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**DEVELOPING EPD PROGRAM TO IDENTIFY  
IMPROVEMENT POSSIBILITIES FOR SUSTAINABLE  
DEVELOPMENT OF ABB WA PRODUCTS**

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# TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT  
School of Energy Systems  
Ympäristötekniikan koulutusohjelma  
Sustainability Science and Solutions

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## **Developing EPD Program to Identify Improvement Possibilities for Sustainable Development of ABB WA products**

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Ympäristötuoteselosteiden markkina ja asiakas vaatimukseen on huomattu, että niiden valmistusprosessi voi antaa niiden tekijälle paljon muutakin etenkin kiertotalouteen ja kestäväan kehitykseen liittyen. Tämän työn tavoitteena on kehittää EPD-ohjelma, jonka avulla voidaan tunnistaa parantamismahdolliset ABB WA- tuotteiden kestäväälle kehitykselle.

Tämä ohjelma tehdään tekemällä ympäristötuoteselosteet kolmelle eri tuotteelle: jakorasia, pistorasia ja termostaatti. Näiden ympäristötuoteselosteiden tekemisprosessia käytetään oppimaan minkä tyyppistä tietoa ja dataa niiden tekeminen vaatii, mitkä ovat niiden valmistusprosessin eri vaiheet ja minkä tyyppistä tietoa ja dataa tästä prosessista saadaan liittyen tuotteeseen ja sen elinkaareen, mitä voidaan hyödyntää päätöksenteossa tuotteen elinkaaren aikana. Työn tulokset sisältävät vaiheittaisen oppaan ympäristötuotteiden tekemisestä PEP Ecopassportin -ohjeiden mukaisesti sekä ekosuunnittelu hallintatyökalun, mitkä yhdessä muodostavat EPD-ohjelman.

## **ABSTRACT**

Lappeenranta–Lahti University of Technology LUT  
LUT School of Energy Systems  
Degree Programme in Environmental Technology  
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### **Developing EPD Program to Identify Improvement Possibilities for Sustainable Development of ABB WA products**

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117 pages, 24 figures, 37 tables and 8 appendices

Examiners: Professor Risto Soukka  
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Keywords: Environmental product declarations, Life cycle assessment, Product category rules, Ecodesign, Circular economy, Life cycle thinking

With environmental product declarations (EPD) starting to be included in market and customer requirements for construction products, it has been identified that the process of making them can result in more than just the EPD especially regarding circular economy and sustainable development. The aim of this thesis is to develop an EPD program that can help identifying improvement possibilities for the sustainable development of ABB WA products.

This program is developed by making EPDs for three different products: junction box, socket outlet and thermostat. The making of these EPDs is used to learn what type of data is required to make them, what are the different steps in the process of making them and what type of information and data is gotten from this process regarding the product and its life cycle, that can be utilized in the decision-making of the product's life cycle. The results of the thesis includes a step by step guide on making EPDs based on PEP Ecopassport guidelines, and an ecodesign management process tool, which together make the EPD program.

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When I first applied to Lappeenranta–Lahti University of Technology LUT, graduating was in the far future. Now the journey comes to an end as this thesis is finalized. However, this is not an end but an exciting beginning of a new area.

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In Porvoo 2020

Ella Helynranta

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## ABBREVIATIONS

BREEAM	Building Research Establishment Environmental Assessment Method
BVB	Byggvarubedömningen
CE	Circular economy
GWP	Global warming potential
EPD	Environmental product declaration
EU	European Union
ISO	International Organization for Standardization
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
LCT	Life cycle thinking
LEED	Leadership in Energy and Environmental Design
OEF	Organization Environmental Footprint
PCR	Product category rule
PEF	Product Environmental Footprint
PEP	Product Environmental Profile
PSR	Product specific rule
RLT	Reference lifetime
WA	Wiring accessories
WEEE	Waste of electrical and electronic equipment

## 1 INTRODUCTION

Sustainability and environmental issues are becoming more important every day, which is why different concepts, that try to give solutions to these issues and challenges, have gained momentum in politics, business, and academia. Especially circular economy (CE) has been promoted by many national governments and the European Union (EU) as well as by several businesses around the world as a concept to answer different challenges like climate change and sustainable design. (Korhonen, et al., 2017, p. 37.) EU for example has a Circular Economy Action Plan, which is one of the main blocks of the European Green Deal (European Commission, 2020).

While CE has been gaining popularity, it has been mainly developed by different practitioners, like policymakers from different fields of business. Therefore, there isn't much scientific research on the topic and why there isn't a definitive definition for CE. (Korhonen, et al., 2017, p. 37.) It can however be seen that all the varying definitions, the exist for CE, are based on the following three principles: design out waste and pollution, keep products and materials in use and regenerate natural systems. (Ellen MacArthur Foundation, 2019, p. 13).

To this day the effort to tackle climate change has focused on the transition to renewable energy, which is complemented by energy efficiency. While this aligns with CE and is an important aspect of it, these measures have been calculated to address only 55% of the overall emissions. Those remaining emissions come from the production of products that are used every day, for which CE also offers a way to answer to those by transforming the way products are made and used. (Ellen MacArthur Foundation, 2019, p. 13.) Especially the construction industry is starting to utilize CE by taking a systemic view of the whole life cycle of buildings, which enables them to move away from 'take-make-dispose' material use philosophy to a circular philosophy (Figure 1). This is done by using new technologies and design approaches. (Leising, et al., 2017, p. 977)

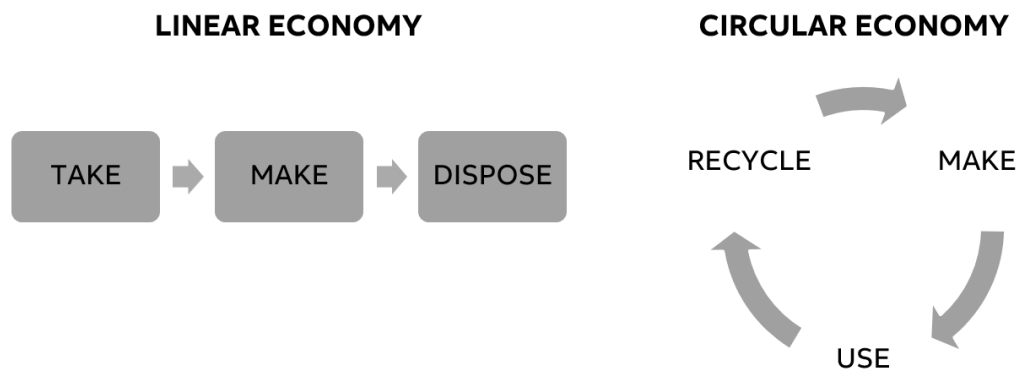


Figure 1: Linear Economy vs Circular Economy (Instarmac, 2018)

Life cycle thinking (LCT) has become an important tool when implementing CE because of its ability to look at and analyze a product's or a service's whole life cycle and the potential environmental impacts from it (Moraga, et al., 2019, p. 454). A core reason why LCT or taking a life cycle perspective of things is done is that it allows identifying and preventing the environmental burden shifting between life cycle stages or processes that happens if taking action to lower environmental impacts in one process or stage unintentionally create possible larger environmental impacts in other process or stages (Hauschild, et al., 2018, p. 12). With LCT, other approaches related to it are also rising in popularity. One of the most popular approaches is life cycle assessment (LCA). These approaches themselves aren't specially made with CE in mind. They however can give companies a comprehensive look at their products or processes from cradle to grave, which is why they are great tools to find the life cycle phases where major losses of resources and energy occur from, for example. (Nygren & Antikainen, 2010, p. 9.)

With these different approaches becoming more popular, having a commonly agreed upon and harmonized criteria, on which the approaches are based, is important. One of the most well-known and most widely used standards are made by the International Organization for Standardization (ISO). Standards related to these different approaches are part of the ISO 14000 management and product-oriented standards. They include the ISO 14040 series

which focuses on LCAs and the ISO 14020 series which focuses on environmental labeling and declarations. (ISO, 2018)

While these different life cycle approaches are great tools in evaluating the products and process, communicating the results is more complex. This is because to understand the results in their right context, the background information of the calculations should also be known. This is especially harder for companies where the information used in the calculations can be confidential information about the company and its products or services. To solve this issue different types of environmental declarations can be used to communicate the results. These different types of declarations are for example eco-labels and environmental product declarations (EPD). These environmental declarations are standardized by the ISO 14020-series and are internationally recognized. (Del Borghi, 2012)

## **1.1 The aim and structure of the Thesis**

The aim of this thesis is to develop an EPD program to help identify improvement possibilities for the sustainable development of ABB WA products. This program includes a guide on the process of making EPDs and an ecodesign management tool that helps to utilize the results and information obtained from the LCA studies in the decision-making of the product's life cycle. The guide to making EPDs is done based on making pilot EPDs for three different products from different product groups. The ecodesign management tool is created by utilizing the results of the LCA calculations and sensitivity analysis for the LCAs where the effect of the different parameters on the results can be compared.

The thesis starts with the overall look at how LCT has been utilized in the construction industry over the last few years. From this EPDs are looked at more closely by answering the following questions:

- What it is?
- What standards are relevant to it?
- What are the drivers for its demand, especially in the construction industry?
- What is the business value of EPDs?

After these questions are answered the general process of making an EPD for a general construction product is gone through. This is based on the relevant standards for making LCAs and EPDs with input from other relevant instructions that are provided for when making EPDs.

The previous parts act as the background information for the EPD program, based on which the program is made. The program itself starts with the process of making the three pilot EPDs. During this each part of the process is documented, with explanations for the decisions made during the process. After the EPDs are done the guide for making an EPD is produced with improvement ideas and other notable considerations learned from making the pilot EPDs, to make the process more streamlined and efficient. The ecodesign management tool is developed by utilizing the made LCA calculations and the results got from them.

## **1.2 Case company introduction**

ABB Oy is a leading global technology company that energizes the transformation of society and industry to achieve a more productive, sustainable future. ABB pushes the boundaries of technology to drive performance to new levels by connecting software to its electrification, robotics, automation, and motion portfolio. ABB employs about 110 000 employees in over 100 countries. (ABB, 2020a)

ABB Wiring Accessories (ABB WA) business unit belongs to the Electrification business area and under that to the Smart building's local division (ABB, 2020b). ABB WA manufactures and markets installation accessories and furniture for residential and commercial construction, as well as intelligent home automation products that promote energy efficiency in housing with the main market being the Nordic countries. The ABB WA unit is located in Porvoo, Finland and it employs about 100 employees. (ABB, 2020c)

## 2 CONSTRUCTION INDUSTRY AND DIFFERENT LCA METHODS

The construction industry has an important role globally regarding the consumption of energy and total consumption of raw materials and the emissions released by them. This is especially important with an increasing population, where there is a need for both quality retrofitting and sustainable new construction. It is estimated that 230 billion square meters of new construction are to be built in the next 40 years. Buildings are responsible for more than 30% of the global final energy consumption as well as large amounts of raw material consumption. The International Energy Agency has predicted that the energy consumption for the construction industry will grow by 50% by 2050 if no action is taken. Solutions to reduce energy consumption especially has become more important for the 2015 Paris Agreement's climate goals to be reached, where energy intensity per square meter needs to be reduced by 30% by 2030. (brands & values, 2019, p. 9.) An important aspect to consider in this is what is the impact of construction products relative to the overall lifetime impact of a building. This has been estimated to be about 10-20% in 2003, but as buildings have and will become more energy-efficient, the impact of construction products will make up an increasingly more significant proportion now and in the future. (Edwards & Bennett, 2003, p. 57.)

In 2011 European Commission (EC) have also taken action to solve this issue by launching the Single Market for Green Products Initiative where new methods are proposed as a common way of measuring the environmental performance of products and services. A few examples of these methods are called the Product Environmental Footprint (PEF) and the Organisation Environmental Footprint (OEF) that are developed in a cross-sectorial approach. (Durão, et al., 2020, p. 2.) The more relevant for construction products, PEF, has only been in a pilot phase that concluded in 2018 and hasn't been widely applied yet, but there is an expectation that future policies are likely to require PEF metrics, especially related to the European Green Deal and existing schemes by the EC. (PRé Sustainability, 2020; Durão, et al., 2020, p. 2.)

Many different methods, especially social, economic, and environmental indicators of sustainable development, are drawing the attention of the construction industry as possible

solutions. LCA method has already been utilized in product development processes to evaluate environmental performances in other industries for a long time and has been part of the construction industry for over 10 years. (Nygren & Antikainen, 2010, p. 13.) LCAs and LCT have been used in a wide-ranging way from the regulatory and governmental level, through industry and production to the level of citizens and consumers (Hauschild, et al., 2018, p. 32).

While complying with the regulatory or governmental regulations related to LCA can be voluntary in many cases, many companies are already looking ahead to possible future regulations. This is especially relevant with the growing utilization of LCA to support policy formulation, policy implementation, and regulation imposed by policies and to perform an evaluation of policies. For example, in 2015 the EC has listed LCA as one of the reference models for impact assessment of policies in the EU. This holds the potential to increase the use of LCA in evaluations of existing policy frameworks and policy development of possible future policies. (Hauschild, et al., 2018) Companies are aware that they can influence future legislation by already adopting LCAs. This means that companies already using LCA can set the market precedence on how LCAs are used which in turn influences future legislation, for example, turning the voluntary requirements to mandatory. LCA can also be a useful tool for supplier chain management, especially for bigger companies that have the power to demand their suppliers to comply with environmental standards or provide information that is based on life cycle approaches. (Nygren & Antikainen, 2010, p. 13.)

With the pressure to find solutions for energy and raw material consumption, there has been a growing interest in expanding the ways LCA methods are used in the decision-making processes of buildings constructions. They could especially be utilized for the selection of environmentally friendlier products as well as for evaluation and optimization of construction and manufacturing processes. There are already some schemes that are evaluating construction and building products or even the whole buildings based on their environmental performance, and in some cases, this evaluation can be done internally by companies using different tools or programs like LCA software and LCI databases. What these different organizations do, is evaluate the information and data provided by companies on their products or buildings. In many cases, this information and data are related to LCA

calculations on some level, based on which certificate or endorsement is provided as a result. These schemes can be divided into two: building certification and product certification or endorsement schemes. (Cabeza, et al., 2013, p. 399.)

## **2.1 Building Sustainability**

With the part that buildings play in the overall environmental impacts of the world, the sustainability of the built environment is becoming more critical. The Green building concept refers to a structure that aims to create energy-efficient, healthy, and productive buildings with minimal impacts on the environment. The central focus of green buildings is to create a healthy, comfortable, and productive indoor environment for building occupants and other transient users. Globally, green buildings appear to be important to the stakeholders in the construction marketplace and continue to increase market share. (Pranab, 2019)

Decision making on the environmental performance of buildings has been accomplished by using various assessment systems and tools. These tools originate from around the world, but especially from European nations, the USA, and Canada. With the concept of green buildings getting more emphasis, many countries have developed or adopted some building assessment tools and methodologies, through voluntary agencies, stakeholder bodies, or government regulations. (Pranab, 2019)

### **2.1.1 Green Building Rating schemes: LEED and BREEAM**

Leadership in Energy and Environmental Design (LEED) is a U.S based green building rating system. It is available to be used for all building types and building phases including new construction, interior fitouts, operations, and maintenance and core and shell, and it provides a framework for healthy, highly efficient, and cost-saving green buildings. LEED certification is also a globally recognized symbol of sustainability achievement and leadership. (U.S. Green Building Council, 2020b) LEEDs certification system deals with the environmental performance of buildings based on the overall characteristics of the project. They are not for endorsing or promoting the use of specific products, but they award credits upon meeting the performance standards outlined in their rating system. So, it is up to the

project teams to determine which products are most appropriate for credit achievement and program requirements. (U.S. Green Building Council, 2020a)

Building Research Establishment Environmental Assessment Method (BREEAM) is a UK based building certification scheme. It recognizes and reflects the value in higher performing assets across the built environment lifecycle, for all building types. BREEAM uses third-party certification of the assessment of an asset's environmental, social, and economic sustainability performance, using standards developed by the Building Research Establishment (BRE). (BREEAM, 2020b)

BREEAM and LEED are the two most widely recognized environmental assessment methodologies used globally in the construction industry today. BREEAM is the older of the two being established in 1990 while LEED was established in 1998. While both are aiming for the same end goal and are relatively quite similar in their technical criteria, their approach to the certification of buildings is very different. For example, with LEED, the project team that is engaged in the design and construction of the building can register the project, consider the requirements of LEED standards, and prepare the necessary documentation. They then form a package of the project documentation that is sent to the U.S Green Building Council, where the examination is conducted in different sections. If everything is in order, it results in a certificate with a certain level. (Varghese, 2020)

BREEAM however has a different approach. When a project is developed it is checked by someone called an appraiser, one person, not a group of experts. The project team provides this person with documents for checking compliance with the established criteria and if everything is in order; they give their approval. This appraiser appears twice during the project: at the design stage and at the stage of putting the project into operation. After both checks, the appraiser prepares a report which is then sent to a selective audit which result is the certificate. This means that in the BREEAM system the certificate is issued twice, for the project itself and at its completion, while the LEED certificate is issued once after the project is completed. (Varghese, 2020)

Another important difference between the two systems is that LEED bases its thresholds on percentages whereas BREEAM relies on quantitative standards. LEED system also has very strict mandatory requirements that are necessary for execution. Otherwise, the building will not be considered green. BREEAM however is more flexible. There are mandatory requirements, but they are much simpler than what LEED has. Under BREEAM the higher the level of certification, the greater are the requirements. All the different levels and scores or points needed for them for both BREEAM and LEED can be seen in Figure 2. (Varghese, 2020)

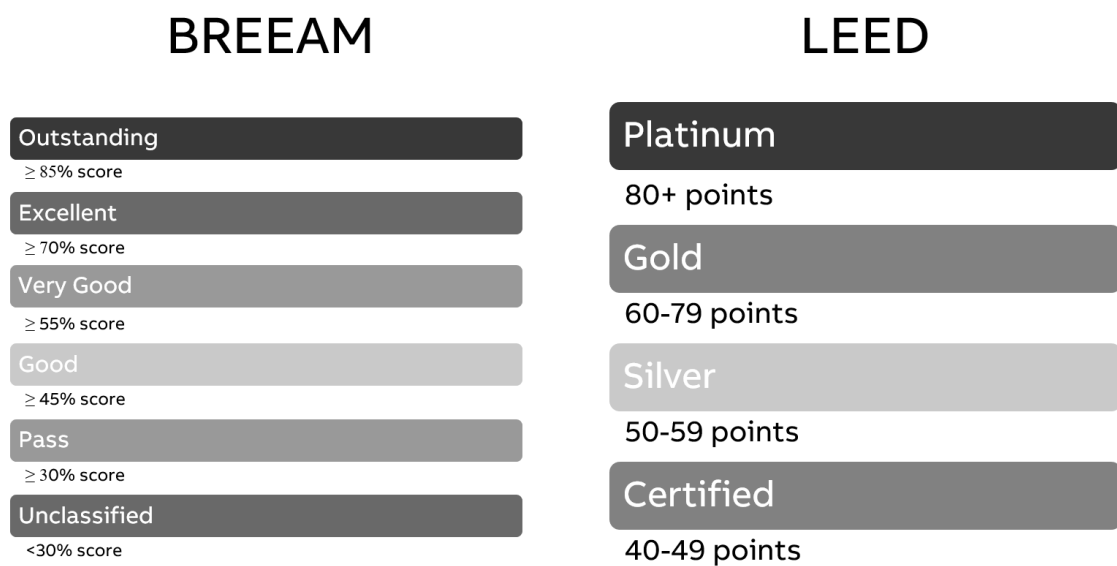


Figure 2: BREEAM and LEED scores or points need for each level (BREEAM, 2020a; LEED, 2017).

At the geographical level BREEAM is more used in the UK, while LEED makes more sense to a global corporative policy. Therefore, LEED is the most known signature because of its presence in more countries, but BREEAM wins at certified buildings in Europe. (Varghese, 2020) For example, BREEAM has been the more popular certification tool in Finland and Sweden than LEED as of today. (GBIG, 2020a; GBIG, 2020a).

These green building certifications are becoming more proponent every day, for example in San Francisco, Portland, and Austin, Texas all new municipal constructions are required to earn a LEED “silver” certification and for BREEAM there are minimum ratings for all new buildings and refurbishments in the UK public sector and voluntary minimum ratings in the

private sector. (Inbuilt, 2010, pp. 5-7.) Many countries have also set carbon neutral targets starting from the early 2030s and the construction industry is a clear place to try to cut emissions (Climate Home News, 2019). For example, Finland is planning to set carbon limits for different building types before 2025 to be able to meet its target of carbon neutrality by 2035. Therefore, minimum ratings for buildings from LEED or BREEAM or at least legislation that incentivises the use of these types of schemes can become more common. (Kuittinen & Häkkinen, 2020, p. 182.)

## **2.2 Product Sustainability**

With the current rise in popularity and future potential for schemes like LEED and BREEAM the need to identify what products are sustainable or environmentally friendly has increased also. Therefore, different product evaluation or certification schemes have risen in popularity. For example, LEED gives credit for the usage of products based on the following criteria: existence or information on EPD, Raw material extraction, and Material Ingredient Reporting (USGBC, 2012). With the different organizations evaluating products based on LEEDs or BREEAMs criteria, they can tell their customers that their products meet LEEDs or BREEAMs criteria in a third party verified way. This can work in multiple ways, where companies can market their products with the point that they meet LEED or BREEAM criteria or possible customers find products from databases or lists from product certifiers or evaluators that the potential customer knows would meet LEEDs or BREEAMs criteria. (Eco Product, 2020)

One of these schemes is a Swedish based Byggarubedömningen (BVB). BVB is a non-profit organization that is owned by large constructors and property owners in Sweden. It was created on the initiative of several major players in the construction and real estate market in Sweden who wanted to work together to minimize risk and substitution. They created an assessment criterion based on which all products can be assessed and thus also creating a database of these assessed products. The assessment is based on chemical content, life cycle, and social responsibility at the supplier stage. Based on the assessment the products are given a result between recommended, accepted, or avoid. From the database of evaluated products, different constructors or similar disciplines can look for products that

they would need. (BVB, 2020a) They have made their assessment criteria so that the products evaluated by them can pass the certifications of BREEA and LEED for example. (BVB, 2020).

With this growing interest in proving environmental information of products, EPDs have risen to be one of the popular tools by which companies can provide and communicate verified environmental and sustainability information and data of their products. For example, LEED gives credits for projects that are using products that can provide EPDs and by providing an EPD for BVB assessment, the changes in getting a good assessment increase. (USGBC, 2012)

### **2.3 Ecodesign**

The overall rise of sustainable issues and sustainable thinking has risen the popularity of tools and process, like ecodesign as well. With the help of standards like ISO 14006 and the Ecodesign directive (2009/125/EC) organizations are beginning to utilize ecodesign for their products and their operations overall. ISO 14006 is not an actual ecodesign manual, but a guideline on how ecodesign activities can be implemented to an organization in the context of environmental management system (EMS), while it can still be used without or within an EMS. (ISO 14006, 2020)

The aim of ecodesign is to ensure that consumers have access to products with high energy efficiency performance but low environmental impact. This is done by setting requirements to better products energy efficiency and reduce their environmental impacts, like material consumption, CE, durability and repairability. The idea of ecodesign requirements is to integrate environmental aspects and LCT into the product design phase. EU have set minimum requirements for different products that need to be fulfilled for the product to enter the EU market. These requirements are expected to become more stricter over time and overall products covered by these requirements is also expected to increase. (Ekosuunnitteli.info, 2020; Ministry of Economic Affairs and Employment of Finland, 2020)

ISO 14006 is based on the idea that product's environmental impact can be fixed by its design. Which is way integrating the principles and practice of ecodesign as early as possible in the products life cycle and development is essential. (Croner-i, 2011)

### 3 ENVIRONMENTAL PRODUCT DECLARATION

With the growing knowledge of environmental issues and the rise of concepts like circular economy, there is a growing interest across the world and especially in Europe to establish measurement and communication of the environmental behavior of products and organizations. This interest has risen with the implementation of different policies on the EU and country level. One of these is the Integrated Products Policy that enhances environmentally friendly products by making their environmental information public. Because of this, different mechanisms have risen that are used to communicate the environmental aspects of products. Many of these are within the ISO 14020 series of standards for ecolabels. The series consists of three different types of environmental labels and declarations that can be used in the communication of environmental performances. These standards can be seen in Table 1. (Ibáñez-Forés, et al., 2015, p. 157.)

Table 1: Three types of environmental declarations (ISO, 2019, pp. 4-8.)

<b>Standard</b>	<b>Name</b>	<b>Kind of environmental labels it covers</b>
ISO 14021	Environmental labels and declarations — Self-declared environmental claims (Type II environmental labelling)	For products and services where there are neither criteria nor labelling schemes
ISO 14024	Environmental labels and declarations — Type I environmental labelling — Principles and procedures	For eco-labelling schemes where there are clearly defined criteria for products
ISO 14025	Environmental labels and declarations — Type III environmental declarations — Principles and procedures	For specific aspects of products using a life-cycle approach, EPD

The series offers internationally agreed and harmonized criteria and methods of labeling. These declarations can be used when communicating externally to customers but also when communicating internally in the company, to stakeholders for example. ISO 14021 and ISO 14024 are most used for business-to-customer communication and ISO 14025 is mainly designed for business-to-business communications. The usage of business-to-customer

commutation has however increased in recent years for ISO 14025. (Blengini & Shields, 2010, p. 485; ISO, 2019, p. 2.)

The ISO 14025 standard for type III environmental declarations is the most comprehensive one of three different types of declarations. This declaration is called an environmental product declaration (EPD). The declaration presents transparent quantified environmental information on the life cycle of a product to make similar products' environmental impacts comparable to each other. The aim is to encourage the demand and supply of products that cause less stress on the environment. Also, with the communication of transparent, verifiable, and accurate information there is potential for market-driven improvement of environmental performance in different products. (ISO 14025, 2010, p. 4.) EPD contains consistent and comparable information about both product attributes and product impacts (Appendix 4) regarding environmental impacts on industrial customers and end-use customers (Bowyer, 2011, p. 3.).

