on climate impact can then be performed in the pre-verified LCA-tool based on the inventory data collection in the uploaded BoM. The considered system boundaries have to be documented to the end in an EPD-report with the final results, which may be delivered to a client.

### *3.4. Data collection*

Swedish construction companies use various IT-based internal systems to store the project-specific information. In one of these systems, cost calculation systems entrepreneurs use to create a spreadsheet with the planned purchase of building materials and machine hours for each infrastructural project. It is important to note that the cost calculation systems have been developed to be able to make a very rough estimation of project costs. A cost calculation is usually updated during the various projects' stages: tender, design and production. In some isolated cases the spreadsheet with the project cost can be updated after the commissioning of a project. In this case this cost calculation will contain the total final cost for the whole infrastructural project: purchased building materials, cost for all work performed and additional costs. However this follow-up calculation isn't the established practice in the construction industry today.

The spreadsheets in cost calculation systems usually contain fragmented input data for the Modules A1 to A3. LCA input data for other life cycle stages are even more difficult to collect from the current production and planning

systems. Data for the operation and the maintenance, percentage of recycled content in building materials, the transportation of building materials to the construction site are examples of input data for LCA-calculations, which aren't stored in the current production and planning system. There are various proposals on how this would be done in the future, for example as part of the information in the Building Information Model (BIM).

Another important aspect is that the selection and comparison of design options is currently conducted in the design software such as AutoCAD, Revit etc. Some construction companies try to link the analysis of design options in the BIM software and the cost calculation system in "real time". This is far from a standardized workable routine in the industry.

The created BoM template in this branch-joint project was based on the rules for the implementation of comparable EPDs for bridges and roads. PCRs must be followed in order to compare the EPDs for infrastructural constructions with a similar function. The project participants had to perform a lot of manual modifications of the existed project data from their cost calculation systems to match the requirements by EN 15804, EN 15978 and PCRs.

### *3.5. Discussions*

The challenge was to break down the vision with this project to a technical specification for implementation of the project. Firstly, several participated contractors tested the data collection process and the LCA-calculation method, which is recommended by PCRs. Secondly, the project participants created a technical specification for pre-verification of a digital LCA-tool in order to produce EPDs for scarp infrastructural projects. The verification procedure to check the accuracy of the project-specific climate calculation was a part of the created specification.

Benefits for the industry from this joint project is more knowledge on the existing gap between the long-term overall planning by the EU and the Swedish government and the contractor's practical work on climate issues in engineering projects. The project has also identified and clarified the requirements for the continued industry-wide cooperation in the development of a verification procedure for calculating the climate impact for civil engineering structures.

The lack of a common business model for using of verified climate calculations and EPDs between different markets players makes it difficult to get any advantage for more sustainable solutions in infrastructural projects. High cost to produce EPDs for materials/building parts/infrastructural projects discourages the broad-wide use of EPDs as well. The automation of an EPD process creation can be achieved by pre-verification of existing commercial LCA-tools. This will reduce the cost for creation of project-specific EPDs.

The working group and the steering committee have had several discussions regarding the approach and the verification process for LCA-data and climate calculations from various commercial LCA-tools. EPD is an environmental declaration of the final product. Adoption of the EPD-format to set up, measure and follow-up operational goals for a scarp project should be developed. There are also some uncertainties with using EPDs as a verification of the environmental performance for a project design in the early stages.

It's also unclear in the current PCR/EPD-system how to aggregate single EPDs for some main construction elements (tunnel, bridge) to calculate the total environmental impact of the entire infrastructural project. Harmonization of the various functional units, assumptions etc. in different PCRs for civil engineering structures (bridges, tunnels, etc.) must be standardized by ISO/EN. It would be a great practical benefit to include bridges, tunnels and even a few more engineering structures in the scope of the same PCR.

Contractors' internal IT-systems for monitoring of ongoing projects (e g Cost Planning System) have a different data structure to store project information, which isn't compatible with EPD/PCR' requirements. There is a need for a technical solution to automate the collection of project-specific data, according to the requirements in the PCR/EPDs. At the moment the data collection for climate calculations requires a manual handling. Some standardized routines and support to collect data for the entire life cycle of engineering works should be established in the construction companies. This will support an unbroken information flow with LCA data between different market players.

A greater transparency through reporting of the climate impact from infrastructural projects in accordance with the internationally established standards will stimulate the development of innovative environmentally friendly products. It will also support the work to achieve the goal for Sweden to be climate neutral in 2050.

### *3.6. Recommendations on the next step*

During this joint project it was foreseen that the participants test some testing examples for one design scenario. More testing scenarios should be developed in the next step (early design, tender, planning, production, additional works and reporting to the client).

This project was the very first step in developing a pre-verified EPD-tool for engineering works. The pre-verification of some LCA-tools may be done in the next step. The industry-joint LCA-model will be implemented in some pre-verified LCA-tools in the next step.

For the early planning stage or the tender phase there should be an industry-wide agreement with listed assumptions regarding the system boundaries (e. g. level of detail on the bill of materials) and generic emission factors to be used for different materials/construction parts.

In the meantime clients should encourage using the EPDs for building parts and the whole infrastructural project. Evaluation of the climate impact from contractor' alternative designs should be done in the early tender phase a soft parameter in the procurements. This will ensure the achievement of the goals of climate neutrality in 2050.

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