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Master’s degree in Environmental Engineering

Environmental management of the Thermowatt company production: Arcevia plant case

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ENVIRONMENTAL MANAGEMENT OF THERMOWATT COMPANY PRODUCTION: ARCEVIA PLANT CASE

TABLE OF CONTENTS

INTRODUCTION **2**

CHAPTER 1 - EUROPEAN GREEN DEAL **3**

1.1. Introduction to Green Deal 4

1.2. Circular Economy 6

1.3. From waste to value – Industrial focus 8

CHAPTER II - ENVIRONMENTAL MANAGEMENT SYSTEM 14001:2015 ..... **9**

2.1. ISO 14001 Overview 10

2.2. Environmental Management System (EMS) Framework 11

CHAPTER III - WORLD CLASS MANUFACTURING (WCM) **20**

3.1. Historical overview 21

3.2. Mission 22

3.3. WCM structure 23

CHAPTER IV - ARCEVIA PLANT CASE **41**

4.1. Procedure to identify Environmental Aspects – "VAIA Analysis" 42

4.2. ENVIRONMENTAL COST DEPLOYMENT 54

4.2.1. Introduction 54

4.2.2. Link with Manufacturing CD 55

4.2.3. Scope and data collection 55

4.2.4. "5R" Concept 56

4.2.5. Input Data – Arcevia Plant Waste Database 56

4.2.6. "A" Matrix 58

4.2.7. "B" Matrix 61

4.2.8. "C" Matrix 62

4.2.8 "C" Matrix Graphs 64

4.3. FINAL RESULTS RECAP 68

CONCLUSION **70**

REFERENCES **71**

INTRODUCTION

The basis of this study is the analysis of the environmental context in which the Thermowatt company, home of my internship, is located and how the company deals with it.

The aim of this thesis is to show how the environmental and economic aspects are easily interconnected in a reality such as the corporate one.

In particular, in the first two chapters, attention is paid to the analysis of environmental aspects and impacts starting from the exposure of ISO 14001, which results today essential to achieve specific environmental objectives by following a well-integrated and drafted management system. Before going into the details of ISO 14001, summarizing all its main parts, a mention of the European Green Deal is a must to understand what are the global environmental objectives that each company, and not only, will be called to achieve in the near future.

Chapter III talks about the World Class Manufacturing (WCM), an integrated system for the identification and elimination of losses present within a company. A particular focus is on the environmental losses and on how they can be localized and economically quantified.

Chapter IV reports the Arcevia Plant case study where all the theoretically parts discussed earlier are applied on. In particular, VAIA analysis and Environmental Cost Deployment are reported and connected between each other by a specific project carried out to get both environmental and economic benefits for the plant.

The results of this project, aimed at eliminating the landfill disposal operations of a specific waste, will be detailed in the final conclusions of this thesis.

CHAPTER 1 - **EUROPEAN GREEN DEAL**

"The European Green Deal is our new growth strategy – for a growth that gives back more than it takes away. It shows how to transform our way of living and working, of producing and consuming so that we live healthier and make our businesses innovative. We can all be involved in the transition and we can all benefit from the opportunities. We will help our economy to be a global leader by moving first and moving fast. We are determined to succeed for the sake of this planet and life on it – for Europe's natural heritage, for biodiversity, for our forests and our seas. By showing the rest of the world how to be sustainable and competitive, we can convince other countries to move with us."

Ursula von der Leyen, President of the European Commission

1.1. Introduction to Green Deal

The European Green Deal provides a roadmap with actions to promote the efficient use of resources, overcoming the linear economy, by moving to a circular and clean economy and halt climate change, undo biodiversity loss and reduce pollution. It describes all the necessary investments and financing instruments made available and explains how to ensure a just and inclusive transition.

The European Green Deal covers all sectors of the economy, in particular transport, energy, agriculture, construction and industries such as steel, cement, ICT, textiles and chemicals.

Figure 1: *The European Green Deal*

The main goal of the European Green Deal is "climate neutrality" to achieve net-zero greenhouse gas emissions by the year 2050. According to this it has goals extending to many different sectors, including biodiversity, energy production, industry and the relative sustainability of its products, buildings and renovation sector, transports and, last but not least, the cycle of edible products with the farm-to-fork formula (*Communication from the commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, 2019, Bruxelles*).

The EU's ambitious program is to progressively and completely reform the European economy over the next 30 years. Not only by improving the structures and economic roots of the old continent but by positioning itself as a world leader in technologies and policies linked to sustainability but by acting as the global engine of this "necessary" economic and cultural revolution.

New technologies, sustainable solutions and radical innovation are essential to achieve the goals of the European Green Deal. To maintain and enhance its competitive edge on clean technologies, the EU needs to significantly increase the large-scale deployment of new technologies across sectors and across the single market, creating new and innovative value chains. This is a challenge beyond the capabilities of individual Member States. For this reason, in synergy with other EU programs, it will be crucial to mobilize national public and private investments to finance new solutions useful for the implementation of the Green Deal (*Communication from the commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, 2019, Bruxelles*).

1.2. Circular Economy

Due to fast economic growth of the last two centuries, the exploitation of planet's resources is increasingly high. Today we are going to find alternative ways to use resources and make business. Until now the economy has worked with a "production-consumption-disposal" model, a linear model where every product is inexorably destined to reach the "end of life". These products are disposed of as waste, this is the paradigm we are used to. Our economy has just started to move beyond this key feature of the first days of industrialization. We have been able to observe the long-term limitations of this linear system.

Great strides have been made for improve resource efficiency and exploration of new forms of energy but less and less provision has been made for the design and handling of the material, especially with regard to waste and disposal.

Economic growth, the increase in the world population and the consequent increase in consumption may influence the future, leading to an increase in the costs of raw materials and energy.

Furthermore, the increase of the population and the spread of wealth in large part of the world are pushing the demand for scarce resources and lead to environmental degradation. According to this, the prices of metals and minerals have risen, fossil fuels, food for humans and animals, as well as clean water and fertile soils; this trend is bound to worsen in the long term if we do not act promptly.

Considering this scenario, the concept of circular economy responds to the desire for sustainable growth since it is based on reusing, fixing, renewing and recycle existing materials and products. What normally it was considered as "refusal" can be finally turned into a resource.

Nothing new, the circular economy is based on the study and observation of living natural systems (biosystems). Just like in biosystems, the transition to a circular economy requires the participation and commitment of different groups of people.

One of our goals should be to reduce residual waste close to zero.

Figure 2: *A graphic example of circular economy*

Companies can redesign supply chains and materials, aiming for efficiency in the use of resources. The industrial sector is one of the best fields where circular economy can be applied: the whole sector consumes annually important quantities of virgin material, the potential for reusing and recycle these materials is huge as well the economical and entrepreneurial opportunities related to this way of thinking.

The circular economy could open up new markets as a consequence of changes in consumption patterns: from product ownership and its use to reuse and sharing of the product itself.

In this field, Europe has already taken its first step with one of the flagship initiatives of Europe 2020, coordinating interventions that concern many areas of the economy and politics. Proposed in 2010, it was a 10 year strategy for advancement of the economy of the European Union, it aims a "smart, sustainable, inclusive growth". Europe 2020 Strategy was born "to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernise our transport sector and promote energy efficiency (*Europe 2020, A strategy for smart, sustainable and inclusive growth)*

With the new European programming, among the most important initiatives we can find the Circular Economy Action Plan. The plan aims to accelerate the change required by the European Green Deal, building on the circular economy actions implemented since 2015. In addition to the political focus, this plan will ensure that the regulatory framework is simplified and adapted to a sustainable future, to speed up and make more affordable the new opportunities offered by the transition, minimizing the burdens for people and businesses.

1.3. From waste to value – Industrial focus

As our case study focuses on industry, we will try to deal with this sector deeply. In particular, the management of production waste, the eventual reuse and marketing of the same.

Industrial waste recycling offers many benefits to companies.

Recycling significantly reduces the costs that a company would otherwise have to incur for the disposal of unused materials and by-products and of course the logistical problems associated with transporting waste materials. Disposal of waste, especially special waste, is usually particularly expensive for companies.

Recycling can transform a cost, both economic and environmental, into a constant and reliable benefit.

In addition to purely economic benefits, recycling contributes to achieving the company's environmental objectives or becoming the first step towards the transition to more efficient and environmentally friendly economic forms and new European regulations.

The activity of a company is part of a local and international social ecosystem, the commitment of a company in the environmental field is always rewarded by a positive and long-term improvement of the company's image.

Improving materials management in a company involves a series of preliminary evaluation and planning steps. As a first step, the flows of materials within industrial processes must be identified, identifying and cataloguing the types and volumes of materials used and the by-products deriving from production activities. Once the exact types of materials involved have been identified, an appropriate recycling program can be devised.

Of fundamental importance is determining how waste is regulated. The definitions and corresponding regulations of industrial materials may vary from state to state and in some cases even locally. This step is important not only to understand the next steps but also to determine which waste should be classified as hazardous and which can be categorized as non-hazardous. This makes reuse and recycling much easier. Finding markets for your recyclables.

CHAPTER II - ENVIRONMENTAL MANAGEMENT SYSTEM 14001:2015

2.1. ISO 14001 Overview

ISO 14001 is the international standard that specifies requirements for an effective Environmental Management System (EMS). It provides a framework that an organization can follow, rather than establishing environmental performance requirements. Part of the ISO 14000 family of standards on environmental management, ISO 14001 is a voluntary standard that organizations can certify to. Integrating it with other management systems standards, most commonly ISO 9001, can further assist in accomplishing organizational goals. The International Organization for Standardization (ISO) defines an environmental management system as "part of the management system used to manage environmental aspects, fulfil compliance obligations, and address risks and opportunities".

The EMS framework (fig 1) can be seen within a plan-do-check-act (PDCA) approach to continuous improvement of the EMS itself over time.

Fig. 3: *ISO 14001 Environmental Management System Framework*

Plan-Do-Check-Act:

The basis for the approach underlying an environmental management system is founded on the concepts of Plan-Do-Check-Act (PDCA)- This model provides an iterative process used by organizations to achieve continual improvement. It can be applied to an environmental management system and to each of its individual elements.

- *Plan*: establish environmental objectives and processes necessary to deliver results in accordance with the organization's environmental policy;
- *Do*: implement the processes as planned;
- *Check*: monitor and measure processes;
- *Act*: take actions to continually improve.

2.2. Environmental Management System (EMS) Framework

The ISO 14001:2015 structure is spilt into ten sections. The first three are introductory, with the last seven containing the requirements for the environmental management system (Fig. 2).