What is however important to note is that an EPD is not an eco-label like ISO 14021 and ISO 14024, whereby a product carrying the label has the association of the product being greener or sustainable. With EPDs this is not the case as it only gives the environmental impacts, consumed resources, and benefits delivered over the life cycle of a product in a standardized format, without taking perspective if the product is greener or sustainable. It can be looked at as an equivalent of a nutrition label on food products in the supermarket. (Bengtsson, 2014)

### **3.1 Standards and other guidelines related to EPDs**

There are many standards and guidelines that the EPDs must comply with. The main standard is the ISO 14025 and this standard gives the overall guidelines for EPDs and the process of making them and instructions on what are the other standards and guidelines that should be followed. Some of these standards are ISO 14044 and ISO 14040. For EPDs made for construction products EN 15804 is a standard that should be considered also. (ISO 14025, 2010; EN 15804, 2012)

### **3.1.1 International Organization of Standardization's Standards**

The standardization process of developing a global standard for LCA was initiated in 1993 by ISO. The overall goal for the standards was to meet concerns from the industries that increasingly wanted to use LCA for product development and marketing of greener products, but had experienced that the lack of a standardized methodology meant that different studies of the same product could give opposite results depending on the concrete methodological choices. The development resulted in the ISO 14040 series standards that concern the LCA methodology. The main standards from this series are ISO 14040 and ISO 14044. (Hauschild, et al., 2018, pp. 24-25.) These standards establish the methodologies based on which the LCA should be based on. ISO 14040 establishes the principles and framework for the LCA while ISO 14044 establishes the Requirements and Guidelines for LCA. (ISO 14040, 2006)

Included in the ISO 14000 series of Environmental Management standards are also standards and technical guidance reports on the different applications of LCA, like ecodesign (ISO 14062 and 14006), communication of environmental performance (ISO 14020 series and ISO 14063), and greenhouse gas reporting and reduction (ISO 14064). (Hauschild, et al., 2018, p. 25.)

ISO 14025 is the standard which EPDs are based on and it is part of the ISO 14020 series (Table 1). This standard establishes the principles and specifies the procedures for developing type III environmental declaration programs and type III environmental declarations. The standard provides requirements for an organization that has chosen to develop and operate as a program operator or to develop and use the declarations. The ISO 14025 also establishes the use of the ISO 14040 series of standards as part of the development of type III environmental declarations programs and type III environmental declarations to generate the data for the different life cycles. (ISO 14025, 2010, pp. 1-4.)

### **3.1.2 EN 15804 standard and other standards related to it**

An important part of making the EPD is something called Product category rules (PCR). They established it in ISO 14025 as a required part of making an EPD and they are a set of

specific rules, requirements, and guidelines for developing an EPDs for one or more product categories. These product categories are a group of products that can fulfil equivalent functions, like floor finishes or insulation. PCRs are particularly important in defining the boundaries of the system being studied and are important in ensuring that all EPDs under the same category report the same information. (ISO 14025, 2010) The PCR is a key aspect when making an EPD under ISO 14025 because they enable transparency and comparability between EPDs because it provides category-specific guidance for estimating and reporting product's environmental impacts. (Subramanian, et al., 2019, p. 1.)

EN 15804 – “Sustainability of construction works. Environmental product declaration. Core rules for the product category of construction products” is a standard that can be looked at as a PCR. Overall, this standard can as significant as ISO 14025 for EPDs that are made for construction products. When LCAs and EPDs started to rise in popularity, especially with construction products, some problems also rose. ISO 14040, ISO 14044, and ISO 14025 on their own leave space for important methodological choices during the LCA study and the development of an EPD. This may lead to a situation where even if two EPDs are compliant with ISO 14025 they may not be comparable, because of the result of the decisions made during the LCA study and the development of an EPD. To combat this problem EN 15804 was developed by better specifying the requirements of EPDs for construction products namely in business to business format. (Durão, et al., 2020, p. 3.)

EN 15804 standard categorizes the life cycle to five different stages: product, construction process, use, end of life and benefits and loads beyond the system boundaries. These life cycle stages are then separated into different modules for better understanding. These modules for each life cycle stage can be seen in Figure 3. The scope of the LCA study is then formed by combining the different modules together (Appendix 5).

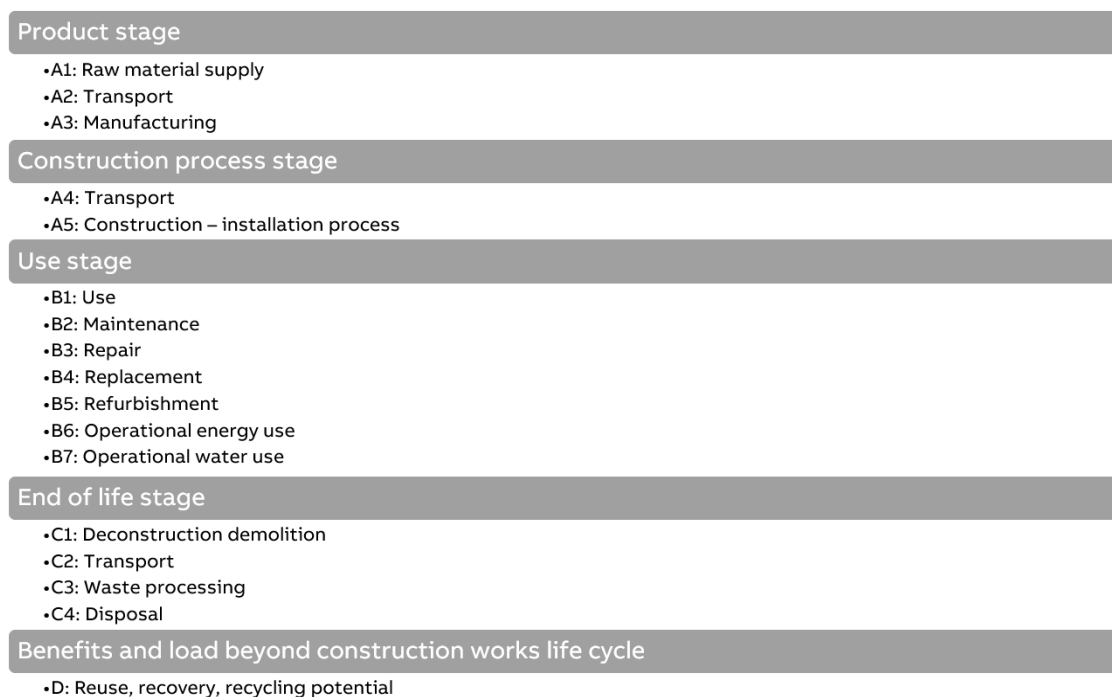


Figure 3: Life cycle modules described in EN 15804

With the emergence of PEF, there have been many instances where the differences and similarities of PEF and EPD based on EN 15804 are looked at. PEF is intended to be a harmonized methodology for the calculation of the environmental footprint of products while EN 15804 goal is transparent reporting of the environmental impact of a building product for each life stage separately. (Durão, et al., 2020, p. 3) Even if it's clear that PEF isn't an EPD scheme as defined by ISO 14025, many European companies and policymakers reportedly perceive both the PEF and EPDs as applicable tools supporting external communication or public procurement requirements, like Green Public Procurement (Del Borghi, 2012, p. 906). To align these two reporting approaches there was an amendment made for EN 15804 to align it more with PEF methodology, which is called EN 15804:2012+A2:2019. However, it will take a while before this version is in implementation because every organization that is issuing EPDs in compliance with EN 15804 needs to update their systems and processes to align with the amendment. This update process has a deadline of July 2022 after which the current version cannot be used. Before this, it is expected that the current version, EN 15804:2012+A1 is used. (One Click LCA, 2019)

One of the biggest changes that the EN 15804:2012+A2:2019 brings is that all products must declare the cradle-to-gate as well as end-of-life phases, while before the mandatory parts were only cradle-to-gate. There are however more changes, the impact indicators and parameters have increased from EN 15804+A1 to EN 15804+A2, the list for both can be seen in Appendix 3 and 4. The addition is gotten by dividing some impact categories into subcategories. For example, climate change or global warming potential is divided into four subcategories: total; fossil; biogenic; and land-use, and land-use change. (One Click LCA, 2020)

With a growing interest in recent years for the environmental aspects of electrical products and systems a core PCR for these products, EN 50693, was published in 2019. With this standard being so new, it has not yet been widely adopted. While EN 50693 is based on EN 15804, it gives more detailed requirements for electrical products that EN 15804 provides. Overall, both standards are like each other with EN 15804 giving more comprehensive requirements in some parts. The differences come from what is included in a life cycle stage. In Table 2 it can be seen what life cycles are covered in EN 50693 and how they correspond to the life cycle stages described in EN 15804. (EN 50693, 2019)

Table 2: Life cycle stages in EN 50693 and the corresponding modules in EN 15804

<b>EN50693</b>	<b>Corresponding module in EN 15804</b>
Manufacturing	A1-A3
Distribution	A4
Installation	A5
Use & maintenance	B1-B7
De-installation	C1
End-of-life	C2-C4

What is important to understand is that EN 50693 includes the potential benefits and avoided loads in their corresponding life cycle stage, meaning if some of these benefits come from

actions during the manufacturing stage, they are accounted in that stage. For EN 15804 all the benefits and loads from each stage are accounted only in module D (Figure 3). (EN 50693, 2019)

Compared to EN 50693, EN 15804 can require different characterization methods for the life cycle impact assessment and additional environmental impact categories to be reported. It is however possible to use the impacts categories described in EN 15804 while using EN 50693 because EN 50693 doesn't set any compulsory requirements regarding impact categories. (EN 50693, 2019)

### 3.2 Demand for EPDs

The number of EPDs made every year is increasing, especially the ones that are compliant with EN 15804. As of January 2019, more than 6000 EPDs, compliant with EN 15804, were published. This and the growth over the years can be seen in the following in Figure 4.

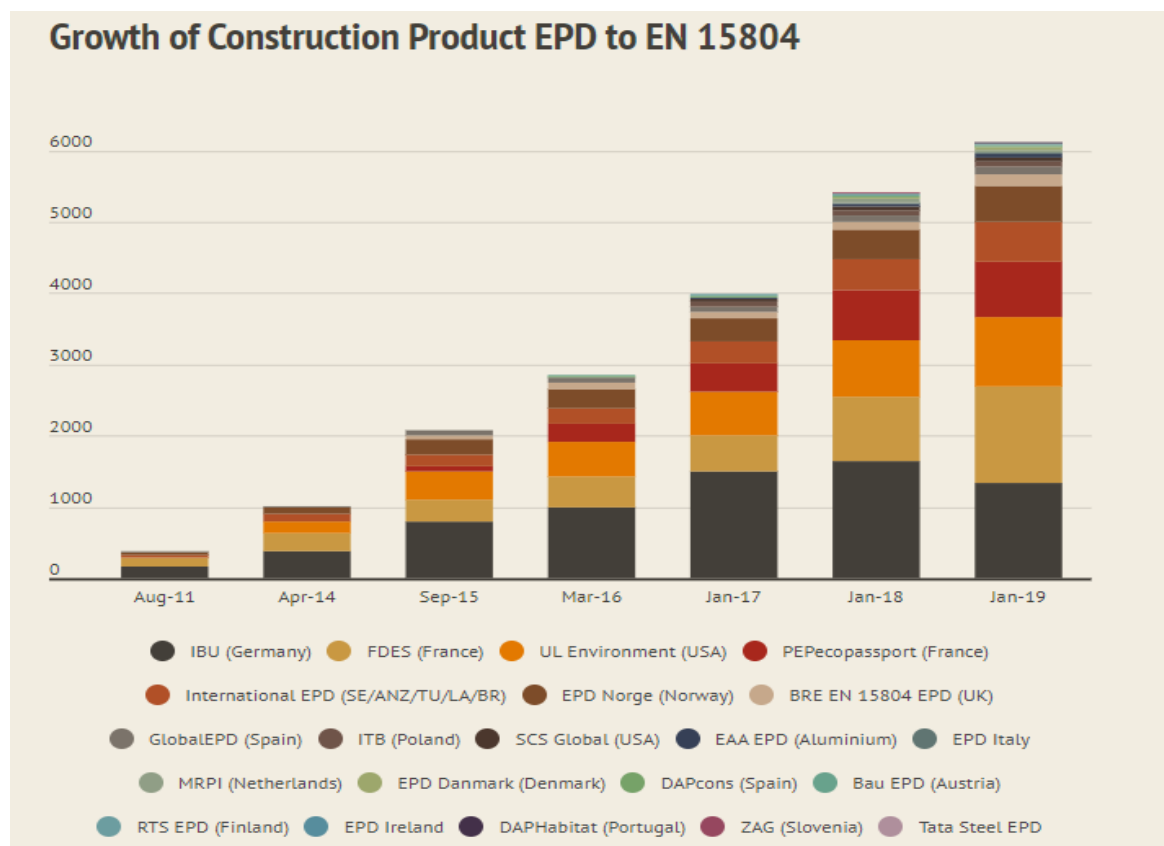


Figure 4: Growth of Construction Product EPD to EN 15804 (Anderson, 2019).

The demand for EPDs comes from many different sources. One of them is buyers and product specifiers who are asking for environmental information about the products more frequently. The EU is one of the biggest organizations that are stimulating this demand by strengthening the link between Public Procurement and EPDs. As mentioned in Chapter 1 different building or product certification schemes, like LEED, BREEAM, or BVB, are also a factor by giving credits or recommendations based on the existence of EPDs for the building and construction products. Finally, the recognition of EPDs in international trades, when exporting products, has also become an important factor. (EPD India, 2020) For example, in 2009 it was already noted that the rising popularity of EPDs around the globe and especially in Europe, can create a legal barrier to trade between markets where the structure of making EPDs hasn't been developed enough, for example in the United States at the time. (Bowyer, 2011, p. 2.)

Overall, the information that companies can gather from the process of making EPDs can be valuable and can also be one of the reasons for the increasing growth of made EPDs. These process-oriented types of reasons were found to be the main reason companies conducted LCAs in the first place and image and market-oriented reasons were some of the drives that are increased the utilization of LCAs in the form of EPDs. With the increasing use of LCA, many companies are trying to find ways to utilize it in multiple ways, to gain more value from the process and tool to justify the investment being put into it. One of these is utilizing the LCA results in marketing for example. Providing LCA results in an ISO-compliant form, like in an EPD or eco-label, gives the information and company providing it more credibility. EPDs present comprehensive information that is third-party verified, in a way that products can be compared fairly. This also provides the companies with another advantage by the possibility of comparing their products to their competitors. Also, by a company just providing an EPD for its products or services it can give the company an already better image than its competitors regarding sustainability and environmental issues in the potential customer's eyes. (Bowyer, 2011, p. 4; Nygren & Antikainen, 2010, p. 13.)

### **3.3 EPD Program operators**

An important part of the development of EPDs is the different programs and program operators which are established in the ISO 14025 standard. To officially publish a type III environmental declaration in an accordance with ISO 14025, it must be administered in the scope of a program operator operating under ISO 14025. The responsibilities of a program operator include preparing, maintaining, and communicating general program instructions, ensuring that requirements established in ISO 14025 are followed, publishing PCR documents and maintaining publicly available lists and records of these PCR documents, and EPDs made within the program. (ISO 14025, 2010, pp. 6-7.)

With EPD gaining popularity, especially in the building sector, the number of these EPD programs has also grown. Many of them are specified for the country they are based in, while some of them are specialized for specific product groups. Some examples of the different programs can be seen in Appendix 1. (ECO Platform, 2019.)

All the programs from Appendix 1 are following ISO 14025 and for many of them, their operation being in some way related to the construction industry these programs also follow EN 15804. This means that when making and publishing an EPD under one of the programs the EPDs can be expected to be following ISO 14025 and EN 15804 standards. For the program operator, this means that their PCR and other guidelines must following EN 15804 as well as ISO 14025. (ECO Platform, 2019.)

#### **3.3.1 ECO Platform**

To make sure that the EPDs and the PCRs are following standards like ISO 14025 and EN 15804 a group of program operators, LCA practitioners, industrial associations and other stakeholders came together and formed a non-profit called ECO Platform. This organization is a European based international non-profit association that aims to guarantee a coherent framework for EPDs based on ISO 14025 and EN 15804. (ECO Platform, 2018; Del Borghi, 2012, p. 294.)

The ECO Platform itself is not a program operator but they are the umbrella organization under which different program operators are recognized, like the programs listed in Appendix 1. All EPDs registered under these program operators have a mutual recognition between the other program operators, meaning one program operator isn't above another. Overall, the ECO Platform is well recognized in all European and International markets, which brings added value to an EPD register under the ECO Platform, because their quality and acceptance is guaranteed in most markets. (ECO Platform, 2018)

### **3.4 Business values of EPDs**

While EPDs are voluntary, their use and the making of them has rapidly increased, as has the awareness about environmental impacts overall. With this, several benefits are related to EPDs, with parties on both sides of the processes benefiting. (One Click LCA, 2020)

One of the most obvious benefits for both parties is the gained knowledge, what differs is what type of knowledge is gained from an EPD. For the company making an EPD, they learn about their product and its life cycle, including how a decision made during its life cycle can affect its environmental impacts. (brands & values, 2019) Several stakeholders have also recognized there is the value in obtaining this knowledge (Andersen, et al., 2019, p. 6). Gaining more knowledge about the products, the raw materials used and the manufacturing process, in general, can be a huge benefit for the company because information learned during the making of EPDs can instruct the company in future decision-making situations and give the company improvement ideas that they would not have gained otherwise. These situations can be choosing between two raw materials or sub-contracted products and changing something in the manufacturing or transportation processes of products to be more environmentally friendly and sustainable. (brands & values, 2019) By utilizing the gained knowledge together with ecodesign can bring several benefits that include economic, legislation fulfilment, innovation and creativity promotion, public image improvement and employee motivation enhancement (Navajas, et al., 2017, p. 1).

For the party receiving the EPD, the main thing they learn is information about the product in question, which they can then use when comparing different products or just overall

knowledge on what type of environmental impacts this product group has or what materials these kinds of products consist of. (brands & values, 2019)

EPDs can also influence the company's brand image. As stated, above image-oriented reasons are one of the drivers for the demand of the EPD. For a company providing an EPD, it shows to the possible customer that the company is thinking about the environmental issues and their transparency in sharing this information gives the potential customer more ways to believe it. This is important in today's world where customers are more environmentally conscious, and these things are starting to be reflected in customers buying decisions. (Andersen, et al., 2019, p. 6; Nygren & Antikainen, 2010)

The possibility of EPDs becoming mandated in some industries or countries is an important aspect to consider also. Like mentioned before many companies are starting to adopt LCAs and EPDs to their business because they are anticipating these could become mandatory in some respects in the future. Gaining a competitive advantage by adopting LCAs and EPDs before this can be a huge advantage for the company. By being on the forefront of these issues can also give companies the possibility of affecting future practices and legislation, by being part of the conversation about the topic in the industry and being a model example of how things are done. They could become the industry norm that other companies would follow. (Andersen, et al., 2019)

### **3.5 Comparability of EPDs**

As mentioned before problems in comparing EPDs have been the reason that guidelines like EN 15804 have been made and the reason for the formation of the ECO Platform. This is because comparability is a critical aspect of EPDs. One of the main goals and purposes of the declarations is to allow people to compare the environmental performance of products on a life cycle basis. Therefore, certain information must be provided transparently, so the one doing the comparison can understand the possible limitations of the comparison. True comparison between EPDs is hard to achieve, especially if the EPDs compared are from different companies. (ISO 14025, 2010)

To help this issue of knowing when some EPDs can be compared with each other, ISO 14025 has specified conditions that should be met for comparability to be achieved. These conditions can be seen in Figure 5 (ISO 14025, 2010, pp. 10-11).

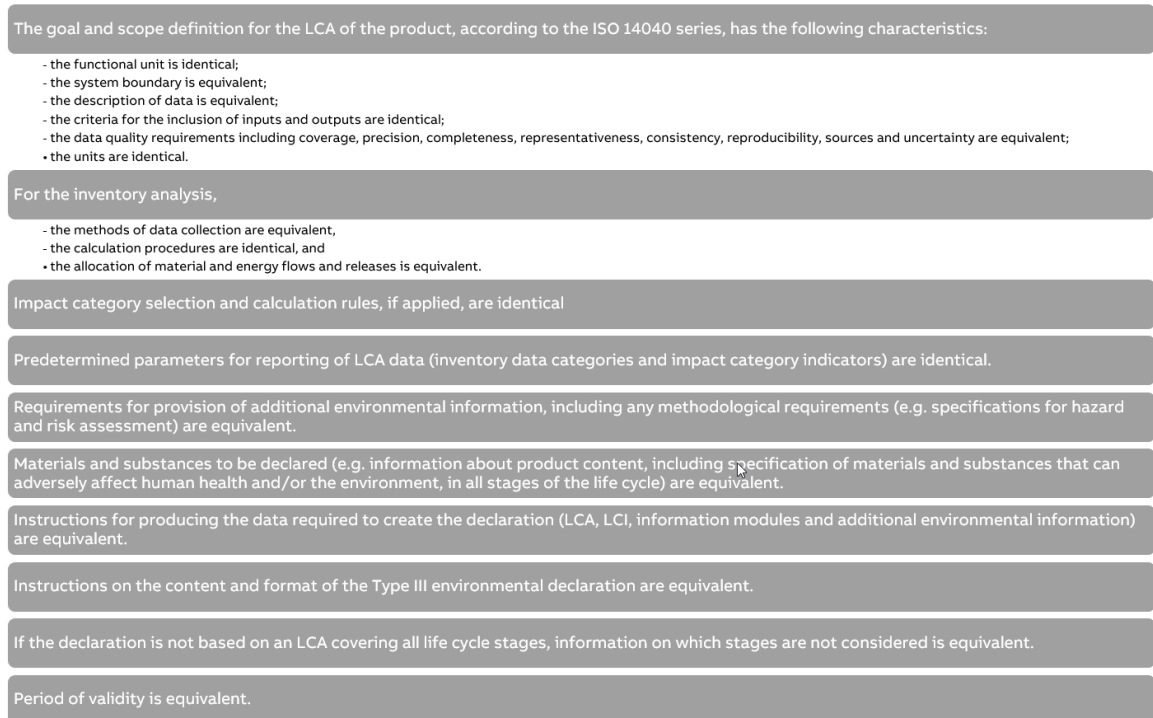


Figure 5: Comparability requirements of the EPDs

Generally, these conditions can be met when choosing EPDs that have been registered based on the same PCR and developed based on the general LCA methodology under the same EPD Program operator. This however doesn't ensure it completely because there can be variation regarding LCI databases and overall process used in the study. And in some cases, the lack of knowledge based on the information provided in the EPD for some life cycle stages can hinder the comparability. For example, the information provided for the End of Life stages can be quite vague in some EPDs, meaning the reader doesn't reliably know what happens to the product in this stage. There is the possibility that EPDs can fulfil the comparability conditions in other cases, but it puts additional requirements on the reader of the EPD to understand if the information is comparable or not. (ISO 14025.)

## 4 STEPS TO CREATE EPD'S FOR CONSTRUCTION PRODUCTS

The steps to creating an EPD for a construction product can be seen in Figure 6. This is based on the different standards for LCAs and EPDs, with input from different EPD program operators' PCRs, and other instructions that they provide regarding the making of EPDs. It is assumed that in this case, it is already known to what product or products the EPD is intended to be made and that these products fall under construction products.

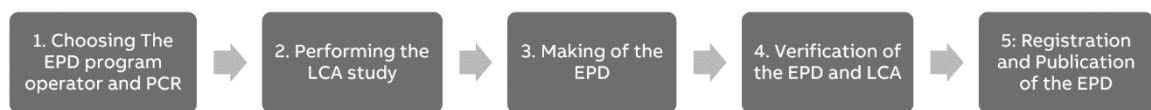


Figure 6: Steps for creating an EPD

Because of the variety of different products that fall under construction products, these steps are looked at in a more general view that applies to all construction products. This means that the chosen PCR is assumed to EN 15804. It is however stated where information can be gathered from if more specific information is need needed or possible to get. Steps like performing the LCA study and making of the EPD contain multiple steps inside them which are also cone thorough.

### 4.1 Choosing the PCR and The EPD program operator

An important aspect that influences the EPD itself and the process of making it, is the chosen PCR. Therefore, the first step of making an EPD is to have a PCR for the product or products the EPD is going to be made for. (Subramanian, et al., 2019, p. 1.)

Because PCRs establishes rules that apply to an entire product category, which can consist of different manufacturers, the PCRs are developed with input from a wide range of stakeholders (Bowyer, 2011, p. 4). The organizations and companies who are making the PCRs are usually separate from the people how are making the EPDs themselves. It is recommended to use already existing PCRs because this saves time and resources for the

one only making an EPD. When using a reliable source for the PCRs, the user can also be sure that they are complying with the necessary standards and that the PCR is third-party verified. One reliable source for these PCRs is the different EPD Program Operators. This is also the reason why the process of choosing the PCRs and the program operator goes hand in hand.

When choosing an EPD Program Operator it is important to know what the intended use of the EPD is. If the EPD is intended to be used in the international market, especially in the EU, it is good to choose one of the program operators that are part of the ECO Platform. (ECO Platform, 2018) The main factors that influence the choice are the location of the company that is doing the EPD and what type of products the EPD is intended to be done for. As seen in Appendix 1, programs can be specified for a specific market or specific product families or groups. For example, a program operator could be a great match otherwise, but it doesn't provide a suitable PCR for the product. Other aspects like where and how the EPD is intended to be used can also influence this decision. One of these can be having the possibility to compare other similar products in the market, which is why choosing the same program operator and therefore the same PCR can be important factors to needs to be fulfilled.

## **4.2 Conducting an LCA study**

To make an ISO 14025 compliant EPD the LCA needs to be also ISO-compliant. This means that the LCA study is made based on ISO 14044 and ISO 14040, as mentioned before. Other guidelines to consider are the general instructions of the program operator, the chosen PCR, or in this case EN 15804. (ISO 14025, 2010)

The ISO 14040 and ISO 14044 standards provides a four-stage iterative framework for conducting LCA analyses. These four steps include goal and scope definition, inventory analysis, life-cycle impact assessment, and interpretation. These phases and their relation to each other can be seen in Figure 7. (ISO 14040, 2006, pp. 7-8.)

