GCSM 11th Global Conference on Sustainable Manufacturing
2013
23rd - 25th September
Berlin - Germany

6.3 Structured identification of business improvement opportunities using Life Cycle Assessment: A case study in the gas turbine industry

P. Martínez-Caballero [1], B. Basdere [1], J. Richter [1], F. Parthey [2], K. Mueller [2]
[1] Turbine Airfoil Coating and Repair GmbH, Berlin, Germany
[2] Siemens AG, Berlin, Germany

Abstract

In the last two decades the power sector has been adopting environmental conscious practices in several business areas and processes. Bridging the identification of environmental "hot-spots" in the product life cycle and the implementation and execution of an environmental management system requires an integrated approach starting with a Life Cycle Assessment to identify the improvement potentials; then analyzing the current management and product development systematics in use, and finally mapping the environmental practices against the improvement potential. The improvement tracking will be embedded in the management system as an Environmental Improvement Roadmap, mapping the efforts required to realize the goals. The methodology has been implemented in pilot studies, focusing on the processes performed in-house to enable further decisions on process alternatives and providing reliable information for strategic decisions within the Siemens Environmental Product Portfolio.

.

Keywords:
Life Cycle Assessment; Eco Design, Environmental Portfolio

1 INTRODUCTION

In the last two decades the industrial sector has been going through an increasing "green" period, in which all industry players have been adopting environmentally friendly practices in several business areas and processes. Companies produce goods and services that require inputs of energy and raw materials. These goods and services in turn serve as inputs for the production of other products, hence interconnecting a complex network of suppliers and customers, all of them consuming resources and disposing waste and emissions to the environment. It is therefore necessary to redesign the industrial systems to create more value with fewer resources, without compromising sustainability.

2 STATE OF THE ART

During the Earth Summit conference in Rio de Janeiro in 1992, a number of agreements were produced and 27 basic principles of sustainability were deduced [1]. Despite the valuable message of these principles, some criticize that there is a high moral claim in the definition, but a lack of guidance on how this aim can be reached [2]. Transferring the sustainability principles to operational and technical goals is not always easy because there is little awareness and understanding of the wider environmental, social and economic impacts among product development teams and the operational departments of an organization [3]. It has been stressed that in order to identify and produce significant improvements in a company's environmental performance, there is a need for integrated business processes that bring together all of the principles, practices and methodologies [1] in order to operationalize environmental and sustainable development [4].

Seen from a company's perspective, the above described situation can be summarized in the following four questions: 1) what to improve? 2) how much to improve? 3) when to improve? and 4) how to improve?. By means of performing a literature review, it has been observed that questions 1) what to improve? and 4) how to improve? have been extensively studied by the academia and the industry. On the one hand, researchers aiming to answer the question: what to improve? have found the answer by focusing in the product and everything around its development process and production system. On the other hand, the question: how to improve? has been answered by focusing in the Environmental Management Systems (EMS) of the companies and the supply chains. In both cases a relatively large amount of research has focused on how to make environmental impacts a measurable variable, and consequently, a vast number of frameworks, methodologies, systems and tools have been developed so the industry is able to assess and control these impacts. A central methodology for identifying environmental impacts of products is the Life Cycle Assessment, which will be explained and employed later on.

In contrast, questions 3) how much to improve? and 4) when to improve? have not received as much attention from the researchers as needed, at least not in an operational level. These questions make reference to the definition of the goal and scope of the environmental improvement efforts; that is an environmental strategy. The strategic component between

G. Seliger (Ed.), Proceedings of the 11th Global Conference on Sustainable Manufacturing - Innovative Solutions
ISBN 978-3-7983-2609-5

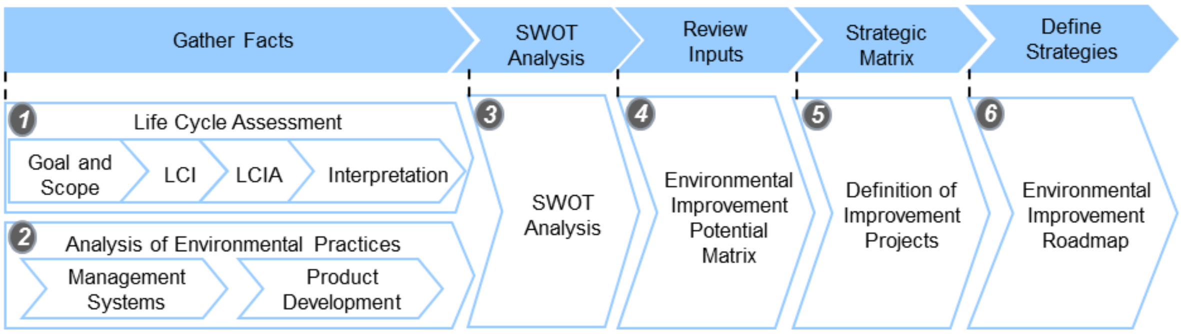

Figure 1: Methodology Definition

the identification of environmental "hot-spots" and the implementation and execution of an Environmental Management System (EMS) has been identified as a gap in the process of identifying environmental improvement opportunities.

