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IMPLEMENTATION OF ENVIRONMENTALLY CONSCIOUS DESIGN IN LOW VOLTAGE PRODUCTS

IEC 62430

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ABSTRACT

Ida-Maria Blomback: Implementation of environmentally conscious design in low voltage products
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Environmentally conscious design (ECD), also called as eco-design, is a systematic approach to reduce harmful environmental impacts of the products or services throughout their whole life cycle. IEC 62430:2019 is a standard addressing this goal. The motivation for organizations in implementing the standard can be driven by market demand, incoming regulations and laws, or a sustainable brand image. Organizations can have problems recognizing their current status in eco-design or challenges in implementing environmentally conscious principles in their processes and management.

The first step in this research was to conduct a literature review of the main eco-design drivers and challenges and the most used eco-design tools. The drivers provide information about the benefits that implementing IEC 62430 in companies could bring. The drivers lead from innovation and lower environmental impacts to improved image and revenues.

This thesis was conducted for the company Smart Power, a unit of ABB, which manufactures low voltage products. The case company has done many actions to achieve environmental improvement in its processes but wishes to continuously develop its principles towards circular economy. Smart Power's documentation and processes were evaluated to analyse its ECD compliance. The main challenges to implementing ECD policies were recognized, and they were compared to challenges that were recognized in the literature review. Development suggestions were given to Smart Power, so the company is able to work on achieving IEC 62430 certification or compliance if it wishes.

The next step was to compare the results from the target company to theory bases, to find similarities and differences. The most common challenges that were recognised from the theoretical bases and case study were related to management. Even a good strategy does not guarantee environmental improvement in processes and product design, the management's commitment and allocation of enough resources to design processes and selecting sustainable suppliers has a big effect on implementing eco-design. Communication needs to work for internal and external stakeholders to add knowledge.

Keywords: IEC 62430, Environmentally conscious design, Eco-design, low voltage products

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TIIVISTELMÄ

Ida-Maria Blomback: Ympäristötietoisen suunnittelun toteutus pienjännitetuotteissa
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Ympäristötietoinen suunnittelu (ECD), jota kutsutaan myös ekosuunnitteluksi, on järjestelmällinen lähestymistapa tuotteiden tai palvelujen haitallisten ympäristövaikutusten vähentämiseksi niiden koko elinkaaren ajan. IEC 62430:2019 on standardi, joka vastaa tähän tavoitteeseen. Organisaatioiden motivaatiota standardin käyttöönottoon voivat ohjata markkinoiden kysyntä, tulevat säädökset ja lait tai kestävä brändikuva. Organisaatioilla voi olla vaikeuksia tunnistaa heidän nykytilansa ekosuunnittelussa tai haasteita ympäristötietoisten periaatteiden toteuttamisessa prosesseissaan ja johtamisessaan.

Ensiksi toteutettiin kirjallisuuskatsaus yleisimmistä ekosuunnittelun ajureista, haasteista ja käytetyimmistä työkaluista. Ajureiden selvittämisestä saadaan tietoa hyödyistä, joita IEC 62430:n käyttöönotto voi tuoda yrityksille. Tunnistetut ekosuunnittelu ajurit kuten innovaatiot ja pienemmät ympäristövaikutukset voivat johtaa muihin etuihin kuten parempaan yritys imagoon ja sitä kautta tuloihin.

Tämä opinnäytetyö tehtiin Smart Powerille, joka on ABB:n yksikkö, joka valmistaa pienjännitetuotteita. Yritys on tehnyt monia toimia parantaakseen prosessejaan ympäristöystävällisemmiksi, mutta haluaa jatkuvasti kehittää toimintaansa kohti kiertotaloutta. Smart Powerin dokumentaatio ja prosessit arvioitiin sen ECD-yhteensopivuuden analysoimiseksi. ECD käytäntöjen toteuttamisen tärkeimmät haasteet tunnistettiin ja niitä verrattiin kirjallisuuskatsauksessa tunnistettuihin haasteisiin. Smart Powerille annettiin kehitysehdotuksia, joiden avulla yritys voi halutessaan lähteä parantamaan käytäntöjään IEC 62430 -sertifioinnin ja standardin vaatimusten täyttämiseksi.

Seuraava vaihe oli vertailla kohdeyrityksestä saatuja tuloksia teoriasta saatuihin tuloksiin ja löytää niiden yhtäläisyydet ja eroavaisuudet. Yleisimmät teoriaosiosta ja tapaustutkimuksesta tunnistetut haasteet liittyivät johtamiseen. Hyväkään strategia ei takaa ympäristön parantamista prosessien ja tuotteiden suunnittelussa, vaan johdon sitoutumisella ja riittävällä resurssien allokoinnilla prosessien suunnitteluun ja kestävien toimittajien valintaan on suuri vaikutus ekologisen suunnittelun toteuttamiseksi. Viestinnän on toimittava, jotta sisäiset ja ulkoiset sidosryhmät voivat saada tarpeeksi tietoa ECD:n toteuttamiseen ja siihen panostamiseen.

Avainsanat: Ympäristötietoinen suunnittelu, ekosuunnittelu, pienjännitetuotteet

PREFACE

This thesis was carried out at ABB, Smart Power as a part of my Master's degree at Tampere University. Work was supervised by Martti Taimisto whom I would like to thank for the guidance, support and feedback throughout this project. I would also like to thank other colleagues from Smart Power for their assistance. Thank you Hannele Auvinen and Jonna Käpylä for taking the time to review this thesis and providing constructive comments.

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Tampere, March 19, 2023

Ida-Maria Blomback

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1. INTRODUCTION

Environmentally conscious design (ECD) also called as eco-design is defined by IEC 62430:2019 as the systematic approach to reduce adverse environmental impacts throughout a product's life cycle by considering environmental aspects in the design and development stage [1]. Eco-design used to focus mainly on the energy efficiency of products, but in recent years the focus has been shifted to circular economy. In addition to curbing climate change, attention must be paid to sufficient and sustainable use of natural resources [2].

In 2019 new eco-design regulations were published and for the first time repairability and recyclability of products were properly considered. In the future eco-design requirements and regulations set by the European Union can be set to apply the entire life cycle of the product including for example the supply chain. The regulations are often specific to a product group or a wider product range. The future regulation by 2030 will include performance requirements e.g. reusability and use of recycled material but also information requirements as digital product passports. [2]

Waste from electrical and electronic equipment (WEEE) is the fastest growing waste stream in European Union due to the low repairability and short lifetime of the products. 10 million tons of electrical and electronic equipment reaches its end-of-life and is disposed of as waste each year and the amount is expected to double within the next decade. [3] The materials used in electrical and electronic equipment are typically complex compounds and the substances used in the processing of the materials are environmentally burdensome [4]. In ideal case, all the components and materials can be collected and sorted but in reality, it is really difficult as the equipment have many components with complicated microstructure. These problems highlight the importance of implementing eco-design requirements to find better solutions and to provide information to consumers concerning repairing and recycling the products.

The purpose of this thesis is to search the current status of ECD in ABB Smart Power unit in Vaasa, later called as Smart Power, compared to IEC 62430, *Environmentally conscious design* standard's requirements. After the status is defined the key areas of development are presented and guidance for implementing the requirements is given.

This thesis is executed as a part of Smart Power's strategy work to help them to accomplish their circularity approach.

Earlier studies as [5]–[9] have focused on identifying challenges in implementing eco-design but there is a lack of identifying deeper level eco-design implementation challenges that can occur in companies that already have included some actions to minimize environmental impacts. This thesis aims to find the challenges that can occur on a practical level, by searching the target company's documents and instructions. The research questions for this thesis are following:

Main research question: How to implement the IEC 62430 standard's requirements in low voltage products?

Sub-questions:

1. What benefits can companies such as Smart Power get from implementing the standard?
2. Which requirements have already been met and how in Smart Power and what actions must be done to meet all the requirements?
3. What are the main challenges for implementing IEC 62430 standards requirements to companies' processes and management system and how can those be overcome?

Chapter two introduces the theoretical background for this thesis by introducing environmental standards and their connection on IEC 62430 standard. Chapter three describes the competitive business advantage that implementing the standard to company's operating procedures gives to company and what kind of tools there is to implement environmentally conscious design. This gives the theorical background to sub-question 1. Also the most common challenges for implementing eco-design are introduced in chapter three to give theory bases for sub-question 3. Chapter four evaluates Smart Power's documents, instructions and processes from the eco-design perspective to give initial data to answer to sub-question 2. The research methods and the stages of the study are presented. Chapter five presents the results of the current state analysis of the IEC 62430 implementation in Smart Power and gives suggestions and advice on how to implement the standards requirements to Smart Power's principles. Chapter six compares the findings with previous literature to discuss their contribution to practice. Finally, the thesis concludes with a summary of the findings and future research.

2. ENVIRONMENTALLY CONSCIOUS DESIGN STANDARDS AND REQUIREMENTS

The definition for ECD as a term according to IEC 62430:2019 standard is a “systematic approach which considers environmental aspects in the design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product”. Other terms used for ECD that have the same meaning are for example eco-design, design for environment, green design and environmentally sustainable design. [1]

2.1 ISO and IEC Standards related to ECD

ISO (the International Organization for Standardization) is a global standard development federation which is composed of representatives from the foremost standards organizations. There is only one member from each country, and they are representing ISO in their country. SFS (the Finnish Standards Association) is representing Finland in this organization. [10], [11]

IEC (International Electrotechnical Commission) collaborates closely with ISO. It is a global standard development organization that prepares standards for electronic and electrical technologies, also known as “electrotechnology”. [1] Sesko participates in IEC’s actions as Finland’s representative and is responsible for the preparation of SFS standards in Finland in the electricity sector. [12]

Figure 1 represents the relationships between ISO 9001, ISO 14001, IEC 62430 and ISO 14006. ISO 9001:2015 – *Quality management systems* is a standard for quality control and in the picture below can be seen that it covers the process for design management. It does not explicitly pay attention to environmental impacts. ISO 14001:2015 – *Environmental management systems* standard covers the management of an organization’s processes while taking into account environmental aspects and impacts. [10]

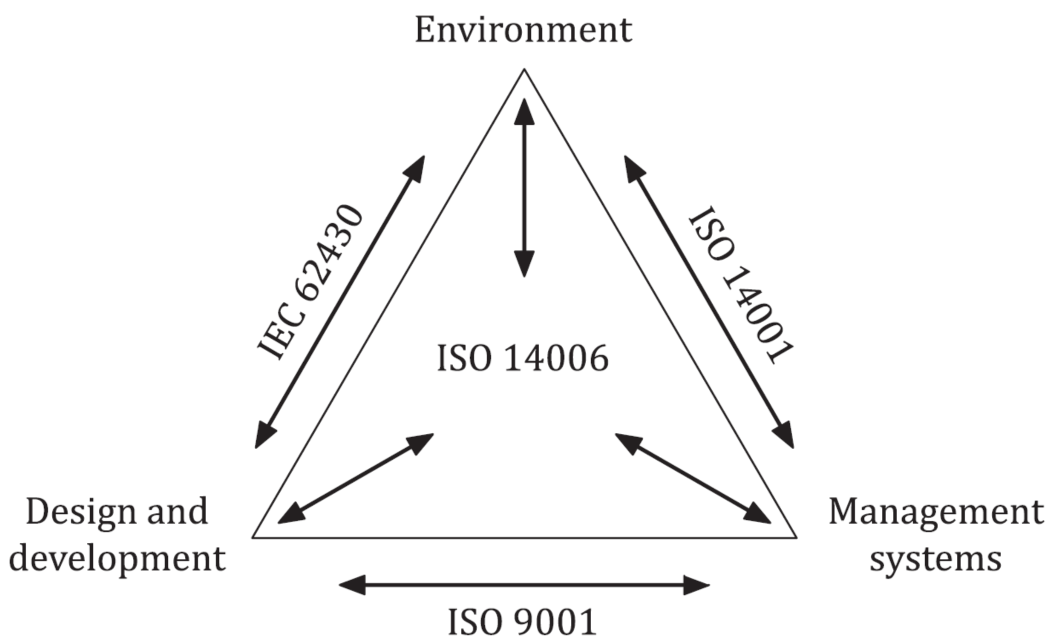

Figure 1. *Relationship between different standards and organizations functions [10]*

IEC 62430:2019 – *Environmentally conscious design* standard's purpose is to assist organizations in integrating environmentally conscious design into their design and development. Design and development is defined in ISO 14006:2020 – *Environmental management systems – Guidelines for incorporating ecodesign* as a "process that transforms requirements into a product". It involves the creation of new products and also the improvement of existing products. The main purposes of the standard IEC 62430 do not include the activities within environmental and business management whereas ISO 14006 includes all three areas: environment, design and development, and management systems. IEC 62430 addresses eco-design from the designer level whereas ISO 14006 addresses it from an organizational level. [1], [10]

ISO 9001 and IEC 62430 have different approaches regarding value creation in design and development. IEC 62430 addresses value creation as a part of design and development whereas in ISO 9001 value creation is in the context of stakeholders' needs and organizational issues. To find the balance between different needs and expectations, it is important to recognize the various environmental aspects and also technical requirements, quality, safety, economic aspects and business risks. [10]