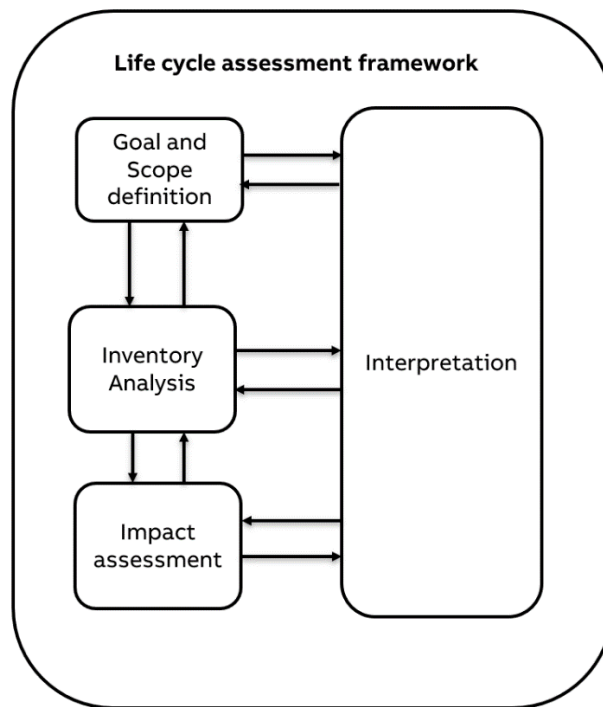


Figure 7: Stages of an LCA

What is important to understand is that an LCA is an iterative methodology, meaning things are refined as the study goes along (Golsteijn, 2018).

#### 4.2.1 Goal and Scope Definition

This step aims to ensure that the LCA is conducted consistently (Golsteijn, 2018). To do this the following aspects for the study are established: the functional unit, system boundaries, and quality criteria for inventory. The study's intended application and the reason for doing the study are also outlined. It is also important to define who the study is intended for and for what purposes the study is intended for. Different aspects like allocation procedures, data requirements, made assumptions, selected impact categories, methodology of impact assessment, and subsequent interpretation that are used in the LCA are also defined. (ISO 14040, 2006) The challenge when making these decisions is to make sure that they don't influence the result too much, especially when working on complex life cycle models (Golsteijn, 2018).

Many of these choices can be subjective and when making an LCA, the study and the results are always unique. With EPDs the importance of transparency and comparability are high, and it is important for the LCA and the EPD that the decisions made in this step are based on information for products of the same category. Therefore, many of the instructions gotten from the PCR or EN 15804 are related to these decisions, like the functional unit, system boundaries, and cut-off criteria, that affect the overall LCA most critically. (ISO 14025, 2010; EN 15804, 2012)

As seen in Figure 3, EN 15804 standard instructs on what life cycle stages can be included in the LCA study. These life cycle stages are separated into different modules for better understanding:

- A1-A3: Product stage, information modules
- A4-A5: Construction process stage, information modules
- B1-B5: Use stage, information modules related to the building fabric
- B6-B7: Use stage, information modules related to the operation of the building
- C1-C4: End of life stage, information modules
- D: Benefits and loads beyond the system boundary, information module

The D module is a new addition in the EN 15804 from the new A2:2019 amendment and is not mandatory in any type of EPD until July 2022. What modules are declared depend on what type of EPD is made, but for all EPDs that are made under the EN 15804 the mandatory modules are modules A1-A3, modules C1-C4 and after July 2022 module D. Based on these guidelines, Program Operators can add more modules to their instructions. In many cases, the use stage is also something that many program operators want to consider, to form a full cradle to grave LCA study. From the table in Appendix 5 there can be seen different examples of different types of scopes for EPDs and what modules are mandatory or optional for each case.

#### **4.2.2 Inventory Analysis**

The life cycle inventory analysis (LCI) phase includes data collection and calculation procedures to quantify relevant inputs and outputs of a product system. Data is collected for each unit process within the system's boundaries. The data can be in the following categories:

- inputs and outputs
- products, co-products and waste
- emissions to air, discharges to water and soil
- and other environmental aspects.

Data collection is an important phase of the LCA because the quality and reliability of the data collected in response affect the quality and reliability of the calculations and so forth the whole study. Following the data collection, calculation procedures are done. These include validation of the data collected, the relation of data to unit processes, and the relation of data to the reference flows of the functional unit that are needed to generate the results for each unit process. The EPDs ISO 14025, EN 15804, and especially PCR give instructions on what type of data should be collected and in what form. These include requirements for the primary data that is collected and what is expectable as secondary data. (ISO 14040, 2006, p. 13.)

After the calculations are done, the flows and releases from the different processes are allocated. This is especially important for cases where the process produces more than one product, or some products are recycled as raw materials inside during the process. An example of this situation is a CHP plant, where both heat and power are produced. The question of how to calculate what share of the resources and environmental impacts go to heat or power, is what this part is about. Instructions and guidelines for these cases with construction products are given in EN 15804 and more products specified instructions in the PCR.

#### **4.2.3 Impacts assessment**

The significance of potential environmental impacts is evaluated in the life cycle impact assessment (LCIA) phase using the results gotten from the LCI phase. To do this the phase involves interpreting and transforming the LCI results into understandable impact categories and category indicators. This phase includes two types of elements: mandatory and optional. The mandatory steps include the definition and classification of impact categories, and characterization. The optional elements include normalization and weighting. How the process of LCIA advances can be seen in Figure 8. What makes this phase critical is that the decisions made during this phase directly affect the results. (ISO 14040, 2006)

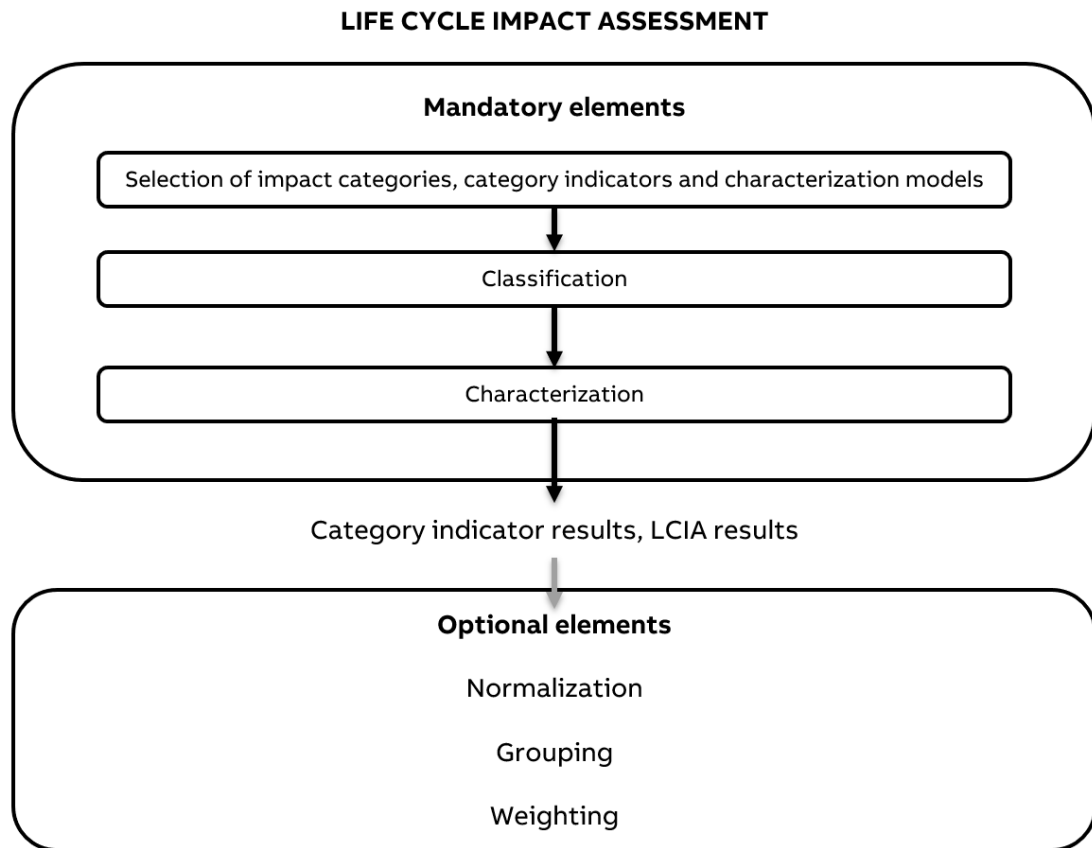


Figure 8: Elements of the LCIA phase

As seen in Figure 8, the first of the mandatory elements include the selection of impact categories, category indicators, and characterization models. Impact categories are a class representing environmental issues of concern to which life cycle inventory analysis results can be assigned, meaning an impact category groups different emissions into one effect on the environment. Because emission data collected during the LCA comes in different shapes and formats impact categories are used to unite the different emissions into actionable numbers, meaning that they are converted into one unit that translates into one impact category, like for example, global warming or ozone depletion.

What impact categories and indicators are chosen depends on the LCA that is made. For this the ISO standards and other instructions or standards used during the LCA study give instructions on what categories and indicators should be selected. Many of these impact categories and indicators are grouped to form an LCIA method. Some of the most well-

known methods are CML, IMPACT, IPCC, and ILCD. Many of these methods contain the same impact categories and indicators, but there are some variations on what impact category or indicator is included in which LCIA method. (ISO 14040, 2006; Hillege, 2019; Acero, et al., 2015)

When making an EPD, EN 15804 standard gives instructions as to what impact categories and indicators need to be chosen for the EPD. These categories and indicators include, for example Global warming potential, Ozone Depletion, Acidification, and Water use. For construction products, there is a mandatory list of impact categories that all EPD must declare if they are following EN 15804. A full list of the impact categories and indicators that are relevant for EPDs can see in Appendix 4. For an EPD there is no need to perform the optional elements of the LCIA phase. (EN 15804, 2012)

#### **4.2.4 Life cycle interpretation**

The results for the LCI and LCIA phase are looked at together in the life cycle interpretation phase. The findings from this phase should align with the goal and scope of the study that was set at the beginning. These findings may take the form of conclusions and recommendations to decision-makers. The interpretation phase is also expected to provide an understandable, complete, and consistent presentation of the results of an LCA. This phase may involve the iterative process of reviewing and revising the scope of the LCA, as well as the nature and quality of the data collected in a way that is consistent with the defined goal. Therefore, the LCA study overall can be looked at as a learning process, where steps are usually revisited and modified during the process. (ISO 14040, 2006, pp. 15-16; Nygren & Antikainen, 2010, p. 9.)

#### **4.2.5 Reporting**

Reporting is an integral part of an LCA because it is the way the calculations and results of the LCA study are presented. ISO 14040 standard gives general instructions for the reporting of the LCA with more specific requirements given in ISO 14044. An important aspect that dictates what the report should consist of is who the report is intended to, mainly is it going to be publicly available or is it internal. Overall, the LCA report should address the different

phases of the study, and the results and conclusions should be reported in an adequate form to the intended audience. It is important to address the data collection methods and assumptions applied in the study, and the limitations these bring to it. If the LCA and its results are intended to be disclosed to the public, ISO 14044 provides more specific requirements for this. For example, ISO 14044 requires full transparency in value choices, rationales, and expert judgments when reporting the interpretation phase. (ISO 14040, 2006, p. 16.)

With EPDs ISO 14025, EN 15804 and the PCR give more specific instruction about what should be considered in the LCA report. It is an important aspect to know that with EPDs the LCA report is not part of the public communication. Overall, the LCA report for EPDs should contain any data and information of importance for the data published in the EPD and as required in the EN 15804. Transparency when reporting how the data and information declared in the EPD that results from the LCA study should be done with special care. The results, data, methods, assumptions, limitations and conclusions of the LCA shall be completely and accurately reported without bias. (EN 15804, 2012, p. 44.)

### **4.3 Making of the EPD**

After the LCA study has been completed, the results of the LCA study and other information mandated by the PCR are compiled in the EPD document. From all these standards and instructions, they provide guidelines on what type of the contents of the EPD should include and how the declared content should be presented. There can be some differences in the reporting methods between program operators and with what PCR is used which is why EPDs can look quite different from each other. This is also extrapolated between different companies when the overall look of the EPD has been made to suit the company and their branding. Some program operators offer generic templates for EPDs that can be used, but this can vary between program operators. The biggest differences in reporting come in the form of how information and results are presented, but all the same core content that is mandated by ISO 14025 and EN 15804 is found in all EPDs that are made for construction products. (ISO 14025, 2010; EN 15804, 2012)

ISO 14025 instructs that the following aspect should be reported in the EPD according to the PCR used:

- identification and description of the organization making the declaration
- description of product and product identification e.g. model number
- name of the program and the program operator's address and, if relevant, logo and website
- PCR identification
- data of publication and period of validity
- data from LCA, LCI or information modules
- additional environmental information
- content declaration covering materials and substances to be declared
- information on which stages are not considered, if the declaration is not based on an LCA covering all life cycle stages
- statement that environmental declarations from different programmes may not be comparable
- information on where explanatory material may be obtained

As it can be seen many of the requirements are related to the identification of the product and company, but also information based on which it can be known what guidelines were used to make the document in the first place.

#### **4.3.1 EPD covering multiple products**

An EPD can cover simultaneously other products than the reference product. There are quite a few instructions on how the other products should be chosen and how they should be taken into account regarding the results in ISO 14025 or EN 15804. (ISO 14025, 2010; EN 15804, 2012) The criterion based on which different products can be chosen is mainly defined in the chosen program operators' PCRs. They define what are the criteria's based on which the products can be chosen and how the chosen products are taken into account in the results.

One example of this type of criteria is that the products chosen must belong to the same homogeneous environmental family as the reference product. This means that the group of products must have the same main functionality, product standards, type of materials, and manufacturing processes. (PEP PCR, 2015, p. 14.)

For many of the other products, the environmental data, material balance, or environmental impacts can differ from the reference product. For these situations' extrapolation rules are

one example of how the data can be estimated at every stage of the life cycle, for each product covered in the EPD and LCA. If these rules are used the PCR will provide more detailed instructions for how this is made, and what process is used. What is important how these estimations are made, and the process should be documented in the LCA report, and all the products that the EPD covers are mentioned in the EPD and LCA report. (PEP PCR, 2015, p. 14.)

#### **4.4 Verification**

After the EPD is complete, it is the turn of the verification process. With EPDs the verification process is managed by the EPD program operators, so for the company making the EPDs the instructions to follow in this stage come from the program operators. The program operators have developed their rules for verification following ISO 14025, ISO 14020, and ISO 14040 standards. Overall, the EPD is reviewed to make sure it complies with requirements from ISO 14020, and ISO 14025 standards, the general instruction of the program operator and the PCR. (ISO 14025, 2010)

What is good to remember is that for the EPD to be accepted, both the LCA study and the EPD must be reviewed and verified. Some differences can be between program operators in how these verification procedures are done. For example, the program operators may want the LCA verification to be done first before the EPD verification and with some programs, the verification of both documents can be done at the same time. The last-mentioned being the most prominent. (ISO 14025, 2010)

Differences in the verification process can also come from is how is accepted as a third-party verifier. For some programs any third-party verifier can work, while some programs have made a list of verifiers that must verify the LCA and EPD so the EPD can be published under that program. In these cases, the program operator has set up their process in verifying these verifiers. For both cases, the program operator has provided the instructions. (PEP Ecopassport program, 2020)

## **4.5 Registration and publication**

There aren't guidelines for the registration and publication of the EPD in ISO 14025 or EN 15804 (ISO 14025, 2010; EN 15804, 2012). The guidelines for these parts are usually given by the used EPD program operator. Generally, after verifying the EPD, the process of registration and publishing the EPD requires the company to send the EPD and related documents to the program operator after which these are checked by the operator and the EPD registered to their program. This is usually followed by the publication of the EPD in the program operator's system and database and after getting the confirmation that the EPD is accepted the company can publish the EPD on their own system and site as well. (The international EPD system, 2020; PEP Ecopassport program, 2020)

## **5 WHY THE ABB WA EPD PROGRAM IS MADE?**

Like mentioned before sustainability and environmental issues have become important aspects for all industries and companies and this is the same for ABB WA. Over the last few years, environmental information and issues have gained a bigger part in the decision-making process. One of the biggest drivers for making EPDs for ABB WA are different market and customer requirements. Organizations like BVB and customers in general are starting to require EPDs or the information that the EPDs provide about the products (BVB, 2019).

EPDs have been done in ABB WA many years ago, but because those haven't been updated, the knowledge of how they were made isn't there anymore. Therefore, making new EPDs, or LCAs for that matter, is looked at as important tool to gain knowledge of how they are done and how they could be useful in the future. Overall understanding more about different products' life cycles and how each life cycle process and different decision can affect the life cycle are important information to learn. There is also interest to incorporate ecodesign to product development that would need use of LCAs. There is also plans to start tracking different environmental aspects of the operations in ABB WA were LCAs and knowledge from them would be useful.

### **5.1 Products the pilot EPDs are made for**

To further enhance the knowledge ABB WA can get from this program and the pilot EPDs, more than one pilot EPD is made. Overall, there will be three EPDs made for three different products or product groups. These products represent the three different types of product categories that are made and sold by ABB WA: wiring accessories, electronic products, and installation materials. By making the EPDs based on these products ABB WA get a variety of information from the LCAs. This is because of the differences in their manufacturing processes and the materials that are used in the products. This will help understand how the process of making the EPDs can change based on which product the EPD is made for. ABB WA also gets benchmark results for each type of product, which helps further the understanding of how the results vary between product types and what aspects of the

products contribute to the results the most, one the bigger scale when comparing different life cycle stages like manufacturing stage and end-of-life stage, but also what contributes most inside these stages.

The selection of the products is done based on what products are the most popular in the representative markets and which represent the product category the best based on the manufacturing process and materials used. The availability of data for the LCA calculations also influenced what products were chosen. Based on these criteria the chosen products are a junction box, a socket outlet, and a combination thermostat.

### 5.1.1 Junction Box

For installation materials choosing the product was the easiest. Junction boxes (APX series) are one of the most popular products made by ABB WA overall, especially the AP9 and AP10 (Figure 9). The reason these were chosen was that they are very similar products, both are made of the same materials using the same manufacturing processes, they are just different sizes.



Figure 9: Picture of AP9

This EPD is planned to include more than one product, this is because the products in this range are all similar in how they are made and what materials they contain. The EPD would contain both AP9 and AP10, and all their different color options as seen in Table 3.

Table 3: AP9 and AP10 different color options

<b>Product Color</b>	<b>AP9 Product Size</b>	<b>AP10 Product Size</b>
White	AP9	AP10
Gray	AP9/G	AP10/G
Black	AP9M	AP10M
Green	AP9V	
Red	AP9R	

For the EPD, the reference product for the LCA calculations is AP9. The other products will be part of the EPD with their results being based on the extrapolation rules.

### **5.1.2 Socket Outlet**

For wiring accessories, the main decision was choosing either a switch or a socket outlet as the representative product, and the socket outlet was chosen from these two. There are however many different types of socket outlets that are made by ABB WA, so a decision on which socket outlet was chosen had to be made also. The chosen socket outlet is a white Impressivo 2-gang socket outlet, 302EUI-84. This socket outlet was chosen because it is one of the popular socket outlets and it is a good representation of the manufacturing processes of socket outlets in ABB WA.



Figure 10: Picture of 302EUJ-84

As with the junction boxes, the possibility of adding more similar products to this EPD is also looked at. In this case, the most logical products that could be added to this EPD would be the different color versions of this product as seen in Table 4.

Table 4: Different socket outlet versions considered for the EPD

<b>Product code</b>	<b>Color</b>	<b>Additional information</b>
302EUJ-84	White	-
302EUJ-81	Anthracite	-
302EUJ-83	Aluminum	-
302EUJ-885	Black matt	-
302EUJ-886	Painted Steel	-
302EUJ-884	White matt	-
302EUJM-84	White	sold in 100 pc packs

The reference product for this EPD would be the 302EUJ-84 socket outlet and the other products results would be based on the extrapolation rules, like with the junction boxes.

### 5.1.3 Thermostat

For the electronic products, Combination thermostat was chosen. It was chosen because it had data available that could be used for the making of the EPD. The thermostat also brings a variance with its main manufacturing not taking place in Porvoo when comparing it to the products from wiring accessories and installation materials. Figure 11 illustrates what the thermostat looks like.



Figure 11: Pictures of the different versions of the thermostats

The thermostat is sold in three different versions. These versions include the thermostat with Jussi or Impressivo design white center plates, and in the third version where the thermostat can be bought as an insert without any center plates. With this version, the thermostat needs center plates that are bought separately. In Table 5 the different types of cover plate options are presented.

Table 5: Different versions of center plates for TC16-20U

Center plates	Design	Color
6435-214	Jussi	White
6435-84	Impressivo	White
6435-83	Impressivo	Aluminum
6435-885	Impressivo	Black matt
6435-866		Painted steel
6435-884		White matt

For the LCA and EPD made for this product range, the reference product for the study is the thermostat with the Impressivo center plate. The other product versions are considered in the EPD with their results being presented based on the extrapolation rules.

## 5.2 EPD Program operator and PCR selection

As stated in chapter 4.1, choosing the PCR and the EPD program operator are the first things that are done when starting to make EPDs. With this case, the biggest factors that influenced the choice of both were the products that the EPDs are planned to be done for and what PCRs and program operators' other companies that make similar products are using. This is for knowing what type of PCRs and program operators are out there and having the future possibility to compare the EPDs of these different products. An important aspect that also drove the decision choosing a program was for the EPD to comply with EN 15804 standard and be registered in one of the international EPD programs (Appendix 1). One way for these requirements to be met is to choose a program operator registered under the ECO Platform.

When starting to look at different program operators it started by looking at some of the biggest and most well-known programs. Mostly to get to know what type of information and instructions these types of programs are providing. The Finland based Program Operator, The Building Information Foundation, was also looked at because of the connection of the

Finland being relevant. The biggest issue with many of these programs and the reasons they weren't chosen were the PCRs that they provided. Some of them are quite general, that are meant for a wide range of construction products and if there were some PCRs made specifically for some product categories those categories didn't match with the ABB WA products that the EPDs are going to be made. (The Building Information Foundation RTS sr., 2020)

Based on these parameters a program called PEP Ecopassport was chosen. It is a French-based EPD program operator with a focus on electrical, electronic, and HVAC (heating, ventilation, air-conditioning, refrigeration) products. It is developed and operated by a non-profit organization called PEP Association. This program is registered under the ECO platform but the main reason that this program was selected was its focus on electrical, electronic and HVAC products and also other companies that similar products are also using this program which gives ABB WA the possibility to compare their products to other similar ones. (PEP Association, 2020)

With PEP Ecopassport there is a general PCR that goes for all product categories that they cover but then there are specific rules for different product categories called Product Specific Rules (PSR) that complements the general PCR. One of these PSRs is chosen that best matches the reference product of the intended EPD. The PSR chosen for this case is called Electrical Switchgear and Control Gear Solutions. (PEP Ecopassport, 2020a) What works well with the products chosen for this case is that this PSR works for all three of the different products (PEP PSR, 2016, p. 6.).

### **5.3 LCA Software and LCA database selection**

LCA calculations are done with specific software. There are many different types of software available that could be used and some of the most well-known software's are Gabi and SimaPro for example. (Ecochain, 2020) However, for these calculations, the software chosen is called openLCA. This is open-source and free software for sustainability and life cycle assessment that plays in the same league as the above-mentioned commercial software's (openLCA, 2020). This software was chosen because there were already some experiences

inside ABB organization with using the openLCA software. This way there would be at least some type of internal support if there are problems with the calculations in a regard to usage of the software.

For the calculations to be made databases are usually needed to get data for some life cycle process that could not be collected otherwise. Some LCA software's can include a few databases but, in many cases, there can be a need to add a specific database that would then be used. For all LCA software's, the databases could be built on the companies or industries own data, but this can be quite time-consuming, and would need this data to be collected already. Probably the most common solution for this is to use already existing databases that have been made with the help of different organizations. Some of the most well-known databases are made by ecoinvent and thinkstep (openLCA Nexus, 2020).

For the ABB WA EPD Program, two databases are used: ecoinvent and ELCD. Ecoinvent was looked at before PEP Ecopassport was chosen because of the experiences that ABB already had internally about the database and working with it on the openLCA software, which was deemed to be a good choice for this type of calculations. Ecoinvent is a world leading LCA database and it provides well-documented process data for thousands of products. The version that is used is for the calculations is ecoinvent 3.6 that was published in the fall of 2019. (ecoinvent, 2020b; ecoinvent, 2020a)

With the knowledge of what program operator and PCR is going to be used for the calculations, some guidelines regarding the chosen database came from those. PEP Ecopassport has instructed that the database called ELCD should be used, for example, with electricity consumption scenarios to ensure comparability of EPDs (PEP PCR, 2015, p. 11). This prompted a question of should this be the only database used, but when looking more into this database more clearly it was found that it hasn't been updated in recent years. Based on this it was decided that both databases are used for the calculations were ecoinvent would be used to fill in the missing data caps in the collected data and ELCD would be used for the situations where the PCR or PSR mandate it, and if something can't be found in the ecoinvent database.

## **6 THE LCA CALCULATIONS AND LCA REPORT**

The LCA calculations for each of the three products or product groups are gone through here in the order of the life cycle stages included in the system boundaries of the studies. The system boundaries are the same for each product and they are set by the PCR of the PEP Ecopassport (Appendix 2). Going through each of these stages will include what the PCR and PSR requires for each stage, what data was then collected and used, what other decisions were done affecting the calculations of the stage and overall how the LCA calculations go. Before going through each lifecycle stages, some overall information for the LCA calculations is gone through, that isn't directly tied to some specific life cycle stage. The information can affect all products or just one specific product or product group. This can be, for example, the functional units, cut-off criteria, reference lifetime (RLT) or the impact categories required in the results.

### **6.1 LCA report**

The LCA report is constructed based on the LCA calculations and the decisions made during the calculations. As stated before the LCA report is not made publicly available, only the authorized verifier sees the report. The report aims to demonstrate that the made analysis, the LCA study and EPD, complies with the rules in the PCR. (PEP PCR, 2015, p. 19)

The PCR gives the overall instructions on what should be included in the report. They are the following (PEP PCR, 2015, p. 19):

- General information
- Scope of the study
- Life cycle inventory
- Environmental impacts
- Additional environmental information

The general information includes the basic information for the LCA report, like date, name author of the report, versions of the used PCR and PSR, and period of validity. This and the scope of the study part works as the same as the goal and scope phase from the ISO 14040 standard (Figure 7). As stated in ISO 14040 standard, in this phase functional unit and the reference flow are indicated, the life cycle stages are considered. The life cycle inventory

part should contain descriptions of each of the life cycle stages, with identification of all material, components, and processes inside it, and justification to all approximations or exclusions made for the calculations. The LCA report should also include a list and units of elementary flows. (PEP PCR, 2015, p. 21)

In the environmental impact assessment part, the software and version used to make the calculations are identified. Overall, the environmental impact results are to be expressed with three significant figures in the corresponding unit for each of the life cycle phases and the total life cycle. If the LCA and EPD are intended to contain other products from the reference product's homogenous environmental family, the extrapolation rules, the definition process of extrapolation rules, and justification of these rules are described also. (PEP PCR, 2015, p. 22)

## **6.2 General information for the LCA calculations**

Before the calculations are done the goal and scope of the LCA study need to be set as stated in chapter 4.2.1. For LCA studies made for EPDs, this information can be found from the PCR and PSR. From those, the functional units, reference flows, system boundaries, cut-off criteria, and others are defined. (PEP PCR, 2015, p. 5; PEP PSR, 2016, p. 5.)

