BEYOND PRODUCT IMPROVEMENTS

The opportunities and challenges of integrating a system approach into the sustainable design strategy of Prysmian Group Delft

A. KOOT

Photo frontpage: Prysmian's production facility in Delft. Source: duurzaamgebouwd.nl

Beyond product improvements

The opportunities and challenges of integrating a system approach into the sustainable design strategy of Prysmian Group Delft

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Abstract

The multinational company Prysmian Group designs and manufactures power and telecom cables. At their facility in Delft, the Netherlands, sustainable design has become increasingly important driven by customer demand. This led to several improvements of their power cables, such as the use of a recyclable plastic. These improvements are technical solutions for a problem in today's product supply chain.

In this thesis research, it is investigated if the sustainable design strategy of Prysmian Group Delft could go beyond these technical product improvements. After all, in order to decouple human consumption from the consumption and pollution of natural resources, we should focus on innovating socio-technical systems, rather than single products. A field of research which aims to support designers to contribute to these system innovations is Transition Design. Different Transition Design frameworks have been developed, but using them in commercial environment proves to be challenging. Therefore, in this research, it is explored how Transition Design theory could be adapted into a design method suitable for Prysmian Group Delft. This method should support the company to change their sustainable design strategy from making incremental improvements on their products to developing product systems that contribute to system innovation.

Through an iterative process, in which interviews, creative workshops and design trials were used, insights were gathered on what this design method should look like. The resulting design method, named Product System Design Method (PSDM), integrates the system approach used in Transition Design into the design process of Prysmian Group Delft. In total, six variations to Prysmian's design process were developed which increasingly address more system elements. Simultaneously, possible designs that follow from the PSDM were developed. Six illustrative designs, each representing one of the design processes, are presented in this research.

In order to be of use for Prysmian Group Delft, it was argued that the PSDM should result in designs that do not only contribute to system innovation but also create value for Prysmian Group Delft. Therefore, the six illustrative designs were qualitatively analysed on to what extent the designs meet this requirement. This evaluation shows the designs that included more system elements do create more long-term benefits for Prysmian Group and make a bigger contribution to system innovation. However, their implementation also requires more changes at Prysmian Group Delft.

Overall, it was concluded that the PSDM and the developed illustrative product system designs are a first step in the integration of system thinking into the design strategy of Prysmian Group Delft. However, given the current business strategy of Prysmian Group, the implementation of the PSDM and the illustrative product system designs is currently not expected.

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1 Introduction

If we could redesign the way in which we bring energy to the people, what would this system look like? No power cables? No electricity grid maybe? Possibly, we would make our society less dependent on electricity to start with. This research explores if asking other questions than the usual ones stimulates fruitful ideas for innovation that were not thought of before. Why this is needed? This will be explained below.

1.1 Background

The multinational company Prysmian Group designs and manufactures energy and telecom cable systems. Their 112 production plants are located in 50 different countries employing about 30,000 people. The company is listed on the stock exchange market in Italy and is global market leader (Prysmian Group, 2019a). One of Prysmian Group's plants is located in Delft, the Netherlands. At this facility, power cables are designed and produced. It is the head quarter of the Benelux and employs approximately 320 people.

Prysmian Group, and in particular the facility in Delft, experiences increasing pressure from shareholders and customers to operate in a more sustainable way. In order to address this request, Prysmian Group Delft uses the Lifecycle Design Strategies (LiDS) wheel (Brezet & Van Hemel, 1997) as a tool for sustainable product design. LiDS supports designers to identify product improvements for each of the stages of a product's life cycle. By the use of this tool, several product improvements such as the use of recyclable plastics – have been made at Prysmian Group Delft.

These design efforts, however, only result in incremental improvements of the product itself. They focus on making a product less bad (Ceschin & Gaziulusoy, 2016). However, the field of Industrial Ecology argues that, in order to reach the needed efficiency gains for the decoupling of human consumption and the de pletion and pollution of natural resources, society should shift this focus from 'less bad' to 'changing the story' (Graedel & Allenby, 2010). We have to radically change the way we feed, power and entertain ourselves (Tukker & Butter, 2007; Greadel & Allenby, 2010).

To make these radical changes, system innovations are needed (Tukker and Butter, 2007). System innovation can be defined as the transition from a certain socio-technical system to a new, more sustainable alternative (Geels, 2005). This implies changes in institutional, social/cultural, organisational and technical system elements that must co-evolve together (Loorbach, 2010; Tukker & Butter, 2007).

Companies play an important role in these system innovations as they develop the technological artefacts of the new systems (Charter et al., 2008). Therefore, in this thesis research, it is argued that large, international companies, such as Prysmian Group, should shift their sustainable design strategy from incremental improvements of their products, to contributing to the innovation of the socio-technical system these products are part of.

However, as a company specialised in the design and production of a physical product, bridging their technology-focussed design method with system innovation is challenging. To investigate opportunities for Prysmian Group to contribute to system innovation, different Transition Design frameworks were investigated. Transition Design is a relatively young field of research which aims to bridge the gap between product design methodology and system innovation (Joore, 2010; Gaziulusoy, 2010; Ceschin, 2012; Irwin, 2015). In theory, the objectives of these frameworks meet the challenge described above. However, recently it was concluded that these frameworks are of limited use in commercial activities as they are time consuming and reason based on societies needs rather than company's interests (Gaziulusoy, 2018). Therefore, it is interesting to explore if Transition Design theory could be used in such a way that it creates value for a company while maintaining its objective to contribute to system innovation.

1.2 Problem definition

Given the environmental challenges humankind is facing (Rockström et al., 2009), it is argued that big companies, such as Prysmian Group, should not only focus on incremental improvements of their own product, but also on how they can contribute to system innovation. Although Transition Design theory has the objective to support designers in doing so, its current frameworks are challenging to use in a commercial environment. Therefore, there is a need to research if and how these Transition Design frameworks could be adapted in order to be of use for Prysmian Group Delft while maintaining their objective to contribute to system innovation.

1.3 Research goal and research questions

This research aims to explore if and how Transition Design theory can be used to develop a new design method for Prysmian Group Delft. This design method should support Prysmian's employees to develop product system designs that create value for Prysmian Group Delft while contributing to system innovation. A product system design does not only include the design of a product, but also addresses partners and their roles required to realise the design. The facility in Delft was considered a suitable case study for this research as, within the global concern, this location is frontrunner in sustainability and sustainable product design.

In line with this research goal, the following research question was developed:

> *How can Transition Design theory be used for the development of a new product system design method that supports Prysmian Group Delft to develop product system designs which create value for the company while contributing to system innovation?*

This research question describes the development of two things: a product system design method and product system designs. This product system design method should be usable for Prysmian Group Delft. The designs that are developed by the product system design method should create value for Prysmian Group Delft and contribute to system innovation. Following from this, four sub-questions were formulated (Figure 1). Sub-question 1 addresses the development of new product system design method. This design method is used to develop product system designs to illustrate possible outcomes of the design method, answering sub-question 3. In sub-questions 2 and 4, the evaluation of both the product system design method and the illustrative product system designs are addressed.

1.4 Scope

This research has been conducted at Prysmian's plant located in Delft, the Netherlands. For the development and evaluation of illustrative product system designs (see sub-questions 3 and 4), the electricity distribution grid and related low-voltage cables (400 V to 1 kV) were selected. Due to the increase in the usage of electric cars, heat pumps and solar panels, this part of the grid is directly influenced by the energy transition.

For low voltage power cables, Prysmian Group Delft mainly serves the Dutch electricity distribution market. Therefore, the Netherlands is selected as a geographical boundary for this research.

The research will primarily focus on environmental and economic sustainability. The "people" pillar of the triple bottom line concept (Elkington, 1998) is not addressed.

1.5 Report outline

An overview of the outline of this report is shown in Figure 2 on the next page. The report starts with the findings of the background research. In Chapter 2, Prysmian's strategy, products and stakeholders are discussed. The literature review done on Transition Design is presented in Chapter 3. This background research forms the basis for the core research. The core research consists of 3 chapters. Firstly, Chapter 4 describes the research set-up and methodology. Chapter 5 discusses the development and evaluation of the product system design method answering the first two sub-questions. In Chapter 6, the developed illustrative product system designs are presented and evaluated. The last two sub-questions are answered in this chapter. Next, Chapter 7 discusses the methodology and findings of the core research after which conclusions are drawn in Chapter 8. In Chapter 9, recommendations for further academic research as well as for Prysmian Group are done.

	Development	Evaluation
Product system design method	**Sub-question 1:** What product system design method could be developed for Prysmian Group Delft based on Transition Design theory?	**Sub-question 2:** What are the conditions that must be met at Prysmian Group Delft in order to use the developed product system design method?
Illustrative product system designs	**Sub-question 3:** What illustrative product systems can be designed by the use of the developed product system design method?	**Sub-question 4:** To what extent do the developed illustrative product system designs create value for Prysmian Group Delft while contributing to system innovation?

Figure 1: The four sub-questions

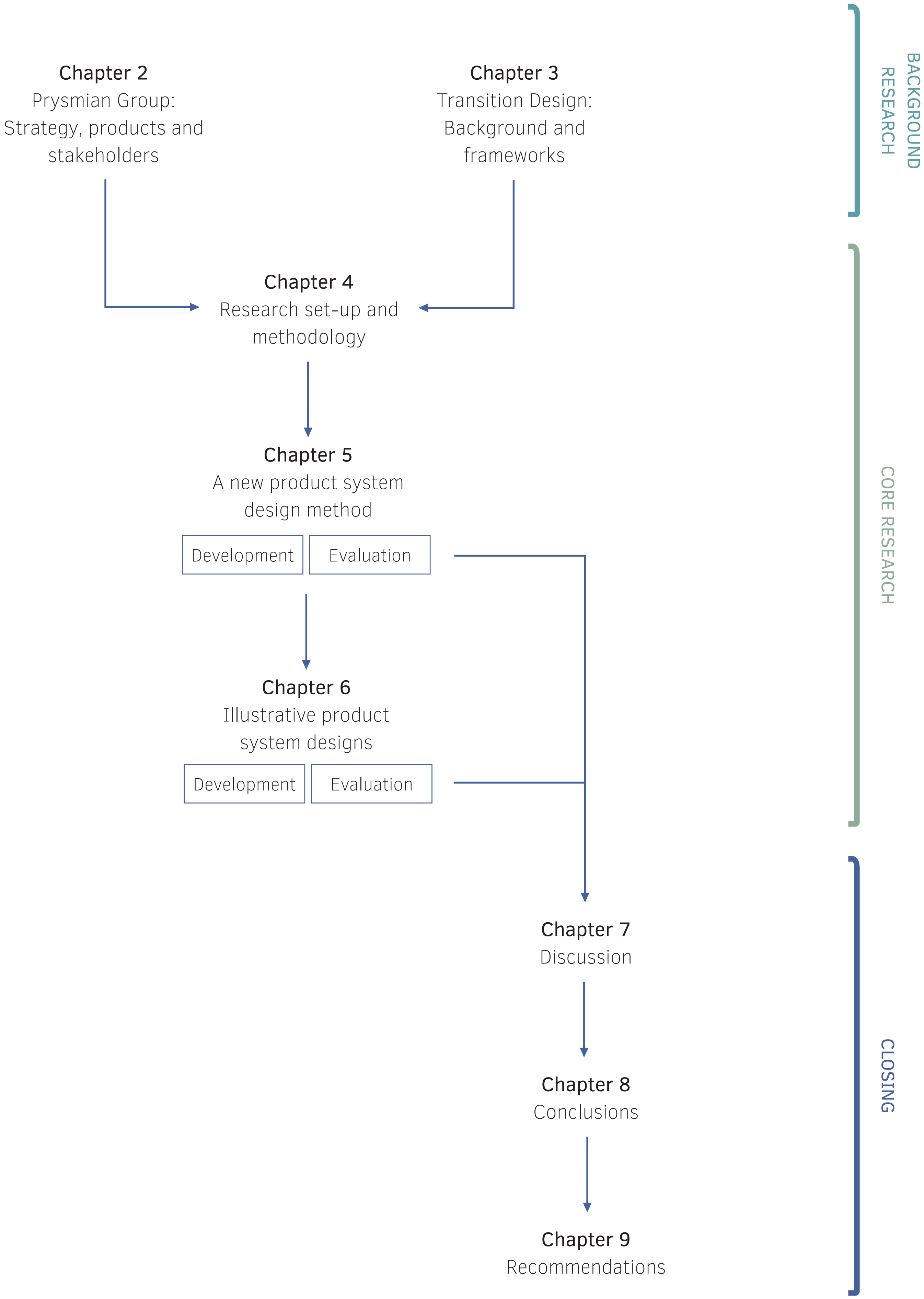
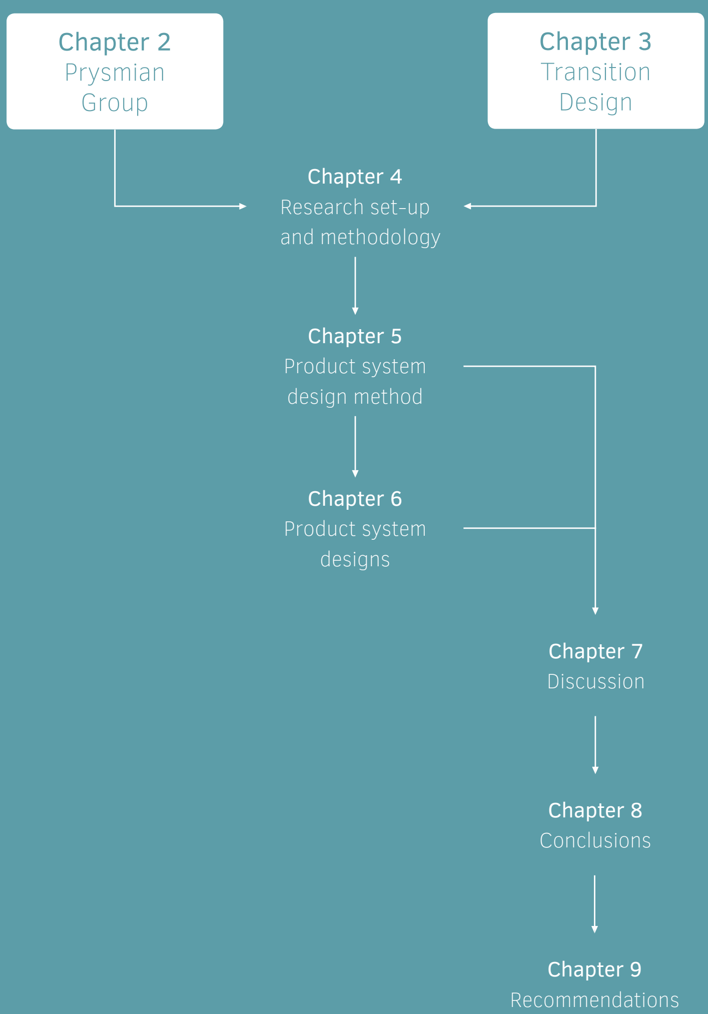


Figure 2: Report lay-out

PART 1

Background research



2 Prysmian Group: Strategy, products and stakeholders

In this Chapter, Prysmian's strategy, their products and their stakeholders are briefly introduced. In sub-section 2.1, it is described how the information presented in this chapter was collected. Sub-section 2.2 and 2.3 discuss Prysmian's business and sustainability strategy respectively. A brief introduction into Prysmian's low voltage power cables and the low voltage grid is given in sub-section 2.4. Last, the most important stakeholders of Prysmian Group Delft are presented in sub-section 2.5.

2.1 Data collection

The information presented in this chapter was gathered in different ways, which are discussed below.

2.1.1 Semi-structured interviews

DDuring the first weeks of the research, nine semi-structured interviews with Prysmian employees were held (Table 1). The first selection of interviewees was based on the advice of the Sustainability Officer of Prysmian Group Netherlands. During these interviews new interviewees were recommended. This was a continuous process throughout the first part of the research.

The interview protocol that was used can be found in Appendix 1. During the interviews, notes of interviews were taken and digitalised afterwards. Through clustering of topics that were discussed, the most important topics were selected. The outcomes of the interviews will be discussed throughout this chapter.

Additionally, during a meeting with Prysmian's CFO later in the research, more information for the background research was collected.

Table 1: Overview of the interviews taken with Prysmian Group employees with the aim to collect information on the company

# of interviewees	Department	Company
1	Logistics and services	Prysmian Group Delft
2	Sales	
2	R&D	
1	Purchasing	
1	Marketing	
1	Marketing	Prysmian Group Milan (head quarter)
1	Management	Draka (sub-brand of Prysmian Group

2.1.2 Multi-department meetings

In total, three multi-department meetings were visited for observation. Possibilities for the innovation of the medium voltage power cables were discussed during these meetings. Visiting these meetings helped to create an understanding of considerations made regarding innovations at Prysmian Group Delft. During the meetings, notes were taken which were digitalised afterwards.

2.1.3 Written content

Prysmian's global website (Prysmian Group, 2019b), Prysmian's sustainability report (Prysmian Group, 2017a) and Prysmian's Dutch sustainability webpage (Prysmian Group, 2017b) were used to gather additional information on the company.

2.2 Business strategy

Prysmian's headquarters in Milan is responsible for setting up and managing Prysmian's business strategy. In this sub-section, it is first described what strategy they communicate via their website. Next, based on the semi-structured interviews, this strategy is further discussed.

2.2.1 Mission, vision and values

On their website, Prysmian's mission is formulated the following:

"We provide our customers with superior cable solutions based on state-of-the-art technology and consistent excellence in execution, ultimately delivering sustainable growth and profit." (Prysmian Group, 2019c).

The related vision is the following:

"Energy and information help communities develop. That's why it's so important that they're always available, and that they're supplied: Effectively. Efficiently. Sustainably." (Prysmian Group, 2019c).

The mission and vision communicate a strong focus on high quality products. As society is 24/7 dependent on both electricity and telecom, reliability of their products is a key priority for Prysmian Group. This is also reflected in their first value: Excellence. Prysmian Group aims to deliver innovative all-round solutions. The other values are Integrity - doing things right, and Understanding - focussing on customers' needs (Prysmian Group 2019c).

2.2.2 Prysmian's operational strategy

Through the interviews with Prysmian Group employees and the meeting with Prysmian's CFO in Delft, insights were collected on how Prysmian Group operates to achieve the mission discussed in the previous paragraph.

Firstly, Prysmian Group is particularly strong in minimising costs. A marketing employee explains that, of Porter's genetic strategies (Porter, 1980), Prysmian Group focusses on cost leadership. The CFO thinks that this is what makes Prysmian Group the market leader. Compared to competitors, they are very effective at cutting costs. This focus on cost leadership is centrally managed and controlled from Milan. A t Prysmian's facility in Delft, cost minimisation is important as well. During the multi-department meetings, opportunities to reduce production costs were the main topic discussed.

This cost-driven strategy results in efficient management of manpower. An employee from Prysmian Group Milan tells that, when they merged with General Cable, Prysmian's marketing department was three times smaller than the marketing department of General Cable while serving the same size market. An R&D employee in Delft tells:

> *"We have a shortage of manpower, so we only focus on things that are bleeding".*

This focus on short-term challenges is also mentioned by others. When discussing a business model in which cables are leased instead of sold, another employees jokes:

> *"We usually don't even know what we will be working on tomorrow. So if we would have to take-back our cables after forty years, we will probably start thinking about what to do with them in 39 years and 364 days from today."*

IIn line with this cost-driven strategy is Prysmian's focus on financial risk minimisation. As the CFO explains, they are not likely to invest money in something that might result in higher profits but also increases the risk of losing the investment. On purpose, Prysmian Group generally waits with innovations until other try it first. In this way, they are not the one making the expensive mistakes.

2.3 Sustainability strategy

Like most companies, Prysmian Group is paying attention to sustainability more and more. For the multinational company, this is mainly stimulated by shareholders. To distinguish themselves from other companies, Prysmian Group uses different sustainability indexes, such as the Dow Jones Sustainability Index (RobecoSAM, 2018). For the facility in Delft, customers are the main driver for sustainable innovation. In this sub-section, Prysmian's sustainability strategy is further discussed.

2.3.1 Global sustainability strategy

Prysmian Group has corporate-wide strategy to improve the sustainability of their business, based on the Sustainable Development Goals (SDGs) (UN, 2018). The five most relevant goals for the company (Figure 3) were translated into three focus areas (Prysmian Group, 2017a):

1. Enable affordable energy and telecom innovations and infrastructure
2. Pursuit responsible consumptions of natural resources and sustainable supply chain
3. Contribute to people and communities development

Each focus area has its own KPIs and targets for 2020. When having a critical look at the sustainability strategy as described in the sustainability report of Prysmian Group global (Prysmian Group, 2017a), it was concluded that the KPIs largely focus on impacts made during the production of products. For example, one of the relevant KPIs is:

"% of annual revenues from low-carbon products".

Whether a product is low-carbon, is based on the energy required in the production process per km of power cable. Higher system-level ambitions are not addressed by the KPIs.

Figure 3: The SDGs selected by Prysmian Group in their sustainability report (Prysmian Group, 2017a)

2.3.2 Sustainability strategy Delft

As said, Prysmian Group Delft is one of the frontrunners within the global concern when it comes to sustainability. This facility has its own sustainability website (Prysmian Group, 2017b) at which the life-cycle sustainability strategy based on LiDS (Brezet & Van Hemel, 1997) is presented. LiDS is used to identify opportunities for product improvements. This resulted in different sustainable adjustments to the power cables, such as the substitution of materials and the use of recycled materials.

During the interviews with Prysmian Group employees, these innovations were also discussed. Especially P-laser was frequently mentioned by employees of different departments as the example of sustainable innovation within Prysmian Group Delft in the last few years. P-laser is a high-performance thermoplastic insulator which is used in medium voltage and high voltage power cables. In contrast to the commonly used plastic, XLPE, this material is recyclable. To give an insight into the innovation process that led to the implementation of P-laser, this process is summarised below.

Initially, the P-laser material was developed in Italy as a response to a request by the management in Milan to be less dependent of a certain plastic supplier. However, in Italy, P-laser became successful as the cable production time significantly decreases by the use of this material which makes last-moment orders possible. In the Netherlands, it was not implemented until their customer Alliander started adding sustainability requirements to their tenders in 2008. Through a collaboration between R&D, sales and other departments, P-laser was introduced and Alliander was convinced to go for this recyclable material. Basically P-laser was a rather random coincidence of the right request meeting the right people at the right time.

Also, the other innovations mentioned were either as a response to a customer demand and/or initiated by Prysmian's management. For example, integrating RFID chips into low voltage power cables to store a material passport is a running project. Also, recycled plastics have been implemented on a pilot-scale, based on customer requests. These innovations are realised though collaboration between different departments.

Overall, it was found that Prysmian Group employees in Delft are generally well informed about the life-cycle impact of a power cable. Also, employees are aware of the changes in the energy system as well as the concept of circular economy. However, these are considered to be issues which should be solved by the grid operators. In general, Prysmian employees see Prysmian's role in improving the cable, not the systems it is part of.

2.3.3 Critical opinions

When it comes to the general attitude towards (sustainable) innovation of Prysmian Group Delft and its stakeholders, several Prysmian employees point out the conservative mind-set of most organisations. They mainly impute this to the focus on electricity supply reliability. However, they agree that the current sustainability challenges demand a more innovative attitude from all stakeholders:

> *"The infrastructure sector has had a few problematic years. Nevertheless, now it is time to show leadership. However, everyone is too afraid to do so".*

When it comes to sustainability, the general attitude is positive as long as it does not cost extra money nor requires changes in behaviour or risks. The lack of ambition regarding sustainable innovation was mainly judged by younger employees. When discussing the high ranking of Prysmian Group in the Down Jones Sustainability Index (DJSI) in 2017:

> *"It's something similar to becoming champion in the third league"*

2.4 Products

The power cables produced at the Prysmian Group Delft are categorised based on voltage capacity (Table 2). The electricity transmission grid (high voltages of long distances) are in the Netherlands managed by TenneT, the only Dutch Transmission System Operator (TSO). The electricity distribution grid is managed by Distribution System Operators (DSOs) and serves to bring the electricity to the consumers. As the low voltage power cable is used as a case study for this research, this cable and the low voltage grid will be discussed in more detail below.

2.4.1 The low voltage power cable

One of the most commonly produced low voltage power cables at Prysmian Group Delft is shown in Figure 4 (next page). This specific cable has a diameter of 49 mm and weights 4.4 kilogram per meter. Cables are designed to last at least 40 years. The different layers of a low voltage power cable are shown in Figure 4 and discussed in more detail in Table 3 on the next page.

A Life Cycle Assessment (LCA) study of high voltage power cables by Beco Group (Hegger et al., 2011), commissioned by TenneT, shows that most of the Global Warming Potential of a high voltage power cable (95% to 99%) can be assigned to its use phase due to electrical losses. In this study, the life-cycle impact of cables with different conductor diameters and safety layers for different power loads is analysed. It was found that increasing the diameter of the conductor, therefore lowering losses during use, significantly reduces the overall Global Warming Potential of the power cable.

These high impacts in the use phase are confirmed by an LCA done by Beco Group (2010) for Alliander on medium voltage electricity cables.

The outcomes of the above mentioned LCAs will change when the electricity they conduct is produced from renewable resources. When excluding the use phase from the analysis, it appears that the production of the conductor material is accountable for about half of the impact for the power cable (Beco 2010; Hegger et al., 2011). It must be mentioned that the recycling of the power cables is not taken into account in these studies. As the conductors are generally recycled while the plastic insulation is not (see Chapter 6), including recycling in the LCA will change this outcome.

No study has been found on the environmental impact of low voltage cables, but similar results can be expected.