To fulfil the requirements of the presented standards, ISO 14000 Family offers different tools for environmental management. ISO 14040- ISO 14044 provides guidance for Life Cycle Assessment (LCA) which supports with analysis of a product's environmental aspects [13]. ISO 14020 series gives guidance on environmental labelling and ISO 14064 on emissions accounting. [14]

Figure 2 represents the connections between different standards, but it also highlights an issue: eco-design implementation is a real challenge for companies despite all the available tools and standards. Standards are often highly abstract and therefore difficult to implement directly in organizations. Environmental tools are operational and can help in the implementation but those do not fully fill the process deployment. For complex industrial systems, there is a lack of operational eco-design methodology. [14]

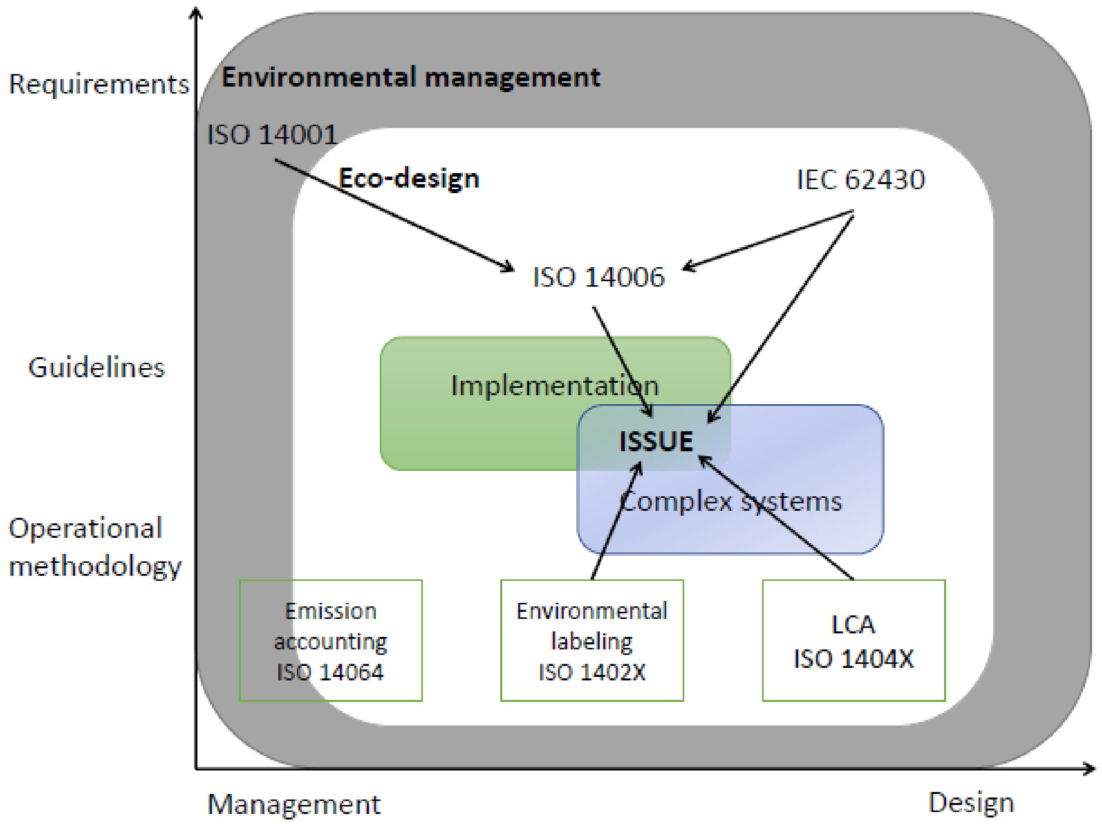

Figure 2. *Environmental standards and tools and the connections between them (adapted from [14])*

IEC 63058:2021 – *Switchgear and controlgear and their assemblies for low voltage* gives specific guidance for assessing the environmental impacts of low-voltage switchgear and their assemblies. It utilizes the principles from IEC 62430 but gives instructions mainly for the conduction of LCA calculations, material declaration and end-of-life instructions for the specified product groups. [13] The standard does not give any step-by-step instructions on how to implement IEC 62430 to company's processes and management, it has more focus on how to evaluate product's environmental performance (LCA) and to communicate its environmental impacts.

2.2 IEC 62430:2019 - *Environmentally conscious design* requirements in low voltage products

IEC 62430:2019 standard includes requirements from Clauses 4.-5.6 for organizations who want to implement ECD into their processes. The standard covers all products and services, but in this section, it is viewed in terms of applicability to low-voltage products. Low-voltage products are switchgear, controlgear and other electrical components [13]. The Low Voltage Directive defines the products as “electrical equipment operating with an input or output voltage of between 50 and 1000 V for alternating current (AC) or 75 and 1500 V for direct current (DC)” [15]. The case study of this thesis is conducted on a company manufacturing low-voltage switchgear products. Low-voltage switchgear products are switching devices used in buildings and industrial areas for example in renewable energy systems such as solar power. They are intended to isolate and protect electrical equipment from overload and short circuits and to allow, separate or prevent the flow of electric current in energy systems. [13], [16]

Before going to a detailed level in the standard, the principles of eco-design are introduced as they are a fundamental part of implementation. Life cycle thinking and policy that reflects ECD are the foundation for implementing the IEC 62430 standard in an organization [1]. Life cycle stages can be depending on the product for example; value proposition, design and development, manufacturing, delivery/installation, use, maintenance and end-of-life [1]. The environmental impact of low-voltage switchgear and controlgear products can be considered relatively small, especially when compared to other components involved in electrical systems [13]. Table 1 presents the clauses of IEC 62430 standard and how they are corresponding to the PDCA cycle (plan, do, check and act).

Table 1. *Clauses of IEC 62430 and PDCA cycle [1]*

PDCA-cycle	**IEC 62430:2019 clauses**	
	4.	Principles of environmentally conscious design (ECD)
	4.1	General
	4.2	Life cycle thinking
	4.3	ECD as a policy of the organization
	5.	Requirements of ECD
	5.1	General
	5.1.1	Integrating ECD into the management system of the organization
	5.1.2	Determining the scope of ECD
	5.1.3	Elements of ECD
	5.1.4	Documented information
Plan	5.2	Analysis of stakeholder environmental requirements
	5.3	Identification and evaluation of environmental aspects
Do	5.4	Incorporation of ECD into design and development
Check and Act	5.5	ECD review
	5.5.1	Process review
	5.5.2	Design review
	5.5.3	Documented information of reviews
	5.6	Information exchange

To determine the scope of ECD, the organization needs to decide whether it concerns a particular product or product group. It's necessary to consider the relevant stakeholder requirements and product's (or product group's, as applicable) and the organization's environmental sphere of influence on relevant environmental aspects. The scope shall be maintained as documented information and relevant stakeholders shall have access to it. [1]

The results obtained from the clauses 5.2-5.6 shall be documented and the documentation shall include subsequent conclusions and assigned responsibilities. [1] Documentation needs to follow company's management system (e.g. ISO 14001 or ISO 9001), ISO 14006 gives advice on that. If the company don't have a management system, the documentation can be done with process instructions. Particular impacts shall be measured and reported to fulfil the ECD requirements. [13]

After defining the scope for implementation, the organization needs to recognize the relevant stakeholders and their environmental requirements when designing and developing a product [1]. This is the first part of **Plan** actions presented in table 1. Figure 3 represents the different extents of stakeholders and their requirements. Requirements from stakeholders, especially legal requirements, can be applicable to all possible products on the market, specific to e.g. all electrical products or only applicable to e.g. switchgear.

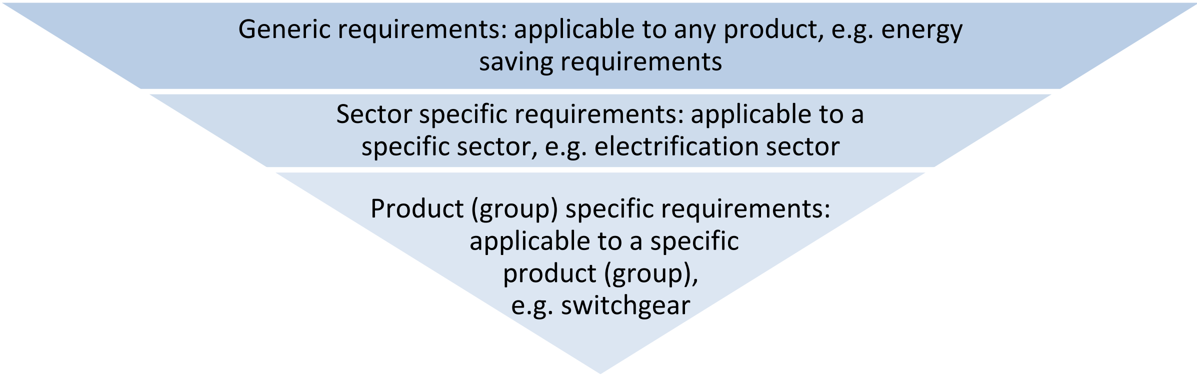

Figure 3. *The extents of stakeholders' requirements (adapted from [1])*

To recognize the relevant requirements, it is worth to consider for example, what is the intended geographic market of the product, what kind of environmental aspects it has and what life cycle stages are included. It is important to review and update the requirements occasionally. Organization should analyse the requirements to recognize the potential functions and life cycle steps that can be affected. As presented in figure 4, the steps shall be repeated occasionally so the organization can address new or changed requirements. [1]

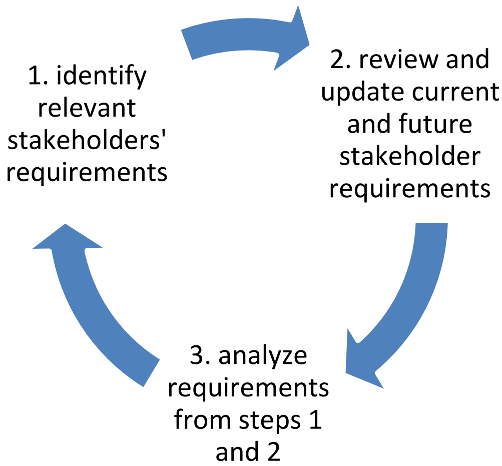

Figure 4. *Steps for analyzing stakeholders' requirements (adapted from [1])*

The second part of **plan** actions is to recognize and evaluate the environmental aspects of the product(s) [1]. This includes the steps presented in figure 5.

Figure 5. *The steps to recognize relevant environmental aspects (adapted from [1])*

To identify products relevant environmental aspects is good to recognize the inputs and outputs from every life cycle stage of the product. Inputs can be for example different materials, subassemblies, spare parts and used energy. Examples of outputs are finished or semi-finished products, wastes and emissions to air and water. The aspects lead to environmental impacts such as pollution, climate change and ozone depletion. Environmental aspects can also lead to opportunities that have a positive impact to environment. When evaluating the environmental impacts, it is encouraged to use quantitative approach. It can be judged by a numerical value, making it repeatable and based on objective criteria. [1] The clearest way to fulfil this requirement for low voltage products is to conduct LCA calculation aligned with ISO 14040 [13]. These calculations can then be utilized to identify and determine the significant environmental aspects and corresponding impacts.

As a **Do** action, the organization needs to incorporate ECD into its design and development activities and functions. These include for example logistics, procurement, sales, suppliers, and design engineers. The challenge here is to achieve a balance between environmental aspects and other requirements such as quality, economic aspects, safety etc. [1]

During design and development processes the organization needs to specify which functions should the product provide. It should determine whether the product should provide multiple functions or should be tailored for a specific use to avoid a complicated structure and excess material use. The second task is to determine significant environmental parameters based on the Plan actions defined earlier. After that, the organization needs to consider what kind of strategies could cause improvement in the selected environmental parameters. The fourth step is to set objectives for the defined parameters that are based on the strategies. The last step is to develop a design specification that considers the environmental objectives while taking into account other design factors. [1] These steps are presented in figure 6.