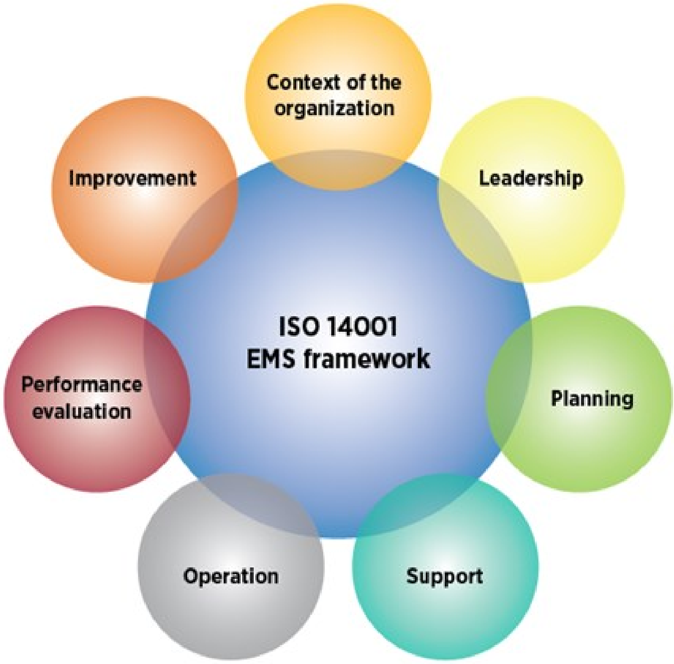


Fig. 4: *ISO 14001 EMS Framework*

Now, I am going to talk about ISO 14001 summarising its main chapters.

Here is what the main chapters are about:

- **Chapter 4:** ***Context of the organization***

This chapter is dedicated to the analysis, by the organizer, of the context in which it operates (4.1), as well as the needs and expectations of the interested parties (4.2).

The intent of 4.1 is to provide a conceptual understanding of the important issues that can affect, either positively or negatively, the way the organization manages its environmental responsibility. Examples of internal and external issues which can be relevant to the context of the organization include:

- environmental conditions related to climate, air quality, water quality, land use, existing contamination, natural resource availability and biodiversity, that can either affect the organization's purpose, or be affected by its environmental aspects;
- the external cultural, social, political, legal, regulatory, financial, technological, economic, natural and competitive circumstances, whether international, national, regional or local;
- the internal characteristics or conditions of the organization, such as its activities, products and services, strategic direction, culture and capabilities (i.e. people, knowledge, processes, systems).

The analysis of the context aims to provide the Organizer with a set of strategic and operational knowledge in order to appropriately direct their efforts for the implementation and continuous improvement of the EMS. The internal and external issues that are determined in 4.1 can result in risks (understood as uncertainty in the achievement of objectives) and opportunities to the organization or to the EMS. The organization determines those that need to be addressed and manages.

It will therefore be essential to understand how the Organization has circumscribed and bounded the context in order to effectively define the operational sphere in which the EMS is inserted. As reported in section 4.2 of ISO 14001, it therefore becomes essential that the Organization identifies and defines:

- The interested parties relevant to its EMS;
- The relevant needs and expectations of those interested parties;
- Which, among these relevant needs and expectations, become "compliance obligation" of its System.

In this context it is necessary for the organization to identify the stakeholders, mapping the subjects operating in the context.
ISO 14001 (chapter 3.1.6) defines interested party as “person or organization that can affect, be affected by, or perceive itself to be affected by a decision or activity”. Customers, communities, suppliers, regulators, non-governmental organizations, investors and employees are some examples of interested parties.

At this point is important to determine the scope of the EMS as set out in ISO 14001:2015 in section 4.3. The organization shall determine the boundaries and applicability of the EMS to establish its scope. When determining this scope, the organization shall consider:
- The external and internal issues referred to in 4.1;
- The compliance obligations referred to in 4.2;
- Its organizational unit(s), function(s), and physical boundaries;
- Its activities, products and services;
- Its authority and ability to exercise control and influence.

To achieve the intended outcomes, the organization shall establish, implement, maintain and continually improve the EMS, including the processes needed and their interactions (4.4).

- **Chapter 5: *Leadership***

This section consists of 3 different parts:
- *Leadership and commitment (5.1)* - Top management shall demonstrate leadership and commitment with respect to the environmental management system by ensuring environmental commitment, defining and communicating the environmental policy and assigning roles and responsibilities throughout the organization.
- *Environmental policy (5.2)* – A commitment to environmental protection is required in the context of the organization like use of sustainable resources, mitigation and adaptation to climate change, biodiversity and ecosystems protection etc.
- *Organizational roles, responsibilities and authorities (5.3)* – Top management shall ensure that the responsibilities and authorities for relevant roles are assigned and communicated within the organization.

- **Chapter 6: *Planning phase* and VAIA analysis**

Section 6 consists of:

- *Actions to address risks and opportunities* (6.1);
- *Environmental objectives and planning to achieve them* (6.2).

It is worth to remember the "Risks and opportunities" definition, which is stated in ISO 14001:2015 clause 3.2.11 as potential adverse effects (threats) and potential beneficial effects (opportunities). The determination of which risks and opportunities will be addressed in the EMS is an organization's decision and it results from:

- Context of the organisation;
- Scope of EMS;
- Environmental aspect and impact (by VAIA analysis);
- Compliance obligations
- Identifying potential emergency situations.

Some examples of context related risk would be:

- Lack of management commitment;
- Lack of competent staff or suppliers;
- Violations to legal or contractual requirements;
- Not meeting expectations of interested parties.

Some examples of opportunities would be:

- Product is well received in market and further opportunity for diversification;
- Partnership with community on EMS issues;
- Ease in license and permits due to good past performance and maintaining leadership in the market;
- Become more competitive due to cost savings.

The environmental aspects identification and the assessment of their significance is a basic activity of the planning phase of the EMS (6.1.2). An organization determines its environmental aspects and associated environmental impacts, and determines those that are significant and, therefore, need to be addressed by its environmental management system. The environmental aspects and impacts analysis (VAIA, Italian acronym) is therefore essential in the planning phase of the EMS.

Changes to the environment, either adverse or beneficial, that result wholly or partially from environmental aspects are called environmental impacts. The environmental impact can occur at local, regional and global scales, and also can be direct, indirect or cumulative by nature. The relationship between environmental aspects and environmental impacts is one of cause and effect. When determining environmental aspects, the organization considers the life cycle stages that can be controlled or influenced by the organization itself. Typical stages of a product life cycle include raw material acquisition, design, production, transportation/delivery, use end of life treatment and final disposal. The life cycle stages that are applicable will vary depending on the product itself.

An organization does not consider each product, component or raw material individually to determine and evaluate their environmental aspects; it may group or categorize activities, products and services when they have common characteristics.

When determining its environmental aspects, the organization can consider:

a) Emissions to air;
b) Releases to water;
c) Releases to land;
d) Use of raw materials and natural resources;
e) Use of energy;
f) Energy emitted (e.g. heat, radiation, noise, light);
g) Waste generation
h) Use of space.

In addition to the environmental aspects that it can control directly, an organization determines whether there are environmental aspects that it can influence. These can be related to products and services used by the organization which are provided by others like for example outsourcings. A significant environmental aspect can result in one or more significant environmental impacts, and therefore result in risks and opportunities that need to be addressed to ensure the organization can achieve the intended outcomes of its EMS. A real and practical example of VAIA analysis will be shown and discussed in chapter IV focusing on the waste generation aspect.

Section 6.1.3 is about *Compliance obligations*, which deals with:

- Identification of compliance requirements relating to its environmental aspects;
- Determine how these compliance requirements are applied to the organization;
- Beware of compliance obligations in establishing, implementing, maintaining and continually improving the EMS.

Examples of compliance requirements depending on some different environmental aspects:

- Waste generation: compliance with the conditions and limits of temporary storage, compilation of loading/unloading registers, etc.
- Emissions to air: chimneys identification, authorizations, emissions analysis, etc.
- Wastewater discharge: authorizations, analysis, wastewater treatment plant, etc.

The organization shall establish the environmental objectives (6.2) related to the relevant functions and levels, taking into account the significant environmental aspects and associated compliance obligations, and considering its own risks and opportunities. The objectives must be consistent with the environmental policy, measurable, monitored, communicated and updated. It is necessary that there is consistency between objectives and environmental policy, significance of the environmental aspects, output of the risks and opportunities analysis.

- **CHAPTER 7 – *Support***

Point 7 concerns the Support Processes, considered as the set of means and resources to allow the implementation of the EMS operation. It is divided into:

- *Resources (7.1)*

The organization has to determine and provide the resources necessary for the establishment, implementation, maintenance and continuous improvement of the environmental management system. Resources are defined as human resources (including knowledge and skills), natural and infrastructural resources (buildings, plants, control systems, distribution systems, etc.), technological and financial resources.

- *Competence (7.2)*

The organization shall:

a) Determine the necessary competence of people doing work under its control that affects its environmental performance and its ability to fulfil its compliance obligations;

b) Ensure that these people are competent on the basis of appropriate education, training or experience;
c) Determine training needs associated with its environmental aspects;
d) Where applicable, take actions to acquire the necessary competence and evaluate the effectiveness of the actions taken.

- *Awareness (7.3)*

The organization has to ensure that people who perform a work under the control of the organization are aware of:

a) The environmental policy, which means people should have been aware of its existence, purpose and role in achieving commitments;
b) The significant aspects and actual environmental impacts associated with their work;
c) Their contribution to the effectiveness of the EMS;

- The implications deriving from not complying the EMS including the compliance obligations as well.

- *Communication (7.4)*

The organization shall establish, implement and maintain the processes needed for internal and external communications relevant to the EMS, including:

a) On what it will communicate;
b) When to communicate;
c) With whom to communicate;
d) How to communicate.

In order to define the internal and external communication correctly, it will be necessary that organization has conducted and adequate Context Analysis including the identification of the interested parties.

- *Documented information (7.5)*

The organization must determine which documents are necessary for the management and effectiveness of the system, and how these are to be managed.

- **Chapter 8 – *Operation***

Operational activities represent the technical heart of EMS, in which processes and activities must develop according to certain criteria and methods.

The organization must establish, implement, monitor and maintain the processes necessary to meet the requirements of the EMS and to implement the actions identified in the phases of determining the risks and opportunities related to the environmental aspects (considering the life cycle), to the obligations compliance and other factors established in the course of the context analysis.

Application examples:
- Carrying out processes with specific codified methods (procedures)
- Use of technology to control the process and prevent undesirable results (i.e. use of automated control systems)

In section 8.1 of ISO 14001 it is specified that the organization has to ensure that outsourcing processes are kept under control. In determining the extent and type of operational controls relating to external suppliers, including contractors, the organization may consider one or more factors including:
- Environmental aspects and associated environmental impacts;
- Risks and opportunities associated with the manufacture of its products;
- Compliance obligations.

- **Chapter 9 – *Performance evaluation***

The organization has to monitor, measure, analyse and evaluate its environmental performance (9.1.1). *Environmental performance* is defined as performance (measurable result) related to the management of environmental aspects (3.4.11).

