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STUDENT REPORT

Master Thesis

Sustainability in the wind industry: An approach of translating organisational-level sustainability targets to product-level and improve the capacity of design departments to create more sustainable products

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Glossary

Term	Explanation
BoM	Bill of Materials
$kgCO_2e$	Kilograms CO_2-equivalents
GHG	Greenhouse Gas
GW	Giga Watt
kWh	kilo Watt hour
LCA	Life Cycle Assessment
LCoE	Levelized Cost of Energy
MW	Mega Watt
MWh	Mega Watt hour
OEM	Original Equipment Manufacturer
SBTi	Science Based Targets initiative
SBT	Science-based target
Scope 1 emissions	Scope 1 describes direct emissions of the organisation, which may occur through its facilities and vehicles. (GHG Protocol, 2019)
Scope 2 emissions	Scope 2 describes indirect emissions from purchased energy sources, such as electricity, or heating and cooling. (GHG Protocol, 2019)
Scope 3 emissions	Scope 3 encompasses all the indirect emissions caused by upstream and downstream activities of the value chain. (GHG Protocol, 2013)

Abstract

An ever-increasing number of companies set science-based targets and formulate sustainability strategies. Now they are challenged by the implementation of the strategy and the operationalisation of the targets within the organisation. Catering towards this need and filling an identified gap in the literature, this study aims to find a way to translate organisational-level sustainability targets to product-level and improve the capacity of design departments to design more sustainable products. This is done via a case study of the wind turbine manufacturer Vestas, who faces above-mentioned challenges. Utilising the example of Vestas' science-based Scope 3 GHG reduction target, this thesis presents a process of translating the organisational-level target to product-level, including the identification of emission hot spots and definition of design departments' respective contribution share towards the product-level target. Finally, it investigates the sustainability opportunities and barriers seen by the design departments and identifies design departments' needs to be able to focus on the design of more sustainable products.

Key Words

Sustainability targets, Sustainability strategy, Translation of targets, Sustainable design, Life Cycle Assessment, Wind industry, Renewable energy

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1 Introduction

In 2015, the Paris Agreement manifested that "[h]olding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (United Nations, 2015, p. 22) would be necessary to avoid the worst impacts of climate change. The agreement heralded a new era in the global governance of combatting climate change (Dimitrov, 2016; Falkner, 2016), as it defined a new polycentric system for climate governance (Ostrom, 2010) in which nations set individual Greenhouse Gas (GHG) emission reduction goals. To keep the global increase in temperature to 1.5 °C above pre-industrial levels, net-zero GHG emissions need to be reached by mid-century, which requires unprecedented efforts (IPCC, 2018). The UNEP Emissions Gap Report discloses that even if all current National Determined Contributions (NDCs) would be delivered successfully, the global temperature increase would only be limited to a 2.3 - 3.3 °C increase over pre-industrial levels (UNEP, 2021). Therefore, contributions from other entities, such as companies are needed, which play a vital role in achieving the goals of the Paris Agreement according to Wright & Nyberg (2017).

Companies contribute directly to GHG emissions through their operations (Scope 1), and indirectly through their purchased energy (Scope 2) (GHG Protocol, 2019), as well as through their upstream and downstream activities (Scope 3) (GHG Protocol, 2013), which are associated with the production, transportation, use and disposal of their products. Due to the significance of corporate GHG emissions, the Global Reporting Initiative has since 2002 encouraged companies to disclose their environmental performance in relation to "*global limits on resource use and pollution levels*" (GRI, 2002, p. 28). However, adoption of the approach lacked in the early stages (Bjørn et al., 2016). Here, companies set their corporate emission targets according to national climate policy, competitor benchmarks, consultancy advice, past performance, or achievability assessments (Rietbergen et al., 2015), with the intention of improving their strategic positioning and image (Dahlmann et al., 2019). First after the Paris Agreement's polycentric governance approach and the UNEP's Emission Gap Reports in 2016 and 2021 highlighting the insufficiency of national contributions (UNEP, 2016, 2021), pressure increased for companies and other non-state actors to take action and align their targets with the goals of the Paris Agreement. In 2015, the Science Based Targets initiative (SBTi) was created, which is a "*partnership between CDP, the United Nations Global Compact, the World*

Resources Institute, and the World Wide Fund for Nature" (Science Based Targets, 2022b) which provides companies with methods, guidelines and tools to set Paris-aligned GHG reduction targets and certifies them. Since 2015, more than 1,400 companies have set science-based targets (SBTs), with an exponential increase in companies seeking verification within recent years (Giesekam et al., 2021), which may be due to the fact that SBTs are now *"widely associated with serious intentions on climate action"* (Bjørn et al., 2022, p. 2). While SBTs are an excellent way of setting company-level targets and align the private sector with the temperature scenarios of the Paris Agreement, the methodology does not cover how the target can be translated within companies any further.

Apart from GHG emission reductions, there is increased focus and awareness on sustainability in general. Therefore, oftentimes GHG emission reduction commitments are not made standalone but as part of corporate sustainability strategies, covering both Environmental, Social and Governance (ESG) aspects. An example of this is the wind industry, where GE Renewable Energy is part of its parent company GE's sustainability programme, and the other large western Original Equipment Manufacturers (OEMs) Enercon, Nordex, Siemens Gamesa and Vestas all pursuing their respective corporate sustainability strategies (Enercon, 2021; General Electric, 2022; Nordex, 2022; Siemens Gamesa, 2021; Vestas, 2022d). With their strategies, the Wind OEMs make commitments within Environmental Sustainability such as reducing their Scope 1, 2 and 3 emissions, but also improving the circularity of their products, reducing waste and increasing the amount of waste for recycling. In terms of Social Sustainability, safety and diversity and inclusion commitments are made, and in terms of Governance, codes of conduct are introduced, to ensure ethical business and compliance with regulations. While the launch of sustainability strategies with a range of commitments clearly shows that sustainability gains more and more significance even in arguably already sustainable sectors like the wind industry, these strategies also represent significant challenges for the business in terms of implementation and execution throughout the organisation. This entails operationalising the commitments and targets made in the strategy to deliver upon them and investigating internal needs for aligning actions with the organisational-level target to be able to equip departments with the right set of knowledge and tools to execute the strategy. This thesis takes the Wind OEM Vestas as a case study, focuses on the company's challenges and conducts empirical research within the organisation. In the following, the organisation, its sustainability strategy and its challenges are presented, after the reading guide (see Figure 1).

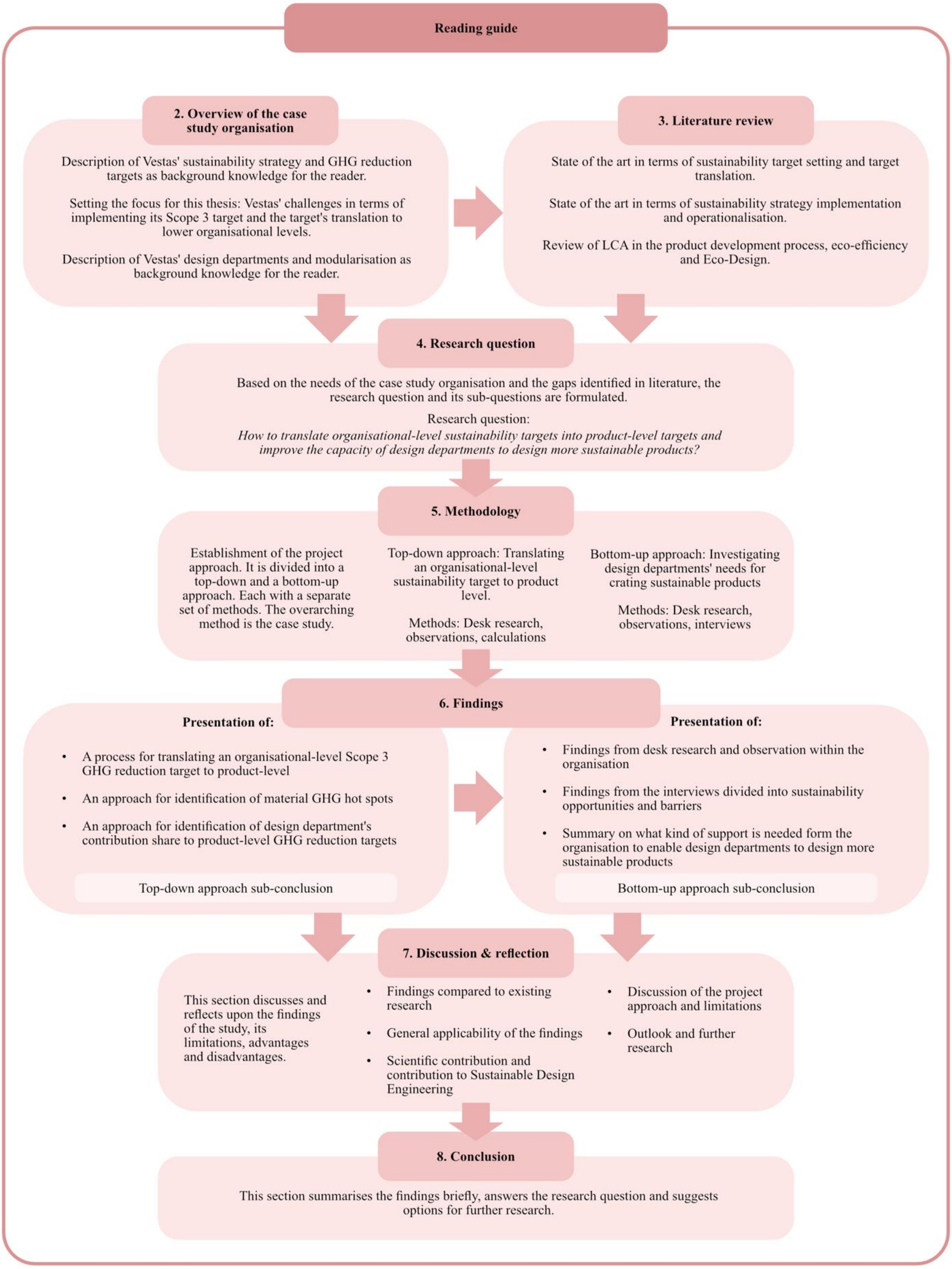

Figure 1: Reading guide

2 Overview of the case study organisation: Vestas

The partner organisation of this research and subject of this case study is the Danish Wind OEM Vestas Wind Systems A/S. In 2022, Vestas is the world's largest Wind OEM with a revenue of EUR 15.6 bn and an employee count of 29,000 (Vestas, 2022e).

2.1 Vestas' sustainability strategy

After a long time with an attitude of 'Sustainability is the business, we are in' the company realised that just providing renewable energy was not sufficient. Customers, shareholders and other stakeholders increasingly focused on sustainability that went beyond the wind turbine that produced renewable electricity. The carbon footprint of the organisation, its production and supply chain became to matter, as well as the circularity of its products, the safety, diversity and well-being of its employees.

To respond to this, in February 2020, Vestas launched its corporate sustainability strategy called 'Sustainability in Everything We Do'. As such, it was the first Wind OEM to launch a comprehensive, overarching sustainability strategy bundling all sustainability activities in the organisation. When defining what sustainability means for Vestas, the company refers to the Brundtland Commission's definition of sustainability, which reads as follows:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 1987, p. 54)

Based on this, Vestas defines sustainability for themselves as:

"Sustainability at Vestas means reducing or eliminating negative environmental and social impacts. It also means maximising the value that our business and products provide for our customers, employees, shareholders, suppliers, local communities, and the planet at large."(Vestas, 2022d, p. 9)

When this report mentions 'sustainability' it is referred to the above definition. The company expands on its sustainability definition by stating:

"It involves upholding sustainability in governance structures, whereby we hold ourselves accountable to internationally recognized principles and standards; whereby we act with integrity and responsibility, and safeguard responsible processes and renumerations."(Vestas, 2022d, p. 9)

Vestas' sustainability strategy contains commitments in four overarching fields:

1. Carbon footprint
2. Circularity
3. People
4. Leadership

From these fields it is evident that the strategy does not only focus on environmental sustainability but also on social responsibility (People) and economic and strategic aspects (Leadership).

Each of the fields contains one key goal (as shown below):

- Carbon neutrality by 2030 without carbon offsets
- Producing zero-waste wind turbines by 2040
- Becoming the safest, most inclusive & socially responsible company in the energy industry
- Leading the transition towards a world powered by sustainable energy

This thesis' focus lies on environmental sustainability and carbon footprint in particular, which is why the following abstract describes Vestas' carbon footprint targets more in detail.

Within the carbon footprint field of Vestas' sustainability strategy, the overarching goal is to achieve carbon neutrality by 2030 in their own operations (covering Scope 1 and Scope 2) without the use of carbon offsets. The company states that *"the problem with carbon offsets is it can be very difficult to ascertain that the projects invested in are real, measurable, permanent and that they would not have taken place without the finance provided by the sale of credits"* (Vestas, 2022c). Due to this reasoning, Vestas decided against the use of carbon offsets to achieve carbon neutrality in their own operations. Consequently, the target is an absolute target meaning that Vestas will reduce their carbon emissions by 100 % by 2030. Moreover, it is verified by the Science Based Target initiative, which confirmed that the target *"is in line with the high-ambition level required to keep global warming to 1.5°C above pre-industrial temperatures"* (Vestas, 2022a). Vestas aims to achieve these reductions by switching their electricity consumption to 100 % renewable electricity, replacing their heating and air conditioning systems in their factories with renewable sources, exchanging their benefit car and service vehicle fleet with battery electric and sustainably fuelled vehicles, and for offshore operations replacing conventional service vessels with alternative, sustainably fuelled vessels.

Vestas' second goal in the carbon footprint field is the reduction of their Scope 3 emissions, which make up more than 99 % of the company's total emissions. Here, Vestas sets itself the target to reduce CO_2 emissions from their supply chain by 45 % per Mega Watt hour (MWh) generated by 2030. This is a relative target, or GHG emission intensity target, which was set deliberately to still allow the business to grow in the future. Nonetheless, the target has been verified by the Science Based Targets initiative for being in line with the ambition level to keep global warming to 2.0 °C above pre-industrial levels. The Science Based Targets initiative requires at least two thirds of emissions to be covered by a target for Scope 3 (Science Based Targets, 2021). In alignment with this, Vestas' Scope 3 target covers a 45 % reduction per MWh of 70 % of its total Scope 3 emissions. Vestas Scope 3 emissions are calculated with the help of Life Cycle Assessments (LCAs). The company has conducted LCAs for each of its turbine models, which disclose the Global Warming Potential in gCO_2e/kWh[1] and can be converted to $kgCO_2e/MWh$[2]. The reduction is then measured annually upon the global average emission intensity for the turbines delivered in the respective year. To achieve the Scope 3 target, the company's approach is initially to partner with their so called 'strategic' suppliers, which cover the majority of Vestas' material spend. These suppliers will introduce measures to both calculate and reduce carbon emissions. This entails for instance switching to 100 % renewable electricity. Once proven and matured, the approach will be extended to smaller suppliers as well.

[1] Grams CO_2-equivalent per kilo Watt hour

[2] Kilograms CO_2-equivalent per Mega Watt hour

Table 1 provides a summary of Vestas' carbon footprint related targets and actions.

Vestas environmental sustainability targets

<table>
<tr><th colspan="4">Carbon footprint</th></tr>
<tr><th>Emission Scope</th><th>Scope 1</th><th>Scope 2</th><th>Scope 3</th></tr>
<tr><td>Target</td><td colspan="2">Reducing CO_2 emissions in own operations by 100 % by 2030, without using carbon offsets</td><td>Reduce the CO_2 emissions from our supply chain by 45 % per MWh generated by 2030</td></tr>
<tr><td>Science Based Target initiative verification</td><td colspan="2">Verified for keeping global warming to 1.5 °C above pre-industrial levels</td><td>Verified for keeping global warming to 2.0 °C above pre-industrial levels</td></tr>
<tr><td rowspan="4">Actions</td><td colspan="2">100 % renewable electricity consumption (achieved in 2020)</td><td>Partnering with 'strategic' suppliers covering the majority of Vestas' material spend</td></tr>
<tr><td colspan="2">Replacement of air conditioning and heating in factories</td><td>Suppliers required to calculate and report on emissions for products delivered to Vestas</td></tr>
<tr><td colspan="2">Exchanging benefit cars and service vehicles with battery electric and sustainably fuelled vehicles</td><td>Suppliers required to commit to switching to 100 % renewable electricity</td></tr>
<tr><td colspan="2">Replacing offshore service vessels with sustainably fuelled alternatives</td><td></td></tr>
</table>

Table 1: Vestas environmental sustainability targets - carbon footprint

All three of Vestas' carbon footprint targets have been verified by the Science Based Targets initiative. The company reports on its carbon footprint in quarterly financial reports and its annual sustainability report. For reporting its environmental impacts, Vestas uses the existing Sustainability Accounting Standards Board's Sustainability Accounting Standard, which offers structure for reporting of enterprise ESG impacts and transparency for stakeholders (SASB, 2018; Vestas, 2022d). The reported Scope 1 and Scope 2 emissions are calculated from internally collected operations data, while LCA methodology according to the ISO 14044:2006 standard is utilised to calculate environmental impacts of its individual wind turbine models as well as its Scope 3 emissions. Finally, Vestas reports data to select sustainability indices like Carbon Disclosure Project, Corporate Knights, Dow Jones Sustainability Indices, and ISS ESG (CDP, 2022; Corporate Knights, 2022; Dow Jones Indices, 2022; ISS ESG, 2022). The scores are publicly available on the company's website (Vestas, 2022b).

2.2 Vestas' challenges & focus of this thesis

Vestas' sustainability department, a global function in the organisation, is responsible for the formulation and implementation of the sustainability strategy as well as for reporting upon its progress. With the sustainability strategy launched in February 2020, the organisation is now at a point where measures which can be taken on the global company-level to achieve Scope 1 and 2 reductions have mostly been introduced, such as switching to 100 % renewable electricity. Since Scope 1 and 2 can be controlled relatively well and represent less than 1 % of Vestas' total GHG emissions, this paper's focus is in particular on the Scope 3 target. Vestas' challenge here lies not only in committing suppliers to sustainability actions, such as setting their own GHG emission reduction targets, but also committing its own organisation to the target and operationalise it within the relevant departments that can meaningfully contribute to Scope 3 reductions. Since the company's Scope 3 emissions are connected to the life cycle of its products, the relevant departments that need to be involved are the different design departments, as well as procurement. With a governance structure in place and sustainability champions in each of Vestas' design departments and procurement, the organisation's global sustainability department now sees the need to make the Scope 3 target more tangible by cascading it down to the design departments and supply them with the necessary knowledge and tools to achieve it. This is the challenge that is intended to be solved by this master thesis. It deals with how the Scope 3 target can be made tangible for and translated to the different departments in the organisation, how their contribution to it can be measured, responsibilities be assigned, and how progress towards the target can be tracked. It aims to conduct, follow and describe the organisational flow-down and methods utilised to translate the organisational-level

Scope 3 target into product-level targets and targets for the individual design departments. Moreover, it investigates, through a number of interviews with employees in the blades design department, whether these targets would support them and what other support in terms of e.g. tools and knowledge is needed to design more environmentally sustainable products.

2.3 Background on design departments and modularisation

In order to ease the reader's understanding of this study's findings the organisational setup of the design departments is described in more detail. For this, it is important to note that Vestas has transitioned towards modular turbine designs. *"The main purpose of modularity is to carry over proven technologies and well-established smart solutions from one tailored product platform to another"* (de Vries, 2020). By re-using components and assemblies in different products, both product and process flexibility are improved, and road transport can be optimised. This enables quick responses to dynamic market needs (de Vries, 2020). This modularity approach is also reflected in Vestas' organisational structure. Due to confidentiality reasons, the full organisational module structure will not be disclosed, however an approximate example is provided. In the modular structure, the organisation is divided into different design departments, so called 'Design Modules', which are each responsible for designing a range of different components, so called 'Configuration Modules'. For the sake of simplicity, the 'Design Modules' are called 'design departments' in this report and 'Configuration Modules' are called 'components'. To provide an example, the tower design department is responsible for designing the majority of components for the tower, while e.g. parts of the internals can be designed by another design department. The design departments follow a stage-gate-model product development process that describes what, when and how to deliver in a product development project. This product development process contains standardised milestones, activities, and deliveries within each gate which can be tailored in the projects depending on the project scope. Moreover, it contains a range of design requirements and turbine level and Key Performance Indicators (KPIs) for the design departments to reach at the gates. For this study, several employees in Vestas' blades design department have been interviewed (see results in Section 6.2) to investigate their needs for support from the organisation to design more environmentally sustainable products and to evaluate whether the translation of organisational-level targets to product-level targets, as well as targets for the different design departments would be of support to them.

3 Literature Review

As this thesis focuses on the challenge of implementing and executing an organisational-level sustainability target within an organisation, literature on the following topics is reviewed.

- Sustainability strategy implementation and execution (success-factors)
- Sustainability target setting and translation (methods)

Due to the challenge of enabling design departments to deliver upon environmental sustainability targets, the following topics are reviewed.

- Implementation of LCA in the product development process
- Eco-Efficiency concept
- Eco-Design

3.1 Implementation and execution of sustainability strategies

In the light of climate change as well as increasing customer demand for sustainable solutions, an increased number of companies intend to follow the goals of the Paris Agreement with their actions (Giesekam et al., 2021). Often this involves launching sustainability strategies including dedicated carbon footprint reduction targets. The main external drivers for corporate sustainability (CS) are found to be reputation, customer demand and expectations, as well as regulation and legislation, whereas internally it is mostly driven by leadership and business cases (Lozano, 2015). However, when formulated and launched, sustainability strategies present organisations with several challenges around its implementation in the organisation and its execution, which several scholars have investigated.

Engert & Baumgartner (2016) find that six factors are decisive in successfully implementing a corporate sustainability strategy: organisational structure, organisational culture, leadership, management control, employee motivation and qualifications, and communication. Their research shows that for sustainability strategy implementation, it is essential that strategies, organisational structure and organisational processes fit together. Moreover, they find the necessity for a clear definition of sustainability plus an associated vision. These ease integrating sustainability into the organisational culture.

Manninen & Huiskonen (2022) added to this by defining organisation-related and employee-related success factors, as well as listing internal activities advancing the implementation of integrated corporate sustainability and business strategies. They find that setting measurable and role dependent targets, such as business unit sustainability targets can advance the implementation of a sustainability strategy, since it enables *"employees to contribute to company level sustainability targets"* (Manninen & Huiskonen, 2022, p. 7), whereas it is harder for them to relate to the organisational level targets. Moreover, the study confirms previous findings that when sustainability targets being integrated in employees' personal KPIs, it becomes easier for them to focus on sustainability and connect it with their daily work (Manninen & Huiskonen, 2022), which is in line with goal-setting theory stating that goals channel attention and effort on activities relevant to achieve the goal rather and away from activities that are less relevant to achieving the goal (Locke & Latham, 2002).

Regarding the implementation of environmental strategies in manufacturing companies, Bey et al. (2013) find that major barriers are the lack of information on environmental impacts, lack of specialist knowledge, the difficulty of finding alternative materials and components, as well as the constraint of no additional resources being allocated to the tasks. Additionally, drivers for environmental strategies were identified as legislation, customer demand as well as proactivity. According to their conclusion, it is recommended to check and improve information flows, pursue the application of product lifecycle management, establish a clear management structure and 'Eco-champions' throughout the company, and follow pre-legislative dialogues.

The review of literature on the implementation and execution of sustainability strategies uncovered a number of success factors, internal activities and barriers. This study intends to add to these with specific success factors, barriers and needs for design departments to design more sustainable products. Moreover, the findings from the review above are compared to the findings from this case study and evaluated upon in Section 7.

3.2 Sustainability target setting and translation

In the past, a number of scholars have studied different approaches of formulating corporate GHG emission reduction as well as energy efficiency improvement targets (Margolick & Russel, 2001; Rietbergen & Blok, 2010; Rosenberg et al., 2012). Rietbergen & Blok (2010) developed a taxonomy distinguishing between different types of targets: absolute/volume reduction targets, physical efficiency improvement targets, economic intensity improvement targets and economic targets.

More recently, Rietbergen et al. (2015) explain the target setting process in the CO_2 performance ladder, which is a "*certifiable scheme for energy management and carbon accounting that is used as a tool for green public procurement in the Netherlands*" (Rietbergen et al., 2015, p. 549). They find that both top-down and bottom-up approaches are applied by companies for setting GHG reduction targets. In the top-down target-setting process, companies take reference in e.g. national climate policies, benchmarks with other companies, and consultancy proposals for credible minimum values or ambitious targets, to set targets for the entire company without carefully analysing the reduction potential. Instead, the feasibility of the targets is then checked through a bottom-up process. In the bottom-up target setting process, a GHG emission inventory is created, where hot spots and reduction potentials through possible reduction measures are identified. Afterwards a number of measures are selected, and the target is calculated according to the reduction impact of select initiatives. Finally, the targets get approved by higher management. The study found that 60 % of the interviewed companies applied a top-down approach and 40 % a bottom-up approach. The top-down approach was popular among large companies, while the bottom-up approach became more dominant when companies renew their GHG reduction targets. (Rietbergen et al., 2015) When the bottom-up approach is taken, a clear pathway for achieving the target is already produced in the process, as the share of GHG emission reductions per initiative is calculated. However, the study does not describe further, how companies taking the top-down approach for setting corporate GHG reduction targets, split these into targets for different functions or split the share of reductions onto different initiatives. Additionally, they criticise that *"target-setting practice is not a rigorous and uniform process mainly due to the lack of well-defined criteria and incomplete conformity checks"* (Rietbergen et al., 2015, p. 559).

