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Introducing life cycle thinking in product development – A case from Siemens Wind Power

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ABSTRACT

How can use of LCA improve the environmental sustainability of wind industry products? An analysis of a case study from Siemens Wind Power identifies the knowledge offered by LCA that is relevant to each step of the product development process (PDP). The study illustrates the difference that this knowledge can make to the decision making in the PDP and to the environmental sustainability of the product. Based on these findings, the study concludes with a discussion of barriers for LCA integration in the PDP of complex products and possible measures to overcome them.

1. Life Cycle thinking in wind power technology development

The total installed capacity of wind power has experienced a 25% annual increase rate over the last decade and International Renewable Energy Agency's (IRENA) projections predict a 500% increase in the electricity generation from wind energy between 2010 and 2030 [1]. This creates a challenge for the manufacturers to keep satisfying the growing demand and market requirements and calls for ensuring the sustainability of production and product development.

During the last decade major manufacturers as well as system operators and academia have published extended life cycle assessments (LCA) of their products and systems (e.g. [2,3]). Despite the transparency of the reporting and its marketing value, little has been published on the integration of life cycle thinking in daily routines in the product development process (PDP) or in the strategic planning of the manufacturers.

Learnings from mature industries such as the automotive highlight the value of integrating such considerations in their PDP in order to set the focus right on ecodesign to avoid trade-offs between environmental impacts and to set road maps for target setting and innovation [4,5]. The business benefits of integrating life cycle considerations and transitioning from a single product to a product service system perspective have also been discussed [6–8]. As for the operational part there is an increasing number of publications linking LCA to product development and management processes and coupling environmental assessments with intelligence systems for effective product life cycle management and decision support towards sustainability [9–13].

However, to invest and effectively uptake tools and services that support LCA integration to daily operations, the business case needs to be proved to the decision makers. In this sense the challenge related to first introducing life cycle thinking in an organization and arguing for the value brought to various stakeholders across the system still remains relevant.

The fact that the wind power industry is young and processes still immature and open to changes makes it fertile for idea exploration in terms of life cycle thinking integration. In the context of responsible innovation it is hence the intention of this paper to use the case of a wind turbine rotor blade manufactured by Siemens Wind Power, one of the global market leaders in the sector, and prove the value brought by integrating LCA in the existing PDP which is currently under development. In the process, conditions, process requirements and barriers that need to be overcome will be identified.

2. Rotor blade product development process (PDP)

To evaluate where in the PDP the knowledge brought by LCA can make a difference, a mapping of the current PDP is done (Table 1). On the strategic level, which is prior to the PDP and outside the scope of the current paper, the need is identified in the market for a new solution (e.g. more power capacity). Then a corresponding product that could provide this solution (e.g. an upgraded blade with larger swept area) is developed following a stage gate PDP model [14] which has a linear form and is divided into five technically distinguished steps (Table 1). There is an initial scoping and feasibility exploration of technical solutions which are prioritized before the best enter R&D. There the product design is specified, tested and validated. At the end of the R&D when all the knowledge is gathered and the product and production details have been settled the PDP ends and the project is handed over for commercialization. Within this PDP six clusters of internal stakeholders have been identified as giving technical input: supply chain, factories, design, sales, field projects and service.

Each cluster is mobilized in the assessment of alternative technology ideas to collect technical cost and risk data and evaluate them against criteria related to technical specifications

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Table 1
PDP steps, corresponding requirements locked at the end of each step and potential application of LCA.

Stage/Milestone / Met requirements	Product definition: Scoping	Product definition: Feasibility exploration	Design: Critical design	Design: Design completed	Design: Prototype runs	Implementation / validation	product handover	Commercialization
Product requirement specification (PRS)	x							
Product design specification (PDS)		x						
Design drawings, manufacturing concepts, serviceability and testability specifications, critical suppliers qualification			x					
Part specifications, tools processes and manufacturing technologies				x	x	x		
Specification of purchased materials, parts, tools and technologies			x	x	x	x	x	
Facilities and equipment developed for production in the supply chain						x	x	
Feedback from transport, installation, and trial operation					x	x	x	
Suggested LCA activity and integration into the PDP	decisions - Screening	Preliminary LCA of reference products	1st iteration	Last iteration/ Manufacturi ng data updated		Production data updated / EPDs		Use stage /EOL data updated

and cost estimations ensuring product quality and economic feasibility and competitiveness within guaranteed health and safety conditions. The gathered relevant knowledge is shared via adequate deliverables that are reviewed and evaluated by the management team at the end of each step ‘gate’. The approval of the deliverables means continuation of the business case, locking of the relevant decisions and passing to the next gate.