The system boundaries are the same for each of the pilot EPDs and that is stated in PCR (Appendix 2). The life cycle of a product is separated into five stages: Manufacturing, Distribution, Installation, Use, and End-of-life stage. What is important to take note of is that reuse, recycling, and energy recovery are out of the system boundaries range. (PEP PCR, 2015, p. 9.)

The cut-off criteria used by default for each of each stage is the following (PEP PCR, 2015):

- The mass of intermediate flows not taken into account shall be less than or equal to 5% of the mass of the elements of the reference product corresponding to the functional unit
- The energy flows not taken into account shall be less than or equal to 5% of the total use of primary energy during the life cycle of the reference product corresponding to the functional unit

As seen with the cut-off criteria the functional unit of the product is important for the whole study. This information is gotten from the PSR. Before this can be done the correct product category inside of the PSR needs to be chosen. These product categories are the following: Unequipped enclosures and cabinets for the junction box; Socket for the socket outlet; Thermostats and programmable thermostats for the thermostat. Based on this the functional unit for each reference product can be seen in Table 6. (PEP PCR, 2015, p. 10; PEP PSR, 2016, pp. 13-17.)

Table 6: Functional units for each product (PEP PSR, 2016, pp. 13-17).

<b>Reference Product</b>	<b>Functional unit</b>
Junction box	Protect persons during 20 years against direct contact with live parts and allow grouping monitoring, control and protection devices in a single enclosure or a cabinet having the following dimensions 86x86x39 mm, while protecting against the penetration of solid objects and liquids (IP65).
Socket outlet	Connect/Disconnect during 20 years the plug of a load consuming 16A under a voltage of 250V while protecting the user from direct contact with live parts and with a protection class IP12.
Thermostat	Control during 10 years the ambient temperature set by the user in N zones, in a range of 0-35, with a temperature step of Y, according to Z temperature set points and characterized by a rated current of 16A

Other information gotten from the PSR for each of the reference products is their RLT. From the above Table 6 it can be assumed that for both junction box and socket outlet their RLT is 20 years while for thermostat it is 10 years. (PEP PSR, 2016, pp. 13-17.)

For environmental impact calculation, the PCR has selected the indicators. These indicators are classified into two categories: a common base of mandatory indicators and optional indicators that companies are free to choose and declare. The detailed definitions of the indicators are specified in Appendix 3. (PEP PCR, 2015, pp. 17-18.)

### **6.3 Data Collection requirements**

The data collected for the calculations can be separated into two groups, primary and secondary data. For both data types, the PCR has set requirements for what each data type should meet. For all unit process within the system boundaries, input, and output related to the reference flow are collected. This includes the following: consumption of materials, energy, and water; emissions to air, water, and soil; waste from the process analyzed. The waste should be classified, and the classification method documented in the LCA report. (PEP PCR, 2015, p. 15.)

#### **6.3.1 Primary data**

In addition to the already mentioned requirements, the collected flows should be averaged over a sufficiently long period, preferably over a year, to even out any seasonal peaks. The data should also be representative of a current scenario in terms of geographic coverage and technological coverage. When data is collected from several sites, the data should be collected from representative sites. The method used to aggregate the multi-site data and the rules applying to the creation of data sources should be documented in the LCA report. Overall, all allocation methods to the reference flow and any deviations or missing should be documented in the LCA report, including the rules for processing missing data. (PEP PCR, 2015, pp. 15-16.)

There is no need to collect data on noise or odor pollution and the use of space because of the difficulty to characterize them. Information of them can however be mentioned in the LCA report and the EPD. (PEP PCR, 2015, pp. 15-16.)

#### **6.3.2 Secondary data**

When secondary data used it should be identified and consistent with the scope of the study in terms of time-related, geographic, and technological coverage, and this should be available in the LCA report. This is done for transparency and traceability. In addition to these requirements, the secondary data should also be selected from one of the following sources (PEP PCR, 2015, p. 16):

1. LCI datasets that have been checked by independent experts attesting to their conformity with this PCR
2. LCI datasets that have been checked by the PEP developer attesting to their conformity with the PCR
3. LCI datasets based on LCA studies compliant with ISO 14040 and 14044 standards or any other reference document referring to these standards and independently verified.
4. LCI datasets that have been pre-checked by the data supplier attesting to their conformity with this PCR
5. LCI datasets with no proof of verification. In this case, the LCA report should justify the selection of this dataset.

While the ecoinvent database hasn't been verified directly for the used PCR and by PEP Ecopassport to the use of this study, the database is one of the most well-known LCI databases in the world and is used widely on LCA and EPDs. If nothing else the LCI datasets of the databases check the requirements of point 3. With the ELCD database, there shouldn't be a problem with the datasets because PEP Ecopassport recommends using some of them in their PCR. (PEP PCR, 2015, p. 16.)

#### **6.4 Energy used by ABB WA**

ABB WA buys its electricity from a local energy company, Porvoon Energia Oy. The purchased energy has the composition of 70% hydropower and 30% wind and solar, for these calculations, it is assumed that the ratio between wind and solar is 50/50 for the main calculations.

This energy model is used for all energy consumption that happens in the ABB WA factory in Porvoo. To use this energy model for the calculations, an LCI process is made in the LCA software. To make this process, other processes from the databases are combined and these can be seen in Table 7.

Table 7: ABB WA Electricity mix - process

Energy type	Database	Name of the process	Percentages
Hydro	ELCD	Electricity from hydroelectric power plants, production mix, at power plant, AC, < 1kV	70%
Solar	Ecoinvent	electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted   electricity, low voltage   APOS, S	15%
Wind	ELCD	Electricity from wind power, production mix, at power plant, AC, < 1kV	15%

Hydro and wind's LCI process are found from the ELCD database. LCI process for solar would have also been chosen from ELCD, but there weren't any suitable options, so one was chosen from ecoinvent. ELCD was the primary source to choose from because PEP Ecopassport has stated in the PCR that LCI datasets for electricity should be chosen from the ELCD database. (PEP PCR, 2015, p. 11.)

## 6.5 Transportation

To help make estimations for these situations a logistic overview, made by one of ABB WA's logistic partners, was used. It is estimated that because Finland can be viewed as an island, sea transportation is used, wherever you are going in Europe. The only thing, that needs to be considered, is where in Europe is the component coming from, because this affects what ports are used to transport it to Finland. These can be seen in Table 8.

Table 8: Differences in sea transportations based on travel locations

<b>Locations</b>	<b>Sea transportation</b>	<b>Traveled distance [km]</b>
Sweden, Norway and Denmark (post numbers 1-4)	Turku - Stockholm	324 ,10
Denmark (post numbers 5-9)	Helsinki - Århus	1383,44
Central Europe	Helsinki – Travemunde, Germany	1396,41
East	Helsinki - Tallin	72,23

The distances between the ports are from Ports.com. The above-mentioned logistic overview has also estimated some of the most frequently traveled destinations around Europe and an estimation of the traveled distance on road. These can be seen in Table 9.

Table 9: Transport destinations and distances in Europe

<b>Locations around Europe</b>	<b>Distance [km]</b>
Norrköping, Se	165
Helsingborg, SE	557
Skedsmokorset 2020, NO	522
Juri, Harjumaa, EE	20
AH, NL	484
Jablonec, CZ	1510
Riga, LV	310
Avizienai, LT	594
Alexsandrow, PL	1124
Ludenscheid, DE	458
Heerbrugg, CH	894

Espanja	1853
Pordeone, IT	1342

All the distances are from the port to the destination. Port for each destination can be found in Table 8. For example, if the destination is in central Europe, the port in question is Travemunde. All the distances are from Google maps, based on these two locations of the port and destination. These estimations are used during the LCA calculations, if there are no certain locations or address available.

The PCR instructs to use the transportation process for the ELCD database when no other information is reliably known than just the transportation method. This is the same for all modes of transport and the processes in Table 10 are the main ones used for all three products (PEP PCR, 2015, p. 12.)

Table 10: LCI process from ELCD database

<b>Transport mode</b>	<b>Process name</b>
Truck	Articulated lorry transport, Euro 0, 1, 2, 3, 4 mix, 40 t total weight, 27 t max payload
Ship	Container ship ocean, technology mix, 27.500 dwt pay load capacity

These processes were used for all the transportations that happen either on the road and sea. If there are some other modes of transportations during some of the stages these will be specified in their cases.

## **7 MANUFACTURING STAGE**

The manufacturing stage is from the extraction of natural resources to manufacturing of product and its packaging materials and their delivery to the manufacturer's last logistics platform. The inputs and outputs, that are needed to be collected, are the following (PEP PCR, 2015, pp. 7-8.):

1. Production of the materials and components making up the reference product and assembly
2. Production of packing raw materials and transportation of the packaging from its manufacturing site to the product packaging site
3. Industrial processes used to assemble the reference product and packaging components
4. Transportation of the packaged product from the packaging site to the manufacturer's last logistics platform.

The first part can be divided into three sections: the production and transportation of raw materials; the industrial transforming and manufacturing processes of the various parts, components and products; transportation of materials, components, and subassemblies from the supplier's production site to the assembly site(s) and or packaging site(s). (PEP PCR, 2015, pp. 7-8.)

### **7.1 Junction Box**

The AP9 junction box consists of a cover and a base, with the packaging of the product consisting two types of packaging plastic films and a carton box. The product structure data has been collected from ABB WA's SAP system. From the data the different components, their materials and weights can be known. Table 11 shows all these components for AP9.

Table 11: Material composition of AP9

Material	Weight-%
Polypropylene	77,89%
SEBS	13,77%
Carton item	7,24%
Packaging plastic	1,10%

The following flow chart shows the overall process of the manufacturing stage for AP9, with the location where the raw material or component is coming from and where the process stage is taking place (Figure 12).

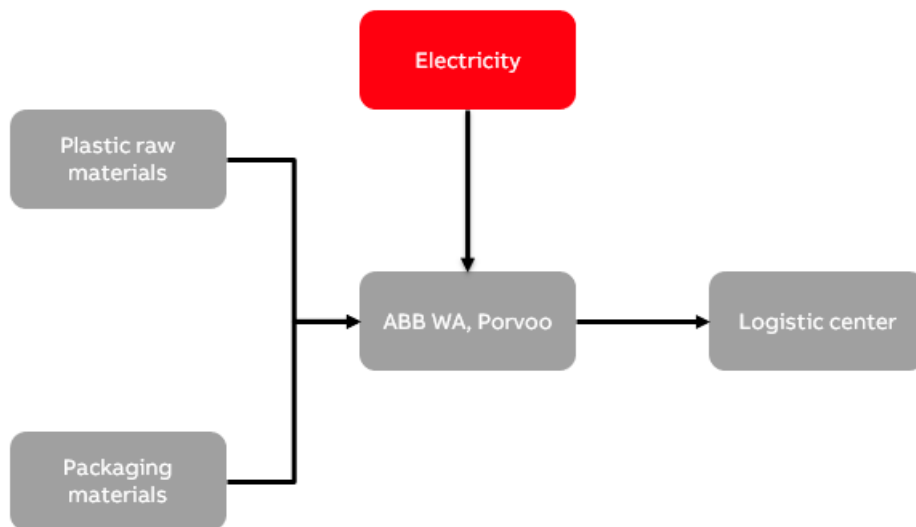


Figure 12: Flow Chart for Manufacturing stage of AP9

The product is manufactured completely at ABB WA's factory in Porvoo. The manufacturing process consists of injection molding of the cover and base after which the product is assembled and packaged.

### 7.1.1 Transportation

To calculate the environmental impacts of transportations, the mode of transport and the distances the components travel, is needed. The cover and base use the same polypropylene raw material, so overall there are five different raw or packing materials for which transportation distances and the mode of transport need to be collected.

The transportation's original locations are based on information ABB WA has on the suppliers. ABB WA has the supplier's addresses and the country of origin for the supplied materials and components. It was assumed, that if the address and the country of origin match, that is where the component or material comes from. In some cases, however, these two locations don't match. This is because the supplier's address, which ABB WA has in their system, is where the orders go to. In some cases, the order can go to one place, but the ordered component or material comes from a different place. In these cases, the country of origin is then used. To estimate the distances and possible mode of transports Chapter 6.5 and Table 8 are utilized. All cases the distances are from Google Maps. These can be seen in Table 12.

Table 12: Transportation distances for different modes of transport

<b>Component</b>	<b>Truck transport [km]</b>	<b>Container ship transport [km]</b>
AP9 transport 1	77,6	
AP9 transport 2	577,0	324 ,10
AP9 transport 3	1387,0	1396,41
AP9 transport 4	1055,0	1396,41
AP9 transport 5	160,0	
AP9 transport 6	51,8	

### 7.1.2 Manufacturing, assembly and packaging of AP9

As stated above, the base and cover for the junction box are made by injection molding, where with one mold four products can be made for both the cover and base. There is water used during the manufacturing process for cooling the product after the injection molding, but this water is reused repeatedly, meaning there isn't any new water coming into the process or used water going out of the process.

Based on the data gathered from the manufacturing unit in Porvoo, there are no waste outputs for the base of AP9, but there is some plastic waste produced during the injection molding of the cover. During one injection cycle for the base, there is about 2,64 g of plastic waste generated. This waste however goes directly back to the process to be reused for the next injection cycle. This means that to produce four covers 3,45% more raw material is needed than the weight of the final product, as can be seen in Table 13.

Table 13: Raw material input and outputs for AP9

Component	Raw material input [g]	Product output
Base	146,3	4 [pc] x 36,575 [g] = 146,3 [g]
Cover	79,268	4 [pc] x 19,157 [g] = 76,628 [g]

Energy consumption is the only other input for the manufacturing stage. The energy consumption consists of injection molding and the automation processes. The calculations for the energy consumption are based on the power of the machine or machines that are used and the time it takes to go through one injection molding cycle.

Based on the estimations made by ABB WA, about 60% of the energy consumption can be allocated to injection molding and another 5-10% goes to the automation processes. The energy consumption values are presented in Table 14 based on these values.

Table 14: Energy consumption of the whole product

<b>Energy consumption [kWh] Injection molding (60%)</b>	<b>Energy consumption [kWh] Injection molding (60%) + automation (5-10%)</b>
0,041	0,043 – 0,046

The automation of the AP9 process includes assembling of the products and partial packaging, where 5 assembled products are packaged together in the packaging plastics. After this 10 of these 5 product groups are packed into the carton box. For the calculations, the average of the energy consumption, which includes both injection molding and automation is used. This would mean that the energy consumption for the whole product would be 0,04457 kWh.

### 7.1.3 LCI Process used from the Databases

To complete the life cycle process, the different databases were used. These include the production of raw and packaging materials. A decision was made not to ask information for these calculations from the suppliers of these materials. The target was to see how much could be done with collecting data in house and using the databases to fill in the caps. All these LCI processes are from the ecoinvent database. The ecoinvent database was chosen, because the database has been updated regularly rather than the ELCD database. The chosen processes are listed in Table 15.

Table 15: Ecoinvent process used for raw and packaging materials

<b>Name of the Process</b>
polypropylene production, granulate   polypropylene, granulate   APOS, S
acrylonitrile-butadiene-styrene copolymer production   acrylonitrile-butadiene-styrene copolymer   APOS, S
packaging film production, low density polyethylene   packaging film, low density polyethylene   APOS, S
corrugated board box production   corrugated board box   APOS, S

The LCI processes for the plastics are based on data from an organization called PlasticsEurope. This organization has assembled and publish detailed environmental information on the processes operated by its member companies, located mainly in Europe. (PlasticsEurope, 2020)

The process used for SEBS production is for a plastic called acrylonitrile butadiene styrene (ABS). This is used because there is no data on the production of SEBS in theecoinvent database and to avoid any data caps, data for ABS is used as a fill-in for SEBS. Both SEBS and ABS are thermoplastics elastomers and they are often composed of ethylene, butadiene, and styrene compounds. So, ABS was looked at as a suitable replacement. This change however should still be noted in the final results when analyzing them in the LCA report. (Johansson, 2018, p. 32.)

The process for the packaging materials was chosen to fill in the gap for the missing data of their manufacturing process. The LCI process for plastic film is based on an average European extrusion process, while the process for carton item is based on the main producers in Europe and it uses the European average of recycled and virgin paper inputs.

## **7.2 Socket outlet**

The socket outlet consists of multiple plastic parts and metal components. But the main parts can be categorized as the housing unit, cover plate, and packaging materials. The reference products, 302EUJ-84, structure can be seen in Table 16 below.

Table 16: Material composition of 302EUI-84

<b>Material category</b>	<b>Material components</b>	<b>Weight-%</b>
Plastic	Polyamide 6 GF20	7,2%
	Polyamide 66 GF30	0,7%
	Polycarbonate	37,9%
Metal	Fe-Zn	0,1%
	Low-alloy steel	20,9%
	CuZn37	17,4%
	X12CrNi 17 7	1,5%
Packaging materials	Carton item	11,8%
	Packaging plastic	2,48%

The components of the socket outlet can be categorized into two: plastic or metal components. The division can be seen in other ways, also. All the plastic components of the socket outlet are manufactured by ABB WA, while the metal components come from the supplier.

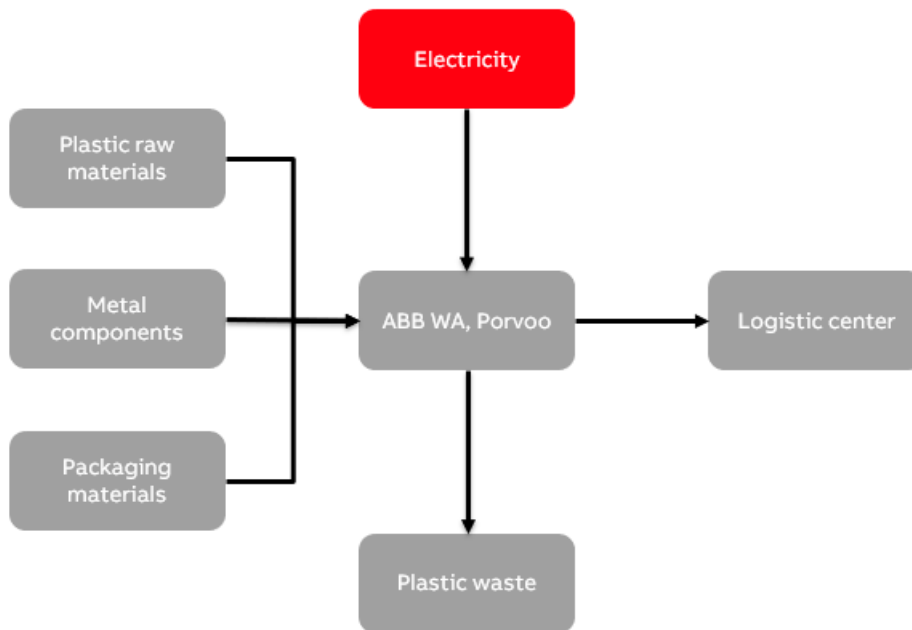


Figure 13: Flow chart of the manufacturing of the socket outlet

### 7.2.1 Transportation distances

As stated above the transportation for this stage can be categorized into two categories: inputs, which include raw and packaging material and metal components and output, which means possible waste, that is produced during the manufacturing. The waste is transported locally and it is assumed, that all go to the same place.

If the addresses matches the county of origin, the distances can be found straight from Google maps. With the components for which the addresses didn't match, the estimation in Table 9 is used, if there is a suitable counterpart.

Table 17: Traveled distances for components of 302EUI-84

<b>Raw materials</b>	<b>Truck [km]</b>	<b>Container ship [km]</b>	<b>Plane [km]</b>
Socket outlet transport 1	503	1396,41	-
Socket outlet transport 2	744	1396,41	-
Socket outlet transport 3	503	1396,41	-
Socket outlet transport 4	676	1396,41	-
Socket outlet transport 5	503	1396,41	-
Socket outlet transport 6	503	1396,41	-
Socket outlet transport 7	503	1396,41	-
Socket outlet transport 8	1387	1396,41	-
Socket outlet transport 9	160	-	-
Socket outlet transport 10	89,5	-	-
Socket outlet transport 11			7966

### **7.2.2 Manufacturing and assembly of socket outlet**

The manufacturing and assembly of the socket outlet consist of the manufacturing of the plastic components and the assembly of the product. The input for this stage is the electricity needed for the manufacturing of the plastic components and in some parts the assembly of the products.

Like with the junction box the energy consumption is based on the power of the machines and the time it takes to produce the components. As with the junction box, it is estimated by the production that 60% of this is needed for the injection molding and a further 5-10% is needed for automation, which can include assembly and some packaging. The time of the

process is from documentations of the process and it considers only the injection molding. The whole energy consumption can be calculated based on this information as well as the assumptions of how much power is consumed during each stage. What needs also to be considered, is that with one injection cycle multiple components can be produced. For the overall energy consumption of the manufacturing stage the energy consumed to manufacture the necessary components of the socket outlet are considered. The energy consumption for one component can be seen in Table 18.

Table 18: Energy consumption, including injection and automation, for plastic components

<b>Energy consuming process</b>	<b>Energy consumption per one component [kWh]</b>
Process 1	0,01995
Process 2	0,009975
Process 3	0,012831
Process 4	0,01848
Process 5	0,055671

Each of these processes include the manufacturing of at least one plastic component, but some of them also include the assembly of plastic and metal components together. The energy consumptions in Table 18 are allocated based on the manufactured plastic component. To get the energy consumption of the whole manufacturing stage, the amount of each component included in the product is considered. The energy consumption for the whole manufacturing stage is 0,12974 kWh. The energy model used during the calculations is the model detailed in chapter 6.4 and Table 7.

As seen in Figure 13, there is waste produced in these processes, which means that more raw material is needed than the weight of end components is. To calculate how much raw material is needed in the injection molding processes, data for this gathered. The data is based on one injection cycle for each component or process and the information that the production gathers during manufacturing process in ABB WA. This data consists of the

weights of components, how many are produced in one cycle and how much waste is produced during the injection cycle. This data is gathered in Table 19.

Table 19: How much is produced and what happens to the waste

Amount of waste during the production of one socket outlet	What happens to the waste?
4,5875 g	waste treatment outside of ABB WA

How the waste is disposed is based on national statistics of how plastic waste is treated in Finland. Based on the statistics 24,02% goes to energy recovery, 75,97% to materials recovery and 0,01% to landfill (Statistics Finland, 2020, p. 4). The estimated distance the waste travels is 100 km (Salanen, et al., 2012, p. 24.). Because of the system boundaries only the waste incineration without energy recovery is considered in the calculations.

### 7.2.3 LCI process used

There are multiple LCI processes from the databases. These can be categorized into two groups based on which database the LCI process is from, ecoinvent or ELCD. The process used from ecoinvent is the production process for the raw materials and packaging materials. The processes are listed in Table 20 below.

Table 20: Raw materials and LCI process used for them

Process name
nylon 6 production, glass-filled   nylon 6, glass-filled   APOS, S
nylon 6-6 production, glass-filled   nylon 6-6, glass-filled   APOS, S
polycarbonate production   polycarbonate   APOS, S
casting, brass   casting, brass   APOS, S
steel production, converter, low-alloyed   steel, low-alloyed   APOS, S
steel production, chromium steel 18/8, hot rolled   steel, chromium steel 18/8, hot rolled   APOS, S

wire drawing, steel   wire drawing, steel   APOS, S
packaging film production, low density polyethylene   packaging film, low density polyethylene   APOS, S
corrugated board box production   corrugated board box   APOS, S
treatment of waste plastic, mixture, open burning   waste plastic, mixture   APOS, S - GLO

Like with the junction box a decision was made to not ask for information from the suppliers of raw materials, metal components and packaging materials. the target was to see how much could be done with the help of the databases, especially ecoinvent. The process where chosen based on their suitability.

The LCI process for the plastic raw materials represent the average production of the plastic. The data for the polycarbonate and the polyamides are from the eco-profiles gathered by an organization called PlasticEurope, which collected the information and data from plastic industries around Europe. The LCI process represent an average for the European industry for that plastic raw material.

The ecoinvent database is also used to complete the life cycle of packaging materials and the different metal components. There are four different LCI processes used for the metal components. Some processes are used for more than one component. These processes were chosen based on the materials of the components. The LCI process for packaging materials is the same that was used for the Junction boxes packaging materials. For waste treatment of the plastic waste the process was chosen based on it representing directly incineration without energy recovery.

### 7.3 Thermostat

What is unique about the thermostat compared to the other products is that it isn't manufactured at ABB WA's factory in Porvoo, but in another site in Germany. This brought its own challenges to how the calculations are made. It is known that the Thermostat consists

of four main components parts. These are the plastic parts, metal parts, electronics and packaging materials (Table 21).

Table 21: Thermostat content

<b>Product content group</b>	<b>Weight-%</b>
Plastic	11,46 %
Metals	15,38 %
Electronics	54,16 %
Packaging materials	19,01 %

Because the product is not manufactured in ABB WA, there is not much data relating to the manufacturing of the product in ABB WA's systems. This means that the calculations are reliant on the data collected from manufacturing site. The information and data that was asked related to the material content of the product and input and output data of the manufacturing process. The material content information was asked with the document seen in Appendix 6.

### **7.3.1 Other inputs and outputs related to the manufacturing stage**

To get more information about the manufacturing of the thermostat the following questions were sent to the manufacturing site of the thermostat (Figure 14).

### The data needed regarding energy

- How much energy is needed to produce this product in your production [kWh]?
  - About 0,45 kWh/product
- What energy is used to generate the energy, and if electricity is used what type of electricity is used (electricity mix)?
  - Conventional power 80% and solar panels 20%

### The data needed regarding water

- Is water used in your manufacturing process of the thermostat? (if yes please answer the questions below)
  - No
- How much water is used?
- Where the water is from? (ground water, surface water, collected rainwater, for example)
- Is the water discharge or is it closed looped? If discharged how is it done?