It is necessary to define:
- What to measure and monitor;
- How to measure and monitor;
- When to measure and monitor, when to analyse and evaluate the results.

Examples of indicators that need to be monitored:

a) Commitment indicators – aimed at measuring the commitment produced by the organization in the management and improvement of EMS (i.e. human resources employed and their training, extent of activities and resources dedicated to the system and extent of actions carried out, extent of involvement in the system of subjects outside the company affected by environmental aspects);
b) Control indicators – aimed at measuring the EMS ability to provide management with timely indications to prevent emergencies and accidents (i.e. sentinel indicators on emissions);
c) Reactivity indicators – aimed at measuring the EMS ability to grasp and respond promptly and adequately to the events that occur (i.e. by Environmental Unsafe Act and Environmental Unsafe Conditions);
d) Economic indicators – i.e. investments, cost savings etc.

Section 9.2 deals with internal audit. The organization shall establish, implement and maintain an internal audit programme, including the frequency, methods, responsibilities, planning requirements and reporting of its internal audits.

Section 9.3 refers to Management review. Top management shall review the organization's EMS, at planned intervals, to ensure its continuing suitability, adequacy and effectiveness. New targets are also fixed in the Management review for the continuous improvement.

- **Chapter 10 – Improvement**

The organization shall determine opportunities for improvement and implement necessary actions to achieve the intended outcomes of its EMS. The improvement concerns the nonconformity, correct actions and continual improvement.

CHAPTER III - **WORLD CLASS MANUFACTURING (WCM)**

"World Class Manufacturing (WCM) is a structured, rigorous and integrated production methodology […], which involves the entire organization, from safety to environment, maintenance, logistics and quality. The primary objective of WCM is continuous improvement in all areas of production in order to guarantee the quality of the final product and meet customer expectations. Projects developed under the WCM methodology – which rely on a high level of employee involvement – target the elimination of all forms of waste and loss with the ultimate objective of achieving zero accidents, zero waste, zero breakdowns and zero inventory."

[https://www.wcm.fcagroup.com/en-us/wcm_at_fca/pages/default.aspx]

3.1. Historical overview

At the beginning of the twentieth century, Frederick Winslow Taylor was the first to introduce the theory of management techniques for improving the efficiency of work processes in a scientific way by the publication of "*The Principles of Scientific Management"* in 1911. In this, he proposed that by optimizing and simplifying jobs, productivity would increase.

In 1910, Henry Ford invented the standardized assembly line for his Ford Model T. There was a limitation to the Ford's system that it lacked variety.

Later, the General Motors, a well-known American company, perfected Ford's system by introducing the assembly line diversity concept: instead of just making one car, like the Model T, GM produced a wide variety of cars for a wide variety of buyers.

After the Second World War, on the other side of the globe, a manufacturing transformation was taking place. In Japan, Taiichi Ohno, a industrial engineer and manager at Toyota Motor Corporation, developed the *Toyota Production System* (TPS) with the aim to make its company more efficient reducing costs and saving time. TPS is an integrated system of production and management that included the concepts of *JIT* (just in time), *Muda* (elimination of waste) and *Kaizen* (continuous improvement).

The TPS took the name of *Lean Production* once it was introduced to the western world by the Woman, Jones, and Roos's book, "*The Machine that Changed the World"*, in 1990. *Lean manufacturing* consists in minimizing waste within manufacturing systems while simultaneously maximizing productivity.

Subsequent to the spread of the TPS, other models have been developed, each of which has made updates and modifications to the *Lean Manufacturing*. The area to which these models belong is called *Operational Excellence*, a term that indicates that set of methods, approaches and tools by which each organization sets the goal of constantly improving its operations towards excellence. TPS represents a typical *Operational Excellence* model, but it is not the only known one; to date in fact there are numerous companies who have developed their own "X-Production System" (XPS), where X is the name of the company itself.

Among the *Operational Excellence* models we find *World Class Manufacturing* (WCM).

The term *World Class Manufacturing* was first used in 1986 by Richard Schonberger, who wrote a book called "*World Class Manufacturing: The Lessons of Simplicity Applied*" where he collected his experience of companies who adopted *Kaizen* methods for continuous improvement with the target of reaching the excellence in production.
Lately the term WCM was adopted by Japanese professor Hajime Yamashina to identify his new model of *Operational Excellence* theorized in the USA around the year 2000 and now adopted by several companies leader in their market.

Yamashina's WCM was adopted in 2005 by Fiat Chrysler Automobiles as a standard method of managing production worldwide and it has been extended to both its suppliers and other related associated companies.

3.2. Mission

WCM is a structured production system finalized to eliminate all types of wastes and losses by applying standardized methods for long lasting improvements. The model aims to customer satisfaction and creation of value, involving the entire organization to increase people awareness and participation for increasing knowledge and sense of responsibility.
To assess the progress of a production plant in terms of WCM activities, it has been developed a WCM Audit system, which evaluate different performance levels following a schematic objective procedure. These Audit give a score to tested plants called Methodology Implementation Index (MII).

WCM structure is divided in 10 Technical Pillars and related 10 Managerial Pillars; each pillar after the audit receives a score from 0 to 5 as function of level of implementation of methodology:

- Score 0: No activity made
- Score 1: Reactive approach
- Score 2: Preventive approach in few model areas
- Score 3: Preventive approach extended to all important areas
- Score 4: Proactive approach in few model areas
- Score 5: Proactive approach extended to all important areas

The sum of the score of each pillar gives the MII and represents the Plant Score (from 0 to 100). WCM divides plants in five levels of methodology application:

- 0 – 49: Method application still at base conditions
- 50-59: Bronze Medal
- 60-69: Silver Medal
- 70-84: Gold Medal
- 85-100: World Class

The goal of each plant is to achieve World Class level, this is possible when each pillar rigidly applies standard methods in all important areas with a proactive approach, which consists in the attitude to think of any possible inconsistency and avert it.

In addition, WCM structures a performance control system based on two classes of indicators:

- *Key Performance Indicators* (KPI): their main purpose is to briefly show how much the company or single function is moving towards the expected results.
- Key Activity Indicators (KAI): they are indicators focused on operations rather than performance and have been used to verify that the operations of the company or of the individual function are in line with what is defined.

Now we are ready to talk about the structure of the WCM.

3.3. WCM structure

WCM, like Lean Production, is based on the concept of continuous improvement and provides for the maximization of added value by eliminating all types of loss and waste and involving all the people who work at any level of the organization. WCM objectives are essentially achieved through three factors:

1. Implementing specific methods (technical and managerial pillars)
2. Applying and disseminating certain tools
3. A change in people's attitudes and abilities

The use of these factors is functional to achieving the WCM target, which can be summarized with the concept of "Zero" as follow:

- ZERO customer dissatisfaction
- ZERO misalignments
- ZERO shareholder dissatisfaction
- ZERO stock
- ZERO injuries
- ZERO waste
- ZERO non-value added activities
- ZERO stops
- ZERO missed opportunities
- ZERO information lost

The achievement of these standards derives from the implementation of specific methodologies and known disciplines: Total Industrial Engineering (TIE), Just In Time (JIT), Total Productive Maintenance (TPM), Total Quality Control (TQC). Before starting to delve into World Class Manufacturing in all its structure, it is necessary to say something about the methodologies just mentioned above.

Total Industrial Engineering (TIE): A system of methods where the performance of labor is maximized by reducing the three main enemies of productivity: *Muri* (unnatural and complicated operations), *Mura* (incorrect operations) and *Muda* (non-value added operations).

Total Quality Control (TQC): A system that involves everyone in the company, both managers and workers, in totally integrated effort toward improving performance at every level. Final goal is to guarantee customer satisfaction and zero defects

.

Total Productive Maintenance (TPM): A system that aims at maximizing machine capabilities maintaining equilibrium between efficiency and maintenance costs. It attacks all possible production wastes due to machine lacks, as stops, leaks, speed reduction to obtain zero breakdowns.

Just in Time (JIT): Methodology based on *Pull* system, which aims at producing exactly what the market needs avoiding overproduction typical of *Push* systems. JIT targets are zero stock and reduction of lead time.

All of these methods, retrieved from Totally Quality Maintenance approach (TQM), are included inside *World Class Manufacturing* structure which can be seen as a temple sustained by 10 Technical Pillars standing on 10 Managerial Pillars, as shown in figure below

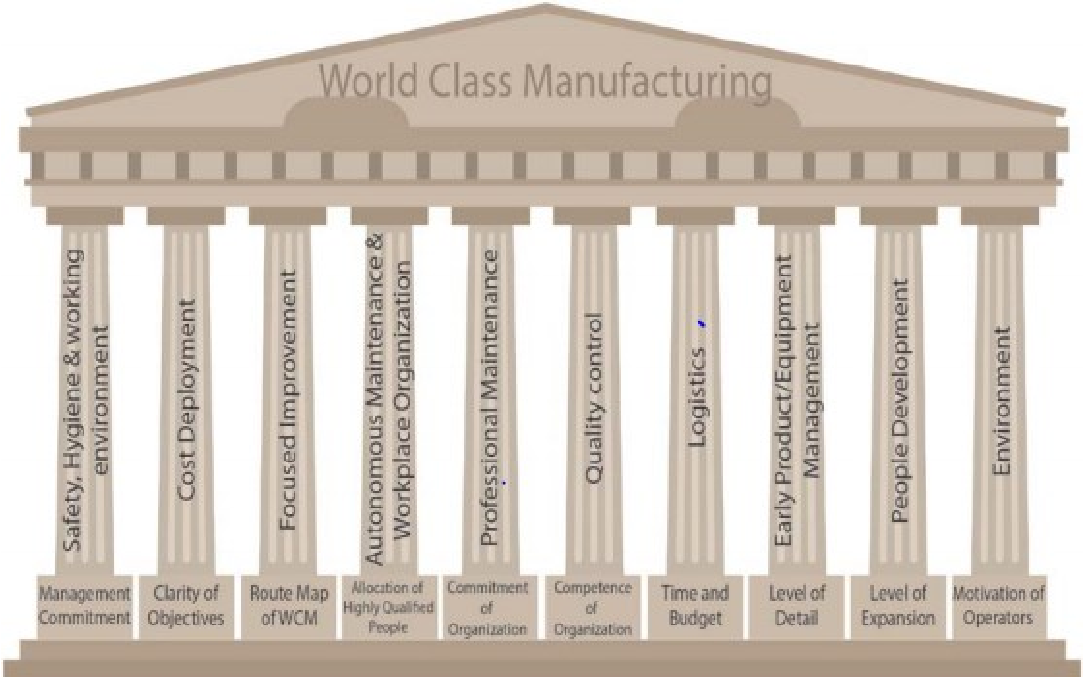


Fig. 5: *The WCM pillars temple (Master MBA Luiss)*

➢ *MANAGERIAL PILLARS:*

- ✓ Management commitment;
- ✓ Clarity of objectives;
- ✓ Route map to WCM;
- ✓ Allocation of people;
- ✓ Commitment of the organization;
- ✓ Competence of the organization;
- ✓ Time & Budget;
- ✓ Level of detail;
- ✓ Level of expansion;
- ✓ Motivation of operators.