Table 2: Overview of different power cable categories produced at Prysmian Group Delft

Cable category	Voltage range	Grid	Connections	System operator
Extra high voltage power cables	220 kV - 380 kV	Electricity transmission	Large power plants, international connections, the high voltage grid	TSO
High voltage power cables	50 kV - 220 kV	Electricity transmission	Power plants, large wind turbine parks, heavy industry, the medium voltage grid	TSO
Medium voltage power cables	1 kV - 50 kV	Electricity distribution	Wind turbines, railways system, industry, the low voltage grid	DSO
Low-voltage power cables	400 V - 1 kV	Electricity distribution	Solar parks, households, small companies	DSO

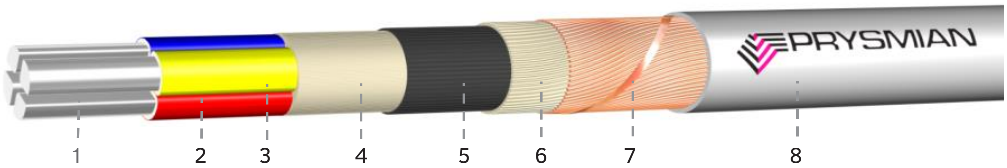


Figure 4: A 4x150alsvm low voltage cable - A frequently produced cable at Prysmian Group Delft

Table 3: Explanation of the different parts of the LV cable shown in Figure 4

# in Figure 4	Name	Material	Functionality
1a	Conductor (4x)	Aluminium	Conduct electricity for households
1b	Auxiliary wires (4x)	Copper	Conduct electricity for other purposes e.g. for street lighting
2	Insulation	PVC	Electrically insulate the conductors
3	Assembly	-	The low-voltage grid is a three-phase grid and therefore consists of 4 conductors (3 phases and ground phase). These different conductors are assembled together in one cable for easier installation.
4	Filler	Rubber	To make the cable perfectly round
5	Inner sheath	PVC	As a base for the bedding
6	Bedding	Rubber	To make sure the wire screen stays in place
7	Wire screen	Copper	Conduct electricity in case the cable gets damaged/lighting strikes/electrical failures in the cables system occur for the sake of human safety and to prevent further damage of the cable system
8	Outer sheath	PVC	To prevent water and other surrounding elements to enter the cable and to protect the cable during installation.

2.4.2 The low voltage grid

The low voltage grid distributes the electricity which enters a neighbourhood at a transformer substation to each individual household. This grid consists of low voltage power cables and joints and usually has a comb layout (Figure 5). Other than most medium and high voltage grids, low voltage grids generally have no parallel back-up grid.

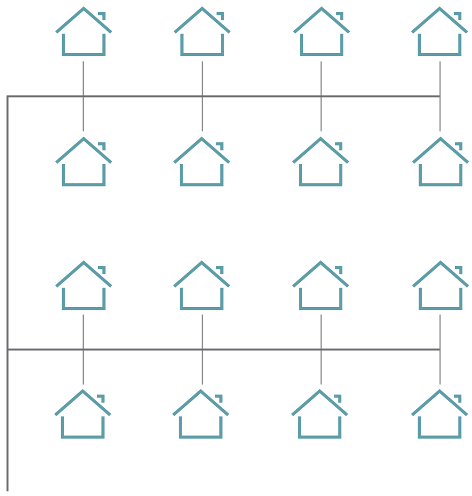


Figure 5: Common lay-out of the low voltage grid. Based on Phase to Phase (2017)

The load on the low voltage grid largely fluctuates. It follows a pattern in which demand peaks in the mornings and the evenings and is relatively low during the night. Assuming that (an adjusted version of) the proposal of the Dutch Climate Agreement as presented on the 21st of December 2018 (Klimaatakkoord, 2018) will be executed, it is expected that more households will electrify a large share of their energy consumption. This means that these peaks are expected to increase. Also, the installation of solar panels on roofs is an increasing challenge as cables might overheat on sunny days (Harmsen & Kruizinga, 2018).

2.5 Stakeholders

TTo create an understanding of which actors are linked to Prysmian Group Delft, a stakeholder map is developed (Figure 6). Prysmian Group distinguishes seven stakeholder groups (Prysmian Group, 2017a). These groups were used as a basis for the stakeholder map and complemented with stakeholder groups relevant for Prysmian Group Delft. The external stakeholders with most power are most important to keep satisfied. They have limited interest in Prysmian's condition while having much influence on it. Therefore, these stakeholder groups are discussed below.

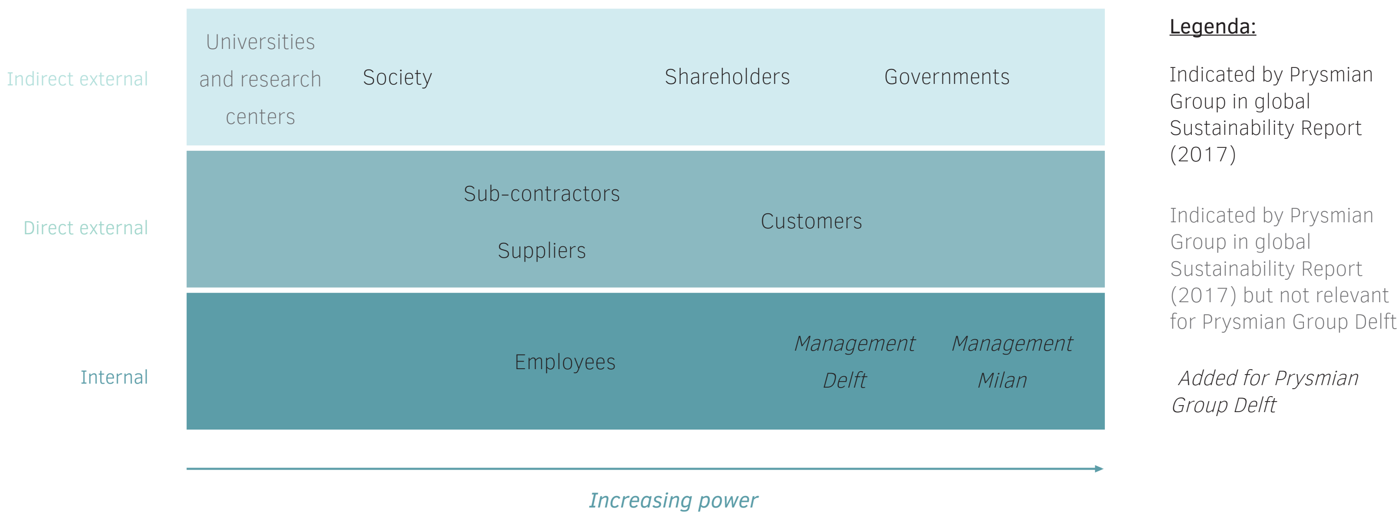


Figure 6: Stakeholder map of Prysmian Group Delft

2.5.1 Customers

Prysmian's most important customers are the Dutch TSO TenneT, other European TSOs, such as Terna (Italy), and the three biggest Dutch DSOs: Alliander, Enexis and Stedin. Besides, they supply power cables to smaller DSOs and sub-contractors.

Grid operators (TSOs and DSOs) are semi-governmental organisations which are responsible for the transmission and distribution of electricity to consumers. Grid reliability to minimise outrages is a key priority. This makes grid operators, in general, a bit reluctant to try out new innovations. However, as a semi-governmental organisation, they do feel the responsibility to pay attention to societal interests. Therefore, reliability, affordability and sustainability are the three main pillars which are at the heart of their decision making processes.

2.5.2 Governments

Like every company, Prysmian Group has to follow legislation. Governmental decisions, such as carbon tax for industry, directly influence Prysmian Group Delft.

Also, local governments do influence Prysmian indirectly. Municipalities determine where and how new neighbourhoods will be build. Municipalities commission DSOs to install a grid, for which Prysmian Group Delft supplies power cables. Demands from the municipality (e.g. gas-free neighbourhoods) do influence the required power cables.

2.5.3 Shareholders

Prysmian Group is a stock listed company in Italy. Although this only influences Prysmian Group Delft indirectly, it does set certain limitations on long-term investments. Maximising profits each quarter is important. Also, shareholders generally request a decent ranking by the Down Jones Sustainability Index in order to invest. This stimulates Prysmian Group to integrate sustainability into their business.

2.6 Closing remarks

As Prysmian Group develops products for a sector of which society is dependent 24/7, product quality is a key driver for the company and their customers. This results in long-lasting products but also limits the willingness to innovate. Another aspect that limits innovation is the strong focus on cost efficiency at Prysmian Group Delft. When considering Porter's genetic strategies (Porter, 1980), Prysmian Group distinguish themselves through cost leadership rather than differentiation. The focus on cost leadership can partly be explained by the conservative sector Prysmian Group is part of. Innovation comes with uncertainty about the actual quality and lifespan of products which is not embraced by customers. These insights will be used in Chapter 5 to discuss the changes Prysmian Group will need to make to use the developed product system design method.

Prysmian's sustainable design strategy is focussed on making sustainable improvements on their products addressing issues in the product supply chain. The innovation process at Prysmian Group Delft depends per project and is often initiated based on customer or management demand. The development and implementation of the different innovations happens in close collaboration between departments. Currently, the innovations focus on single changes to the physical product. Prysmian Group employees are generally well aware of the supply chain impact of a power cable.

3 Transition Design: Background and frameworks

In this chapter, the Transition Design research field is further explored by the use of a literature review. As Transition Design aims to support designs to develop product systems that contribute to system innovation, system innovation has been defined first in sub-section 3.1. Next, the origins of Transition Design and its frameworks are described in subsection 3.2 and 3.3 respectively.

3.1. System innovation

Transition Design combines design methodology with system innovation theory. In this sub-section, this system innovation theory is briefly introduced.

3.1.1 Socio-technical systems

The field of system innovation is based upon the concept of socio-technical systems: dynamic systems which consist of technological artefacts as well as social structures and organisations that together fulfil a certain societal function (Elzen et al., 2004; Geels, 2005). Socio-technical systems are complex adaptive systems which means that they show certain properties such as emerging behaviour and resilience (Gaziulusoy & Brezet, 2015; Cilliers, 2002). A socio-technical system consists of smaller subsystems that can be both horizontally or vertically nested and is also part of a bigger system itself. Where the boundaries between these different (sub-)systems, is up to the observer (Gaziulusoy et al., 2013). As sustainability is a dynamic property of a system, rather than a property of an individual element within this system (Clayton & Radcliffe, 1996), a system perspective is needed to analyse sustainability challenges.

3.1.2 Differentiating innovation from improvements

The Cambridge Dictionary defines innovation as: "(the use of) a new idea or method" (Cambridge Dictionary, 2019). In line with this, system innovation can be defined as the transition from a certain socio-technical system to a new more sustainable socio-technical system (Elzen et al., 2004; Geels, 2005). This transition does not only cover new products or processes, but also includes changes in regulation, culture, markets, infrastructure and other system elements. It entails a whole new way of providing a certain societal function to society (Gaziulusoy & Brezet, 2015).

How system innovation differs from innovation of products and processes was addressed by Brezet (1997). He distinguishes four levels of design innovation for sustainability (Figure 7, next page):

1. Product improvements, which focus on how a single environmental impact of an existing product can be reduced.
2. Product redesign, in which a product is redeveloped while considering its environmental impact throughout its life cycle.

3. Function innovation, in which the function a product provides is delivered to the customer by a new type of product, such as a product-service system.
4. System innovation, in which a whole socio-technical system is replaced by a new, more sustainable system, including new artefacts, economic models, institutional frameworks and other system elements.

As shown in Figure 7, product improvements and redesigns take a relatively short transition period but only result in relative small gains in sustainability. System innovation, on the other extreme, takes decades but could result in a much more sustainable future society. This difference can be explained by the complexity of the system that is innovated. Socio-technical systems consist of many different and interdependent elements. Its complexity makes that the system cannot be redesigned but rather evolves in a certain direction based on small actions of different actors in the system. As there are many and interdependent elements, this rearrangement of these system elements takes long.

However, in socio-technical systems, there is also a higher degree of freedom. This allows more possibilities for improvements. Physical products have to fit in the existing socio-technical systems which results in less freedom and therefore decreases the possibilities to improve a product's sustainability performance. But, as less actors will be involved in a product redesign, this innovation can be realised relatively fast.

As discussed in the introduction, only focussing on product improvements will not add-up to the needed system innovation to tackle the environmental challenges society is facing (Brezet, 1997; Tukker & Butter, 2007). Therefore, this research aims to explore the possibilities for Prysmian Group Delft to contribute to system innovation through product redesign or function innovation.

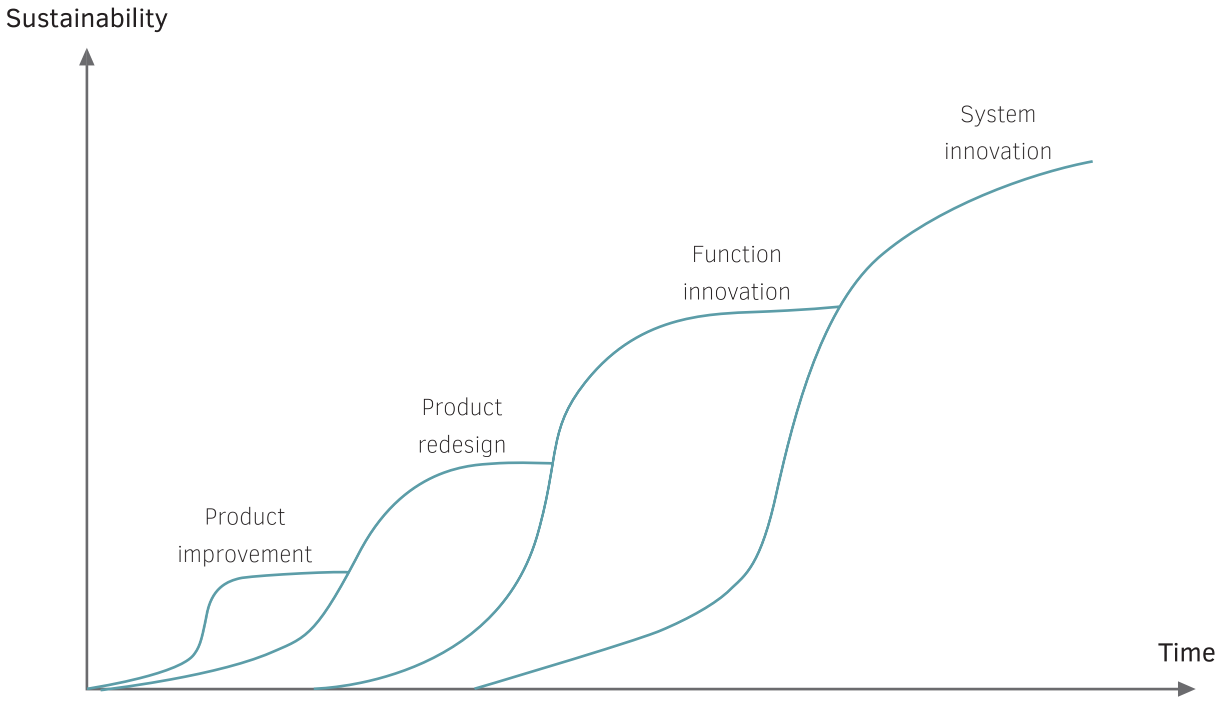


Figure 7: Different levels of design innovation, based on Brezet (1997). Source: Gaziulusoy & Brezet (2015).

3.1.3 System innovation and companies

Currently, most companies focus their efforts to become more sustainable on product improvements and product redesign, often driven by regulatory pressure (Greenstone, 2003). On these levels, the company is fully in charge of the transition. For a contribution to function and system innovation, collaboration with (new) stakeholders is needed (Gaziulusoy & Brezet, 2015). The longer duration of these types of innovation is an additional barrier for companies to innovate in this way.

3.2 The emergence of the Transition Design field

Transition Design is a relative young movement within the Design for Sustainability (DfS) field. DfS is a diverse field of study containing all efforts that have the goal to design more sustainable products. In this sub-section, the development of the DfS field is briefly discussed with the aim to explain how Transition Design differs from other DfS approaches. This development roughly follows the different levels of design innovation by Brezet (1997), which were discussed in the previous sub-section.

3.2.1 Design for product improvement

The first efforts of integrating environmental considerations into the design process date from the late sixties (Ceschin & Gaziulusoy, 2016). However, the first widely known work regarding this topic was by Papanek (1985) in which he criticised the design world for contributing to the degradation ecosystems and social justice by stimulating consumption. In these early days of the DfS field, the focus was mainly on improvements of single properties, a movement known as green design (Ceschin & Gaziulusoy, 2016).

3.2.2 Product redesign

As a response to green design, eco-design was gaining ground in the late nineties (Ceschin & Gaziulusoy, 2016). The main difference compared to green design is the life-cycle focus. The impact of the product, throughout its whole life cycle was taken into consideration, supported by environmental assessment tools such as LCA (Luttropp & Lager, 2006; Ceschin & Gaziulusoy, 2016). It was recognized that designers should strive to develop products that were actually different and therefore more sustainable (eco-effective) rather than products that are a little less bad (eco-efficient) (Karlsson & Luttropp, 2006). A wide range of eco-design tools and frameworks were developed, such as LiDS (Brezet & Van Hemel, 1997). In order to support designers to make the right decisions, Luttropp and Lager (2006) summarised all these different tools into '10 Golden Rules' which address the different stages of the product life cycle. These rules, as well as several eco-design tools, are still being used in design education and at companies. However, their focus on environmental impact only, as well as product-centred approach, were points of critique which resulted in a shift of focus to the product-service level (Ceschin & Gaziulusoy, 2016).

3.2.3 Design for function innovation

As said, as a response to the product-focussed eco-design approach, The DfS field evolved into the research of product service systems (Ceschin & Gaziulusoy, 2016). In a product-service system, the focus is not on delivering a product to the consumer, but on fulfilling a consumers need (Ceschin, 2012; Ceschin & Gaziulusoy, 2016) - by Brezet (1997) formulated as 'fulfilling a certain function'. The change in ownership of the product from the consumer to the service provider should stimulate more radical changes in production and consumption patterns (Lifset, 2000). The service provider, which is often the manufacturer, has the economically incentive to improve the durability and energy efficiency of its products (Halme et al., 2004; Lifset, 2000). Although product-service systems are common in certain industries – e.g. bike rental – implementation by companies remains often challenging as it requires corporate, regulatory and cultural changes (Ceschin, 2012; Ceschin 2013; Ceschin, 2014).

3.2.4 Design for system innovation

The last and most recent design innovation level identified in the DfS field is design for socio-technical system innovation. It aims to combine system innovation theory with design methodology to contribute to the transition of a certain socio-technical system into a more sustainable one.

This relatively young movement of design research builds on three PhD theses (Gaziulusoy, 2010; Joore, 2010; Ceschin, 2012). Irwin and her colleagues adopted the idea, named it Transition Design and made it into an actual field of study and education (Irwin, 2015; Carnegie Mellon University, 2018). Irwin (2015) describes Transition Design as "a proposition for a new area of design practice, study, and research that advocates design-led societal transition toward more sustainable futures." In contrast to other DfS movements, Transition Design is based upon longer-term visions in order to develop solutions which are part of new and more sustainable socio-technical systems (Irwin, 2015). To summarise, Transition Design is based upon the belief that design is a powerful tool in the transition towards a more sustainable society and that, by identifying which solutions are needed in this future sustainable society, this transition can be steered.

In the next sub-section, the frameworks developed in the Transition Design field are discussed and compared.

3.3 Transition Design frameworks

In this sub-section, the different frameworks that were developed by Transition Design researchers are presented and compared.

3.3.1 The Multi-level Design Model

Joore (2010), later republished in an article (Joore & Brezet, 2015), addresses the need to support designers in design for system innovation by describing the relationship between products and their societal context. To do so, he developed the multi-level design model (MDM) (Figure 8) which systematically links these products with their context.

This model is a matrix in which product design phases are combined with different system levels. The system-level approach was borrowed from physics, stating that each element of a system is a system itself. What is considered the system and what are considered as elements of this system depends on the scale you are looking at it. This vertical system nestedness is a well-known feature of complex systems (Gaziulusoy & Brezet, 2015).

The system levels on the vertical axis of the MDM were explained the following:

- The societal system level describes the community of people that together live in a certain area with shared customs and laws.
- The socio-technical system level was already described in paragraph 3.1.1. This system level includes technological, organisational, institutional and social/cultural elements that together fulfil a societal function.
- The product-service system level describes systems that are a combination of physical and organisational elements that together fulfil a certain function defined by time and space.
- The product-technology system level describes human-made physical objects.

The design phases on the horizontal axis of the MDM were explained the following:

- The reflection phase, in which the problem in the current situation is identified.
- The analysis phase in which an abstract vision of a new desired situation is developed.
- The synthesis phase in which new concepts are generated by the use of creative methods.
- The experience phase in which the developed concept is tested by the use of a prototype or simulation.

The results of the experience phase can be the input for a next iteration starting again at the reflection phase.

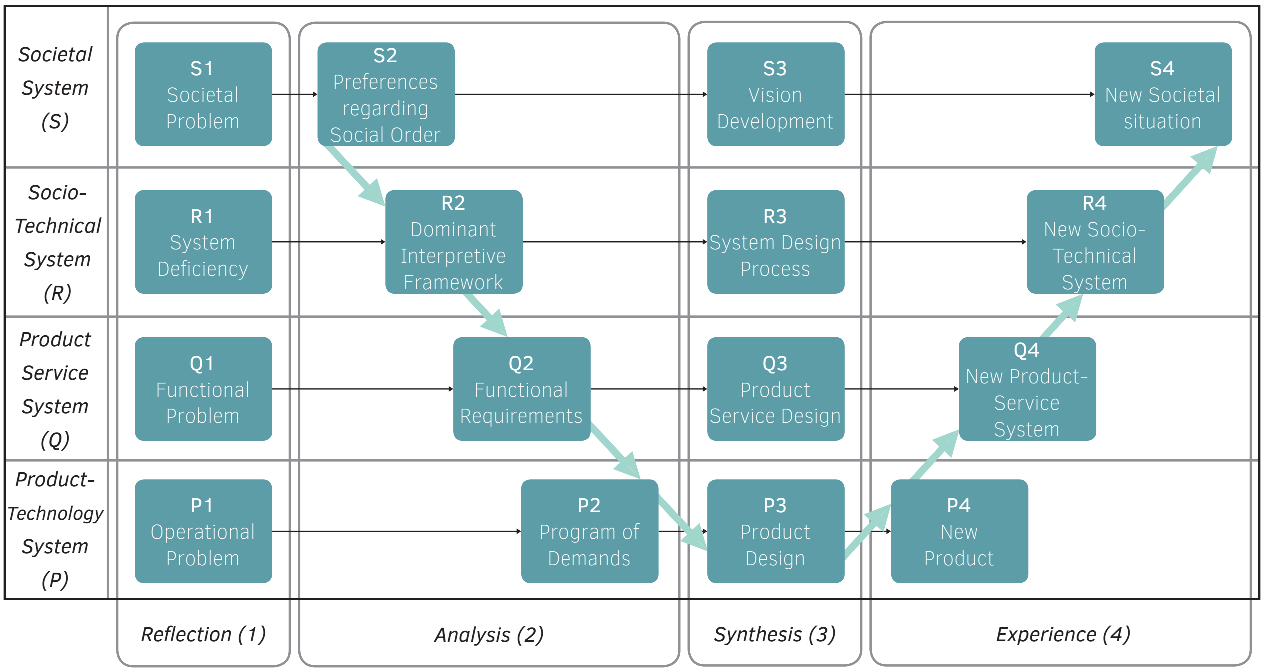


Figure 8: Multilevel Design Model (MDM) by Joore and Brezet (2015).

3.3.2 Theoretical model linking design activities with system innovation

Gaziulusoy (2010) uses a similar approach as Joore (2010) of combining design research theory with system innovation theory. In her PhD thesis (Gaziulusoy, 2010; later republished in articles (Gaziulusoy et al. 2013; Gaziulusoy & Brezet, 2015)), she addresses the necessity to support firms with aligning their products, business models and strategies with the long-term visions on sustainability on a societal system level. To do so, she developed a framework to bridge this long-term vision with the everyday reality at the design department of a company. This framework consists of a theoretical, a conceptual and an operational part.

The theoretical framework (Gaziulusoy, 2010; Gaziulusoy & Brezet, 2015) mainly borrows models from the field of transition management and combines these into a model that links system level innovation with product development (Figure 9). The different axes represent the three levels of the multi-level perspective (Geels, 2005), the four design innovation stages of Brezet (1997) and timeframes for strategic decision making.

The theoretical model in Figure 9 does show the trade-offs that occur when trying to combine actions on a small (product) level with innovations on societal level. The larger the scale you are looking at, the more complex it is. This is a challenge for industry as firms and designers have to live up to short-term demands while keeping an eye on long-term developments (Gaziulusoy & Brezet, 2015). How this theoretical framework could be used at firms is described by the Scenario Method (Gaziulusoy et al. 2013), discussed below.

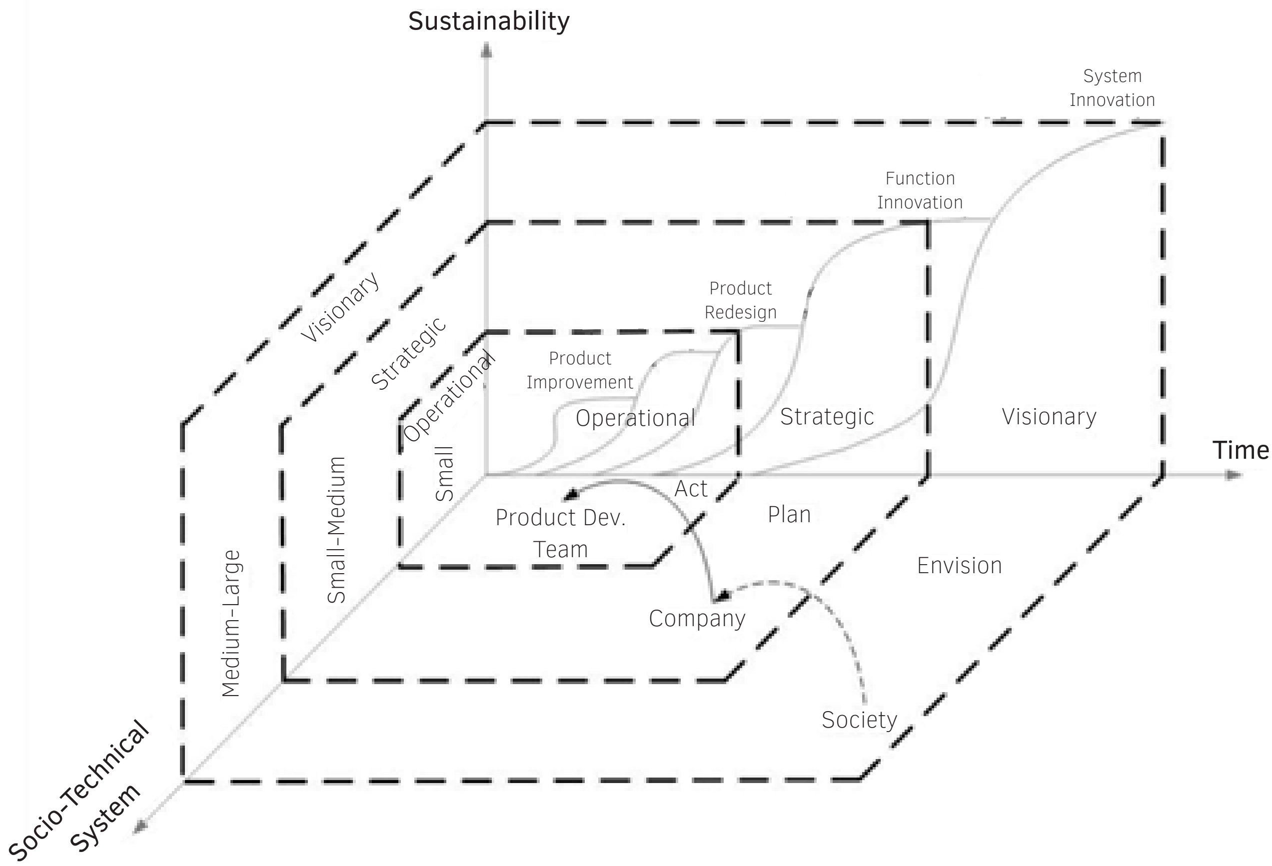


Figure 9: Model that links system level innovation with product development (Gaziulusoy & Brezet, 2015)

3.3.3 The Scenario Method

After the theoretical framework, Gaziulusoy (2010) developed a conceptual and operational framework by using a scenario method, later republished as Gaziulusoy et al. (2013). This framework consists of three phases: preparation, scenario development and completion (Figure 10). These phases consists again of smaller steps which should be executed in meetings with different stakeholders. The action plan that follows from the use of the Scenario Method should support the group of stakeholders to align their sort-term actions with long-term sustainability goals.