### The data needed regarding the waste generated

- What type of waste is generated during production and how much [kg or tons]?
  - per product:
    - old oil 0.5 ml
    - plastic 9 gram
    - paper 10 gram
- What is the end-of-life treatment of the waste? reused during your manufacturing process or shipped offsite for end-of-life treatment (landfill, energy waste)?
  - plastic is partly reused and not included in data above. Paper is recycled by external supplier
- If shipped offsite what is the location?
  - Germany

Figure 14: Questions regarding the manufacturing of the thermostat

Based on the answers an electricity usage mix (Figure 14) is made. It is made the same way that the electricity mix for ABB WA was made, and it can be seen in Table 22.

Table 22: Thermostat Manufacturing electricity mix

Electricity type	Share	Name and database
Solar	20%	electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel, mounted   electricity, low voltage   APOS, S – DE <u>Database</u> : ecoinvent
Conventional power	80%	Electricity Mix, consumption mix, at consumer, AC, 230V, DE <u>Database</u> : ELCD

For the waste generated from the manufacturing, based on the answers, there are three types of waste generated during the manufacturing: plastic, paper and oil. The end of life treatment of these is based on answers and the instructions from the PCR. With paper it is known that

it goes to recycling. For plastic and oil, it is assumed that they go do landfill, because no other information is provided. The landfill LCI process is chosen based on the instructions in the PCR. Different from the end of life scenario in the PCR it is assumed that the transportation distance is shorter than the 1000 km based on the answers to the questions because the end of life treatment is assumed to happen locally. (PEP PCR, 2015, p. 13.) It is estimated that the distance would be 100 km, based on the assumption and estimations made for the other products, junction box and socket outlet end of life scenarios. Both used landfill LCI processes are from the ELCD database and they can be seen in Table 23.

Table 23: Landfill process for plastic and oil waste

<b>Waste type</b>	<b>Process name</b>
Paper	recycling – no LCI process
Plastic	Landfill of plastic waste, at landfill site, landfill including landfill gas utilisation and leachate treatment and without collection, transport and pre-treatment
Old oil	Landfill of glass/inert waste, at landfill site, landfill including leachate treatment and without collection, transport and pre-treatment

The transportations included in the manufacturing stage are based on known transports that happens to some of the components of the thermostat and the thermostat itself and estimations made for the transportations, where there is not much information.

Table 24: Estimated transport for the manufacturing stage not including waste transport

<b>Truck [t*km]</b>	<b>Ship [t*km]</b>
0,14594297	0,273551971

### 7.3.2 LCI Process used for the Manufacturing stage

Because of the nature of the products' content being mainly electronic components and the information that is known and not known about the manufacturing process, the use of the databases is much more prevalent than it was for the junction box or socket outlet. For the

manufacturing process, many LCI processes are utilized to fill in the manufacturing stage for the thermostat as well as it can be done. These LCI processes are mainly for electronic components, plastic raw materials and metal components. The list of these can be seen Table 25.

Table 25: LCI process used during the manufacturing stage of Thermostat

<b>LCI process name</b>
activated carbon production, granular from hard coal   activated carbon, granular   APOS, S - RER
aluminium production, primary, ingot   aluminium, primary, ingot   APOS, S - RER
battery cell production, Li-ion   battery cell, Li-ion   APOS, S - RoW
bisphenol A epoxy based vinyl ester resin production   bisphenol A epoxy based vinyl ester resin   APOS, S - RER
cable production, unspecified   cable, unspecified   APOS, S - GLO
capacitor production, for surface-mounting   capacitor, for surface-mounting   APOS, S - GLO
casting, brass   casting, brass   APOS, S - RoW
copper production, primary   copper   APOS, S - RER
corrugated board box production   corrugated board box   APOS, S - RER
diode production, glass-, for surface-mounting   diode, glass-, for surface-mounting   APOS, S - GLO
electronic component production, active, unspecified   electronic component, active, unspecified   APOS, S - GLO
electronic component production, passive, unspecified   electronic component, passive, unspecified   APOS, S - GLO
epoxy resin production, liquid   epoxy resin, liquid   APOS, S - RER
flux production, for wave soldering   flux, for wave soldering   APOS, S - GLO
glass fibre production   glass fibre   APOS, S - RER

injection moulding   injection moulding   APOS, S - RER
iron pellet production   iron pellet   APOS, S - RoW
liquid crystal display production, minor components, auxilliaries and assembly effort   liquid crystal display, minor components, auxilliaries and assembly effort   APOS, S - GLO
manganese production   manganese   APOS, S - RER
nickel mine operation, sulfidic ore   nickel, 99.5%   APOS, S - GLO
nylon 6 production   nylon 6   APOS, S - RER
nylon 6-6 production   nylon 6-6   APOS, S - RER
offset printing, per kg printed paper   printed paper, offset   APOS, S - RoW
polycarbonate production   polycarbonate   APOS, S - RER
polydimethylsiloxane production   polydimethylsiloxane   APOS, S - GLO
primary lead production from concentrate   lead   APOS, S - GLO
primary zinc production from concentrate   zinc   APOS, S - RoW
printed wiring board production, surface mounted, unspecified, Pb free   printed wiring board, surface mounted, unspecified, Pb free   APOS, S - GLO
transistor production, surface-mounted   transistor, surface-mounted   APOS, S - GLO
resistor production, surface-mounted   resistor, surface-mounted   APOS, S - GLO
silicone product production   silicone product   APOS, S - RER
soft solder production, Sn97Cu3   soft solder, Sn97Cu3   APOS, S - RER
solder production, paste, Sn95.5Ag3.9Cu0.6, for electronics industry   solder, paste, Sn95.5Ag3.9Cu0.6, for electronics industry   APOS, S - GLO
steel production, converter, chromium steel 18/8   steel, chromium steel 18/8   APOS, S - RER
steel production, converter, low-alloyed   steel, low-alloyed   APOS, S - RER

sulfur production, petroleum refinery operation   sulfur   APOS, S - Europe without Switzerland
tin production   tin   APOS, S - RoW
titanium dioxide production, chloride process   titanium dioxide   APOS, S - RER
titanium production, primary   titanium, primary   APOS, S - GLO

These LCI processes are all from the ecoinvent database. These processes were chosen based on the criteria that they either represent the individual component or component's material. Overall, the manufacturing stage for thermostat is much different than of the junction box or socket outlet because of the information that is known about the manufacturing and what is not known information of the production and assembly process itself, when compared to the socket outlet or junction box. This is why this stage has much more uncertainty in its results compared to the others.

## 8 DISTRIBUTION STAGE

The distribution stage considers the transportation of the product from the manufacturer's last logistics platform to the distributor and from the distributor to the installation place. As can be assumed this stage only includes transportation and the related input and outputs to that. However, if there are any reconditioning of packaging materials that happen during this stage, the production and transportation of these materials are considered during this stage also. Also, where appropriate end-of-life management of the packaging materials is considered.

The products are transported from ABB WA's logistic center to the eventual customer. For the calculations this is considered as one transport, while in reality it can include more than one stop during the transport. An advantage that ABB WA has with its local production in Porvoo, is its close connection to its customers. ABB WA's products main market is the Nordic countries, while other countries around Europe and Russia can also be included. What distances are used for each of the products can be seen in Table 26.

Table 26: Traveled distances in distribution stage

<b>Product</b>	<b>Market</b>	<b>Traveled distance estimate [km]</b>
Junction box	Europe and Russia	600
Socket outlet	Nordic countries	600
Thermostat	Europe	600

In the estimated distance, an emphasis is put into the Nordic market. The same distance was used for all three products because it represents the traveled distance quite well for each of the products. The used LCI process is the one specified for truck transportation in Table 10.

## 9 INSTALLATION STAGE

This stage includes the process, components, and energy that are included in the installation process. The inputs and outputs that are considered are from the following aspects:

- for all products, generating waste when installed
- manufacturing, packaging and procurement of materials and components not supplied with the reference product but required for its installation
- installation processes
- management of the waste generated at the installation place, this includes packaging, discarded installation materials and waste associated with installation processes

Based on this there are three main aspects to consider during this phase:

1. Are there any installation elements not included in the package?
2. The installation process itself, how is it done?
3. What waste is generated during the whole stage? What happens to it?

Based on the answers to these questions, the different processes included at this stage for each product are formed. If there are any additional installation elements needed for the products, it should be checked what they are, how much or many are needed, where they come from, and how they are made.

For the packaging waste produced in this stage, the waste treatment methods are based on Finland's national statistics of packaging materials waste treatment from 2019. From them it is found that 33% of the fiber-based packaging materials, like paper and carton items, go to energy recycling and 77% goes to material recovery. For plastic packaging materials 42% of the them go to material recovery and 56% go to energy recovery, the last 2% is assumed to go to landfill. (Ympäristö.fi, 2020) These ratios are based on the assumption that the different waste types are sorted and collected correctly.

### 9.1 Junction box

For the installation of junction boxes, two nails are needed that aren't included with the packaged product. This means that the production process and transportation of these screws are to be considered during this stage. However, if it is assumed that one screw weights

around one gram, the accompanied weight of the two screws falls under the cut-off criteria as the mass flow is lower than 5% of the mass of the reference products. Because the mass flow is not considered then the whole manufacturing process of the nails also is not considered.

The installation itself is done with just a screwdriver, so there aren't any energy consumptions or other input and outputs that should be considered in the calculations. This is because the process of using the screwdriver, power tool or not, is considered to have minimum impact on the overall results and are excluded from the system boundaries as stated in the PCR. (PEP PCR, 2015, p. 8.)

The main waste that is generated during this stage is from the different packaging materials of the product. These are the two different plastic packaging films and the carton box. The end of life of these is calculated by the above-mentioned national statistics. Because of the system boundaries set for the study by the PCR and that system expansions aren't allowed, the only relevant waste treatment is the landfilling of about 2% of the plastic packaging materials. The traveled distance during this is assumed to be about 100 km (Salanen, et al., 2012, p. 24.).

## **9.2 Socket outlet**

The socket outlet packaging offers everything that is needed in the installation of the product. This means that there aren't any installation materials which production processes or transportation are needed to be looked at for this product.

There is however waste generated during this stage from the packaging materials. Like with junction box, the national statistics that are mentioned above are used for the socket outlet as well. This means that the only relevant waste treatment is the landfilling of about 2% of the plastic packaging materials. The traveled distance during this is assumed to be about 100 km (Salanen, et al., 2012, p. 24.).

## **9.3 Thermostat**

As with the socket outlet, the thermostat installation can be done without any power tools. This means that the installation process doesn't consume any energy or generate emissions that would be within the scope of the study.

There will be however waste generated during this phase from the packaging materials. These consist of a carton box and paper that come with the product. Based on the national statistics mentioned above, these go to either energy recovery or material recovery. And because of the system boundaries of the study their impacts and benefits aren't considered in this study. The most influential aspect of this stage regarding environmental impacts is then the transportation of the waste. Like for all the other end-of-life scenarios the waste treatment is assumed to happen locally, so transportation distance is assumed to be 100km.

## 10 USE STAGE

This stage considers product operation under normal conditions of use. During these conditions the inputs and outputs associated with the following aspects are included:

- energy consumption and other flows of the product during its use over the RLT
- production, distribution, installation, and end-of-life of elements required to operate, service and maintain the product over the RLT

During this stage, the use scenarios defined in the PSR are used to help calculate the energy consumptions and other flows during the products RLT. The use scenarios consist of two different aspects in almost all cases: load rate and use rate. The results of this process can vary greatly between the products.

If there is energy consumption during this stage, the same electricity mix is used for all the products. The electricity mix is chosen based on the geographical area where the product is used. Based on the assumptions made for each product is that the most representative electricity mix is the mix made for EU countries.

The electricity mix chosen for the life cycle stage is a consumption mix that represents the EU-27 regions specific electricity mix, called Electricity grid mix, consumption mix, at consumer, AC, < 1kV. The process is from the ELCD database and it is chosen because the PCR instructs that ELCD database processes should be chosen when considering electricity consumption. However, what should be considered during the analysis of the results for this stage is that the ELCD database hasn't been updated in a few years. For example, the electricity mix chosen is originally from 2008 and hasn't been updated from at least 2015. The electricity mix can be seen in the following Figure 15.

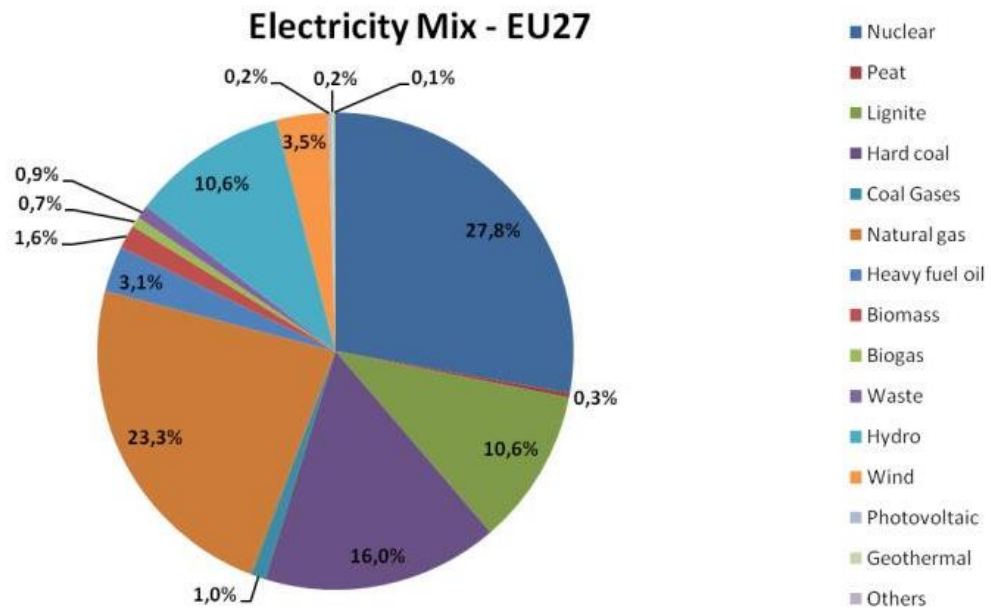


Figure 15: Electricity Mix of EU27 from ELCD database

So, this model doesn't necessarily represent the most current electricity mix, where for example, the share of wind has risen to 11% and solar to 4% (Eurostat, 2020).

## 10.1 Junction box

The use stage for the junction box is quite simple. The product doesn't consume any energy during its use, and it doesn't need any maintenance under normal conditions of use. This means that all the environmental impact of this stage is zero.

## 10.2 Socket outlet

The PCR gives the overall guidelines on how to calculate the energy consumption during this stage by giving the use scenario for the socket outlet, as seen in the following Table 27. Based on these guidelines the energy consumption of the product is calculated.

Table 27: Use scenario of socket outlets

Load rate	50% of Rated current of the socket (A)
Use rate	50% of RLT

The reference product has a rated current of 16 A meaning the current used to calculate the load for the outlet is 8 A. As stated in chapter 6.2 the RLT for the socket outlet is 20 years. To further clarify how the product is used during the RLT, the socket outlet is used non continuously for the 20 years at 50% of the rated load, during 50% of the time. This is interpreted so that during 50% of the RLT there is no use, meaning no energy consumption, and for the other 50% of the RLT, the socket outlet is used non-continuously. The non-continuous is defined by ABB WA as 75% of the time there is nothing connected to the socket outlet, which is called passive use, and the rest of the 25% of the time it is connected to something, which can be called active use. This can be seen in Table 28.

Table 28: RLT categorized based on use rate

Use	Description
50% of the RLT: 10 years	no energy consumption
50% of the RLT: 10 years	Passive: 75% of the time as just a socket outlet (not connected to anything) Active: 25% of the connected to something

To calculate the energy consumption during the non-continuous use time, what needs to be taken into account with the socket outlet is that when something is connected to the socket outlet, the energy consumed is solely allocated to the connected item and not the socket outlet. There however occurs some power loss inside the socket outlet that is regarded as the socket outlet's energy consumption during its life cycle. This energy loss happens when something is connected to the socket outlet but also when something is not connected to it.

This occurred power loss was calculated in a laboratory in ABB WA. With the results from this calculation and the assumptions made in Table 28, the energy consumption for the whole RLT was calculated to be 7,884 kWh.

### 10.3 Thermostat

For a thermostat, the PCR gives the overall guidelines on how to calculate the energy consumption during this stage by giving the use scenario for the product, as seen in the below Table 29.

Table 29: Use scenario for Thermostats

Load rate of the product	100% of In during 100% of the RLT
Load rate of the closed contact	30% of IL during 14% of the RLT
*In: Maximum rated current of the product (A) and IL: maximum allowed current when the relay is closed (A)	

This use scenario was more complex than the one for socket outlet (Table 29). To better understand how the energy consumption could be calculated, another product category, called Other equipment, in the PCR was utilized. This was looked at as a reference because when looking through exciting EPDs made for PEP Ecopassport on similar thermostats, some of them had used this product category to conduct the EPD.

Based on the two product categories the use scenario can be stated the following way. Because of the nature of the product, it can be assumed that it operates on standby most of its use time. Then there is the time when the product is actively used when the consumption of energy is at its peak. It is assumed that the thermostat is used actively for about 50 minutes per month, which corresponds to about 100 hours for the 10 years. The ratio of these two use modes can be seen in Table 30.

Table 30: Use mode ratio during RLT of Thermostat

Use mode	Percentage
Standby	99,89%
Active use	0,11%

Based on the technical data provided with the product the thermostat has a power consumption of 0,05 W at the maximum during standby. With the estimations made for the energy consumption for the active use, the energy consumption for the whole RLT was estimated to be 104,375 kWh.

## 11 END-OF-LIFE STAGE

For the End-of-life stage the following inputs and outputs are included:

- required transportation to collect the end-of-life product and transport it from the installation site to the final treatment site
- Treatment processes, that are landfilling or incineration without waste-to-energy recovery, including depollution treatment of items to be sent to special end-of-life product treatment centers, up to final treatment.

As seen in Appendix 2, system expansion is not allowed for this study meaning environmental benefits from energy recovery and recycling are excluded from the scope of the study. This brings an interesting situation for the ABB WA products.

All the products are designed in a way that the whole products can be recycled, meaning they don't include any materials that shouldn't prevent recycling and they are designed to different materials can be separated. However what really happens at the end-of-life stage isn't really known for a single product and while there are different legislation and regulations in place at the national and EU level, how these are enforced in the field can vary from country to country and city to city.

Therefore, the data at this stage's calculations are mainly based on the industry and national or municipal legislation and statistics, for the relevant products and materials. For some of the ABB WA products, there is however legislation for the products specifically, like for a thermostat which is included in the WEEE directive (European Union, 2012). For construction products and demolition waste in general there is a legislation in Finland and the EU that has established a target that 70% of this waste should go into material recovery by 2020 (Lassila & Tikanoja, 2020).

There are some basic assumptions made that apply to all three of the different products. The overriding legislation that is followed is the EU Construction and Demolition Waste Management Protocol made by the EC in 2018. Many EU nations have made their national protocols or legislation based on this. This would mean that there are specific waste

categories that if technically and economically possible should be collected and kept separate from other waste categories. Relevant for the junction box, socket outlet and thermostat, is that the waste categories include plastic and metal. Getting reliable statistics for the waste treatment of construction and demolition waste can be hard because at least based on national legislation in Finland, the responsibility of the waste to the contractor and builder. (Kojo & Lilja, 2011, pp. 21-22.) Municipal waste statistics are used for the calculations, because the produced waste from the products can also be found in municipal waste, meaning mainly plastic and metal. Based on this, it is assumed that the waste either goes to energy recovery, material recovery or landfill are based on the municipal waste statistics of Finland. (Statistics Finland, 2020)

This would however mean that because of the system boundaries set in the PCR for the LCAs and EPDs (Appendix 2), a part of the end-of-life process are out of the scope of the study. For these cases, an end-of-life scenario from the PCR is utilized. In the scenario, the stage ends in the storage of the materials, which then obtain the status of end-of-waste. Any environmental benefits and loads relating to secondary material, secondary fuel, or recovered energy going out of the production system are not considered. (PEP PCR, 2015, p. 13.)

The transportation distance can vary by a huge amount with where the product is used. If the place of use is near a bigger city or a metropolitan center there will be a waste treatment center relatively near it also. But if the place of use is in a sparsely populated area, the possibility of having a waste treatment center relatively near it is quite low. This is especially the case in Finland and many EU nations. (Pöyry, 2015)

Considering the population density, where the waste incineration plants are located, and where the construction of new buildings and refurbishment of older ones are mainly taking place. It can also be assumed that for most cases the act of collecting and sorting of the waste is done by a professional constructor that uses some type of bigger waste containers. These containers transport waste, while still being economically viable for about 80-100 km. (Salanen, et al., 2012, p. 24.) For these calculations, the transportation distance is assumed to be 100 km and its transportation mode is by road.

## 11.1 Junction Box

For junction boxes, because they are entirely made of plastics, their end-of-life scenario is the simplest of the other products. The junction boxes are assumed to be sorted on-site with other plastic wastes after which they are transported to waste treatment facilities for energy recovery or material recovery. This is based on the national statistics of Finland that were mentioned above, and the waste management protocol that applies to the EU and Finland, it is estimated that 24,02% of the plastic waste goes to energy recovery, 75,97% goes to materials recovery and 0,01% goes to waste incineration without energy recovery. As detailed above the estimated traveled distance is 100 km and it is assumed to be done by road.

But because system boundaries don't include these processes and system expansions aren't allowed (Appendix 2), the energy recovery and material recovery of junction boxes don't lead to waste disposal. These end in the storage of materials, which obtain the status of end-of-life. The incineration without energy recovery is considered in this. The LCI process used in the calculations is the following that is from ecoinvent:

- treatment of waste plastic, mixture, open burning | waste plastic, mixture | APOS, S - GLO

The used nails would also take part in this stage, but with their weight taking up less than 5% of the mass of the reference product they fall into the cut-off criteria, so their waste treatment isn't considered. These nails would however most likely go to metal recycling based on their condition. And it would be assumed that they are transported the same 100 km.

## 11.2 Socket outlet

The socket outlets' end-of-life scenario is a bit more complicated than for the junction box. Because the socket outlet consists of both plastic and metal components, it can be hard to assume that these metal parts are separated from the plastic components during the waste collection on-site, although possible if time is taken for this. One part that can be assumed to be separated during the collection on-site is the socket outlets cover, PMR2761-84,

because this part is easy to separate from the rest of the components during the disassembly of the socket outlet from the wall. It is assumed to be separated from the rest of the components during the collection and goes directly to energy recovery or material recovery, based on the estimations.

The rest of the components are assumed to be collected together for the calculations to the waste treatment facility, where the components will then be separated. How the separation is done can change between treatment facilities, but for these calculations, it is assumed that this is done by shredding and magnetic separation. This is one of the most common methods used around the world and there is an LCI process available in the ecoinvent database for this process. The process is indented for products under the WEEE directive. While the socket outlet is excluded from this directive, the process itself only includes shredding and sorting of the products. This works for this situation where it can be assumed that the rest of the components go through a similar process. This can be seen in Table 31.

Table 31: LCI process used for Socket outlets End-of-life stage

<b>Component groups</b>	<b>Waste treatment</b>	<b>LCI Process</b>	<b>Database source</b>
Rest of the components	First sorting treatment, then material and energy recovery	treatment of waste electric and electronic equipment, shredding   waste electric and electronic equipment   APOS, S	ecoinvent 3.6

After the sorting process of the plastic and metal components, it is assumed based on municipal waste statistics that of the plastic waste 24,02% goes to energy recovery, 75,97% goes to materials recovery and 0,01% goes to incineration without energy recovery. And of the metal waste 100% goes to material recovery. Like stated above, because of the system boundaries set for the study energy recovery or material recovery these are not included in the scope (Appendix 2). For incineration of the plastic waste the used LCI process is the same that was used for junction box. For transportation, the same principals used for the junction boxes is used for this case as well. It is estimated that the transported distance is about 100 km for the whole product.

### 11.3 Thermostat

The thermostat is the most complex product of the three. The product is part of the WEEE directive and consists of different electronic components. Like with the socket outlet, the cover plates of the thermostat are assumed to be separated during the disassembly of the product from the wall and sorted straight to plastic waste. The rest of the product however is assumed to be collected as a group and that it goes to waste treatment based on the WEEE directive. Like with the junction boxes and socket outlet it is estimated that the transportation distance is about 100 km.

In 2018 of the WEEE waste collected in Finland nationwide, approximately 11,23% was directed to reuse either as whole product or as components, 82,5% went to material recovery, 1,62% was recovered as energy and the rest, 4,65% went to landfill (Pirkanmaan ELY-keskus, 2020). For the calculations these assumed to be the ratio how the waste is disposed. From Figure 16 it can be seen what the process is assumed to look like.

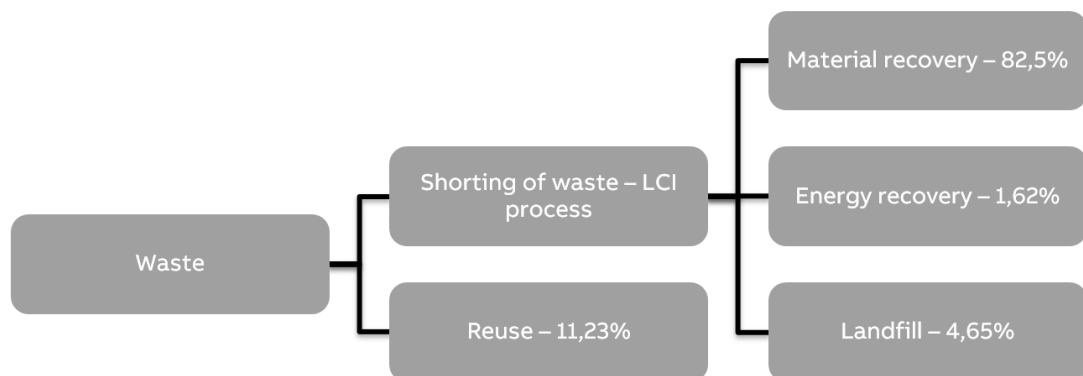


Figure 16: Waste treatment process for thermostat (Pirkanmaan ELY-keskus, 2020).

The parts of the products that are reused are separated before the products goes through the LCI process for treatment of waste electric and electronic equipment, which was also used for the socket outlet (Table 31). After this it is assumed that the waste goes to either material recovery, energy recovery or landfill. The percentages are related to the whole product. This would mean that based on the materials composition of the product without the cover plate

would be about 14,15% would be plastic, 18,99% would be metal and 66,87% would be electronic components. For all these three waste types different LCI process where used that matched their material that can be seen in Table 32.