Since then, the Science Based Targets initiative (SBTi) has been established in 2015, which acts as a verification body for SBTs and supplies companies with methods, tools and guidance for calculating SBTs. Faria & Labutong (2020) find that there are four methods for setting science-based corporate GHG emission targets (SBTs): the sectoral decarbonisation approach (SDA) (Krabbe et al., 2015; Science Based Targets, 2015); the GHG emissions per unit of value added (GEVA) approach (Randers, 2012) ; the corporate finance approach to climate stabilising targets (C-FACT) (Stewart & Deodhar, 2009); the linear emission reduction to target year (LERTY), also known as Absolute Contraction Approach (ACA) (Faria & Labutong, 2020). With the SDA method, either absolute GHG emission reduction targets or physical intensity targets can be calculated. With the GEVA and C-FACT emission intensity targets can be calculated, and with the LERTY/ACA method absolute emission reduction targets can be calculated. All methods require the following input values: base year, base year emissions, growth projections, GHG intensity, activity, and target year. As an output, the target year value or a pathway expressed either as absolute emission or emission intensity is provided. (Faria & Labutong, 2020) A similar evaluation of methods for setting SBTs has been made by Bjørn et al. (2021), who also developed a characterisation of methods to present them in a systematic way and criticised the SBTi for a lack of transparency when recommending certain methods. While all methods translate the temperature targets set by the Paris agreement to quantifiable GHG emission reduction targets on organisational-level, they do not cover, how these targets can be further translated to lower levels within the organisation.

Moshrefi et al. (2020) deal with operationalisation of SBTs within an organisation through product portfolio analysis, which is how companies select the most advantageous product portfolio for achieving their financial targets. Their proposed methodology is an adaptation of the Boston Consulting Group (BCG) matrix or Growth-Share matrix (Hax & Majluf, 1983) for conducting product portfolio analysis and takes into account a products' environmental impacts, market growth and volume. Similar to the BCG matrix, their Total Environmental Impact-Total Profit matrix is a two-by-two matrix dividing products into environment-profit stars, environment-profit cash cows, environment-profit question marks and environment-profit dogs. As such, it provides an overview of which products support the company in meeting its SBTs while at the same time generating profits, supporting environmentally conscious strategic decisions on products, families, and new product development. (Moshrefi et al., 2020) While providing a tool for strategic decision making towards achieving SBTs, this method does, however, not cover how product-level targets can be set from an organisational-level SBT.

Rekker et al. (2022) propose a science-based approach for measuring corporate Paris compliance. Their Paris-Compliant Pathway (PCP) takes a previously calculated SBT with one of the recognised Paris-aligned methods as basis and sets a range of operationalisation requirements. Firstly, when the SBT was set with a methodology relying upon a future variable, such as market share or sales forecasts, it is required that this variable is adjusted as soon as updated information on it is available. Secondly, an annual reduction target of the PCP is not met, 're-alignment' needs to be carried out, which means that the failure of meeting the reduction target needs to be compensated for by increased reductions in the following years. Thirdly, in *"case of a merger or acquisition the combined company must reduce its emissions as if both companies have been one company since the base year"* (Rekker et al., 2022, p. 7), and fourthly, in case the company in question is newly founded, it is given five years to establish its market share and emission, after which a PCP needs to be established. The company's performance against the PCP is then measured according to three metrics: performance to date (measured against base year), projected performance, and re-alignment decarbonisation rate. (Rekker et al., 2022) This work enables companies to stay Paris-aligned throughout their pathway towards their SBT. It is through another approach focussing on the organisational-level target and does not provide any guidance on how it can be broken down further in the organisation.

According to Giesekam et al. (2021), more and more companies seek to verify their targets with the SBTi. Their assessment of a selected number of companies' progress towards their verified targets showed that especially the progress towards Scope 3 emission targets lagged behind. This may be because it is more challenging to influence emissions that the company is only indirectly responsible for than emissions that the company can directly control by its operations. Another aspect could be that it is challenging to translate organisation-level Scope 3 targets into targets on product or department level, due to their complexity.

Rogelj et al. (2021) criticise both countries and companies setting net-zero targets for their vagueness and lacklustre plans. They call for clarification of three aspects of the targets set: *"their scope; how they are deemed adequate and fair; and concrete road maps towards and beyond net zero"* (Rogelj et al., 2021, p. 366). In the target scope, clarifications are needed in terms of which temperature goal the target contributes to, which GHGs are covered by the commitment and what share of reductions, removal and offsets is intended. In adequacy and fairness, it is called for a clarification of the principles applied and how they will affect others. Finally, it is called for concrete road maps and implementation plans, including milestones, policies, and specification of monitoring and review systems. This last call especially emphasises the need for further translation of high-level targets to lower-level incremental targets including more concrete steps and action plans.

For translating product-level life cycle sustainability targets over modules, production systems, individual production lines all the way to technology and tool level, Rödger et al. (2016; 2019) propose the sustainability cone framework, which is aligned with the stage-gate-model product development process and can enable production line planners to apply life cycle thinking to the manufacturing process. It enables a fact-based approach of tracking performance towards environmental sustainability targets on the respective production level and towards the overall product-level sustainability target. The framework has potential of being applied across other industries, however, the gap that the framework does currently not address is the alignment between organisational-level targets and product-level targets. In their example of the automotive industry, it is stated that *"[t]he strategy department besides others sets absolute environmental and financial targets for [the] product and those are translated by the designers into base specifications"* (Rödger & Bey, 2019, p. 80). The setting of product-level GHG reduction targets in line with the company's SBT and its further translation is where this thesis sets it focus.

From this literature review of sustainability target setting and translation a gap has been identified between the literature that focuses on setting organisational-level sustainability targets, like SBTs, and the literature that focuses on translating product-level sustainability targets to the different manufacturing steps like the sustainability cone framework. This gap is the translation step between the organisational-level target and the product-level target.

3.3 LCA in the product development process

Due to the importance of LCA for the calculation of both Vestas' products' environmental impacts and the company's Scope 3 emissions, a review of existing studies on the implementation of LCA in the product development process is conducted below.

The Life Cycle Assessment (LCA) is an established tool, which assesses a product or service's impacts throughout its entire life cycle spanning from raw material extraction all the way to End-of-Life. It follows a standardised procedure defined in the ISO 14040-44 standard with four phases: definition of goal and scope, inventory analysis, impact assessment, and finally, interpretation of the results (ISO, 2006).

By utilising LCAs, impact hot spots throughout the life cycle can be identified. These can be i.e. certain materials used or even entire life cycle phases. As such, LCA provides a basis for product or service improvement, and is often associated with eco-efficiency (Hauschild et al., 2020) (see Section 3.4). Due to this, Luz et al. (2018) developed a methodology for the integration of LCA into the product development process, aimed at supporting companies in developing sustainable products, and concluded that information drawn from LCA can be used in all phases of the product development process. In the planning phase, hot spots identified by LCA can be utilised to identify improvement strategies. In the conceptual design phase, LCA scenario analysis can support selecting the product solution with the best environmental performance. In the detailed design phase, LCA can quantify environmental performance improvements relative to the reference product. In the testing phase, it can help review and evaluate whether the environmental objectives for the product have been met. Finally, at product launch, the environmental performance data from the LCA can be published to create transparency and support marketing material. (Luz et al., 2018)

In a study on the introduction of life cycle thinking in product development in the wind industry, Bonou et al. (2015) found that the application of LCAs in the product development process can *"[p]rioritize target setting related to the impact intensity, the improvement potential and the feasibility for each stakeholder"* (Bonou et al., 2015, p. 47) as well as prioritising actions across the product development process and across company stakeholders. Moreover, LCAs can contribute by identifying potentials for energy and waste reduction throughout the life cycle. The paper also found that due to the nature of the product development process in the wind industry, sustainability considerations need to be made at the very beginning of the process, during the approval of product development specifications, because after this stage no structural changes to the product can be undertaken. As such *"product material related environmental targets should be part of the product requirement specifications (PRS) defined during scoping"* (Bonou et al., 2015, p. 47). This is similar to what Rödger et. al (2016; 2019) state in their studies on integration of sustainability assessments and targets in car manufacturing. Moreover, a need for a dynamic process was identified, in which each design iteration is informed by LCA results, so that at any point the environmental performance of the product can be accurately reflected.

3.4 Eco-efficiency

LCA is tightly associated with the eco-efficiency concept. Given the vital role of LCA in this study, it is heavily leaning into the concept. Hence, it needs an introduction.

The eco-efficiency concept can be defined as *"adding maximum value with minimum resource use and minimum pollution*" (Huesemann, 2004, p. 264) and as such aims to reduce the negative environmental footprint of human activities. According to Bjørn & Hauschild (2013), during the past decades eco-efficiency *"has gained wide acceptance as a necessary […] means to ensure sustainability through technological innovation"* (Bjørn & Hauschild, 2013, p. 322). Moreover, it *"has been accepted as the key strategic theme for global business in relation to commitments and activities directed at sustainable development"* (Ehrenfeld, 2005, p. 6) as it combines two aspects of sustainable development, namely environment and economics. Furthermore, eco-efficiency can be related to the I=PAT equation, which expresses that environmental impacts (I) are equal to the product of population (P), the material affluence per capita (A) and technology (T); where eco-efficiency is material affluence per environmental impact (1/T) (Bjørn & Hauschild, 2013). Improvement in eco-efficiency is commonly measured with LCAs, which is why it is a concept that is actively applied in this study.
Eco-efficiency is criticised by Ehrenfeld (2005) for the lack of consideration of the Earth's carrying capacity, as the concept is only meaningful in the context of the economic model of sustainable development, which is based on standard economic theory assuming limitless resources. It is suggested to couple the concept with other indicators and tools to become useful for decision-making.

3.5 Eco-Design

Eco-Design is linked to the concept of eco-efficiency and often a practical means of achieving it through design. In the ISO standard, Eco-Design is defined as a *"systematic approach that considers environmental aspects in design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product"* (ISO 14006, 2020, p. 3). In their Design for Sustainability framework, Ceschin et al. (2020) place Eco-Design in the product-level space as a technocentric and product focused approach of Design for Sustainability. As such, it *"is considered the most suitable design framework for allowing engineers to perform environmentally conscious design and development of a product"* (Fargnoli et al., 2014, p. 31). Having been introduced in the 1990s, the field is very well developed. Engineers and product designers can refer to it for principles, guidelines, strategies and methods (Bovea & Pérez-Belis, 2011; Luttropp & Lagerstedt, 2006; Pigosso & McAloone, 2015). In a recent study, Brambila-Macias et al. (2021) add to the Eco-Design concept by suggesting a to support the implementation of Eco-Design in organisations by introducing the position of a 'Lifecycle Engineer', who could coordinate Eco-Design through their expertise in the field.

Faber et al. (2005) and de Pauw et al. (2015) describe Eco-Design as a relative approach, which it is criticised for. Eco-Design "*starts with the present state of affairs and identifies existing problems, which people subsequently attempt to solve. Improvements take place incrementally. […] In contrast to the absolute approach, the focus of this relative approach is not the good, but the less worse or better*" (Faber et al., 2005, p. 8). De Pauw et al. (2015) criticised this relative approach since it puts designers in the predicament of having to envision and design sustainable innovations even though the current methods only lead them to optimise the already existing. When relating the relative approach to achieving sustainability, Ehrenfeld (2008) critiques that *"[…] reducing unsustainability, although critical, does not and will not create sustainability"* (Ehrenfeld, 2008, p. 7).

4 Research question and scope

The literature review reveals a gap been between the literature that focuses on setting organisational-level sustainability targets and the literature that focuses on translating product-level sustainability targets to different manufacturing steps. On the one hand, several methods for setting STBs exist, which align organisational-level targets with the goals of the Paris Agreement. On the other hand, a framework exists, which can translate product-level sustainability targets further to the different levels of manufacturing. The gap to be filled by this research is the translation step between the organisational-level target and the product-level target.

The case study organisation faces the challenge of having to translate its organisational-level Scope 3 target to product level. Moreover, it sees the need to operationalise its Scope 3 target within its design departments. Based on this need from the case study organisation and the identified gap in the literature, this study's research question reads as follows:

How to translate organisational-level sustainability targets into product-level targets and improve the capacity of design departments to design more sustainable products?

The focus lies on the Scope 3 target and environmental sustainability specifically. Other aspects of sustainability are out of this thesis' scope. The research question can be further divided into two main questions that each have several sub-questions.

1. How can organisational-level sustainability targets be translated into product-level targets?
    - What is the benefit of translating sustainability targets within the organisation?
    - What tools, inputs and calculations are needed for the translation of the targets?
    - What are the calculation steps?
    - How can design departments' contribution shares to the product-level target be determined?
2. How to improve the capacity of design departments to design more sustainable products?
    - Where do design departments see sustainability opportunities and barriers?
    - What support do design departments need from the organisation to design more sustainable products?

The approach taken to systematically answer the above research question and its sub-questions is described in the Methodology (see Section 5.1.1).

5 Methodology

To answer the research question and its sub-questions, this paper employs a case study as leading method, with methods like desk research, observation and interviews used for gathering of empirical data. Moreover, mathematical calculations were applied to calculate targets, which take LCA data and sales forecasts as basis. Each of these methods is described below.

5.1 Case study

This paper is defined by qualitative research as the leading method chosen is a case study. It was deemed that a setting in an organisation would be beneficial to answer and exemplify a solution to the research question. Even though case studies are excelling at particularisation (Stake, 1995), it has been found that generalisations from case studies can be made (Flyvbjerg, 2006). The general applicability of this case study's findings is discussed in Section 7.

The subject of this case study is the Danish Wind OEM Vestas Wind Systems A/S. The company was chosen because the author previously conducted a project with the organisation on Life Cycle Assessments and was affiliated with the organisation as a student worker. Since 2020, Vestas has a sustainability strategy with a number of organisational-level commitments around carbon footprint, circularity, safety, diversity and inclusion and leadership. Out of these commitments, the focus of the case study is on the carbon footprint, which is where the organisation was in need of a translation of their organisational-level target to product-level. Vestas' carbon footprint reduction commitment is split into a combined Scope 1+2 target and a Scope 3 target. The company wants to become carbon neutral in its own operations (Scope 1+2) by 2030 without the use of carbon offsets. Scope 1 and 2 emissions combined only make up approximately 1 % of the company's carbon footprint, and the company makes controlled progress toward reaching its 2030 target. Scope 3 emissions, however, make up 99 % of the company's total emissions and are more difficult to control. Here, Vestas set a target of reducing the emissions of its supply chain by 45 % per MWh produced and shipped by 2030. Since these emissions are indirect emissions from upstream and downstream activities, it is challenging to translate it into company-internal targets that can be measured and tracked. However, the sustainability department, a global function in the organisation, finds it necessary for the implementation and the execution of the sustainability strategy to set targets throughout the organisation and to be able to track progress towards the organisational-level target. This is where this thesis contributes and proposes an approach and a procedure. Furthermore, to evaluate whether the introduction of these targets would support the design departments in working toward the organisational-level target, research is presented on what sustainability barriers and opportunities these departments see and what their need from the organisation is to design more sustainable products. The approach applied to the case study with Vestas is described in the paragraphs below.

5.1.1 The approach applied to the case study

To systematically work on answering the research questions and its sub-questions, this paper combines a top-down approach with a bottom-up approach that was followed when conducting the case study (see Figure 2). Both the top-down and the bottom-up approach are explained in detail below.

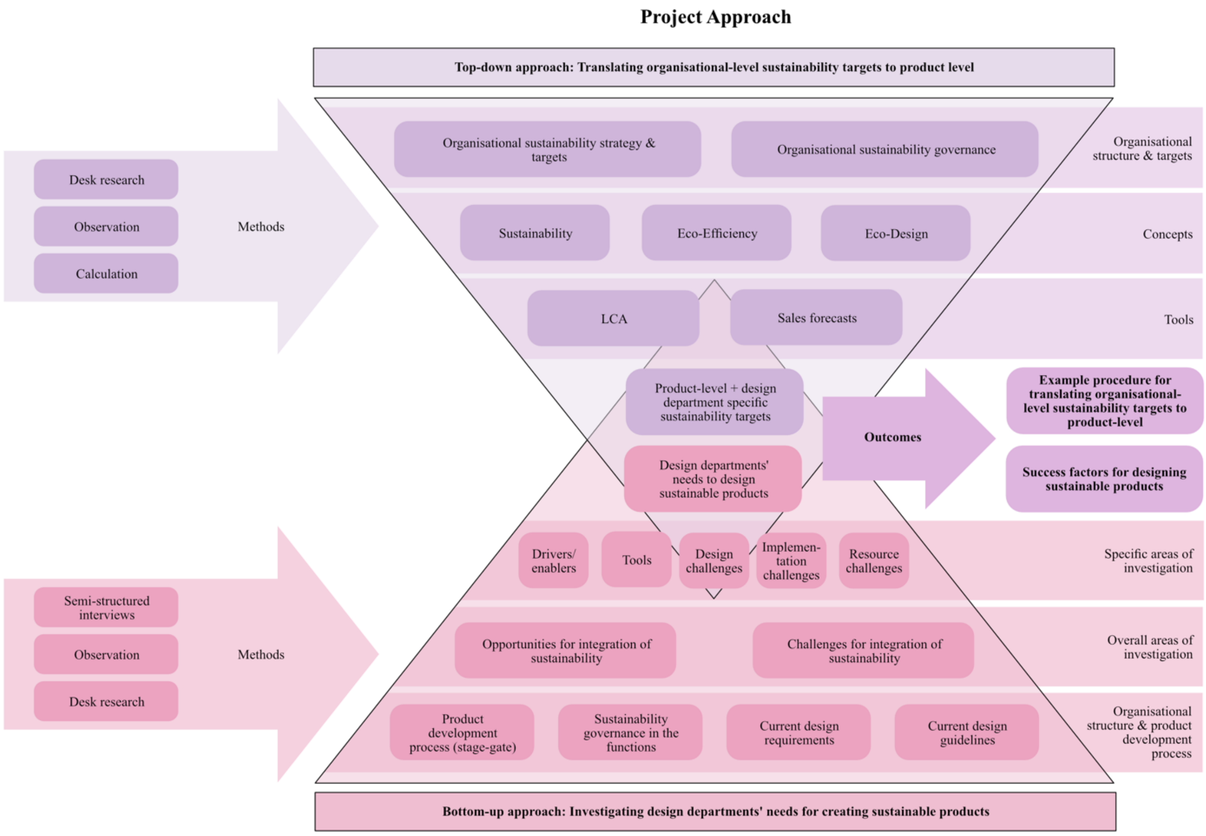

Figure 2: Project approach

5.1.2 The top-down approach

The top-down approach is about translating organisational-level sustainability targets into product-level targets, as well as determining the contribution share of each design department towards the product-level target. It takes reference in the organisational-level sustainability targets and the organisational sustainability governance of the case study organisation, found through desk research, document review and observation. The translation is guided by the concepts of sustainability, eco-efficiency and Eco-Design. With the help of sales forecasts, focus products are identified and GHG emission forecasts for each product are created. The necessary GHG emission data per product is drawn from LCAs. Through this GHG emission forecast per product, the gap for reaching the reduction target can be identified. Once the gap is identified, the allowed emissions can be divided onto the products corresponding to their respective share of the annual sales volume. Based on the allowed emissions per product, product-level targets can be formulated. This is followed by an assessment of which materials contribute most to overall Scope 3 emissions to determine material hot spots that require immediate action. Finally, an investigation of each design department's contribution to product emissions is conducted to identify the most emission intensive design departments to be able to then set department-specific reduction foci.

5.1.3 The bottom-up approach

The bottom-up approach is taken for qualitative research in the case study organisation which is to evaluate whether there is a match between the perceived need by the global functions of the organisation to translate its organisational-level targets to product-level vs. the needs of the design teams to design more sustainable products.

For data gathering in a case study organisation, Stake (1995) recommends interviews, observation, and document reviews (desk research). To follow this approach, semi-structured interviews with employees in the blades design department at Vestas were conducted to answer the sub-questions on where design departments see sustainability opportunities and barriers and what support they need from the organisation to design more sustainable products. Moreover, the participant observation method was applied throughout the stay at the case study organisation and as part of desk research, an internal document review was conducted. These findings were then compiled with those of the interviews and are compared in Section 7 to findings from existing research. Each of the methods is described in more detail in the following paragraphs.

5.2 Desk research & document review

Firstly, desk research was conducted to review existing literature and the state of the art related to the topic of this thesis, which was then collected in the literature review (See section 3). For this, searches in Scopus have been conducted with suitable combinations of keywords, such as sustainability strategy implementation, sustainability strategy execution, sustainability target setting, sustainability target translation, science-based target setting. In addition to the keyword search, the reference/citation search method was applied.

Secondly, desk research and document reviews were conducted in the case study organisation for the purpose of empirical data collection. This provided an overview of the product development process, as well as existing sustainability related design guidelines and current design requirements that the design departments are working with. This enables a picture of the advancement of the organisation in terms of implementation of its sustainability strategy and helps to identify gaps that need to be closed to enable design departments to design more sustainable products.

5.3 Observation

Furthermore, the participant observation method was applied according to Jorgensen (1989), where the author took part in meetings, calls and discussions in the case study organisation, partly solely as observer and partly as active participant. Observations were noted down, coded and where applicable combined with the findings from the semi-structured interviews and desk research to produce a full picture of sustainability opportunities, barriers and the needs of the design departments to design more sustainable products.

5.4 Calculations

For the translation of the sustainability targets in the case study organisation, calculations were essential. The calculations were conducted with actual LCA data, procurement data and sales forecasts from the case study organisation. Due to the confidentiality of the data used and for the reason of simplification, the calculations were re-done for this paper using generic numbers and publicly available data. The calculations have mainly been conducted in Excel and are illustrated with graphs and tables (see Appendix B). The calculations, together with their inputs and outputs, serve as example procedure for how organisational-level sustainability targets can be translated to product-level, so that the target can be quantified and progress towards it can be measured. To achieve this measurability, Life Cycle Assessment data was imperative.

5.5 Life Cycle Assessment

To set measurable targets, a measurement tool is necessary. LCA allows for quantification of environmental impacts and comparison of different solutions serving the same purpose as the assessed product. Consequently, it can be used to measure environmental performance differences, for instance between different products compared with the same functional unit or between iterations of one product. In manufacturing businesses, where certain departments are responsible for designing and producing certain components of the product, LCA can therefore be integrated in the product development process to measure the departments' progress toward their respective environmental performance or sustainability targets (Bonou et al., 2015; Luz et al., 2018).

In this study, LCA is applied in several ways. In the case study organisation, the products' environmental impacts are calculated via LCA. Moreover, LCAs are the basis for the company's calculation of Scope 3 emissions and thereby its Scope 3 GHG emission reduction target. To translate the organisational-level Scope 3 target to a product-level target, product-level GHG emission data calculated by LCA is used, in combination with sales forecast data. Once product-level targets are established, LCA is used to further break down the product's GHG emissions in two ways. Firstly, to conduct a hot spot analysis and identify which materials have the largest impact on total Scope 3 GHG emissions. Secondly, to allocate GHG emissions to the different design departments, which are each responsible for designing a certain number of components of the product. Consequently, LCA is used as a vital tool in the translation and quantification of organisational-level GHG emission reduction targets to product-level and beyond.

5.6 Interviews

Seven interviews have been held to answer the sub-questions:

- Where do design departments see sustainability opportunities and barriers?
- What support do design departments need from the organisation to design more sustainable products?

The interviews were of semi-structured nature and were conducted according to the guidelines from Silverman (2014) and Adams (2015). In a semi-structured interview, first an initial topic of conversation is established with the intent to guide the discussion into the desired direction while at the same time letting the interview unfold without major constraints (Silverman, 2014). This type of interview allows the participants to build on each other's comments, which is particularly beneficial since spontaneous follow-up questions can be asked. As such, questions are neither asked in a fixed order, nor read out word-by-word, but instead they take reference in *"the agenda for the interview guide, the outline of planned topics, and questions to be addressed, arrayed in their tentative order"* (Adams, 2015, p. 496).

The agenda for the interviews was to answer the above questions to better understand what an organisation can do to support internal activities to systematically work towards achieving its sustainability targets and to verify whether the translation of organisational-level targets is valuable. Each of the interviews lasted approximately 30 - 45 minutes and had the following agenda:

1. Short introduction of the interviewer and the research objective
2. Short introduction of the interviewee, their role and daily tasks at the case study organisation
3. Questions
    a. Where are your touchpoints with sustainability in your daily work?
    b. Where do you see opportunities for sustainability in your department?
    c. Where do you see barriers for sustainability in your department?
    d. What support do you need from the organisation to design more sustainable products?