Especially interesting is the scenario development step in which both explorative (looking forward) and backcasting scenario's (looking back) are combined. The forward scenarios are based upon the current situation and are therefore easier to implement. Backcasting, on the other hand, helps to generate more innovative scenarios. By combining these two types of scenarios, an innovative but implementable action plan can be developed.

A few years after her PhD thesis, Gaziulusoy reflects on her and colleagues work. Gaziulusoy (2018) writes that practitioners outside the academic sector start using the Transition Design theory in their work, but admits that it remains challenging for commercial activities when clients are involved. Often, the Transition Design process needs more time than the duration of a commercial project. Also, practitioners mainly work at governmental organisations focussing on service design. She concludes that designers generally see the value of the new approach but find it challenging to integrate it in their work.

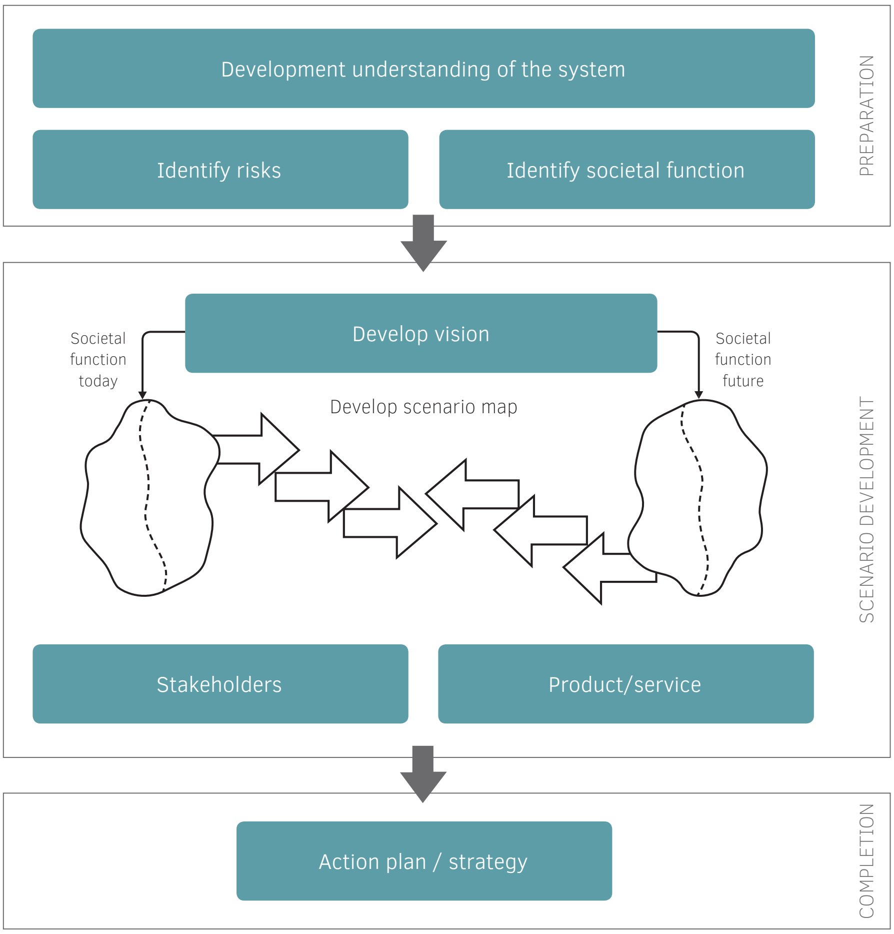


Figure 10: Simplified version of the scenario method by Gaziulusoy et al. (2013)

3.3.4 Conceptual framework for sustainable product-service systems

Ceschin (2012; 2013; 2014) specifically focusses on sustainable product service systems, and how system innovation theory can support designers to develop them. He investigates how socio-technical experiments can be executed in the protected niche environment in order to learn about and develop radical changes. In his research, he looks at case studies to identify characteristics of companies that support the implementation of sustainable product service systems (Ceschin, 2013). As his work is specifically addressing product service systems, it is not further analysed for this research.

3.3.5 The Transition Design Framework

The insights of the above mentioned PhD theses were shared with the wider design community by Irwin (2015). She named the movement 'Transition Design' and developed the Transition Design Framework (Figure 11). This framework contains four areas of knowledge, self-reflection and action which the Transition Design field should further explore.

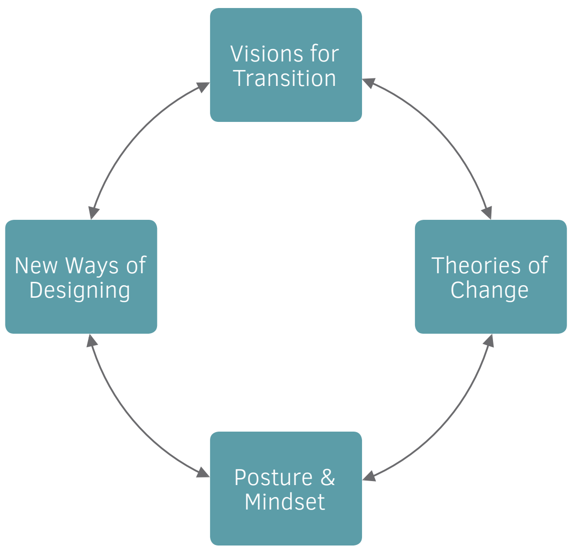


Figure 11: The Transition Design Framework by Irwin (2015)

1. Vision for transition, which describes the need to have a long-term vision on a higher system level. This vision is described as a magnet that pulls innovation.
2. Theories of change, which addressed the need to understand how things change. Backcasting is mentioned as a tool to link the long-term vision with short-term design tasks. Every step in time, these short-term tasks will be redefined based upon the situation at that point in time.
3. Mind-set & posture, which points out that every designer has his/her own assumptions and experiences which determines decisions made during the design process. Irwin (2015) states that designers must be aware of their own mind-set and should strive to adapt a holistic world view.
4. New ways of designing, which describes the necessity for designers to be able to deal with wicked problems.

3.3.6 Discussion of the frameworks

The different frameworks that were described in the previous paragraph have different challenges when using them during the product design process at Prysmian Group Delft. In Table 4, these limitations of the frameworks are summarised.

3.4 Closing remarks

In this chapter, the background and frameworks of the In this chapter, the background and frameworks of the Transition Design field were discussed. It is found that the existing frameworks all have limitations which make them not directly usable at Prysmian Group Delft. By the development of the scenario method by Gaziulusoy et al. (2013), an attempt is done to develop a useful tool for companies to combine product design methodology with system innovation theory. However, this frameworks proves to be challenging for commercial activities (Gaziulusoy et al., 2018) and lacks information on the actual design process for new product systems.

Table 4: Overview of the different Transition Design frameworks and their limitations

Authors	Framework	Framework description	Limitations of framework for its use at Prysmian Group Delft
Joore (2010) / Joore & Brezet (2015)	Multi-level Design Model (MDM)	Framework showing the relationships between different design phases and system levels	No guidelines provided on how the framework can be used in practice. No link made to the use at a company.
Gaziulusoy (2010) / Gaziulusoy & Brezet (2015)	Theoretical model linking design activities with system innovation	Framework showing the relationships between levels of complexity on three axis	Theoretical approach, not directly applicable in a design process. The scenario method (see next) is the related operational framework.
Gaziulusoy (2010) / Gaziulusoy et al. (2013)	Scenario method	Step-by-step method describing how to translate a long-term vision on a high system level to a concrete strategy for a company. Tested at 2 companies	The method ends at the strategy formulation. How this strategy could be translated into a design and how this could be evaluated is not discussed. In later research (2018), Gaziulusoy concludes that the use of this framework remains challenging for commercial activities.
Ceschin (2012)	Conceptual framework for product-service systems	Descriptive framework which shows factors that contribute to the introduction and scaling up of sustainable product service systems	Specifically focussed on product service systems which is too narrow for this research
Irwin (2015) and later work of Irwin and her research group	Transition Design Framework	Descriptive framework showing the four co-evolving areas of the Transition Design field	A rather academic and theoretical approach, no link to business practice

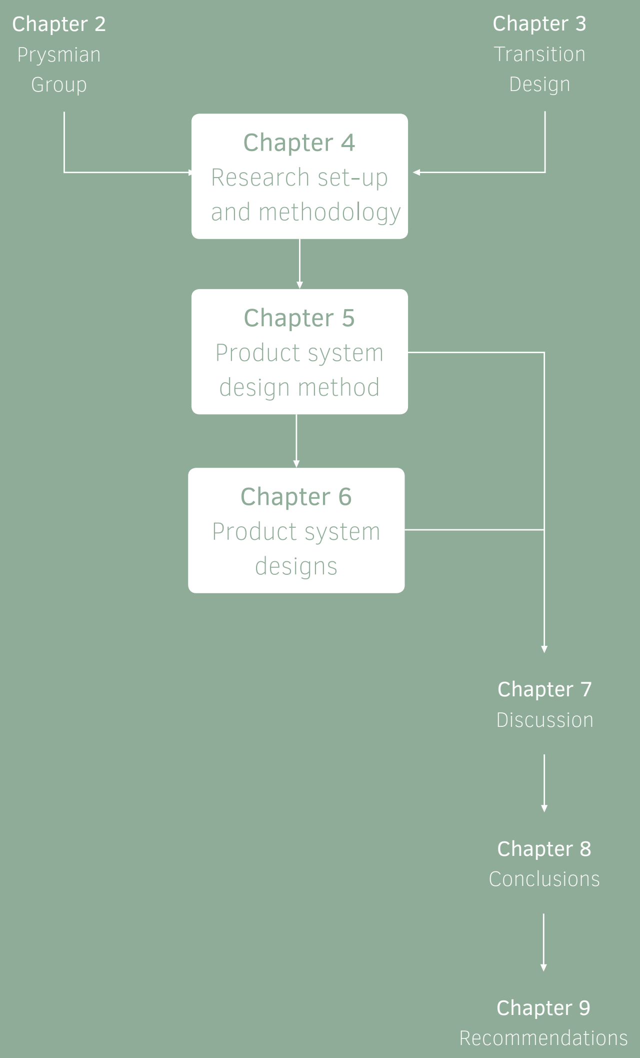
Also, none of the frameworks communicate how to include a company's resources or interests into the design process.
Although the different frameworks have different objectives, they do overlap in multiple ways:

- The concept of system levels, based on the multi-level perspective theory by Geels & Schot (2007) was found in the frameworks of Joore & Brezet (2015), Gaziulusoy & Brezet (2015) and Ceschin (2012).
- The use of a vision on the future socio-technical system was mentioned by Joore & Brezet (2015), Gaziulusoy & Brezet (2015) and Irwin (2015).
- The idea that the designer is not only responsible for developing a technological artefact but should also understand the relationship of this artefact with innovations at other system levels can be found in different papers (Joore & Brezet; 2015, Ceschin, 2013; Irwin, 2015).

These similarities will be combined into a general Transition Design design process in Chapter 5.

PART 2

Core research



4 Research set-up and methodology

In this chapter, the research-set up is presented. In sub-section 4.1, the different system levels used in this research are defined by combining information from Chapter 2 and Chapter 3. In sub-section 4.2, it is briefly discussed how material-related environmental issues are addressed in this research. Next, sub-section 4.3 describes how the research was divided into two phases: the exploration phase and the evaluation phase. The last two sub-sections discuss the methodology used during these two phases in more detail.

4.1 Defining system levels relevant for this research

Both Joore & Brezet (2015) and Gaziulusoy & Brezet (2015) describe different system levels in their frameworks. This idea of system levels was adopted for this research. In this sub-section, it is described how the frameworks of Joore & Brezet (2015) and Gaziulusoy & Brezet (2015) were combined into system levels relevant for Prysmian Group Delft.

Joore & Brezet (2015) and Gaziulusoy & Brezet (2015) use different ways to distinguish system levels (Table 5). The system levels described in the MDM by Joore & Brezet (2015) are increasingly more complex. This means that, the higher the system level, the more different types of elements are included. Gaziulusoy & Brezet (2015) use multiple axis to distinguish system levels. Firstly, they distinguish system levels based on the size of the system, so the number of elements that are part of it. Secondly, they distinguish system levels based on who in charge of operating in the system.

Table 5: Different scales used to define system levels by Joore & Brezet (2015) and Gaziulusoy & Brezet (2015)

Complexity (based on Joore & Brezet, 2015)	Size (Gaziulusoy & Brezet, 2015)	Operating community (Gaziulusoy & Brezet, 2015)	Design innovation level (Gaziulusoy & Brezet (2015); based on Brezet, 1997)
Technical elements	Small	Design department	Product improvement
			Product redesign
Technical and organisational elements	Small-medium	Company	Function innovation
Technical, organisational, social/cultural and institutional elements	Medium-large	Society	System innovation

Also, they use the design innovation levels by Brezet (1997) which were presented before to distinguish different system levels.

The system levels Joore & Brezet (2015) are relatively easy to understand. However, as shown in Table 5, they lack information on who is operating at the different system levels and what type of innovations can be initiated. Gaziulusoy & Brezet (2015) do address these aspects in their theoretical framework. However, because of the three axis of this framework, is harder to understand. As the outcomes of this research will be communicated with people at Prysmian Group Delft and their stakeholders, it is important that the system levels are easy to understand. Therefore, it is decided to combine the two frameworks into a set of system levels that are easy to understand, contain different ways to distinguish them and are relevant for Prysmian Group Delft. How this was done is explained below.

A power cable can be described as a set of technical elements. Changing these elements would be a product improvement or product redesign. These changes are executed by the design department. Only the company will need to adjust to these changes. For example, when replacing a certain plastic with a recycled alternative, this will influence the procurement department. However, customers will do not need to change their behaviour. Therefore, the first row of Table 5 was chosen as the first system level used in this research. This first system level was named the **product-technology system level** and represents a power cable.

The function a power cable fulfils can be described as conducting electricity. In order to conduct electricity, a power cable must connect two points which have different electrical potentials. In practice, this means that the power cable is connected to an infrastructure, the grid, as well as to organisational elements that arrange this potential difference. Changes on this system level need to be approved by related stakeholders, such as a municipality. So, electricity transmission and distribution system matches the second row of Table 5. This system level was named **function-organisational system level** as it describes how a certain function is delivered through organisational and technical elements.

When zooming out further, the societal function of the power cable is to provide society with energy. The **socio-technical** energy **system** consists of many different elements. The energy transition demands changes on this system level. Changes on this system level is a gradual process in which many different actors are involved. Innovations on this system level, such as phasing out natural gas for households influence society directly.

The MDM by Joore & Brezet (2015) describes another system level: the societal system level. This system level consists of all the socio-technical systems in place in society. This system level was not addressed in the theoretical framework by Gaziulusoy & Brezet (2015). Also, when discussing the MDM by Joore & Brezet (2015) with Prysmian Group employees during the interviews described in Chapter 2, the societal system level was hardly discussed. Therefore, it was decided to leave out the societal system level for this research.

To summarise, the three system levels suitable for this researched are shown in Table 6.

Table 6: Description of the three system levels used in this research

System level	Definition	Elements that are part of the system	Type of innovation	Enables of innovation
Product-technology	Human-made physical objects build-up of technical components (adapted from Joore & Brezet, 2015)	A power cable, consisting of different materials in different shapes which has certain properties, such as minimal bending radius.	Product innovation	Execution: design department. Approval: company
Function-organisational	Combination of technical and organisational components that together fulfil a certain function which can be defined by time and space (adapted from Joore & Brezet, 2015)	Electricity transmission and distribution enabled by the grid (a collection of technical elements) and an organisational part with actors which regulate demand and supply	Function innovation	Execution: company / multi collaborating companies. Approval: stakeholders
Socio-technical	A network of technical and social components, such as artefacts, markets, knowledge, regulation, infrastructure and cultural meaning which together fulfil a certain societal function (adapted from Geels, 2005).	The Dutch energy sector with the societal function of providing society with energy consisting of infrastructure, markets, regulations, cultural believes, et cetera.	System innovation	Execution: a group of stakeholders. Approval: society

4.2 Integrating material-related environmental issues

As presented in the previous sub-section, the socio-technical system that is focussed on in this research is the Dutch energy sector. This is the socio-technical system a power cable is part of during its use phase. In Chapter 2, it was discussed that this phase is accountable for most of the Global Warming Potential of a power cable. Therefore, contributing to the energy transition does indirectly contribute to reducing the environmental impact of a power cable.

However, sustainability is a multi-issue challenge which cannot be addressed by focussing on one issue in isolation. So aiming to contributing to the energy system only may cause a shift in environmental impact to non-energy related issues. In particular, as power cables are a physical artefact, attention must be paid to the sourcing and disposing of materials. Therefore, material-related challenges are also addressed in this research. The energy-oriented systems as defined in the previous sub-section are used as a starting point. However, within these boundaries, material related challenges are considered as well. So, the product systems designs developed in this research are not only evaluated on their contribution to the energy transition but also on to what extent they address responsible material management.

4.3 Research set-up

In this sub-section, the research set-up of the core research is explained. This research set-up is based upon the four sub-questions presented in Chapter 1. As discussed in Chapter 1, these sub-questions address two different topics of research. The first topic researches what the product system design method could look like and what would be needed to implement this design method at Prysmian Group

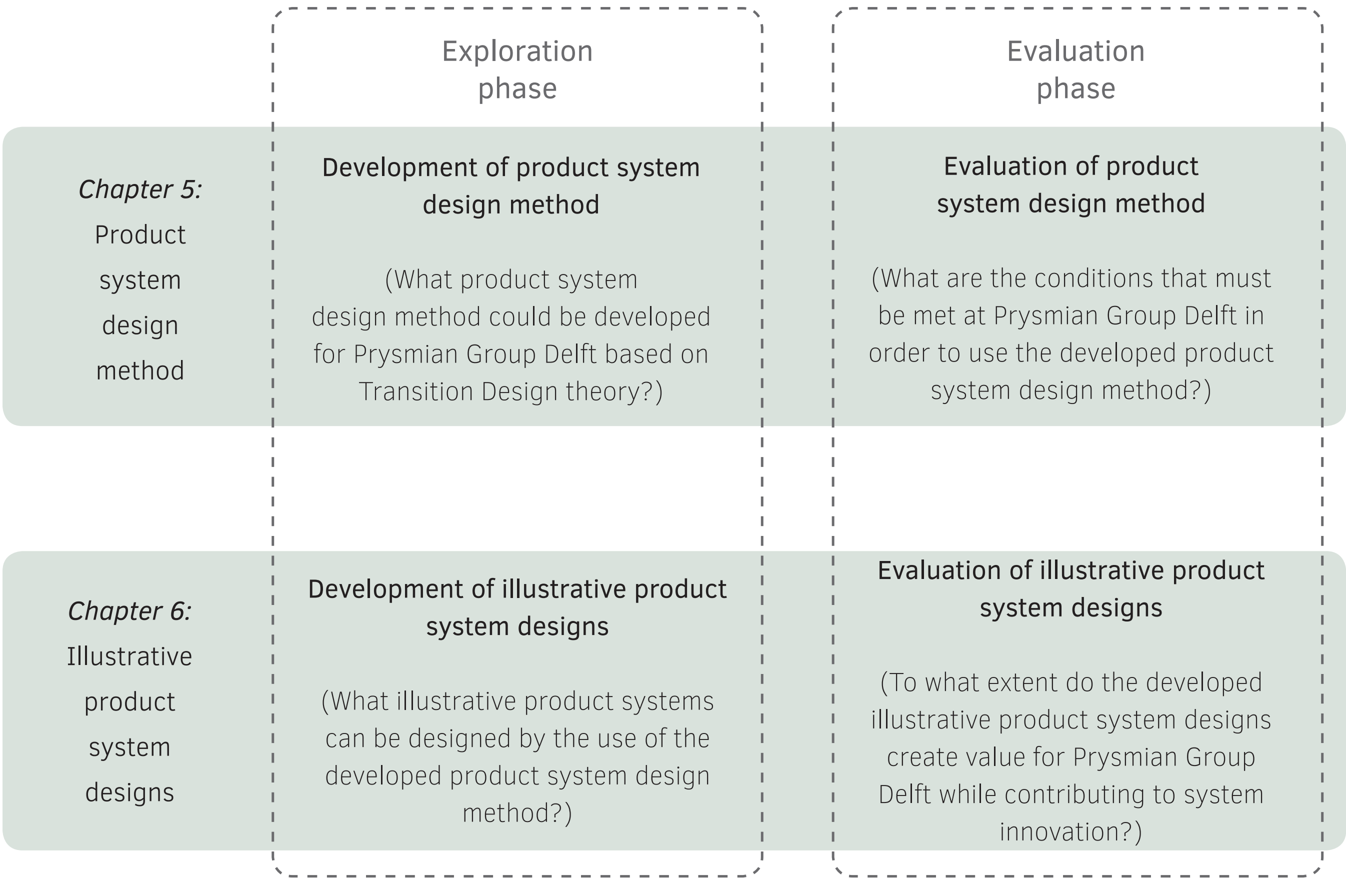


Figure 12: Overview of the connection between the two research phases and the two parts of the research

Delft. This part answers the first two sub-questions. The results of this part of the research are presented in Chapter 5. The second topic of research focusses on the product systems that can be designed by the developed product system design method through the design of illustrative product systems. It also evaluates the value of these illustrative product system designs for Prysmian Group Delft as well as their contribution to system innovation. The results of this part are presented in Chapter 6.

Secondly, the sub-questions split the research into a part in which the product system design method and the product system designs are developed, and a part in which they are evaluated. Although the development of the product system design method was separated from the design of illustrative product systems in the sub-questions, in practice these parts were developed simultaneously. A new product system design method was tested through the design of product systems which gave again input into for the design method development. This simultaneous development of method and related product system designs happened in the first phase of this research and was named the exploration phase. The part in which the findings of this first phase are evaluated is evaluation phase. In the following sub-sections, the methodology used in the two phases is discussed in more detail.

An overview of the research set-up is shown in Figure 12.

4.4 Methodology used during exploration phase

During the exploration phase, an iterative process was used to explore how Transition Design theory could be used at Prysmian Group Delft. This iterative approach was chosen as it allows to explore different possibilities in a systemic but flexible way.

As shown in Figure 13, each iteration was build-up of two steps: a prototyping step and a reflection step. Three types of prototyping steps were used: creative workshops, design trials and design workshops. These different types of prototyping are discussed in more detail in the coming paragraphs.

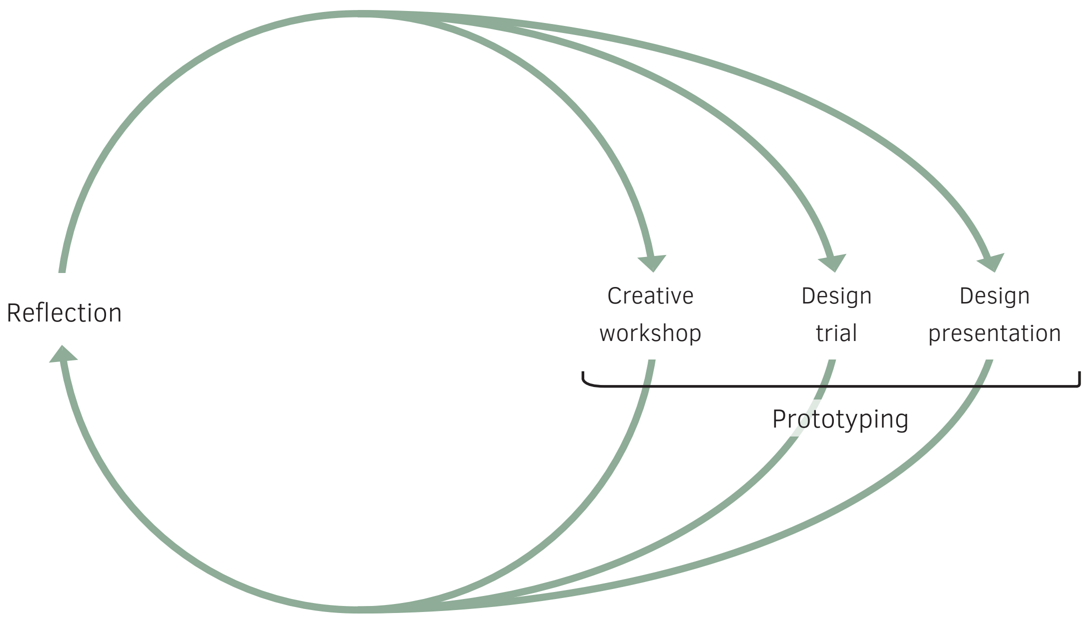


Figure 13: Systematic overview of the iterative process used in the exploration phase

During the reflection step, the outcomes of the prototyping step were interpreted and discussed with both the supervisor at Prysmian Group Delft as well as the supervising professor. Based on these discussions, the set-up and goal of the next prototyping step was determined.

4.4.1 Creative workshops

Creative workshops were organised as it is a quick tool to gain a wide range of insights. These workshops were used to try-out different product system design methods and to collect product system design ideas. As Transition Design requires a different mind-set (Irwin, 2015), creative methods were used to get participants out of their traditional way of thinking. The number of workshops organised and their goal was determined during the exploration phase and is therefore presented in Chapter 5.

Workshop set-up

The creative workshops were based on the Creative Facilitation methodology by Tassoul (2012) and developed in collaboration with MSc Design for Interaction graduate who organised multiple creative workshops himself. Each creative workshop consisted of the following steps:

1. Welcome and introduction, where the research and the goal of the workshop was explained to the participants
2. Warming-up, in which the participants had to do a short unrelated assignment for which creativity is needed
3. The actual workshop
4. Closing, in which participants are asked how they experienced the workshop

During the workshops, notes were taken. These notes, together with the maps and ideas developed during the workshops were digitalised and evaluated in the next iteration. The detailed descriptions of the different workshops organised can be found in Appendix 3.