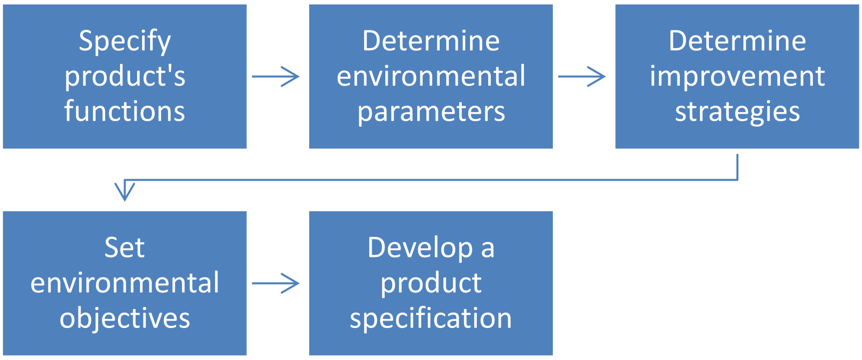

Figure 6. *Incorporation of ECD into design and development (adapted from [1])*

Check and **act** actions are combined as an ECD review. Continual improvement is an important part of organization's processes to ensure that upcoming changes from internal and external factors are taken into account, and organization is reacting to them. These reviews can be implemented, for example, when new information about products aspects or interaction with environment arises, when the organization's strategy is updated, or stakeholders' requirements change. [1]

As a final step to achieve its environmental goals, the organization should maintain proper information exchange with relevant stakeholders in the value chain. If the proper information is not available, the organization must take actions to obtain the required information for other procedures. The information should facilitate the reduction of the harmful environmental effects of the product throughout its whole life cycle. [1]

To provide confirmation that the organization's products are designed according to IEC 62430 standard's requirements, IECQ, the IEC Quality Assessment System for Electronic Components, provides certification [17]. Many organizations have claims about operating according to eco-design principles and having green products. With IECQ certification to IEC 62430, a company has an opportunity to provide independent assurance that the eco-design requirements are actually being met and maintained [18]. IECQ certification bodies conduct assessments to IEC 62430 using an assessment report. This assessment report reviews the organizations documentation, interviews representatives of the organization, and includes an assessment of implementation. The documents reviewed can be, for example, checklists and customer specifications. [19] To achieve the certification for IEC 62430, it is important that all the requirements are filled. The assessment report will be filled and presented in the results chapter to show the current situation and possible gaps.

3. ECO-DESIGN AS A COMPETITIVE BUSINESS ADVANTAGE: DRIVERS, CHALLENGES AND TOOLS

Research for eco-design implementation and its drivers and challenges is rapidly developing [6]. A common approach for these studies is to identify the drivers for eco-design implementation and/or the challenges that can occur in the implementation process [5]. Many literature reviews have been focused on classifying eco-design tools without showing results of their effectiveness in companies [7]. There is very little research available for detailed eco-design implementation cases as there are not many companies having significant experience in eco-design [5]. The other reason can be that companies do not want to share details of their activities that could affect their market advantage [5].

3.1 Drivers for eco-design

Li & Sarkis [6] compared in their study the drivers and challenges for eco-design implementation in non-China countries and China. Iranmanesh et al. [20] studied the drivers of eco-design adoption from 255 manufacturing firms located in Malaysia and Australia. The third study which is chosen for this review from Dahmani et al. [9] analyses lean design and eco-design practices' challenges and drivers in a literature review covering 140 articles from 40 countries. These three studies are from years 2019-2022 so the information can be assumed as up to date. The identified drivers and the articles where these are addressed, are presented in table 2. The drivers are divided to external and internal from the organization's perspective.

Table 2. *Eco-design drivers*

Drivers	References
External	
Consumer’s and market demand	[6], [9]
Environmental regulations and legislation	[6], [20], [9]
Stakeholder pressures	[6], [20]
Internal	
Innovation	[6]
Environmental impact of the product	[9]
Resources management	[9]
Competitive advantage	[6], [20]
Reputation, improved image	[6], [9]
Market increase, business benefits	[20], [9]
Social responsibility	[20]

External drivers are related to risk-avoidance and seeking for opportunities. First external driver market demand can be seen as a pressure from consumers that demand eco-friendly products or services [9]. [6] The demand can be driven by energy consumption when discussing on electrical products. Customers expect that suppliers are designing as energy efficient products as they can to help customers meet their market demands as well. It is important to analyse how much there is competition in organization’s market sector and have the competitors been active in the area of environmental marketing. [21]

The second external driver is environmental regulations and legislations. These include eco-design practices such as EU’s 2009 Eco-design for Energy-related Products Directive. IEC 62430, which is presented in chapter 2, can be utilized to implement the Eco-design directive. [6], [21] Regulations set in other countries and continents effect to manufacturers that export throughout the world [20]. Many references used in research from Dahmani et al. identify this driver as the most important one of external drivers [9].

Stakeholder pressures can come from primary or secondary stakeholders. Primary stakeholders can be suppliers, consumers, recyclers or governmental authorities, secondary stakeholders like media or financial institutions have a smaller impact. [6] Customers are the major financial stakeholders, so in order for the companies to maintain their customers, the pressure from a customer is extremely valid if they demand more environmentally conscious manners [20]. It is important to keep good cooperation with suppliers and customers and to find solutions in joint business issues. Building supportive relationships with them can improve eco-design implementation as well economic performance. The situation can be in some cases upside down, companies might need to train their customers to understand the importance of eco-design as some choices in a company's products are only justified if the products are accepted by their customers. [6]

Internal drivers can rise from organizational culture and the values of decision-makers. These can drive to innovations that lead to products that have smaller environmental impacts. [6] When designing environmentally conscious products, managing resources can lead to a significant reduction in costs for example with the usage of recycled materials or better use of raw materials [9].

It can be noticed that internal drivers can cause a snowball effect where the next internal drivers are the result from earlier drivers. Products that have smaller environmental impacts than competitors' products, can lead to competitive advantage especially in markets that environmentally aware [6], [20]. Figure 7 shows the process where innovation finally leads to business benefit through different steps.

Figure 7. *Snowball effect in internal drivers*

Reputation and image are big drivers for companies to engage in eco-design. Organizations that have environmental problems risk reputational loss. [6] Improvement in an organization's image can help the organization access certain markets which leads to market increase and business benefits as the revenues will grow [9], [20].

Apart from the economic perspective, Dahmani et al. addressed social responsibility as an internal driver for implementing eco-design principles. Recent studies have shown a sense of responsibility in large companies towards the society they work for. Organizations select green practices that are mainly in line with society's values. Social responsibilities come also from the pressure from countries' governments so this driver is both internal and external. [20]

3.2 Challenges for implementing eco-design

Organizations face challenges and barriers when implementing eco-design. Rossi et al. [7] made a literature review of eco-design implementation challenges and tools. Singh &

Sarkar [8] identified in their study the challenges in implementing eco-design practices in small and medium enterprises and give solutions to overcome them. Dekoninck et al. [5] addressed the eco-design implementation challenges that were faced by nine manufacturing companies from five different countries; Denmark, Brazil, France, Germany, UK. Also, the studies from Li & Sarkis [6] and Dahmani et al. [9] were addressed in recognizing the relevant challenges. The obstacles are divided into external and internal and are presented in table 3.

Table 3. *Challenges for implementing eco-design*

Challenges	References
External	
Market demand, Unpredictable behaviour of customers	[6], [7], [8]
Policy: Legislation, complexity of regulations	[6], [9], [7], [8]
Internal	
Strategy	[5], [6], [8]
Tool related: Resources, high number	[5], [6], [9], [7], [8]
Knowledge	[5], [9], [8]
Management	[5], [6], [9], [8]
Collaboration	[6], [9]

Market demand which was recognized as a driver can also be a challenge. Products with eco-properties are often seen as too expensive, and most priorities money over green product image [6]. Customers' behaviour is often hard to predict which can lead to a perception that there is no demand for green products from the market [7].

Regulations and laws vary a lot in different countries [6]. There is very little support in application of regulations and laws from the governments which leads to slow development in eco-design activities. Specific legislations are often limited to small category of products so all the product groups don't face as much pressure for lower environmental impact as others [8]. [7]

Many organizations find it difficult to make radical strategic changes that eco-design principles require [6]. Eco-design practices require a strong commitment and continuous strategy developing over time. The lack of long-term strategy is an issue in many organizations as they consider eco-design strategies as a short-term commitment. [5], [8]

All the addressed articles mentioned tool-related challenges. The challenges were the failure to find the most suitable tool for eco-design purposes as there is a high number available in the market [9]. The amount of resources, especially LCA tools require in terms of time and knowledge, was a big concern [7] [5]. Also, the data from the tools and its reliability rose as an issue [8]. The data from LCA calculations can be hard to utilize to be helpful in decision-making processes as the calculations provide very detailed and large amounts of information [5]. While tool challenges are a widely noticed concern, they are not considered as serious as challenges in other categories [5].

The information flow in everyday jobs is huge, and it can be hard to keep up. It requires a lot of knowledge from the staff for effective eco-design. The lack of environmental knowledge in design and supporting business functions has been noticed as a big challenge for eco-design as well the disbelief about environmental benefits. Sometimes the attention can be drawn to insignificant aspects or when the real problems have been noticed, it is difficult to find alternatives e.g. materials that would have a lower environmental impact. [9], [8], [5]

Management issues are one of the biggest challenges for implementing eco-design as most of the studies name it as a barrier. Cost is a big if not the biggest driver in product development activities so it is hard to implement an eco-design solution that would be less cost-effective. The most common management issues related to eco-design are the lack of a systematic approach to the implementation, lack of continuous improvement, managing trade-offs, and allocating resources [21]. In product design processes, the designers need to do continuously trade-offs between different requirements, and often eco-design solutions stop being supported if those are challenged by another trade-off. A notable problem that occurred in many companies was the lack of motivation from internal stakeholders but the stakeholder group that had problems with motivation varies between companies. The designers might be on board with eco-design but other departments are questioning the instructs for the decision making or the designers might have a lack of motivation as they think that consumers are not demanding environmental improvement. [5]

3.3 Methods for implementing eco-design

IEC 62430 does not demand any specific ECD method or tool to be used, but it recommends some widely used and globally accepted methods. For life cycle thinking (LCT) based assessment, life cycle assessment (LCA) is a widely used tool. [1] LCA quantifies the environmental aspects and impacts of a product along its life cycle. It is a decision support tool but it does not give answers on how to change the product's properties, but it helps to find the aspects that have the biggest impact on the environment. [9] [7]

Checklists and guidelines can be used for a quick evaluation and the results are most useful in the early stages of the design phase. Checklists are useful especially in material selection and many eco-design guidelines can be retrieved from the literature. However, these are very general as they are intended for many different products. Checklists and guidelines are good alerts, but they do not provide perfect and straight solutions to achieve minimal environmental impact. [7]

Design for X approaches are strategies to optimize specific requirements of a product. They were developed to meet customers' needs and to answer market competitiveness. There are many possible Design for X approaches in the field of eco-design; Design for Energy Efficiency, Design for Disassembly, Design for recovery, etc. [7] IEC 62430 standard lists several options for design improvement that are related to a certain life cycle of a product. These are very useful if the environmental hotspots have been identified by using for example LCA method, so the organization is able to focus on relevant design approaches. These can help to solve trade-off situations as well [7].

FMEA, Failure mode and effects analysis, is a tool to identify and manage potential failures that can occur in a product. Sculte & Knuts [22] introduced a tool that has the same format as FMEA but addresses sustainability risks. FMEA tools could support sustainable product development using for example LCA results to calculate an Environmental Priority number. This tool would be useful in the early stages to spot potential circularity issues.

4. MATERIALS AND METHODS

In this chapter is described the phases of the study and the materials used in conducting the current state analysis of ECD compliance in Smart Power. The methods used in different phases are also described.

4.1 Overview of the study

The analysis of the current stage in ECD compliance in Smart Power was conducted systematically following the clauses of IEC 62430:2019 standard. The content of the standards requirements was introduced in chapter 2. Qualitative research was used as the research method by reviewing target company's existing documentation and process descriptions.

Two workshops were conducted in May and December 2022 which provided insights from the employees. The *Ecodesign workshop* in May included eco-design brainstorming to innovate new products and features, and the *Circularity approach – ONE workshop* in December included brainstorming on a specific product range to improve its circularity approach. Observations were collected from the workshops to get an overall picture of different departments' responsibilities and how communication is working between them. The output of the workshops was shared and its utilized in sections 4.4 and 4.5 when identifying the environmental aspects. Figure 8 presents the steps, which are also the sections of this chapter, when evaluating Smart Power's processes and materials from an ECD perspective.

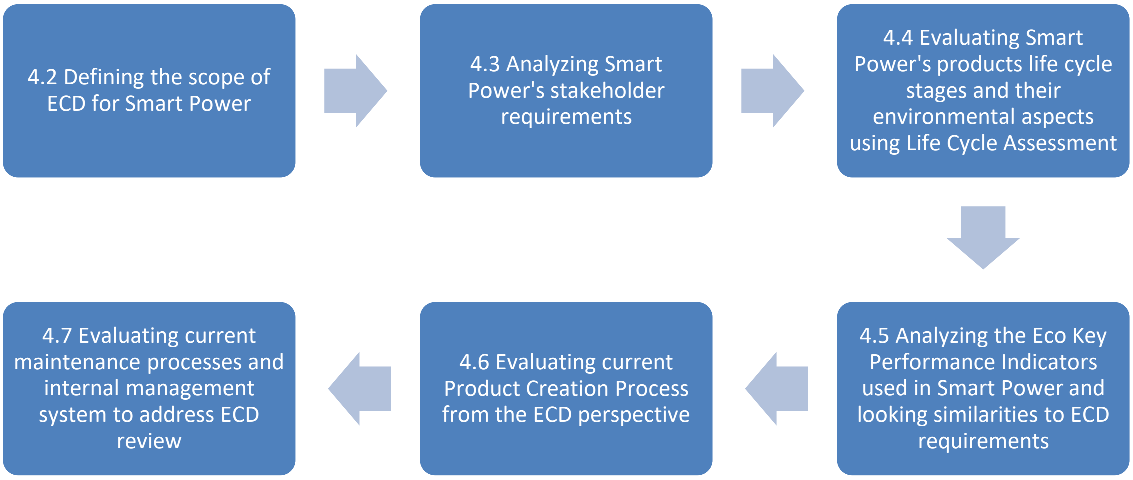

Figure 8. *Flow chart for evaluating ECD implementation in Smart Power*

These sections follow the structure from IEC 62430 standard. Sections 4.3 and 4.4 correspond to Plan phase, chapters 4.5 and 4.6 correspond to Do phase and chapter 4.7 correspond to Check and Act phases. As a result, filled assessment report is presented in chapter 5 and development actions are provided for the case company. The results are later discussed and generalized to other companies in chapter 6.