Due to the semi-structured nature of the interviews, occasionally not all the questions were asked, and some of the questions were altered and adapted to the flow of the conversation.

The interviews were held via Microsoft Teams and the software's integrated transcription function was used to auto-generate a transcript. In addition to the transcript, notes were taken during the interview.

A qualitative analysis was then conducted by first marking and labelling bits in the transcripts and later sorting these into categories on a mind-map-like whiteboard and produce summaries, which are presented in Section 6.2 (Silverman, 2014).

6 Findings

In this section, the findings of the study are presented following the project approach described in the methodology (see Section 5.1.1). Accordingly, the findings from the top-down approach are presented first, followed by the findings from the bottom-up approach, each closing with an individual sub-conclusion.

6.1 Top-down approach

In this section, the top-down approach described in Section 5.1 is followed to answer the first part of the research question, which is about how organisational-level sustainability targets can be translated to product-level and further (see Figure 3).

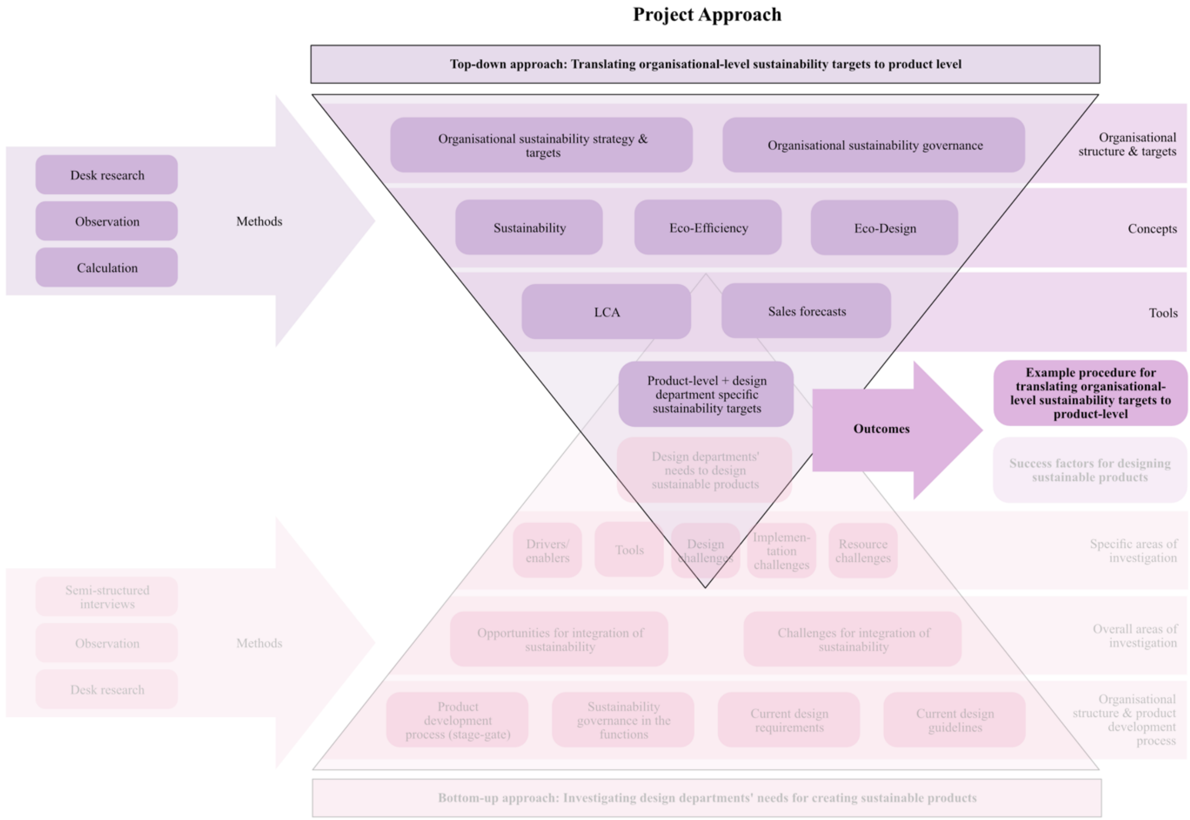

Figure 3: Top-down approach

It outlines the procedure of translating an organisational-level sustainability target to product-level, as well as how material hot spots can be identified, and how design departments can track their contribution to the product-level target. The procedure describes the process of translating the targets, including all inputs, tools and calculations needed to do so. It is illustrated at the example of Vestas' Scope 3 GHG emission reduction target, but it does not contain actual data from the organisation, in order not to disclose any potential confidential information. Instead, for GHG emissions, fictional values are used and for sales forecasts it is referred to the publicly available numbers from Wind Europe (Wind Europe, 2022).

6.1.1 Translation: organisational-level target to product-level target

In this example procedure, Vestas' organisational-level Scope 3 GHG emission reduction target of 45 % per MWh by 2030 is translated to product-level. From the perspective of the organisation, this translation is important because Scope 3 emissions are indirect emissions from upstream and downstream activities in the value chain and as such can only indirectly be influenced by the organisation. Since there is only a vague connection between the target for indirect emissions to the actions and decisions taken every day by the departments within the company, making this connection becomes even more important. Achieving the target requires external collaboration with suppliers but also internal collaboration across departments, in this case the different design departments as well as procurement. The organisation is interested in the different functions working towards the target in a controlled and uniform manner, which can be achieved by providing them with common targets. Product-level targets give the different functions a much more tangible and quantifiable goal than the organisational-level target.

To illustrate the translation process, a fictional product portfolio of four different products is built with fictional power ratings and GHG emission intensities (see Table 2). The fictional portfolio is comprised of four models. One the one hand an Offshore Model, which is deployed in wind farms at sea where wind speeds are high and high yields can be achieved, which is why this model has the highest power rating. On the other hand, three different Onshore Models, which for wind farms on land. Each of these have different power ratings, optimised for different wind conditions. Each product's GHG emission intensities are fictional as well but taken within the realistic range of GHG emission intensities for wind turbines (Bonou et al., 2016). GHG emission intensities are obtained via LCAs of the respective products, which is why LCA is an important tool and input in the process of translating the target.

Turbine Model	Power rating [MW]	GHG emission intensity [kgCO2e/MWh][3]
Offshore Model	13	6
Onshore Model 1	5	8
Onshore Model 2	2	5
Onshore Model 3	7	10

Table 2: Fictional product portfolio

To create sales forecasts for each of the wind turbine models, Wind Europe's (2022) outlook for 2022 - 2026 (see Figure 4) is utilised and modified to fit the example. Sales forecasts and the respective share of sales per product play a vital role in both setting the target GHG emission intensity that products need to reach in 2030, in order for the organisational-level target to be hit.

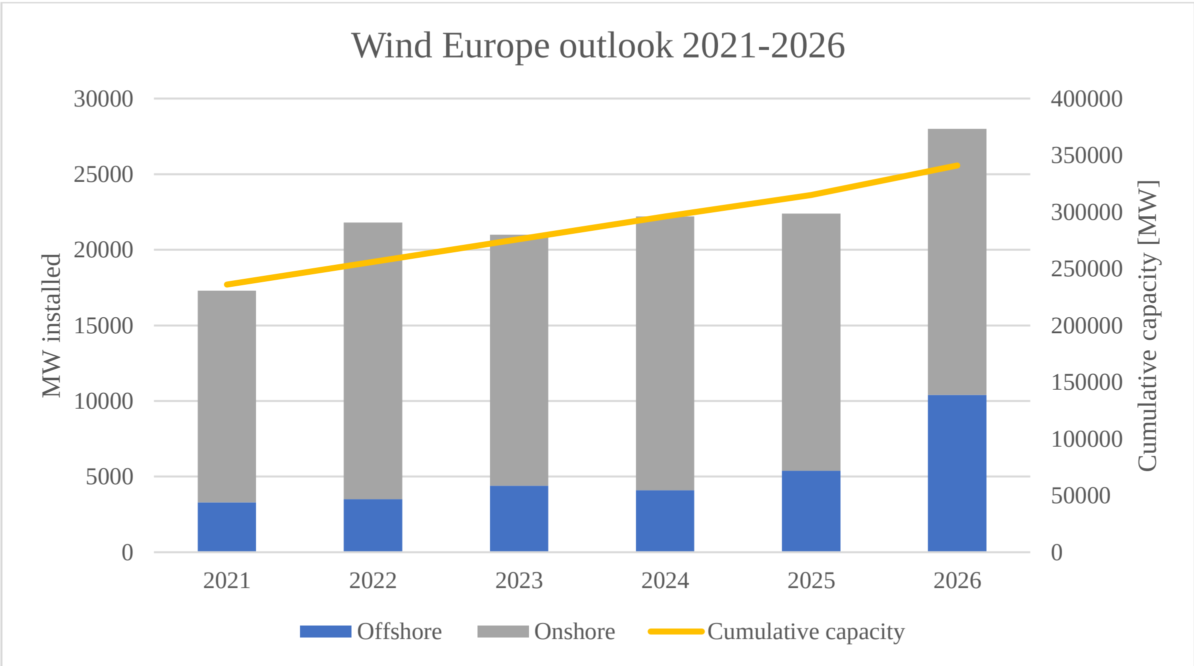

Figure 4: Wind Europe outlook 2021 - 2026

[3] Wind turbines have close zero GHG emissions in their operating phase. However, in the manufacturing phase of their Life Cycle, GHG are emitted, as well as during their installation, service and decommissioning (see (Razdan & Garrett, 2019, p. 58). LCA adds up the GHG emissions of the wind turbine's entire Life Cycle. These are then divided by the amount of MWh the is expected to turbine produce during its entire lifetime to obtain the GHG emission intensity.

Since the outlook only extends to 2026, but the Scope 3 target is set by 2030, the average growth rate between 2021 and 2026 was calculated and applied to both Onshore and Offshore to obtain a full forecast until 2030 (see Figure 5) (for calculations, see Appendix B, Tab 1, section 1.1). This is a simplification and approximation, however, the accuracy of the sales forecast in this fictional scenario is not crucial. The purpose is rather to create a basis on which the later target translation calculation can be illustrated.

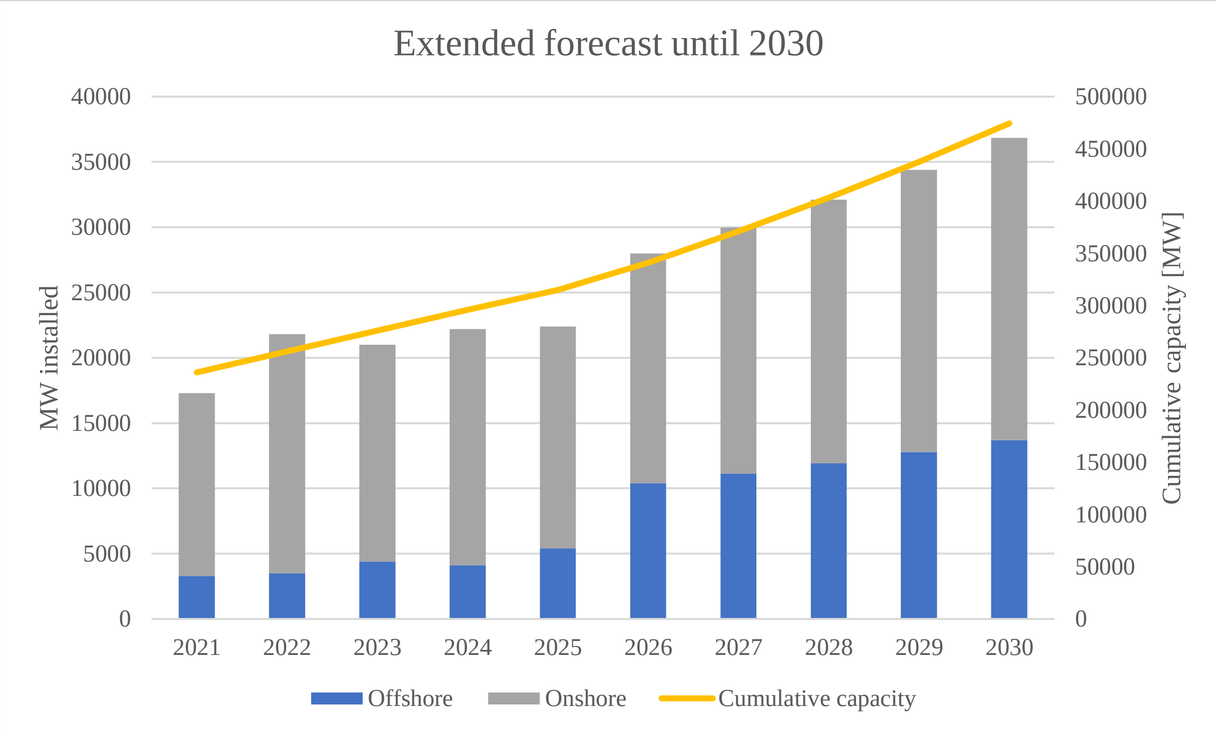

Figure 5: Extended forecast until 2030

The forecast is then broken down by turbine model. Since the fictional product portfolio only features one single Offshore Model, the entire installed Offshore capacity is assumed as the sales volume of this model. However, the product portfolio contains three different Onshore Models, which is why the annually installed Onshore from the forecast capacity needs distributed amongst these models to obtain individual forecasts for each of the Onshore models. Since the Onshore market is slowly moving toward turbines with larger rotors and larger power output it is assumed that the sales share of the Onshore Model 2 with a power rating of 2 MW decreases significantly, with the Onshore Model 1 with a power rating of 5 MW also losing sales share until 2030. Instead, Onshore Model 3 with a power rating of 7 MW will continuously gain sales share until accounting for 70 % of the sales volume in 2030. The assumed sales share trajectories are presented in Figure 6 (for calculations, see Appendix B, Tab 1, section 1.2). The numbers are purely fictional and only serve the purpose of providing an example. In a real setting, actual forecasts on share of sales should be utilised.

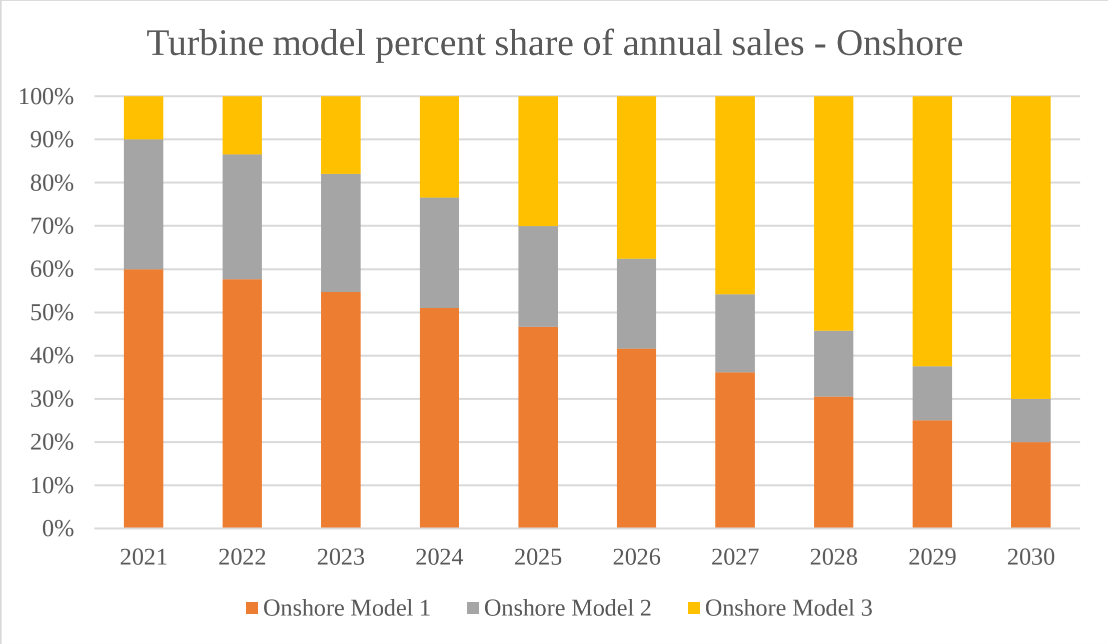

Figure 6: Turbine model percent share of annual sales – Onshore

When now allocating the annually installed Onshore capacity from Figure 5 according to each turbine model's annual percentage of sales from Figure 6, a complete sales forecast in by turbine model can be obtained (see Figure 7) (for calculations, see Appendix B, Tab 1, section 2.1). This sales forecast, shown in annually installed capacity per turbine model in MW is crucial for the following steps in the target translation.

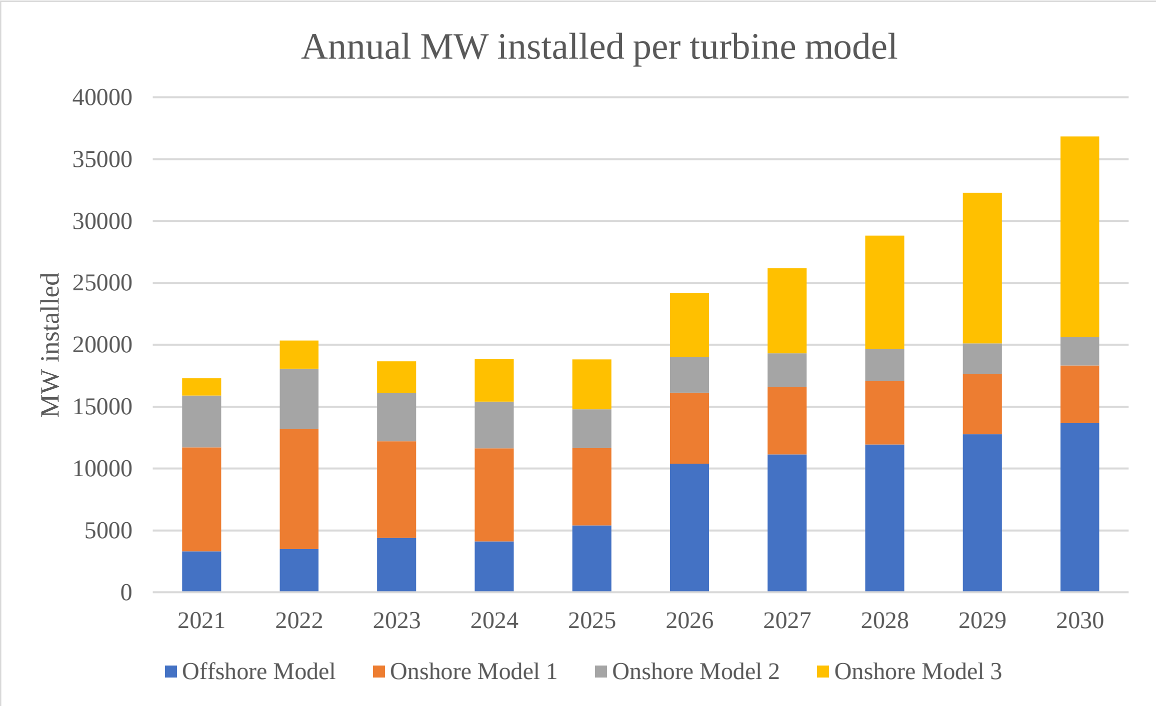

Figure 7: Annual GW installed per turbine model

With the help of this forecast of annually installed capacity per turbine, the number of MWh generated by each model's annually installed capacity for the years up to 2030 can be calculated. This is necessary because the Scope 3 target is measured in percent GHG emission reduction per MWh generated. To be able to calculate e.g. the amount of MWh that the installed capacity of Onshore Model 1 in 2021 generates throughout its Life Cycle, two variables are important: a) capacity factor, and b) expected lifetime of the turbine model. *"The capacity factor of a wind turbine is its average power output divided by its maximum power capability"*(Center for Sustainable Systems, 2021). Wind Europe (2022) discloses that for 2021 the average capacity factor for onshore was 23 %, whereas the average capacity factor for offshore amounted to 35 % in the EU and the UK. The expedited lifetime of an onshore turbine is 20 years (Razdan & Garrett, 2019), while an offshore turbine is expected to last for 25 years (Siemens Gamesa, 2019). These values are used for the MWh forecasts for the

Onshore and Offshore Models respectively. The conversion of MW to MWh is made as shown in Equation 1.

Equation 1: Calculating MWh

$$MWh = MW\ installed\ [MW] * 24\ [hours] * 365\ [days] * Expected\ lifetime\ [years] * Capacity\ factor\ [percent]$$

The below calculation in Equation 2 shows an example of the MWh generated over the lifetime of the installed capacity of Onshore Model 1 in 2021.

Equation 2: Example for calculating MWh

$$8{,}400\ [MW] * 24\ [hours] * 365\ [days] * 20\ [years] * 23\ [percent] = 338{,}486{,}400\ [\mathrm{MWh}]$$

By use of this calculation, a MWh forecast is made for the installed capacities until 2030 (see Figure 8) (for full calculations, see Appendix B, Tab 1, section 2.3). It can be seen that the Offshore Model takes a bigger share of the annual MWh compared its share of the annual GW installed (compare Figure 7). The Offshore Model produces comparatively more MWh in its lifetime because its expected lifetime is 5 years longer and its capacity factor is 12 percentage points higher than that of the onshore models.

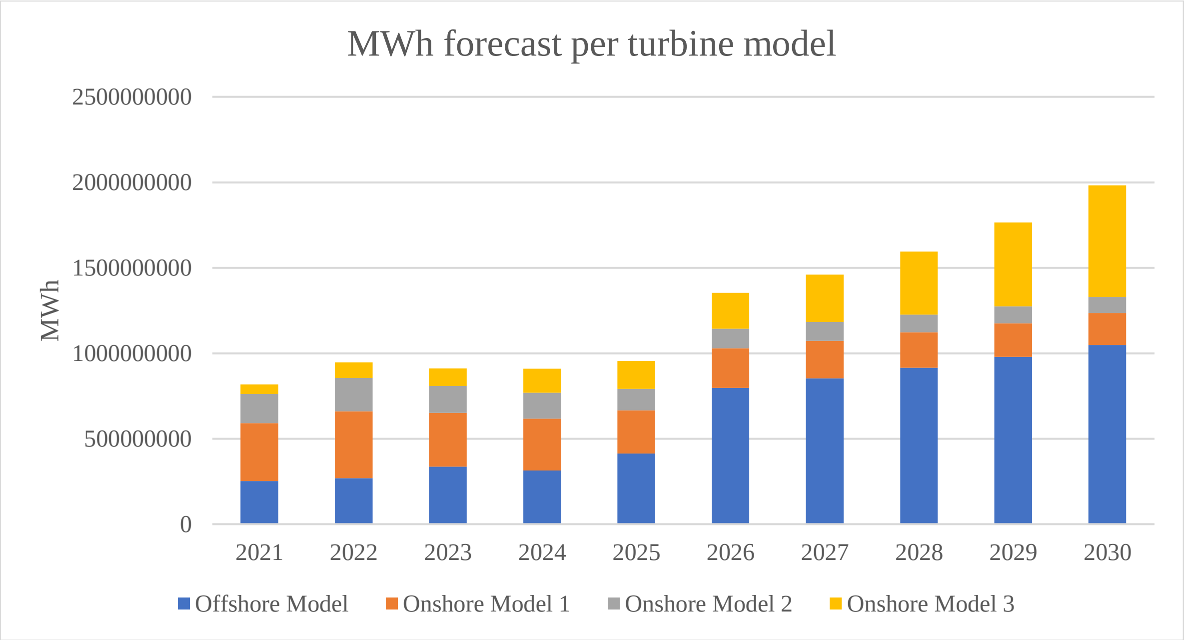

Figure 8: MWh forecast per turbine model

Utilising the share of MWh per turbine model, a weighted average GHG emission intensity can be calculated. The share of MWh per turbine model in 2021 is as displayed in Table 3.

Turbine Model	**Emission intensity [kgCO2e/MWh]**	**MWh in 2021**	**Percentage of total MWh**
Offshore Model	6	252,945,000	31%
Onshore Model 1	8	338,486,400	41%
Onshore Model 2	5	169,243,200	21%
Onshore Model 3	10	56,414,400	7%
Total	?	817,089,000	100%

Table 3: Share of MWh per turbine model in 2021

To now obtain the GHG emission intensity of the installed fleet in 2021, one needs to calculate the weighted average of the individual turbine models' GHG emission intensities (see Equation 3).

Equation 3: Calculating fleet GHG emission intensity

$$
\begin{aligned}
&Fleet\ GHG\ emission\ intensity\ \left[\frac{kgCO2}{MWh}\right] \\
&\quad = Offshore\ Model\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] \\
&\quad * Offshore\ Model\ share\ of\ MWh\ [percent] \\
&\quad + Onshore\ Model\ 1\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] \\
&\quad * Onshore\ Model\ 1\ share\ of\ MWh\ [percent] \\
&\quad + Onshore\ Model\ 2\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] \\
&\quad * Onshore\ Model\ 2\ share\ of\ MWh\ [percent] \\
&\quad + Onshore\ Model\ 3\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] \\
&\quad * Onshore\ Model\ 3\ share\ of\ MWh\ [percent]
\end{aligned}
$$

Filling the equation with values, one obtains a weighted average emission intensity of 6.9 kgCO2e/MWh in 2021 (see Equation 4).