Participants

As can be read in Chapter 5, initially, different workshops with Prysmian Group employees were organised. For these creative workshops, the participants were selected in collaboration with the Sustainability Officer of Prysmian Group Netherlands. Also students participated in two workshops. They were used to bring in certain expertises which are not present within the company. These students could enrol themselves if they had the required study background.

4.4.2 Product system design trials

During the exploration phase, several attempts were done to design examples of product systems. The insights gathered during these design trials were used to further develop the product system design method. The design trials were time bound (mostly two working days) and were done by one individual. The outcomes of the design trials were visualised in simple sketches which were used for the discussions with both supervisors during the reflection step of the next iteration.

4.4.3 Design presentations

Different meetings with Prysmian Group employees and their customers were organised to discuss the developed product system designs. These design presentations served two goals. Firstly, the comments made were used to improve the product system designs to make them more relevant for Prysmian Group Delft and/or its customers. Secondly, it gave insight into the required changes that Prysmian Group Delft and its stakeholders would need to make to realise the proposed product system designs. These insights could be used in the evaluation phase, described in the next sub-section.

Design presentation set-up

Three types of design presentations were organised. The first type of design presentations were one-to-one meetings with a Prysmian Group employees in which sketches of the developed product system designs were presented. The goal was to discuss these sketches to identify what their implementation would mean for Prysmian Group Delft. An overview of the meeting protocol can be found in Appendix 4.

The second type of design presentations were meetings with customers. Ideas that were developed during the design trials, such as the use of above-ground cables, were casually mentioned during a conversation. No sketches were shown to prevent a focus on details rather than concepts. A sales employer of Prysmian Group Delft joined the meetings.

The third type of design presentation also took place at a customer (Alliander) but focussed more on concrete product system designs. Here, more time was taken to explain the background of the research. Next, the solutions found in this research were presented and discussed. A detailed description of the set-up of this meeting can be found in Appendix 4.

The three types of meetings gave input into the product design process in different stages and from different perspectives. An overview of all the design presentations organised can be found in Table 7. Notes of comments during the design presentations were taken and digitalised.

Attendees

Table 8 shows that the design presentations with Prysmian Group employees were held with employers of different departments. Most of these employers were also interviewed earlier in the research (see chapter 2). The employees that were particularly interested and able to understand the different system levels during these interviews were selected for the design presentations. These employees were expected to be able to give most valuable feedback.

For the attendees of the design presentations at customers, the advice of a sales employee of Prysmian Group Delft was followed. Attention was paid to reaching out to all three big DSOs and, within these organisations, to different types of employees. While the asset manager is in charge of today's products and therefore up-to-date in the DSOs strategy, the trainees were more able to think long-term and out-of-the-box.

4.5 Methodology used during evaluation phase

During the evaluation phase, the second and fourth sub-question were answered. This second sub-question asks what conditions must be met at Prysmian Group Delft in order to use the developed product system design method. The fourth sub-question question addresses whether the illustrative product system designs developed during the exploration phase create value for Prysmian Group Delft and whether they contribute to system innovation. Both evaluations are discussed in more detail on the next page.

Table 7: Overview of the design presentations organised

Type of design presentation	With who
Discussing design sketches	5 Prysmian Group employees (sales, R&D (2x), sustainability, finance)
Discussing design concepts	Technical consultant Alliander
Discussing design concepts	Asset manager Enexis
Discussing design concepts	2 Trainees Stedin
Discussing developed product system designs	5 Alliander employees (asset management, purchasing, R&D) and 2 Prysmian Group employees (R&D and sales)

4.5.1 Evaluation of the developed product system design method

When evaluating the developed product system design method, it was discussed what conditions need to be met at Prysmian Group Delft in order to implement the product system design method. Based on Prysmian's current business strategy and resources - as formulated in Chapter 2 - it was identified which of these conditions are currently not met. For the conditions that are not met, suggestions were done on how they can be fulfilled in the future.

4.5.2 Evaluation of the developed illustrative product system designs

The illustrative product system designs were evaluated on to whether they create value for Prysmian Group Delft while making a contribution to system innovation. This was done by a qualitative discussion of each illustrative product system design.

Value creation for Prysmian Group Delft

The value created for Prysmian Group Delft was defined as the benefits the product system design could deliver to Prysmian Group compensated by the changes that need to be made to implement it. These benefits could be short-term (within 1 year after implementation) and long-term (more than 1 year after implementation). These long-term benefits were determined based on to what extent the design meets trends in the energy sector as well as the material sector. Basically, it was analysed to what extent the designs are future-proof.

The changes required at Prysmian Group Delft were also identified by discussing each product system design separately. These changes could include new logistic, economic and/or information processes and the related changes in resources that are required when implementing the illustrative product system design.

As a product system design can only be implemented if there is a customer willing to pay for it, a similar analysis has been done from a customer point of view. Only when a new product system design creates value for the customer, they might consider purchasing it. Again, the short-term and long-term benefits as well as the required changes were discussed and compared. An overview of how the developed product system designs were evaluated in relation to Prysmian Group Delft is shown in Figure 14.

Contribution to sytem innovation

The contribution of the illustrative product system designs to system innovation was discussed by the use of the SDGs. The SDGs are globally recognised as a blueprint for a sustainable future (UN, 2018). Of the five SDGs selected by Prysmian Group for their sustainability report (Prysmian Group, 2017a), SDG 7, 9 and 12 were selected for a qualitative discussion on to what extent the product system designs contribute to the specific SDG. SDG 5, focussing on gender equity and DSG 11, focussing on sustainable cities, are outside the scope of this research.

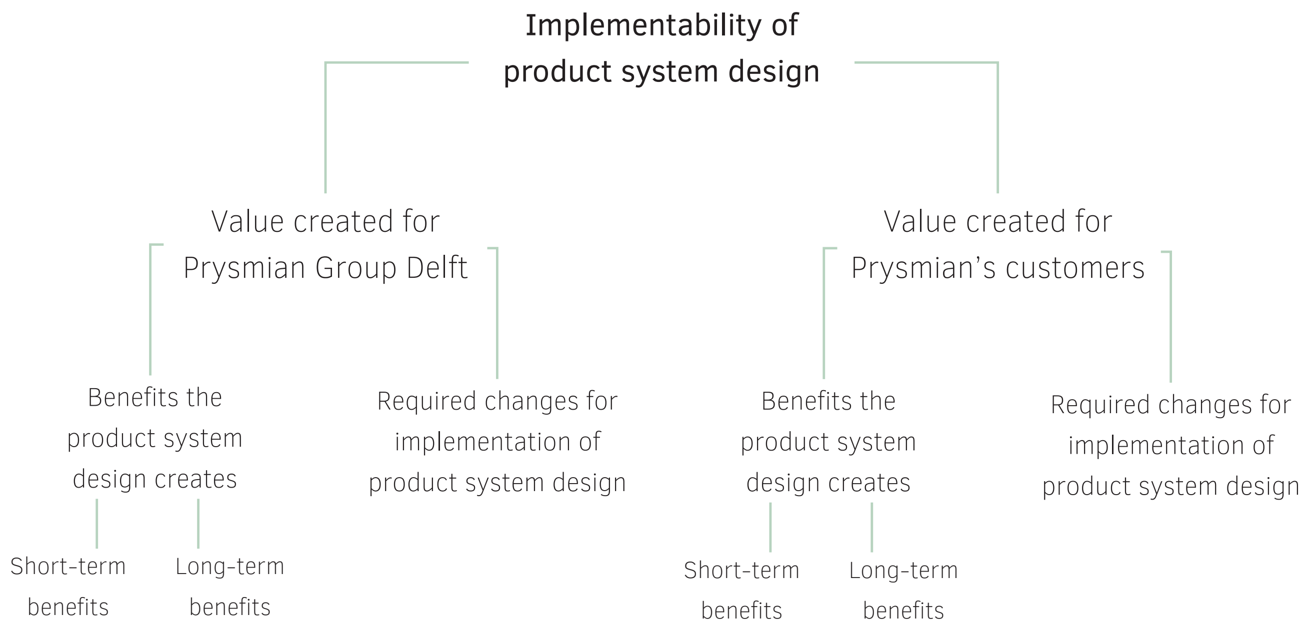


Figure 14: Overview of the set-up of the evaluation of the illustrative product system design in relation to Prysmian Group

5 A new product system design method: Development and evaluation

In this chapter, the first two sub-questions of this research will be answered. The first question: ***What product system design method could be developed for Prysmian Group Delft based on Transition Design theory?*** will be answered in sub-section 5.1 in the form of a product system design method which is based on Transition Design theory but adapted to be of use for Prysmian Group Delft. This question was answered during the exploration phase. ***The second sub-question: What are the conditions that must be met at Prysmian Group Delft in order to use the developed product system design method?*** will be answered in sub-section 5.2. Here, it is described what conditions must be fulfilled at the company to make the developed product system design of use. This question was answered as part of the evaluation phase.

5.1 Exploration: the development of a new product system design method

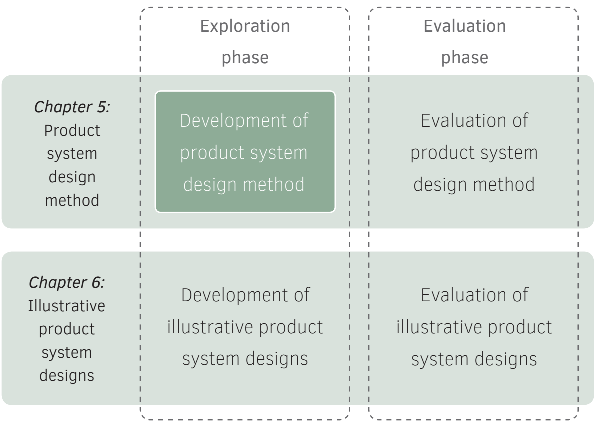


Figure 15: Sub-section 5.1 describes the development of the product system design method

During the exploration phase, a product system design method for Prysmian Group Delft was developed by the use of creative workshops, design trials and design presentations. This sub-section describes a summary of this explorative process. First, it is discussed how the idea of six innovation areas emerged by combining the design method of Prysmian Group Delft with a design method based on Transition Design literature. These innovation areas form the basis of the product system design method that is developed. Next, the highlights of the iterative process that led to the actual product system design method are described.

5.1.1 Understanding the differences between Prysmian's design method and Transition Design

In order to explore how Transition Design could be used at Prysmian Group Delft for the design of product systems, the differences between the two were identified first. Below, the design method of Prysmian group Delft is conceptually compared to a design method based on Transition Design literature. Next, by the use of two creative workshops, the differences between the use of both design methods in practice are researched.

Conceptual comparison of design methods based on background research

In Chapter 2, the design method used at Prysmian Group Delft is explained. Chapter 3 describes different Transition Design frameworks and what they have in common. Based on these two pieces of information, it was concluded that a major difference between the two design methods lies in the design process that is followed. The design process of Prysmian Group Delft uses challenges in today's product supply chain and addresses these through technological improvements (Figure 16.a). On the other side, Transition Design theory reasons that, in order to contribute to system innovation, the designer must understand the processes at socio-technical system level. Through the use of a vision on how this socio-technical system would ideally look like in the future, ideas can be developed on what could be done today to realise this vision. Based on what could be done today on socio-technical system level, innovations on function-organisational and product-technology system level can be developed (Figure 16.b).

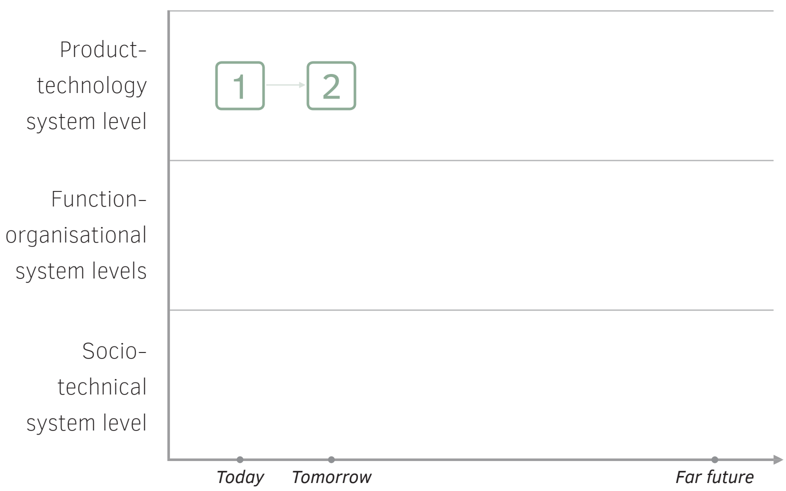


Figure 16.a: Simplification of the product system design process at Prysmian Group Delft

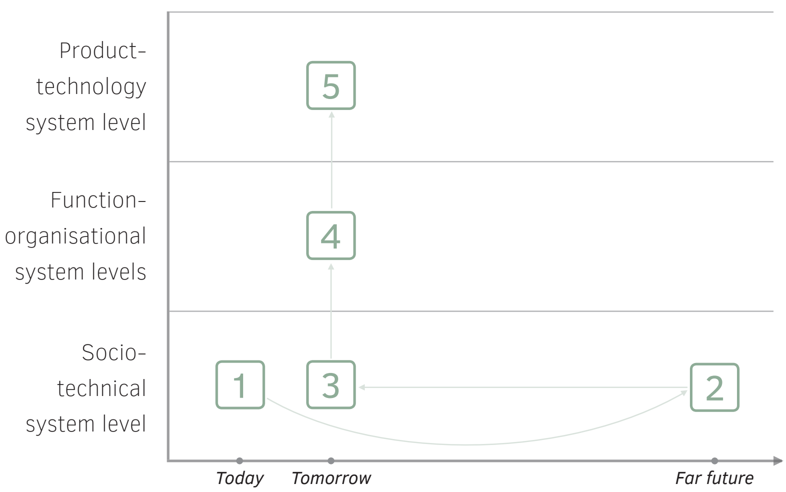


Figure 16.b: Simplification of the product system design process based on different Transition Design frameworks

This difference in design processes between Prysmian Group and Transition Design was further explored by creative workshops with Prysmian Group employees. These workshops will be discussed in the next paragraph.

Operational comparison of design methods by the use of creative workshops

The two design processes described in previous paragraph were simulated during two creative workshops with Prysmian Group employees. The first workshop, simulating Prysmian's current design process (Figure 16.a) aimed to identify existing ideas that are currently not realised and to develop more ideas. The second workshop, simulating the Transition Design design process (Figure 16.b), aimed to verify if Transition Design is indeed challenging in a commercial environment and to get an understanding of what these challenges exactly are.

An impression of both workshops is shown in Figure 17. The detailed description of the set-up and outcomes of both workshops can be found in Appendix 3.

The nature of the ideas developed as well as the general attitude of Prysmian Group employees during the two workshops are discussed in Table 8.

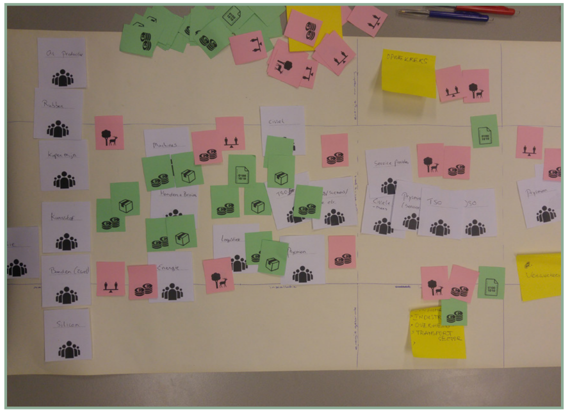
The evaluation of the two creative workshops shows the benefits and shortcomings of the two design processes. Using Prysmian's current design process resulted in concrete and relevant ideas which, however, lack innovativeness. Using the Transition Design process in a similar type of workshop results in ideas that were new to Prysmian Group Delft. However, it was found that translating abstract ideas on the socio-technical system level into concrete opportunities for Prysmian Group Delft (step 4 and 5 in Figure 16.b) is challenging. Therefore, the ideas developed remained rather vague.

How these insights were used to develop the basis of the new product system design method for Prysmian Group Delft is described in the next paragraph.

Table 8: Summary of the evaluation of the two creative workshops organised

	Description	Nature of ideas developed	Experience of the workshop
Creative workshop 1	Set-up based on current design process at Prysmian Group Delft (Figure 16.a)	Concrete ideas on what Prysmian Group could do. None of the ideas mentioned were new to the participants	Focus on 'what could be done', rather pessimistic approach towards innovation. The discussion was mainly about the limited willingness of actors in the value chain to innovate.
Creative workshop 2	Set-up based on design process as described in Transition Design literature (Figure 16.b).	The developed ideas are new to the company but lack relevance for Prysmian Group Delft and remain rather vague. Translating an abstract idea on socio-technical system level into something concrete is challenging.	Focus on 'what is needed'. Participants were enthusiastic the different view on innovation used in the workshop.

1. Simulating design process Prysmian Group Delft



Goal

Identifying existing ideas and developing more ideas based on Prymian's current design process.

Summary of the steps taken

Mapping Prysmian's current supply chain, identifying challenges within this supply chain and developing solutions for these challenges.

Participants

3 Prysmian Group employees (sales, services, R&D).

2. Simulating design process Transition Design

Goal

Getting an understanding of the possibilities and barriers of the use of the Transition Design design process at Prysmian Group Delft.

Summary of the steps taken

By the use of scenario's, developing a vision of the future energy system and, by the use of backcasting, identify what Prysmian could do today.

Participants

4 Prysmian Group employees (sales (2x), R&D, sustainability) and 2 interns (R&D).

Figure 17: Impression of the first two creative workshops organised

5.1.2 Development of product system innovation areas

The use of the two different design processes shown in Figure 16 during creative workshops with Prysmian Group employees resulted in product system ideas that have opposite strengths and weaknesses. Therefore, it might be interesting to combine the two by integrating the system approach of Transition Design into the design process of Prysmian Group Delft. Based on the Transition Design design process, two variations to Prysmian's current design process were identified:

1. The Transition Design design process starts at the socio-technical system level while the design process of Prysmian Group Delft focusses on the product-technology system level only. Therefore, the first variation to Prysmian's current design process is the system level at which the design process starts. As the function-organisation system level lies between the two outer system levels, starting the design process at this system level was also included as a variation.
2. In the design process of Prysmian Group, today's challenges are the driver to develop new solutions. In the Transition Design design process, the development of a vision is included before focussing on solutions. During the second workshop, this proved to be a good way to stimulate innovative ideas. These ideas were not only technical solutions but also included other types of innovations. Therefore, whether the design process includes a vision or not is another variation to Prysmian's design process that will be used.

The two variations for the product system design process of Prysmian Group Delft can be combined as shown in Figure 18. This results in six product system innovation areas describing six different design processes. These six innovation areas form the basis of the developed product system design method for Prysmian Group Delft. In the next paragraph, it is explained which other steps were taken during the exploration phase to get an understanding of how the innovation areas could be used at Prysmian Group Delft.

5.1.3 The use of the innovation areas at Prysmian Group Delft

The six innovation areas defined in the previous paragraph form the basis of the new product system design method for Prysmian Group Delft. How the six innovation areas can be used at Prysmian Group Delft for the development of new product system designs was explored by different creative workshops, design trials and design presentations. Below, the highlights of this iterative process are discussed.

Developing a shared understanding of systems

During the creative workshops and the design presentations, it was found essential that everyone involved had a shared understanding of what each system level entails. Similar to the Scenario Method of Gaziulusoy & Brezet (2015), this was achieved by the use of system maps. When visually representing the elements that make up the systems, the discussions during these workshops and presentations were more focussed and therefore more in-depth.

These system maps are also useful to identify system challenges at each system level. These challenges could be either today's problems (as used in the MDM by Joore & Brezet (2015)) or potential future risks (as used in the Scenario Method by Gaziulusoy & Brezet (2015)). In the interviews with Prysmian Group employees and visits to other stakeholders, today's problems and future risks were unavoidably mixed. This did, however, not bother the process. Therefore, it was decided to combine these two and name them system challenges.

The system challenges are used as an input for the design processes of innovation areas A, C and E. As said, these innovation areas contain solutions which are addressing today's challenges. During the second creative workshop described in paragraph

5.1.1, it was found that the design processes of the other innovation areas (B, D and F) also require clear system challenges. The identification of system challenges was not included in the workshop. However, when asking the participants to develop visions, unavoidably they focussed on challenges first. These challenges were needed to discuss what should be solved in the vision. Therefore, also for the other innovation areas, the identification of system challenges is needed.

Both the system maps and the system challenges used in this research were based on interviews with stakeholders at each system level and literature.

Idea generation methods

Idea generation is an important step in each design process and was therefore explored in different creative workshops and design trials. The design processes which generate ideas based on today's challenges require different idea generation techniques than the design processes which use a vision.

How-to questions (Tassoul, 2006) were used in 2 creative workshops and during different design trials. They proved to be a useful tool to generate ideas for product system innovation areas A, C and E. How-to questions are a commonly used ideation tool for designers used to generate solutions for individual problems. By translating the system challenges into how-to questions and combining ideas that were generated by these questions, product system designs can be developed.

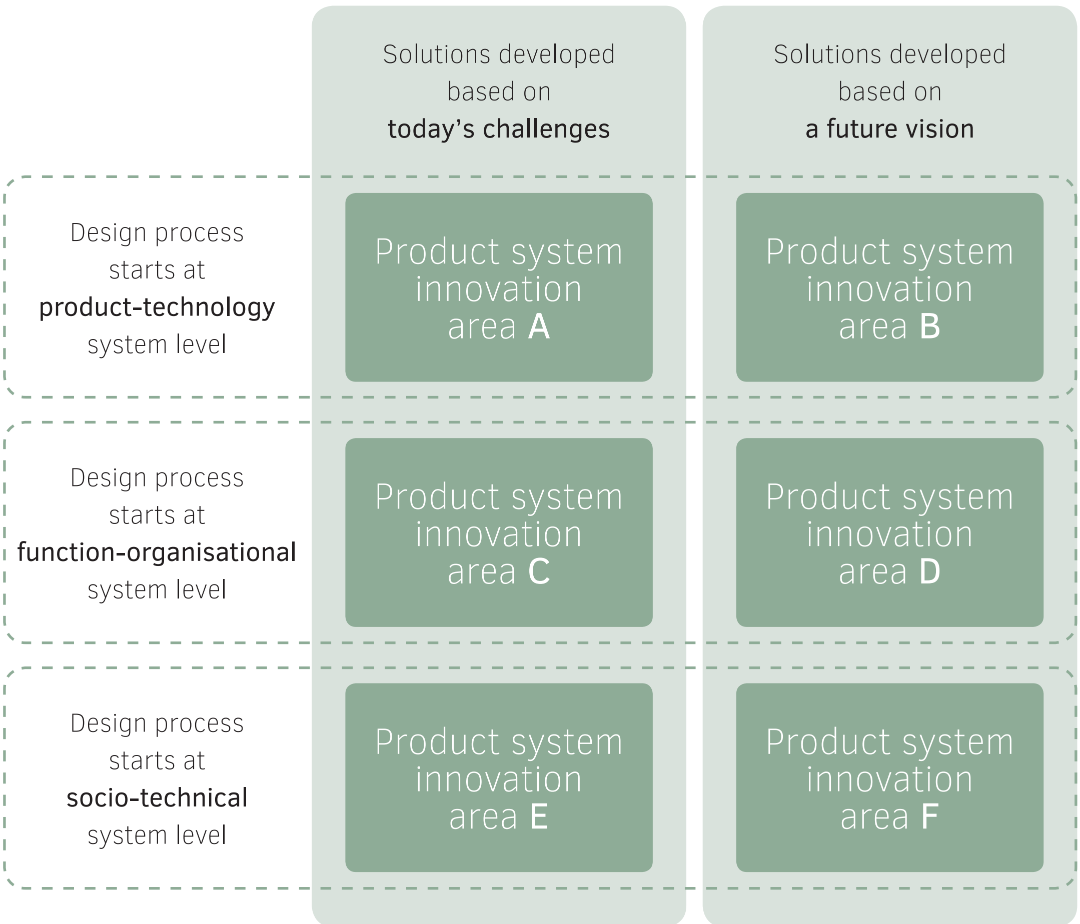


Figure 18: Overview of the different product system innovation areas used as a basis of the new product system design method for Prysmian Group

In the other innovation areas (B, D and F), a vision is developed first. The second creative workshop showed that scenarios are a useful tool to develop these visions. The scenarios describe extreme possible futures of the system. By first exploring these extremes, more realistic but innovatory visions can be formulated.

During a creative workshop with students, which will be discussed below, it was explored how this vision could be translated into concrete product system designs. This showed that it is important to temporary forget about Prysmian's role and interests. First, ideas for product system designs should be generated based on what is needed to reach the developed vision. Next, it can be decided what type of organisations are required to realise this product system design and what role Prysmian Group could take.

Use of targeted workshops

The design trials during the exploration phase were done by an individual designer. To improve the quality of the product system designs that were developed, a second round of creative workshops was organised. These workshops aimed to collect more ideas.

Unlike the creative workshops described in paragraph 5.1.1, these workshops were organised for participants with a similar background that matched with the topic of the workshop. These so-called targeted workshops addressed the different innovation areas defined in the previous paragraph as shown in Figure 19. An impression of the creative workshops is shown in Figure 20. The detailed description of the set-up and outcomes of both workshops can be found in Appendix 3.