4.2 Defining the scope

The target company for this thesis is ABB Smart Power unit. IEC 62430 assists the organization to determine the scope of ECD, so in this thesis's the products that are manufactured in Smart Power Vaasa factory are only included. Smart Power is a part of Electrification business area in ABB and has focus on electrical products and solutions. The factory manufactures switch-disconnectors, switch fuses, transfer switches and bypass switches. These low voltage switchgears are used in applications related to production and transmission of electrical energy. The most common applications are solar power, back-up power, IT control rooms and industrial power supply backup systems. [16] The reviewed documents from Smart Power were KPI Guidelines [23], Environmental Product Declaration [24], Product Creation Process [25], Active product maintenance process, Management's reviews, group level Sustainability strategy 2030 [26] and other public ABB's webpages. These were chosen from the target company as these are actively used and include or have potential to address ECD principles. Figure 9 presents the inputs and outputs and the scope where IEC 62430 standard's requirements are affected.

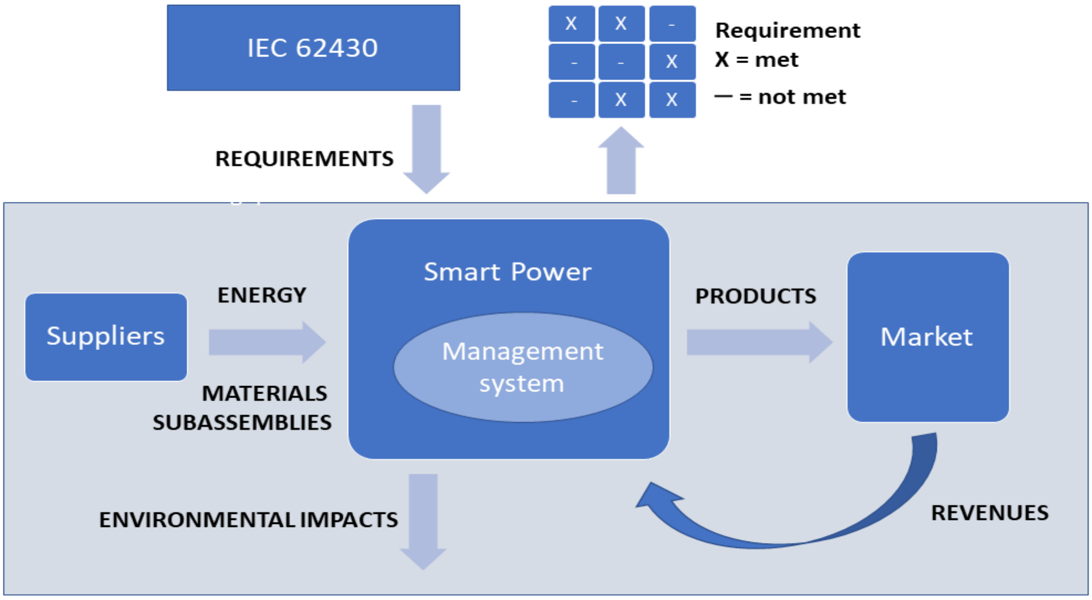

Figure 9. *Extent to which the requirements of IEC 62430 standard are affected including inputs and outputs*

The matrix in the figure 9 presents the IEC 62430 standard's requirements. X markings refer to fulfilment of a requirement and empty boxes refer to non-fulfilment of a requirement i.e., gaps. Those are aimed to be identified and presented in the results chapter to answer to research question two and the results chapter provides development suggestions to fill all the requirements. IEC 62430 affects also Smart Power's suppliers and market and the inputs and outputs with them, so they are also presented as a part of the scope. Implementing IEC 62430 could potentially reduce the environmental impacts from Smart Power and suppliers and increase the revenues from the market.

4.3 Stakeholders' expectations on Smart Power's product development

The first step of the stakeholders' environmental requirements analysis is to recognize the relevant stakeholders considering the organization's products. Figure 10 represents the relevant stakeholders that have expectations towards Smart Power's products. One stakeholder group, Supplier, has expectations from Smart Power, so the arrow points to opposite direction.

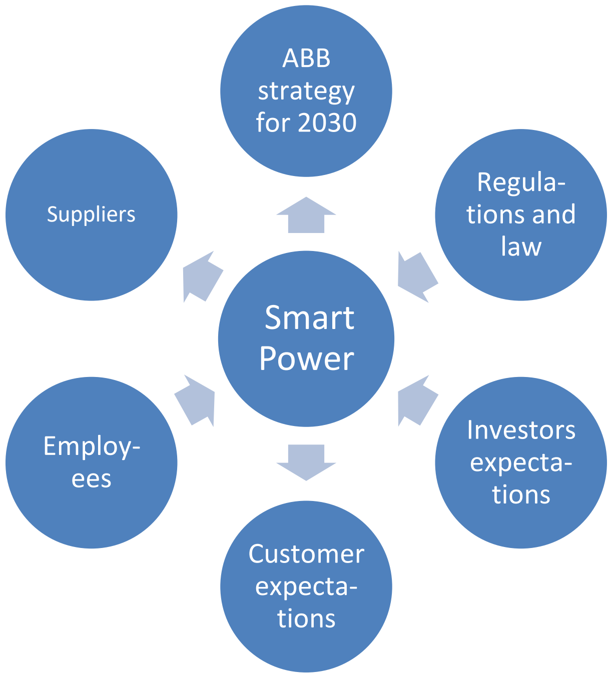

Figure 10. *Relevant stakeholders regarding ECD compatibility in Smart Power*

The stakeholders were identified by searching the ABB Stakeholder engagement site and from the insight of Smart Power's management. ABB's Stakeholder engagement site [27] recognizes customers, investors, suppliers, employees, public policy, community and external partnerships as the key stakeholder groups and topics. Community and external partnerships are excluded from the scope as they can be considered as a part of social dimension of sustainability. ABB's strategy for 2030 is included as ABB gives upper-level guidance for Smart Power.

The next step was to identify the requirements of the relevant stakeholders since ECD needs to be an integral part of design and development. Company's documents and policies should reflect these stakeholders and their requirements. Therefore, to provide proper guidance on how to implement ECD, it is necessary to have an idea of the framework. This helps for example to avoid changes in design and development that could have a disadvantage for the customer or not to comply with regulations. The analysis consists of questions such as: Are the requirements identified and how? How are the identified requirements met? The results of the analysis are presented in the results chapter.

The requirements from ABB's Sustainability strategy towards Smart Power were searched from its web page [26]. As compliance with the requirements is applicable to all the products and multiple processes and departments, it is challenging to analyse if all targets of the sustainability strategy are actively guiding the actions. Smart Power's strategy 2025 was searched to see if the targets are in line with the whole ABB group's goals.

Regulations and laws were discussed in a meeting with Smart Power's Product Specialist, who is specialized in Sustainability. The information was searched from European Union's web pages [28] and from the European Green Deal web page [29]. The applicability of the requirements were searched from product pages to see if the products have CE-markings, which are the proof of high level of health, safety, and environmental protection [30] and/or other declarations.

Investors requirements were obtained from Q3 2022 document from ABB's web pages [31] which is intended for the press and public. The actions for fulfilling the requirements were searched from the same document.

Customers may have a large variety of requirements, and these were discussed during the Eco-design workshop. The information was collected from the materials used in the workshop. Stakeholder engagement site provided answers to the question "how are the requirements met" and EPD documents that are available from products' product pages were searched to find out what kind of information about the sustainability aspects is available for customers.

Information about employees' requirements were searched from Stakeholder engagement web page [27] and I also reflected on my own experience as a Smart Power employee. Additionally, the internal web page concerning the Engagement survey was searched. Requirements for suppliers were searched from stakeholder engagement site [27] and the significance of suppliers' impact on Smart Power's products was discussed in both workshops.

This thesis was conducted during a time when the company's eco-design principles were constantly developing. ABB published its first integrated report [32] in the end of February 2023, which contains a lot of information about its sustainability actions and meeting its stakeholders' requirements. By the time of publication, data collection had already been completed to limit the research to a specific scope.

4.4 Smart Power's products' life cycle stages and environmental aspects

The next step was to investigate if Smart Power has a process to identify and evaluate the environmental aspects and impacts of its products, which is the second plan action in IEC 62430. Smart Power has conducted LCA calculations for some of its products to recognize their environmental impacts. The goal is to have LCA calculations for all of its products in the near future. The method used in these life cycle assessments is from cradle to grave and consists of main life cycle stages: manufacturing, distribution, installation, use and end-of-life [33]. OTDC400FV11 is the selected product for this analysis as it has an LCA document [33] and for this product, the environmental hotspots have already been identified. Figure 11 presents OTDC400FV11's environmental impacts, which is from the materials of the Ecodesign workshop.

OTDC400FV11

Impact category	Unit	Total	Manufacturing	Distribution	Installation	Use	EOL
Climate change	kg CO2 eq	45.57	25.14	0.48	0.14	19.14	0.68
Climate change - Fossil	kg CO2 eq	45.11	24.93	0.48	0.04	19.00	0.66
Climate change - Biogen-ic	kg CO2 eq	0.40	0.18	0.00	0.09	0.11	0.02
Climate change - Land use and LU change	kg CO2 eq	0.06	0.03	0.00	0.00	0.03	0.00

Figure 11. *OTDC400FV11 LCA and identified hotspots [34]*

LCA documents for products OTCD400FV11 and OT125F3 were used to identify their environmental aspects and impacts. The total climate change impact of OTDC400FV11 is 45,57 kg CO2 eq and manufacturing and use phase together cover 97 % of the impact [34]. When evaluating the manufacturing phase should be noticed that most of the inputs to the product's come from already produced components. In Smart Power the manufacturing phase includes the assembly of different components and subassemblies and the packing of the product. The energy mix used in Smart Power includes only renewable energy; hydroelectric and wind. The LCA calculation includes all the logistics from first manufacturing supplier to the next and to Smart Power manufacturing unit. All the components and semi-finished products are from ABB's suppliers. [24] Figure 12 presents the life cycle stages and how the manufacturing is structured in Smart Power. Figure is from the Ecodesign workshops materials.

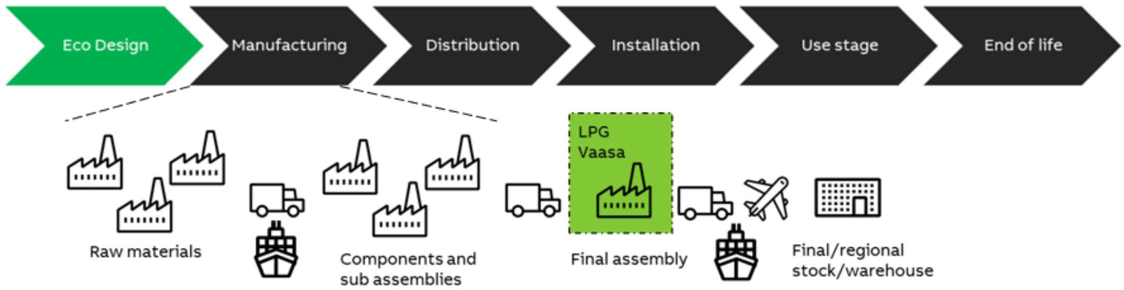

Figure 12. *Smart Power's products life cycle stages and manufacturing structure [34]*

Distribution phase includes the transport from Smart Power manufacturing unit to the distribution centres. The installation phase is assumed to be non-energy consuming, so it only includes the disposal of the packaging and paper instructions. The environmental impact of the use phase is the result from power losses of the product. The data used in calculations is from the product testing results and follows the rules from PEP Ecopassport. End-of-life phase consists of transportation from place of use to the place of disposal. [24]

4.5 Key performance indicators as environmental improvement strategies

As a part of ABBs circularity approach, 80 percent of their products will be evaluated against environmental key performance indicators (KPIs) by 2030 as mentioned earlier in ABBs strategy. These KPIs correspond to different stages of the products' lifecycle. There are four dimensions which all have two levers and two corresponding KPIs. [23] Dimensions and levers are presented in figure 13.