Equation 4: Calculating fleet emission intensity for 2021

$$6\left[\frac{kgCO2e}{MWh}\right] * 31\,[percent] + 8\left[\frac{kgCO2e}{MWh}\right] * 41\,[percent] + 5\left[\frac{kgCO2e}{MWh}\right] * 21\,[percent] + 10\left[\frac{kgCO2e}{MWh}\right] * 7\,[percent] = 6.9\,[\frac{kgCO2e}{MWh}]$$

Given the product portfolio of the four turbine models, this emission intensity represents the entire Scope 3 emissions of the company. Remembering the target being reduction of supply chain emission by 45 % per MWh by 2030, it is this fleet emission intensity which needs to be reduced by 45 %. This reduction would mean going from 6.9 kgCO2e/MWh in 2021 to only 3.8 kgCO2e/MWh in 2030.

Now that there is a starting point and an ending point, the annual fleet emission intensity target can be created. In the case of Vestas, this has already been done as part of the process of setting the Scope 3 target as an SBT. To do so, it should be identified what actions are essential to achieving the necessary reductions. Here, LCA comes in again, helping to identify high-level environmental, or in this case, GHG emission hot spots of the products. Once the emission hot spots are known, alternative solutions can be assessed according to their technology readiness, feasibility and scalability. Based on this high-level assessment, a feasible fleet emission reduction trajectory can be drawn between the start value of 6.9 kgCO2e/MWh and the end value of 3.8 kgCO2e/MWh. To allow enough room for the launch of GHG reduction projects and sustainable procurement, as well as development of technology and alternative designs, it is likely that the GHG reduction trajectory takes the shape of a hockey stick, staying flat for the first half of the period, before dropping more sharply downward at the end. For the example shown in Figure 9 the gap between start value and end value was filled so that a hockey stick shaped curve was obtained that was deemed reasonable by the author (see Appendix B, Tab 1, section 2.4).

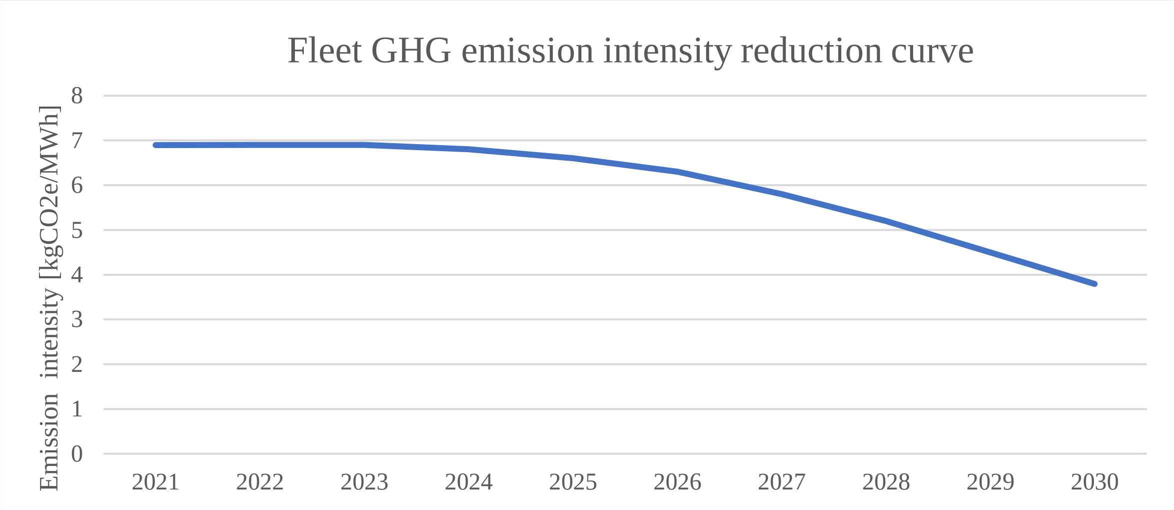

Figure 9: Fleet GHG emission intensity reduction curve

Now, annual GHG emission intensity targets for the installed fleet are set, however, it is still unclear how the individual products should be contributing to achieving them (see Table 4).

Year	Offshore Model [kgCO2e/MWh]	Onshore Model 1 [kgCO2e/MWh]	Onshore Model 2 [kgCO2e/MWh]	Onshore Model 3 [kgCO2e/MWh]	Fleet average [kgCO2e/MWh]	Reduction vs. base year
2021	6	8	5	10	6.9	0%
2022	?	?	?	?	6.9	0%
2023	?	?	?	?	6.9	0%
2024	?	?	?	?	6.8	-1%
2025	?	?	?	?	6.6	-4%
2026	?	?	?	?	6.3	-9%
2027	?	?	?	?	5.8	-16%
2028	?	?	?	?	5.2	-25%
2029	?	?	?	?	4.5	-35%
2030	?	?	?	?	3.8	-45%

Table 4: Annual GHG emission intensity targets

If the GHG emission intensities of each of the products stayed constant until 2030, the fleet average GHG emission intensity would in fact increase to 7.5 kgCO2e/MWh, due to the more emission intensive Onshore Model 3 gaining in sales share. Figure 10 illustrates the gap between the fleet average target scenario and the fleet average no-action scenario (see also Appendix B, Tab 1, section 2.4).

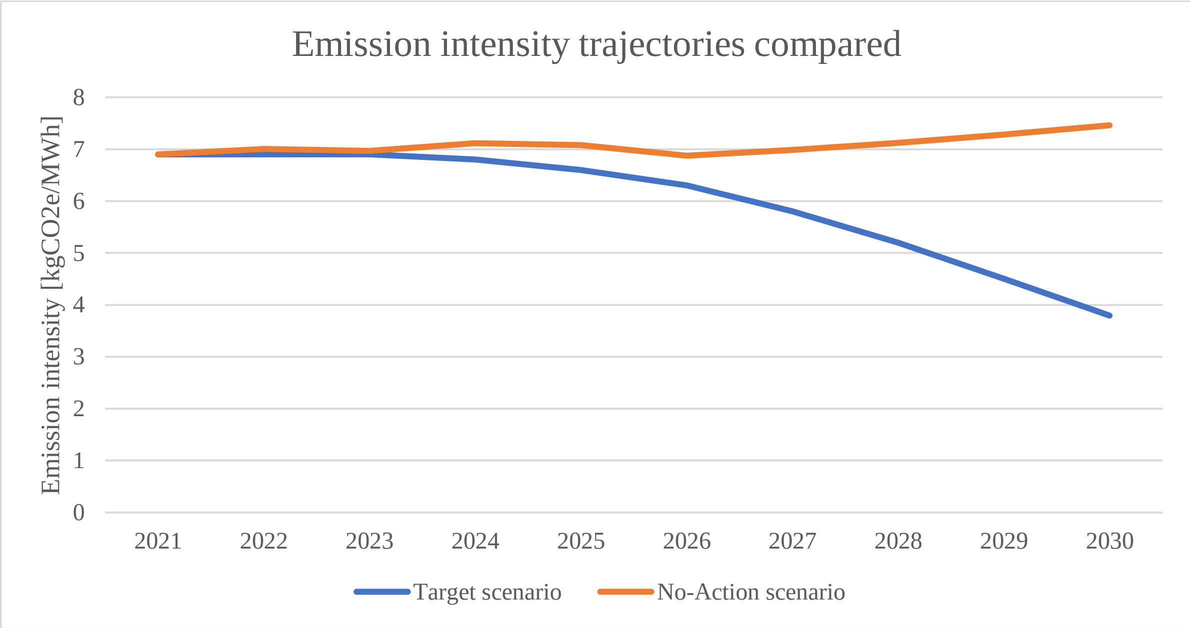

Figure 10: Emission intensity trajectories compared

From the fleet average target scenario, annual total allowed GHG emissions can be calculated by multiplying the respective annual target GHG emission intensities by the respective total annual MWh generated, which were calculated earlier (refer to Figure 8). Figure 11 compares the annual total GHG emissions of the no-action scenario to the total allowed annual GHG emissions of the target scenario (see also Appendix B, Tab 1, section 2.5).

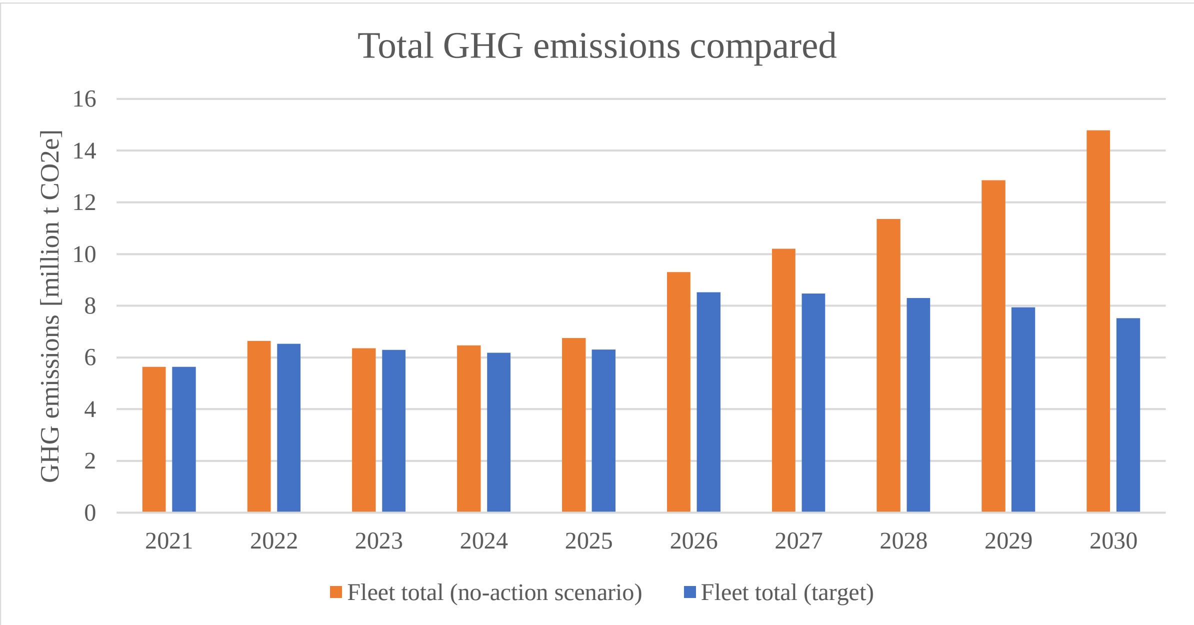

Figure 11: Total GHG emissions compared

The total allowed annual GHG emissions (Fleet total (target)) are taken as a threshold for the calculation of the product-level targets. Additionally, a product prioritisation can be made, based on the respective models' annual share of MW installed and MWh generated. Looking at Figure 7 and Figure 8, both show a downward trend for both Onshore Model 1 and 2. Starting with making up combined 73 % of the MW installed in 2021, their combined share declines to only 19 % in 2030. Looking at MWh generated, this trend is similar, with the two models comprising 62 % of the MWh generated in 2021, but only 14 % in 2030. At the same time, the Offshore Model and Onshore Model 3 increase their share of both MW installed from 27 % in 2021 to 81 % in 2030 and their share of MWh generated from 38 % in 2021 to 86 % in 2030. Given their significant increase in these two metrics by 2030, the Offshore Model, as well as Onshore Model 3 should be chosen as focus products to achieve GHG emission reductions. Since the absolute values for both annual MW installed for Onshore Model 1 and 2 decrease, total emissions caused by these products will decrease as well. Consequently, these two products can be de-prioritised in terms of GHG emission reductions (see also Appendix B, Tab 1, section 2.6).

Now that the Offshore Model and Onshore Model 3 are prioritised, their annual GHG emission intensity targets need to be calculated so that the annual fleet emission intensity targets can be achieved, while the emission intensities of Onshore Model 1 and 2 stay constant. Multiplying the GHG emission intensities of Onshore Model 1 and 2 by their respective MWh generated for each year until 2030, the total GHG emissions for these models can be calculated (see Equation 5). Figure 12 plots those against the maximum allowed emissions curve (for calculations, see Appendix B, Tab 1, section 2.7).

Equation 5: Calculating Turbine Model annual GHG emissions

$$
\begin{aligned}
&Turbine\ Model\ annual\ GHG\ emissions\ [kgCO2e] \\
&\qquad = Turbine\ Model\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] \\
&\qquad * Turbine\ Model\ annual\ MWh\ generated\ [MWh]
\end{aligned}
$$

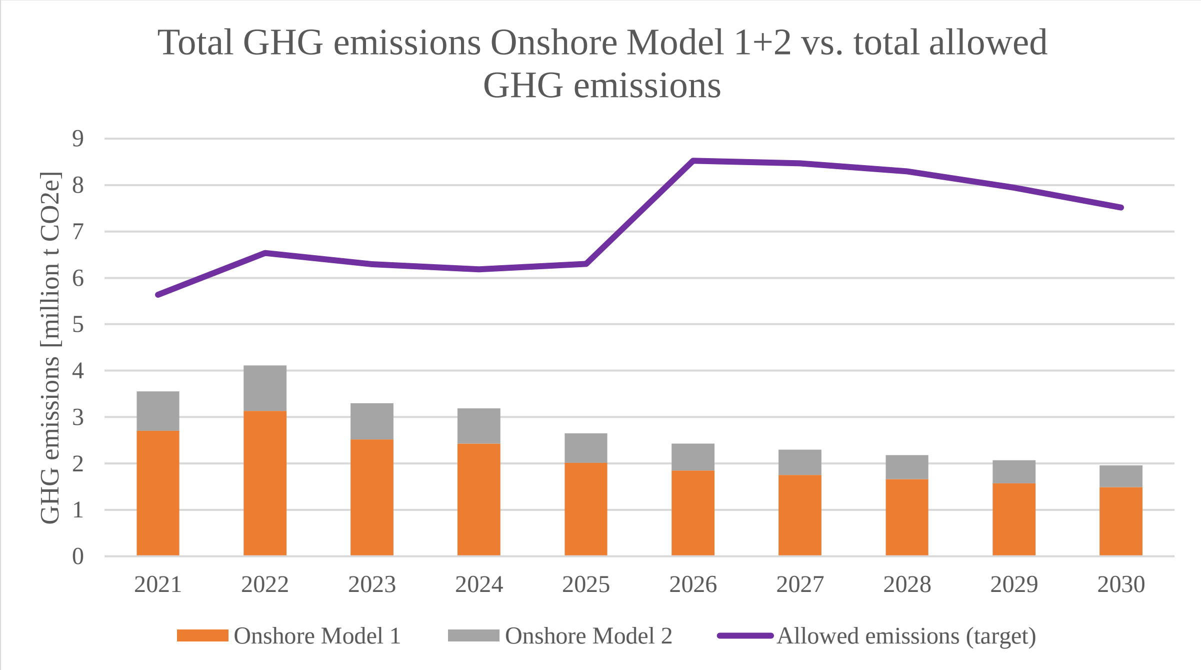

Figure 12: Annual total GHG emissions Onshore Model 1+2 vs. total allowed annual GHG emissions

The emissions that the Offshore Model and Onshore Model 3 are allowed to emit is the difference between the combined emissions of Onshore Model 1 and 2 and the total allowed emissions from the Target scenario, as illustrated in Figure 13 (see also Appendix B, Tab 1, section 2.7).

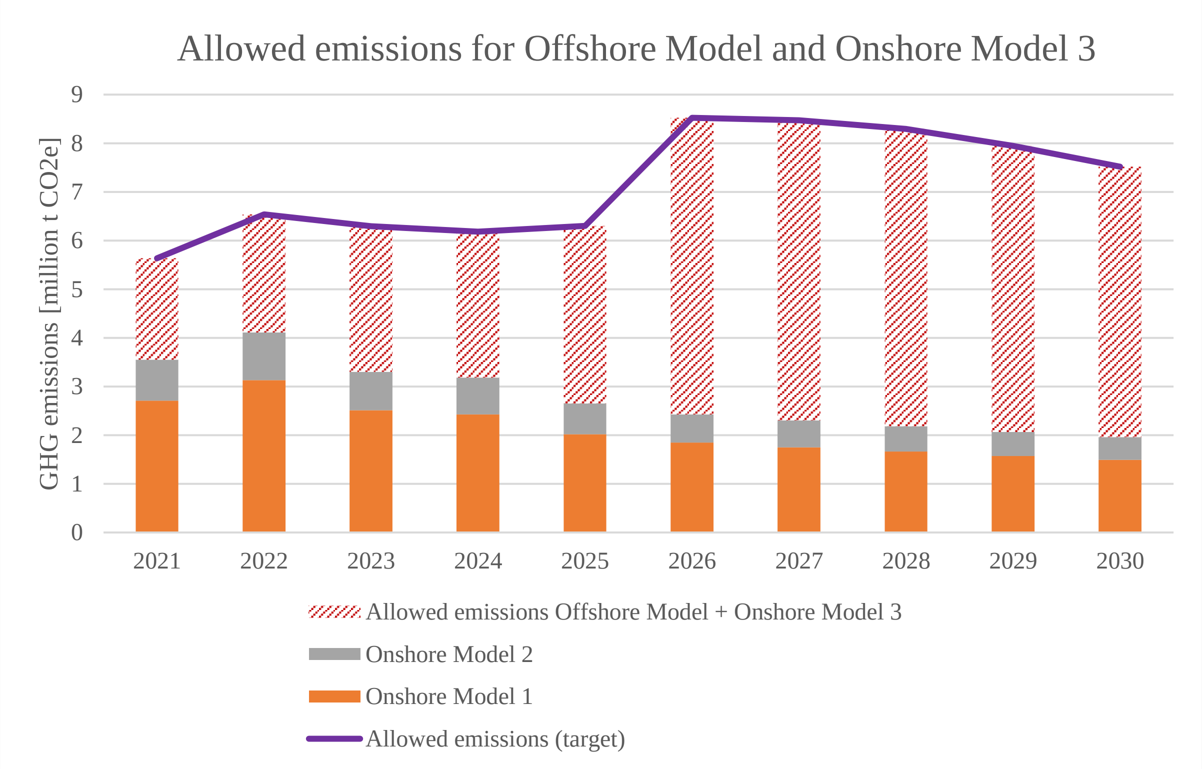

Figure 13: Allowed emissions for Offshore Model and Onshore Model 3

According to the respective share of MW installed of the Offshore Model and Onshore Model 3 for each year, the annually allowed emissions can be allocated to the two models. Thereby, the amount of reduction that each of the two models needs to deliver is linked to their respective sales performance in MW. For instance, in 2021 the Offshore model makes up 70 % of the combined MW installed of the two models. Consequently, it gets allocated 70 % percent of the allowed GHG emissions. In 2030, the Offshore model only makes up 46 % of the combined MW installed of the two models. Therefore, only 46 % of the allowed emissions are allocated to it (see Figure 14) (for calculations, see Appendix B, Tab 1, section 2.8).

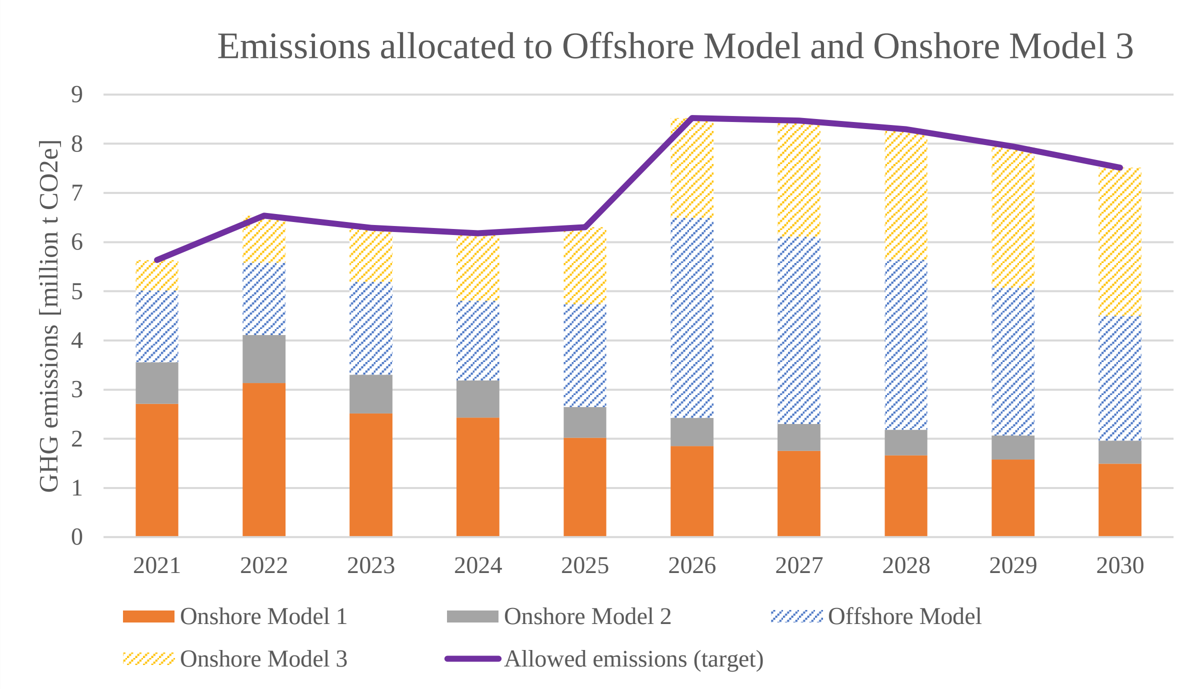

Figure 14: Allowed emissions allocated to Offshore Model and Onshore Model 3

With the entire allowed annual GHG emissions now being allocated to the four different products, GHG emission intensity trajectories with annual targets for each turbine model can be obtained. This is done by applying Equation 6 (for calculations see Appendix B, Tab 1, section 2.9).

Equation 6: Calculating turbine model annual GHG emission intensity targets

$$Turbine\ model\ annual\ GHG\ emission\ intensity\ \left[\frac{kgCO2e}{MWh}\right] = \frac{Tubine\ model\ annual\ allowed\ GHG\ emissions\ [kgCO2e]}{Turbine\ model\ annual\ MWh\ [MWh]}$$

As a result of the calculation, Table 5 is obtained, showing annual GHG emission intensity targets for all products from 2021 to 2030 that add up to the respective annual fleet average intensity target and subsequently to the 45 % reduction target. Since Onshore Model 1 and 2 were de-prioritised due to decreasing share in sales, their GHG emission intensities stay constant from 2021 to 2030. Therefore, the prioritised Offshore Model and Onshore Model 3 each need to deliver an overall GHG emission intensity reduction of 58 % respectively until 2030. However, some of the cells in the table need to be adjusted to represent a more realistic reduction trajectory for the two models. These cells have been marked in orange. Referring back to Table 2, the Offshore Model starts out with a GHG emission intensity of 6.0 kgCO2e/MWh and Onshore Model 3 with 10 kgCO2e/MWh in 2021, which needs to be corrected in the table here. Moreover, the reduction trajectory for the Offshore Model is unrealistically steep in the years up to 2025, while the emission intensities for Onshore Model 3 are above its 2021 value.

Year	Offshore Model [kgCO2e/MWh]	Onshore Model 1 [kgCO2e/MWh]	Onshore Model 2 [kgCO2e/MWh]	Onshore Model 3 [kgCO2e/MWh]	Fleet average [kgCO2e/MWh]
2021	5.8	8.0	5.0	11	6.9
2022	5.5	8.0	5.0	10.4	6.9
2023	5.6	8.0	5.0	10.7	6.9
2024	5.2	8.0	5.0	9.8	6.8
2025	5.1	8.0	5.0	9.6	6.6
2026	5.1	8.0	5.0	9.7	6.3
2027	4.5	8.0	5.0	8.5	5.8
2028	3.8	8.0	5.0	7.2	5.2
2029	3.1	8.0	5.0	5.8	4.5
2030	2.4	8.0	5.0	4.6	3.8
Overall reduction	-58%	0%	0%	-58%	-45%

Table 5: Annual GHG emission intensity targets (non-adjusted)

Adjusting the marked values upward for the Offshore Model and downward for Onshore Model 3 produces Table 6, with the adjusted cells marked in green (see also Appendix B, Tab 1, section 3.0). Now, both the Offshore Model and Onshore Model 3 need to begin to reduce their GHG emission intensities in 2024. To achieve the target of a fleet average of 3.8 kgCO2e/MWh, the Offshore Model needs to reduce its GHG emission intensity by 60 % compared to 2021 and Onshore Model 3 needs to reduce its intensity by 54 % compared to 2021. Making these adjustments means that in the period from 2022 to 2025, the fleet average emission intensity is above the originally calculated trajectory (cells marked in orange). This, however, is not a concern, since the organisational-level target of reducing supply chain emissions by 45 % per MWh will be achieved because the fleet average GHG emission intensity will be down to 3.8 kgCO2e/MWh in 2030 (see Table 6).