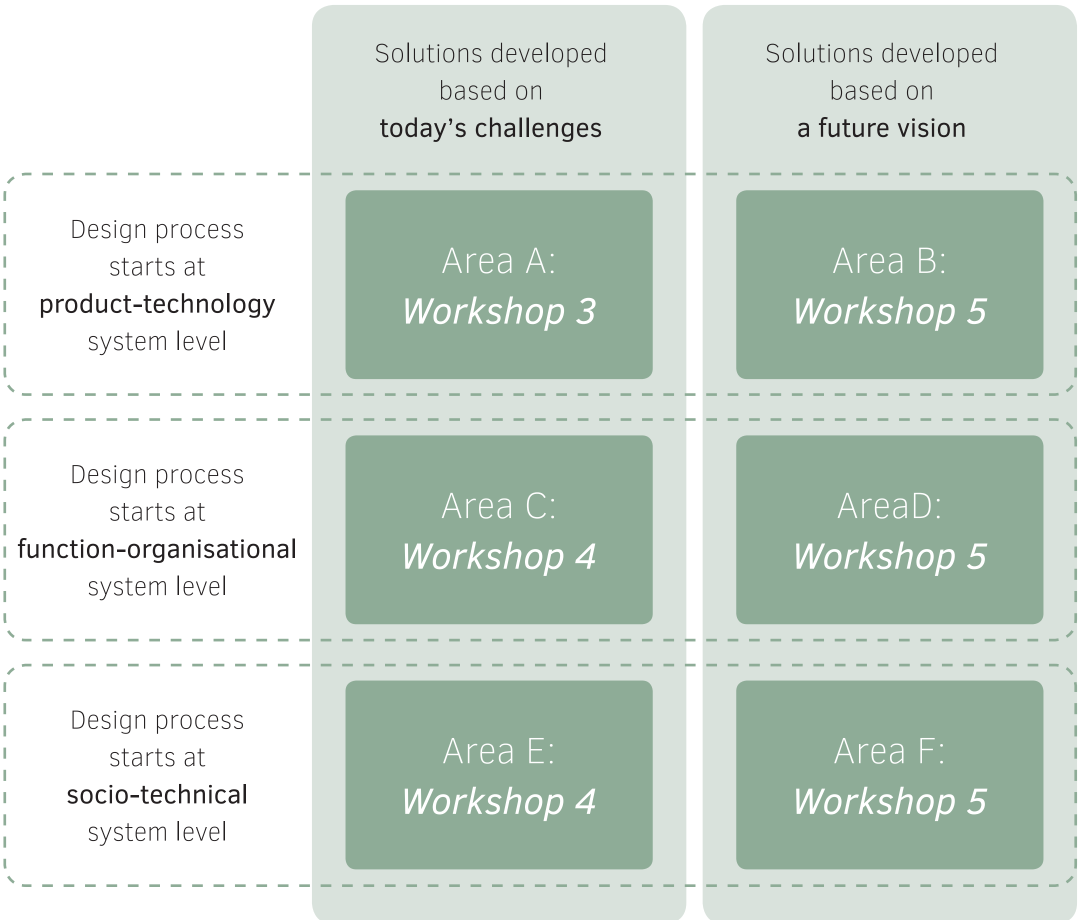


Figure 19: Overview of the product system innovation areas addressed during the different targeted workshops

3. Innovative technical cable solutions

Goal

Exploring other technical solutions that could improve a low voltage power cable.

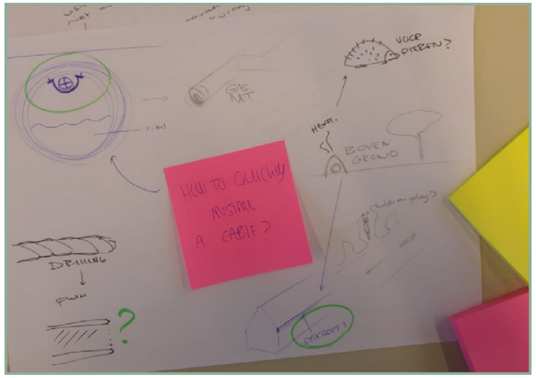
Summary of the steps taken

Rewriting the four core functions of a power cable into how-to questions and brainstorming on each of them.

Participants

6 Prysmian Group employees (R&D, sustainability).

4. Product solutions for challenges at higher system levels



Goal

Developing product solutions on all system levels

Summary of the steps taken

Rewriting the challenges defined at each system level in how-to questions and brainstorming on each of them.

Participants

3 BSc Industrial Design Engineering graduates.

5. Product system solutions for all system levels

Goal

Develoing more ideas on how Prysmian Group could contribute to higher system levels.

Summary of the steps taken

Developing visions on each system level, adressing the challenges at these levels and developing a strategy on how Prysmian Group could realise these strategies.

Participants

10 second-year MSc Industrial Ecology students.

Figure 20: Impression of the three targeted workshops

As can be seen in Figure 20, in workshop 4 and 5, the participants were students which had limited knowledge of the energy sector and Prysmian Group Delft. During these workshops, it was found that most of the ideas developed are not feasible or already thought of before. Therefore, it was concluded that it does help if the participants of the targeted creative workshops have a certain level of background knowledge. However, when doing a brief brainstorm with Alliander employees, it was concluded they again lack the skills the students had in creative thinking and system thinking. Therefore, to make these targeted creative workshops most effective, it is argued that it would be ideal if a mixed group of people with different expertises relevant for the workshop are participating.

Collecting feedback on the illustrative product system designs

Design presentations were used to explore how product system designs could be communicated best in order to gather useful feedback. Also, the presentations at customers aimed to convince them to collaboratively improve and implement the product system designs.

Based on the one-on-one meetings with Prysmian Group employers meetings, different adjustments of the illustrative product system designs were made. During the design presentations at customers, it was found that showing sketches rather than discussing general ideas helped to gather useful feedback. The meeting with Alliander provided information on which ideas were already tried in the past, which ones were considered interesting and which ones were not. These insights can be used to improve the product system designs, either by reformulating the system challenges or redoing the ideation stage.

Besides, it was concluded that the Alliander employee who was involved earlier in the research as well was better able to understand the idea behind the product system designs compared to his colleagues. He was therefore also more positive about their potential. Although no conclusions can be drawn upon a single person, it is argued that customers should be given time first to get used to the different kind of designs that were presented. Later, a collaborative project to further develop the designs can be discussed.

5.1.4 The outcome: a product system design method for Prysmian Group Delft

In the previous paragraphs, the key insights gained during the development of a product system design method for Prysmian Group Delft were described. This design method that followed from this was named the Product System Design Method (PSDM), shown in Figure 21. The PSDM consists of three stages: preparation, ideation, and evaluation.

During preparation stage, a system map of each system level is developed and related system challenges are formulated. The challenges can be today's problems or future risks. To do so, semi-structured interviews with stakeholders at each system level must be conducted.

The ideation stage consists of two approaches which can be executed in parallel. Each approach is executed on all three system levels. This means that, in total, six different ideation processes are followed. The two different ideation approaches are discussed below.

The challenge oriented ideation approach uses system challenges to formulate how-to questions. Each how-to question represents one system challenge. Next, for each how-to question, a variety of ideas is developed. Here, general brainstorm rules such as 'quantity of quality' and 'postpone judgement' are important (Osborn, 1953). To create a wide variety of ideas, organising creative workshops with a mix of skilled creative thinkers and stakeholders with knowledge of the system is advised. The most fruitful ideas can be combined into product system designs.

The second ideation approach starts with the development of a vision for each system level. These visions describe a desired future system in which the system challenges are eliminated. Preferably, this is done during creative workshops with involved stakeholders as well as people skilled in system thinking. Based on these visions, it is discussed what needs to be changed in the current system and which types of actors should be involved in this. Last, it is decided which of the actor types can be fulfilled by Prysmian Group and for which actions they need partners. Following from this are one or more product system designs.

The evaluation stage is the last stage of the PSDM. Here, the selected product system designs are presented to a customer. Depending on the feedback of the customer, it can be decided to collaboratively further develop the idea or first internally improve the product system designs by going through the PSDM again.

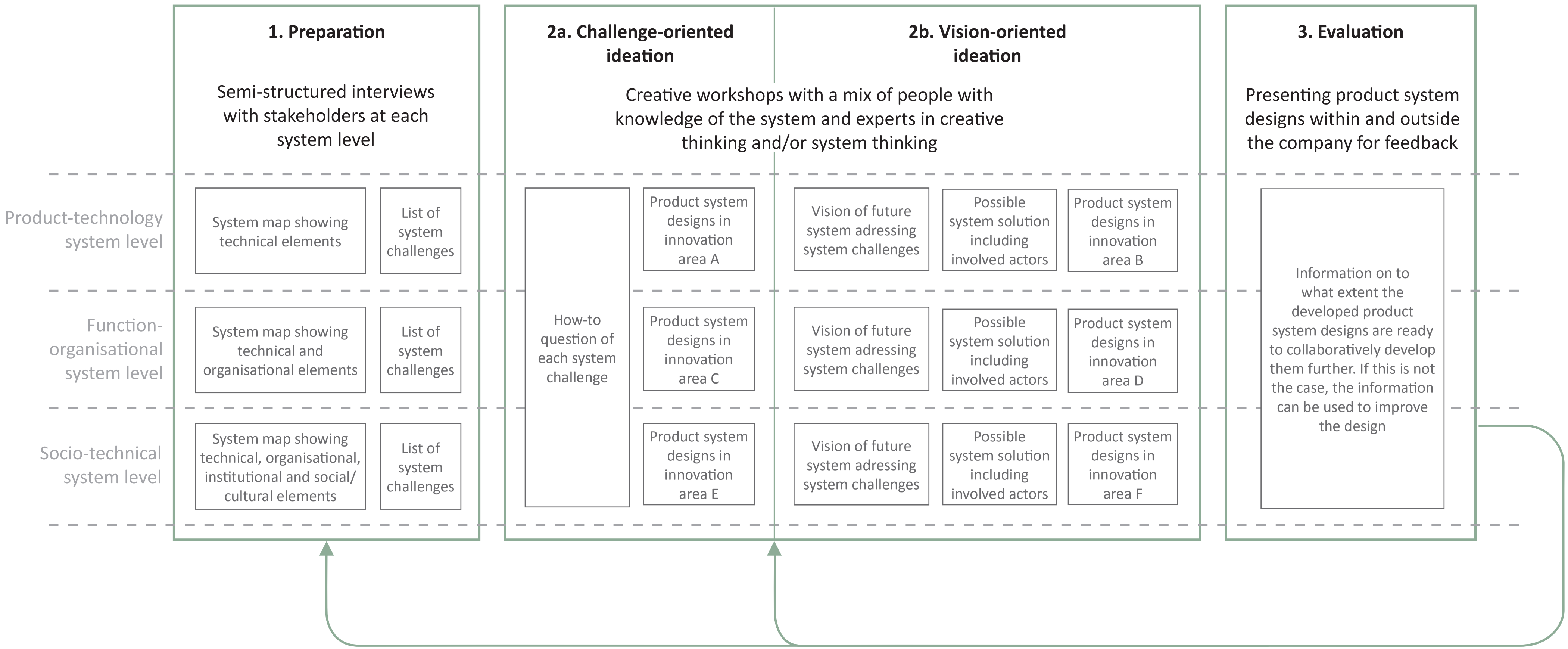


Figure 21: Schematic summary of the product system design method developed in this research

5.2 Evaluation of the PSDM: Conditions for Prysmian Group Delft

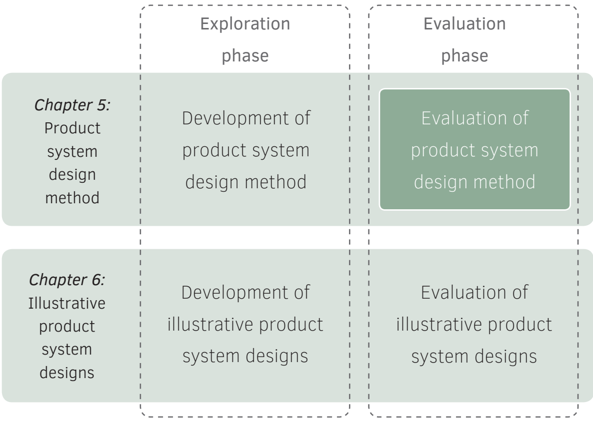


Figure 22: Sub-section 5.2 describes the evaluation of the product system design method

This sub-section answers the second sub-questions by discussing what conditions must be met at Prysmian Group Delft in order to use the PSDM. It is described what these conditions are, which ones are already fulfilled at Prysmian Group Delft and – for the ones that are not met – how they were fulfilled in this research and how they could be achieved at Prysmian Group Delft in the future.

5.2.1 Sector knowledge and stakeholder contacts

In order to develop the system maps and formulate system challenges during the preparation stage of the PSDM, knowledge of the systems of each system level is needed. During this research, this knowledge was collected through conversations with relevant stakeholders. Therefore, knowledge on the different system levels and contacts with stakeholders within this systems are conditions that must be met in order to use the PSDM. Also, these stakeholder contacts are of use during the ideation stage, as the stakeholders can be invited for creative workshops.

Based on the semi-structured interviews held with Prysmian Group employees (see Chapter 2), it was concluded that the knowledge of the different system levels is limited among Prysmian Group employees. When it comes to the product-technology system level, obviously employees know a lot about power cables. However, which considerations a recycler has to recover a certain material or not were unknown. Relatively much information was available at Prysmian Group Delft regarding the function-organisational system level. This is the system level at which their customers operate. For a sales employee, knowing your customers' activities and challenges is important. When it comes to the energy sector as a whole, it was found that most employees do have a certain level of knowledge which can be expected from an average person who follows the news. The key issues of the energy transition were mentioned frequently. However, more in-depth knowledge was lacking.

As not all information of the different systems was available within Prysmian Group Delft, desk research and interviews were done during the first months of this research. Also, visits to relevant stakeholders provided more in-depth knowledge. These visits were very useful to get a better understanding of what drives these stakeholders. No stakeholders were involved in the creative workshops due to time constrains.

So, in order to implement the PSDM, Prysmian Group Delft must invest in contacts on each system level. This is needed to improve the quality of the preparation and ideation stage of the PSDM. Some contacts, such as the contact with DSOs and recyclers already exist. However, they do not primarily exist to exchange information but rather focus on business-related collaboration. Therefore, a different type of conversations with these contacts must be held. Besides, contacts with other stakeholders must be set up.

5.2.2 Skills

Transition Design - and consequently the PSDM as well - combines product design methodology with system innovation theory. Therefore, in order to use the PSDM, a certain expertise in creative thinking and system thinking is required.

Most Prysmian Group employees are engineers with strong technical skills. The required expertise described above was not found within the company. This was also witnessed during the different creative workshops organised for Prysmian Group employees.

Therefore, during this research two targeted workshops with students in the two fields of study mentioned above were organised. These workshops, which were part of the ideation stage, did help to generate more ideas. However, it was also found that single workshops were not enough to develop relevant ideas and translate these into product system designs. As discussed in sub-section 5.1, the students lacked the required background knowledge to develop new and implementable ideas.

So, in order to improve the ideation stage, it is argued that Prysmian Group Delft could do two things. They either organise more and longer workshops with external experts in system thinking and creative thinking. The experts should have sufficient time to acquire sufficient knowledge. On top of that, they could be supported by people with a lot of system knowledge during these workshops. The second option is that Prysmian Group invests in new manpower within the company with the required background.

5.2.3 Time

The design of product systems takes time. Unlike an engineering project, which generally has a clear purpose, the outcomes of the PSDM are not clearly defined. During this research, the bright moments in which new ideas were developed came at unexpected moments. This is something that can only partly be speeded up. Therefore, it is argued that the employee(s) responsible for developing the product system designs by the use of the PSDM should have enough time available for this.

As identified during the semi-structured interviews described in Chapter 2, Prysmian Group employees have little time available and therefore focus on core tasks only. This contradicts the condition described above. On the other hand, Prysmian Group Netherlands did assign one of their employees as Sustainability Officer in January 2019. The fact that an employee can full-time dedicate to sustainability-related activities is a good starting point.

Because this research was executed by an intern over a long period, sufficient time was available. In collaboration with the Sustainability Officer, the product system designs were developed. The Sustainability Officer supported in providing knowledge on Prysmian Group and contacts that might be of use.

Therefore, it can be stated that, if Prysmian Group wants to use the PSDM in the future, the people in charge of it should be allowed to spend sufficient time on this task.

5.2.4 Multidisciplinary collaboration

As product system designs include more than just a technical solution, its development should not only be done by an R&D department. It should be a joined effort of people managing the required partners, people developing the technological artefacts and people focussing on sales.

As discussed in Chapter 2, this collaboration between departments is something that is already happening at Prysmian Group Delft. Maintaining this collaborative attitude between departments is important.

In this research, through regular meetings with people from different departments at Prysmian Group Delft, this collaboration was simulated.

6 Illustrative product system designs: Development and evaluation

In this chapter, the third and fourth sub-question of this research will be answered. First, in sub-section 6.1, the PSDM is used to develop six illustrative product system designs answering the following sub-question: ***What illustrative product systems can be designed by the use of the developed product system design method?*** Next, the last sub-question: ***To what extent do the illustrative product system designs create value for Prysmian Group Delft while contributing to system innovation?*** is answered by describing what benefits the illustrative product system designs could bring to Prysmian Group Delft and its customers. Also, it is discussed what changes should be made at Prysmian Group and their customers when implementing the product system designs. Last, it is discussed to what extent the product system designs contribute to system innovation.

6.1 Using the product system design method: the development of illustrative product system designs

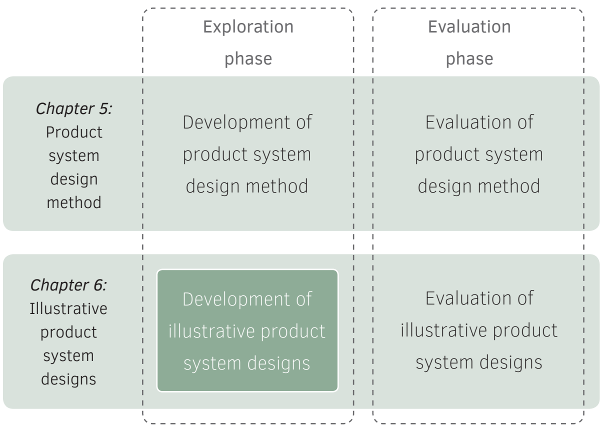


Figure 23: Sub-section 6.1 describes the development of the illustrative product system designs

In this sub-section, it is shown how the PSDM can be used by describing the development of six illustrative product system designs. These illustrative product system designs are examples of possible outcomes of the PSDM. The different stages of the PSDM are discussed separately.

6.1.1 Stage 1: Preparation

The first stage of the PSDM is the preparation stage, aiming to develop system maps of each system level and identify related system challenges.

The semi-structured interviews with Prysmian Group employees (see Chapter 2) were used for the development of the system maps and the formulation of system challenges. On top of that, three visits were organised to stakeholders on different system levels (Table 9, next page). A more elaborate description of these visits can be found in Appendix 2. Due to time constrains, no visits to

Table 9: Summary of the evaluation of the two creative workshops organised

Type of visit	Stakeholder	Input for system level
Meeting and guided tour (Figure 25)	KRT (cable recycling firm)	Product-technology system level
Meeting with CEO	Stedin (customer)	Product-technology system level and function-organisational system level
Joining the activities of an installation instructor for one morning (Figure 26)	Alliander (customer)	Function-organisational system level

stakeholders on the socio-technical system level were done. Therefore, information on this system level was gathered through literature. In the following paragraphs, the different system maps and related challenges are presented.

Product-technology system map and system challenges

From a technical perspective, a power cable is a collection of materials which were initially joined together into a certain shape. At the end of life, these different materials are separated again, either through recycling or incineration. During its use phase, electricity is conducted which results in electrical losses in the form of heat. A simplified system map of power cable system is shown in Figure 24.

During the interview with the CEO of Stedin, he pointed out two sustainability challenges when it comes to power cables:

1. Electrical losses
2. Their poor recyclability

These two challenges were further discussed with Prysmian Group employees. During a meeting with an R&D employee, it was concluded that – from a product-technology perspective – the electrical losses can only be reduced by copper conductors and/or bigger conductors. These are options that are already elaborately researched by Prysmian Group Delft and their customers and an optimum has been found. Therefore, these are not further discussed in this research.

To research the poor recyclability, a power cable recycler was visited. Here, it was shown how the metals are separated from the other materials for recycling. Most of the plastics in Prysmian's cables are incinerated with heat recovery. The reason behind this is the fact that a large share of the plastics in power cables is not recyclable. As plastics are relatively cheap, separating these unrecyclable plastics from the recyclable ones is not profitable.
Also, the majority of the power cables entering the recycling facility are end-of-life cables. These cables have been underground for decades and consist of materials which are currently not commonly used anymore.

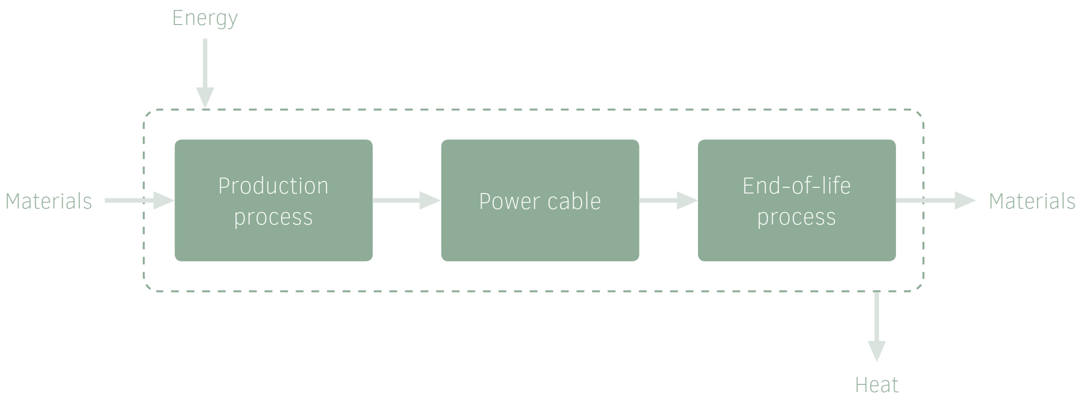


Figure 24: A system map of the product-technology level representing a power cable

Figure 25: Shredded power cable at a cable recycling facility

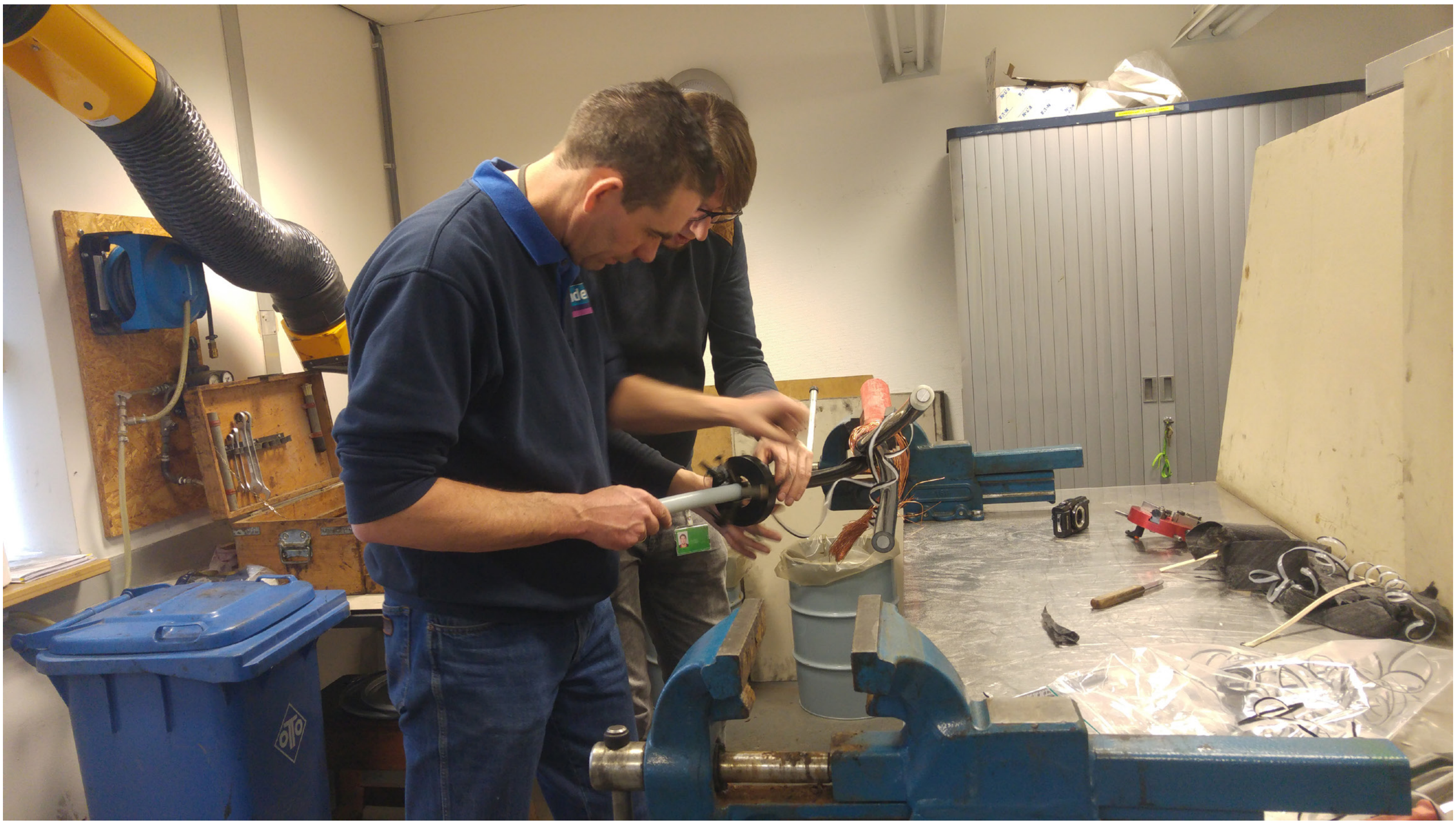


Figure 26: Inspection and dismantling of a damaged medium voltage power cable at Alliander

Prysmian Group Delft is investigating if the percentage of recycled content in their products can be increased. For copper, this is feasible. For aluminium this is not allowed as recycled aluminium has more impurities lowering its conductivity. The use of recycled PVC turns out to be challenging as the supply of the recycled material is less consistent than virgin material. Also, pilots have been done with the use of recycled poly-ethylene. Fifty percent recycled content in the outer insulation proved to be feasible and workable. However, as this alternative is not cheaper than the virgin material, it was not implemented on a large scale.

To summarise, the most dominant challenges on the product-technology level are

- A large share of the plastics in power cables is not recyclable.
- Separating the recyclable plastics from the non-recyclable plastics is not profitable.
- The use of recycled aluminium in power cables in not allowed.
- The use of recycled plastics in new cables is challenging is it does cause changes to the product while not being cheaper.
- Implementation of new innovations only happens if it reduces costs.

Function-organisational system map and system challenges

The system defined on the function-organisational system level is the electricity transmission and distribution system. This system consists of technical elements, together forming the grid, as well as organisational elements. In the electricity transmission and distribution system, grid operators are the most important actors. They manage both the continuous process of electricity transmission and distribution as well as intermittent processes such as maintenance. A simplified system map of electricity transmission and distribution system is shown in Figure 27.

As this study focusses on low voltage power cables, only the challenges in the electricity distribution system were investigated. When discussing the energy transition with different DSOs, the limited grid capacity is their main concern. This concern has three underlying causes.

On the short run, there is a shortage of skilled employees who can install and maintain power cables. This causes delays in the construction of more grid where needed.