Table 32: LCI process of waste process for Thermostat

<b>Waste type</b>	<b>LCI process</b>	<b>Database</b>
Plastic	Landfill of plastic waste, at landfill site, landfill including landfill gas utilization and leachate treatment and without collection, transport and pre-treatment – EU-27	ELCD
Metal	Landfill of ferro metals, at landfill site, landfill including leachate treatment and without collection, transport and pre-treatment – EU-27	ELCD
Electronics	process-specific burdens, residual material landfill   process-specific burdens, residual material landfill   APOS, S – Europe without Switzerland	ecoinvent

The cover plate of the is assumed to be treated separately and the same statistics is used for calculating its treatment as with the plastic waste for junction box and socket outlet. In this 24,02% goes to energy recovery, 75,97% material recovery and the rest 0,01% goes to incineration without energy recovery. The incineration is calculated with the same process used as before for junction box and socket outlet.

## 12 OVERALL LCA RESULTS

The overall results of the LCA calculations for all the life cycle stages are presented in the Table 33.

Table 33: LCA results for the total life cycles for the three products

Impact category	Unit	Junction box	Socket outlet	Thermostat
Abiotic depletion potential for non-fossil resources (ADPE)	kg Sb eq.	2,153E-08	1,345E-06	6,694E-06
Abiotic depletion potential for fossil resources (ADPF)	MJ	4,117E+00	5,073E+01	6,542E+02
Acidification potential of soil and water (AP)	kg SO <sub>2</sub> eq.	4,241E-04	1,805E-02	2,844E-01
Eutrophication potential (EP)	kg (PO <sub>4</sub> ) <sup>3-</sup> eq.	9,338E-05	1,245E-03	5,276E-02
Global warming potential (GWP)	kg CO <sub>2</sub> eq.	1,354E-01	4,771E+00	6,234E+01
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11 eq.	2,533E-09	2,533E-07	4,533E-06
Formation potential of tropospheric ozone (POCD)	kg C <sub>2</sub> H <sub>4</sub> eq.	2,957E-05	9,924E-04	1,554E-02
Non-hazardous waste dispose (NHWD)	kg	4,111E-04	1,440E+01	1,921E+02

Use of net fresh water (FW)	m <sup>3</sup>	3,768E-04	3,375E-02	5,317E-01
Total use of non-renewable primary energy resource (PENRT)	MJ	4,306E-02	6,737E+01	8,924E+02
Total use of renewable primary energy resources (PERT)	MJ	2,113E-01	1,042E+01	1,301E+02

For every indicator that isn't listed in the table can be found in Appendix 8. All their values are zero. One of the biggest differences can be seen how the values increase from the simplest product, the junction box, to the most complex product, the thermostat. It is also interesting that the indicators that have a value for the products are the same for each product.

The following figures, Figure 17, Figure 18 and Figure 19, show the percentage of how much each life cycle stage contributes to each impact categories for all products. This gives a way to analyze how the impacts are not the same even within same product group.

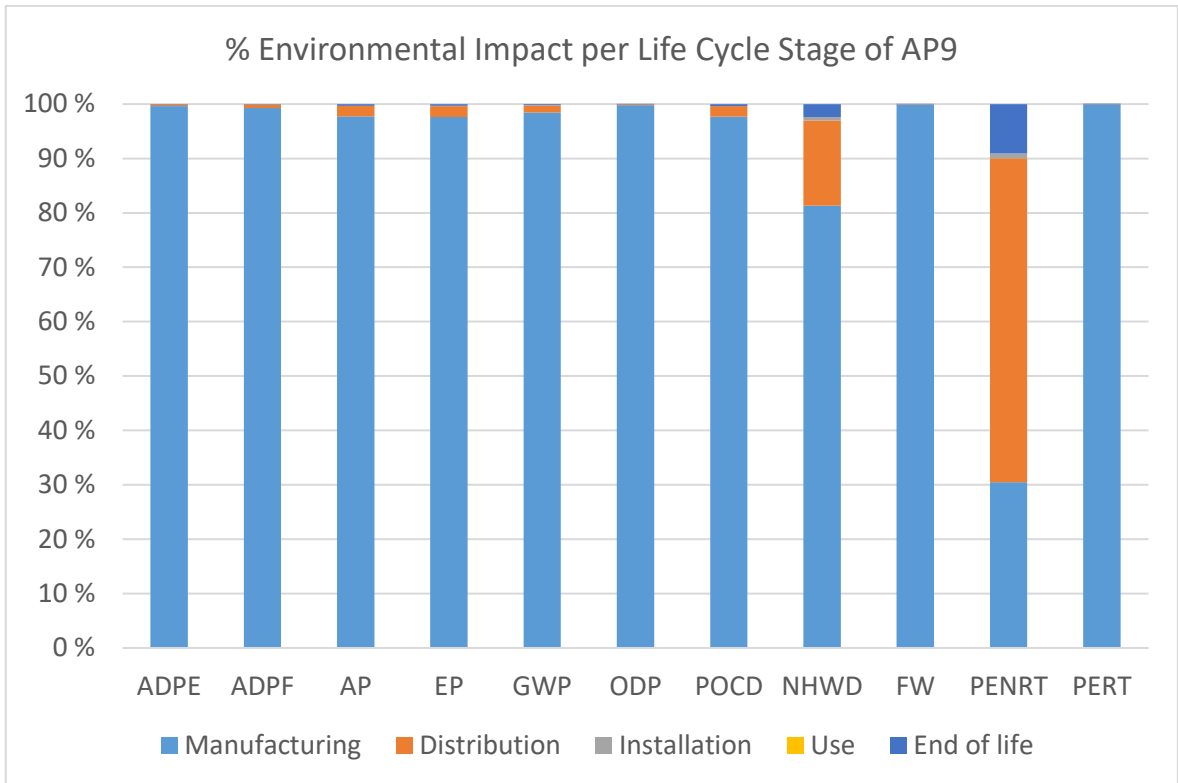


Figure 17: % Environmental Impact per Life Cycle Stage of AP9

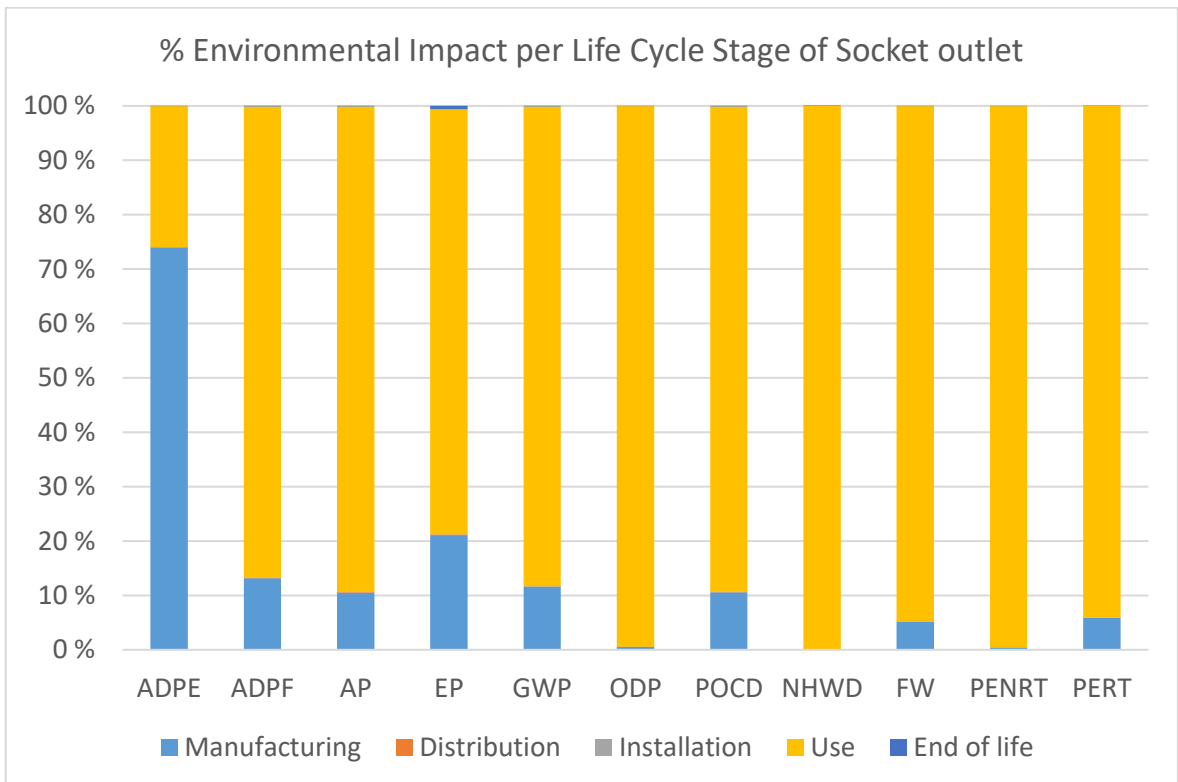


Figure 18: % Environmental Impact per Life Cycle Stage of Socket outlet

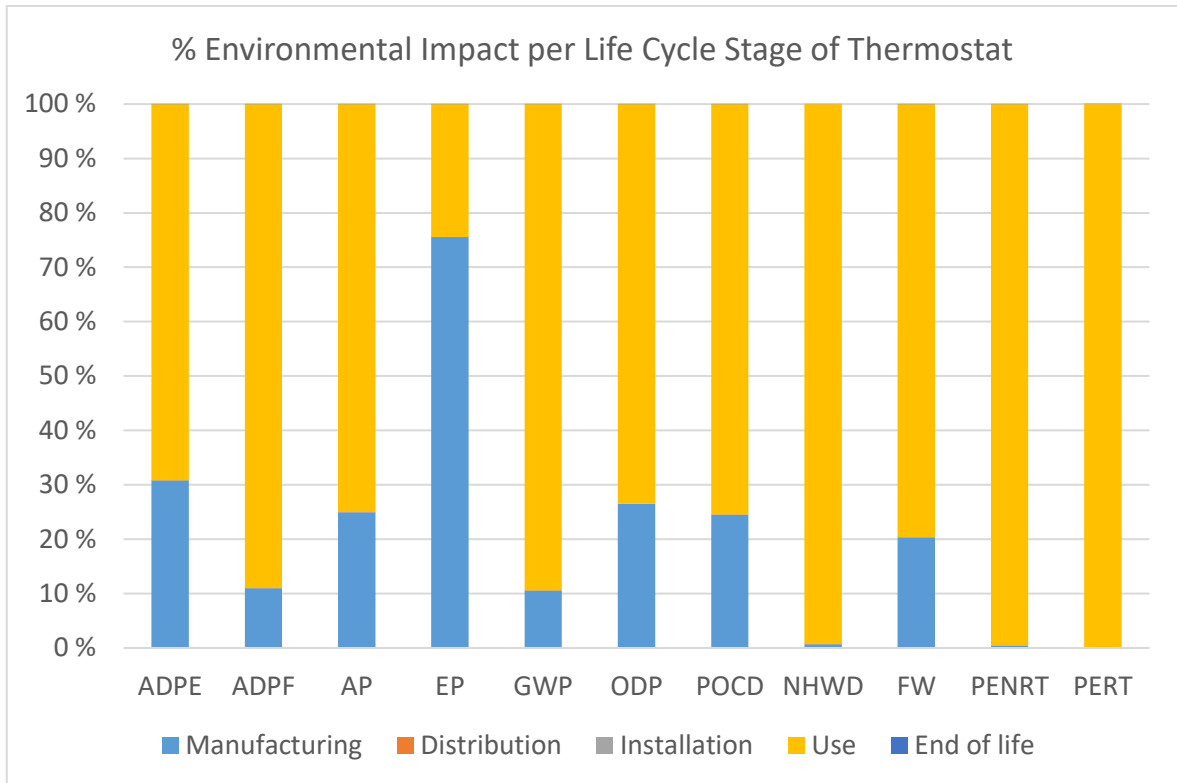


Figure 19: % Environmental Impact per Life Cycle Stage of Thermostat

Manufacturing and use stage are the biggest contributors for the total results. The junction box is the odd one out because it doesn't have any impact in the use stage, but this has only increased the contribution manufacturing stage has overall. It is interesting that the distribution, installation and end of life stages only make an impact on a hand full of categories, but this is only if there are no impacts on from the use stage. A surprise from the results was also how big the impact of the use stage is for the products.

### **13 COMPILING INFORMATION AND RESULTS TO THE EPD**

With the LCA calculations and the report ready the results can be compiled to the EPD. However, before this can happen, a template in which the results and information are accompanied must be available. Many EPD programs have made their own templates according to ISO 14025 and EN 51804, which companies can use when making their EPDs. With PEP Ecopassport they have not made this kind of template available, but companies can create their own unique template based on the Editorial Policy. The made EPD for ABB can be seen in Appendix 7.

So, to make the EPD, a template for it must be made first. This is made based on the instruction from ISO 14025, EN 51804, PCR, PSR, and editorial policy. To better understand the instructions and guidelines from these documents, existing EPDs that have been registered to PEP were also used as examples. A general example was also looked at from other EPD program templates and EPDs, this was mainly to have more examples on how information is presented, what type of information is presented, and how the presented information can change from one EPD program to another. Looking at already existing EPDs and other programs templates also give ideas of how ABBs template can be made to stand out from the others and are there some type information that should be highlighted in the template to separate themselves from the competition. The template made for these EPDs are also intended to be used by other ABB units, so this had to be considered when making the template.

Overall, there are four different sections where the information and results are described: General information, Constituent materials, Additional environmental information, and Environmental impacts. Unique for EPD made with PEP Ecopassport is that the name of the document should be called “Product Environmental Profile (PEP)” and not just Environmental Product Declaration. The general information section consists of information about the PEP Ecopassport program, the company that is making the EPD, and the product or products the EPD is made of. In the constituent materials section, the total mass of the product, packing, and any additional elements supplied with the product by the manufacturer

is presented. After this, the percentage of the total mass is indicated in the following categories: plastics, metals, and others. (PEP PCR, 2015, pp. 22-25.)

In the additional environmental information section, the environmental information of the product's life cycle is presented. The information is presented in the following categories: manufacturing, distribution, installation, use, and end-of-life. These categories correspond to the categories in which the LCA calculations are made. For all categories, the actions to reduce the environmental impacts of the life cycle stage are presented. For some cases like the manufacturing phase and use phase, there can be additional information provided if it is relevant like an absence of certain hazardous substances for manufacturing and noise level for use. (PEP PCR, 2015, pp. 25-27.)

The final section of the EPD consists of the results for the LCA calculations. The results are presented as each stage of the life cycle that is considered in the calculations with the total of the complete life cycle assessment. The most challenging part was with the environmental impacts where the LCA results are presented. The challenge comes with what indicators must be presented and what are optional. This was difficult because the information was quite scattered among different documents. In the end it was found that the obligatory indicators that must be presented can be found in the PCR that is used to make the EPD. (PEP PCR, 2015, p. 27.)

## **14 VERIFICATION AND PUBLICATION**

For the EPD to be registered to the PEP Ecopassport program, the EPD must be independently verified to certify its conformity with the programs PCR, PSR, and editorial policy. For PEP Ecopassport this verification must be done by a verifier that has been accredited by the program and is independent of the PEP publication process, meaning they can't be part of the making of the EPD. This however brings an interesting possibility that the person who verifies the EPD can be from the same company that the EPD is made from. This can be a benefit in terms of time and money that can be saved by not having to use another organization for verification. This however also brings the question of which is more creditable for the customer, having an internal or external verification. Whether the verifier is internal or external, the overall process of the verification process is the same. This process can be seen in Figure 20.

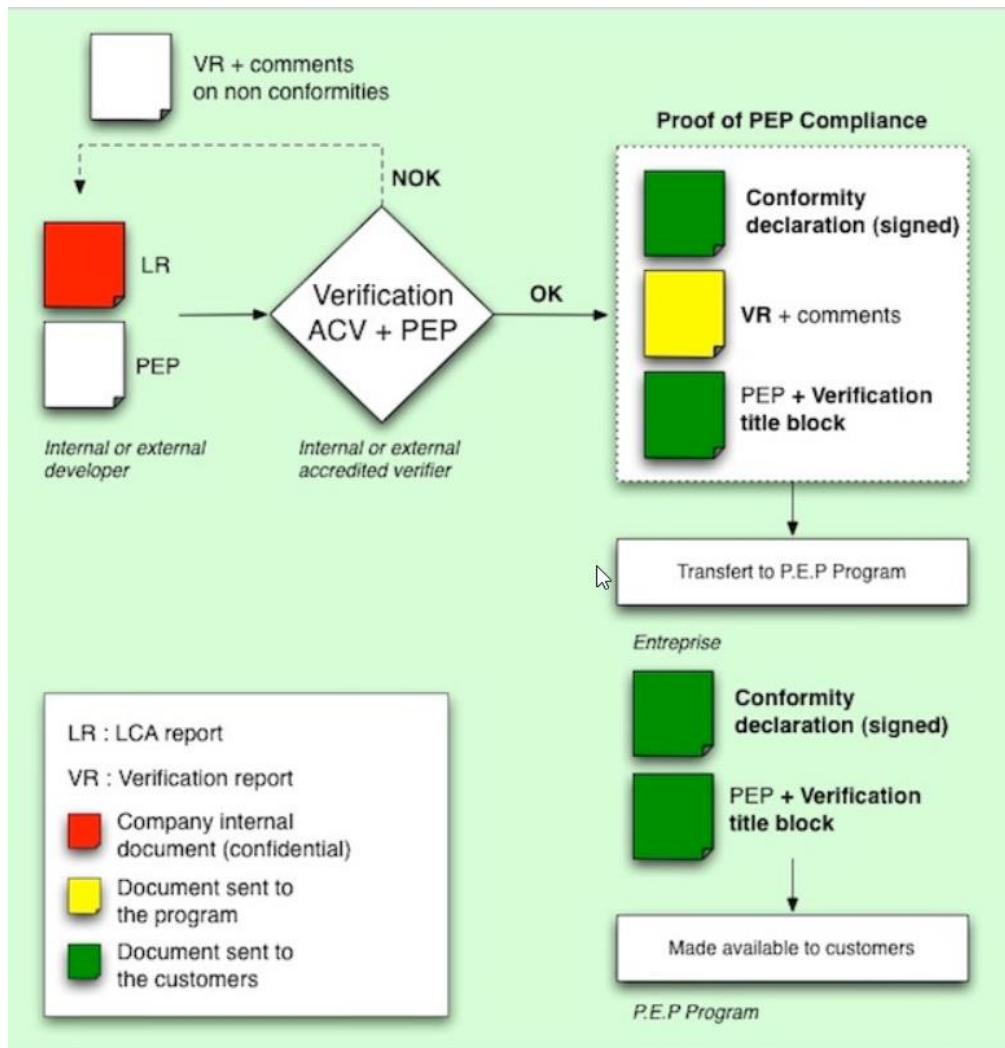


Figure 20: PEP programs verification process

From the Figure 20, it can be seen what steps are in the verification process and what type of documents are needed in every step. Also, it can be seen what steps of the process the independent verifier, the PEP program, and the company are responsible for. (PEP Ecopassport program, 2020)

Figure 20 also shows broadly what happens after the EPD has been verified. With the PEP Ecopassport having the necessary documents for the proof of compliance, the EPD is transferred to their program and after this, the EPD can be made available for customers.

What is also useful, is that the PEP program provides a draft version of the verification report on their website. This document consists of the topics and questions that the verifier looks

to find the answers from the EPD and LCA report. The list can be used already during the process of making the EPDs, to check everything necessary is available and can be found clearly.

## **15 DEVELOPING THE ECODESIGN MANAGEMENT PROCESS TOOL**

The idea for the ecodesign management process tool for ABB WA would be to utilize the LCA that are made for the EPDs already in product design and development. The end aim is that this type of tool would become a standard procedure when designing new products or changing something in existing products. The ecodesign management process tool would be somewhat based on ISO 14006. The defined ecodesign process in ISO 14006 includes six steps (ISO 14006, 2020):

1. Specify product functions
2. Environmental assessment of the product
3. Strategies of improvement
4. Environmental objectives;
5. Product specification and
6. Technical solutions

The first step can be simplified into choosing what product is looked at during this process. It can be for example, a junction box, a socket outlet or a thermostat. For step 2 LCA is one of the most useful tools for what is the aim of the step. The aim of this step is to identify which life cycle stage or process of the product's life cycle has the highest environmental impact. While ISO 14006 doesn't refer to LCA, it is still looked at as the most objective and frequently used tool for identifying the environmental performance of products. The aim for the remaining steps is to find solutions that can be implemented into the design to lower the impacts. (Navajas, et al., 2017, pp. 1-3.)

When looking at the figures (Figure 17, Figure 18 and Figure 19) for the junction box, socket outlet and thermostat it can be seen what life cycle stages are the biggest contributors for each impact category, but also what is the starting point of the process. Based on these types of figures the objective for the process can be set. The objectives and targets that are set would be unique for each product but in general they can relate to the following topics for example (Navajas, et al., 2017, p. 9):

- Cutting impacts related to a specific aspect of the product, like raw materials or transport
- Cutting environmental impacts of some specific life cycle stage as whole, like manufacturing or use stage
- Addressing end-of-life aspects, like disassembly, possibility to reuse or recycle the product
- Introducing a new material or manufacturing process

A specific life cycle stage can be looked at from many different angles with the LCA assessment producing results for many impact categories. Deciding what impact category is going to be the focus of the process, will help to set the targets for the process. After this is decided, the impact category results for the chosen life cycle stage can be looked at more closely. As an example, the global warming potential of the manufacturing phase for the AP9 can be seen in Figure 21.

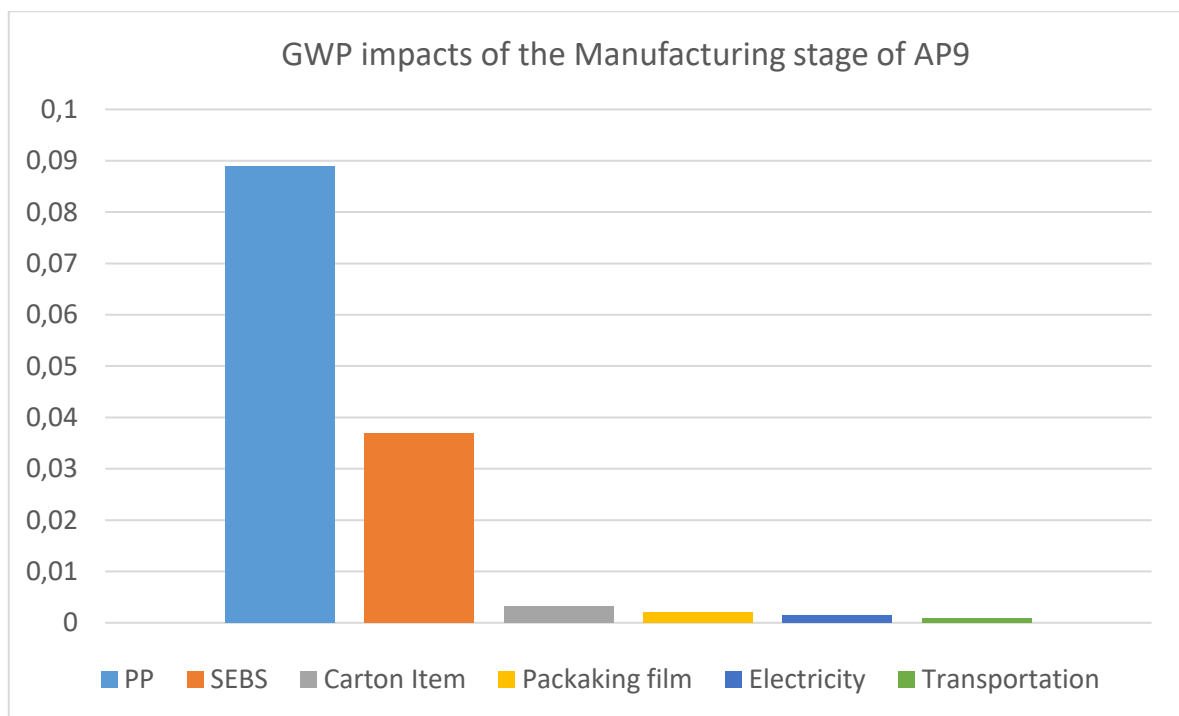


Figure 21: GWP impacts of the Manufacturing stage of the AP9

This figure shows that biggest factor for the overall GWP impact of the manufacturing stage is the raw materials of the junction box. The targets for the process should be set so that they show if the objective has been met and how well. In Table 34 examples of the type of objectives and targets that can be set based on Figure 21.

Table 34: Examples for objectives and targets

<b>Objective</b>	<b>Target</b>
Cutting the GWP impacts of manufacturing process	A specific percentage amount of the impacts
Introducing a new raw material for the product	the new materials impact to be lower than the old ones - a percentage target or an overall target of the impacts being lower

With the objectives and targets set the next part is to find solutions how they can be fulfilled. During this it can be good to find and work on multiple possible solutions that could theoretically be used as the solution. An important aspect when utilizing ISO 14006 process is that the end solutions shouldn't change the overall product, this means that the when implementing the possible solution any other design or technical standards related to the product should also be met.

## 16 CONCLUSIONS

The aim of this thesis was to make an EPD program that can help identify improvement possibilities for the sustainable development of ABB WA products. This program includes a step by step guide to make an EPD, based on the PEP Ecopassport guidelines and an ecodesign management process tool.

### 16.1 Guide to make an EPD

From the experiences with the three EPDs, a program for the making of the EPDs was created. This program consists of a step by step guide. One of the basic assumptions for this program is that the EPD program operator is the PEP Ecopassport and the PCRs are chosen from its published PCRs. These steps can be seen in Figure 22.