Year	Offshore Model [kgCO2e/MWh]	Onshore Model 1 [kgCO2e/MWh]	Onshore Model 2 [kgCO2e/MWh]	Onshore Model 3 [kgCO2e/MWh]	Fleet average [kgCO2e/MWh]
2021	6.0	8.0	5.0	10.0	6.9
2022	6.0	8.0	5.0	10.0	7.0
2023	6.0	8.0	5.0	10.0	7.0
2024	5.8	8.0	5.0	9.8	7.0
2025	5.6	8.0	5.0	9.8	6.9
2026	5.1	8.0	5.0	9.7	6.3
2027	4.5	8.0	5.0	8.5	5.8
2028	3.8	8.0	5.0	7.2	5.2
2029	3.1	8.0	5.0	5.8	4.5
2030	2.4	8.0	5.0	4.6	3.8
Overall reduction	-60%	0%	0%	-54%	-45%

Table 6: Annual GHG emission intensity targets (adjusted)

The final emission intensity trajectories for each product and the fleet average are represented in Figure 15. Both Table 6 and Figure 15 can be utilised to provide design departments with an overview of which products' GHG emission reduction efforts should be focussed on and by when reductions need to be delivered.

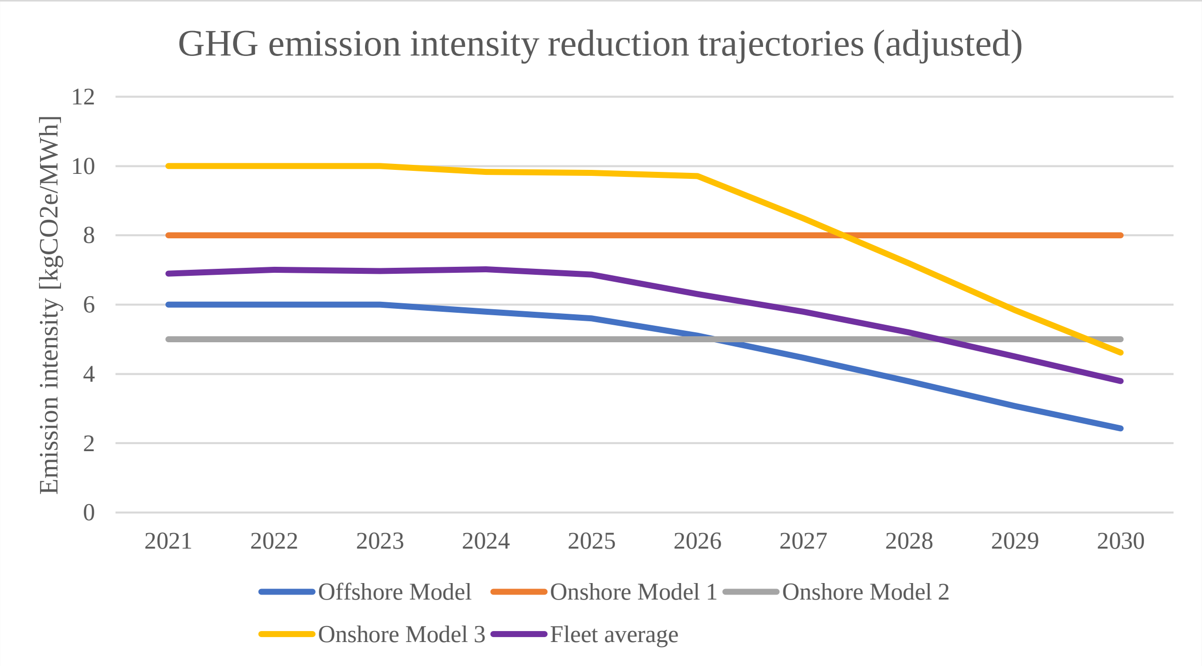

Figure 15: GHG emission intensity reduction trajectories (adjusted)

With this, the translation of the organisational-level Scope 3 target to product-level targets is complete. All detailed calculations can be found in Appendix B, Tab 1. Furthermore, Appendix B, Tab 2 presents the same translation process with the difference that only Turbine Model 2 is de-prioritised, leading to annual GHG emission intensity targets for the Offshore Model, Onshore Model 1 and 3. However, with the product-level targets in place, now it needs to be specified which materials used in the products need to be focussed on and how the different departments, which are responsible for the design of certain parts of the turbine need to contribute to reaching the targets.

6.1.2 Identification of material hot spots

With product-level targets set, it now needs to be investigated how these can be reached. For organisations like Vestas, whose Scope 3 emissions largely come from raw material extraction and fabrication, it is imperative to evaluate which materials contribute mostly to the overall GHG emissions to be able to then launch strategies for reducing their emission intensity or substituting them.

Referring back to Figure 11, the bars showing the overall GHG emissions caused by the annually installed fleet in the no-action scenario can be split to show the contribution of each material type. Moreover, the amount that each material contributes to the total GHG emissions per year can be forecast until 2030, as well. The necessary data on the contribution of materials to the total GHG emission can be obtained in two different ways. One option is to gather the purchased amount of each material from procurement and multiply it by the materials' respective GHG emission factors. Another option is to gather the material breakdown of each turbine model from their respective LCAs, multiply it by the number of turbines sold for each model in the year and then multiply it by the respective emission factor for the material. This way, not only the total annual GHG emissions per material type can be obtained but also the GHG emissions per material type per turbine model. This enables a more accurate forecast of total GHG emissions per material type based on the number of turbines sold form each model. Due to the sensitivity of the data, no actual numbers from Vestas can be disclosed. To provide an example anyhow, the forecast created in Section 6.1.1 based on Wind Europe (2022) data is divided by the material contribution based on the assumed values displayed in Table 7. Since it is looked at the entire Scope 3, GHG emissions not originating from raw material extraction and fabrication, such as transport and logistics, are collected in the ‘Other Scope 3’ category in the table.

Material	**Percent contribution to total emissions**
Steel	50%
Iron	10%
Aluminium & alloys	3%
Copper & alloys	1%
Glass & carbon composites	12%
Polymer materials	3%
Electrics/Electronics	5%
Lubricants & fluids	1%
Other Scope 3	15%
Sum	100%

Table 7: Material percent contribution to total emissions

Figure 16 plots the forecasted material contribution to the total GHG emissions against the target emission curve originating from the 45 % Scope 3 reduction target. It illustrates that, to reach the target in 2030, GHG emissions originating from raw material extraction and fabrication need to be significantly reduced, or GHG intensive materials need to be swapped out with alternative solutions. It also clearly shows material hot spots such as steel, glass & carbon composites and iron, which together make up 72 % of the total GHG emissions in this fictional scenario. However, materials like electrics/electronics, aluminium & alloys, as well as polymer materials should not be neglected either.

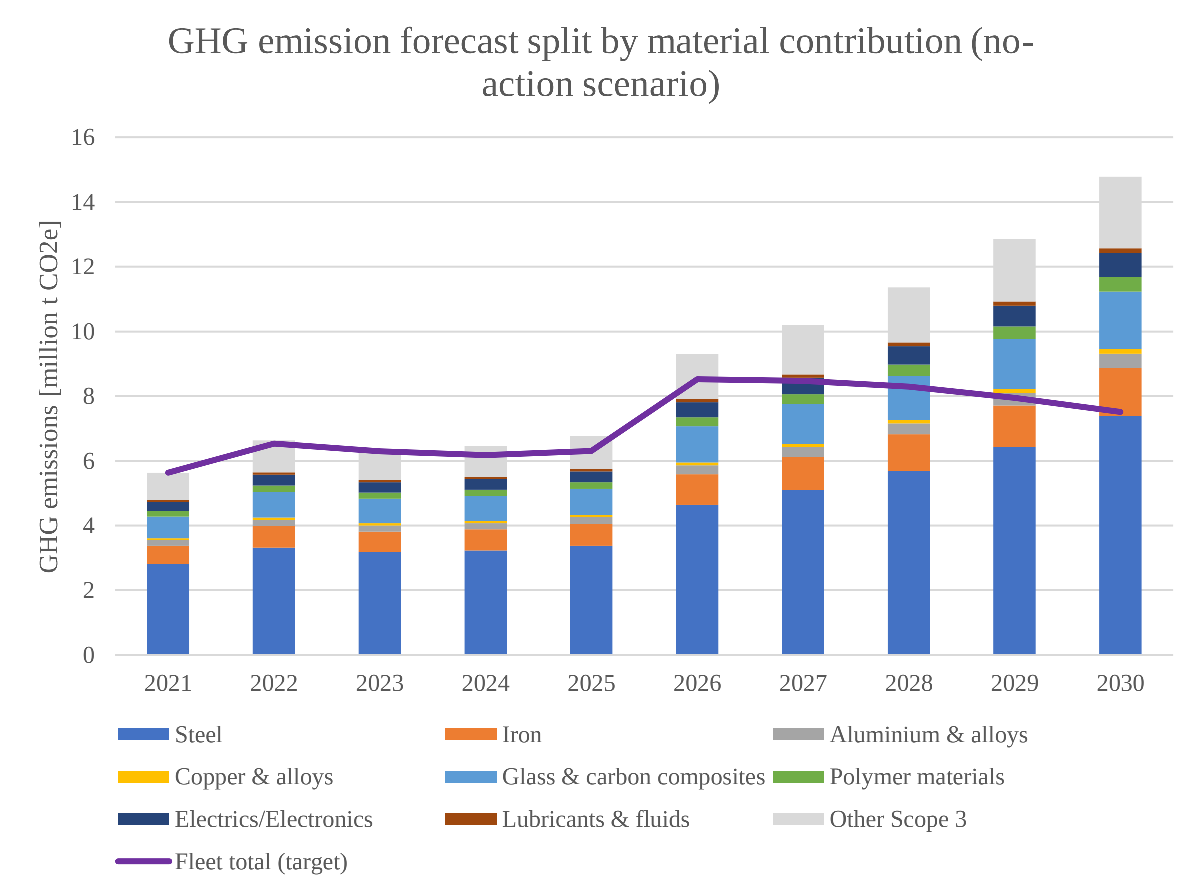

Figure 16: GHG emission forecast split by material contribution (no-action scenario)

With the material hot spots identified, foci can be set both for the design departments working with the materials, for procurement and for research & development to investigate technology readiness and roadmaps for GHG intensity reduction of the existing materials, as well as for alternative materials including their respective scalability, cost and availability. Subsequently, it can be forecast how much each of the alternatives can contribute to GHG emission reductions and to reaching the 2030 target. Based on that, implementation can be driven forward in collaboration with the supply chain.

However, to keep the internal focus on the organisation, the material usage of each design department needs to be quantified, so that, if possible, ownership over the different materials can be assigned and foci for each department can be set.

6.1.3 Setting foci for design departments

Now that annual GHG emission intensity targets for the prioritised turbine models are set, and overall material hot spots have been identified, it needs to be specified how the different design departments, which are responsible for the design of certain parts of the turbine need to contribute to reaching the targets.

To be able to work towards the emission intensity targets set for each turbine model, it is important that each of the design departments understands the carbon footprint of their components and their materials. To provide this overview, first the design departments' contribution to the total emissions of each turbine model needs to be calculated. There are several ways this can be done. One option is to build an LCA model of each turbine in which the components are grouped by 'Design Module' and therefore by design department. Since LCAs are Bill of Materials (BoM) based, the components need to be mapped to the respective design department they are designed by, which can be a tedious process if no automation through e.g. identifiers exists. When the LCA model of the turbine is grouped by design department, it is possible to read the Global Warming Potential caused by each design department in the results. Another option is to gather data on each design department's purchased material per turbine model and multiply the quantities by the respective material GHG emission factor to obtain the design department's contribution to the product's total carbon footprint. Here, it is crucial to verify the reliability of the used GHG emission factors and which life cycle stages these refer to (e.g. raw material extraction, fabrication, etc.). However, an advantage of the second option is that it enables both the creation of the departments' contribution to a product's GHG emissions and the identification of material hot spots at the same time.

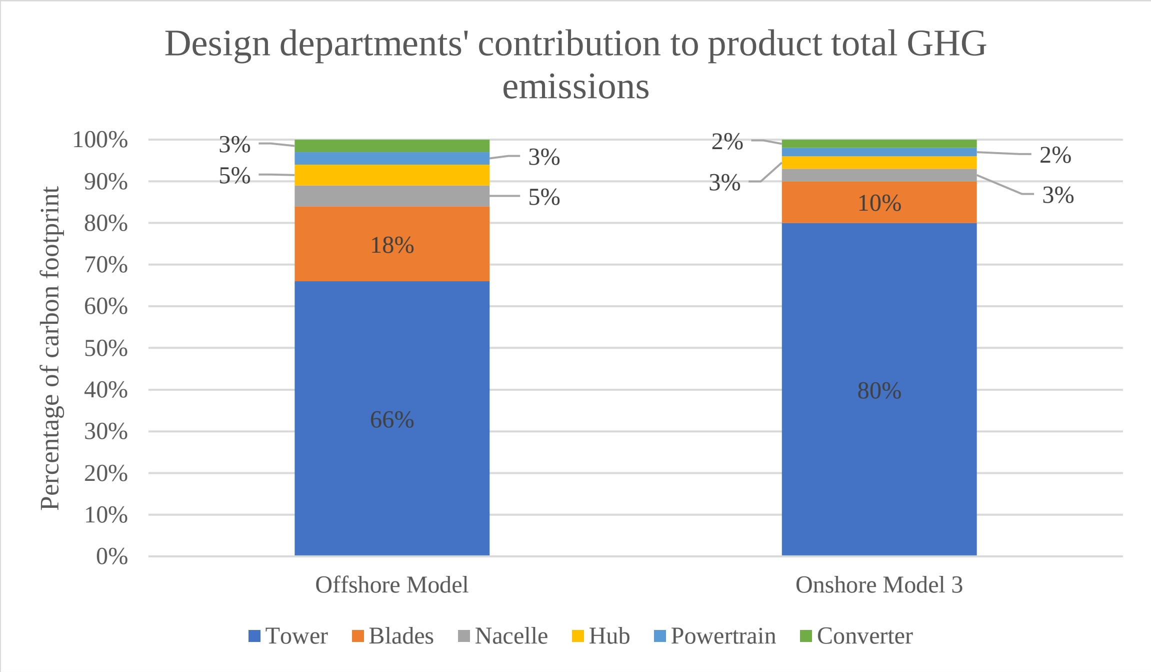

Figure 17: Percent contribution to CO2 per Turbine Platform

Figure 17 illustrates a rough example of a percentage breakdown of GHG emissions per design department for the fictional Offshore Model and Onshore Model 3 that can be obtained with an LCA model grouped by design department. For offshore turbines, the tower is smaller relative to the rotor diameter than for onshore turbines. Therefore, the amount the tower design department contributes to the total emissions of the offshore turbine is less and the percentage of the blades design department is higher. In both cases, the tower design department and the blades design department are the largest contributors to the total emissions, which is due to both the GHG emission intensity of the materials they use and their respective mass. If a prioritisation is desired, these two design departments can be prioritised for carbon reduction initiatives.

As a next step it can be investigated, which materials each design department uses and how each of the materials contributes to their carbon footprint per turbine model. An example of such a hot spot analysis can be seen in Figure 18 using approximate percentages.

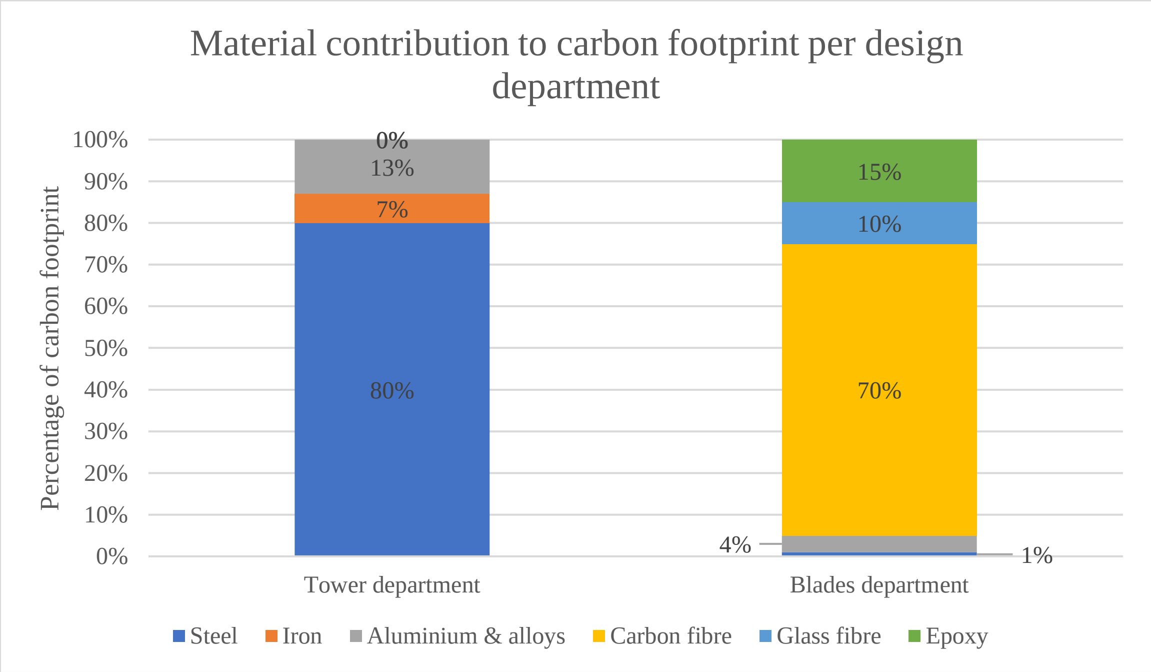

Figure 18: Material contribution to carbon footprint per design department

From an overview like this, material hot spots within the departments can be seen. In the case of this example, the largest hot spots are steel and carbon fibre. As identified in Section 6.1.2, steel and glass & carbon composites, of which carbon fibre is a major part, are two of the major material hot spots that together make up 62 % of the entire Scope 3 emissions. Accordingly, a major focus for the tower department should be to reduce the carbon footprint of steel or replace the material with alternatives, whereas the blades department should have the same focus on carbon fibres. Initiatives can be started within each department to for instance reduce the quantity used of the materials until the in Section 6.1.2 described assessments on technology readiness, roadmaps, cost, scalability, and availability of alternatives are completed and supply chain strategies for each of the material hot spots are implemented. The reductions achieved by the supply chain strategies will then have an impact that has an effect on all design departments, which often use the same materials. For instance, a strategy for procurement of low-carbon steel will have the biggest impact on the carbon footprint of the tower department, however, it will also have an impact on the hub and the nacelle design departments, which both also use steel. Therefore, it is imperative that the impact of expected reductions from alternative materials or GHG reduction strategies for existing materials are mapped against the no-action scenario in Figure 16. This way, the reduction potential per material or per GHG reduction strategy can be shown. This in turn enables a gap assessment and can guide both research & development, procurement, and the design departments on the actions they need to take based on the knowledge they gained from the overview of their individual carbon footprints. The overviews in Figure 17 and Figure 18 are mainly to educate design departments on their contribution to the carbon footprint of the products and point them towards their individual material hot spots to be tackled in the short term by design changes and re-designs until a supply chain strategy for each material is implemented.

6.1.4 Conducting LCAs to evaluate design improvements and progress towards targets

To aid design departments in design changes and re-designs for the sake of GHG emission reductions, LCAs can be utilised as a tool in the product development process. According to Luz et al. (2018) LCAs can support the process in multiple ways, here illustrated at the example of the blades department. Firstly, it can be used to create GHG emission baselines for each blade model. Turbine models are being sold for many years and in this timespan, it is common that the turbine is upgraded to improve performance, competitiveness, and cost. As such, original blade's global warming potential on the first-generation turbine can be used as baseline for measuring improvements of future generations. To create the baseline, the exact material breakdown of the original blade needs to be known and an LCA model needs to be created. From the results of the LCA model, blade specific hot spots can be identified to which the blades department can apply Eco-Design for achieving a lower carbon footprint of the upgraded blade. Once upgrades have been made, LCAs can calculate the global warming potential of the upgraded blade and compare it to the baseline to quantify the improvement (Luz et al., 2018).

Since this is an example of an existing blade for an existing turbine, the room for changes and improvement through Eco-Design is limited. The above-described steps fall into what Luz et al. (2018) categorise as detailed design phase. While this is a suitable approach for existing products, the support of LCAs can have a much larger impact in the development of new products and components. For instance, following the suggestion by Luz et al. (2018), learnings taken from the hot spot analysis of above original blade can be fed into the planning phase of an entirely new blade for an entirely new turbine to identify improvement strategies. This could be that a change in shape is needed to support the reduction of carbon fibre in the blade to reduce its carbon footprint without compromising its structural integrity. Once several concepts of a new blade have been designed, LCAs can help selecting the concept with the best environmental performance, or lowest carbon footprint in this case. After choosing a blade concept, which is then designed in detail, LCAs can be utilised to compare the performance of the detailed design to that of the initial concept. These steps can be applied and, as suggested by Brambila-Macias et al. (2021), conducted by a life cycle engineer, which is a position that could be established in every design department.

When the prototyping and testing phase is reached, an LCA of the entire turbine can be conducted to quantify overall environmental impacts, upon which can be evaluated, whether the product-level GHG emission intensity target has been achieved. Consequently, by following Luz et al's (2018) methodology of integrating LCAs into the product development process, Eco-Design applied to existing products can be supported and enhanced, entirely new products can be developed with a focus on environmental sustainability and carbon footprint reduction and progress towards sustainability targets, such as the product-level GHG emission intensity targets can be tracked.

6.1.5 Conclusion on the top-down approach

The purpose of the top-down approach was to answer the first part of the research question, namely how organisational-level sustainability targets can be translated into product-level targets. The translation process has been illustrated with an example translation of Vestas' Scope 3 emission reduction target using fictional and publicly available numbers. Since the process shown is quite specific to the wind industry, a more generic process is demonstrated in Figure 19.

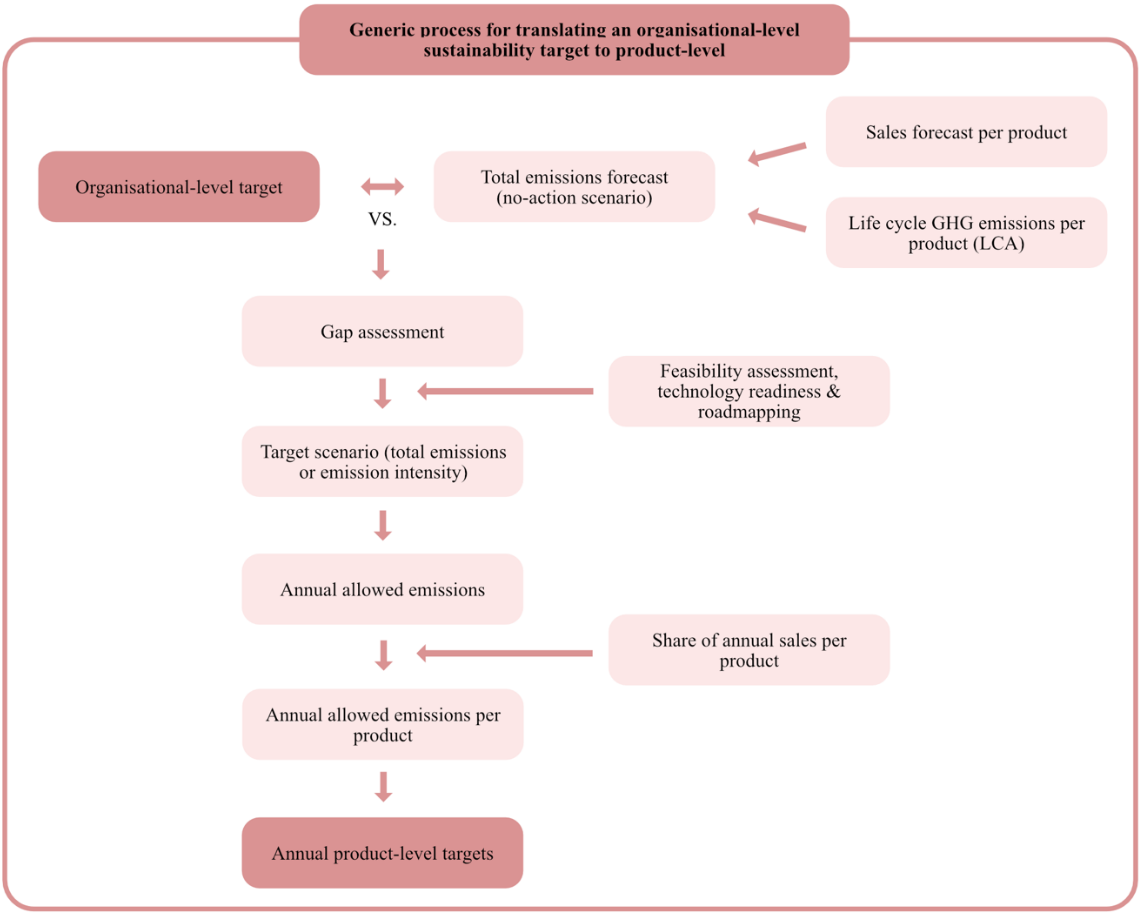

Figure 19: Generic target translation process

First the life cycle GHG emissions per product need to be obtained from LCA, as well as the sales forecasts for each product. These life cycle GHG emissions per product are multiplied with the sales forecast per product, so that a forecast of total emissions can be created, which does not factor in any reductions and is therefore called no-action scenario.