Secondly, managing supply and demand will become significantly more challenging in the coming years if the number of solar panels, heat pumps and electric cars continues to grow. Traditionally, households follow a similar pattern in consumption. DSOs collect data enabling them to predict this demand. Based on this relatively predictable demand, supply can be managed. However, the supply of electricity has become less flexible and manageable due to the renewable energy sources which are subject to weather circumstances. Also, on the demand side, there is a growing problem. When a household invests in a heat pump and/or an electric car, its electricity demand will raise significantly. However, a DSO does not know which household does so as they are not allowed to monitor individual electricity consumption. Only when a lot of households increase their electricity demand and people start contacting the DSO about electricity issues, they know there is a problem. The same counts for solar panels. On a sunny day in a street with many solar panels, the grid might have too little capacity to deal with the large amounts of electricity produced. However, this is something that only becomes clear on a sunny day.

On the long run, the uncertainty of the energy transition is a major challenge for DSOs when it comes to investments. As power cables are in use for decades, decisions made today influence the electricity distribution system for a long time. Some experts predict a fully electrified society while others consider other energy carriers more feasible (TNO, 2017; ENC, 2017). Also, to what extent electricity generation will decentralise has a major impact on the grid. Installing a overcapacity to be prepared for the electrified scenario might result in a huge loss of public money. However, not investing in a bigger grid might cause issues on the long run which means that the DSOs have to open-up the ground again in a few years' time to install more power cable. This would also cost more money.

To summarise, the most dominant challenges on the function-organisational system level are:

- The limited workforce to install and maintain the electricity grid.
- The high uncertainties caused by differences between households when it comes to consumption and production of electricity.
- The long life-time of cables in a rapid-changing sector of which nobody know which direction it will go.

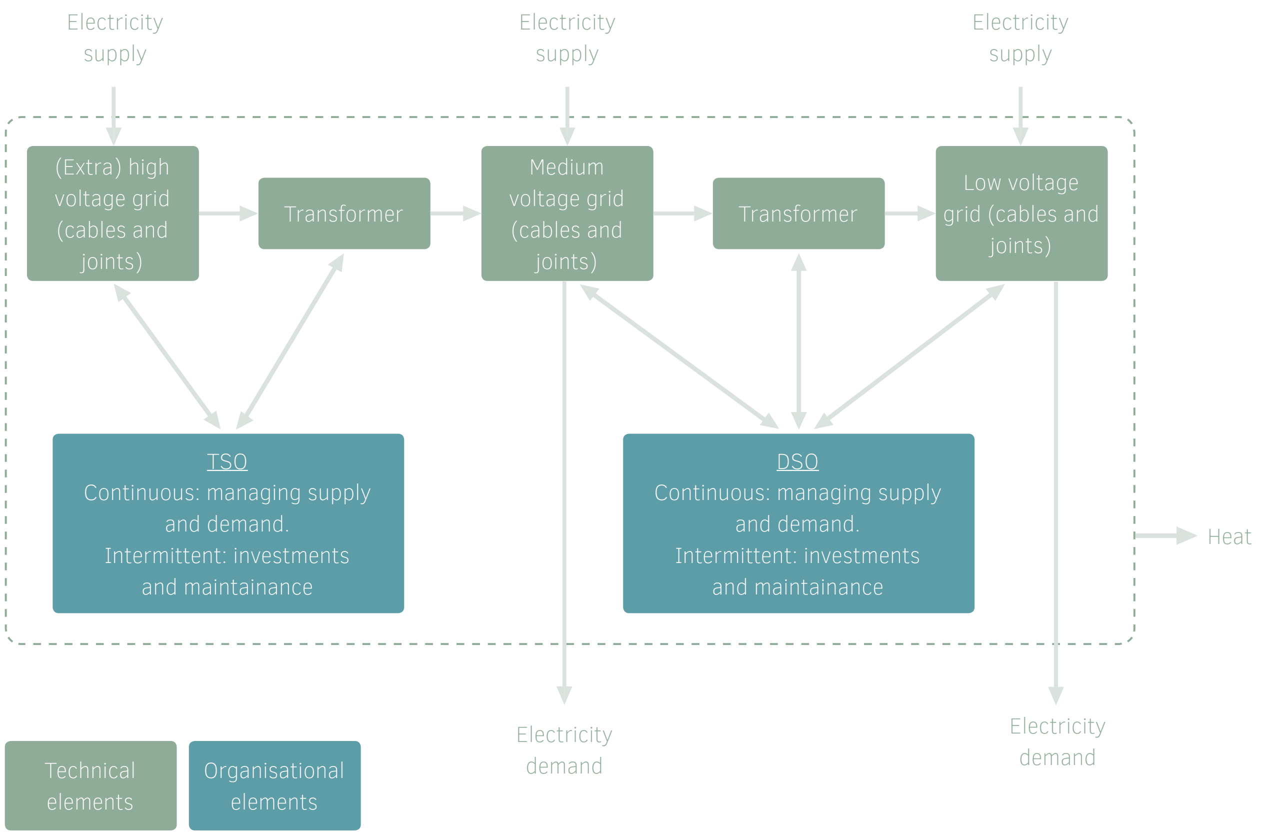


Figure 27: A system map of the function-organisational level representing the electricity transmission and distribution system

Socio-technical system map and system challenges

The socio-technical system map is largely based on the energy system map by Chappin (2011). This system map describes the most important technical, organisational, economic and social/cultural elements which together provide the Netherlands with energy. A simplified system map of the energy sector is shown in Figure 28.

No opportunity has been found to speak to some of the key stakeholders on this system level, such as the government and electricity suppliers. However, much research has been done into the energy transition and the challenges that come with it. Based on different reports, the key challenges at this system level are formulated below.

Firstly, a challenge frequently mentioned is the transition from fossil-based energy sources to renewable energy sources (DNG GL, 2018; van Bracht & Wetering, 2017; Sinke et al., 2016). These renewable energy sources require high investments in technologies, much space and encounter social resistance. This slows down the transition which continues the dependency on fossil-fuels to guarantee supply security (van Bracht & Weterings, 2017).

Secondly, Electricity production of renewable energy technologies is intermittent and therefore cannot be balanced with electricity demand. Consequently, there is an increasing need to store electricity (van Bracht & Wetering, 2017; Sinke et al, 2016). However, large-scale electricity storage, either in the form of batteries or another energy carrier is currently often not financially attractive.

DNV GL (2018) also points out the electrification of the energy sector and the related challenges for the electricity grid. However, this has already been

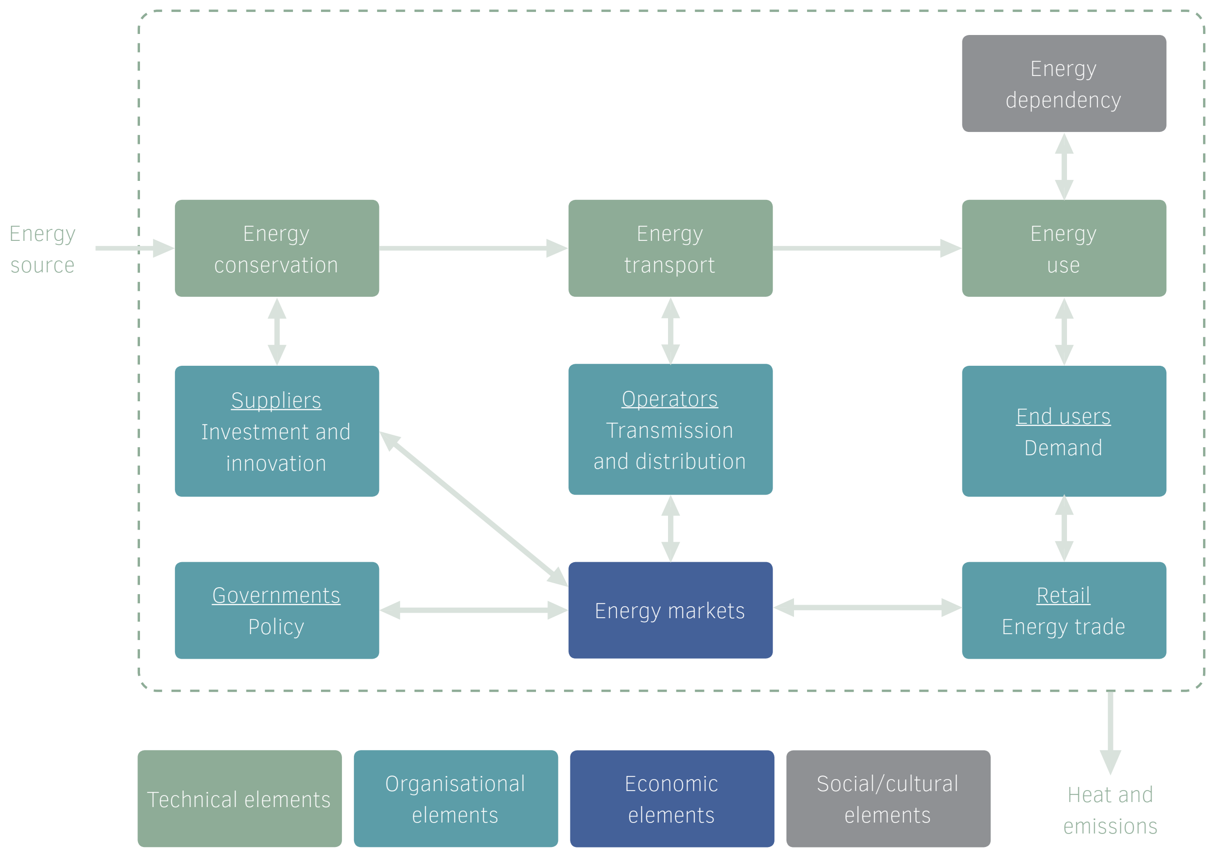


Figure 28: A system map of the socio-technical system level representing the Dutch energy system

addressed on the function-organisational system level and will therefore not be further discussed here.

Last, the energy transition is causing social challenges (Straver et al., 2017). How to make the energy transition as ethical as possible is another challenge. However, this research focusses on environmental and economic sustainability so this challenge will not be further addressed.

To summarise, the most dominant challenges on the socio-technical system level used in this research are:

- Investing in renewable energy sources is not attractive enough which causes our continuing dependency on fossil-fuels.
- Electrical energy storage is not developed well enough to store energy on a large scale for a long time, which is something that will be needed in the future.

6.1.2 Stage 2: Ideation

The system challenges identified in the previous paragraph serve as an input for the ideation stage. During this stage, product system designs are developed. In the following pages, one illustrative product system design for each innovation area is presented. These illustrative product system designs are examples of possible designs that can be developed by the use of the PSDM.

A The fully seperatable and recyclable power cable

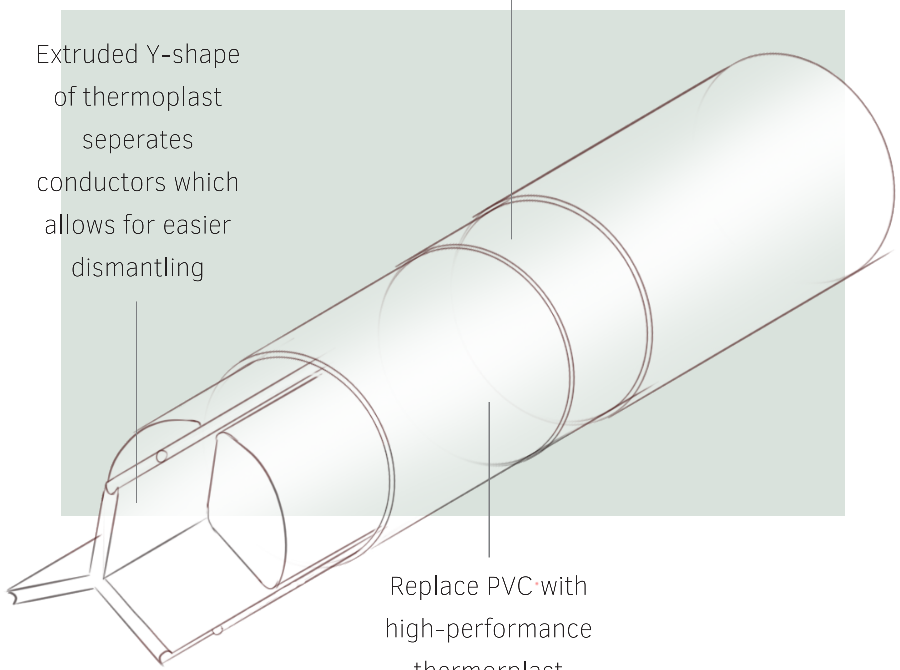
By stripping all unnecessary layers from Prysmian's current low-voltage power cable, much simpler power cable is designed

Background

System challenges	Related how-to question	Selected solution
A large share of the plastics in power cables is not recyclable	How to design a cable of only recyclable materials?	Replace PVC (currently downcycled) and rubber (not recycled) with high-performance theromoplastics
Separating the recyclable plastics from the non-recyclable plastics is not profitable	How to make the separation of different types of plastics profitable?	Colouring of the high-performance thermoplastics so recyclers can easily see that the materials are different
The use of recycled aluminium in power cables in not possible	How to enable the use of recycled aluminium?	The use of an extruded y-shape which separates conductors. This makes manual disassembly of the cable easier and therefore stimulates the use of the conductor as a part.
The use of recycled plastics in new cables is challenging is it does cause changes to the product while not being cheaper	How to make the use of recycled content more attractive?	No specific solution selected. However, communicate the ambition to use recycled plastics with suppliers to stimulate investments in improving their properties
Implementation of new innovations only happens if it reduces costs.	How to reduce costs?	Simpler design - less manufacturing steps

Required partners

Partner	Role	Value creation opportunity
Prysmian Group Delft	Design and production of the power cable	Sales of the power cable
Material supplier	Investments in improving properties of recycled poly-ethylene and poly-propylene	Competitive advantage compared to other material suppliers



B The alliance for the next generation of power cables

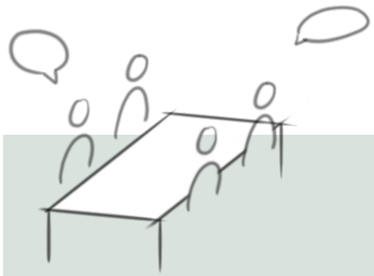
By pairing up with ambitious supply chain actors, a new standards for more circular power cables can be initiated

Background

System challenges	System vision
A large share of the plastics in power cables is not recyclable	***The power cable of the future:*** Each power cable producer uses the same, recyclable materials. These cables are clearly marked and send back to the producer at their end-of-life. The producer can refurbish the cable or send it to a contracted recycler who knows how to handle the cable. Through better supply-chain collaboration, material suppliers are able to deliver high-quality materials with close to 100% recycled content
Separating the recyclable plastics from the non-recyclable plastics is not profitable	
The use of recycled aluminium in power cables in not possible	
The use of recycled plastics in new cables is challenging is it does cause changes to the product while not being cheaper	
Implementation of new innovations only happens if it reduces costs.	

Required partners

Partner	Role	Value creation opportunity
Prysmian Group Delft	Find actors willing to join the alliance and pull the cart. Deliver cables for pilot	Being part of the first movers leaving behind competitors with less innovation power
Other cable producers	Join the alliance and deliver cables for the pilot	Being part of the first movers
Material suppliers	Give input into the process of developing the ideal solution	Being able to integrate their interests in the new standard
Cable recyclers	Give input into the process of developing the ideal solution	Being able to integrate their interests in the new standard
NEN	Coordinating the standardisation process after the pilot	Making their standards more up-to-date



1. Create alliance with supply-chain parties that are willing to make changes.

2. Collaboratively discuss what would be the most ideal solution and run a pilot in which the ideal solution is tested.

3. Use the outcomes of the pilot to improve the solution and start the process with NEN to officially standardise it.

C Temporary parallel grid

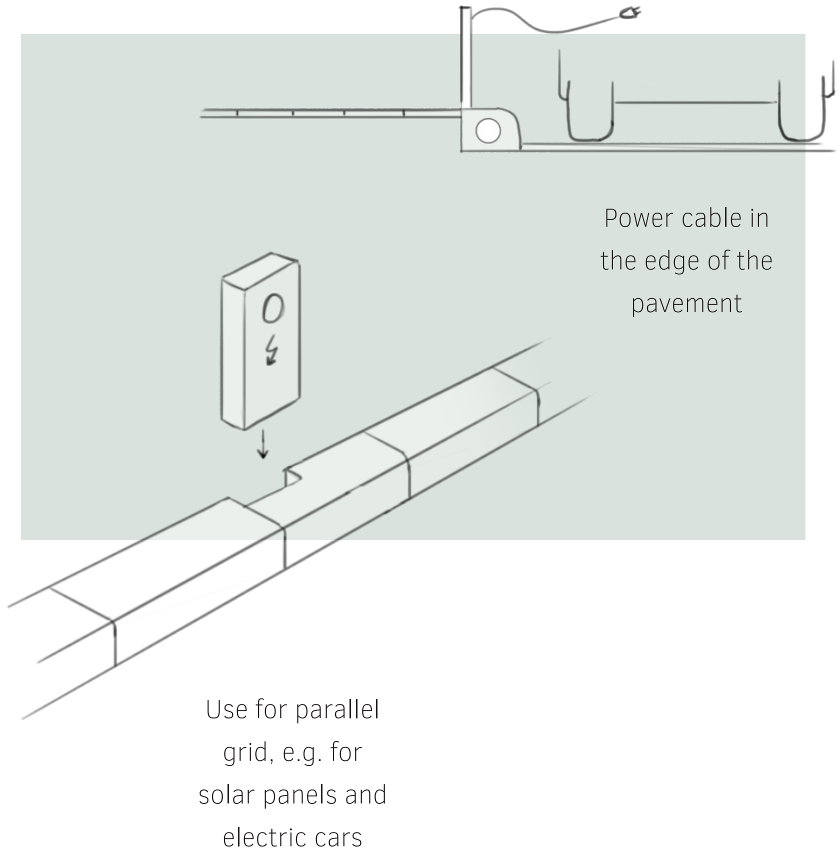
By installing a temporary parallel above-ground grid, the most urgent upgrading of existing grids can be realised in a quick and cheap way

Background

System challenges	Related how-to question	Selected solution
The limited workforce to install and maintain the electricity grid	How to make the installation and maintainance of a power cable less labor-intensive?	An above-ground grid, installed in the edge of the pavement
The high uncertainties caused by dif-ferences between households when it comes to consumption and production of electricity	How to deal with the high differences in production and consumption between households?	Quickly-to-install parallel grid for (parts of) neigh-bourhoods where there are many electric cars
The long life-time of cables in a rapid changing sector of which nobody know which direction it will go	How to deal with the unpredictable future of the energy sector?	Parallel cable system designed to be installed for only 1-10 years. After this, smart-grids, batteries and/or other carriers are likely to be further developed

Required partners

Partner	Role	Value creation opportunity
Prysmian Group Delft	Design and production of the power cable, connecting other stakeholders during design process	Sales of a second power cable
Producer of pavement components	Development of new product suitable to hold a cable	Sales of pavement edge
Producer of electric vehicle charging systems	Development of new type of charging system	Sales of charging system
(Installers at) DSOs	Installation of power cable via new method	No need to open-up ground and replace power cable in problem areas in neighbourhood



D The flexible grid

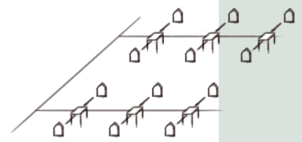
A data-generating grid that can easily be up- or downgraded in the future by the use of modular power cables in tubes.

Background

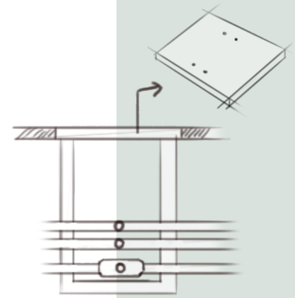
System challenges	System vision
The limited workforce to install and maintain the electricity grid	***The low-voltage grid of the future:*** A grid which generates data and, based on this data, can grow or decrease in capacity with relative ease. Also, by the collected data, predictions can be made on when this growth or decrease will be needed.
The high uncertainties caused by differences between households when it comes to consumption and production of electricity	
The long life-time of cables in a rapid-changing sector of which nobody know which direction it will go	

Required partners

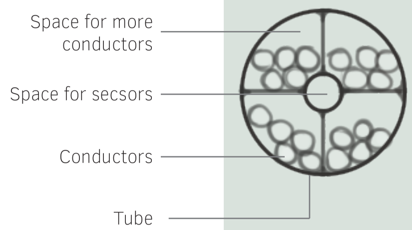
Partner	Role	Value creation opportunity
Prysmian Group Delft	Producing conductors and tubes, facilitating market place, initiating project	The sales of conductors and tubes. Use materials from e.o.l. production of market space
Sensor producer	Developing suitable sensors	The sales of sensors
Software developer	Developing a tool that monitors data from cables and estimates needed up/ downgrades	The sales of the software tool
DSO	Using the software tool and up/ downgrading the grid	Making investments where it is needed and prevent the risk of losing investments



Multi-utility underground system with sufficient access points



Access points that are integrated in street design



Power cables have empty spaces in which multiple smaller conductors can be inserted. Also, there is space to integrate technology for data generation

Data can be used to determine if the number of conductors is still in line with the required capacity. Left-over conductors can be resold on a marketplace

E Extending Prysmian's portfolio with batteries

Through combing power cables and batteries, a more responsive grid can be build.

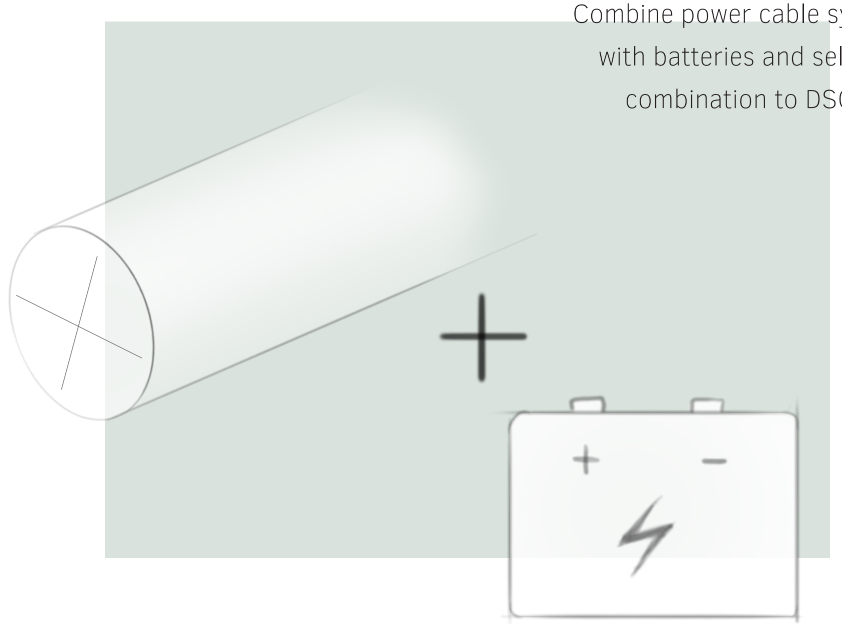
Background

System challenges	Related how-to question	Selected solution
Investing in renewable energy sources is not attractive enough which causes our continuing dependency on fossil fuels	How to make investments in renewable energy sources more attractive?	Through energy storage, energy generated when energy is cheap (e.g. there is a lot of wind) can be sold at a later point in time
Energy storage is not developed well enough to store energy on a large scale for a long time, which is something that will be needed in the future	How to improve energy storage?	Investments in energy storage R&D

Required partners

Partner	Role	Value creation opportunity
Prysmian Group Delft	Expert in power cables	The sales of cable-battery combinations
Battery producer	Expert in batteries	The sales of cable-battery combinations

Combine power cable systems with batteries and sell the combination to DSOs



F Investments in renewable energy production

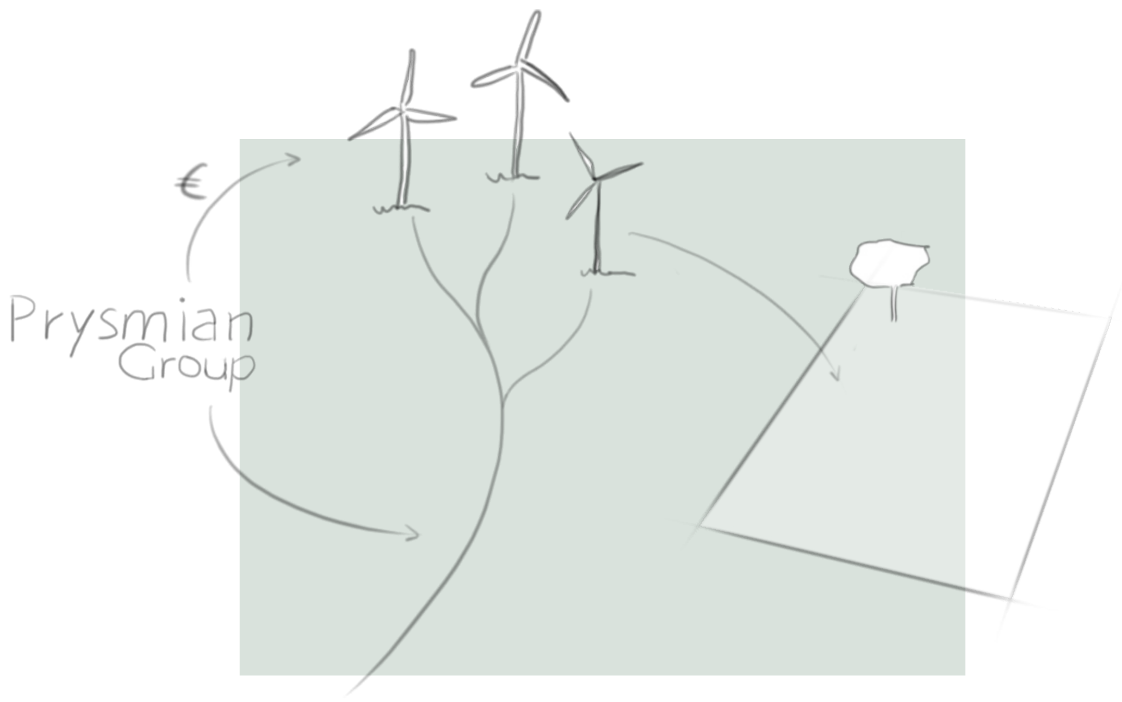
Offering the required investment to land owners so they can install renewable energy technology. In exchange, Prysmian's power cables are used

Background

System challenges	System vision
Investing in renewable energy sources is not attractive enough which causes our continuing dependency on fossil fuels	*The energy system of the future:* A society in which investments into renewable energy sources and energy storage are made by parties who have the capital to invest.
Energy storage is not developed well enough to store energy on a large scale for a long time, which is something that will be needed in the future	

Required partners

Partner	Role	Value creation opportunity
Prysmian Group Delft	Making the investment for installation of renewable energy technology	Sales of power cable and a share of the sales of electricity
Land owner with limited capital to invest	Setting up and maintaining the energy technology infrastructure on its land	Sales of electricity



6.1.4 Stage 3: Evaluation

The six illustrative product system designs were The goal of the third phase of the PSDM is to collect feedback on the developed product system designs. Additionally, it is an opportunity to set-up collaborative projects with stakeholders to which the product system designs are presented.