➢ *TECHNICAL PILLARS*

As just mentioned, the WCM methodology is structured on ten technical pillars and ten managerial pillars. Technical pillars are called technical because they act directly for continuous improvement and each one is focused on a specific aspect of the plant and structured into 7 steps to follow through which we aim to achieve excellence in the plant by conducting the process of continuous improvement.

The seven steps can be grouped according to three different phases (Fig 6):

A. REACTIVE (Past): The problem is identified and analysed and then corrective solutions are implemented. Therefore, the action takes place after the problem is encountered.
B. PREVENTIVE (Present): Actively seeks the identification of hazardous conditions through the analysis of the organization's processes.
C. PROACTIVE (Future): Analyses system processes and environment to identify potential/future problems.

Fig. 6: *The seven steps according to the three different approaches*

Here below a brief description of the ten technical pillars are reported. In particular, I will explain in more details just two of them, the Cost Deployment and the Environment pillars, since these two are directly involved in the environmental management of Thermowatt company.

- **SAFETY**

In WCM Temple, Safety represents the first pillar. This pillar aims to continuously improve the working environment and the elimination of conditions that could cause accidents and injuries. The worker must be placed in the condition to work without exposing yourself to the risk of accidents, in a workplace equipped with precautions and tools to provide a reasonable level of protection.

Every country has specific workplace safety regulations. In Italy the health and safety at work are regulated by Legislative Decree 81/2008 known as "*Testo unico sulla salute e sicurezza sul lavoro*", coordinated with Legislative Decree 106/2009 and subsequent.

Safety is not only important as regulated by law, but also allows the company to enhance its performance. Managers play a fundamental role in raising people's awareness and in building and spreading a culture of safety.

The safety pillar aims at eliminating accidents passing through the analysis and improvement of the person/machine system and company organization. The Heinrich pyramid is used to quantify anomalous safety events, which occurred in a plant, according to their severity. This tool groups anomalous events into seven levels of increasing severity.

The seven levels concern (Fig.7):

1. Fatal (F): Fatal accidents
2. Severe Lost Time Accident (Sever LTA): accidents with permanent damage or with a prognosis > 30 days
3. Lost Time Accident (LTA): accidents with prognosis < 30 days
4. First Aid (FA): dressings
5. Near Misses (NM): accidents that did not cause any injury
6. Unsafe Conditions (UC)
7. Unsafe Acts (UA): potentially dangerous actions

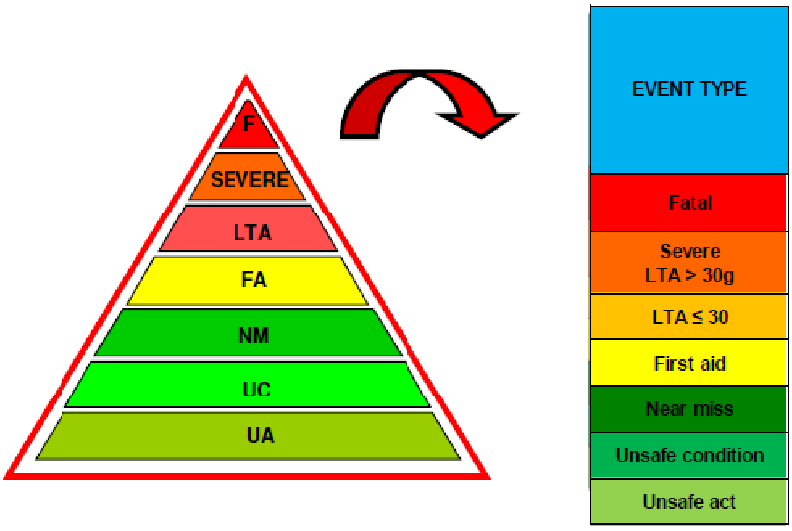


Fig. 7: *Heinrich Pyrimid [Source: CNHi, 2009]*

The Heinrich's concept is that in order to reduce the most serious accidents, it is necessary to work on minor ones and on unsafe actions and conditions. That is why we think about the reduction of the base of the pyramid, in such a way as to reduce the upper part.

The main activities carried out are two:

I. Process analysis: for each activity, the presence of risks related to accidents, near misses, unsafe conditions (UC) or unsafe acts (UA) are verified.

II. Process monitoring: a matrix is built to trace the relevance of injuries and the relationships between them and the UC and UA, the parts of the body involved, the root causes.

The continuous improvement process of the Safety technical pillar (Ketter and Massone, 2007) is described below:

- *Reactive Phase* (Step 1-3): In this phase past accidents are examined with the aim of applying the correct countermeasures.
- *Preventive Phase* (Step 4-5): operators are trained in the culture of safety, to avoid behaviours that could lead to accidents.
- *Proactive Phase* (Step 6-7): the proactive phase aims at the evolution of the safety management system in order to make possible the continuous improvement of the safety standards just achieved.

- **COST DEPLOYMENT**

Cost Deployment is a method to rationally and systematically establish a cost reduction program, based on the cooperation between Finance and Manufacturing.

The goal of CD is to implement an effective improvement plan which deals with the most significant causal losses with the utmost effort and the right methodologies.

The production process is seen as a source of losses in terms of plants, people, materials and energy. Through a massive phase of data collection, the CD tracks waste and losses in the plant, defines a relationship between the causal and resulting losses, and after the collaboration with FI and PD, defines an improvement plan for priority losses evaluating its actual benefits. Subsequently, it monitors the progress of the planned activities and sets the activities for the following year.

Following what has just been said, the main activities of the CD during the calendar year can be summarized in:

  - Identification of losses
  - Classification of losses
  - Selection of instruments to eliminate losses
  - Valorisation of expected benefits (€)
  - Identification of the activities and their planning
  - Impact of projects on the budget

All this is performed in the seven pillar steps. However, before going deep on them it is important to well understand the concept of waste/loss and cost.

A waste or loss occurs when more resources are used in production than those strictly needed. In general, we can define a loss as the use of any resource (labor, materials, energy), to which a cost is associated, which does not add benefit in the customer’s eyes.

The figure below shows how the losses are involved in the total cost of a final product (Total Transformation Cost, TTC).

Fig. 8: *Total Transformation Cost, TTC*

TTC is defined as the sum of value added cost and non-value added cost. Non-value cost cosists in attackable loss and non attackable loss. We are asked to reduce as much as possible the attackable one in order to maximize the company's profit margin.

Losses/wastes are measured in physical units (hours, materials, kwh). A cost is associated with each loss and a cost in its turn is measured in economic units (€).

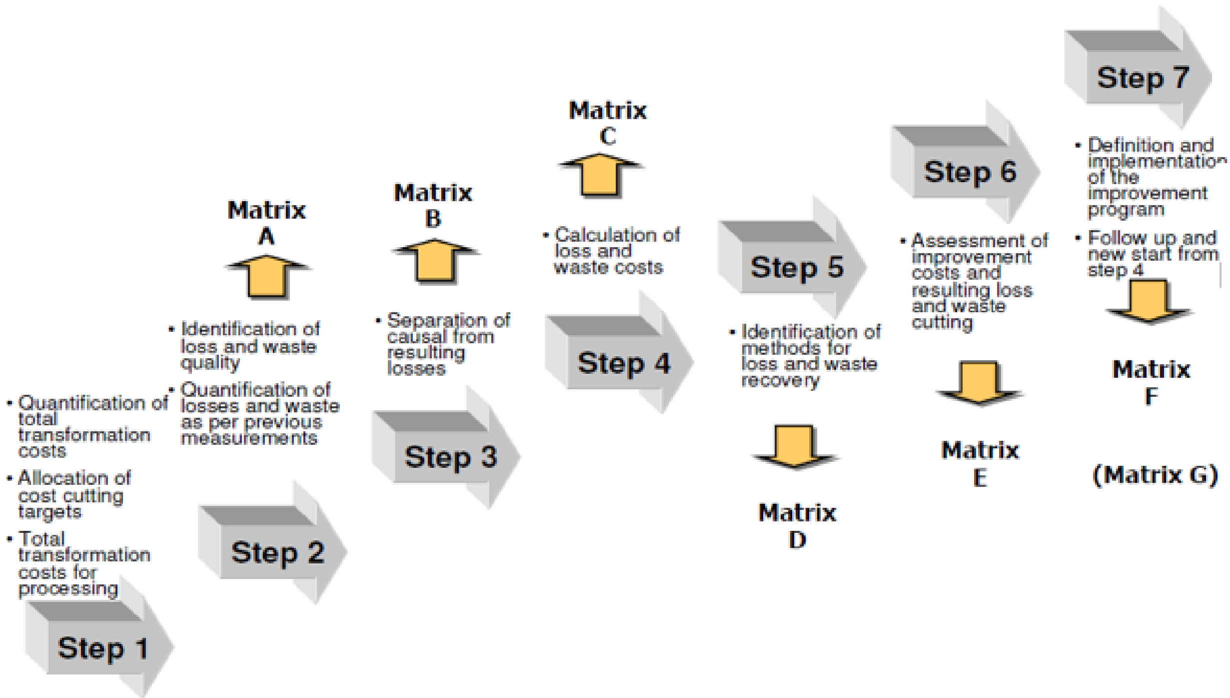


Figure 9: *The seven steps of the Cost Deployment pillar*

Now, It is time to talk about the seven steps and therefore about the CD matrices (Fig. 7):

- Step 1: *TTC* (*Total Transformation Cost*) is calculated. It represents the sum of all costs necessary to convert raw materials into finish goods: direct labor costs, indirect costs (personnel costs, variable costs, fixed costs) and scraps. The Top Management defines the *target reduction* that has to be achieved by the implementation of improvement projects. TTC is always linked to a specific period, typically a fiscal year.

- Step 2 = *A Matrix*: This matrix underlines the connection between wastes, losses and plant sub-processes. It is a qualitative representation of the level of impact of each loss on the processes of the plant. We assign a different colour depending on the level of impact: no impact (no colour), low impact (green), medium impact (yellow), high impact (red). An example of *A Matrix* has been reported in table 1.

A MATRIX		PLANT PROCESSES				
		A	B	C	D	...
LOSSES	A					
	B					
	C					
	D					
	...					

Table 1: *A Matrix structure*

- Step 3 = *B Matrix*: It divides losses in causal and result losses and evaluates the existing linkage between the former and the latter, process by process.

Losses can be classified into two different types:

- Causal losses, which originate directly from a process or plant problem.
- Resultant losses, linked to losses of plant, material, labor, energy, logistics, which originate as a consequence of a causal loss.