3 METHODOLOGY DEFINITION

In order to bridge this strategic gap, and with the purpose of defining the goal and scope of an environmental improvement plan, a methodology based on the current industrial practices and developments has been compiled and defined. The approach, which can be seen in Figure 1, comprises the strategic environmental planning and starts with the development of a Life Cycle Assessment (LCA) to identify the environmental improvement potential. Then, it analyses the management and product development systems currently implemented within the organization. By combining the results of the last two steps, an analysis of the organization's strengths, weaknesses, opportunities and threats (SWOT Analysis) in the context of environmental practices is performed. By using a so called environmental improvement potential matrix, the organization's current position is mapped against the product improvement potential and the required management effort to realize it. This tool supports the definition of improvement projects and leads to the creation of an environmental improvement roadmap, describing the actions required for achieving an environmental target within a defined time span.

With the purpose of implementing the Strategic Environmental Planning and proving its efficacy and effectiveness in the identification of improvement opportunities, the methodology has been applied in a case study in the power generation sector. The outcomes have been analyzed and discussed in relation to the objectives and its possible applicability in different organizations and industries.

4 CASE STUDY

The scope of the case study covers a state-of-the-art combined cycle power plant as part of the Siemens Environmental Portfolio. Obtaining the environmental footprint of all components all the way down to a single turbine blade or vane is of particular interest due to the important role in the turbine operation and its specific design and manufacturing characteristics, such as: the highly advanced alloys from which these components are casted; the specific casting processes that have to be carried out; the accuracy and precision of the machining processes due to the limiting dimension tolerances; and the corrosion resistant- and thermal barrier coatings that are applied. All these processes are energy-intensive and use specific materials and machinery of large value and specificity, which besides influencing the costs of the blade, might also influence the product's impact on the environment.

5 LIFE CYCLE ASSESSMENT

A full scale Life Cycle Assessment has been carried out according to the ISO 14040 standard and contains the following four components: (1) Goal and Scope definition, (2) Life Cycle Inventory, (3) Life Cycle Impact Assessment and (4) Interpretation.

5.1 Goal and Scope Definition

The LCA study had the following goals:

1. Identification and comparison of the dominating causes of environmental impacts along the supply chain.
2. Identification and comparison of different process alternatives.
3. Comparison between the life cycles of the Tla1 and Tla2 blade types.
4. Comparison of several life cycle scenarios with a different number of refurbishment (service) processes carried out after an operation phase.

Functional Unit:

The LCA focuses on the first and second stage blades of the SGT5 4000F gas turbine, named Tla1 and Tla2 respectively (see Figure 2). These blades have to withstand the largest loads and stresses, in mechanical, chemical and thermal terms; meaning that they wear faster and therefore have shorter operation life cycles. Consequently, these blades are refurbished one or more times after an operation phase (other blades and vanes might not need refurbishment),

Figure 2: Blade types

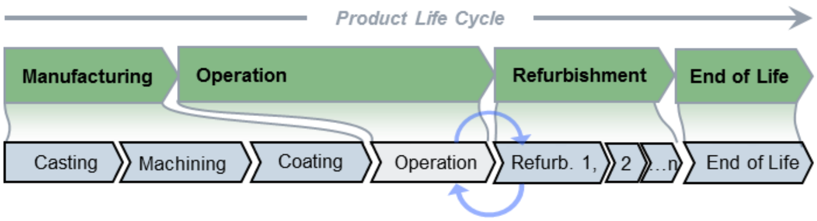

Figure 3: Modeled Life Cycle

which adds the "service" phase to the product life-cycle; hence enriching the system under study and the scope of the analysis. The functional unit of the LCA is therefore one (1) blade of the corresponding blade type (Tla1 and Tla2) fulfilling its operating function within the turbine.

Examined Life Cycle

Each single blade, independent of its type, has a different life cycle and life span depending on its use and damage during operation within the turbine. Nonetheless, since there is a finite number of fundamentally equal life cycle phases, a generic life cycle (shown in Figure 3) composed by the following four main phases can be defined.