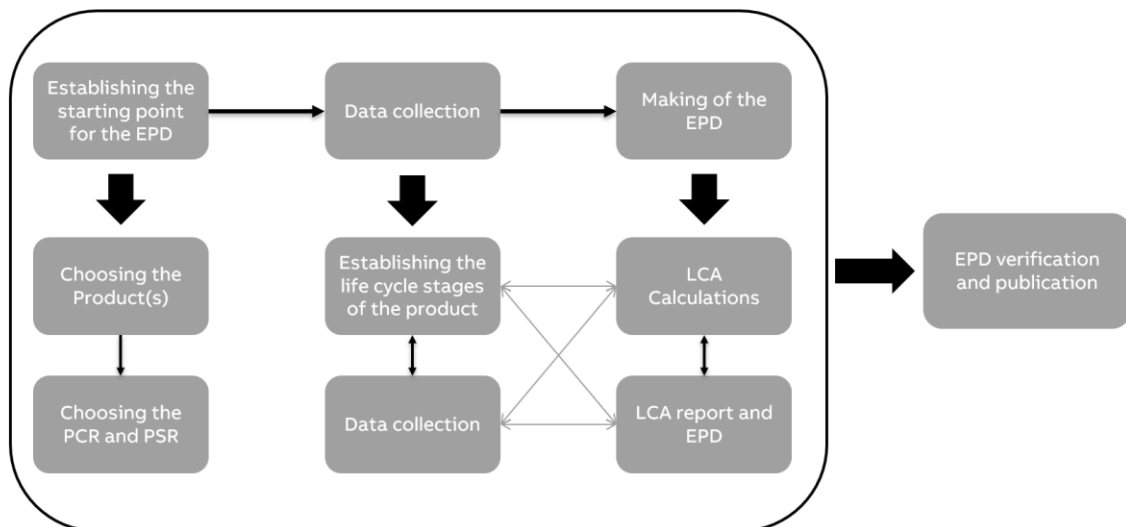


Figure 22: Steps to create an EPD

While the steps show a certain order do for the process, this doesn't mean that earlier steps can't be revisited based on things learned or noticed during the later steps, as can be seen in Figure 22. Probably the most common situation is where during the LCA calculations it is noticed that some data is still missing or needs to refine. Some of the steps can also happen concurrently, like establishing the life cycle stages and data collection, doing the LCA

calculations, and writing the LCA report can happen at the same time and they can both influence each other.

Before starting to gather any data and calculations it is good to establish for what product or products the EPD is intended to be made for and what are the overall parameters of the study. This helps make a baseline for the EPD, from which the data collection and the LCA study and EPD are then based.

### **16.1.1 Choosing the Products**

Naturally, the first stage before making anything for the EPDs is knowing for what products the EPD is made for. Because EPD can be cover multiple products, it would be efficient to include as many products as reasonably possible to one EPD. How many products is reasonable for one EPD varies between products and product groups. For this, it is good to follow the guidelines set by the PCR for what products can be included in the EPD. They were the following (PEP PCR, 2015, p. 14):

- Same main functionality
- Sama product standards
- Similar manufacturing technology, meaning same type of materials and manufacturing processes

Based on these guidelines, safe starting point for looking at what products can be included is a product range or family. An important factor for this is also to decide what is the reference product of the EPD. There are almost no guidelines on how the reference product should be chosen but based on the three products, it is good to have a product that represents all the other products well. (PEP PCR, 2015, p. 14)

### **16.1.2 Choosing the PCR and PSR**

Knowing what EPD program operator is used, choosing of the PCR and PSR is quite straight forward. As with the making of the three EPDs all of them were made under the PEP Ecopassport program, so the same main PCR was used for all of them. The PSR however is

dependent on what type of products the EPDs are planned to be made. PEP Ecopassport as all their PSR listed on their website where the PSR can be chosen from. The possible PSR can be seen in Table 35.

Table 35: The different PSR provided by PEP Ecopassport (PEP Ecopassport, 2020a).

<b>PEP Ecopassport PSR codes</b>	<b>Products covered by the PSR</b>
PSR0001	Wires, cables and accessories
PSR0002	Direct, visible, fixed electric heating appliances
PSR0003	Cable management
PSR0004	Individual and standalone domestic storage water heater
PSR0005	Electrical switchgear and control gear solutions
PSR0006	Drives for blinds and closures installed in buildings
PSR0007	Self-contained emergency electrical equipment
PSR0008	Ventilation Air Treatment Filtration and Mechanical Smoke Exhaust Equipment
PSR0009	Comfort Terminal Units
PSR0010	Uninterruptible power supply (UPS)
PSR0011	Hot water radiators or towel radiators
PSR0012	Gas, fuel oil, or biomass boilers
PSR0013	Thermodynamic generators with electric compression for heating and/or cooling of premises and/or the production of domestic hot water
PSR0014	Luminaires
PSR0015	Wood heating system appliance for individual dwellings
PSR0016	Storage Tanks
PSR0017	Thermal solar collectors

It can be assumed that for most of ABB WA's products the PSR that was used for the three products, PSR0005, would work for them as well. But if there are some exceptions then the PSR is chosen by going through them and finding the one that fits best for the product in question.

Many of the PSR cover multiple product categories, like with the PSR0005, so it is important to also choose which product category is right for the product the EPD is going to be made for. Many of these can be straight forward, but for some products, it can be more difficult to choose.

Overall if there are any problems with choosing the PSR or the product category, already published EPDs can be used as guidance. PEP Ecopassport has a database of EPDs published under their program, where these can be looked at (PEP Ecopassport, 2020c).

### **16.1.3 Data collection**

Before starting the data collection for the LCA calculations it is good to get know what type of processes are included in the reference products life cycle stages and what type of information is needed for the LCA study and for the EPD itself.

This can be started by gathering the information from the PCR and PSR that is relevant for the reference product. This can be for example the functional unit, use scenario, and system boundaries. Some of this can be done by filling in the information to the EPD template based on the PCR and PSR. This can help see what type of information is already known, what information needs to be gathered for the EPD template, but also the whole process can help understand what type of information is needed for the LCA calculations. This is especially good for data regarding all the life cycle stages but the manufacturing stage.

For the manufacturing stage before starting the data collection, it is good to understand what the manufacturing process is like and what are the different stages in it and what is their purpose in the process. This will help during the data collection process itself by already

knowing what inputs and outputs need to be collected based on the PCR and PSR, but also what type of inputs and outputs should be expected for each process. This can also help when gathering the data to the LCA software, and therefore help getting the calculations correct.

The data collection can be divided into two main categories: Data related to manufacturing and Data related to the other life cycle stages. For the manufacturing stage, it can be also divided further into the production process of the product itself, transportation that happens during this stage, and data from the suppliers on the raw material and possible components.

The data for the production of the product or components, already knowing how the product or components are made, can help when gathering the data those process. Because the different steps of the production are known, like manufacturing of different components of the product, in what order the product is assembled and packaged and how these are made, mainly by hand or by machine, these should help to gather the data for each step of the production. Generally, the data that needs to be gathered for all types of products are the listed in Table 36.

Table 36: Data needed to be collected for manufacturing stage

<b>Aspect of Manufacturing stage</b>	<b>Data needed to be collected</b>
Material information	- Materials and weight of each component included in the product, including packaging materials
Waste	- What type of waste and how much? - What happens to the waste? Unsorted or sorted? Material recovery, energy recovery or landfill?
Energy consumption	- How much energy is consumed during the manufacturing of the products?
Transportation	- Distance and the transportation mode

With waste disposal it is good to know the waste types sorted before collection and where they should go after they are collected. This would mean either going to material recovery, energy recovery, or landfill. At least how the waste is collected should be known while information on where the waste goes can be more unreliable.

For the energy consumption, the information can be a measurement of the energy consumption straight from the manufacturing process or it can be data based on which the energy consumption would be calculated, like process time and power need. From these two the preferable option would be the measurement because it is more accurate, but if the measurement option isn't available then the data works well also.

The transportation of the manufacturing stage includes the transportation of raw materials and other components to ABB WA, but also transportation of possible waste and the transportation to ABB WA last logistic step. The needed information for the EPDs is what is the traveled distance and what is the mode of transportation. For the data collection, this means gathering the following information: where the supplier's products come from and where the waste and product go from the factory. The more accurate location also leads to more accurate results from the calculations, so the aim should be to get an as accurate location as possible. For the transportation methods the same aim applies to get the most accurate information, but for the situation where this isn't possible then estimations like shown in figures Table 8 and Table 9 can be used. It can be helpful to get the same type of estimations from all logistic partners, so the right estimation could be used for the right product. This would also mean getting information on which logistic partner handles which raw materials and products.

Related to the transportation of supplier's materials or components, it also good to get data from the suppliers on the raw materials or components. This way the LCA calculations would be more accurate. The asked data from the suppliers could be in the form of an EPD or LCA data of the raw material or component, or also the answers to the same type of questions as seen in figure/table. What is important to understand is that the needed data is mainly focused on the production or manufacturing of raw materials or components, the suppliers input in especially the end-of-life stage can be useful also. Especially, if the data is in the form of an EPD or LCA data, then there can be information in them that is useful for the later life cycle stages, especially for the end-of-life.

Overall, the information and data that is needed to be collected for the other life cycle stages can be seen in Table 37.

Table 37: Data need for the other life cycle calculations

Life cycle stage	Data needed to be collected
Installation stage	<ul style="list-style-type: none"> <li>- Installation process is there any energy consumption or material consumption</li> <li>- Need for additional installation materials: How much and assumption where it comes from</li> <li>- Waste generated during this stage: what is the waste and what happens to it?</li> </ul>
Use stage	<ul style="list-style-type: none"> <li>- Energy consumption estimation based on the use scenario</li> <li>- Need for maintenance: how often and consumed materials and/or energy during it</li> </ul>
End-of-life stage	<ul style="list-style-type: none"> <li>- How much waste there is?</li> <li>- What happens to it? Material recovery, energy recovery or waste disposal (landfill or incineration without energy recovery)</li> </ul>

The aim for this part of the process should be that collected would be primary data as specified in chapter 6.3.1. This is especially for the manufacturing stage and this would be the aim because the quality of the data would make the quality of the results more accurate. There are some exceptions, like with the use of databases for electricity mixes and transportation methods for example. It can also be assumed that it will be better to use the different end-of-life processes provide in the databases. But for all the other situations using the database should be the last option.

#### 16.1.4 Making of the EPD

This stage would include making the LCA calculations, writing the LCA report and EPD document. With this stage there isn't a strict structure that in which order the parts should be made. Doing the first version of the LCA calculations can help start the whole process, but also writing some parts of the LCA report can help when constructing the LCA calculations in the LCA software. It can be preferable that these parts are made in some aspect at the same time, as this can help see and find mistakes and problems that otherwise maybe wouldn't be possible otherwise.

The LCA calculations start with building the life cycle stages and process included in them to the LCA software. This building would be based on the information and data gathered during the data collection. To not make the process too complicated, it can be good to divide some processes into small pieces. For example, focusing on only one main task per process. These can be, for example, transportation of a specific raw material, component, or a product, or production of a specific component, or focusing on a specific production process, like injection molding or packaging. This will help to build the processes overall, but it can also help with the allocation of input or output flows.

By distinguishing what processes belong to which of the five life cycle stages can also help with getting the results for each of these stages. How this is done can depend on what LCA software is used, but this is something that can be worked out with each software and what works best for one doing the calculations. With open LCA for example it is possible to get the results for just one life cycle stage at a time. This can also be useful for situations where there is more than one product included in the EPD. If there are only changes in the manufacturing stage, then the other life cycle stages made for the other product version can be this product also.

Using parameters in the process can also help when all processes for a product are ready and connected, and there is a need to change a specific value, as with parameters this can be done easily. This is especially for situations like the one mentioned above where there is more than one product included in the EPD. If the only change is the weight of the product, for example, the calculations for the product can be done by just changing the value of the parameter.

Important for the calculations is to check what type of results are gotten from the LCA calculations at that time and are they anything that should be expected. For this it can be helpful to look at the calculations and results with someone who hasn't been part of the making the calculations, this can bring a new perspective and some mistakes or abnormalities can be brought up this way. Looking at already made EPD that is based on the same PSR and product category can also help with some reference in what value range the results should be in. It should be noted that the results for other products are unique to those

products, but if there are some major differences in what range the results are, it can give an indication that there is something wrong with the calculations.

If something seems to be wrong in the LCA results, the first action should be to check if there are any calculation mistakes, like a wrong value in the wrong place, point or comma mistakes, or unit mistakes. It is also important to check that all the necessary flow connections for the process are connected and that the flows from process to process meet the expectations. If nothing is found from these then the data of the process or processes should be checked as the mistake is most likely there.

These types of checks are good to make at least a few times during the calculation process, to make sure everything is correct. How many of these checks are needed is depended on the LCA calculations and the product. For simpler products, that consist of only a few components, it can be assumed that the need for these checks is fewer than for more complex products that consist of multiple different types of products.

As stated above there isn't a correct point when the writing of the LCA report or EPD should start. For the EPD some parts can already be written during the data collection process as stated before, but some parts must be written at the very end, like the LCA results. Overall, it can be said that the major writing stage for these starts at the earliest after the data collection. Does this happen after some LCA calculations are already made or before, can depend on what type of product is in question. For some products it can be helpful to write a first draft for some parts of the LCA report, like the description of the life cycle stages for example, before starting the LCA calculations. It can help in understanding the life cycle stages better which in turn can make the calculation process much easier. For some products there isn't any difference which is started first, making the calculations or writing the report.

Like with the LCA calculations it is good to have other people, who may know about the product or process more, look at the report during the process, because they can notice some mistakes or if something is missing that may not have otherwise be noticed. And by having these types of checkups at least a few times during the process can help cut down the time that it then would take to make the possible change in the calculations and the report.

## 16.2 Ecodesign management process tool

Based on the process defined in ISO 14006 and findings from the made LCAs, the process steps for the ecodesign management process tool would be the following (Figure 23).

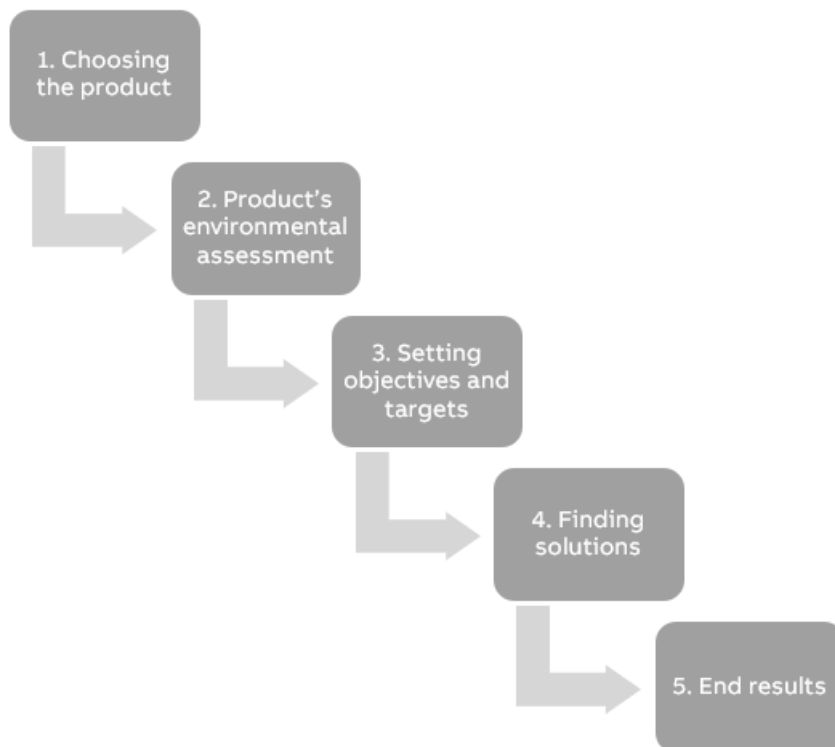


Figure 23: Ecodesign management process tool for ABB WA

The first and second stages are relatively simple. The aim of these two steps is to perform an LCA for the chosen product, which then is used to identify which life cycle stage or process of the product life cycle has the highest environmental impact. The LCA should be made following the same guidelines that the LCAs intended for EPD are made. This way there is consistency in all the LCAs that are made inside ABB WA. The objectives and targets that are set in step 3 are set based on the finding from the findings from the LCA. These can relate to the impact of the product or a life cycle stage, introduction of a new raw material or a process to a life cycle stage for example.

The next step (Figure 23) is about finding different solutions on how the objective and target can be met while also taking into account other design considerations that are relevant for the product. In some respects, the challenge of this stages is to find compromises that meet the objective and target, while not changing the product overall. The result of the process is the product with the found solution implemented into it.

Figure 24 shows an example on how this tool can be used and what type of findings can be made during each step. The example is based on the findings from Figure 17 and Figure 21.

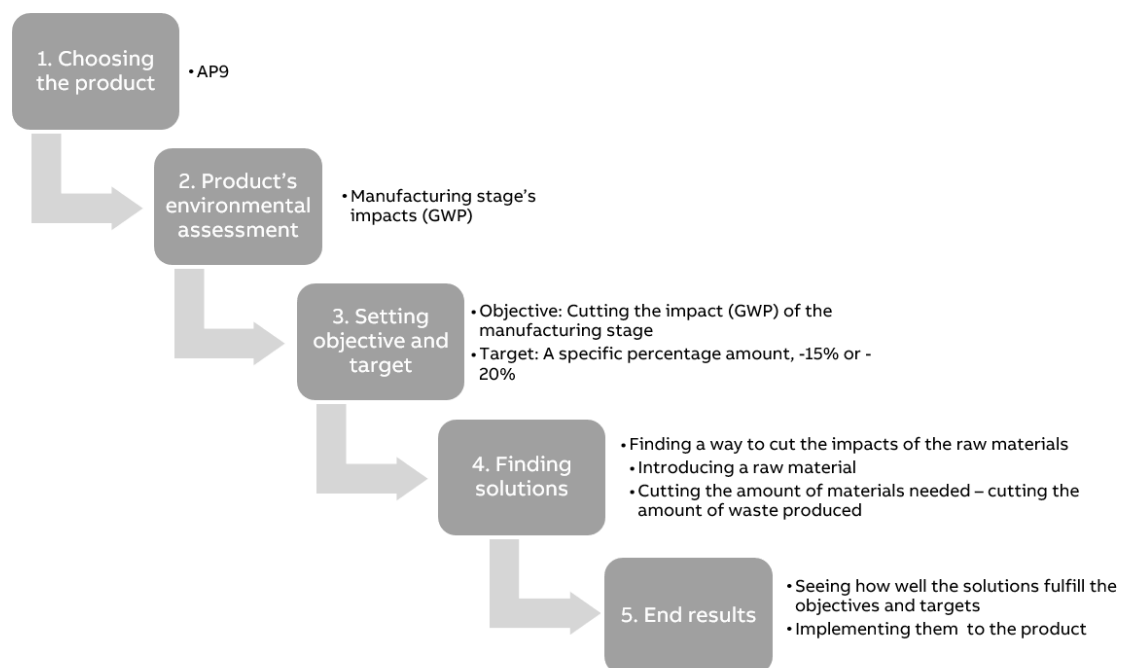


Figure 24: Example on how the ecodesign management process tool can be utilized

The implementation and the use of this kind of process will become easier and more seamless when the collection of already made LCAs for different products has grown and the amount of data that is available on different aspects of products and life cycle stages has grown also. This way the time it takes to make the environmental assessment for the product would be cut down, and more effort and time can be put into finding new solutions to fulfil the objectives and targets. It is also important to remember that every time this process is used, even if an LCA has already been made for the product in the past, it is good to check possible

earlier LCAs if something's has changed so the starting point of the process is the most representative of the current situation.

The ecodesign management process tool, if utilized during the process of making an EPD for the product, would overlap several steps of the creating the EPD but the main step is that this would take place in would be LCA calculations. This process can also work in the order that the main purpose would be to utilize the ecodesign management process tool and during this an EPD is made for the end results of this process.

## 17 SUMMARY

The aim of this thesis is to create an EPD program for ABB WA. The program consists of a step by step guide for making EPDs and an ecodesign management tool. The thesis first goes through what are EPDs, what things are driving its demand, especially in the construction industry, what type of business value does the EPD have and how EPDs are made based on ISO 14025 and EN 15804. After this three EPDs are made for junction box, socket outlet and thermostat., based on ISO 14025, EN 15804 and the guidelines of PEP Ecopassport. Finally, the step by step guide and ecodesign management tool are made based on the experience and what is learned from the making the EPDs. For the step by step guide an emphasis is put on parts and steps that are important and affect ABB WA. For the ecodesign management tool ISO 14006 standard is also utilized in the making of.

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### Appendix 1: List of different EPD Program Operators

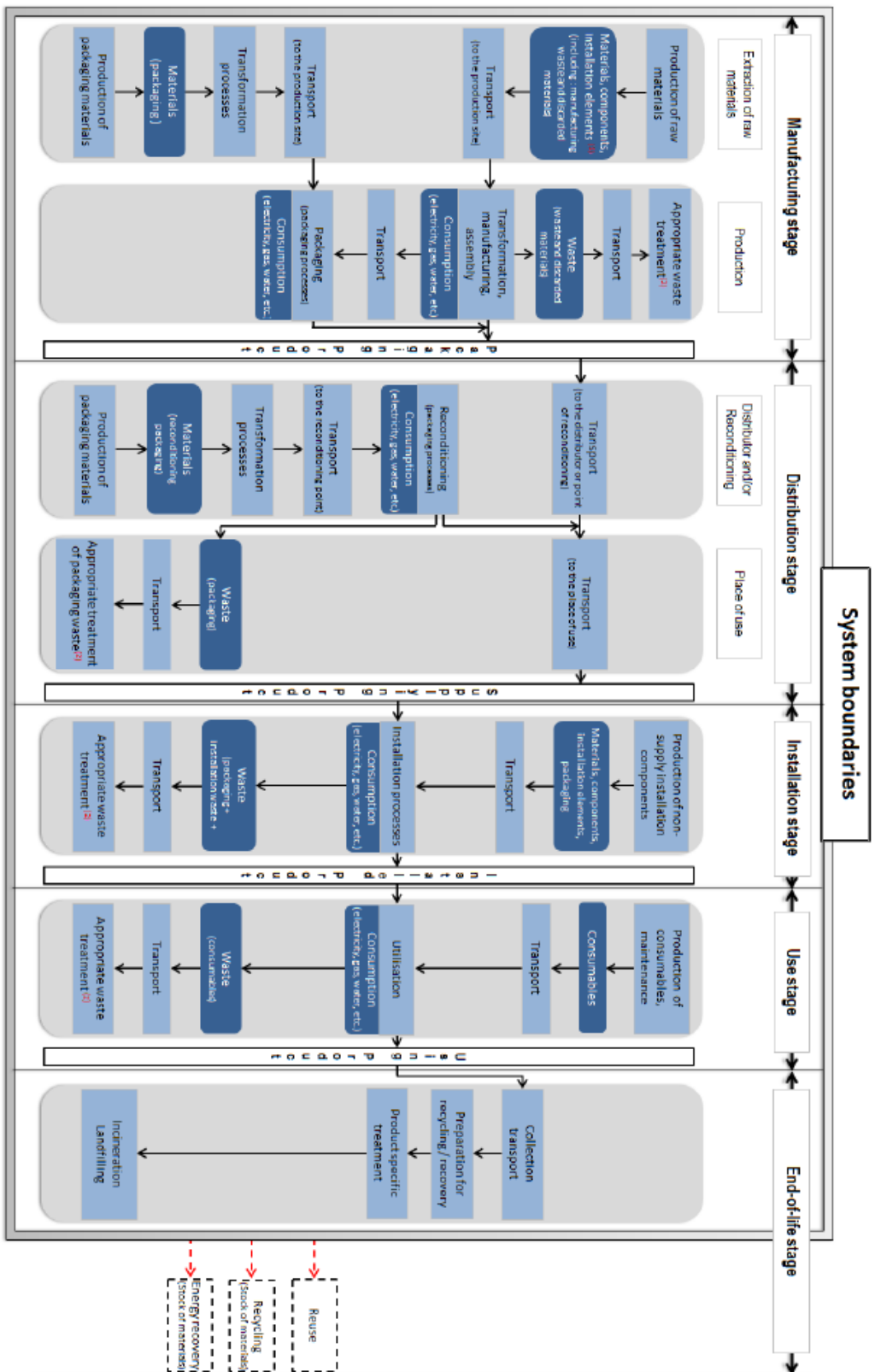
<b>Product name</b>	<b>Country</b>	<b>Language</b>	<b>Geographic</b>	<b>Scope</b>
The International EPD® System	SE	English	International	Generic
Earthsure – Institute for Environmental Research and Education	US	English	International	Generic
SCSglobal	US	English	International	Generic
ECO-LEAF	JP	English/Japanese	International	Generic
Korean Environmental Industry & Technology Institute EDP	KR	Korean	International	Generic
The Association for Environmental Relevant Product Information	NL	Dutch	National	Building and construction
The Norwegian EPD Foundation	NO	English/Norwegian	International	Generic
Institut Bauen und Umwelt e.V.	DE	English/German	International	Building and construction
Instytut Techniki Budowlanej	PL	English/Polish	International	Building and construction
European Aluminium Association	EU	English	Europe	Aluminium
Danish Environmental Protection Agency	DK	English/Danish	International	Generic
Environment and Development Foundation	TW	Taiwanese	Unclear	Unclear

FDES INIES	FR	French	International	Building and construction
PlasticsEurope	EU	English	International	Uncompounded polymer resins, or reactive polymer precursors
PEP Ecopassport	FR	English/French	International	Electric, electronic and HVACR products
BRE Global Limited	UK	English	International	Building and construction
Sistema Declaraciones Ambientales de Productos por la construcción	ES	Spanish	National	Building and construction
The Green Standard	US	English	Unclear	Unclear
Carbon Leadership Forum	US	English	International	Building and construction
Agence de l'Environnement et de la Maîtrise de l'Energie   AFNOR	FR	French/English	International	Generic
Confederation of European Paper Industries	EU	English	Europe	Paper
FP Innovations	CA	English	Unclear	Wood products
ift Rosenheim	DE	German	National	Building and construction
NSF International	US	English	North America	Generic

The Spanish Association for Standardisation and Certification	ES	Spanish	International	Generic
UL Environment	US	English	International	Generic
Centrum environmental ích prohlasení	CZ	Czech	National	Generic
Canadian Standard Association Group	CA	English	International	Generic
Declaracion Ambiental de Productos de Construcccion	CL	English/Spanish	National	Building and construction
Global GreenTag (old name: ecospecifier)	AU	English	International	Generic
ICC Evaluation Service	US	English	North America	Building and construction
ASTM International	US	English	North America	Generic
National Ready Mixed Concrete Association	US	English	International	Ready mixed concrete
Product Environmen al Footprint	EU	English	Europe	Generic
Slovenian National Building and Civil Engineering Institute	SL	English/Slovenian	National	Building and construction
The Austrian EPD Platform	AT	English/German	Europe	Building and construction
The DAPHabitat system	PT	Portuguese	National	Building and construction

The International EPD® System Türkiye	TR	Turkish	National	Generic
Australian and New Zealand EPD System	AU/NZ	English	International	Building and construction

Appendix 2: System boundaries for the LCAs



### Appendix 3: Environmental impact indicators from the PEP Ecopassport program

#### PCR based on EN 15804 + A1

#### Environmental impact indicators

Indicator	Description	Unit
Global warming	Indicator of potential global warming caused by emissions to air contributing to the greenhouse effect	kg CO <sub>2</sub> eq.
Ozone depletion	Indicator of emissions to air that contribute to the destruction of the ozone layer	kg CFC-11 eq.
Acidification of soil and water	Indicator of the potential acidification of soils and water caused by the release of certain gases to the atmosphere	kg SO <sub>2</sub> eq.
Eutrophication	Indicator of the contribution to eutrophication of water by the enrichment of the aquatic ecosystem with nutritional elements, e.g. industrial or domestic effluents, agriculture, etc.	kg (PO <sub>4</sub> ) <sup>3-</sup> eq.
Photochemical ozone creation	Indicator of emissions of gases that affect the creation of photochemical ozone in the lower atmosphere (smog) due to the effect of the rays of the sun.	kg C <sub>2</sub> H <sub>4</sub> eq.
Depletion of abiotic resources - elements	Indicator of the depletion of natural non-fossil resources	kg Sb eq.
Depletion of abiotic resources – fossil fuels	Indicator of the depletion of natural fossil resources	MJ (Lower Heating Value)

Water Pollution	Indicator of the quantity of water necessary to dilute the toxic elements poured into water in all the stages of the product life cycle.	m <sup>3</sup>
Air pollution	Indicator of the quantity of air necessary to dilute the toxic elements emitted into the air in all the stages of the product life cycle.	m <sup>3</sup>

## Resource use indicators

<b>Indicator</b>	<b>Unit</b>
Use of renewable primary energy, excluding renewable primary energy resources used as raw materials	MJ, Lower Heating Value
Use of renewable primary energy resources as raw materials	MJ, Lower Heating Value
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, Lower Heating Value
Use of non-renewable primary energy, excluding non-renewable primary energy resources used as raw materials	MJ, Lower Heating Value
Use of non-renewable primary energy resources as raw materials	MJ, Lower Heating Value
Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, Lower Heating Value
Total use of primary energy [Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) + Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)]	MJ, Lower Heating Value
Use of secondary materials	kg
Use of renewable secondary fuels	MJ, Lower Heating Value
Use of non-renewable secondary fuels	MJ, Lower Heating Value
Net freshwater use	m <sup>3</sup>

## Waste category indicators

<b>Indicator</b>	<b>Unit</b>
Hazardous waste disposed	kg
Non-hazardous waste disposed	kg
Radioactive waste disposed	kg

## Output flow indicators

<b>Indicator</b>	<b>Unit</b>
Components for reuse	kg
Materials for recycling	kg
Materials for energy recovery	kg
Exported energy	MJ by energy vector

## Appendix 4: Environmental indicators described in EN 15804 + A2

### Core environmental impact indicators

Impact category	Indicator	Unit
Climate change – total	Global Warming Potential total (GWP-total)	kg CO <sub>2</sub> eq.
Climate change - fossil	Global Warming Potential fossil fuels (GWP-fossil)	kg CO <sub>2</sub> eq.
Climate change - biogenic	Global Warming Potential biogenic (GWP-biogenic)	kg CO <sub>2</sub> eq.
Climate change - land use and land use change	Global Warming Potential land use and land use change (GWP-luluc)	kg CO <sub>2</sub> eq.
Ozone Depletion	Depletion potential of the stratospheric ozone layer (ODP)	kg CFC 11 eq.
Acidification	Acidification potential, Accumulated Exceedance (AP)	mol H <sup>+</sup> eq.
Eutrophication aquatic freshwater	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater)	kg PO <sub>4</sub> eq.
Eutrophication aquatic marine	Eutrophication potential, fraction of nutrients reaching marine end compartment (EP-marine)	kg N eq.
Eutrophication terrestrial	Eutrophication potential, Accumulated Exceedance (EP-terrestrial)	mol N eq.
Photochemical ozone formation	Formation potential of tropospheric ozone (POCP)	kg NMVOC eq.