In this research, the six illustrative product system designs developed in the ideation stage were discussed with four Prysmian Group employees (sales, R&D, services and sustainability), Prysmian's CFO and three customers. The comments given on the different product designs are discussed below.

Prysmian Group employees did see value in a wide range of system designs. The Y-profile separating the conductors in product system design A was highlighted by different employees. Its simplicity, the lower number of materials, and the cheaper production costs were considered interesting. The attendees of the design presentation at Alliander also showed interest in this new type of power cable design. However, something that must be researched further are the related changes in installation that will be needed when implementing this product system design. For example, a solution must be found for the lack of color-coding of the different conductors.

The enthusiasm for product system design B depended per Prysmian Group employer. Some agree that Prysmian Group Delft, as a large player, should play a leading role in the standardisation of the next generation of power cables. However, it is important to have a clear plan on how Prysmian Group Delft will benefit from the new standard.

The relevance of a more flexible grid, addressed in product system designs C and D was clear to all people that commented on the designs. Both within and outside Prysmian Group, people are most positive about these two designs. Opinions on whether these designs can actually be implemented differed. At Prysmian Group Delft, employers generally point at the DSOs and their limited willingness to make such big changes. When speaking to an asset manager of a customer, this expectation was confirmed. He asked Prysmian Group Delft to first focus on improving their power cables before focussing on long-term projects like this. Above-ground cables were also a no-go for him. Another customer pointed out the resistance for above-ground cables as well. He advised to make a rough calculation on the costs saved to convince the DSOs. Besides, some technical challenges of both designs were mentioned. Safe installation and product lifetime are elements that will need to be researched further.

Product system design E could be a useful add-on to Prysmian's portfolio. However, currently, it is addressing a demand that is not there yet. DSOs have different pilots with batteries within people's houses rather than as part of the electricity grid. Therefore, this design could be interesting for Prysmian Group depending on how the energy sector develops. Also, as pointed out by one of the customer's employees, currently DSOs are not allowed to own these batteries as they should not compete with private organisations.

Last, product system design F was considered interesting by different Prysmian Group employees as it offers an additional way to promote Prysmian's green image while selling its own cables. However, the CFO explained that this is far out of the strategy of Prysmian Group as it is too high risk.

6.2 Evaluation of illustrative product system designs

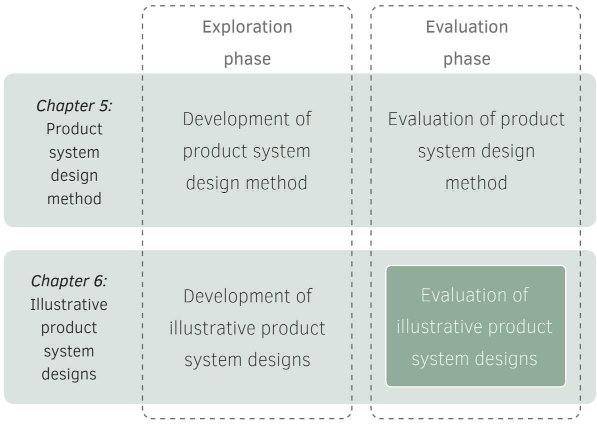


Figure 29: Sub-section 6.2 describes the evaluation of the illustrative product system designs

Besides the evaluation based on the design presentations, which was discussed in the previous sub-section, the developed illustrative product system designs were evaluated on to what extent they create value for Prysmian Group Delft. Next, by the use of SDGs, it is discussed how they contribute to system innovation.

6.2.1 Value created for Prysmian Group Delft and customers by illustrative product system designs

As stated in the first Chapter of this report, in order to implement a product system design, it must create value for Prysmian Group Delft. In this paragraph, it is qualitatively discussed what value the illustrative product system designs create for the company. To do so, value was defined as the benefits the product system design delivers to Prysmian Group compensated by the changes that need to be made to implement it. A similar analysis was done for the customer of the product system design, as the design will only be implemented if it creates value for them as well.

Benefits for Prysmian Group Delft related to the product system design ideas

The short-term benefits all the illustrative product system designs could bring to Prysmian Group Delft are a greener and more innovative image of the company. Product system design A is estimated to be cheaper to produce compared to the current low voltage power cables. As the other illustrative product system designs are less detailed, the short-term benefits of these designs are harder to predict.

To determine the long-term benefits of the different product system designs, it was discussed to what extent the product system designs prepare Prysmian Group for energy and material related trends.

Product system designs A and B do not address the trends in the energy sector other than the current power cables of Prysmian Group do.

As decentralised and intermittent electricity production is expected to rise, product system design C could serve as a useful addition to Prysmian's portfolio in the coming years. However, as smart-grids and batteries might become commercially attractive in the future, they could be replaced by these technologies. Product system D offers a more long-term solution which reduces the need for batteries or other energy carriers. This would strengthen the position of power cables as an important element in the energy sector. Besides, product-system D offers a solution which allows a cost-efficient grid in the future, no matter what the energy sector develops. This makes it much more future-proof than the previously discussed product-system designs.

Product system E conflicts product system D. This product system design expects an inevitable shift to electricity storage and aims to profit from this transition. The success of product system E highly depends on the developments in the energy sector. If the installation of decentralised energy production and storage continues, the low-voltage grid might become almost redundant. Therefore, gradually replacing these cables with batteries is an opportunity for Prysmian Group to stay in business.

The investment proposed in product system F could result in high benefits in case the energy transition causes energy scarcity in the coming decennia. However, if other, cheaper, energy sources remain available, less benefit can be expected.

Next, the material-related trends are discussed. Product system designs A and B both contribute to the reuse and recycling of materials. Therefore, they prepare Prysmian Group Delft for future customer demands and legislation when it comes to circularity. Product system B creates stronger relationships with supply chain partners which would ease future sustainable improvements of the power cables.

Product system C promotes reuse of power cables which is a competitive asset if the sustainable strategy of customers does not only focus exclusively on recycling. This is currently still the case. Besides, by making (de-)installation easy, materials will be used only where needed which is a competitive advantage when prices of materials are increasing. Product system D has the same advantage but its modular design makes reuse and recycling easier.

No research has been done into the development of recyclable batteries and the possible material scarcity of materials needed in batteries. Therefore, no statements can be made here. The same accounts for the investments in renewable energy technologies as described in product system F.

Operational changes needed at Prysmian Group Delft

For each illustrative product system design, it is investigated what changes Prysmian Group will need to make to implement the design.

Product system design A, C and E use a very similar business model to Prysmian's business model today. Therefore, little changes in logistic, economic and information flows are needed. However, product system C and E do require new collaborations with partners from sectors Prysmian Group Delft never worked with before. This means that more time must be invested in setting up and managing these partnerships.

When it comes to the internal changes needed to realise product system design B, it was concluded that most elements that make up the product system design have been done before by Prysmian Group Delft. Firstly, the Sustainability Officer of Prysmian Group Netherlands has joined an alliance for circular cables in 2017. Through collaboration with customers, a more circular cable was designed and piloted. Also, when implementing P-laser in 2008, the standards had to be changed. So there is experience changing standards as well. However, in order to realise this product system design, a collaborative attitude must be developed. This requires a change in mind-set which should become natural to Prysmian Group employees in all departments.

This mind-set change is also required for product system designs D and F. Product system design D will optimise power cable usage which lowers the need for new power cables. Therefore, additional income for Prysmian Group Delft must be generated by collecting used conductors for resale. Product system design D also requires logistical changes. Prysmian Group Delft will have to take back and reuse the used conductors via the market place. To summarise, unlike the designs discussed before, product system D requires significant internal changes at Prysmian Group Delft when implemented.

Product system F does not meet Prysmian's current financial risk prevention strategy. However, besides a change in financial flows, little internal changes need to be made as this product system solution does not require redesigns of Prysmian's products.

Benefits for customers related to the product system design ideas

When analysing the benefits the product system designs could bring to Prysmian's customers, it was found that product system A and B do contribute to

DSOs targets on circular purchasing. In the long-term, the higher recyclability of these power cables will reduce or eliminate their waste treatment costs as well.

Product systems C, D and E address the increasing problem of managing supply and demand caused by the energy transition. Product system C does directly result in benefits due to its easy-to-install features. Product systems D and E will become worth their investment on the longer run.

Product system F will allow a land owner with little capital to invest in renewable energy. Therefore, it is expected that receiving the required investment from Prysmian Group is beneficial. How this investment differs from other ways to acquire money is not investigated in this research.

Operational changes needed at customer

The changes Prysmian's customers need to make to implement the illustrative product system designs were investigated as well. Product system design A, C, D and E involve a new method for installation. This requires investments in educating the installers and changing other grid components. The same is likely to be the case for product system design B. However, in this case, as the cable design is standardised, this new installation method will apply to all new cables installed.

Product system design C does require extra time investment as well because the permission of municipalities is needed. The relationship between DSOs and municipalities is not new but it is another actor that needs to be convinced of the relevance of this product system design.

Product system design D does not only requires a new installation method, but also demands DSOs to invest in the monitoring of the data. This requires skilled employees. Also, it implies changes in logistical flows. As the power cable does consist of different smaller components that can be (de-) installed at different points in time, logistics will become more complex. To conclude, DSOs do need to change their way of working when implementing product system design D.

When integrating batteries into the electricity grid, this would change the way DSOs manage supply and demand. Research will need to be done on how to do this, which demands an extra investment of DSOs.
Product system design F has a different customer, namely the land owner. If this land owner was already planning to use the land for energy production, no changes are needed. However, an agreement must be set up on who owns the renewable energy technologies and which share of the electricity produced is for Prysmian Group Delft.

6.2.2 Contribution to system innovation

Starting point of this research was the belief that companies should strive to contribute to system innovation rather than focus on product improvements only. In this sub-section, it is discussed to what extent the different illustrative product system designs do contribute to system innovation. The analysis is presented in Table 10 on the next page.

Based on the analysis shown in Table 10, it was concluded that product system design D is the only product system design contributing to all SDGs. Also, it does contribute most to two out of three SDGs. Based on this single product system design, no conclusions can be drawn on the value of innovation area D compared to the other innovation areas.

6.2.3 Interpretation of the product system design evaluation

The aim of the developed PSDM is to support Prysmian Group with the design of product systems that create value for Prysmian Group while contributing to system innovation. Because this approach was only tested once in the form of six illustrative product system designs, no conclusions can be drawn upon to what extent the PSDM always meets this goal. However, the evaluation of the illustrative product system designs does show that it is possible to develop product system designs with the PSDM that combine value creation for Prysmian Group Delft with making a contribution to system innovation. Below, the most important outcomes of the qualitative evaluation of the product system designs are discussed.

Product system design A, developed by the design process currently used at Prysmian Group Delft, creates limited long-term benefits and only contributes to one of the SDGs. The other product system designs score better on both. However, these product system designs require more changes of Prysmian Group and its customers.

Product system D was mentioned specifically when analysing the changes required at Prysmian Group Delft and their customers when implementing this design. In contrast to product systems A, B and C, this design does require significant changes in economic and logistic processes. On the other hand, the contribution of product system D to the different SDGs was the highest. This sketches a trade-off between value for the company and societal benefits.

Based on the feedback collected during the different design presentations, it can be said that product system designs C and D were considered most innovative and interesting by Prysmian Group Delft and its customers. During the design process, it was found that these innovation areas have the right balance between not being too abstract while still allowing for much freedom. This resulted in product system designs that successfully combine energy-related issues with material-related issues. So in this research, innovation area C and D proved to be most valuable for the involved stakeholders. However, as said, no general conclusions can be drawn based upon these findings.

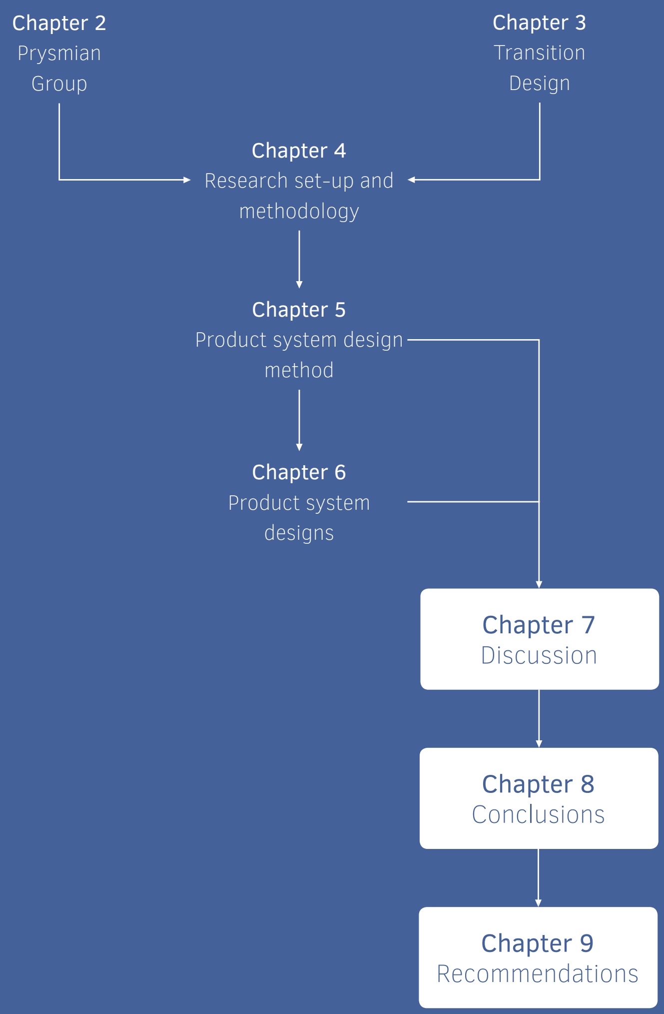
Table 10: Analysis of the contribution of the illustrative product system designs to different SDGs

SDG		Product system design A	Product system design B	Product system design C	Product system design D	Product system design E	Product system design F
7	Ensure access to affordable, reliable, sustainable and modern energy	No effect compared to current power cables	No effect compared to current power cables	Solution prevents delay energy transition caused by limited grid capacity	Solution can support different kinds of developments in energy transition	Batteries are able to reduce challenges of intermittency and reduce losses of electricity distribution	Investment in renewable energy technologies speeds up the energy transition
9	Build resilient infrastructure, promote sustainable industrialization and foster innovation	Little innovation compared to current power cables	Collaboration stimulates innovation	Little innovation compared to current power cables	Design allows space for future (digital) upgrades	Large investments in battery technology	Little innovation as renewable energy technologies will not specifically be developed
12	Ensure sustainable consumption and production patterns	Design supports recycling	Collaboration guarantees recycling	Smart use of materials, cables only installed where needed	Modular design and marketplace support component reuse	Depends on battery design. Research must be done to compare material requirements power cables and batteries	Not addressed

Legend
No / negative contribution to SDG
Has the possibility to contribute to SDG
Expected small contribution to SDG
Expected significant contribution to SDG

PART 3

Closing



7 Discussion

The results described in Chapter 5 and 6 provide the answer to the main research question. However, before drawing conclusions, these findings are first put into perspective by critically analysing the methodology and outcomes of this research. First, the methodology is discussed in sub-section 7.1. Sub-section 7.2 and 7.3 describe the outcomes of the research in relation to Prysmian Group and Transition design. Last, in sub-section 7.4, it is discussed how the outcomes of this research might have been influenced by circumstances outside the scope of research.

7.1 Discussion of methodology

When developing and using the methodology of this research, different decisions were made that are up for discussion. These points of discussion are described below.

7.1.1 Scope of research

The research focuses on the development of a design method for product systems. Underlying this focus is the decision to primarily address product innovation as mean to contribute to the transition towards a more sustainable society. However, companies can also innovate in other ways, such as process innovation or market innovation (Johne, 1999). Combinations are possible, as shown in the product system designs developed in this research. However, the illustrative product system designs are all based around the existence of a new product. When other types of innovation would have been taken as a starting point, different frameworks would have been used and different outcomes would have been generated. Based on this research, no conclusions can be drawn on whether a focus on product innovation does indeed lead to the most sustainable solutions.

Besides, the research took place at a single company and therefore resulted in findings specific for this company. The developed product system design method and the related insights should not be copied one-to-one and applied to other case studies.

7.1.2 Iterative approach

The iterative process used in the exploration phase helped to explore how a system approach could be integrated into the design process at Prysmian Group Delft in a systemic but flexible way. The iterative process was managed and documented carefully. Nevertheless, the process was less structured than the methodology describes. In-between discussions with supervisors, related news articles and other events did contribute to how the iterative process evolved. This is inherent to a flexible research method and did improve the quality of the results. However, it does make it hard to trace back which event led to certain insights. Often, it was a combination of these events that together resulted in a decision on what the next iteration should address. This means that, when redoing the research and speaking to different people and reading different articles in a different order, other decisions may be made.

7.1.3 Semi-structured interviews

Semi-structured interviews with Prysmian Group employees were conducted throughout this research. Also, multiple meetings with stakeholders were organised. These interviews and meetings were not recorded and transcribed afterwards. This increases the risk of errors in the outcomes. Although the interviewer did take notes of each part of the conversation, individual assumptions and expectations can influence the interpretation of the things said. This error is not fully avoided when recording the interviews, but would have been minimised.

Besides, the order in which the interviews were done was dependent on the agendas of the interviewees. Therefore, not all interviews were optimally used. To give an example, the meeting with the CEO of Stedin was scheduled very early in the research. Therefore, the questions that were asked were rather general. If this interview had taken place a few weeks later, possibly, more information could have been gathered.

7.1.4 Product system design evaluation

The developed product system designs were evaluated on the value they create for Prysmian Group Delft, as well as on to what extent they contribute to the SDGs. This was done in a qualitative manner in collaboration with the sustainability manager of Prysmian Group Delft. Three elements of this evaluation are up for discussion.

Firstly, the evaluation is subjective to assumptions of the reviewees. No data was used on how much value the developed product system designs would actually create. The lack of a quantitative comparison makes it challenging to draw conclusions on the value of the Illustrative product system designs.

Secondly, the use of the SDGs selected by Prysmian Group could be questioned. These SDGs represent issues that were focussed on in the design process. However, possibly other SDGs are negatively impacted by the developed designs. This possible shift of problems is something that should be avoided.

Last, it is important to note that the conclusions drawn based on six illustrative product system designs cannot be generalised. The illustrative product system designs are examples of possible outcomes of the product system design method and aim to show how the method could be used.

7.2 Relevance for Prysmian Group Delft

The aim of the PSDM is to support Prysmian Group to develop more innovative product system designs. This means that, inherently, these product system designs imply more changes compared to the incremental product improvements Prysmian Group is currently focussing on. This results in more insecurities, and therefore an increase in (financial) risk. As discussed in Chapter 2, Prysmian Group is focussed on minimising financial risks. So, the innovative product system designs developed in this research contradict one of the core strategies of Prysmian Group.

A question frequently raised during this research was why Prysmian Group should change its strategy. Their current strategy has proven to be effective for a long time, as they are global market leader. As long as there are no clear signs that governments, customers or shareholders require a more innovative strategy, there is limited incentive for the company to change.

A similar conclusion can be drawn for Prysmian's customers. Although their business strategy was not discussed as in-depth as the business strategy of Prysmian Group, Chapter 2 explains why grid reliability is a key driver for DSOs. This makes them reluctant to try out new innovations which have not been proven yet. In line with Prysmian Group, there is a fundamental contradiction between the strategy of DSOs and the innovative approach used in this research. Because DSOs are largely assessed based on reliable electricity distribution, there is no incentive to change this.

Given the limited incentives for Prysmian Group Delft and their customers to adopt a more innovative strategy, the implementation of the PSDM is not likely to happen anytime soon. However, the system approach that forms the foundation of the design method as well as some of the illustrative product system designs are still of value for the company. Different Prysmian Group employees pointed out that the concept of system levels did bring them new insights when it comes to sustainability. Also, some of the illustrative product system designs might be investigated further in the coming years. Additionally, the Sustainability Officer of Prysmian Group Netherlands suggested to present the product system designs at customer Alliander. The research will also be presented during a so-called Lunch & Learn session for Prysmian Group employees. This shows that the systems approach used in this research is considered worth sharing with people that were not involved with it.

Therefore, when evaluating on what this research brought to Prysmian Group Delft, it was concluded that it mainly offered a new perspective on sustainability. The system levels help the company to systemically explore and discuss how far Prysmian's sustainable design strategy could stretch.

7.3 Comparison with the Transition Design objectives

In this research, based on Transition Design, a system approach was integrated into the design process of Prysmian Group Delft. Chapter 6 shows that these design processes can result in product system designs that contribute to the SDGs. However, Transition Design aims to go beyond contributing to system innovation. It is based upon the belief that design is a powerful tool in the transition towards a more sustainable society. By identifying which solutions are needed in this future sustainable society, this transition can be realised. So, Transition Design does not only aim to contribute to system innovation, but rather focusses on steering or initiating these innovations.

Given the fact that the design process used in innovation area F is the same as the design process defined based on Transition Design literature, it can be expected that product system design F is in line with the ideas of the Transition Design research field. However, whether this product system design is a solution that steers the transition towards a more sustainable socio-technical system can be questioned. It is basically a solution addressing today's challenges by contributing to transitions that are already happening, rather than initiating the transition.

Two possible causes for this gap between Transition Design and product system design F are identified.

Firstly, as already discussed in Chapter 5, translating abstract ideas of a desired socio-technical system into concrete product system designs is challenging. Irwin (2015) writes: "Transition Designers learn to see and solve for wicked problems and view a single design or solution as a single step in a longer transition toward a future-based vision". This is a skill that requires practice. As the designer in this research has limited experience with this type of design, the gap between Transition Design theory and the illustrative product system designs can be partly explained.

Secondly, Transition Design assumes a certain power of the designer to influence the socio-technical regime. Joore & Brezet (2015) even formulate a system design process as one of the steps of the MDM. However, as discussed in Chapter 3, socio-technical systems are complex systems which cannot be designed but which continuously evolve. As complex systems are resilient, an innovation somewhere in the socio-technical system will not directly change all the elements of the system. To take the example of product system design F, if Prysmian Group invests in renewable energy, this will not directly change the Dutch energy system. However, if all companies start doing so, the impact on the energy system might be significant enough to initiate the rearrangement of other element in the system. It could, for example, result in different roles for energy suppliers, new legislation and new infrastructure.

So, Prysmian Group - like every individual stakeholder - does not have the power to steer the energy transition in a certain direction. All illustrative designs are developed based on the prerequisite that Prysmian Group must be able to realise the product system design. Innovations outside Prysmian's circle of influence, such as tax systems, may be more effective tools to steer the energy transition but are not considered in the developed product system designs. Therefore, unlike Transition Design theory, the developed product system designs do not aim to innovate socio-technical systems directly, but rather focus on understanding these systems and knowing how the company could contribute to them.

7.4 Identifying causes

Lastly, it is discussed to what extent the findings of this research are influenced by other things then intended. The illustrative product system designs developed were new to Prysmian Group Delft and in general enthusiastically received. It is however not possible to trace back what exactly contributed to the newness of these product system designs. The use of a system approach, based on Transition Design theory, is likely to have a stake in it. However, other circumstances might have contributed as well. For example, the fact that an intern focused on sustainable design full-time for six months means that much more attention has been paid to the topic than usual. Also, as none of Prysmian Group's employees have a background in product design, the fact that the intern has a background in design could have made a difference as well. To conclude, there is a limited understanding of what causes resulted in the development of new-to-the-company product system designs.

8 Conclusions

This research is based upon the belief that large companies, such as Prysmian Group, should change their sustainable design strategy from making incremental improvements on their products to developing product systems that contribute to system innovation. To support Prysmian's facility in Delft in doing so, the Product System Design Method (PSDM) was developed for the company. In the PSDM, the system approach used in Transition Design is integrated into the design process of Prysmian Group Delft. In total, six variations to Prysmian's design process were developed which increasingly address more system elements.

In order to be relevant for Prysmian Group Delft, the PSDM should result in product system designs that do not only contribute to system innovation but also create value for the company and their customers. By the use of a qualitative analysis of six illustrative product system designs developed with the PSDM, it was found that the product system designs developed by a design process which includes more system elements create more long-term benefits for Prysmian Group. Also, these illustrative product system designs contribute more to system innovation. However, the implementation of these designs also requires more changes at Prysmian Group and their customers. As the discussion was not quantitative, it could not be determined to what extent the benefits outweigh the required changes.

The product system designs that were developed by focussing on middle system level, the function-organisational system level, were generally most positively received by Prysmian Group employees. Also, these designs create the most long-term benefits for Prysmian Group and contribute most to system innovation. Although no conclusions can be drawn based upon the single design attempt done in this research, it does show the benefits of using different design processes. These different design processes help to explore the balance between system thinking and company interests. This focus on company interests is something that is lacking in the existing Transition Design frameworks.

Also, Transition Design assumes a certain power of the designer to influence the socio-technical system level. In practice, Prysmian's actions on their own have a minor impact on the energy system. Therefore, in contrast to Transition Design theory, the illustrative product system designs are not developed to steer the innovation of the energy system. They rather focus on understanding this system and how the company can contribute to making it more sustainable. The evaluation of the illustrative product system designs showed that this still resulted in designs that contribute to system innovation, which are new to Prysmian Group Delft and can be executed as they lie within the scope of influence of the company.

Despite that the illustrative product system designs seem promising, the actual implementation of these designs and the PSDM at Prysmian Group Delft remains challenging. Firstly, it requires investments, such as the employment of people with the right expertise to use the method. More importantly, it contradicts Prysmian's business strategy which is focussed on cost and risk minimisation. Prysmian Group is, on purpose, not a frontrunner in innovation and there is little incentive to change this. Also Prysmian's customers are reluctant towards innovation as they prefer to use proven products to secure grid reliability. As the PSDM has the main objective to develop more innovative ideas, its implementation at Prysmian Group is not expected anytime soon.

However, it is argued that the value of this research goes beyond the PSDM. The PSDM is one possible way for Prysmian Group Delft to contribute to system innovation. Different employees pointed out that the system approach, the foundation of the PSDM, brought them new insights related to sustainability. They offered opportunities to share the system approach towards sustainability with other employees and customers of Prysmian Group Delft. All of this contributes to the bigger goal of this research: changing Prysmian's sustainability strategy towards a stronger focus on contributing to system innovation. Changing Prysmian's sustainability strategy is something which cannot be done within a single thesis research project. However, by asking different questions than the usual ones, a first step is made in this direction.