The aim of this activity is to identify the causal losses per each process since they must be removed. It is inefficient to concentrate the effort on the result losses since they are just a consequence as already mentioned.

<table>
<tr><td colspan="2" rowspan="2">B MATRIX</td><td>RESULT LOSSES</td></tr>
<tr><td>PLANT PROCESSES</td></tr>
<tr><td>CAUSAL LOSSES</td><td>PLANT PROCESSES</td><td>RELATIONSHIP BETWEEN CAUSAL AND RESULT LOSSES</td></tr>
</table>

Table 2: *B Matrix structure*

- Step 4 = *C Matrix*: This matrix assigns a cost (€) to each identified causal losses. The evaluation utilizes the cost structure of the plant.

<table>
<tr><td colspan="2">C MATRIX</td><td>COST STRUCTURE OF THE PLANT</td></tr>
<tr><td>CAUSAL LOSSES</td><td>PLANT PROCESSES</td><td>CAUSAL LOSSES EVALUATION</td></tr>
</table>

Table 3: *C Matrix structure*

- Step 5 = *D Matrix*: It is fundamental to assign priority to losses. Which losses should I attach first? ICE *(Impact*, *Cost*, *Easiness*) index is the way to know it.

<table>
<tr><td colspan="2">D MATRIX</td><td>I</td><td>C</td><td>E</td><td>ICE</td><td>PRIORITY</td><td>PROJECT</td></tr>
<tr><td>CAUSAL LOSSES</td><td>PLANT PROCESSES</td><td colspan="6">ESTABLISH THE PRIORITY OF LOSSES TO BE FIGHTING</td></tr>
</table>

Table 4: *D Matrix example*

- Step 6 = E Matrix: It consists of a list of improvement projects, established by all the pillars, to fight wastes and losses, following the D Matrix priorities. A cost/benefit analysis of each project is carried out.

E MATRIX							
PROJECT	TEAM	BUDGET		FINAL BALANCE		TARGET	ACUTAL
		BENEFITS	COSTS	BENEFITS	COSTS	KPI	KPI
A PROJECT							
B PROJECT							
... PROJECT							

Table 5: *E Matrix structure*

- Step 7 = *F/G Matrix: F Matrix* monitors the results for each improvement projects by creating monthly reports about the actual savings, while *G Matrix*, which comes after the *F Matrix*, identifies project to be implemented the following year to achieve the TTC Reduction expected by the management. TTC Reduction is drawn up in the budget, generally from October/November onwards.

F MATRIX		% PROJECT ACHIEVMENT			
		January	February	March	···
A PROJECT	Target				
	Actual				
B PROJECT	Target				
	Actual				
... PROJECT	Target				
	Actual				

Table 6: *F Matrix example*

- **FOCUS IMPROVEMENT (FI)**

The purpose of this pillar is to eliminate major losses identified previously within the Cost Deployment, which have a strong impact on the budget and plant KPIs. In this way, organizations focus on relevant losses not wasting resources on minor problems. The aim of this pillar is to achieve waste reduction in the production system and eliminate activities not generating value added, using the logic of focused improvement (Palucha, 2012).

Since in most cases, the source of a loss materializes in the deviation from a process standard, in the logic of FI, we are not limited to identify a buffer solution but a cycle aimed at finding the root causes of the deviation in order to apply corrective actions that aim to definitively eliminate them (PDCA approach). It is important to notice that the seven steps of this pillar reflect the steps of the PDCA cycle itself.

In addition to the propensity for continuous improvement and the techniques used to achieve it, FI also deals with the management of knowledge of WCM tools within the plant and the distribution of workload among the players in the WCM.

- **AUTONOMOUS ACTIVITIES**

The Autonomous Activities pillar is divided into two activities: Autonomous Maintenance (AM) and Workplace Organization (WO). The AM pillar defines the operator's relationship with the machinery while the WO the operator's relationship with the work environment.

Autonomous Maintenance: Autonomous Maintenance means all those first level preventive maintenance activities such as cleaning, checks, inspections, disassembly, replacements and minor repairs. It essentially aims to prevent micro-stops and failures due to lack of basic condition of the machinery.

Workplace Organization (WO): The Workplace Organization pillar is a set of technical criteria, methods and tools with the aim of creating an ideal workplace to ensure the best quality, maximum safety and maximum value (Guglielmino, 2018). There is a need to create, in the work areas, standards that allow to standardize the behaviour of the operators to guarantee the repeatability of the process.

- **PROFESSIONAL MAINTENANCE (PM)**

Professional Maintenance is the pillar that deals with the activities aimed at structuring a maintenance system capable of eliminating faults and micro-stops due to lack of professional maintenance and that extends the life cycle of machinery by increasing the life of individual components, maintaining an efficient approach to processes. Basically, it is the pillar that reports for the good health of the machinery in coordination with the AM and Focus Improvement pillars.

Its aim is initially the elimination of the stops due to lack of professional maintenance (step 1-3) and then focus on the costs associated with the same activities (step 4-6).

- **QUALITY CONTROL (QC)**

QC pillar has the main target of guaranteeing Customer Satisfaction by minimizing the costs incurred to achieve it. Quality Control attack quality issues to find their root cause and apply adequate countermeasures. The aim is to monitor the production identifying non-compliances and avoid their reappearing. Quality Control also helps to reduce costs related to reworks and scraps.

The main activities of QC pillar are:

- Define a QA Matrix to relate each identified defect to the process that generates it, highlighting the frequency with which it occurs, the cost it represents, the severity and the detection zone of the non-compliance;
- Analyse defects to find the root cause;
- Apply countermeasures, also to similar cases and monitor the results to guarantee the effectiveness of solutions;
- Helps AM and PM measuring process capability and supplying guidance for evaluations related to product and process quality.

- **LOGISTICS & CUSTOMER SERVICE (LOG)**

Another Pillar of WCM Temple is represented by Logistics, which controls all material flows inside and outside the Plant. The main goal is to apply Just In Time to all areas, in order to maintain an efficient control of all materials, supplying each production process with required material just when it is required. This can be possible through an accurate analysis and control of the demand.

The main targets of LOG pillar are:

- Supply material to production areas strictly following production plans;
- Improve flows inside and outside the plant to limit material handling and its related risks and costs;
- Reduce stocks and avoid material obsolescence;
- Deliver the right material just in time in each production area.

- **EARLY EQUIPMENT MANAGEMENT (EEM) / EARLY PRODUCT MANAGEMENT (EPM)**

This pillar is dedicated to the introduction of new machines / products in the production system. It cooperates with supplier of the machines and product development up to the ramp up phase, to improve both machine and process reliability, and to avoid future costs. The role of Early Equipment Management and Early Product Management is similar, but EEM refers to introduction of new machines and equipment, while EPM is dedicated to new products.

In particular, Early Equipment Management therefore consists in the collaboration between designers, production and suppliers of the machinery with the aim of:

- Install machinery with performance indicators;
- Reduce the Life Cycle Cost of the machinery;

Speed up the start-up of the machinery.

- **PEOPLE DEVELOPMENT (PD)**

Humans represents the most important factor influencing the success of a company. The PD pillar concerns people and their technical development, it provides trainings to improve worker competencies on Autonomous Activities, but especially on WCM methods.

Main targets:

- Avoid accidents caused by inexperience or lack of knowledge;
- Guarantee adequate skills and competencies to every worker of the plant;
- Train every worker to WCM for a faster continuous improvement of the plant.

- **ENVIRONMENT (ENV)**

Environment and Energy deals with the management of environmental programs implemented by the plant, which include the organizational structure, planning and resources to develop, implement and maintain environmental protection. It therefore represents a tool to improve environmental performance, to manage environmental affairs in the organization, the immediate and long-term impact of products, services and processes on the environment, and is dedicated to the continuous improvement of the entire system. The plant must have zero impact from an environmental point of view.

The continuous improvement process of the Environment and Energy technical pillar is described her below (Ketter e Massone, 2007):

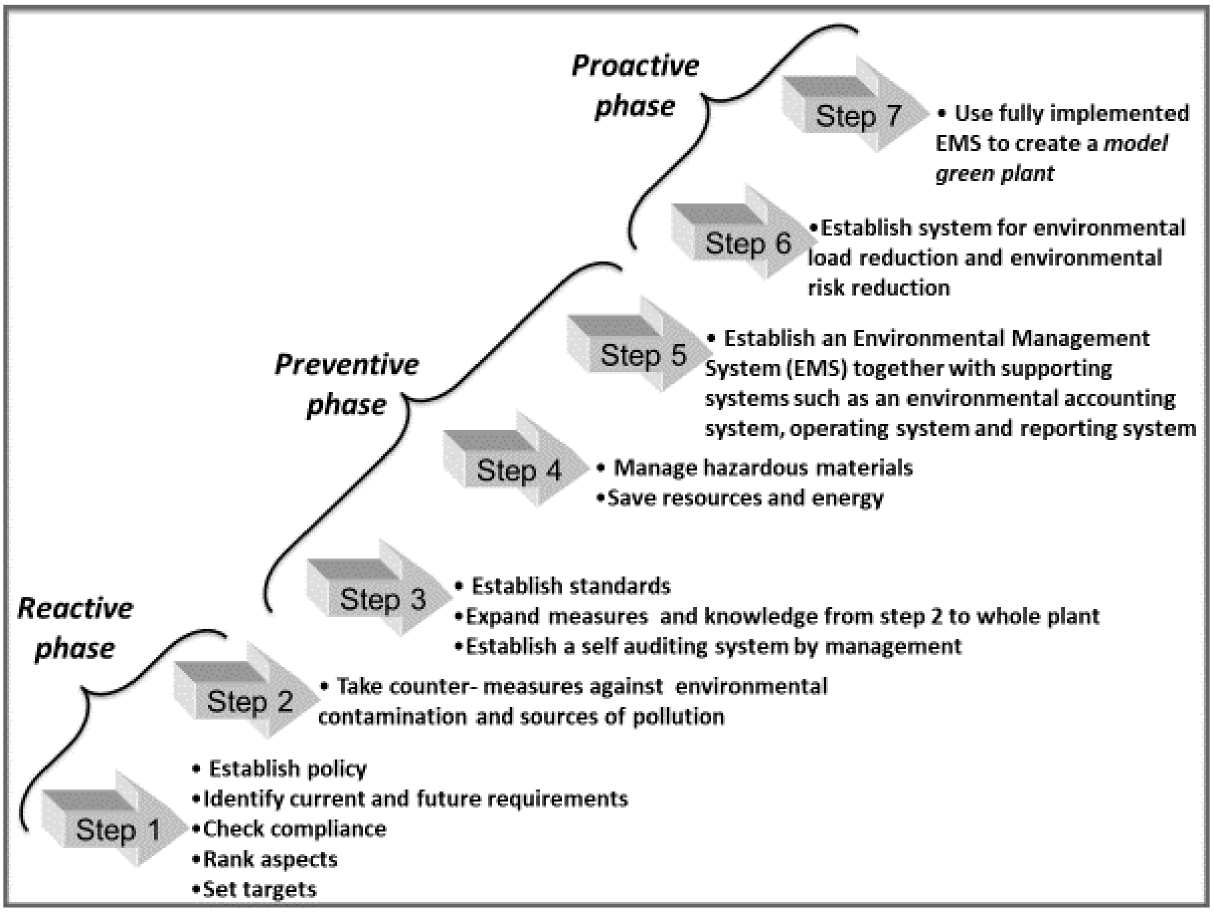


Figure 10: *The seven steps of Environment and Energy*

The reactive phase includes steps 1 and 2. This phase defines the environmental conformity assessment process according to ISO 14001, in order to systematically and regularly monitor the updating and compliance with the legal requirements applicable to the plants.
In the preventive phase (step 3, step 4 and step 5), standards and a Self Audit System by the Top Management are started to be used to test and monitor environmental behaviour and working conditions in the plant. We also try to understand what are the factors that create an environmental impact and, for each factor, we define the quantity, the unit of measurement and the value in economic terms by the environmental cost deployment. The appropriate countermeasures to be implemented to minimize losses and waste are defined. At the end, the Environment Management System (EMS) is created, which represents the integration of all the activities carried out by the pillar.
In the proactive phase (step 6 and step 7), one must be able to show examples of technical analysis, business plan and action plan for environmental sustainability and risk reduction with the goal of creating a green plant model, in order to carry out production activities with minimum environmental impact.