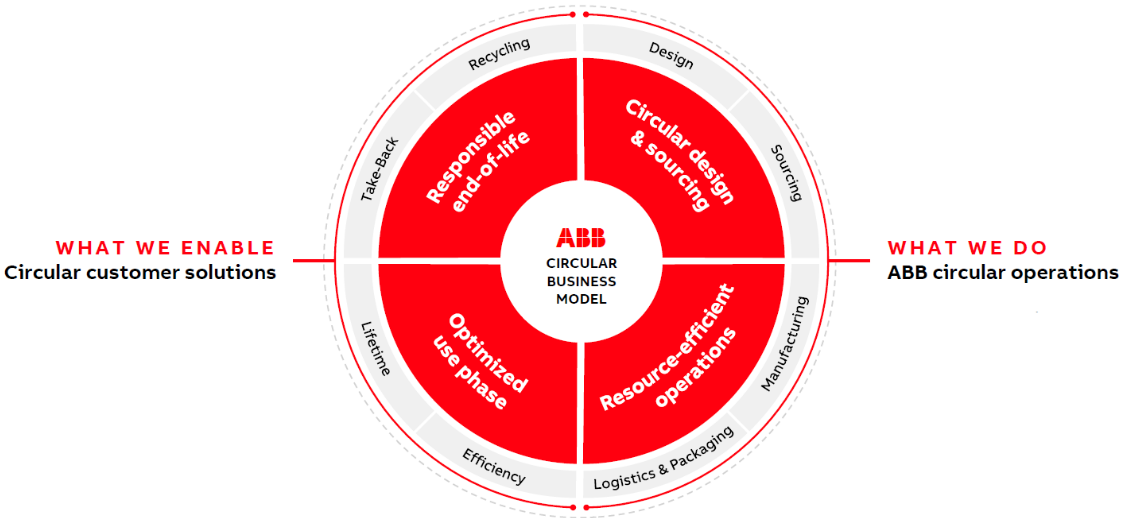

Figure 13. *ABB Circular Business Model [35]*

The next step of the research was to investigate the environmental KPIs used in Smart Power. These were analyzed based on how well they correspond to the identified environmental aspects and have potential to decrease their environmental impacts. In the Circularity approach - ONE workshop, these KPIs were used to improve the environmental aspects of a new product range. In that workshop the functionality of the KPIs were observed in practice and the KPIs from the levers 1,3,5 and 6 were used to achieve environmental improvement. The KPIs from all the eight levers are presented in table 4.

It also introduces the measurement of the KPI. KPIs 1,2 and 4 are measured with thresholds and the rest are with simple checks (yes or no). The information is gathered from the KPI Guidelines document [23].

Table 4. *KPIs, their measurement and definition*

Lever	KPI and its measurement [23]	KPIs definition [23]
1. Design	Designed for recyclability – 40 % of recyclable material in product + 4 other options	Materials used in the product are easy to recycle
2. Sourcing	Sustainable material content – 25 % of sustainable raw materials	Using materials with lower environmental impact or with closable material loop when the product meets its end-of-life
3. Manufacturing	Zero waste to landfill – Yes or No	ABB sites operations should avoid sending non-hazardous waste to landfill, if legally possible
4. Logistics & Packaging	Sustainable material content in packaging – 60 % of sustainable materials	Add the use of recycled and biobased materials in products' packaging
5. Efficiency	Improved resource efficiency for customers – Yes or No (one option fulfilled)	1. Product efficiency: product is more energy-efficient against the compared products on the market or older products from the same line 2. Process efficiency: product optimizes and makes the customers' processes more reliable and energy-saving 3. Digital efficiency: target to optimize the customer systems by digitally-enabled products
6. Lifetime	Offered with extended lifetime – Yes or No	Options: Providing services, maintenance or repairs for the products, modular design, upgradable with digitalization or with spare parts
7. Take-Back	Offered with takeback services – Yes or No	Collect the used products from customers and then either recycle, reuse, refurbish or remanufacture the products
8. Recycling	End-of-life instructions available – Yes or No	Provide recycling or disposal instructions for the customers and recycling companies

IEC 62430 gives examples of strategies that can be used to achieve environmental improvement in products. These improvement strategies are considered as Do actions, so they are applicable to clause 5.4 from the standard. To evaluate the environmental improvement ability of the KPIs, the corresponding strategies from IEC 62430 were gathered to a table form. These are presented in the results. It should be noted that there are multiple improvement strategies presented in the standard and only the corresponding ones are addressed.

4.6 Simplifying Smart Power's Product Creation Process

Product Creation Process (PCP) contains all of the organization's functions and their actions when creating a new product. The roadmap is presented in Appendix A. It includes five stages: concept, design, development, tooling validation, and maturation and volumes ramp-up. Between these stages are four gates that are passed when all of the required deliverables have been completed. The purpose of gates is to monitor and control the project process. Every deliverable is allocated to a business function that has the responsibility for fulfilment. The functions are presented on the left in the PCP roadmap to create transparency and logic in the process. [25]

In this section, a simplified version of the full PCP map was conducted, including only the deliverables relevant to IEC 62430 implementation. The pruning was carried out based on a discussion with the company responsible of this thesis, in which we agreed that only the first three stages are relevant for ECD implementation. After that, detailed information about the remaining deliverables was searched, and the pruning continued to only include the deliverables that could reflect ECD policies. These deliverables are presented in the results.

The aim is to evaluate the PCP according to its deliverables task lists, which are collected in the PCP handbook [25]. The question is whether the deliverables possibly contain references to ECD or, if not, how ECD principles could be added to them. For each gate, there is a set of deliverables that needs to be fulfilled.

The first stage, concept, includes the technical solutions development based on the specifications. Usually, many different design concepts can appear, but at the end of this phase, only one of them will be approved. [25]

The second stage, design, includes the creation of prototypes for the chosen concept. Prototypes are tested, and as a result, a Technical Requirement Specification (TRS) is created to pass the gate 2. The TRS includes the main component specifications that are needed to design the product in detail. [25]

The third stage, development, consists of creating bulk samples and nominating suppliers for critical parts. As a result, final drawings, product structure and materials, and production line design are released. [25] Here, it is important to maintain the ECD view when selecting the best possible option from the different designs.

4.7 Evaluation of IMS and Active Product Maintenance Process

Smart Power's Integrated Management System (IMS) was searched to find a possible review process for evaluating ECD compliance. Also, a discussion with the company responsible for this thesis provided insight of where the IEC 62430 standards clauses 5.5.1 Process review and 5.5.2 Design review could be implemented as the IMS search did not provide a solution.

Finally, the last step was to evaluate Active product maintenance process for its potential to be part of the Design review. The process is presented in appendix B. It is similar to PCP, as it is including gates and stages and different deliverables to be achieved. Its purpose is to make changes to existing product(s) when a problem has occurred or there is some other reason to make changes. The problems that can occur are for example quality problems, changes in suppliers or raw materials, production problems and tools aging.

5. RESULTS

In this chapter, the results of the evaluation of Smart Power's current stage in ECD compliance are presented. To those requirements that are not already fulfilled will be offered suggestions to implement to Smart Power's principles.

5.1 Current state analysis of ECD compliance in Smart Power

The results of Smart Power's stakeholder analysis are presented in section 5.1.1, the comparison of Smart Power's environmental KPIs and IEC 62430 improvement strategies in section 5.1.2, and the Simplified PCP map in section 5.1.3. The filled assessment report in section 5.1.4 uses the structure from the IEC 62430 standard and the IECQ report base. It concludes the results of the current state of ECD compliance in Smart Power by grading every clause of the standard IEC 62430.

5.1.1 Results of the stakeholder analysis

The first stakeholder expectations come from ABB Sustainability strategy 2030. This strategy applies to the entire ABB Group. The requirements were clearly listed on the Sustainability strategy 2030 web page. Smart Power needs to follow these targets as they come from the upper level, so these stakeholder requirements can be considered as recognized and followed.

The European Green Deal rose as one of the biggest initiatives at the moment. Also, new regulations and laws come into effect regularly concerning, for example, packaging materials and energy use. Smart Power's products have CE-markings, which are a proof complying with EU directives affecting these products.

Investor requirements were met with meetings focused on sustainable investing and press release documents. Customers who have environmental requirements can access information about products' environmental aspects from Environmental Product Declarations. Smart Power's goal is to have EPD for the whole product portfolio.

Employee requirements are met with available trainings and info meetings. Suppliers are receiving requirements through the Supplier Code of Conduct. The results of the whole stakeholder analysis are presented in table 5.

Table 5. *The results of the stakeholder analysis*

Stakeholder group	**Requirements**	**How are the requirements met at the moment?**
ABB Sustainability strategy 2030	Reduce carbon emissions by supporting customers to reduce their carbon emissions by at least 100 megatons [26] Carbon neutrality by 2030 in own operations and to reduce supply chain emission by 50 % with cooperation with suppliers [26] 80 % of ABB products and solutions will be covered by their circularity approach [26]	Making actions in every department to achieve the requirements and reporting on the progress Smart Power's strategy 2025
Regulations and laws	Set by EU: regarding e.g. energy efficiency of the products and climate change and recyclability of the products European Green Deal: climate neutral EU by 2050, 55 % reduce in net greenhouse emissions compared to 1990 . [29] Standards	Market requirement specification and the next steps in Product Creation Process are trying to meet those requirements Certificates and declarations which respond to different standards and regulations are communicated in every products' product page
Investors	Receiving income for their investments Reliable sustainability assessment [36] Economic waves can be driven by different disasters -> actions against the climate crisis [36] Data and proper communication to stakeholders from companies [37]	Quarterly released document [31] for the press and public including own section for sustainability. CO2 emissions from own operations is presented and the main sustainability targets are updated. Newest regulations that have an impact on ABBs policies and introduces environmental problems that ABB has been able to solve are presented ABB engaged meetings with investors and analysts about sustainable investing [27]
Customers	Sustainability aspects are not yet in the main focus for smaller companies, but some general environmental aspects are a part of their criteria when selecting the company whom to buy the product from [34] Bigger companies are demanding for LCA and EPD documents and sustainability is a big part of their strategy. That is why they pay attention to sustainable supply chain [34]	Requirements for environmental information of the products is filled with Environmental Product Declarations [24] Meetings with clients to discuss about customers' requirements, their sustainability challenges and how ABB's offerings could help them to reduce their CO2 emissions [27] Value creation process in PCP.
Employees	Safety, good communication between departments and from management	Engagement Survey, also questions concerning on sustainability [27] Internal Strategy info quarterly. Helping employees to be aware of the sustainability goals and give motivation for achieving those through daily work tasks. Development of employees [38]
Suppliers	Requirements from ABB to Suppliers are gathered to a Supplier Code of Conduct [27]	ABB provides training to support its suppliers and does on-site evaluations. The performance is monitored through Supplier Sustainability Development Program [27]

The problem that can be seen from the table 5, is that Product Creation Process which is one of the key elements when implementing IEC 62430 requirements, only addresses regulations and laws in Market requirement specification and customers' requirements in Value creation process. Requirements from relevant stakeholders seem to be identified, but the requirements from all stakeholders are not integral part of Smart Power's design and development process.

5.1.2 Smart Power's products key environmental aspects, impacts and improvement strategies

From the LCA document for OTDC400FV11 could be recognized that the most significant life cycle stages of the product OTDC400FV11 are manufacturing and use phase and for OT125F3 the use phase was even more significant, 96% of CO_2 emissions contributed by use phase [34]. Smart Power manufactures many different products but the products in the same product range have very similar components, structures and as result similar environmental impacts.

IEC 62430 standard requires the organization to identify and evaluate its products' environmental aspects and corresponding impacts as mentioned in chapter 2. For those products that have LCA documentation, it can be assumed that the identification requirement has been filled, as the standard recommends LCA tools to be used for identification. Smart Power's products are very similar to each other and LCA calculations have shown that the manufacturing and use phases have the biggest impact on environment in most of the products. The use of thermoplastics in Smart Power's products rose as a concern in the Ecodesign workshop as the manufacturing use non-renewable raw materials and as they are mostly incinerated at their end-of-life.

The environmental KPIs used in ABB are comparable to environmental improvement strategies provided in IEC 62430. The KPIs and similar strategy/strategies are presented in table 6.

Table 6. *ABBs environmental KPIs and corresponding environmental improvement strategies from IEC 62430:2019 standard*

Lever	KPI and definition [23]	Environmental improvement strategy from IEC 62430 [1]
1. Design	Designed for recyclability - Materials used in the product are easy to recycle	Maximize the ability to reuse and recycle components and materials, e.g. by design for disassembly Minimize design aspects detrimental to reuse and recycling e.g. mixtures of materials
2. Sourcing	Sustainable material content - Using materials with lower environmental impact or with closable material loop when the product meets its end-of-life	Increase use of recycled materials to replace virgin materials Use materials with a low environmental footprint
3. Manufacturing	Zero waste to landfill - ABB sites operations should avoid sending non-hazardous waste to landfill, if legally possible	Reduce process waste
4. Logistics & Packaging	Sustainable material content in packaging - Add the use of recycled and biobased materials in products' packaging	Increase use of recycled materials in packaging
5. Efficiency	Improved resource efficiency for customers 1. Product efficiency: product is more energy-efficient against the compared products on the market or older products from the same line 2. Process efficiency: product optimizes and makes the customers' processes more reliable and energy-saving 3. Digital efficiency: target to optimize the customer systems by digitally-enabled products	Reduce energy consumption in use Reduce consumption of natural resources, including water, in use Maximize product lifetime by designing for durability and reliability
6. Lifetime	Offered with extended lifetime - Options: Providing services, maintenance or repairs for the products, modular design, upgradable with digitalization or with spare parts	Maximize product lifetime by designing for ease of maintenance Maximize product lifetime by designing for reparability Maximize product lifetime by designing for refurbishment/remanufacturing
7. Take-Back	Offered with takeback services - Collect the used products from customers and then either recycle, reuse, refurbish or remanufacture the products	-
8. Recycling	End-of-life instructions available - Provide recycling or disposal instructions for the customers and recycling companies	Maximize the ability to reuse and recycle components and materials, e.g. by design for disassembly

The KPIs in the first lever, Design for recyclability, and in the second lever, Sustainable material content, can certainly be consider relevant for Smart Power's switches as the manufacturing phase has a significant environmental impact. These use a quantitative approach, as the standard recommends, which is a repeatable and comparable method.