9 Recommendations

Following from this research, different recommendations are formulated. First, recommendations for further academic research are presented after which a few recommendations for Prysmian Group Delft are listed.

9.1 Opportunities for further research

In this research, an alternative design method suitable for Prysmian Group Delft was developed. However, it was concluded that both at Prysmian Group Delft as well as at their customers, there is currently little incentive to use this innovation-focussed product system design method.

Therefore, it would be interesting to see if a similar approach in a different sector does result in other outcomes. In this research, the close relationship between Prysmian Group Delft and its customers was considered a plus as it was relatively easy to collect feedback during the design process. However, the fact that these customers were semi-governmental organisations did limit the possible innovations. Therefore, it is recommended to focus on a business-to-business sector as this allows for direct feedback while having more freedom to innovate.

Also, by redoing this research at other organisations, knowledge should be collected on which elements of the PSDM are company specific and which parts are of use for all sorts of organisations. Based on these insights, possibly a more general product system design method could be developed.

When doing a similar research at other organisations, it is also interesting to research what conditions must be met at these organisation to actually implement a product system design method which includes a system approach. This would help to get a better understanding of what contributes to the ability of a company to contribute to system innovation. Companies can again use this information innovate their organisation.

Last, it is argued that the evaluation stage of the PSDM should be investigated further. In comparison to the preparation and ideation phase, little time was invested into the exploration of this stage. It is recommended to further investigate when and how to involve stakeholders. Currently, this point in time was set at the end of the research. Adding knowledge on how to involve stakeholders differently in order to have a more collaborative design process, either through literature or by case studies, will improve the PSDM.

9.2 Recommendations for Prysmian Group Delft

Prysmian Group is a large and powerful company with proved to be profitable over a long time. This research proposed a few changes to their strategy which are contradicting the current strategy. Therefore, fully adopting this PSDM is not expected. However, as concluded in the previous chapter, parts of this research can still be of use.

Firstly, it is important to continue the discussion on Prysmian's sustainability strategy. Currently, Prysmian's sustainability KPIs are found to be rather unambitious and production-oriented. These KPIs are set in Milan. As Prysmian Group Delft is one of the frontrunners when it comes to sustainability within the global concern, possibly, Prysmian Group Delft could set their own targets for the coming years which address the system approach used in this research. In this way, they can keep up their position as one of the frontrunners in sustainability.

When trying to achieve these more ambitious KPIs, the system levels used in this research could be of help to identify and structure opportunities. Also, in the conversation with Alliander and other customers, adopting and using this idea of system levels could be very relevant to convince them.

Last, in order to achieve more ambitious KPIs, it is advices to invest in employees with a background in design. Sustainability is complex and cannot be addressed by linear thinking. Therefore, hiring someone skilled in creative problem solving is recommended.

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APPENDIX

A1 Interview protocol semi-structured interviews Prysmian Group employees

Opening

Introduce myself

- Introduce the research by the use of the MDM of Joore & Brezet (2015)
- Explain the purpose of today: getting to know Prysmian Group Delft and how they innovate

Questions

The questions below were prepared in advance. During the interviews, other questions were asked as well, based on the answers of the interviewees.

General questions

1. Please explain me about your job

- What are your responsibilities?
- With whom do you collaborate most?

2. What are past (sustainable) innovations at Prysmian Group I should know of?

- Were you involved with this innovation and what was your role?
- What was the reason behind this innovation?
- What limited/speeded up the implementation of the innovation in practice?

3. Would you say Prysmian Group is ahead of competitors when it comes to sustainable innovation?

4. Do you have any recommendations for people I should speak with, either within or outside Prysmian Group?

Specific questions sales

1. Can you describe the relationship with customers?
How do you communicate?

- Who is leading and who is following when it comes to innovation?
- Do you feel like your customers are open for more innovative ideas?

Specific questions R&D

1.What does the design method at Prysmian Group look like?

2.When looking at the NEN standards

- What is the purpose of the copper wire screen and why is it made out of copper?
- What is the purpose of the smaller conductorsHow are the different cables connected?
- Can I see such a joint?
- Why are you using PVC and rubber in the low-voltage cables?

3. Most of the environmental impact of a power cable is caused by the electrical losses during use. What changes could be made to a power cable to reduce these losses?

4. When ignoring customer demand, what would be the first improvement you would make to today's power cables?

Specific questions specific marketing

1. Who is responsible for the development of the content of Prysmian's sustainability strategy?

Specific questions specific purchasing

1. What are the criteria they use when purchasing materials?
2. Where did they buy the recycled plastics for the pilot with Alliander?

Closing

- Thank them for their time
- Ask if they would like to be invited for future creative workshops or design presentations

A2 Visits to stakeholders

Visit KRT (cable recycler)

Preparation

The following questions were prepared:

1. What happens to power cables after they arrive at their facility?
2. Which parts of power cables do they recycle?
3. What are considerations for recycling certain materials while incinerating others?
- Are fillers (in PVC) troublesome for the recycling process?
- Is rubber troublesome for the recycling process?

4. To what extent is P-laser interesting for him?
5. (When) do they use manual disassembling?
6. Collaboration:
- What should Prysmian Group do to improve the recycling of their power cables?
    - Better sorting
    - Different cable design
    - Marking of cable types
- How could the collaboration with their suppliers, such as Prysmian Group, be improved?

7. Future:
- How does he foresee the future of recycling?
- What will his company look like in 20 years from today?

Outcomes

During the visit, the recycling plant was shown and the recycling process was explained. Below, the highlights are summarised:

- Recycling process
    - All the incoming cables are shredded directly
    - Separation:
        - The metals are separated by air and electrostatic separators. This is the part that is most profitable and therefore most investments done here.
        - PVC is also separated out. A mix of 75% PVC and 25% other materials can be sold and is used for rigid building products.
        - Other plastics are incinerated. As Prysmian's waste does not contain high enough percentages of PVC and they cannot tell whether the plastics in the other cables are recyclable or not, all Prysmian's plastics are currently incinerated.

- Improvements Prysmian Group could make
    - Power cables with one type of plastics
    - Separation of own power cables so the ones with high performance thermoplastics can be shredded in separate badges.
- Their main focus is currently on high volumes. In the past, they did plastic separation as well but their cancelled that. From 2019 on, they will also stop recycling aluminium power cables. Copper recycling is currently too profitable to focus on other things as well.

Visit Stedin for interview CEO

Preparation

In collaboration with a sales employee of Prysmian Group Delft, the following questions were prepared:

Questions related to Stedin:

- Does you see the energy transition as a challenge for Stedin? What is this challenge exactly?
- Making the grid future proof while guaranteeing 24/7 supply of electricity is a demanding and also expensive task. How are you planning to keep down the costs?
- Is the slightly higher risk of outages, for the sake of a cost reduction, something you discuss with the ministry?
- You will be installing power cables that will be in use for at least 40 years. Have you ever asked yourself what the energy system will look like in 40 years from today? How is Stedin dealing with this issue?

Questions related to the Dutch climate agreement

- In the draft climate agreement (published in summer 2018), the focus is primary on renewable electricity production. As the chair of the grid operator branch association, do you feel like electricity distribution is not getting enough attention?
- In 20 and 30 years from today, all the solar panels and wind turbines that will be installed in the coming years will be end of life. Is circular economy something that is discussed during the climate agreement meetings?

Outcomes

Stedin's approach

- Stedin developed their 'One Planet Strategy', in which they investigated what their biggest impacts are and how these could be reduced. Their biggest impacts are:
    1. Losses during electricity distribution
    2. The materials that they buy
    3. Their own energy consumption (for buildings, cars, etc.)
- Currently, they are working on enabling the development of new parks by signing a purchasing contract for the produced electricity. These parks are usually financed by banks and as Stedin is very likely to still exist in the coming years, this makes investing less risky for banks. Marc thinks that more (semi-)governmental organisations should do this. It costs them money but the management at Stedin decided that this is 'the right thing to do'.

Material passports

The second highest impact of Stedin, the impact of the materials they buy, is the most challenging for them to tackle. Currently, they are taking the first steps in addressing this challenge by asking their suppliers which materials they use. This enables them to understand what they can ask in their tenders. Of course, they prefer to buy fully recyclable cables but he just has no idea whether that is a realistic request. In the end, they want different suppliers to be able to meet the requirements so they can pick the best one.

Electrification

Marc states that the Dutch Climate Agreement is beneficial for Prysmian Group. Almost all sectors are focussing on electrification. Stedin is planning to invest 20% more in the coming years. Considering the fact that they will be investing less in gas, the investments in electricity will rise significantly. This is needed as the current grid is not build for powering electric cars.

In the coming years, Stedin will be focussing on adding more capacity to the grid. For the coming 10 years, this is cheaper than making the grid more flexible, e.g. by adding storage. Only for temporary infrastructure, other alternatives are sometimes cheaper.

Long-term vision

I explain that I feel that everyone is very focussed on increasing the percentage of renewable energy produced by 2030. However, the cables that they are currently using will last for over 40 years. I am wondering whether they consider this long lifespan when designing the grid infrastructure. This makes him think, he is wondering what the electricity grid will look like in 40 years' time. He finds this question interesting but he has no answer.

Circular cables

The grid operators are paying for getting rid of old cables that are at their end of life. Therefore, for them it is beneficial if these cables would be easily recyclable, as this increases their value at the end of life. However, grid operators are reimbursed all their expenses if these are relatively lower than their market share. So, if all grid operators are doing more or less the same, this does not result in any benefits for an individual grid operator.

I am asking him if circularity is discussed at the discussion table focussing on electricity for the Dutch climate agreement. This is not the case. I explain to him that in 20-40 years' time, high amounts of solar panels, transformers and cables will be end of life. These products are currently designed to be as efficient as possible, often making them more complex and therefore harder to recycle. Again, he finds it interesting that I look at the bigger picture. He thinks this is something the producing companies should be solving. For him, the focus in on increasing the percentage renewables in the energy mix.

Adoption of new technologies

I am asking him how he deals with the fact that new technologies might be needed to reach the targets of the Climate Agreement, while the reliability of these technologies in practice is still uncertain. How to balance supply security and innovation?

He agrees that their purchasing policy is quite conservative. He starts explaining that the amount of outages is decreasing. Currently, they are researching a self-recovering system that can trace a failure and reset the system automatically.

He thinks that the company is definitely open for purchasing more innovative materials, as long as these are elaborately tested. He does not know why they do not have P-laser.

Supply chain collaboration

The cable supply chain is very much focussed on client demand. Stedin installs infrastructure based on what a client wants. Prysmian Group needs to meet the requirements of Stedin. Prysmian Group does the same with their suppliers. Possibly, when the supply chain would collaborate more, more innovative solutions to supply the final consumer with electricity might be possible. Marc agrees but again this is not on their priority list at the moment. He thinks that Prysmian Group could take the lead in this by organising 'innovation days'. Also, he thinks Prysmian Group could play a role in standardising the cables that are used by the different grid operators.

Visit Alliander to join activities installation instructor

Preparation

The following questions were prepared:

- What is the major difficulty when installing power cables?
- Do you have any ideas on how this could be made easier?
- Can I see a low voltage joint? How does it work?

Outcomes

During the visit, a medium voltage power cable had to be dismantled to inspect if there were any damages. During this process, there was plenty of time to ask questions. The most important finding were:

- When installing a power cable, it is a challenge to keep it dry and clean
- Installing a power cables is challenging and needs to happen by skilled people. Changing this installation procedure, additional training is needed which costs time.
- Grid operators are also handling based on customer demand. If a customer wants to install the grid in a certain way, the grid operator can advise to not do so often the grid operate ends up installing it in that way anyways.

A3 Creative workshops

Workshop 1: Simulating design method Prysmian Group Delft

Set-up

Three Prysmian Group employees (sales, services, and R&D) were invited for a creative workshop during lunch. The workshop aimed to identify existing ideas and develop more ideas based on Prysmian's current design method. In table A1, the workshop steps are described.

Outcomes

The identification of stakeholders and mapping of value destructions went relatively smooth. However, the participants did some trouble to map stakeholders they do not usually work with (e.g. waste treatment companies, electricity producers).

The most relevant value destructions identified were:

- Electrical losses during use
- The use of unrecyclable materials
- The small lengths of left-over cable after installation which remain unused
- The reactive rather than preventive maintenance approach (only repair a cable once it is broken rather than regular maintenance)

These value destructions as well as the developed opportunities were not new to the Prysmian Group employees.

Table A1: Overview of the workshop steps during the first workshop.

Step		Description	Relevance
1.	Introduction	Brief presentation of the background of the session + setting the rules	To manage expectations of the participants
2.	System development	Participants map the most important stakeholders	Setting up the socio-technical system
3.	Identification values	All the exchanges of value between the stakeholders are identified	This creates a better overview of what the different stakeholders actually do and collaborate
4.	Identification value destructions	All places in the value chain where value (environmental, social or economic) gets lost are identified	This shows where value could be gained which is an interesting starting point for a new business model
5.	Brainstorming	Opportunities to address the identified value destructions are formulated	These opportunities are the outcome of the session.
6.	Closing	Participants were asked what they thought of the workshop	To understand the relevance of this workshop for Prysmian employees

Workshop 2: Simulating design method Transition Design

Set-up

The second workshop was based upon the scenario method by Gaziulusoy (2010). However, the workshop described by Gaziulusoy took 2 days, rather than 45 minutes. Therefore, certain steps were skipped or simplified (Table A2). During this workshop, six Prysmian Group employees (R&D, sales, sustainability) of which two interns participated. Again, the workshop was organised during lunch.

Table A2: Overview of the workshop steps during the first workshop.

	Step	Description	Relevance
1.	Introduction	Brief presentation of the background of the session + setting the rules	To manage expectations of the participants
2.	Vision presentation	Presentation of different scenarios of the future energy sector (see Figure A1) based on reports	To structure the vision-development process. By starting from scratch, the vision development would take long
3.	Refining vision	In teams of 2/3, the participants have to refine the vision for 2050. This should include technical, economic, institutional and social elements	Gets the discussion started and helps the participants to actually 'understand' the vision
4.	Backcasting	In the same teams, participants formulate the changes (technical, economic, institutional and social) needed on the medium and short term to reach the long-term vision	The development of this timeline gives insights in necessary changes on the short-term that need to be made to reach to long-term vision. These short-term changes are used in the next step.
5.	Role of Prysmian	Of each short-term action, the participants need to think how Prysmian could contribute to this action	This links the society-oriented view that has been used so far with the company resources and values. Hopefully, this makes the ideas more tangible.
6.	Presentation of brainstorm	One member of each team present their findings briefly to the other teams	
7.	Closing	Discussion on whether the participants think that the selected actions are indeed relevant for Prysmian	Receiving input from participants whether they thought the method delivered new insights and whether these insights have potential to be put in action.

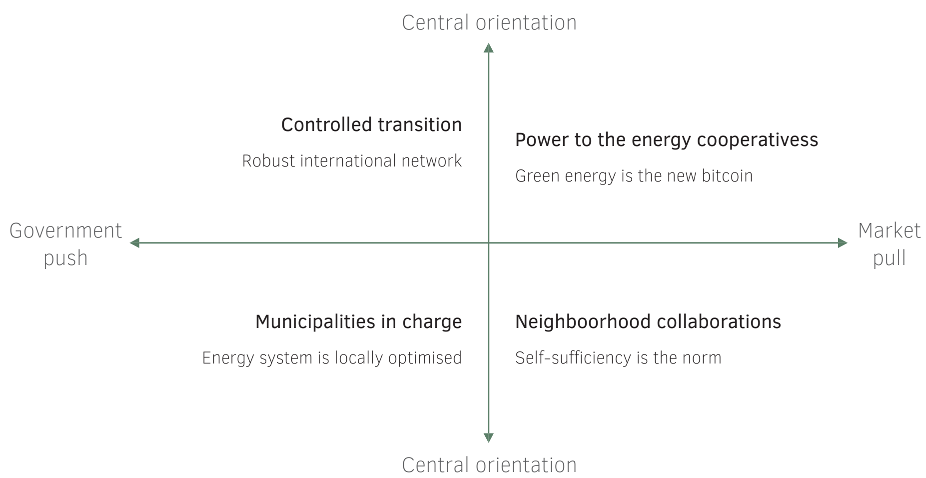

Figure A1: The scenario's used during the second workshop

Outcomes

Initially, they were a bit surprised that they had to do something, rather than just listening. However, soon they got the idea and slowly the discussions got more in-depth discussions. The participants did find it challenging to develop the visions based on a certain scenario, so therefore the workshop took a bit longer than expected. It was interesting to note how one team immediately understood and used the interconnectedness of the different types of elements (technical, economic, etc.) while the other team worked them out separately.

When closing the workshop, one of the participants confirmed that he thought that, based on this workshop, Prysmian Group Delft should actively develop products that contribute to the energy transition. However, as other participants address as well, Prysmian is highly dependent on the choices the government makes. Therefore, being ready for different scenarios is important.

The outcomes of the two scenarios selected by the participants are briefly discussed below.

Neighbourhood collaboration (decentral - market pull):

In 2050, citizens become prosumers who together invest in new energy sources. By then, a wide range of small-scale renewable energy technologies are on the market (e.g. micro turbines, hydrocarbon biomass and storage equipment). The government only has a small role by setting the energy tariff ranges and regulating the connections between different neighbourhoods. The investments in the national grid are small while the local grids have gained capacity and flexibility. From a cultural perspective, attitudes towards energy has changed. Citizens feel responsible for supplying themselves with energy and do not want to be dependent on the government.

Having a fully decentralised energy system is considered to be more relevant and likely for less-developed countries. Prysmian Group facilities in those regions could support this transition by developing smart cables with inbuilt control and monitoring capabilities. Also, Prysmian could stimulate the transition by micro-financing certain projects.

Municipalities in charge (decentral – government push):

In 2050, each municipality has its own system to supply inhabitants and companies with energy. This means that different municipalities can have different energy infrastructures and related energy prices. Local DSOs are in charge of managing the grid. Competition between different municipalities to attract inhabitants by their low energy prices is common.

The municipalities arrange deals with citizens to invest in renewable energy technologies. Some people are unsatisfied by the system as they do not want to be dependent on their municipality for energy production and rather arrange things themselves.

In order to make this future scenario happen, the efficiency of energy conservation and storage needs to increase significantly. Subsidies will be needed to stimulate this efficiency increase. From an organisational perspective, it is expected that neighbourhood districts slowly start organising their energy supply themselves after which the government decides to organise these initiatives by the establishment of local DSOs. Initially, this will lead to limited amounts of energy as renewable energy technologies are still under development. However, around 2040, it is expected that energy supply is secure.

In order to stimulate this transition, Prysmian should invest more time and people into technical innovations. Also, Prysmian could stimulate the transition to an electrical system (rather than a hydrogen-based system) by subsidising renewable energy projects.

Workshop 3: Innovative technical cable solutions

Set-up

For the third workshop, 6 R&D employees were invited. There employees were asked to forget about the NEN standards, with which they usually work, and come up with creative solutions to the core functionalities of a power cable. The steps taken during this lunch session are shown below (Table A3).

Outcomes

The workshop served its goal, in the sense that many technical solutions were formulated to fulfil the core functions of a power cable. The participants enjoyed the creative thinking, as it is very different from what they usually do. However, the ideas generated were mainly materials or the use of a 12 Volt Direct Current grid. The how-to questions did not trigger the participants to think about the shape and build-up of a power cable.

Table A3: Overview of the workshop steps during the third workshop.

	Step	Description	Relevance
1.	Introduction	Brief presentation of the background of the session + setting the rules	To manage expectations of the participants
2.	Idea generation	In teams of three, the participants were asked to develop as many ideas as possible for the following how-to questions: • How to conduct electricity? • How to insulate the conductor electrically? • How to prevent accidents in case of emergency? • How to prevent mechanical contact with its surrounding (water, etc.)?	The core of the workshop in which the ideas are generated
3.	Closing	The participants were asked what they thought of the workshop	To hear if the participants enjoyed the workshop

Workshop 4: Product solutions for challenges at higher system levels

Set-up

During the fourth workshop, three Industrial Design graduates were asked to join a brainstorm addressing different how-to questions. The steps taken during this workshop are discussed in Table A4.

Outcomes

In total, eleven how-to questions were answered by, in total, dozens of ideas. Some of these ideas proved to be very relevant for the development of illustrative product systems C and E. Also, although this was not thought of before, the ideas were also useful in the development of product system D.

Table A4: Overview of the workshop steps during the fourth workshop.

	Step	Description	Relevance
1.	Introduction	Brief introduction into Prysmian, electricity distribution and the energy sector	Provides the participants with the basic knowledge needed during the workshop
2.	First round of idea generation	• Of each of the stakeholder challenges identified in the function-organisational system level and the socio-technical system level, a how-to question was formulated and written down on a large piece of paper. Through brainwriting, the participants are asked to generate as many ideas as possible	By splitting the designs into different how-to questions, many ideas could be generated for which limited knowledge was needed
3.	Selection	Collaboratively, the most relevant ideas that need some further thinking were selected. These were again rephrased into a how-to questions	As the first how-to questions were very general, it was found that more in-depth idea generation would improve the concreteness of the ideas
4.	Second round of idea generation	The newly developed how-to questions were answered in a similar way as in step 2	To create more concrete ideas on specific topics
5.	Closing	Thanking the participants for joining	

Workshop 5: Product system solutions for all system levels

Set-up

During the fifth workshop, the use of an external strategic consultant was simulated though the inviting Industrial Ecology students. Industrial Ecology students are expected to be familiar with the concept of complex systems, which was expected to be of use for the product system designs based on visions.
The workshop consisted of the following steps shown in Table A5.

Outcomes

First of all, the students enjoyed the workshop and they enjoyed the tour in the manufacturing plant that followed afterwards.
The strategies developed by the different groups of students were the following:

- Cable as a service (2x)
- Partnering with other utility infrastructure manufacturers to create a multi-utility system
- The use of scenario-based LCA studies
- Development of modular cable systems

On the one hand, the developed ideas were considered interesting as they could create value for Prysmian's customers to offer these solutions. On the other hand, all the ideas mentioned were already thought of before. It was expected that a few view on the problem statement might bring new insights. However, it was concluded that only a few hours might be quite short for this.

Table A5: Overview of the workshop steps during the fifth workshop.

	Step	Description	Relevance
1.	Introduction by Sustainability Officer	Welcome, introduction Prysmian, their products and their sustainability strategy by Frank	To inform the students about the basis
2.	Introduction to the problem statement	Summary into the research done so far to introduce the problem statement that the participants will be working on.	So the students understand the relevance of the problem
3.	General brainstorm	Participants are asked to write down all the thoughts they have regarding the problem statement (first individually, then in teams of 2-3)	To get the first ideas out of the way and start the discussion
4.	Roles	The teams are asked to come up with solutions for the problem statement out of 3 different perspectives: the grid operator, a tree hugger and Prysmian's management	This adds new ideas to the conversations
5.	Scenarios	The same scenarios as used in the first iteration are introduced. The teams are asked to pick two opposite scenarios, develop a vision for these scenarios and develop solutions based on these vision.	This adds new ideas to the conversations
6.	Strategy development	The teams are asked to come up with one final advice for Prysmian on what they should be doing to address the problem statement	This forces the students to make choices
7.	Pitch	Each team pitches their final strategic advice	This helps to exchange thoughts between the different groups
8	Concreti-sation	The teams are asked what they would advise the R&D manager of Prysmian to work on	This translate the vague strategy in concrete focus areas

A4 Design presentations

As discussed in Chapter 5, three times of design presentations were organized during the exploration phase. These presentations are described more in-depth below.

Discussing design sketches with Prysmian employees

During the design presentations with Prysmian employees, the developed product system designs were presented one-by-one after which feedback was asked:

- Which designs do you find most interesting and why?
- What would make this product system design even more interesting for Prysmian Group?
- What changes would Prysmian Group have to make when implementing this design?
- What barriers do you expect when implementing this design?

Meeting notes were taken and used for the improvement of the product system designs

Discussing design concept with customers

As discussed in Chapter 5, it was chosen to not show the design sketches at customers as the aim was to explore what they would think about certain concepts rather than end up in a discussion on details. During the meetings with Exexis, Alliander and Stedin, the following concepts were discussed:

- Above-ground power cables, e.g. hidden in the pavement or on roofs
- A lease system for power cables
- Power cables that of which the capacity of the conductors can easily be increased or decreased depending on future demand
- Replacing the copper wire screen with an aluminium alternative

Design presentation at Alliander

To communicate the findings of this research with one of Prysmian's customers, Alliander, a creative workshop was organised. The aim was to hear their opinion on the system-levels thinking as well as to explore if a creative workshop is a useful way to communicate this.

Set-up

During a 2-hour meeting with five Alliander employees and two Prysmian employees, the new design method and related product system designs were communicated. The workshop plan that was used can be found in Table A6.

Outcomes

The meeting was considered by the attendees as it was a new type of discussion between Prysmian Group and Alliander. Not many new ideas were generated but insights were gathered on projects that happened in the past that were similar to the product system designs developed. The most relevant discussion started when presenting the developed product system designs. However, it was challenging to keep the discussion on the topic.

Table A6: Overview of the workshop steps during the fifth workshop.

	Step	Description	Relevance
1.	Opening	Introduction round of all people on the table	To discuss backgrounds and expectations
2.	Introduction	Introducing the research and the aim of the meeting	To manage expectations of the participants
3.	Discussing circular cables	Asking the attendees how they would describe a circular power cable	Opportunity to gather information on their view on the future power cable.
4.	Presenting product system design A	Presenting the design and asking for comments	To gather feedback for this design
5.	Introduce Transition Design	Explain Transition Design and its relevance. Introduction to the problem statement: long lasting products in quickly changing sector. Possible solution: flexible grid	To provide the required background knowledge
6.	Brainstorm flexible grid	Make groups of 2 and ask them to discuss what this flexible grid could look like	To start the idea generation process
7.	Presentation ideas	Ask groups to quickly explain what their discussion was about	To share knowledge between the groups
8.	Introduce 3 different types of application low-voltage grid	Explaining that different applications might require different types of solutions. Ask groups to discuss specific solutions for these three applications	To make the ideas more specific
9.	Identification partners	Ask groups to formulate which partners would be needed to implement their solutions	To improve the solutions (might bring more ideas) and make them more concrete
10.	Presentation ideas	Ask groups to quickly explain what ideas they developed	To hear all the ideas developed
11.	Present product system designs C and D	To show what this research brought and to ask for feedback	Extra input for the discussion on whether this is an interesting way to go
12.	Closing	Discuss what they thought of it and what everyone is planning to do with the information gathered	To gather feedback