Now let's talk more deeply about the first four steps of Env Pillar.

STEP 0

The step 0 aims to define the vision and strategy of the plant on the environment through the adoption of the document of Principles of Environmental Policy and introduce the concept of assessment of environmental impacts and aspects.

Main activities:

- Implementation of preliminary activities necessary for a correct definition and implementation of environmental management (Environmental Management System Manual).
- Definition of an Environmental policy.
- Definition of a plant "vision".
- Identification and evaluation of all significant environmental aspects and impacts (direct and indirect) (VAIA).
- Economic evaluation of environmental aspects (per unit, per carrier, through technical parameters).

After Step 0, Step 1 and Step 2 are necessary, which deal with data analysis and counter measures.

STEP 1

The step 1 aims to understand and keep under control legal regulations.

Main activities:

- Understand the local laws and regulations as they exist today and also where they are like to be in the future.
- Identify the environmental issues the plant must deal with and rank/prioritize them.
- Establish an education system to develop employee awareness on environmental issues and possible ways to manage the associated risks.

STEP 2

The step 2 aims to analyze all environmental incidents in the plant, identify root cause and take countermeasures against them following PDCA approach. High significance environmental impacts, coming from VAIA analysis, have to be reduced.

Main Activities:

- Take action against contamination sources.
- Identify proper methods and implement countermeasures against the sources of the identified environmental problems.
- Investigate environmental risk and take countermeasures against them.

Once Step 1 and Step 2 are well defined, standardization phase has to be implemented by working on Step 3, 4 and 5.

STEP 3

Step aims to define the initial standards of environment management and to set audit work.

Main Activities:

- Prepare provisional standards and procedures.
- Horizontally expand in other areas the know-how created in Step 2.
- Establish a self-auditing system by the top management, in order to:

- assess the compliance of the system,
- identify the causes of non-compliance,
- establish corrective actions appropriate to the problems and environmental impacts encountered.

STEP 4

The purpose of this step is to implement the audits, to assess the data gathered by the environmental management system and its savings and simulate how to intervene in case of environmental emergency.

Main Activities:

- Check input materials such as raw materials and energy, etc. to the plant, area, block and processes and identify how they will come out as outputs such as products, scraps, dust, heat, noise, to the processes, block, area and the plant.
- Quantify them and based on their priorities, take countermeasures against the un-demanded outputs step by step.
- Hazardous materials management. Define prevention and protection measures. Carry out training and Visual Aid for workers involved.
- Chemical substance control. Identify where and how all chemicals are used. Acquire the material Safety data sheets (SdS) and keep them updating over time. Define how they should be handled and disposed of after use. Look for alternative substances with lesser or no environmental impact.
- Initiate a resource saving exercise. Look for ways to minimize the use of raw materials. Look for ways to minimize scrap and to find useful outlets for scrap. Draw up the Environmental Cost Deployment to locate losses to be eliminated or reduced.
- Energy saving. Initiate an energy awareness and saving exercise. A large number of simple actions can make a significant reduction in overall energy usage.

CHAPTER IV - **ARCEVIA PLANT CASE**

The objective of this chapter is to show, through a practical and real example, how to apply and join together all the theoretical concepts just discussed in order to obtain both environmental and economic benefits for the company itself.

In particular, I will initially identify the most significant environmental aspects and impacts related to the activity of Thermowatt company, home of my internship. From this analysis it will appear that the most significant aspect is that related to “Waste Generation”. In order to reduce the significance of this aspect, action will be taken on the total elimination of the disposal process of a specific waste, magnesium oxide (MgO), which will be recycled and reused as a new material by a specialized company.

Many different wastes produced by the company exist but only MgO will be considered here as it appears to be the waste produced in greater quantities with consequent high disposal costs, which will be economically quantified by drafting the Environmental Cost Deployment.

4.1. Procedure to identify Environmental Aspects – "VAIA Analysis"

The purpose of the Environmental Impacts Assessment is to systematically identify which environmental aspects related to production activities, products and services have or could have a significant impact on the environmental.

Before starting talking about how the analysis can be performed, it is worth to take in mind some fundamental definitions:

- *Environmental management system (EMS):* part of an organization's management system used to develop and implement its environmental policy and to manage its environmental aspects.

- *Environmental aspect*: element of an organization's activities or products or services that can interact with the environment. An environmental aspect can cause an (some) environmental impact(s). A significant environmental aspect is an environmental aspect that have or can have one or more significant environmental impacts.

- Environmental impact: any change to the environment, wheter adverse or beneficial, wholly or partially resulting from an organization's environmental aspects.

- *Life cycle*: consecutive and interlinked stages of a system of products, from raw material acquisition to final disposal. Life cycle stages include:

- ✓ Acquisition of raw materials
- ✓ Design and manufacturing;
- ✓ Transportation/delivery
- ✓ Use
- ✓ End-of-life treatment and final disposal.

- *Continuous improvement*: recurring process of enhancing the environmental management system in order to achieve improvements in overall environment performance consistent with the organization's environmental policy.

- *Environmental policy*: overall intentions and direction of an organization related to its environmental performance as formally expressed by top management.

Now, let’s talking about how Thermowatt Company identifies Environmental Aspects.

The goal of this analysis is to consider all the environmental aspects of the company as basis for establishing its Environmental Management System (EMS).

For the determination of the site environmental aspects, it is important to proceed by applying a life cycle perspective, considering those stages just reported above.

The Environmental aspects taken into account are:

1. Air emissions
2. Water discharge
3. Generation of waste
4. Releases to soil
5. Use of raw materials
6. Use of energy
7. Noise
8. Light
9. Electromagnetic emissions and ionizing radiations
10. Use of space

In addition to those environmental aspects that the organization is able to control directly, each plant shall also consider other aspects that could cause indirect impacts: goods and services used by the organization but supplied by external parties or products and services that the organization provides to external parties.

Classification of the environmental aspects mentioned above shall take into account both normal and abnormal operating conditions and possible emergencies. The indirect impacts from outsourcing activities shall be also evaluated.

The purpose of this assessment is to establish a priority process by identifying those aspects that need to be addressed with more urgency than others, according to 4 significance levels: AA, A, B, C.

AA	Significant Impact
A	Less Significant Impact
B	Insignificant Impact
C	No Impact

Table 7: *significance classes*

4.1.1. Determination of significance under normal operating conditions

For each environmental aspect, the Significance Index is calculated using the following formula:

Sn = 0,30*Is + 0,40*L + 0,10*CPI + 0,20*I

where

- Sn: Significance Index in normal/abnormal operating conditions;
- Is: Severity Index, determined as function of two factors IRA and SA;
- IRA: Relative Importance;
- SA: Sensitivity of the environment;
- L: Legislation;
- CPI: Attention from Interested parts;
- I: Environmental Impact, estimation of the impact generated in terms of Reversibility (R) and Extension (E);
- R: Reversibility;
- E: Extension.

An aspect is significant when **Sn is equal or greater than 2,1.**

Now, I am going to show how each index can be defined.

I. Severity Index Is

Severity Index Is is determined as function of two factors:

- Sensitivity of the environment (Sa): estimation of the influence that generic or specific aspects can have on the neighboring areas;
- Relative importance of the aspect (Ira): estimation of how a specific environmental aspect arises in the production process of the plant.

The following tables define the criteria for conferring the value (1,2,3) to the above indexes:

S_A	3	2	1
Air emissions	Emissions in residential areas or areas of particular environmental interest	Emissions in mixed areas (industrial and residential)	Emissions in industrial areas
Water discharge	Discharge into a receiving water body with ecological status (quality of the water) very good, good or fair	Discharge into a receiving water body with ecological status (quality of the water) poor or very poor	Discharge into the municipal sewer
Generation of waste	Percentage of waste sent to disposal operations: >20%	Percentage of waste sent to disposal operations: 5% ÷20%	Percentage of waste to disposal operations: <5%
Releases to soil	Direct release on soil with high level of permeability	Direct release on soil with low level of permeability	Release on paved/waterproofed soil
Use of raw materials	Raw materials purchased from local suppliers: <20%	Raw materials purchased from local suppliers: 20% ÷80%	Raw materials purchased from local suppliers: >80%
Use of energy	No use of renewable energies	Use of renewable energies <20%	Use of renewable energies >20%
Noise	Site located in a residential area or in areas of particular environmental interest (classes I-III)	Site located in urban area (class IV)	Site located in industrial area (classes V-VI)
Light	Site located at a distance <5 km from a highly protected area with limited lighting (zone 1)	Site located at a distance <25 km from a protected zone adjacent a zone 1	Site located in areas not classified as zone 1 or 2
Electromagnetic emissions and ionizing radiations	Site located in a residential area or in areas of particular environmental interest	Site located in urban area	Site located in industrial area
Use of space	New settlements in green areas	New settlements in previously not industrial areas	Absence of new settlements or new settlements in areas already designed for industrial use