Depletion of abiotic resources – minerals and metals	Abiotic depletion potential for non-fossil resources (ADP-minerals&metals)	kg Sb eq.
Depletion of abiotic resources – fossil fuels	Abiotic depletion for fossil resources potential (ADP-fossil)	MJ, net calorific value
Water use	Water (user) deprivation potential, deprivation- weighted water consumption (WDP)	m <sup>3</sup> world eq. deprived

## Additional environmental impact indicators

<b>Impact category</b>	<b>Indicator</b>	<b>Unit</b>
Particulate Matter emissions	Potential incidence of disease due to PM emissions (PM)	Disease incidence
Ionizing radiation, human health	Potential Human exposure efficiency relative to U235 (IRP)	kBq U235 eq.
Eco-toxicity (freshwater)	Potential Comparative Toxic Unit for ecosystems (ETP-fw)	CTUe
Human toxicity, cancer effects	Potential Comparative Toxic Unit for humans (HTP-c)	CTUh
Human toxicity, non-cancer effects	Potential Comparative Toxic Unit for humans (HTP-nc)	CTUh
Land use related impacts/ Soil quality	Potential soil quality index (SQP)	dimensionless

## Parameters describing resource use

<b>Parameter</b>	<b>Unit</b>
Use of renewable primary energy excluding renewable primary energy resources used as raw materials	MJ, net calorific value
Use of renewable primary energy resources used as raw materials	MJ, net calorific value
Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ, net calorific value
Use of non-renewable primary energy resources used as raw materials	MJ, net calorific value

Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
Use of secondary material	kg
Use of renewable secondary fuels	MJ, net calorific value
Use of non-renewable secondary fuels	MJ, net calorific value
Net use of fresh water	m <sup>3</sup>

## Other environmental information describing waste categories

Parameter	Unit
Hazardous waste disposed	kg
Non-hazardous waste disposed	kg
Radioactive waste disposed	kg

## Environmental information describing output flows

Indicator	Unit
Components for re-use	kg
Materials for recycling	kg
Materials for energy recovery	kg
Exported energy	MJ per energy carrier

## Information describing the biogenic carbon content at the factory gate

Biogenic carbon content	Unit
Biogenic carbon content in product	kg C
Biogenic carbon content in accompanying packaging	kg C



## Appendix 6: Document used to ask about Thermostat material content



ABB, 1 OCTOBER 2019

## Building product declaration Byggvarudeklaration

ABB Document ID:	
Document creation date:	
Product group description:	

### Revision

Modified (Date)	User (Name)	Changes done

### Supplier/Manufacturer information

Supplier:	
VAT-number:	
Contact person:	
Address:	
E-mail:	
Phone number:	
Company website:	

The company possesses certification in compliance with:

ISO 9001

ISO 14001

### Appendix:

Appendix I: Product list

For more information please contact:

**Marie-Sofie Seger**  
Phone: +358 50 33 577 17  
Email: marie-sofie.seger@fl.abb.com

**ABB Oy**  
Porvoon Sääkehä 2  
FI-06100 Porvoo  
Finland



### Supporting documents

- Declaration of conformity covering the RoHS-directive (2011/65/EU).
- Environmental product declaration in accordance with EN 15804.
- Declaration of performance in line with European Construction Products Regulation (EU) no 305/2011.

### Product information

Products/articles included in this declaration are listed in Appendix I: Product list.

- |   |                                  |                                   |
|---|----------------------------------|-----------------------------------|
| Type of product   | <input type="checkbox"/> Article | <input type="checkbox"/> Chemical |
| Is the chemical composition different, for the products when applied (cured product) compared to the content at delivery? | <input type="checkbox"/> Yes     | <input type="checkbox"/> No       |
| Are the products in compliance with RoHS-Directive 2011/65/EU?  | <input type="checkbox"/> Yes     | <input type="checkbox"/> No       |
| Are the products covered by an exemption according to RoHS-directive (2011/65/EU)?  | <input type="checkbox"/> Yes     | <input type="checkbox"/> No       |
| Are the products in compliance with REACH Regulation (EC) No 1907/2006?   | <input type="checkbox"/> Yes     | <input type="checkbox"/> No       |
- ABB Wiring Accessories has a process in place to ensure compliance with the legal requirements.*

### Declaration of contents

#### Byggarubedömningen

The data and declaration of contents provided in this Building product declaration is in accordance with Byggarubedömningen's criteria for chemical content and lifecycle aspects, Version 5.0. Valid from 2019-07-01.

#### SundaHus

The data and declaration of contents provided in this Building product declaration is in accordance with SundaHus Environmental data guidelines and declaration/information requirements for assessment of product, Bedömningskriterier 6.1.4.

#### Nordic Swan ecolabel

The data and declaration of contents provided in this Building product declaration is in accordance with Nordic Ecolabelling guidelines and declaration/information requirements for assessment of product, Version 3.7 • 09 March 2016 – 31 December 2022.

*Table 1. Contents of included substances and material in declared products/articles, on delivery. (Declaration of content in accordance with requirements)*

Included material	Constituent substances	EG No. /CAS No.	Weight-% (of the product)	Comments (state any application of non-harmonized classifications)

**Table 2. Please declare if the product(s) contain the following substance group/substance**

---



Arsenic and its compounds	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Brominated flame retardants	<input type="checkbox"/> Yes	<input type="checkbox"/> No
PFOA (perfluorooctaneacids)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
PFOS (perfluorooctane sulfonate)	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Organotin compounds	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Biocidal product applied on products (surface treatments) to provide a disinfectant or anti-bacterial effect.	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Medium chain chlorinated paraffins (C14-C17)	<input type="checkbox"/> Yes	<input type="checkbox"/> No

#### Nanomaterials

Does the product contain any nanomaterial that has been purposefully added to achieve a specific function?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If yes, specify the material.</i>		

#### Recycling

Does the product contain any recycled material?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If Yes, specify in the material in Table 3.</i>		

Table 3. List of recycled material included in the product.

Material	Percentage (%) of the recycled material that has not reached the consumer level, such as production waste, etc. (pre- consumer)	Percentage (%) of the recycled material that has reached the consumer level (post- consumer)	Comments

#### Production

##### Energy efficiency

Has an active effort been taken to minimize the energy consumption in production?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If yes, describe the type of efforts made:</i>		



<b>Has an active choice been made, regarding the electricity supplier, in order to promote electricity production from renewable energy sources?</b>	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>Describe the type of energy source, percentage of energy stemming from the renewable source, how long the agreement has been applied, electricity supplier, and for which part of the production it is valid for:</i>		

### Distribution

The packages used for the products are made from cardboard. In some cases the products are sealed in plastic foil.

Does the supplier apply any system for returning load carriers for the product?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Does the supplier apply any systems involving multi-use packaging for the product?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Does the supplier take back packaging for the product?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Is the supplier affiliated to REPA?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Are the products packages in compliance with Directive 94/62/EC?	<input type="checkbox"/> Yes	<input type="checkbox"/> No

<b>Are the packages recyclable?</b>	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>Enter the proportion of recycled material, included in the packaging.</i>		

### Construction

Are there any special requirements for the product during storage?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Are there any special requirements for adjacent building products because of this product?	<input type="checkbox"/> Yes	<input type="checkbox"/> No

### Use

Are there any operating/care instructions for the product?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Is the product energy labelled in accordance with the Energy Labelling Directive (2010/30/EU)?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
	<input type="checkbox"/> Not relevant	

<b>Reference service life estimated as being approx.</b>	
--	--

### Disassembly

<b>Does the product require any special measures to protect health and environment during demolition/disassembly?</b>	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No
<i>If "yes", please specify</i>		



#### Waste management

- Is the product covered by the WEEE-directive 2012/19/EU?  Yes  No
- Is energy recycling possible for all or parts of the product when it becomes waste?  Yes  No
- When the supplied product becomes waste, is it classified as hazardous waste?  Yes  No

Is it possible to re-use all or parts of the product? (can the product be reused within the product's expected lifetime)?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If "yes", please specify</i>		
Is material recycling possible for all or parts of the product when it becomes waste?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If "yes", please specify</i>		

#### Indore environment

- Has the product a critical moisture condition?  Yes  No

Is the article (or chemical product) intended for indoor use?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
<i>If yes, has emission data been produced for volatile organic compounds?</i>		

All statements are made after our best knowledge and based on information from our suppliers. These details places particularly no assurance (e.g.in the guarantee legal meaning).

---

*Name, signature, title & date*

---



**Appendix 7: EPD template made for the ABB**



[CATEGORY TITLE]

**PRODUCT ENVIRONMENTAL PROFILE**  
Environmental Product Declaration



ORGANIZATION CLICK OR TAP HERE TO ENTER TEXT.		CONTACT INFORMATION CLICK OR TAP HERE TO ENTER TEXT.			
ADDRESS CLICK OR TAP HERE TO ENTER TEXT.		WEBSITE CLICK OR TAP HERE TO ENTER TEXT.			
STATUS <b>Draft</b>	SECURITY LEVEL <b>Internal</b>	REGISTRATION NUMBER [1ABC123456]	REV. <b>A</b>	LANG. <b>en</b>	PAGE <b>1/7</b>
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## ABB Purpose & Embedding Sustainability

ABB is demonstrating their commitment to sustainability by making themselves sustainable. Across their own operations and value chain, aspiring to become a role model for others to follow. With **ABB Purpose** ABB is focusing on reducing harmful emissions, preserving natural resources and championing ethical and humane behavior to achieve this.

ABB has also taken part of the **The Ellen MacArthur Foundation's**.



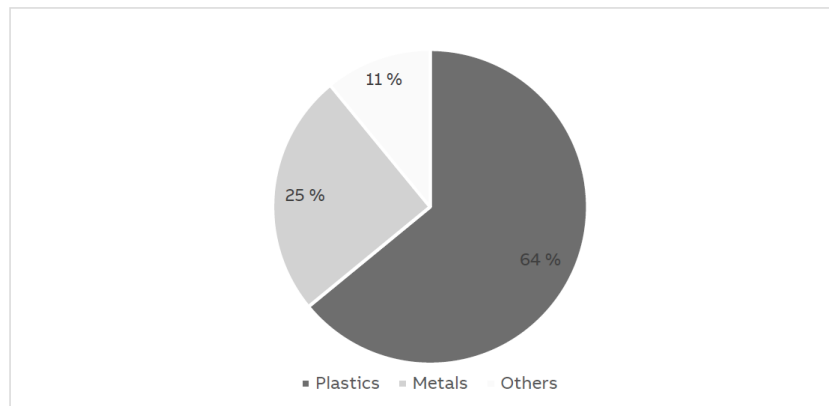
## General Information

Reference product	
Description of the product	
Functional unit	
Products concerned	



## Constituent materials

Total weight of Reference product	
-----------------------------------	--



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PRODUCT ENVIRONMENTAL PROFILE

Plastics as % of weight		Metals as % of weight		Other as % of weight	
Name and CAS number	Weight-%	Name and CAS number	Weight-%	Name and CAS number	Weight-%
	%		%		%
	%		%		%
	%		%		%
	%		%		%



### Additional Environmental Information

Manufacturing	
Distribution	
Installation	
Use	
End of life	
Software and data-base used	
Standards	



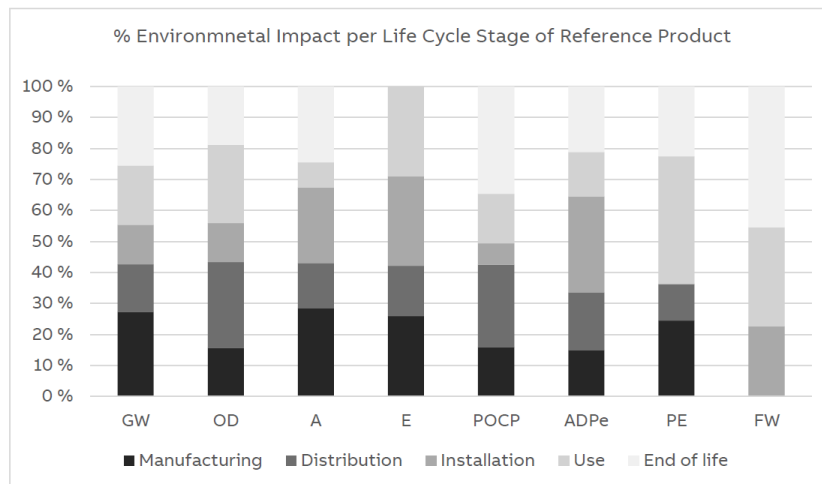
### Environmental impacts

Reference lifetime				
Product category				
Installation elements				
Use scenario				
Geographical representativeness				
Technological representativeness				
Energy model used	Manufacturing	Installation	Use	End of life

STATUS	SECURITY LEVEL	DOCUMENT ID.	REV.	LANG.	PAGE
Draft	Internal	[1ABC123456]	A	en	3/7

PRODUCT ENVIRONMENTAL PROFILE

Compulsory Indicators							
Impact indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Global warming (GW)	kg CO <sub>2</sub> eq.						
Ozone depletion (OD)	kg CFC-11 eq.						
Acidification of soil and water (A)	kg SO <sub>2</sub> eq.						
Eutrophication (E)	kg (PO <sub>4</sub> ) <sup>3</sup> eq.						
Photochemical ozone creation (POCP)	kg C <sub>2</sub> H <sub>4</sub> eq.						
Depletion of abiotic resources – elements (ADPe)	kg Sb eq.						
Resource use indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Total use of primary energy (PE)	MJ						
Net freshwater use (FW)	m <sup>3</sup>						



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## PRODUCT ENVIRONMENTAL PROFILE

Optional Indicators							
Impact indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Depletion of abiotic resources – fossil fuels	MJ						
Water pollution	m <sup>3</sup>						
Air pollution	m <sup>3</sup>						
Resource use indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Use of renewable primary energy, excluding renewable primary energy resources used as raw materials	MJ						
Use of renewable primary energy resources as raw materials	MJ						
Total use of renewable primary energy resources	MJ						
Use of non-renewable primary energy, excluding renewable primary energy resources used as raw materials	MJ						
Use of non-renewable primary energy resources as raw materials	MJ						
Total use of non-renewable primary energy resources	MJ						
Use of secondary materials	kg						
Use of renewable secondary fuels	MJ						
Use of non-renewable secondary fuels	MJ						
Waste category indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Hazardous waste disposed	kg						
Non-hazardous waste disposed	kg						
Radioactive waste disposed	kg						
Output flow indicators	Unit	Total	Manufacturing	Distribution	Installation	Use	End of life
Components for reuse	kg						
Materials for recycling	kg						

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PRODUCT ENVIRONMENTAL PROFILE

Materials for energy recovery	kg
Exported energy	MJ
Environmental Cost Indicator	€

\* represents less than 0,01% of the total life cycle of the reference flow

For products covered by the PEP other than the Reference product, the environmental impacts for each phase of the lifecycle are obtained by multiplying the values of the Reference product by the following coefficients:

Product	Manufacturing	Distribution	Installation	Use	End of life

Registration number:	Drafting Rules <i>PCR-ed3-EN-2015 04 02</i> Supplemented by <i>PSR xxxxx</i>
Verifier accreditation number:	Information and reference documents: <a href="http://www.pep-ecopassport.org">www.pep-ecopassport.org</a>
Date of issue: <i>MM-AAAA</i>	Validity period: 5 years
Independent verification of the declaration and data, in compliance with ISO 14025: 2010	
Internal: <input type="checkbox"/>	External: <input type="checkbox"/>
The PCR review was conducted by a panel of experts chaired by Philippe Osset (Solinnen)	
PEP are compliant with XP C08-100-1: 2016 The elements of the present PEP cannot be compared with elements from another program	
Document in compliance with ISO 14025: 2010: "Environmental labels and declarations. Type III environmental declarations"	
In compliance with ISO 14040:2006: "Environmental management – LCA – Principles and framework"	
In compliance with ISO 14044:2006: "Environmental management – LCA – Requirements and guidelines"	
Environmental data in alignment with EN 15804:2012+A1:2013: "Sustainability of construction works - EPD's - Core rules for the product category of construction products"	

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## PRODUCT ENVIRONMENTAL PROFILE

## Environmental Impact Indicator Glossary

Impact indicators	Description	Unit
<b>Global warming (GW)</b>	Indicator of potential global warming caused by emissions to air contributing to the greenhouse effect. Includes fossil and biogenic	kg CO <sub>2</sub> eq.
<b>Ozone depletion (OD)</b>	Indicator of emissions to air that contribute to the destruction of the ozone layer	kg CFC-11 eq.
<b>Acidification of soil and water (A)</b>	Indicator of the potential acidification of soils and water caused by the release of certain gases to the atmosphere	kg SO <sub>2</sub> eq.
<b>Eutrophication (E)</b>	Indicator of the contribution to eutrophication of water by the enrichment of the aquatic ecosystem with nutritional elements, e.g. industrial or domestic effluents, agriculture, etc.	kg (PO <sub>4</sub> ) <sup>3</sup> eq.
<b>Photochemical ozone creation (POCP)</b>	Indicator of emissions of gases that affect the creation of photochemical ozone in the lower atmosphere (smog) because of the rays of the sun.	kg C <sub>2</sub> H <sub>4</sub> eq.
<b>Depletion of abiotic resources – elements (ADPe)</b>	Indicator of the depletion of natural non-fossil resources	kg Sb eq.
<b>Depletion of abiotic resources – fossil fuels (ADPF)</b>	Indicator of the depletion of natural fossil resources	MJ (lower heating value)
<b>Water pollution (WP)</b>	Indicator of the quantity of water necessary to dilute the toxic elements poured into water in all the stages of the product life cycle.	m <sup>3</sup>
<b>Air pollution (AP)</b>	Indicator of the quantity of air necessary to dilute the toxic elements emitted into the air in all the stages of the product life cycle.	m <sup>3</sup>
Resource use indicators	Description	Unit
<b>Total use of renewable primary energy resources</b>	Primary energy and primary energy resources used as raw materials	MJ (lower heating value)
<b>Total use of non-renewable primary energy resources</b>	Primary energy and primary energy resources used as raw materials	MJ (lower heating value)
<b>Total use of primary energy</b>	Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) + Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ (lower heating value)

STATUS	SECURITY LEVEL	DOCUMENT ID.	REV.	LANG.	PAGE
Draft	Internal	[1ABC123456]	A	en	7/7

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### Appendix 7: LCA results for all three products

#### Junction box, AP9

Impact category	Unit	Manufacturing	Distribution	Installation	Use	End of life
ADPE	kg Sb eq.	2,144E-08	7,268E-11	1,182E-12	0,000E+00	1,110E-11
ADPF	MJ	4,087E+00	2,551E-02	3,682E-04	0,000E+00	3,898E-03
AP	kg SO2 eq.	4,146E-04	8,158E-06	1,165E-07	0,000E+00	1,273E-06
EP	kg (PO4)3- eq.	9,118E-05	1,875E-06	3,235E-08	0,000E+00	2,927E-07
GWP	kg CO2 eq.	1,333E-01	1,816E-03	2,618E-05	0,000E+00	2,908E-04
ODP	kg CFC 11 eq.	2,529E-09	3,679E-12	9,091E-14	0,000E+00	5,620E-13
POCD	kg C2H4 eq.	2,888E-05	5,797E-07	8,323E-09	0,000E+00	1,018E-07
CRU	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
EEE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
EET	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
HWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MER	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MFR	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
NHWD	kg	3,343E-04	6,452E-05	2,448E-06	0,000E+00	9,857E-06
RWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
FW	m3	3,766E-04	1,625E-07	3,617E-09	0,000E+00	2,483E-08
NRSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00

PENRE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRT	MJ	1,312E-02	2,564E-02	3,714E-04	0,000E+00	3,917E-03
PERE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERT	MJ	2,113E-01	3,422E-05	9,045E-07	0,000E+00	5,227E-06
RSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
SM	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00

## Socket outlet

<b>Impact category</b>	<b>Unit</b>	<b>Manufacturing</b>	<b>Distribution</b>	<b>Installation</b>	<b>Use</b>	<b>End of life</b>
ADPE	kg Sb eq.	9,953E-07	1,449E-10	4,222E-12	3,496E-07	9,135E-11
ADPF	MJ	6,673E+00	5,085E-02	1,273E-03	4,397E+01	4,315E-02
AP	kg SO2 eq.	1,900E-03	1,626E-05	4,016E-07	1,611E-02	1,798E-05
EP	kg (PO4)3- eq.	2,602E-04	3,737E-06	1,173E-07	9,729E-04	7,563E-06
GWP	kg CO2 eq.	5,542E-01	3,619E-03	9,047E-05	4,209E+00	3,870E-03
ODP	kg CFC 11 eq.	1,500E-09	7,332E-12	3,532E-13	2,516E-07	1,621E-10
POCD	kg C2H4 eq.	1,051E-04	1,155E-06	2,873E-08	8,854E-04	8,026E-07
CRU	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00

EEE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
EET	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
HWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MER	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MFR	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
NHWD	kg	1,387E-03	1,286E-04	1,002E-05	1,440E+01	1,842E-05
RWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
FW	m3	1,746E-03	3,239E-07	1,381E-08	3,199E-02	1,777E-05
NRSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRT	MJ	2,329E-01	5,111E-02	1,285E-03	6,708E+01	7,320E-03
PERE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERT	MJ	6,093E-01	6,820E-05	3,550E-06	9,810E+00	9,768E-06
RSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
SM	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00

## Thermostat

Impact category	Unit	Manufacturing	Distribution	Installation	Use	End of life
ADPE	kg Sb eq.	2,065E-06	2,342E-10	6,774E-15	4,629E-06	2,031E-10
ADPF	MJ	7,200E+01	8,220E-02	2,378E-06	5,821E+02	9,229E-02
AP	kg SO2 eq.	7,101E-02	2,629E-05	7,603E-10	2,133E-01	3,881E-05
EP	kg (PO4)3- eq.	3,985E-02	6,040E-06	1,747E-10	1,288E-02	1,744E-05
GWP	kg CO2 eq.	6,604E+00	5,849E-03	1,692E-07	5,572E+01	8,381E-03
ODP	kg CFC 11 eq.	1,202E-06	1,185E-11	3,428E-16	3,331E-06	3,644E-10
POCD	kg C2H4 eq.	3,814E-03	1,868E-06	5,403E-11	1,172E-02	1,737E-06
CRU	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
EEE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
EET	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
HWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MER	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
MFR	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
NHWD	kg	1,393E+00	2,079E-04	6,013E-09	1,907E+02	1,541E-04
RWD	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00

FW	m3	1,081E-01	5,236E-07	1,515E-11	4,235E-01	3,957E-05
NRSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PENRT	MJ	4,258E+00	8,261E-02	2,390E-06	8,880E+02	1,264E-02
PERE	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERM	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
PERT	MJ	2,003E-01	1,102E-04	3,189E-09	1,299E+02	4,992E-05
RSF	MJ	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00
SM	kg	0,000E+00	0,000E+00	0,000E+00	0,000E+00	0,000E+00