This no-action scenario is then compared to the organisational-level target that is set and the gap is assessed. With the help of feasibility assessments and technology road mapping a target scenario with annual emission intensities or total emissions can be created. Usually, this trajectory is shaped like a hockey stick (see Figure 9) to allow time for technology development and implementation before reductions can be achieved. From this target scenario, the maximum allowed emissions per year can be derived. These function as threshold. The maximum allowed emissions per year can then be divided onto the different products based on their share of sales all the way to the year that the target needs to be achieved. This way, annual product-level emission or emission intensity targets can be obtained.

To provide additional guidance to the design departments, material hot spots have been identified as part of the top-down approach. Material hot spots can be identified in several ways depending on which data is available. Figure 20 shows an approach where annual purchase data for each material needs to be obtained from procurement. This data is then multiplied by the respective emission factor to obtain the total annual emissions per material. This way, hot spots can be identified.

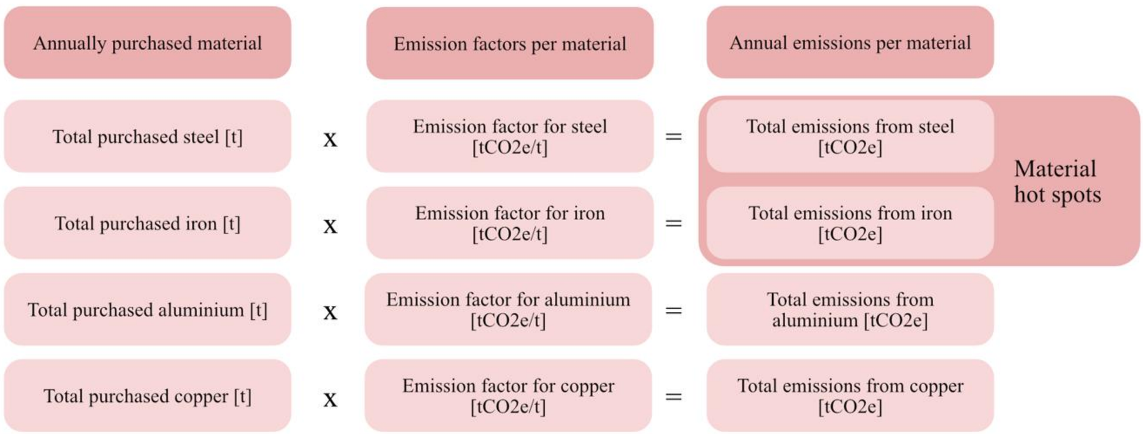

Figure 20: Generic material hot spot identification approach I

A second approach is shown by Figure 21, where material breakdowns are extracted from product LCAs. The material data is then multiplied by the number of units sold and the respective emission factor for the material to obtain the total emissions per material per product for one year. This can be done for each product and added up to obtain the annual emissions per material for the entire product portfolio. This way, material hot spots can be identified. The advantage of this approach is that in the same process, material hot spots per individual product can also be identified. Using the sales forecast for each product, emissions for each product per material can then also be forecast into the future.

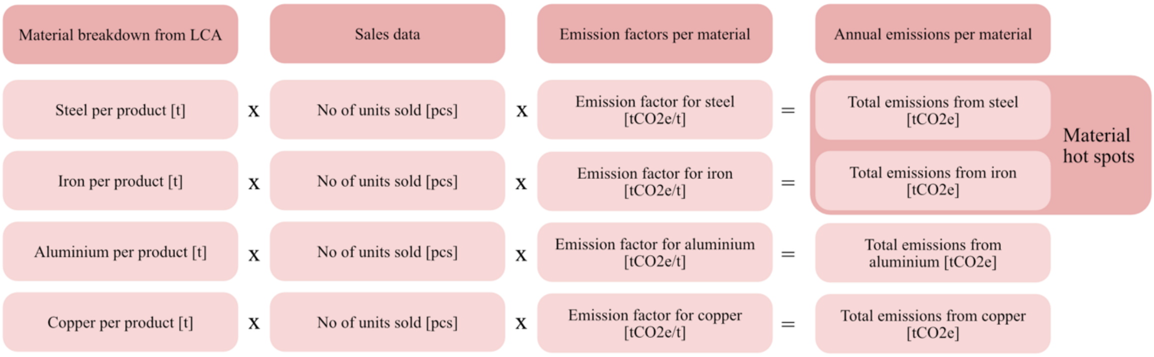

Figure 21: Generic material hot spot identification approach II

Moreover, an example was given on how to identify individual design departments' share of a product's carbon footprint so that the departments understand their hot spots and can track their progress towards the product-level target. There are several approaches to this. One approach is to build an LCA model of each product in which the components are grouped by the department they are designed by, which makes it possible to read the Global Warming Potential caused by each design department in the results. Another approach is to gather data on each design department's purchased material per product model and multiply the quantities by the respective material GHG emission factor to obtain the design department's contribution to the product's total carbon footprint. The overviews provided by either of these approaches can then further be used to identify which materials are the largest contributors to the department's emission share of the product. Once the materials with the largest emission shares are known, it can be worked on reducing their impact through both design changes and technology development in the supply chain or they can be swapped out if feasible. This will be aided by the implementation of LCA in the different phases of the product development process.

6.2 Bottom-up approach

The previous section concludes the top-down approach of translating organisational-level sustainability targets to product-level, answering the first part of the research question. This section focuses on the bottom-up approach taken to answer the second part of the research question, which is about finding out how to improve the capacity of design departments to design more sustainable products (see Figure 22).

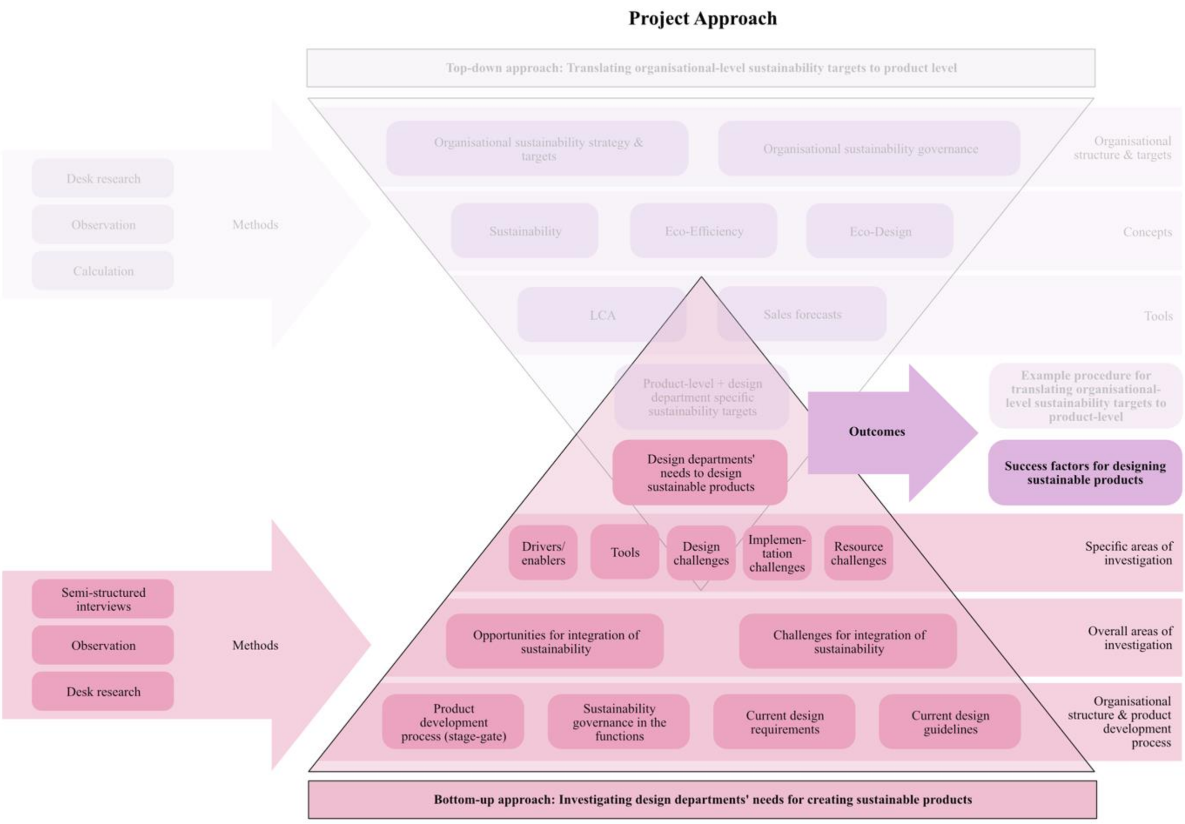

Figure 22: Bottom-up approach

To follow the bottom-up approach, first the findings from desk research, document reviews and observation are described, after which the findings from the semi-structured interviews are presented. The findings from desk research and observation start with a review of Vestas' product development process, move on to the review of Vestas' existing sustainability related design guidelines and close of with other relevant observations gathered throughout the stay in the organisation. This is followed by a section on the semi-structured interviews. Seven semi-structured interviews (Silverman, 2014) have been conducted with employees in the blades design department, each in a different part of the department and with different responsibilities to account for different angles on the subject. Amongst the interviewees was one aerodynamic specialist, a structural engineer, a materials engineer, a process design engineer, a senior function lead, a module design owner and the sustainability champion in the blades department. The blades department was chosen, because it faces sustainability challenges, both in terms of carbon footprint reduction, having the second largest carbon footprint (see Figure 17), and in terms of circularity and waste reduction, due to the nature of the composite materials mainly used in blades manufacturing. In particular, the interviewees were asked where they currently had touchpoints with sustainability in their daily work, where they see opportunities and barriers for sustainability in their department, and what support they require from the organisation to design more sustainable products (For interview transcripts, see Appendix A, section 3). In the following, the findings from these interviews are presented in a clustered form. First, sustainability challenges are described, which are clustered into design challenges, resource challenges, and integration challenges. Afterwards, the identified sustainability opportunities are elaborated on, which are divided into drivers/enablers, tools, and design opportunities. Finally, conclusions are drawn from the empirical material to answer the questions on how the organisation can improve the capacity of its design departments to design more sustainable products and systematically work towards organisational sustainability targets.

6.2.1 Findings from desk research and observation

Desk research, document reviews and observation in the case study organisation were conducted as part of the bottom-up approach. The following sub-sections summarise the findings from these.

6.2.1.1 Product development process

Document revies reveal that Vestas follows a stage-gate model in their product development process. This stage-gate model clearly defines the activities and milestones in the process as well as the outputs of the process. The product development is driven according to the turbine-level design requirements, which are e.g. market requirements, feature requirements, cost requirements, or weight requirements, which apply to the entire turbine and are set in the beginning of the process by higher management. The stage-gate product development process also defines standard tools and processes used during project execution. It was found that at two gates in particular, LCA should be conducted. In the early stages of the project, a streamlined LCA should be conducted as a preliminary assessment to guide the design departments on where to focus efforts in terms of Eco-Design, design for disassembly, reduction of carbon footprint and increase of recyclability. For each of these, a dedicated design guideline exists. Then, at a later stage, a full ISO LCA should be made, which would then be based on the BoM of the actual product and assesses environmental impacts in detail. However, from discussions with the environmental specialist, it became clear that the assessments do not have the desired effect, since Eco-Design is not required to be conducted in the process. Subsequently, only a few design departments actively work with it and follow the process as intended.

6.2.1.2 Review of sustainability related design guidelines

Vestas has several sustainability related design guidelines, namely an Eco-Design guideline, a CO_2 footprint design guideline, a recyclability design guideline, and a disassembly design guideline. The aim of each guideline is to support design engineers to reduce the environmental impacts over the life cycle of the product and to support the organisation’s aim to develop products with lower overall environmental impacts and lower LCoE. Each of them contains a definition of the topic, as well as general principles to be followed to optimise the design, as well as general process steps or an application example. Practical advice is provided, such as a complete procedure for Eco-Design according to ISO 14006, a list of emission factors for the 50 most commonly used materials, a list of materials’ and substances’ theoretical and actual recyclability, and a disassembly checklist ready to be used by design departments. These guidelines represent a good knowledge base for the design departments to utilise when designing components and products. However, the usage so far has been limited due to the environmental sustainability not being a hard requirement in the product development process. Consequently, Eco-Design activities, CO_2 footprint reduction activities, recyclability increase and design for disassembly activities are either not assessed at the gates in the product development process, or their assessment does not have the significant consequences due to the low prioritisation.

6.2.1.3 Relevant observations

As part of the stay at Vestas, the author participated in meetings of the sustainability department, the environment department and a meeting of both departments with the sustainability champions throughout the organisation.

During this meeting with the sustainability champions, a few relevant observations were made. Firstly, there is a scepticism towards the organisational-level commitments and targets. In the current state, it is unclear to the sustainability champions how these are intended to be achieved. To do away with this uncertainty, it was called for lower-level, quantifiable targets for the departments. Each department desires to know how much it needs to contribute to reach the organisational-level targets and how they currently perform in relation to it. Moreover, the introduction of sustainability requirements on product-level was requested to enable the departments to allocate resources to work towards the organisational-level target.

From the observations in the sustainability department and the environment department, the following could be gathered. With regard to the organisation's Scope 3 target, most potential is seen in the supply chain and in reducing the carbon footprint of materials through different technologies as opposed to design changes. As such the main focus is on a global strategy for accelerating the so-called green steel or CO_2 reduced steel, which is produced at a much lower the carbon footprint, with Electric Arc Furnace steel showing reduction potentials of 63-97% over conventional steel (IPOL, 2021). Given steel is the single largest contributor to the organisation's Scope 3 emissions (see Figure 16) and also the single largest contributor to the life cycle GHG emissions of a turbine, green steel would reduce product GHG emission intensity significantly. However, there is also an awareness that green steel alone will not be enough to reach the target, and that other materials with a large contribution to Scope 3 emissions need to be taken into consideration, as well. Moreover, it is seen as important to introduce lower-level, quantifiable sustainability targets within the organisation and the process of translating the Scope 3 target has begun (see Section 6.1). The department that sets product-level design requirements has been involved to sign off the targets and introduce the design requirements that are being called for.

6.2.2 Interview findings: Sustainability challenges

The interviewees mentioned numerous sustainability challenges in their department. During the analysis of the interviews, it was possible to cluster the challenges into design challenges, resource challenges, integration challenges and other challenges. Each of these are elaborated on below. The full interview transcripts can be found in Appendix A, section 3.

6.2.2.1 Design challenges

The first sub-cluster within the sustainability challenges mentioned by the employees can be described as design challenges. Within the design challenges, three areas were identified which are described in detail below: balancing trade-offs, difficulty in assessing impacts of alternative solutions, and the designers' perceived limited influence on sustainability. An overview can be seen in Figure 23.

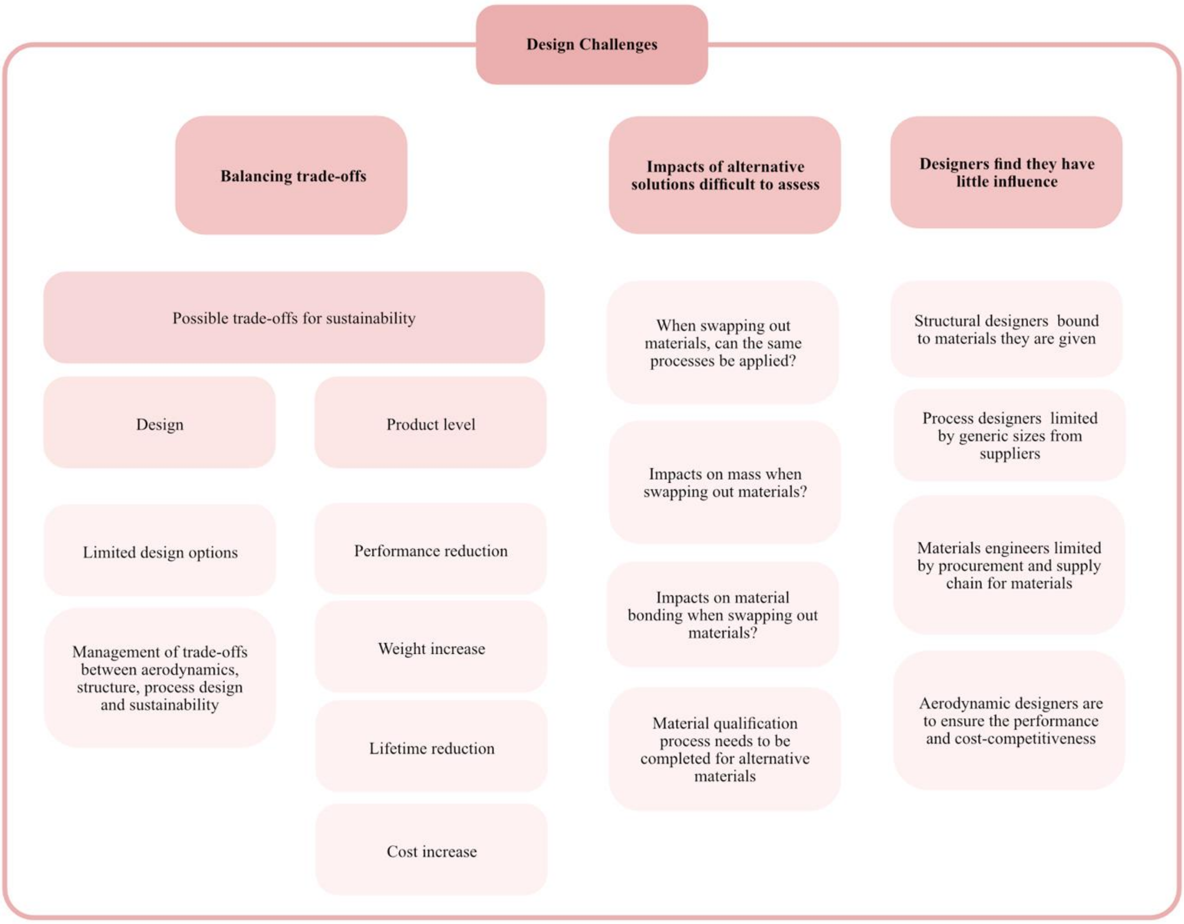

Figure 23: Interview findings: Design challenges

Many of the design challenges faced by the interviewees and their colleagues revolve around balancing trade-offs. The interviewees identified that introducing sustainability in blades design can result both in trade-offs in the design process and on product-level. The first trade-off mentioned for the design process is that an increased focus on sustainability could limit the designers' design options, i.e. in terms of choosing materials, which then also has an impact on weight, structure, shape and aerodynamic performance. This in turn means that trade-offs between the different design areas within the blades design department, such as aerodynamic design, structural design, materials engineering, and process design, need to be managed. Currently, there are already trade-offs between the different design areas, which need to balance the different requirements brough forward to them. These are usually product-level (turbine-level) requirements and are derived from current market needs, so that the overall product increases competitiveness by serving the market needs in the best possible way. The interviewees mentioned turbine-level design requirements such as Annual Energy Production, Decreasing Levelized Cost of Energy (LCoE), quality, reduction in BoM cost and mass, time-to-market and noise levels. These requirements are then translated to performance requirements, structural requirements and process requirements, which are used by the materials engineers to create a technical purchase specification. Using the turbine-level design requirements as guidelines, potential trade-offs are managed. The interviewees pointed out that if there should be a focus on sustainability, a sustainability design requirement would have to be added to the turbine-level design requirements and made a KPI.

Moreover, a number of trade-offs on product-level were prognosticated, when designing a more sustainable blade. Here, the interviewees assumed that a reduction of certain materials, like carbon fibre, or the introduction of different, more sustainable materials would be necessary to achieve a more sustainable blade. This could require significant changes to the blades' shape and structure. Accordingly, the following trade-offs were brought up: performance reduction, weight increase, lifetime reduction, and cost increase. It was made clear that not necessarily all of them would occur simultaneously and with severance, but the consensus was that it would not be possible to achieve more sustainability without these trade-offs, at least until the sustainable solutions are matured. The structural engineer summed it up like this: *"[…] I think when these new materials come online, I think there will have to be some kind of drop but of course to compensate for that you'll have the ability to have a much better sustainable product on the market. So and maybe it will be 2 tracks you'll do in parallel for a while. We'll still use our materials that we use today and we'll have our high-performance blades, but we'll have our sustainable kind of track where it's not such a high-performance* *product"* (Structural engineer, 2022). Consequently, most of the interviewees wished for guidance from the organisation on which trade-offs should be taken and to which extent.

Another theme of design challenges was that impacts of alternative solutions are difficult to assess. The structural engineer in particular had the following concern when speaking about the introduction of alternative materials: *"So process wise, what does it mean? Again, the cost of the process. Can you use that material with the materials we use today?"*. There might be challenges using the same processes used today at the same cost as today when creating alternative solutions and the impacts on component mass and on material bonding when swapping out materials is difficult to assess. Additionally, it was brought up that the material qualification process for alternative materials needs to be conducted first before the materials can be used by the structural designers, who choose their materials from a qualified catalogue in a database. Subsequently, the assessment of effects from the introduction of alternative materials needs to be eased.

The final theme that was found within the cluster of design challenges is designers' and engineers' perception that they have little influence on sustainability. For instance, when wanting to reduce waste, process designers are limited by the generic sizes from supplier: *"There are other restrictions like our manufacturers have restrictions, the raw material manufacturer has some restrictions. They cannot make a manufacturing process specific to Vestas. They have a generic manufacturing which suits for large customers"* (Process design engineer, 2022). Similarly, the structural engineers are bound to the materials they are given by the materials engineers: *"[...] we would always be set a specification or a requirement. You must use these materials. Generally, the requirements of designing a blade are normally very tight. So, it's not like you can say I'm going to use this material, it's nowhere near as good as this other material but it's got a better footprint. Because then you wouldn't hit the actual design requirements, if that makes sense"* (Structural engineer, 2022). Additionally, materials engineers are bound to the technical purchase specification derived from the design requirements and limited by procurement and suppliers while aerodynamic designers are to ensure the performance and decrease LCoE. From this it can be concluded that it would aid the designers and engineers if there was one or several sustainability-related design requirements, which would allow them to overcome some of the present restrictions they are facing.

6.2.2.2 Resource challenges

The second sub-cluster within the sustainability challenges uncovered by the interviews is called resource challenges (see Figure 24).

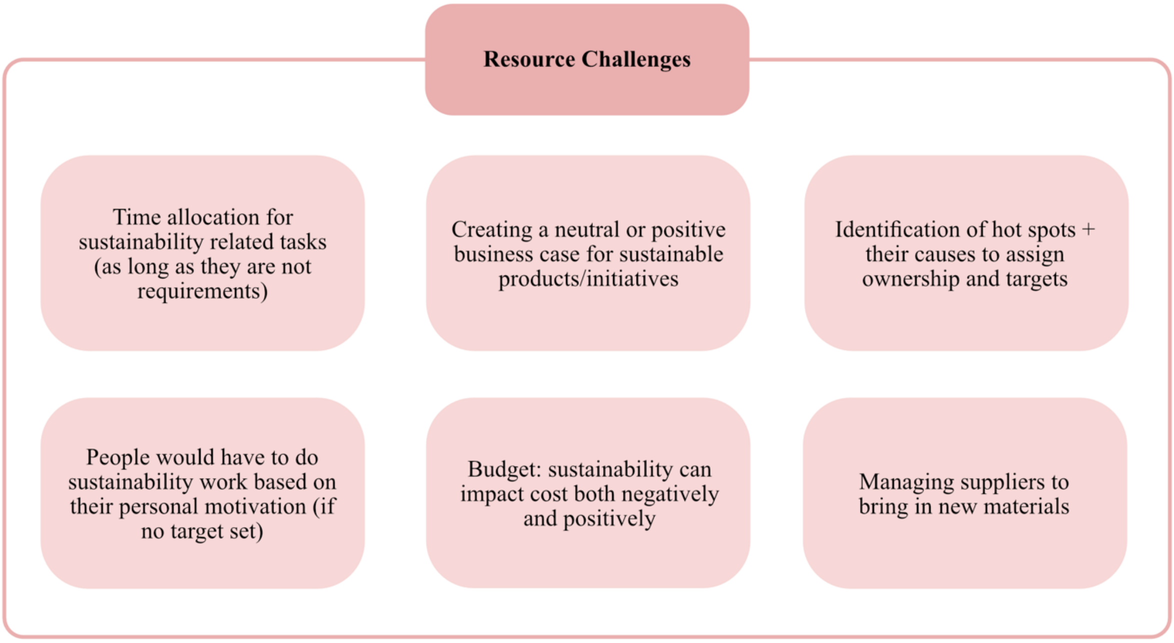

Figure 24: Interview findings: Resource challenges

Here, the interviewees mentioned difficulties in time and resource allocation to sustainability related tasks as long as sustainability is not part of the formal design requirements, which is why employees currently do sustainability related work mainly based on their personal motivation. *"[…] I mean the other thing is funding to spend on technology. […] That doesn't come for free, and we need to commitment from the company to give hours and costs to developing that."* (Senior function lead, 2022).