1. Manufacturing: It is comprised by the following stages, each performed by a different company.
    a. Casting: The blades are casted out of a special Nickel-alloy into the blade shape using an investment casting process
    b. Machining: The blade foot is grinded and milled to obtain its final shape and surface finish
    c. Coating: The blade is coated with a corrosive resistant layer and a ceramic thermal barrier
2. Operation: During the operation of the turbine, and hence the power plant, the blade plays the role of a passive component of a greater product or system, whose operation characteristics are dependent of several other components, and therefore not attributable or allocable to the blades. The reason why this phase is part of the life cycle is because the operating lifetime of the blade is of importance.
3. Refurbishment (Service): Depending on its condition, the blade is either repaired and coated again to later go back to operation; or it is designated as waste. Therefore this phase could or could not take place during a life cycle.
4. End of Life: The blades that cannot be repaired are disposed following a waste treatment process that includes recycling.

System Boundaries:

The system boundaries, illustrated in Figure 4, were selected based on the study objectives and to be compatible with the defined functional unit and with the turbine and power plant system boundaries. The following observations are important to recognize:

- The system boundaries are valid for both Tla1 and Tla2 blades.
- The operation phase is outside the system boundaries and therefore no inputs and outputs have been considered. The transportation to and from the operation site is however included
- All the inputs and outputs have been modeled using information from databases, and not as additional processes or systems.

5.2 Life Cycle Inventory

The collection of the data has been performed in six different sections. This classification has been rather based on the supply chain structure than on the product life cycle.

1. Production Step: Casting
2. Production Step: Machining
3. Production Step: Coating
4. Life Cycle Phase: Refurbishment
5. Life Cycle Phase: Operation (only transport)
6. Life Cycle Phase: End-of-life

All process data and the inventory have been modeled with SimaPro software and using the Ecoinvent Database.

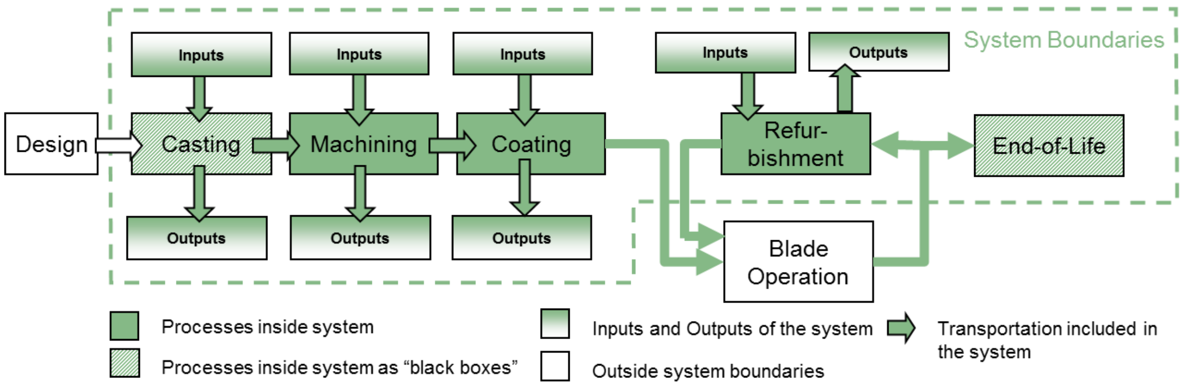

Figure 4: System Boundaries

5.3 Life Cycle Impact Assessment

Impact categories

A comprehensive set of impact categories has been analyzed to identify all hot spots and trade offs of the product life cycle. However the Global Warming Potential impact category, measured in CO_2e equivalent units (CO_2e) has been selected for further communication and comparisons.

For blade types TIa1 and TIa2 there is an average life cycle that represents the normal life path that a blade of these types undergoes, based on its wear propensity and its reparability. In average, these blades can be repaired and consequently be submitted to several operating cycles.

6 IDENTIFICATION OF IMPROVEMENT OPPORTUNITIES

6.1 Environmental Improvement Potential Matrix

Based on the environmental management system and product development status of the analyzed organization and a following SWOT analysis, the improvement potential matrix has been prepared. The descriptions of the current position and the improvement potential are the following:

Current Position

Management level:

- The Environmental Management System (EMS) is an ISO conforming and certified system
- The EMS focuses on the operational aspects of the environmental management
- The EMS is implemented locally within the company organization.
- The planning is based on a strategic target

Product level:

- Manufacturing is not the owner of the blade design
- The Technology department interacts with the design owner to develop and certify the processes

Improvement potential

Management level:

- The current EMS has the potential to grow and become a fully integrated system within the organization functions
- The proactive engagement of the top management in the planning of supply-chain targeted projects can lead to an increased reduction of the environmental footprint

Product level:

- The services provided by the organization have the potential to be improved in the short- and mid-terms, and redesigned in the long term.
- Innovation of the coating services

6.2 Definition of Improvement Projects

In order to reach the improvement potential plotted in the Environmental Potential Matrix and based on the SWOT Analysis, a list of 15 projects with defined improvement potential has been created. The input information for deriving the list of projects includes the results of the LCA and further methodology steps, as well as ideas developed during the development of the LCA due to empirical observations and information exchange with employees.