During the workshop, new design solutions were innovated to reduce the use of virgin materials or increase the recyclability of the product group that was the target of the workshop. For these KPIs, purchasing has a big impact on the values when choosing suppliers.

The KPI in the third lever, Zero waste to landfill, is easily achieved in Smart Power's operations, so for the manufacturing phase, the goal could be more ambitious. From OTDC400FV11's manufacturing process, only plastic and some wood waste go to incineration, and the rest is recycled. There could be an option to aim for a 100% recycling rate for process waste. This KPI is relevant, and IEC 62430 recognizes the same improvement strategy.

The KPI in the fourth lever, Packaging & Logistics: Sustainable material content in packaging, is the exact same as the improvement strategy in the IEC 62430 standard. Many directives from EU consider packaging materials, so it is essential to meet this KPI and update the threshold to be higher when necessary.

In the Circularity approach – ONE workshop, the fifth's lever's KPIs, Improved resource efficiency for customers, led the innovation to the direction where only necessary components and features remain in the products. The IEC 62430 standard lists the same kind of improvement strategies for product and process efficiency. The standard does not have the same kind of design strategy listed as the last Digital efficiency KPI but it fits well in Smart Power's products that include software-based solutions.

The KPI in the sixth lever, Lifetime: Offered with extended lifetime, is related to the maintenance stage of the products. Utilizing this in workshops and in the concept phase could lead to new innovations and an upgraded business model, as well the KPI from seventh lever, Offered with takeback services. The IEC 62430 standard does not have the same kind of improvement strategy, but this service could be really helpful when offered for products that have rare or hazardous materials. The KPI in the eight lever is a necessary part of meeting the communication requirements of ECD.

5.1.3 Simplified PCP map

In this section, the simplified PCP map is presented, from which excess deliverables were pruned. Among the deleted deliverables was e.g. test, cost and production line related deliverables and many others that can also be influenced by ECD but are not the first deliverables to be under ECD policies implementation. Figure 14 presents the simplified PCP map, which includes only deliverables with ECD compliance potential.

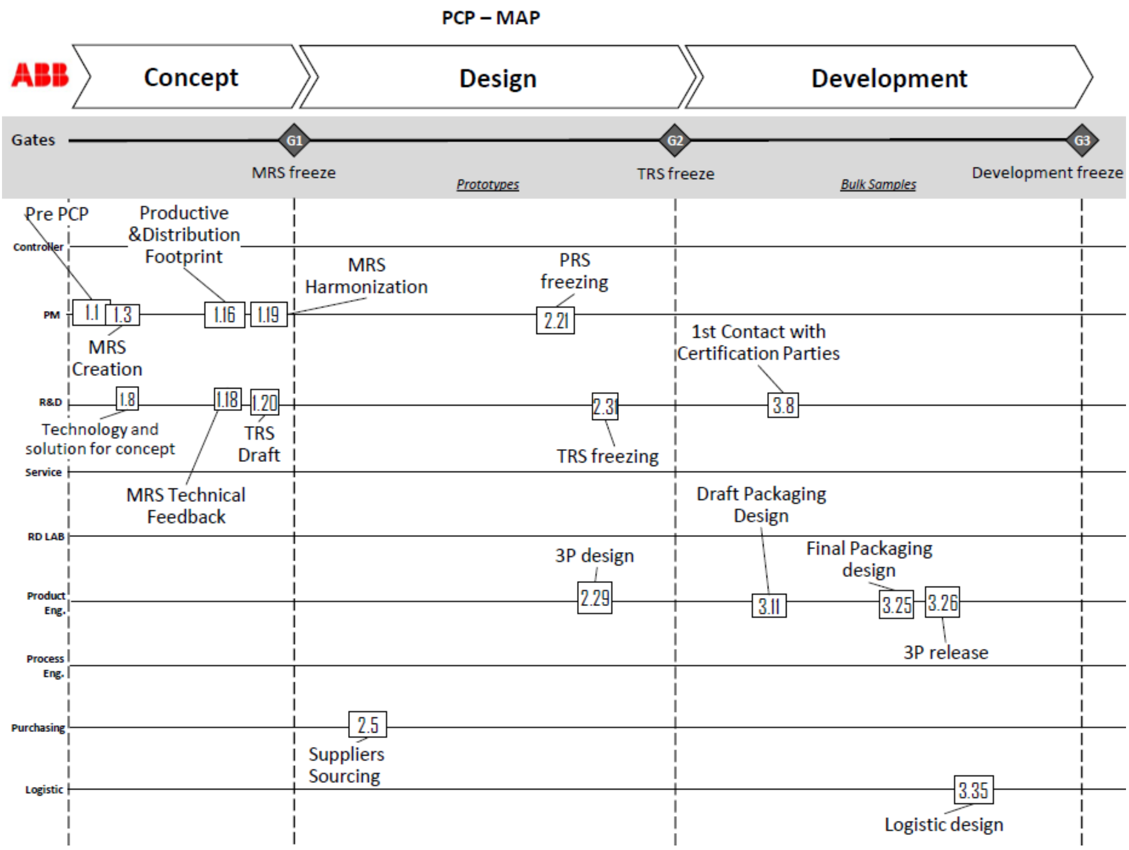

Figure 14. *Simplified PCP map*

Deliverable 1.1, Pre-PCP, is an important phase as it involves creating the value proposition that describes the possible problem and solution for the customer. The IEC 62430 standard requires the value proposition's creation to consider, which environmental aspects could be optimized so that the adverse environmental impacts are as small as possible. These aspects could then be used when setting KPI thresholds. Pre-PCP also includes the analysis of the target market situation, and it should present the main deviation to the former product family as an output.

Deliverable 1.3, MRS (Market requirement specification) Creation, is the phase when IEC 62430 standards requirement stakeholder analysis can be met. The process includes collecting all standards, certificates, and environmental conditions that need to be filled to meet the market's requirements. The output is an MRS document that includes the previously mentioned aspects. In deliverable 1.18, MRS Technical Feedback, the created concept is evaluated based on the MRS so that it can be recognized if the requirements have been assessed or not. Deliverable 1.19, MRS Harmonization, finally freezes the MRS to pass the Gate 1. The fact that MRS appears in several deliverables, tells that it is used in evaluating the concepted product and implemented into the design.

Preparations for TRS (Technical requirement specification) start in the deliverable 1.20, TRS Draft. In this phase. detailed solutions are presented that could meet the earlier defined market requirements. IEC 62430 sets requirements for incorporating ECD into the design phase of the product. To comply with ECD, the TRS should include specifications that also address environmental objectives. The PRS (Product requirement specification) describes the product's architecture at an aggregate level, and it is based on the MRS. There is a possibility to set improvement strategies for environmental parameters as the specification table includes suggestion of KPIs. While TRS and PRS don not directly address ECD requirements with environmental aspects, those are, of course, included if the MRS has demands from customers. However, to comply with IEC 62430 the demand is to set environmental objectives, whether it is a market demand or not.

Deliverable 2.5, Suppliers Sourcing, is a key element in applying ECD. Subassemblies are often used in Smart Power's production, so it is important to evaluate the environmental impact of the materials and how the subassemblies are manufactured. In this phase, suppliers are selected "according to material categories and vendor rating" [25]. This is ECD applicable if the rating includes environmental aspects and sustainability. Deliverable 3.25, Final Packaging Design, is an important phase to affect to recycling rate of the packaging which is one of the introduced KPIs.

5.1.4 Filled assessment report concluding the current state

Tables 7 presents the organization's documents viewed and their grade of requirements fulfilment. The possible markings in the table are: Y=yes, N=no, N/A=not applicable, P=pass and F=fail.

Table 7. *The results of the current state analysis of IEC 62430 compliance in Smart Power*

Phase	IEC 62430:2019 clauses	Assessed (Y, N, N/A)	Organization's document(s) viewed	Verdict (P, F, N/A)
	4. Principles of environmentally conscious design (ECD)			
	4.1 General	Y	Strategy 2030 [26], Circularity Approach [23]	P
	4.2 Life cycle thinking	Y	Strategy 2030 [26], Circularity Approach [23]	P
	4.3 ECD as a policy of the organization	Y	Strategy 2030 [26], Circularity Approach [23]	P
	5. Requirements of ECD			
	5.1 General			
	5.1.1 Integrating ECD into the management system of the organization	Y	Strategy 2030 [26], IMS	P
	5.1.2 Determining the scope of ECD	N/A	-	N/A
	5.1.3 Elements of ECD	N/A	-	N/A
	5.1.4 Documented information	Y	Environmental Product Declaration [24]	F
Plan	5.2 Analysis of stakeholder environmental requirements	Y	Stakeholder engagement [27], MRS [25]	F
	5.3 Identification of ECD into design and development	Y	LCA calculations [33], Environmental Product Declaration [24]	P (for products that have LCA)
Do	5.4 Incorporation of ECD into design and development	Y	Product Creation Process (contains Value Creation, MRS, TRS) [25], KPI [23]	F
	5.5 ECD review			
Check and Act	5.5.1 Process review	Y	SA-M-15 Management Review	F
	5.5.2 Design review	N	Problem report (Active product maintenance process)	F
	5.5.3 Documented information of reviews	N	-	F
	5.6 Information exchange	Y	Environmental Product Declaration [24], EoL instructions, Web pages [26]	P (for products that have EPD)

It can be assumed that the general requirements are met in Smart Power, as the strategy on general policies reflects ECD. Clauses from 4.1 to 4.3 have focus on life cycle thinking in design and development, and on the management's commitment to ECD. ABB's Sustainability Strategy 2030 strongly communicates for circularity through its circularity approach. Life cycle thinking is presented in the Circularity Approach document, which provides guidance for each life cycle of the product and KPIs to indicate the product's circularity performance.

Clause 5.1.1 requires the organization's strategy to reflect ECD. ABB's Sustainability Strategy 2030 fulfils this requirement. This clause also requires the organization's policy to reflect ECD. Clauses 5.1.2 and 5.1.3 are excluded from the analysis. 5.1.2 requires the organization to determine its scope of ECD if it wants the certification to be for a specific product or product group. In clause 5.1.3 are listed the clauses from 5.2 to 5.6 so it does not include any additional requirements to the listed clauses.

Clause 5.1.4 requires the results of clauses 5.1.2 and 5.1.3 to be available to relevant stakeholders as documented information. These is failed, as all the following requirements are not met. However, Environmental Product Declaration documents, which are publicly available, partly fulfil this requirement.

Different stakeholders are recognized on Smart Power's web page Stakeholder engagement, and there are surveys and processes to identify their requirements concerning sustainability. However, clause 5.2 is marked as Fail, as the MRS does not reflect ECD as much as it should. It acknowledges legislation and different directives and quality aspects, mandatory standards, and certificates, but there is a lack of environmental aspects. It recognizes the mandatory requirements, but it does not address the life cycles that could improve its environmental impact and beat the competitors. MRS could fulfil clause 5.2, especially if it recognizes some requirements concerning the environmental impact of the product.

Clause 5.3 requires the organization to identify and evaluate its products' environmental aspects. This is applicable to products that have LCA documentation. Additionally, Environmental Product Declarations are a great way to communicate these results. The evaluation of environmental impacts is done by searching the LCA calculations and comparing them between different products. LCA calculations enable clause 5.3 to be passed, and they are at the moment conducted for the whole product portfolio. The determination of significant environmental aspects is fulfilled by setting relevant KPIs and setting thresholds to them.

Clause 5.4 sets requirements for the organization's design and development. To fulfil this clause, PCP should incorporate ECD into its deliverables. PCP does not reflect ECD, so this clause is marked as Fail. KPIs reflect ECD and have great environmental improvement strategies but these are not really showing in PCP.

For clause 5.5.1 Smart Power's management arranges at least twice a year Management Review meeting where the Process review could be implemented, but at the moment the meeting is not ECD compliant. Clause 5.5.2 Design review could be tackled with tracking with KPI, but there is no ready document for this requirement, but it could be implemented in Product audits. The IEC 62430 standard requires the organization to take actions when the environmental objectives of a product or products have not been met as a part of design review. The first gate of active product maintenance process can be seen as ECD applicable, as it includes the problem report. The driver for a change in product can be related to environmental problems and the maintenance process is applicable when implementing environmental improvement in products. In problem report the problem has been already recognized so it can be seen as the result of a design review. Smart Power does not have an ECD review system so the clause 5.5.3 is failed.