Moreover, managing suppliers to bring in alternative materials and products was pointed out as an additional challenge that could put strain on resources. *"If you think about it, the majority of that carbon is in our supply chain. So, a large part of that activity is managing the suppliers. And therefore, we need to plan for that. Which is partly the hours required to audit the suppliers to work with them, to bring in new products, et cetera."* (Module design owner, 2022). Another challenge in terms of resources is building a cost neutral or cost positive business case for sustainable products and sustainability initiatives since *"sustainability impacts both positively and negatively from a cost perspective. […] If we can reduce our waste that has a positive impact on cost […]. Some materials which have more functionality, for example recyclability,* *have a potential to increase price. And that has a negative impact on us. […] And that's the challenge. We need to achieve this level of sustainability, but we have to do it in a way that is a positive business case or is neutral"* (Module design owner, 2022). To aid the design departments in this challenge, the module design owner made a call for clear guidance on whether to take cost increases for sustainability initiatives or not and on the amount of hours that is expected to be spent on sustainability related tasks. Lastly, the sustainability champion in the blades module mentioned two more challenges: the identification of hot spots and their causes, and assigning ownership over them and set targets to work towards. Here, they pointed out that responsibilities need to be made clearer and resources need to be assigned.

6.2.2.3 Integration challenges

The third sub-cluster of the sustainability challenges was coined integration challenges, as they refer to the lack of integration of the sustainability strategy and its targets throughout the organisation and in the design departments (see Figure 25).

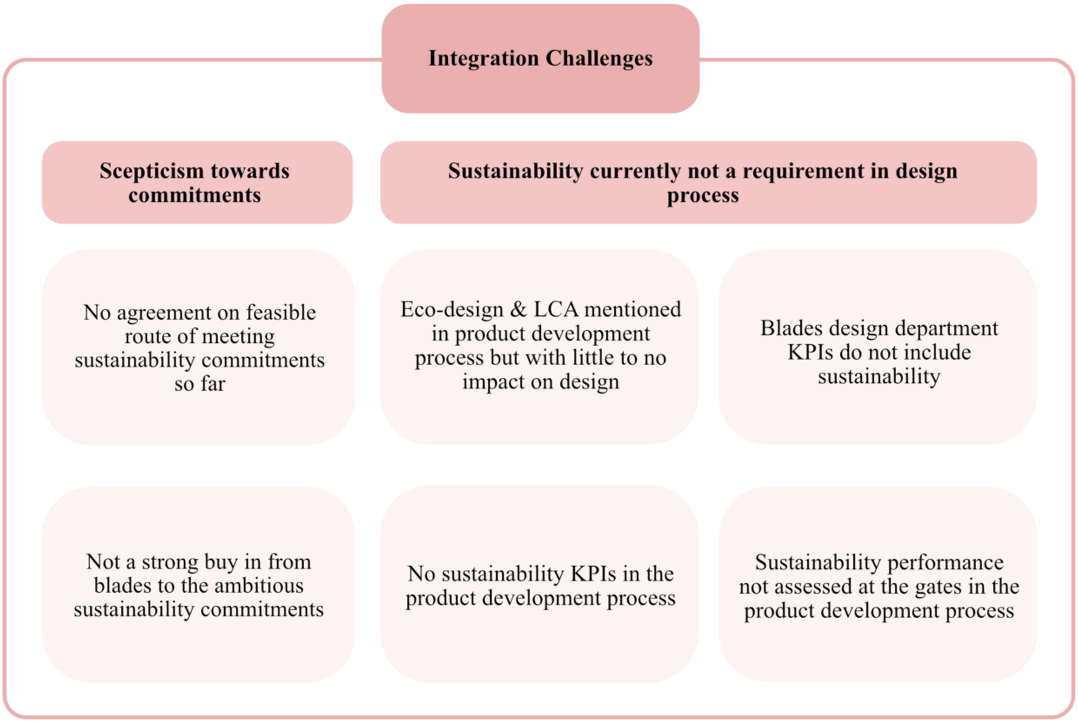

Figure 25: Interview findings: Integration challenges

The senior function lead in particular described the issue as follows: *"So, to some extent the actual sustainability targets, you know they were a commitment that's been made in the town hall, but I don't really see that we have an agreed and a feasible route to meet them so far"* (Senior function lead, 2022). This perception is supplemented by the following statement from the module design owner: *"It doesn't feel yet that we've got a concrete plan that we're now actioning in a very focused way"* (Module design owner, 2022). These perceptions lead to scepticism towards the organisation's organisational-level sustainability commitments: *"In terms of the new ambitious commitments that Vestas has made, I see that there's still, there's not really a very strong buy in from blades module yet."* (Senior function lead, 2022)

The overarching theme is the lack of integration of the sustainability commitments through, e.g. sustainability requirements and quantifiable targets in the product development process, which makes it challenging for the design teams to focus on sustainability activities. For instance, there is a lack of integration of impact quantification tools like LCA and concepts like Eco-Design in the product development process: *"It is definitely not specific enough. So, the eco-design is mentioned, you know LCA awareness is mentioned. That's where we need to have some strengthening […]. So, there's a mention of it, but it doesn't really explain or push for specifics"* (Sustainability champion, 2022). With this lack of integration, there are no sustainability KPIs at the gates of the product development process and sustainability performance is subsequently not assessed, or if assessed it does not have a significant impact on design: *"[…] KPIs for example don't yet include this sustainability really. It's yeah, we're judged on the cost and the quality and the speed that we can get things done really […]"* (Senior function lead, 2022).

After mentioning that there is awareness of the overall sustainability strategy and its organisational-level targets, the Senior function lead pointed out the integration challenge: *"Either we need, like, the blades module, for example, needs to be given a KPI or something from management to say that in X number of years […] we need to see the percentage of recyclability increasing or we need it in the actual product requirements. […] And either way can work, […] I think it just needs to be tied into the bigger strategy of Vestas. At the moment we're not going because we don't have these targets and no one's pushing for them"* (Senior function lead, 2022).

Judging from the statements of the interviewees, there is currently a lack of integration of the sustainability strategy in the organisation and in its product development process. Especially the lack of lower-level targets and KPIs is pointed out as a severe hinderance for the design departments to allocate time and resources to sustainability related tasks. Finally, it seems to be necessary to implement sustainability KPIs at the gates of the product development process, so that Eco-Design can be applied more systematically and LCA results can have an impact on design choices instead of being de-coupled from the process.

6.2.2.4 Summary of sustainability challenges

All in all, the interviews uncovered a number of sustainability challenges that the blades department is facing. These were grouped in design challenges, resource challenges, and integration challenges. The identified design challenges revolve around trade-offs in the design process and between different product performance parameters, the difficulty of assessing impacts of alternative materials, and the engineers' perceived little influence on sustainability. Here, the interviewees wished for a clear expectation for which trade-offs to accept and for sustainability design requirements, which would enable a collectively driven effort to design more sustainable products.

The second group of challenges are resource challenges in terms of time allocation for sustainability related tasks (as long as there is no clear target to work towards), managing suppliers, creating neutral or positive business cases for sustainability projects and defining responsibilities for assessing environmental impacts and hot spots. To overcome these challenges, it was suggested that lower-level targets should be set, clear expectations regarding cost limits of sustainability projects should be communicated by management, and responsibilities should be clarified by management. Finally, integration challenges have been identified, such as the scepticism towards organisational-level targets as no feasible route of delivering upon them is seen, and the integration of sustainability in the product development process, where there is currently a lack of sustainability design requirements and KPIs, and sustainability is not assessed at the gates, which renders LCA and Eco-Design ineffective. With the introduction of sustainability product-level sustainability requirements and sustainability KPIs within the process, this challenge should be overcome.

6.2.3 Interview findings: Sustainability opportunities

Apart from sustainability challenges, there are numerous sustainability opportunities and action suggestions pointed out by the interviewees, which are elaborated on in this section. During the analysis of the interviews, the three clusters of sustainability opportunities became evident: drivers/enablers, tools and design opportunities. The full interview transcripts can be found in Appendix A, section 3.

6.2.3.1 Drivers/enablers

The first sub-cluster of the sustainability opportunities is called drivers/enablers. When conversing about what drives the integration of sustainability in the organisation and in the respective design department, the interviewees pointed out several internal but also external drivers. Amongst the external drivers mentioned was customer demand, which automatically creates a necessity for the organisation to produce more sustainable solutions if it wants to stay competitive. Subsequently, this is one of the most impactful external drivers along with an industry consensus on the prioritisation of sustainability. Moreover, legislation that the organisation needs to comply with was identified as a driver, as well as partnerships with research facilities to i.e. stay up to date with the lates technology developments and finally the availability of substitute materials (see Figure 26). However, since this thesis has an organisation internal focus, these external drivers will not be elaborated on further here.

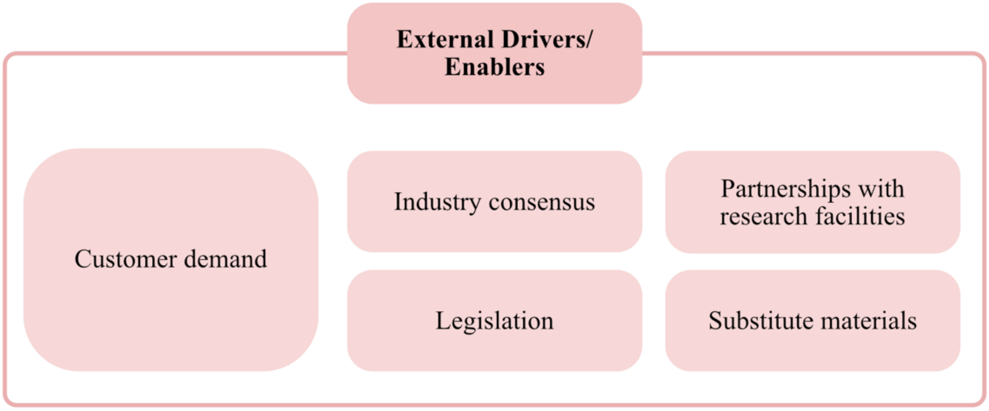

Figure 26: Interview findings: External drivers/enablers

The identified internal drivers/enablers revolve around clear long-term business-level commitments being translated to transparent and quantifiable annual internal targets for the different departments, including clear expectations in terms of contribution share per department, a clear scope of resources to be used and cost limits. Additionally, sustainability requirements for the supply chain were mentioned as drivers, too (see Figure 27).

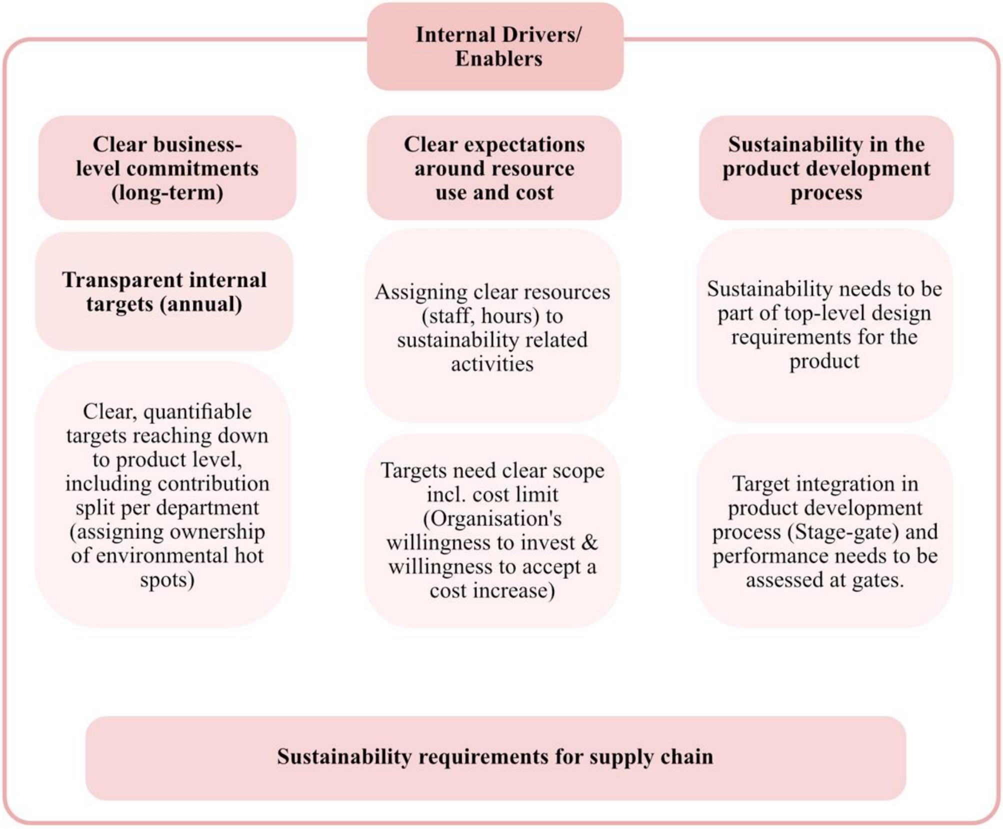

Figure 27: Interview findings: Internal drivers/enablers

As previously described in Section 6.2.2.3 Integration challenges, the buy-in in terms of the high-level business commitments needs to be improved. To do so, the long-term organisational-level commitments need to be translated to targets that the individual departments can work towards: *"[…] you need to decide what you can achieve. And that's to take the high-level targets and actually cascade them down into something which you can define within your area"* (Module design owner, 2022). Moreover, a trajectory of annual targets should be outlined in order to identify on an annual basis whether performance is on track: "*[…] now what we have is really in top level big targets like in 2030 or 2040. But what is meant for 2022 to 2023, like where we need to be there so that we achieve the 2030 target?"* (Process engineer, 2022). Annual targets would enable the different departments to spend time and resources on sustainability related tasks. However, the interviewees suggested that these targets need to fulfil a number of criteria. They need to be quantifiable, on both product-level and department-level, and the contribution per department needs to be clear, so that ownership over e.g. certain material hot spots can be assigned, as the sustainability champion points out: *"[…] it will be significant to know it [sustainability target] on turbine level and then a certain split also on annual basis, what is gonna be the pie we [blades design department] need to fulfill to improve in our performance as well, then we get more concrete"* (Sustainability champion, 2022). Moreover, with the targets, clear expectations must be cascaded down as guidance for assigning resources, such as staff and working hours, to sustainability related activities: *"The key thing […] is the business needs to be completely transparent about the expectation. […] The business needs to be really clear how much it wants this and what it's willing to put in. That's simply the point I was making"* (Module design owner, 2022). Clarification as part of internal targets also includes providing a clear expectation in terms of the organisation's willingness to accept cost increases to create more sustainable solutions, which the module design owner insists on: *"You have to give the team a clear scope. And if you're unwilling to take on any extra cost, the team need to know that up front. So, they don't waste their time qualifying materials which have a price delta"* (Module design owner, 2022).

To summarise, quantifiable, annual targets would enable the departments to assign resources to sustainability tasks and focus on the assigned impact hot spots, track their progress and set it into perspective to the long-term organisational-level target. Additionally, these individual targets would assure the departments that they are making exactly the contribution they are expected to deliver towards the organisational-level target. Moreover, the business setting clear expectations as to how much it is willing to invest into sustainability in terms of staff and working hours would enable the departments to plan and allocate resources in line with the expectations. Finally, a clear declaration as to whether at all or how much of a cost increase for more sustainable solutions the business is willing to accept would enable the departments to make design choices accordingly and communicate with suppliers clearly and effectively on the subject.

To then further enable the design departments to focus on sustainability in their design work, sustainability needs to become a part of the product development process, as discussed in Section 6.2.2.3. Part of this integration can come from introducing product-level sustainability design requirements according to which new products need to be developed. Another part is the integration of product-level or even component-level sustainability targets at the gates of the product development process, which would enable the design departments to actively work towards them in a step-by-step fashion.

Finally, the interviewees evaluated that sustainability requirements for the supply chain is also an enabler, as this would provide them with more guidance on how to select suppliers, what to expect from suppliers, and what to work towards in collaboration with suppliers. Moreover, they move the supply chain into a more sustainable direction driven by the demand from Vestas.

Overall, the major enablers identified by the interviewees are:

- the introduction of transparent, quantifiable, annual internal targets,
- clear expectations from management in terms of resource use and cost limits to achieve these targets,
- the introduction of sustainability-related requirements on turbine-level,
- sustainability targets at the gates of the product development process,
- sustainability requirements for suppliers.

6.2.3.2 Tools

Another part of the sustainability opportunities mentioned by the interviewees could be combined into a cluster called ‘tools’. The interviewees either see a necessity to introduce these tools to enable them to work towards the targets mentioned in Section 6.2.3.1 or as something that could enhance the integration of the sustainability strategy in the design departments and the organisation as a whole. The tools suggested were divided into three groups: project analysis & prioritisation, design and information flow (see Figure 28).

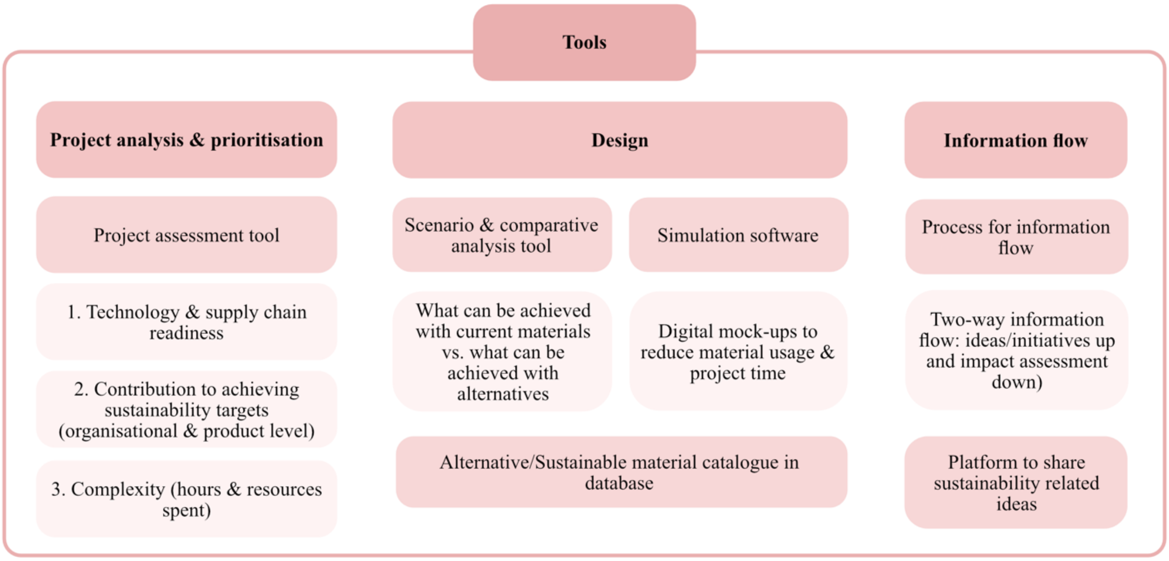

Figure 28: Interview findings: Tools

The first tool for which a need was identified is a project analysis and prioritisation tool. Some assessment and tracking of sustainability projects within the blades design department had been started at the point in time when the interviews were conducted. Assessing sustainability projects was seen as difficult because several dimensions need to be taken into account. That's why a standardised assessment tool for sustainability projects that can be used across departments was suggested: *"So, we almost need a diagram where we check the projects in the three dimensions: complexity of the project with respect to market readiness or industry or supply chain readiness, the impact that it makes into targets or in the performance of overall. And in a way [...] resource needs"* (Sustainability champion, 2022). This indicates that the needed tool would have to assess three dimensions. Firstly, the technology and supply chain readiness of the solutions needed to carry out the project, secondly, the project's contribution to achieving product-level and organisational-level sustainability targets and thirdly, the complexity of the project in terms of hours and resources spent, including cost.

The second group of tools the interviewees spoke about was design tools. A need for scenario analysis and comparative analysis tools was identified: *"I think LCAs and good comparative analysis is quite important"* (Materials engineer, 2022). This would enable design departments to make informed choices and decisions on e.g., which materials to choose and which concepts to develop further. The sustainability champion identifies the need for LCA and comparative analysis to assess how much optimisation of current solutions can contribute to reaching the targets to define what a future solution needs to deliver: *"I think one thing we really need to* *some sort of LCA and Makersite [product data management software] combination. Like design choices versus the minimum we can reach with current materials versus what should be a future enabler"* (Sustainability champion, 2022). A second design tool, which has recently been introduced, is a simulation software that bears the potential of both reducing material waste and project time, according to the structural engineer. *"The idea of having a digital mock up blade using the [simulation software] and the new tools that we've got is that we'll go down to one, maybe even zero mock up builds. So, there's a huge amount of material save and of course, project time"* (Structural engineer, 2022). This can enable the design department to contribute to the organisation's zero-waste commitment. The final design tool suggested is a catalogue of alternative/sustainable materials in the material database, which the structural engineers can choose from: *"[…] if we get to one day, where we have a catalogue of, let's say, more sustainable material properties that we can use, then there's no reason why we can't design with those properties"* (Structural engineer, 2022). This catalogue could enable a design on the most sustainable materials that are suitable and available. In summary, the introduction of LCA and other scenario analysis and comparative analysis tools is desired, as well as an increased use of simulation software and the creation of a catalogue with sustainable materials.

The third type of tools mentioned by the interviewees are to enhance the information and data flow within the organisation:*"If we get some help in that direction somebody is processing the data and just sharing with us"* (Process engineer, 2022). In particular, a process for a two-way information flow was suggested, where ideas, project suggestions as well as descriptions of initiatives would flow up and impact assessments in terms of contribution to the organisational-level targets of these would flow down along with a prioritisation. *"[…] I obviously would like to have more concrete connection. How we can do you know, even sometimes smaller tasks and what do they serve into the horizon and into the targets or how do they serve? What's their contribution? What's the impact they will make?"* (Sustainability champion, 2022). Along with this, a platform for ideas was suggested, where employees can share and discuss their ideas for sustainability initiatives.

All in all, the above suggested tools would support assessment and prioritisation of sustainability projects, design for sustainability, and the connection between the top level and the lower levels of the organisation.

6.2.3.3 Design

The remainder of the sustainability opportunities discussed in the interviews can be clustered as design opportunities. These are primarily seen in structural design, aerodynamic design, as well as in waste reduction (see Figure 29).

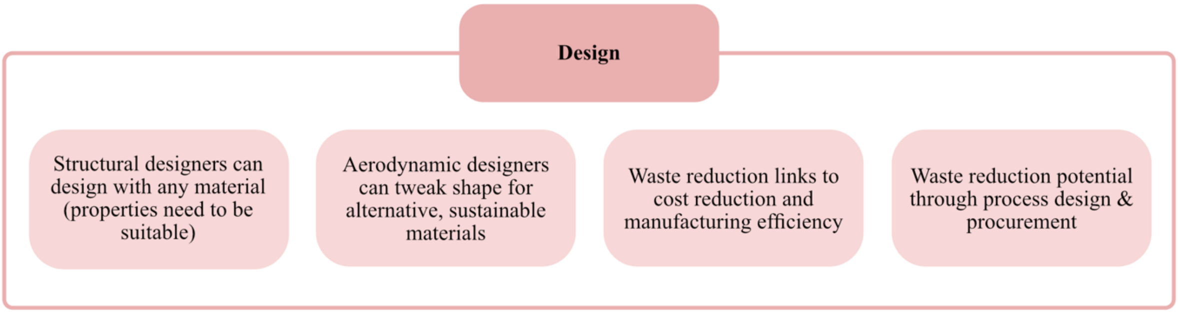

Figure 29: Interview findings: Design opportunities

The first design opportunity is suggested in structural design, which deals with ensure the structural integrity of the product throughout its expected lifetime. It was suggested that structural designers can work with alternative materials: *"We can design with any material. Essentially, we just need to know the properties and then that feeds into how much of that material we need, what material to be using, let's say in terms of sustainability"* (Structural engineer, 2022). Combined with the before mentioned catalogue of sustainable materials, this opens a clear opportunity of improving the sustainability of components and the overall product.

Moreover, when it comes to the airfoil design specifically, the option of optimising the shape for alternative materials is recognised in the aerodynamics team. *"We are looking at this sustainability from the point of view. So, what we can do in terms of shape of the airfoils and the blade that could help reduce in certain materials or making the blade more environmental friendly"* (Aerodynamic designer, 2022). Consequently, when the use of certain materials is reduced or alternative materials are introduced, both the structural design and the aerodynamic design teams are optimistic that a good design can be found.