***Table 8:** Sa scores*

I_{RA}	3	2	1
Air emissions	Emission of substances as VOC (Volatile Organic Compounds)	Emission of substances as NO_X, dust, etc.	Emission of substances not listed in criteria for score 3 and 2
Water discharge	Industrial, civil and rainwater not separated and without any waste water treatment	Industrial, civil and rainwater separated but not sent to any waste water treatment	Industrial, civil and rain water separated and sent to a waste water treatment
Generation of waste	Increased quantity of the rate IRT (hazardous waste/ products), compared to the previous year	Unvaried quantity of the IRT rate	Decreased quantity of IRT rate compared to the previous year
Releases to soil	Possible releases of hazardous substances at liquid state	Possible releases of hazardous substances at powder state or	Possible releases of hazardous substances at solid state
Use of raw materials	Increased use of raw materials per product compared to the previous	Unvaried use of raw materials per product	Decreased use of raw materials per product compared to the
Use of energy	Both IEE (kW/h/#products) and IGM (gas m^3 /# products) indices increased compared to the previous	At least one of IEE and IGM indices decreased compared to the previous year or both unvaried	Both IEE and IGM indices decreased compared to the previous year
Noise	100% of outdoor activities without soundproof protections	Partially indoor activities or outdoor activities without soundproof protections	100% of indoor activities or outdoor activities with soundproof protections
Light	Outdoor lighting systems with upward light emissions >200 cd/klm	Outdoor lighting systems with upward light emissions from 30 to 200 cd/klm	Outdoor lighting systems with upward light emissions <30 cd/klm
Electromagnetic emissions and ionizing radiations	Presence of unshielded sources of electromagnetic emissions and/or ionizing	Presence of unshielded sources of electromagnetic	Presence of shielded or absence of sources of ionizing radiations
Use of space	Increased covered surface compared with the previous year	Unvaried covered surface	Decreased covered surface compared with the previous year

***Table 9:** Ira scores*

Crossing these data we can identify the Severity Index Is:

I_{RA}	3	2	3	3
	2	1	2	3
	1	1	1	2
		1	2	3
		S_A		

Table 10: *Is scores*

II. Legislation L

L	Criteria
3	Mandatory regulations - Authorizations WITH specific requirements for the site
2	Mandatory regulations / Authorizations WITHOUT specific requirements for the site
1	Absence of dedicated regulations

Table 11: *L scores*

III. Involvement of Stakeholder

This factor defines the attention/sensitivity of community, neighbors, associations, mass media, public authorities to the environmental aspect/impact. The CPI value goes from 1 to 3.

C_{PI}	Criteria
3	The aspect is object of complaint by Public Authorities
2	The aspect is object of complaint by community, neighbors, environmental associations , mass media, etc.
1	Aspect without interest by any external part

Table 12: *CPI scores*

IV. Environmental Impact I

The Environmental Impact Index is the estimation of the impact generated in terms of Reversibility (R) and Extension (E) and it is obtained crossing E and R scores. I index score varies from 1 to 3.

Extension (E) is the area interested by the impact:

E	Global	Regional	Local
	3	2	1

***Table 1**3: E scores*

Reversibility (R) is strictly linked to the sensitivity of the environment on which the aspect insists. It considers the possibility that the impact itself can regress completely or not and in the long or shot term:

R	Irreversibility	Long term reversibility	Short term reversibility
	3	2	1

***Table 14:** R scores*

Crossing these data we can identify the Environmental Impact Index I:

		E		
		1	**2**	**3**
R	**1**	1	1	2
	2	2	2	3
	3	3	3	3

***Table 15:** I scores*

Once each factor has been quantified, the Significance Index (Sn) is calculated using the above algorithm.

The 4 levels of significance are shown in the following table:

AA	Sn ≥ 2,1	Significant Impact
A	1,8 ≤ Sn < 2,1	Less Significant Impact
B	1,5 ≤ Sn < 1,8	Insignificant Impact
C	Sn < 1,5	No Impact

Table 16: *significance classification under normal operating conditions*

After the determination of the significance of environmental aspects, each plant shall proceed setting its environmental targets, taking into account all environmental requirements and opportunity for improvement coming from the analysis results.

4.1.2. Determination of significance under emergency conditions

The significant index under emergency conditions is calculated as follows:

$$\mathbf{Se = M*p}$$

Where

- **M = q + h** : magnitude

I. Magnitude M

Quantity/Intensity (q): is an estimation of the quantity/intensity of a potentially involved agent determined by statistical analysis of quantities present on site and/or involved in past accidents occurred in the recent past:

q	Criteria
3	High
2	Medium
1	Small

Table 17: *q scores*

Risk (h): is an estimation of the hazardousness of the potential agent and it is defined and evaluated according to the following table:

h	Criteria
3	High
2	Medium
1	Low

Table 18: *h scores*

II. Probability p

Probability (p): defined and quantified on the basis of the frequency of similar events that have already occurred in the past.

p	Criteria
3	Frequently
2	Occasionally
1	Never happen or it is presumed it will never happen

Table 19: *p scores*

Once each factor has been quantified, the Significance Index under emergency conditions (Se) is calculated using the above algorithm.

The 4 levels of significance are shown in the following table:

AA	$Se \geq 8$	Significant Impact
A	$4 \leq Se < 8$	Less Significant Impact
B	$3 \leq Se < 4$	Insignificant Impact
C	$Se = 2$	No Impact

Table 20: *significance classification under emergency conditions*

4.1.3. VAIA final outcomes

Applying the procedure indicated in the previous sections and considering these specific life cycle stages of Themowatt products:

- Design
- Acceptance of raw materials
- Raw materials storage
- Raw material storage
- Copper heating element assembly
- Copper heating element sealing
- Copper heating element testing and packaging
- Steel heating element assembly
- Steel heating element testing and packaging
- Assembly and calibration of thermostats
- Testing and packaging of thermostats
- Laboratory tests
- Final products storage
- Final products distribution

The final results of the analysis come out and shown in the table below, where the significance impacts are calculated for each single life cycle stage of the product itself.

In the first line of table 11 is reported the analysis referred to the whole Arcevia plant, which groups all the results coming from each life cycle stage of the products (Copper heating element, Steel heating element, Thermostats).

In table 21 are shown, in detail, the Arcevia plant results considering data of year 2019 (VAIA 2020).

Product Life Cycle stages	Air emissions		Water discharge		Waste generation [Kg]		Releases to soil		Raw materials use		Energy use		Noise		Light	
	NC	EC	NC	EC	NC	EC	NC	EC	NC	EC	NC	EC	NC	EC	NC	EC
PLANT	AA	A	A	A	AA	A	A	A	C	-	A	-	AA	-	C	C
Design	-	-	A	C	C	-	-	-	-	-	A	C	A	B	-	-
Raw materials acceptance	-	-	A	A	C	A	B	C	C	C	A	C	A	B	-	-
Raw materials storage	-	-	A	A	C	A	B	C	-	-	A	C	A	B	-	-
Copper heating element assembly	AA	A	A	A	AA	A	A	A	C	-	A	-	AA	-	-	-
Copper heating element sealing	A	A	A	A	C	A	A	A	C	-	A	-	A	-	-	-
Copper heating element testing and packaging	-	-	A	A	C	A	-	-	C	-	A	-	A	-	-	-
Steel heating element assembly	AA	A	A	A	AA	A	A	A	C	-	A	-	A	-	-	-
Steel heating element testing and packaging	-	-	A	A	C	A	-	-	C	-	A	-	A	-	-	-
Thermostats assembly and calibration	AA	A	A	A	C	A	A	A	C	-	A	-	A	-	-	-
Thermostats testing and packaging	-	-	A	A	C	A	-	-	C	-	A	-	A	-	-	-
Final product storage	-	-	A	A	C	A	B	C	-	-	A	C	A	B	-	-
Final products distribution	-	-	A	A	C	A	B	C	-	-	-	-	A	B	-	-
Lab tests	-	-	A	A	C	A	A	B	C	C	A	C	A	B	-	-

Table 21: *VAIA RECAP*

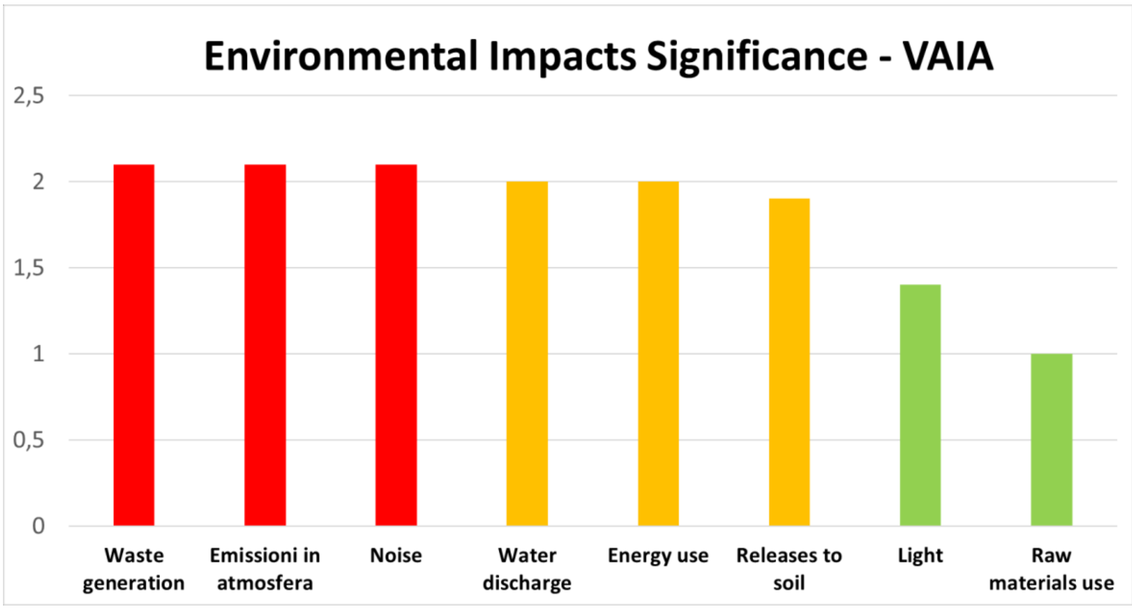


Figure 11: *VAIA RECAP*

The scope of this analysis is to identify the most significant environmental impacts in order to reduce as much as possible their significance. So reduction projects are carried out starting from those environmental impacts with significance AA (red columns).

In this work I am focus on the significance reduction of the **Waste Generation impact**. A specific project was implemented with consequent reduction of its significance which passes from **AA** to A. I will talk about that in the following pages.

4.2. ENVIRONMENTAL COST DEPLOYMENT

4.2.1. Introduction

The Environmental Cost Deployment is one of the "technical" Cost Deployment and it is used during the Step 4 of the Environment Pillar, where one of the main topic is "Resource Saving". This is the tool used to prioritize among all the environmental losses in order to define the projects to reduce the cost linked to waste management.