Clause 5.6 is fulfilled with EPD document as it provides information to customer and to other relevant stakeholders about the products' environmental aspects and impacts. For some products, there are end-of-life treatment instructions available for customers and recyclers.

5.2 Suggestions to support the work towards ECD

This chapter provides suggestions for filling the requirements that are not at the moment passed in Smart Power. These were identified in chapter 5.1 and they provide information to refine the main challenges for implementing ECD to Smart Power.

Table 8 presents the strengths in Smart Power regarding ECD requirements as there are a lot of methods that are ECD compliant. Table also presents the challenges for implementing eco-design and actions needed for implementing fully IEC 62430 in Smart Power's processes and principles. These were conducted to clauses 5.1-5.6 of the IEC 62430 standard as all of them included both strengths and challenges even if these were earlier strictly marked as passed or failed.

Table 8. *The current state analysis and development suggestions*

	Strengths	Challenges	Development actions
5.1 General	Sustainability strategy 2030 that reflects ECD policies and has clear goals that are measurable	Management and employee engagement	Management showing commitment to eco-design by implementing the principles Motivating employees to achieve environmental improvement through innovation and e.g. sustainable material or supplier choices
5.2 Stakeholder requirements	Informative documents for investors and customers Environmental Product Declarations for providing information to customers	Environmental awareness of the customers	Research customers' requirements concerning environmental performance of the products → meet the market need
5.3 Identification of environmental aspects and impacts	LCA calculations EPD documents	LCA calculations are not available to all products	LCA calculations to whole product portfolio Usage of LCA calculations to identify the environmental hotspots
5.4 Incorporation to design processes	Valid eco-KPIs Own operations have low environmental impact	Product Creation Process: MRS, TRS documents, Lack of environmental parameters in PCP Supply chain management prioritizing price	Additions to MRS document: Environmental VOC New deliverable to Design stage in PCP: Preliminary LCA calculations Eco-design workshops for new products to improve their environmental aspects, using eco-KPIs Favour suppliers with better environmental parameters or demand better environmental performance from current suppliers
5.5 ECD review	Management review which has potential to address ECD	Missing review process	Process review as an integral part of Management review once a year Design review for existing products; Continual improvement with eco-KPI values for existing products, corrective actions with Active maintenance process when needed
5.6 Communication	Internal: Strategy follow-ups External: EPD documents, End-of-life treatment instructions	Internal: information exchange between departments External: EPD documents and end-of-life instructions not available to all products	Internal: Different departments should communicate issues they have noticed and then try to find solution together External: EPD documents and end-of-life treatment instructions to whole product portfolio

Smart Power has the potential to fulfil the requirements of IEC 62430 soon, as it completes the LCA calculations for the entire product portfolio and the management allocates resources for environmental improvement. For example, it could focus on sustainable suppliers and arrange workshops or other functions where the designers have dedicated time to develop products' functions that could lead to environmental improvement. Development actions concerning the Product Creation Process and ECD Review are described more preciously in the next chapters 5.2.1 and 5.2.2.

5.2.1 Additions of ECD policies to Product Creation Process

During the creation of value proposition, which is done at the very beginning of the PCP, Smart Power should determine the aspects of the product that could be optimized to achieve environmental improvement. Improvement strategies can be made to beat old products from their own offering or competitors' products. The importance here is to make a better product from an environmental perspective, price or quality aspects should not be the only drivers here.

To fulfil the clause 5.2 analysis of the stakeholder requirements, the MRS document with an additional paragraph could fulfil this clause. For example, the Environmental VOC (voice of a customer) used in Environmental quality function deployments (E-QFD). There KPIs could be in a table form, and they would be scored from 1-5 based on how relevant those are for each stakeholder groups. Based on the scores, the designers are able to focus on the most relevant environmental improvement strategies.

The input for TRS document is D-FMEA, so to achieve ECD compliance in this process, the organization needs to transfer the environmental aspects into products properties. The D-FMEA process should address environmental aspects by adding environmental risks as potential issues, for example.

The Product Creation Process could benefit from using preliminary LCA calculations. A new deliverable on PCP, "Preliminary LCA calculation" in the design phase, which would aim to achieve LCA calculations for the prototypes on the table, could point out environmental impacts of the prototypes. This information could help to choose the best prototype and to develop the product(s) to be as environmentally friendly as possible when the problems have been identified.

In all of the PCP's deliverables, the requirements of eco-KPIs should be considered. For example, in package design, the responsible employees need to be aware of the fourth lever's KPI requirements. Eco-KPIs requirements should be kept in mind in every step, so they will not become a separate action.

5.2.2 Review process for existing products and management

Clauses 5.5.1-5.5.3 require the organization to maintain a process that reviews the state of IEC 62430 compliance in its processes and documents. These reviews should be conducted in planned timelines or whenever needed. A suitable timeline is once a year. For arranging the review, below flow chart can be used for advice in figure 15.

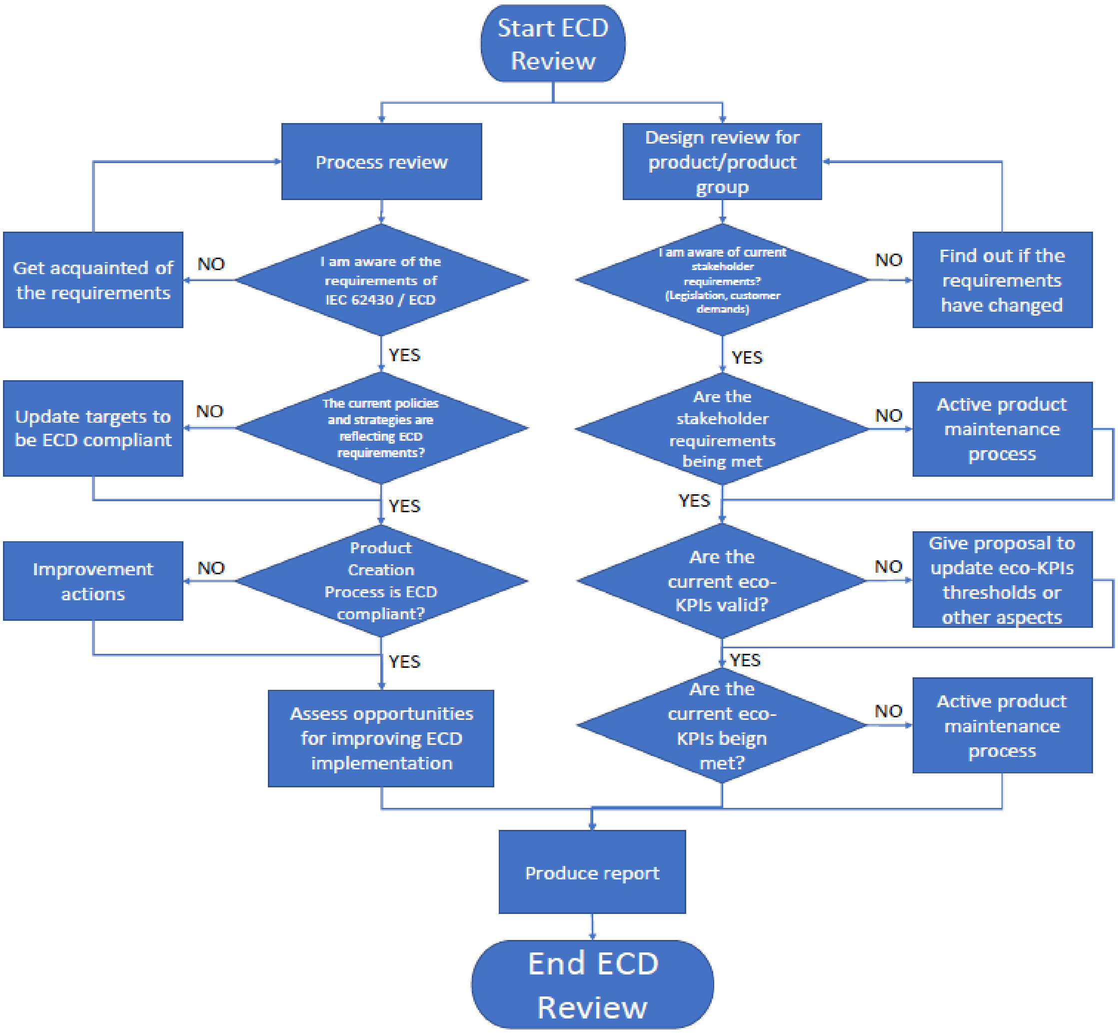

Figure 15. *Flowchart for ECD review*

The process review could be implemented to Management reviews which are held twice a year. Participants should be aware of the IEC 62430 requirements in order to conduct the review. The current strategies and policies should reflect the ECD requirements, and if they do not, they should be updated. Instructions such as PCP should be ECD compliant and checked annually to ensure that they correspond to the latest requirements. Whether or not the organization's policies need to be updated, each review should include assessing opportunities to improve ECD implementation.

During the design review, stakeholders' requirements should be considered first to determine whether they are being met in the product's design. Next, eco-KPIs should be used to check the product's environmental objectives and requirements. If a problem is identified during the design review, active product maintenance should be used to fix the issue and ensure compliance with ECD requirements. The assigned actions from both reviews, design and process, should be documented for future development.

When the organization has implemented development measures, it is recommended to conduct an internal audit of the state of ECD and to search whether is it is ready for an external audit. Based on the internal audit, improvements can be made to the system and correct the deviations.

6. DISCUSSION

This chapter discusses the results of the research by reflecting on the theoretical basis and generalizing the results to other companies. The research question and the sub-questions are represented in figure 16, along with the section in which they are answered. Sub-question 2 provided answer to case company about its current state and its fully answered in results. The other questions are discussed in this chapter.

RQ: How to implement the IEC 62430 standard's requirements in low voltage products?

- How to implement in Smart Power → 5. Results
- Other companies → 6.2 Main ECD implementation challenges in low voltage products and how to overcome them

1. What benefits can companies such as Smart Power get from implementing the standard?

- 6.1 What is the market benefit for implementing IEC 62430

2. Which requirements have already been met and how in Smart Power and what actions must be done to meet all the requirements?

- 5. Results

3. What are the main challenges for implementing IEC 62430 standards requirements to companies' processes and management system and how can those be overcome?

- 6.2 Main ECD implementation challenges in low voltage products and how to overcome them

Figure 16. *Research question and sub-questions and the section where they are answered*

Section 6.3 describes the limitations of the research. It also highlights the facts that must be considered when assessing the reliability of the work.

6.1 What is the market benefit for implementing ECD

It is no secret that, for most for-profit organizations, financial aspects are the biggest drivers, so the motivation for implementing a sustainable mission can be challenging.

The drivers for eco-design implementation from chapter three can be generalized for almost every organization. Recognized external drivers, such as market demand, environmental regulations and legislation, and stakeholder pressures [6], [9], [20] from chapter three, partly drive eco-design implementation for Smart Power. Although there is currently no market demand from smaller companies, bigger companies, especially those from the EU, are demanding proof of compliance with ECD policies. Having documented information on eco-design compatibility can help to achieve market share, especially if competitors do not have proof of meeting requirements of ECD or if there is clear customer demand. In particular, certification for eco-design is proof that the organization is not engaging in greenwashing.

As EU markets usually have the strictest regulations and laws, implementing ECD can help the organization be prepared for new incoming regulations and law. Also, since Smart Power is delivering its products globally, it is important to be aware of regulations in other continents [20]. This thesis presents a long-term vision for assessing ECD policies in Smart Power. Long-term commitment helps the organization be aware of changing stakeholder requirements, new innovations, and to continuously improve its processes and product designs. The European Green Deal was recognized as a significant driver in Smart Power, so it is good to keep an eye on coming initiatives from the European Commission.

In chapter three was recognized that innovations are often driven by the values of decision-makers [6]. This leads to smaller environmental impacts in products and, ultimately, improved image and revenues [6], [9], [20]. Additionally, implementing eco-design principles can improve the working environment and business culture for staff. This conclusion comes from my own experience and motivation for, for example, this thesis, the topic of which I find meaningful. Environmental improvement in products' design or in company's processes can help employees to find their work more meaningful, leading to increased motivation, which in turn can lead to new innovations and better economic performance, and increase the employees' commitment to the organization.

6.2 Main ECD implementation challenges in low voltage products and how to overcome them

When reflecting on the theoretical basis and comparing it to the results of the case study, can be noticed that even if a company's policies have many proofs of complying with eco-design policies, in every-day work there can be struggles for implementing ECD. The pressure to achieve as low cost as possible in operations can lead to ignoring eco-design principles [8]. To successfully implement ECD into a company's principles, commitment from management is required as they need to allocate enough resources to achieve environmental improvement in design processes. In chapter 3, the main challenges for implementing ECD were presented, and management issues rose as one of the most common. To tackle those issues, management should demonstrate the importance of ECD through its own activities by participating in the implementation of the system, ensuring the availability of the necessary resources, and sharing responsibilities.