Another design opportunity mentioned by the interviewees is waste reduction. There is a large potential of saving waste through process design and procurement. Additionally, what supports waste reduction initiatives is the fact that waste reduction is connected to cost reduction as well, as the senior function lead points out: *"And so, there's a lot of waste reduction and activities like that because of course there's a clear link to the waste reduction to not only sustainability, but also the cost and manufacturing efficiency"* (Senior function lead, 2022). At the current state, sustainability initiatives can best be justified when they have a cost reduction effect at the same time.

6.2.3.4 Summary of sustainability opportunities

In summary, through the interviews, a number of sustainability opportunities were identified and grouped into drivers/enablers, tools, and design opportunities.

The major drivers/enablers are:

- the introduction of transparent, quantifiable, annual internal targets,
- clear expectations from management in terms of resource use and cost limits to achieve these targets,
- the introduction of sustainability requirements on turbine-level,
- sustainability-related targets at the gates of the product development process,
- and the introduction of sustainability requirements for suppliers.

The suggested tools revolve around

- analysis and prioritisation of sustainability projects,
- enabling design for sustainability through scenario analysis, comparative analysis, simulation, and a sustainable material catalogue,
- and improving the connection between the top level and the lower levels of the organisation with the help of processes and idea sharing platforms.

Finally, design opportunities are seen in structural and aerodynamic design working with alternative materials and in waste reduction, which goes hand in hand with cost reduction.

6.2.4 Conclusions on the bottom-up approach

The intent of the bottom-up approach was to answer the second part of the research question, which is about finding out how to improve the capacity of design departments to design more sustainable products. To do so, seven interviews with employees in the blades design department have been conducted, as well as desk research and observation. The analysis of the findings shows that a clarification of expectations and targets from the management level, the improvement of governance and the introduction of tools are necessary to improve the capacity of the design departments to design more sustainable products (see Figure 30).

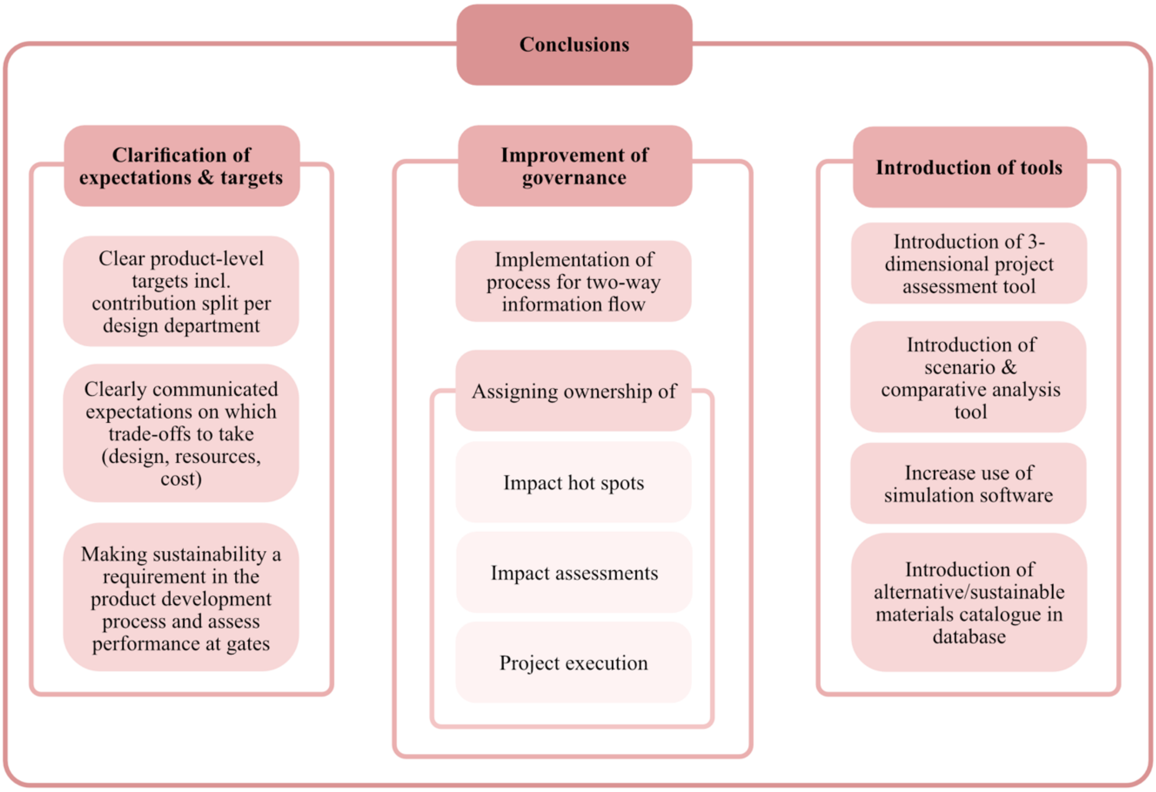

Figure 30: Conclusions: Bottom-up approach

The analysis shows that a number of expectations and targets need to be clarified. Firstly, clear, transparent, quantifiable, annual product-level targets need to be introduced including a clarification on the expected contribution per design department. This will enable the design departments to work purposefully on their individual hot spots while resting assured that their work contributes to achieving the organisational-level target. Having quantifiable targets ensures that progress can be measured, and actions can be taken accordingly. Additionally, it will enable the design departments to spend more resources on designing more sustainable products. Secondly, management needs to clearly communicate their expectations on which trade-offs should be made by the design departments. This includes both design trade-offs, such as product performance, weight and lifetime, as well as how much resources are expected to be committed and whether cost increases are tolerated for the sake of sustainability improvements. If this is given, design departments will clear boundaries within which they can design without having to worry about spending time and resources on designs that are going to be scrapped due to i.e. an increase in cost. Thirdly, sustainability needs to be made a requirement in the product development process in the form of product-level sustainability design requirements as well as KPIs at the gates of the process. Once established this would on the one hand give more weight to the environmental impact assessments provided by LCA during the process and on the other hand enforce the usage of the existing sustainability related guidelines, like the Eco-Design guideline or CO_2 footprint guideline, which enable the design departments to effectively tackle the hot spots identified by LCA.

The second conclusion is that the governance around sustainability needs improvement. Here, the design departments would benefit from the implementation of a clear process for a two-way information flow. This process would funnel ideas for sustainability projects and initiatives from the lower levels of the organisation up to the top level, where impact assessments can be made in relation to the organisational-level targets. These impact assessments can be passed down, along with information on whether the project should be prioritised or not. Additionally, ownership impact hot spots, should be clearly assigned to design departments for them to understand where to focus their efforts and what initiatives to prioritise. Ideally, this should be done in combination with a quantifiable target. Moreover, it needs to be clarified which entities in the organisation are responsible for which kind of impact assessment. For instance, whether the environment department is supposed to do all assessments and cascade the results down to the design departments, or whether the design departments should be able to make assessments on their own for different concepts or for product upgrades. Lastly, the ownership of project execution needs to be clarified. This includes making clear which projects and initiatives are steered by global functions like the sustainability department or the environment department, and which projects and initiatives the design departments have ownership over.

The third conclusion of the bottom-up approach is that design departments require the introduction of additional tools to improve their capacity of designing more sustainable products. Amongst these suggested tools is a standardised three-dimensional project assessment tool, which enables the design departments to prioritise projects according to their technology and supply chain readiness, their impact towards the organisational-level targets and their complexity in terms of working hours, resources and costs. Another tool is proposed to conduct scenario and comparative analysis of e.g. different concepts or optimisations of conventional solutions vs. complete re-designs. This tool could then be used throughout the course of the product development process once sustainability requirements are introduced. Moreover, increased use of simulation software was suggested to reduce the amount of material and money spent on mock-ups and prototypes. Finally, a catalogue of alternative, sustainable materials should be introduced in the database the design engineers use. Once these materials have gone through the qualification process, they will enable engineers to improve components' and products' sustainability by adjusting the design to the new materials.

7 Discussion & reflection

In this section the findings of this study, as well as the study's limitations, advantages and disadvantages are discussed and reflected upon.

7.1 Findings compared to previous research

This section discusses how the findings from the empirical research in this study compare to findings from existing research that was reviewed in Section 3.

To start with, Lozano (2015) pinpoints the internal drivers of corporate sustainability as leadership and business cases. This can be confirmed by the findings from the interviews. Strong leadership including clear commitments and expectations have been identified as imperative for the departments to work effectively on designing more sustainable products. Moreover, the business case has been emphasised as a very important factor in determining whether sustainability projects are pursued or not. In addition, findings from Engert & Baumgartner (2016) can be confirmed stating that a fit between strategy, organisational structure and organisational processes needs to exist for a sustainability strategy to be implemented successfully. A plethora of statements from the interviewees leads to the conclusion that the absence of sustainability requirements and KPIs in the product development process hinders the development of more sustainable products. Moreover, some of the findings from Bey et al. (2013) are being confirmed through the findings from the interviews as well. For instance, the barrier of lack of information on environmental impacts is evident through the interviewees' need for impact assessments, as well as scenario and comparative analysis tools. Similar to Bey et al.'s (2013) results, this study found an emphasis on the need for alternative materials, as well as resources. Their recommendations of establishing a clear management structure and improving information flows are reflected in the interviewees' calls for assigning ownership of projects and hot spots and establishment of a two-way communication process. However, the findings of this research differ from the above to the extent that these are specific to a design department in a large organisation. Another difference is the identification of the need for specific tools used for the design of more sustainable products.

Manninen & Huiskonen (2022) find that it is harder for employees to relate to organisational-level sustainability targets than it is to business unit or role dependent sustainability targets.

This finding can also be confirmed by this research, with multiple interviewees asking for cascading down the organisational-level targets to be able to define what they mean for them and their department. This makes the finding even more significant that both the top level and the lower levels of the organisation agree upon the importance of translating organisational-level sustainability targets to product-level and beyond to design departments. This finding provides a clear argument for applying the developed target translation process.

7.2 General applicability of the findings

Here it is discussed whether and to what extent the findings can be applied in other organisations and for other types of targets.

The aim of this thesis was to present the findings in a way that it would be possible for other organisations to draw knowledge from them. For instance, for the target translation process, a more generic flow diagram has been created (see Figure 19) and the calculation process for the material hot spots have been illustrated in general terms, as well (see Figure 20 & Figure 21). Since these are still based upon this specific case study, their applicability in other organisations needs to be proven to be able to generate generic processes. Moreover, other organisations can draw on the findings from the interviews, together with the existing literature on the topic to improve the implementation of their sustainability strategies.

Moreover, the simplified and generalised translation process should also be applicable to other targets, such as product-level waste reduction targets (for more on waste reduction and circularity, see Appendix A, sections 1 and 2). In principle, it should be possible to replace the life cycle GHG emissions per product in Figure 19, with the amount of production waste per product, while the rest of the process remains the same. As such, the amount of production waste per product would be combined with the respective sales forecast, leading to a total waste forecast (no-action scenario). This forecast can then be compared to the reduction pathway (target-scenario) that has been created when setting the organisational-level waste reduction target. The gap can be assessed, and the annual allowed waste (derived from the target scenario) can be divided onto the different products according to their share of annual sales to produce annual product-level targets.

7.3 Scientific contribution and contribution to Sustainable Design Engineering

This research fills the gap between the literature that focuses on setting organisational-level sustainability targets, like SBTs, and the literature that focuses on translating product-level sustainability targets to the different manufacturing steps like the sustainability cone framework. To fill this gap, this thesis proposes a translation process for existing organisational-level sustainability targets to product-level. Moreover, the research confirms findings of prior research on drivers, success factors and barriers for the implementation of sustainability strategies. It adds further depth to the literature by providing insights into what support design departments need from the organisation to be able to focus on the development of more sustainable products.

Additionally, this master thesis contributes to the field of Sustainable Design Engineering in several ways. Firstly, it identifies the needs of design departments for designing more sustainable products. Sustainable design engineers can draw on these findings for their research or for implementation in organisations. Secondly, this master thesis contributes with a translation process for sustainability targets, which can be applied by sustainable design engineers as a tool to bridge the gap between formulation and implementation of sustainability strategies in organisations. Finally, when implemented, both the target translation process and the actions derived from the conclusions of the interviews have the potential to greatly improve the capacity of designers and engineers in design departments to create more sustainable products.

7.4 Discussion of the project approach and limitations

In this section, the project approach, as well as methods and choices are discussed including advantages, disadvantages and limitations.

The overall project approach, divided into top-down and bottom-up approaches provided both insights into the mindset, perceptions, decisions and management approach at the top level of the organisation and into the mindset, perceptions, needs and way of working at the lower levels of the organisation. Subsequently, it supported the author in gaining insights into both perspectives, as well as gathering knowledge and information from both sides. In addition to that, it helped structuring the work and structuring the thesis report. However, there is improvement potential. For instance, as part of the bottom-up approach, further interviews with representatives from other design departments could have been conducted to get a more complete picture on their needs for designing more sustainable products.

In the top-down approach, the target translation approach requires a lot of sales data, which has a direct influence on the distribution of targets across the product portfolio. The disadvantage of this is that the sales data needs to reach far out into the future, where it becomes less accurate. Therefore, it is even more important, as Rekker et al. (2022) state in their Paris-Compliant-Pathway, to revise and re-align the product-level targets every time new sales data becomes available. Another factor that can limit the accuracy of the product-level targets is the lack of reflection of different product configurations in LCAs. Like many other products, wind turbines come in different configurations depending on the site conditions. These configurations often have different environmental impacts. For instance, one variable in the configuration of a wind turbine is the hub height, or tower height, which has a large influence on GHG emission intensity of the turbine. This is due to the high emission intensity of steel used in the tower. An onshore turbine with a 100m hub height has a lower GHG emission intensity than the same turbine with a 150m hub height, given the same wind conditions. In the wind industry, LCAs are commonly conducted for a standard configuration of the turbine, with one single hub height in a certain wind condition. If now the LCA data of this standard configuration is taken to calculate product-level targets and track progress toward the target, it might skew the picture, a number of products installed in the given year might have actually been installed in a different configuration with a different hub height. This could be circumvented by basing the GHG emission intensity calculation per product on the amount of material that has actually been purchased.

Another point of discussion is that the process of setting annual product-level targets is based on eco-efficiency. This because the Scope 3 target is a reduction target, which aspires a gradual reduction of products’ emission intensities. This can be a suitable for improving the emission intensity of existing products, however, it might not be the most beneficial concept to use for the development of new solutions, as it reduces unsustainability instead of creating sustainability. In its place, the eco-effectiveness concept could be applied, which differs from eco-efficiency in being an absolute design approach. Introduced and developed by McDonough and Braungart (2002) eco-effectiveness and its application in the Cradle-to-Cradle concept strives to create products that have a beneficial impact on the environment. As such, it could be favourable to develop new solutions according to the principles of eco-effectiveness rather than eco-efficiency. However, the downside of eco-effective products is that they can perform worse in current sustainability assessments, like LCA, since these assessments are geared towards assessing eco-efficiency (Bjørn & Hauschild, 2013). Consequently, LCA would either have to be adapted or other assessment methods would have to be introduced to aid the development of eco-effective products.

7.5 Outlook and further research

To create better cohesion and to make it easier for organisations to take an integrated approach for setting their sustainability targets, the target translation approach presented in this study could be combined with the findings from other existing studies and put into an encompassing framework. This combined framework could contain findings on SBT setting methods from Faria & Labutong (2020) and Bjørn et al. (2021) account for Paris-aligned organisational-level target setting. For the following translation to product-level, the translation approach presented in this thesis could be supplemented with Moshrefi et al.'s (2020) Total Environmental Impact-Total Profit matrix for portfolio management to achieve a more thorough prioritisation of products and product families. Once product-level targets are formulated, Rödger et al.'s (2016; 2019) sustainability cone framework can be utilised to translate the target further and implement life cycle thinking in manufacturing, if applicable.

Further research should be done investigating the general applicability of this study's target translation process including material hot spot identification and determination of contribution share per design department. Additionally, it should be further explored to what extent the target translation process can be applied to non-GHG emission targets, such as circularity targets or waste reduction targets. Finally, the above-described integration of the target translation process with other research, concepts and frameworks from Faria & Labutong (2020), Bjørn et al. (2021), Moshrefi et al. (2020) and Rödger et al. (2016; 2019) could be pursued further.

8 Conclusion

The objective of this report was to answer the research question and its sub-questions posed in Section 4 to fill a gap in existing literature on the translation of sustainability targets in organisations as well as to add new insights to the literature on implementing and executing corporate sustainability strategies.

The first part of the research question '*How can organisational-level sustainability targets be translated into product-level targets?*' was answered via the application of a top-down approach (see Figure 3). With the help of the top-down approach, a process for translating an organisational-level SBT to product level was produced, which is illustrated in generic terms in Figure 31. The process has the prospect of being applicable for other organisations, as well as for other types of sustainability targets, such as waste reduction targets (see Section 7.2).

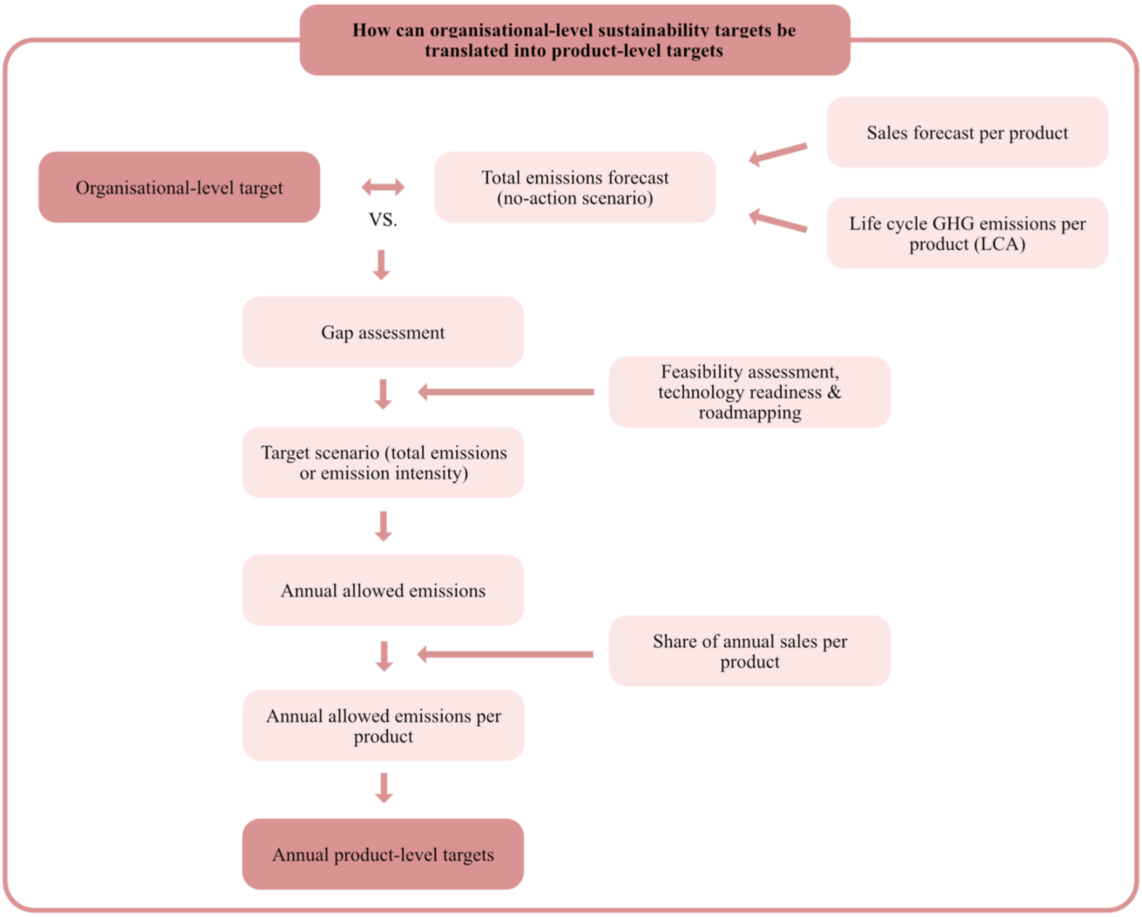

Figure 31: Conclusion - Generic process for translation of an organisational-level target to product-level

During the creation of the translation process, several sub-questions were answered. Firstly, the benefit of translating sustainability targets within the organisation can be identified as improved alignment and relatability towards the organisational-level targets for lower-level departments, easier allocation of resources and launch of initiatives, and trackability of progress towards the organisational-level targets. Secondly, the tools, inputs and steps necessary to translate the target are listed in Figure 31, with the most important inputs being an organisational-level target including target scenario, sales forecasts as well as environmental impact data per product (e.g. GHG emission intensity from LCA). Thirdly, once product-level targets are set, design department's contribution share towards these can be determined. One option for this is to link components to their respective design departments and subsequently group the product LCA by design department. Another option is to identify the design department's material consumption per material type and multiply this by the material's emission factors (see detailed conclusion on the top-down approach in Section 6.1.5).

The second part of the research question '*How to improve the capacity of design departments to design more sustainable products?*' was answered by applying a bottom-up approach (see Figure 22). A major part of the bottom-up approach was the conduction of seven semi-structured interviews, which also helped answer the remaining sub-questions. The qualitative analysis of these interviews, combined with the findings from document reviews and observation within the organisation, showed that the capacity of design departments to design more sustainable products can be improved in three major ways: by the clarification of expectations and targets through management, by improving governance and by introducing tools that support the design of more sustainable products (see Figure 32).

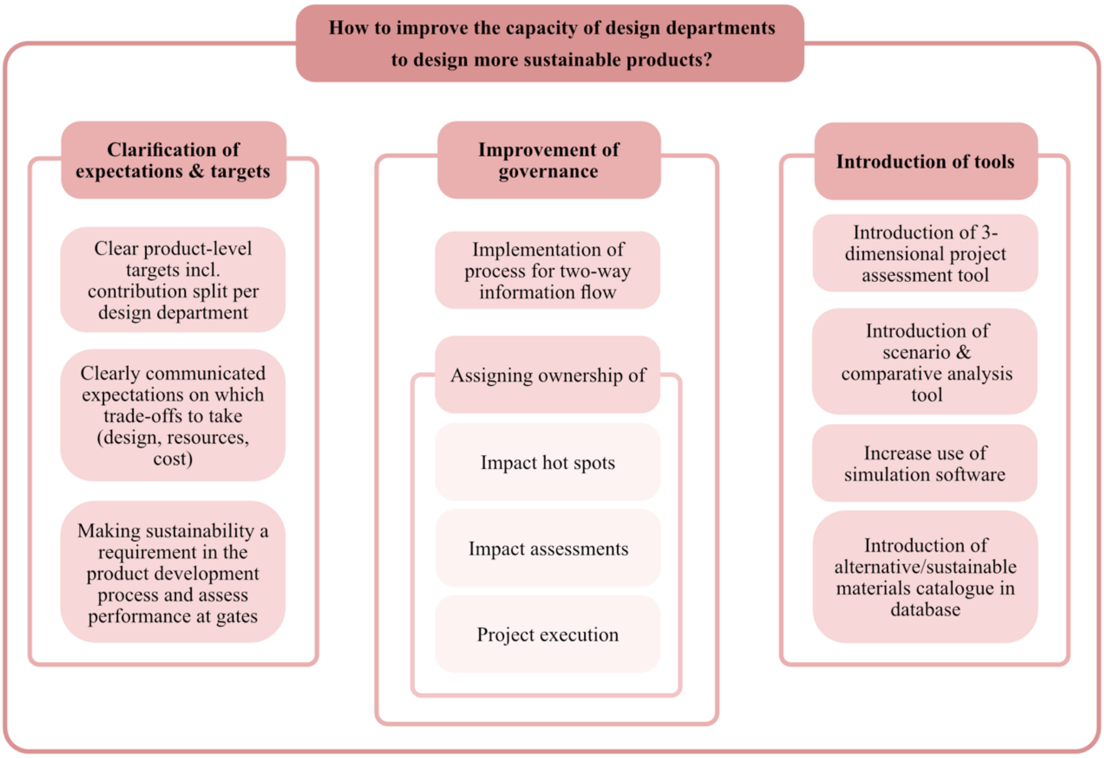

Figure 32: Summary: Improving the capacity of design departments to design more sustainable products

The findings from the bottom-up approach confirm the need for a target translation process developed through the top-down approach. Moreover, they confirm previous research on success factors for the implementation of sustainability strategies (see Section 7.1). Additionally, they provide insight into the specific needs of design departments to design more sustainable products. The findings from the top-down approach contribute to filling a gap in literature. Previously, there was existing literature on setting organisational-level targets that are aligned with the Paris Agreement (namely on SBT methods) and literature on how to translate product-level sustainability targets to manufacturing. Now, the process target created in this study on translating an organisational-level target to product-level fills the gap that existed between the two types of literature.

Further research should be done investigating the general applicability of this study‘s target translation process to different organisations and to different targets. Moreover, the target translation process could be integrated with higher-level and lower-level translation processes from existing literature.

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