2.1. Requirement for environmental target

The current version of the PDP does not contain mandatory deliverables for environmental targets. However, there is a strategic requirement for gate level environmental targets to be followed up throughout all the PDP steps. To operationalize that a conceptual framework was developed for integrating environmental considerations in the PDP in the form of a design for environment (DfE) process based on the technical report ISO/TR 14062, integrating environmental aspects into product development. According to this DfE environmental requirements need to be set indicating life cycle stages affected and evaluating improvement potentials.

3. LCA of a rotor blade

An attributional LCA study was performed to quantify the overall environmental performance of a wind power blade. Its goal was to support a weak point analysis and detailed ecodesign and since it is not a comparative LCA the functional unit and the reference flow of the LCA coincide as ‘one rotor blade of 58 m with a lifetime of 20 years’. Primary data was gathered for the foreground system, representing actual conditions at the manufacturer driving material use and consumption in the production stage based on: (1) bill of materials (BOM): material composition of the final product; (2) indirect material: cut off/losses during the production process and auxiliary material required for the manufacturing processes; (3) other material consumed in background in the production facilities and not related directly to the final product nor to the manufacturing processes; and (4) energy consumption, and waste production and treatment during manufacturing. All alternative suppliers providing the aforementioned materials were identified and quantities for transported mass and transport distances accurately specified.

Generic data from the life cycle inventory database ecoinvent v2.2 [15] was used for modelling of the background system, i.e. extraction of resources and production of materials and standard components, power supply, water supply, waste treatment technologies and transport technologies.

Since the aim of the present study is to identify the added value brought by LCA in each step of the PDP rather than to provide specific LCA results for all impact categories and areas of protection, the results are shown only for climate change in CO_2-eq for simplification and given that stakeholders in this first experience with LCA are familiar with CO_2-eq but are easily overwhelmed by multiple impact categories or highly aggregated endpoint impacts.

LCA results are used to identify potential environmental improvements according to impact intensity. The main impact contributors (hot spots) are identified in two dimensions: across the life cycle of the product and within each life cycle stage to the maximum resolution level according to the available data (Fig. 1a–c). It allows the stakeholders in each level to identify the activities over which they have an authority or influence. It also provides the scientific basis for environmental target setting. However the absolute impact scores do not give an indication of the environmental improvement potentials. To get these, the impact can be correlated with the consumption levels through an equi-diagonal plot (Fig. 2) so that a prioritization of environmental initiatives can be made based on the relative importance of materials.

4. LCA integration in PDP

The LCA results need to be coupled with the PDP in order to evaluate the feasibility of potential initiatives and answer questions such as: where in the PDP are the decisions locked? Which is the appropriate gate for each target? To which stakeholder group are the initiatives relevant? What kind of changes can the LCA results trigger? These questions will be answered here for the two life cycle stages that according to the LCA results count for more than 90% of the emissions viz. Direct materials and Manufacturing (Fig. 1a).

4.1. Direct materials

It includes the BOM that will end up on the final product (fibreglass, epoxy, wood etc.). Consumption of these materials is responsible for more than 60% of the total impacts (Fig. 1a). Epoxy and fibreglass are the prevailing contributors accounting respectively for 50% and 30% of ‘direct materials (BOM)’ (Fig. 1a).

Decisions related to the final product are taken and locked at the very front end of the PDP with the approval of the product development specifications (PDS) at the end of ‘product definition’ (Table 1). After that PDP point structural changes are no longer feasible and no improvement initiative can be taken. Consequently

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