The knowledge issues arose from both the theory and the case study. Knowledge challenges can occur in the present and in future as ECD policies require continuous improvement and learning. The management has an opportunity to ensure that its staff is educated to ECD and incoming changes in environmental regulations by providing training when necessary [5]. This way, the design and supporting functions can better focus on the relevant aspects of the products and create new innovations. Communication aspects are closely related to knowledge aspects because good communication can increase the knowledge of the staff when they know which environmental aspects each department can affect. Communication between different departments in the organization is not always smooth, which can lead to misunderstandings of the environmental aspects that can be affected in different stages of the product. For example, during the Ecodesign workshop, it was noticed that other departments were not very aware of the problems that for example purchase was facing, such as bad material availability and challenges in finding replacement suppliers. These problems complicate the process of selecting the most sustainable materials and other environmental aspects.

From the case study, it was noticed that customers' demand towards eco-design is mainly dependent on the geographical location and the size of the customer's business. These geographic differences were also noticed in theory when comparing the demands in China and Europe, as Europe is seen as a forerunner [6]. This is one of the main aspects that needs to be consider when identifying stakeholder requirements. If the companies want to educate their customers to be invested in their environmental improvement actions, communication needs to be clear and highlight the benefits to customers' operations to convince also the smaller companies to purchase environmentally conscious products.

Strategy was mentioned as one of the biggest challenges for implementing eco-design in the theory [5], [6]. The case company sets a good example of how the strategy is implemented in the long-term and the development is continuously monitored. Smaller companies do not have as many resources, which can explain the challenges for many companies. However, the strategy and ECD policies are the foundation of implementing the IEC 62430 standard [1], so those should be the starting point for companies that do not yet have eco-design principles in their processes. An effective long-term strategy helps the organization to concentrate on relevant actions and directs resources to the desired direction.

6.3 Limitations and reliability of the research

The research was conducted as a case study, which sets certain limitations on the generalizability of the results. A case study has limitations on breadth, but it provides the opportunity to analyse the selected company in depth. The company's documents and processes were search using qualitative analysis, which is not precisely measurable. The analysis is affected on the foreknowledge and understanding of the standard and the analysed material. The results are based on the interpretation of the author of the work. The list of development actions has been prepared for the company based on the current stage analysis. The development actions were not implemented during the creation of this thesis, so their applicability cannot be evaluated yet.

7. CONCLUSIONS

The goal of this thesis was to study IEC 62430 – Environmentally conscious design standards requirements and how those can be implemented in low voltage products. In order to implement the requirements as an integral part of Smart Power's processes and product design, relevant documents related to the product's environmental performance and process instructions were searched and evaluated. While some documents reflect ECD policies, others need to be modified to be ECD compliant.

The motivation for complying with ECD policies comes from the business advantages that can be gained. If an organization can minimize the negative environmental impacts of its products, it can achieve revenues through improved image and by responding to market demands as more and more consumers demand products that are environmentally conscious. Regulations and laws are constantly updated due to increased environmental awareness, so organizations need to be prepared for incoming changes and ECD policies can be helpful in that sense. The certificate for IEC 62430 is a great proof that company's policies reflect environmental awareness, which can help avoid the accusation of greenwashing.

To successfully implement ECD, Product Creation Process and review processes need modifications and additions. Documentation is a proof of ECD compliance, so changes in processes alone are not enough to meet the requirements. When making and providing documentation, both internal and external stakeholders need to be taken into account.

Earlier studies have described the common challenges in eco-design implementation as a missing strategy or lack of knowledge and how companies that have put very little effort in environmental improvement can make changes. This thesis provides information to companies that have actively improved their actions to be environmentally conscious but need additional information about problems that can occur in daily tasks, and solutions to them. Operating according to the IEC 62430 standard would ensure that environmental work becomes proactive, and that continuous improvement becomes a daily operating method for the company. Challenges were identified in communication and knowledge, which need improvement actions from the management level so that they can be conducted in processes. Smart Power's challenges reflected mostly the same subjects that arose from the articles, but the company's strategy was not one of them as sustainability is one of the key factors. The challenges occur at a deeper lever where the ambitious goals are difficult to implement into decision making, as price is a significant factor when deciding on suppliers that have the most significant impact on global warming potential in Smart Power's products.

The development actions that all organizations can implement include staff training for eco-design principles, good communication between different departments and from management, and a review process for existing products and/or services. While new products are easier to design to follow eco-design requirements, it is important not to forget about existing ones. At least in Smart Power, the review process is missing, so it is possible that many organizations have room to improve their existing product portfolio and implement a design review for it regularly.

As the main result based on the discussion and the results of the case study, it can be stated that the most important factor in implementing eco-design principles is management's commitment. Management issues were the most common challenges based on theory, and in the case study, it was noticed that the designers would not focus on improving the environmental aspects of the products if the demand was not prioritized enough from the management and resources were not allocated enough for choosing more responsible suppliers. This does not mean that the management of the case company or other companies are doing nothing for eco-design, but they have the biggest chance to affect many challenges. That is why the next step in ECD implementation is to search for the possibility of implementing ISO 14006, which provides more guidance on how to implement ECD into existing management system.

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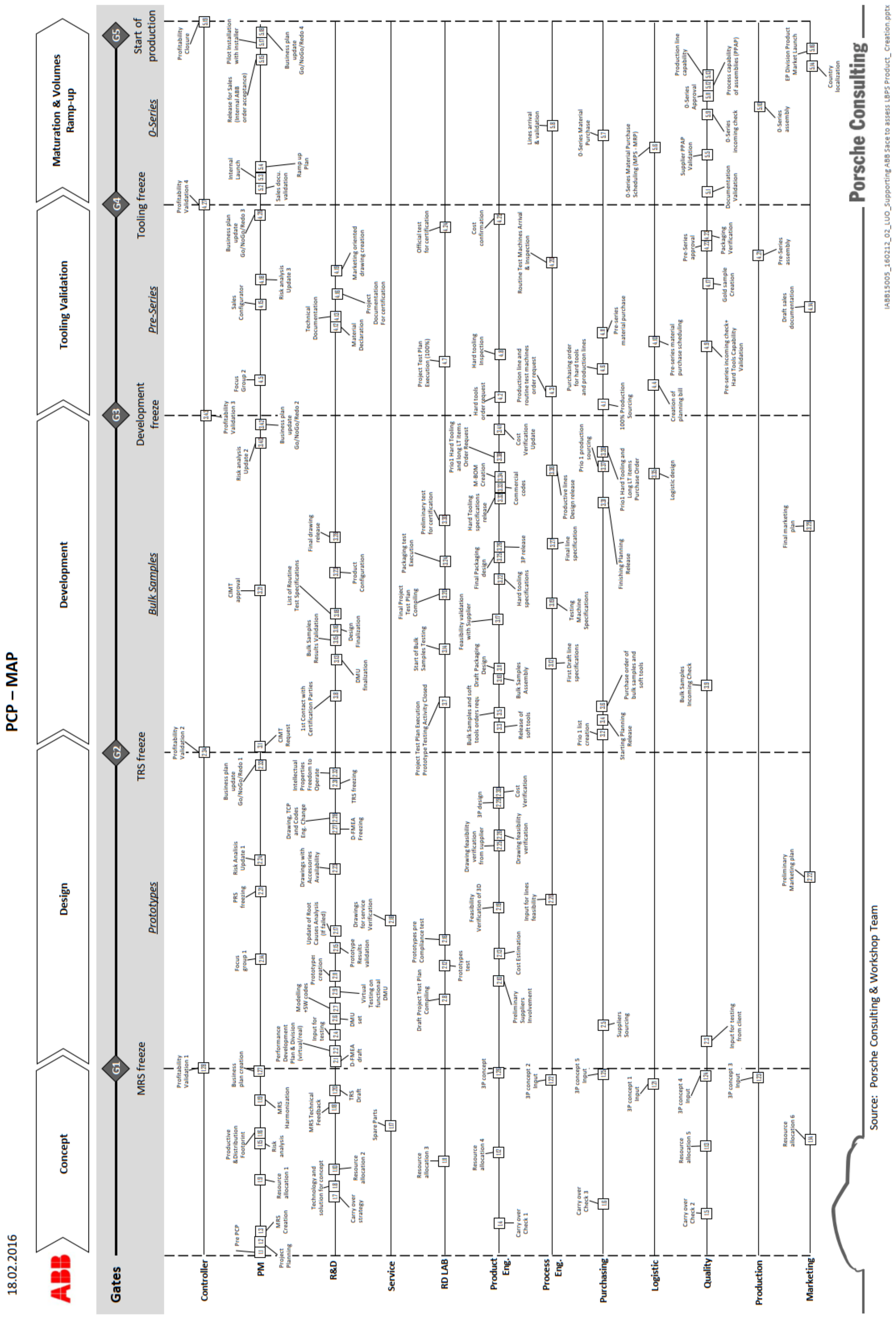
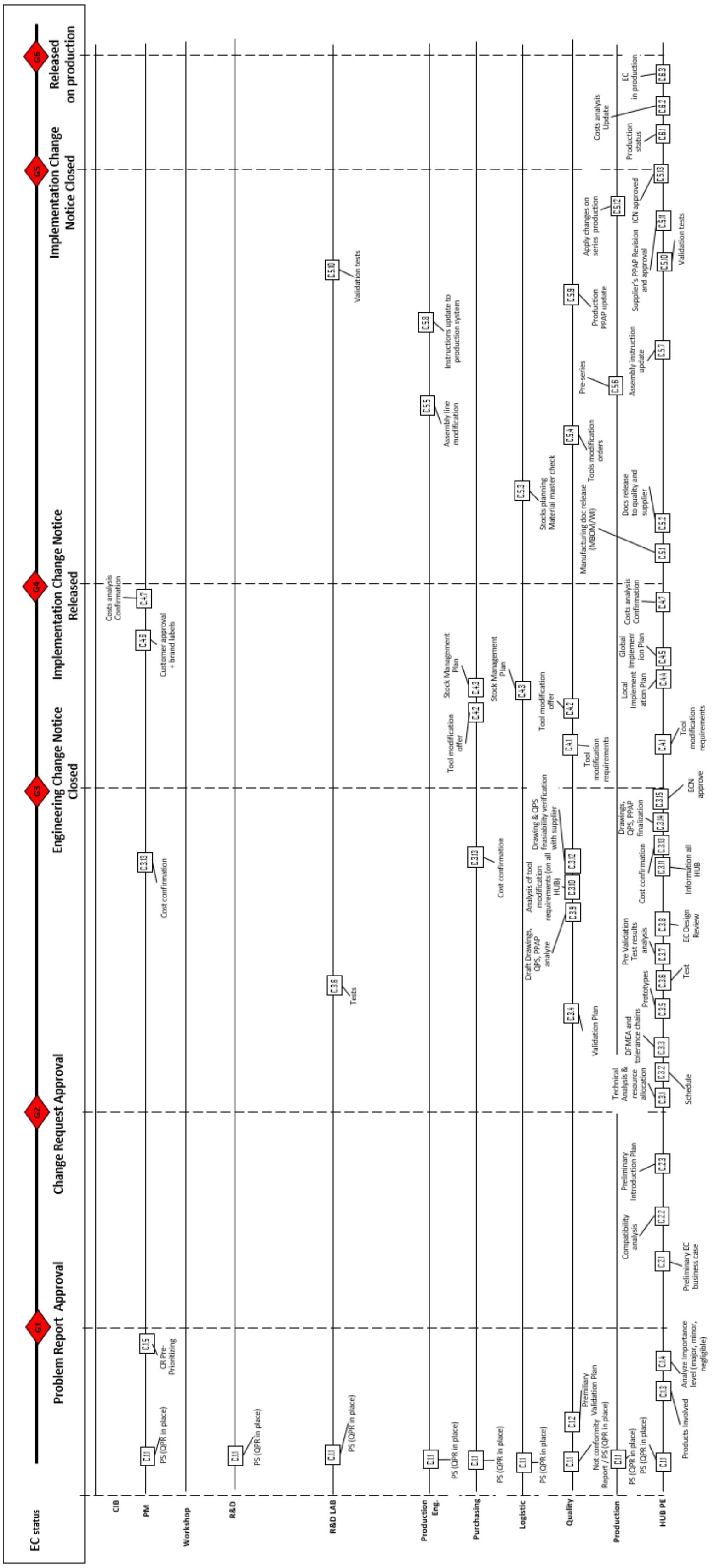
APPENDIX A:



PCP – MAP
18.02.2016
Gates
Concept
Design
Development
Tooling Validation
Maturation & Volumes Ramp-up
G1
MRS freeze
G2
TRS freeze
G3
Development freeze
G4
Tooling freeze
G5
Start of production
Prototypes
Bulk Samples
Pre-Series
0-Series
Controller
PM
R&D
Service
RD LAB
Product Eng.
Process Eng.
Purchasing
Logistic
Quality
Production
Marketing
Source: Porsche Consulting & Workshop Team
Porsche Consulting

APPENDIX B:


EC status
Problem Report Approval
Change Request Approval
Engineering Change Notice Closed
Implementation Change Notice Released
Implementation Change Notice Closed
Released on production
CIB
PM
Workshop
R&D
R&D LAB
Production Eng.
Purchasing
Logistic
Quality
Production
HUB PE