6.3 Environmental Improvement Roadmap

Figure 5 shows the resulting Environmental Improvement Roadmap comprising the suggested projects in order of implementation and related by means of predecessor and sequence connectors. The roadmap has two vertical axes for the two stages of the blades. While the primary axis is scaled in proportion to the target value, the secondary axis is not

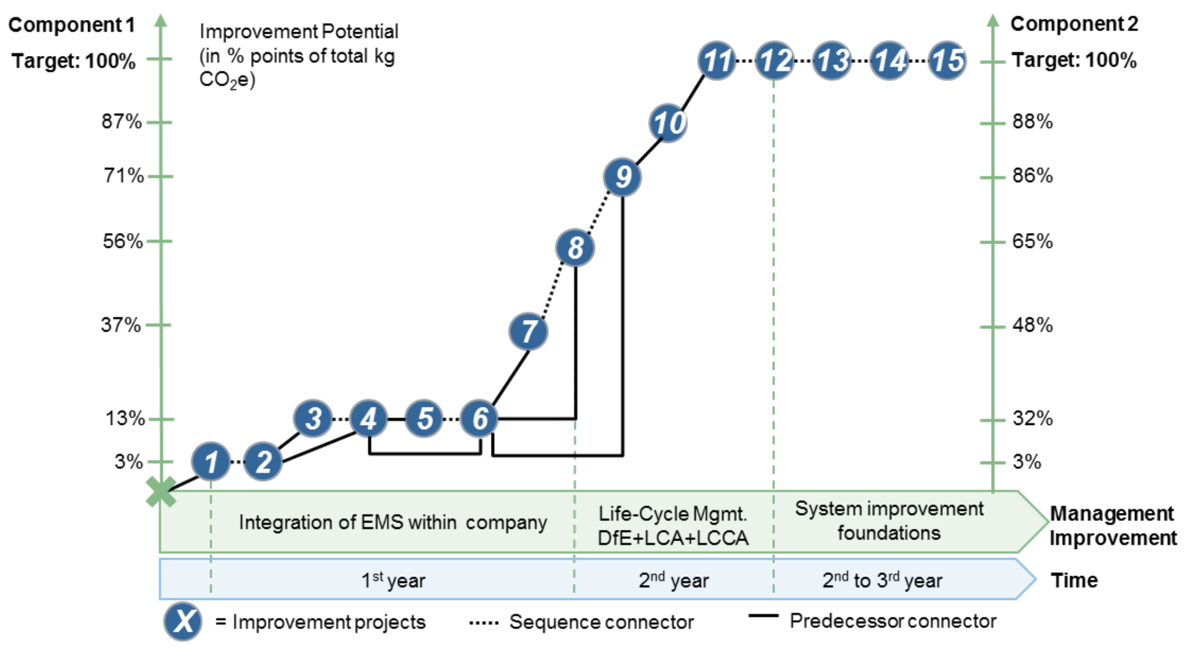

Figure 5: Environmental Improvement Roadmap

However, the labeled values match the real increments of the respective projects for both blade types. The Management Improvement horizontal axis is descriptive, and therefore arbitrarily labeled according to the characteristics of the improvement curve shaped by the project implementation sequence, as well as to each project characteristic. The Time horizontal axis is also descriptive and the time periods were defined considering each project's implementation duration and the natural business planning and execution cycles.

7 CONCLUSIONS

- The identified improvement potential represents a direct reduction of the carbon footprint of the respective components
- The application of the Strategic Environmental Planning methodology increased the strategic planning time-span
- to three years (long-term perspective) and considered the expansion of the EMS to other functional areas of the company (systems perspective); therefore the identified potential and target resulted significantly larger than the current annually planned improvement.
- The methodology does not consider economic aspects; however these can be integrated by using trade-off analysis tools or project portfolio techniques.
- The Strategic Environmental Planning methodology clearly fulfills its objective of defining the scope and goal of an environmental plan.

8 REFERENCES

[1] Fiksel, J.R., 2009. Design for Environment: A Guide to Sustainable Product Development, McGraw-Hill.

[2] Klöpffer, W., 2003. Life-Cycle based methods for sustainable product development. The International Journal of Life Cycle Assessment, 8/3:157–159.

[3] Howarth, G., Hadfield, M., 2006. A sustainable product design model. Materials Design, 27/10:1128–1133.

[4] Seuring, S., 2004. Emerging issues in life-cycle management. Greener Management International, 45/Spring 2004:3–8.

9 DISCLAIMER