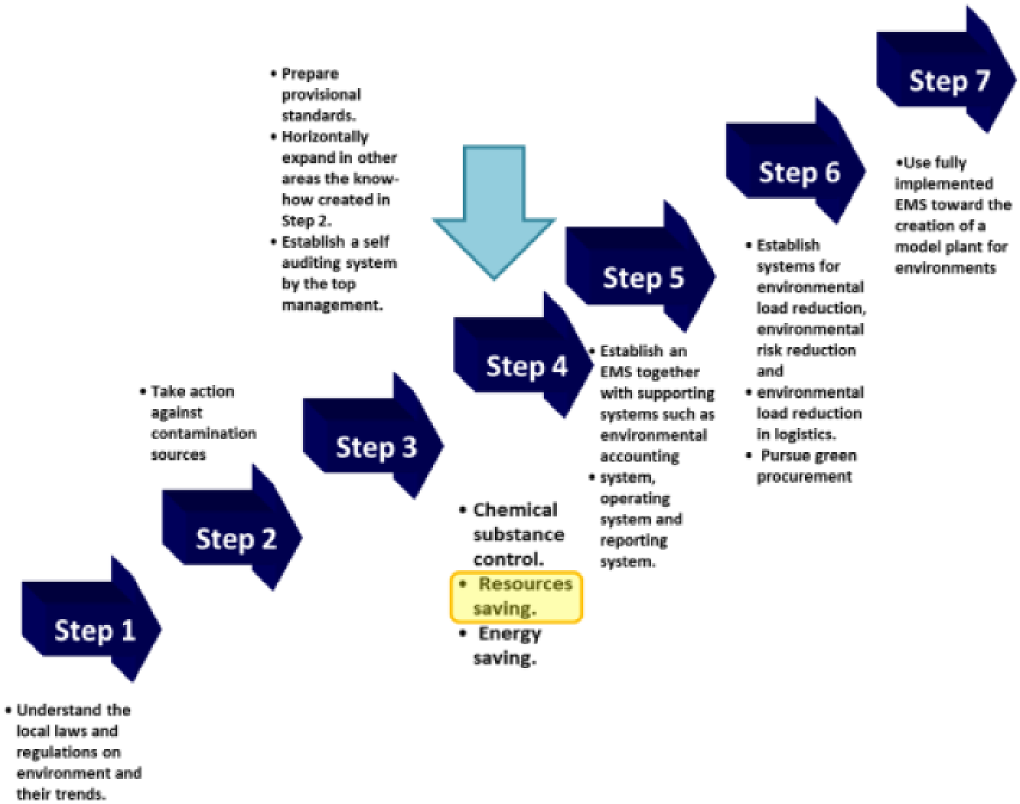


Figure 12: *ENV CD localization*

It is introduced only in Step 4 because there are not only economic reasons to work on environmental topics, but also legal and moral reasons which are indeed the main drivers of Step 0-3 activities. So it means that ENV CD is used only after having:

- defined Policy, Targets and have assessed Environmental Issues and Impacts (Step 0);
- ensured the comprehension and compliance to Laws and Regulations (Step 1);
- reduced and environmental impacts and improved the trend of main KPIs (Step 2);
- set environmental standards and an auditing system to maintain the results obtained along the time (Step 3).

4.2.2. Link with Manufacturing CD

Environment and Energy Cost Deployment are completely inside the perimeter of the Manufacturing CD. It is important when introducing these technical cost deployments to be careful not to double count the losses. In this phase if fundamental the collaboration with CD pillar.

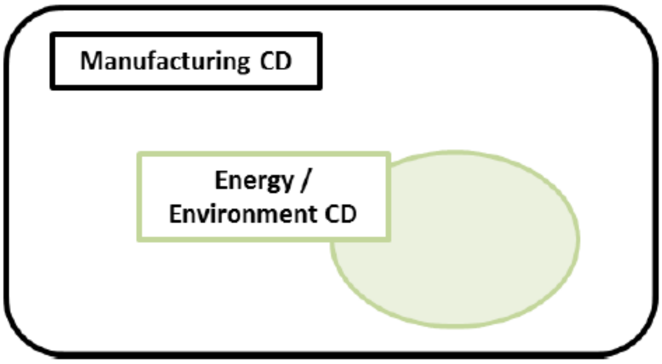


Figure 13: *Relation with manufacturing CD*

4.2.3. Scope and data collection

ENV CD aims to attacking the loss associated to waste management and disposal that is a cost inside the Total Transformation Cost perimeter (TTC), which represents the sum of all costs necessary to convert raw materials into finish goods.

So the starting point and the viewpoint it is not the quantity of raw materials used but the quantity of waste produced. Using fewer raw materials is for sure a way to reduce the wastes and the related costs, but this is outside the "perimeter" and competence of the Environment pillar and it is more under the responsibility of Product Development.

Generally speaking, the competence of the Environment pillar is to work on the losses in order to limit and save on the "waste" of natural resources.

The assumption we do is to consider 100% of the wastes as a loss.

4.2.4. “5R” Concept

The 5R concept is the prioritization principle to attack environmental losses. According to it when we want to attack a specific environmental loss the first and preferable way should be the elimination of the waste, so to Refuse. If it is not possible to refuse it, the second chance is to Reduce, then to Reuse or to Recycle. Finally, to Recover. So, the 5R principle is not taking into consideration the option of the Disposal to a Landfill.

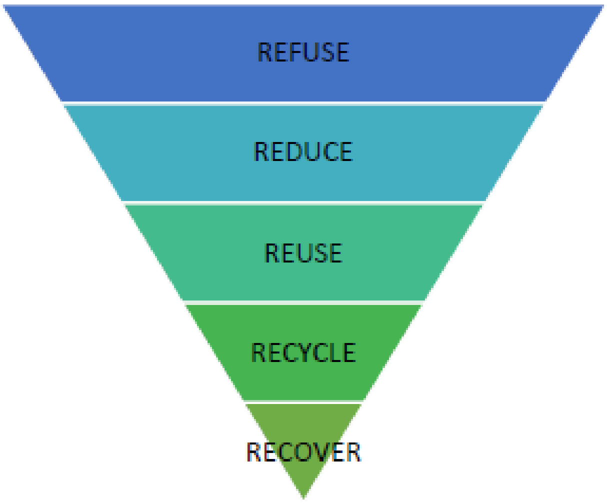


Figure 14: *5R Concept*

4.2.5. Input Data – Arcevia Plant Waste Database

The losses have to refer to a full year, it means considering the quantity of wastes produced during a full year.

Here, in this work, I will show the Env CD 2020 referred to year 2019 considering as period of reference what goes from 01/01/2019 to 31/12/2019 (Table 22).

The sum of all wastes produced by Arcevia Plant is equal to **630.162 kg**.

I highlighted the line related to MgO since it is the waste on which this thesis is focused on.

EWC CODE	WASTE NAME	R / D	QUANTITY [kg/year]	€/kg	DISPOSAL [€]	TRANSPORT [€]	CONTAINER RENTAL [€]	TOT CER [€]
06 03 16	Metallic oxides (MgO)	D	38.620	1,28	48.275 €	1320,00€	-	49.595,00€
06 05 02* Liquid	Sludge from on-site effluent treatment	D	10.280	0,68	6.682,00€	300,00€		6.982,00€
06 05 02* Solid	Sludge from on-site effluent treatment	D	3.800	0,70	2.388,00€	195,00€	80,00 €	2.663,00€
12 01 03	Non-ferrous metal filings and turnings	R	82.520	-1,05	- 86.233,96€	- €	- €	- 86.233,96€
14 06 03*	Other solvents and solvent mixtures	D	740	2,20	1.480,00€	111,88€	35,00 €	1.626,88€
15 01 01	Paper and cardboard packaging	R	81.740	0,04	- €	2.350,65€	929,10€	3.279,75€
15 01 03	Wooden packaging	R	69.630	0,10	1.130,40€	4.709,60€	929,10€	6.769,10€
15 01 06	Mixed packaging	R	57.080	0,20	8.390,20€	2.350,65€	929,10€	11.669,95€
15 01 10*	Packaging containing residues of or contaminated by hazardous substances	D	2.680	0,99	2.412,00€	195,00€	35,00 €	2.642,00€
15 02 02*	Absorbents, filter materials, wiping cloths, protective clothing contaminated by hazardous substances	D	1.980	1,05	1.782,00€	195,00€	110,00€	2.087,00€
16 02 14	Discharge equipment	R	9.840	-0,11	- 1.082,40€	- €	- €	- 1.082,40 €
16 03 06	Organic wastes	D	1860	0,92	6.930,00€	111,88€	80,00 €	7.121,88€
17 04 01	Copper, bronze, brass	R	125.173	-2,13	- 266.992,93 €	- €	- €	- 266.992,93€
17 04 05	Iron and steel	R	139.179	-0,31	- 43.820,81€	- €	- €	- 43.820,81€
20 01 21*	Fluorescent tubes and other mercury-containg waste	D	40	15,75	120,00 €	110,00€	400,00€	630,00€
20 03 04	Septic tank sludge	D	5.000	0,22	250,00 €	300,00€	540,00€	1.090,00€

Table 22: *Arcevia Plant Waste Database (from 01/01/2019 to 31/12/2019)*

As we can see by table 22, MgO represented one of most expensive waste in year 2019. In fact, the **cost** related to its **disposal** was **1.25 €/kg** which mean a total cost of 49285 €. For this reason, as anticipated before, a project on MgO was developed during year 2020 so that it can be totally recycled and no longer disposed.

4.2.6. "A" Matrix

The A matrix has on the columns the processes and sub processes of the plant, while on the rows the waste codes. The final aim of the A matrix is to split the total quantity for each type of waste among all the processes.

Two different types of A Matrix exist: Qualitative A Matrix and Quantitative A Matrix.

Qualitative A Matrix – This matrix is called qualitative because it should be done without physical units, before the quantitative A matrix. There are two goals in doing it:

1. To have a first draft idea of which are the processes that are impacting more in terms of waste production, in order at the beginning to focus only on the most important losses (red and yellow) without carrying in the next matrixes low/no impact.
2. To create awareness and involvement in the people, since their believes can then be compared with the evidence of the Quantitative A matrix.

To fill in the qualitative A matrix it is needed to say what is the impact of each process on each waste, which is at the cross of rows and columns. The legend to be used is the one in Figure 23.

IMPACT	
High	
Medium	
Low	
No impact	

Table 23: *Qualitative A Matrix legend*

Here below, an extracted part of Arcevia Plant Qualitative A Matrix is reported:

A MATRIX qualitative		COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	RAME
EWC code	**Waste Description**	Forming and cutting steel tube	Copper tube cut	Spiral formation	Solder spiral pins	cr 15	cr 16	cr 17	cr 18	Manual filling	Filling ST3	Offline laminatio n	Transfert 1
06 03 16	Metallic oxides (MgO)	0	0	0	0	3	3	3	3	3	3	0	0
06 05 02* Liquid	Sludge from on-site effluent treatment	0	0	0	0	0	0	0	0	0	0	0	0
06 05 02* Solid	Sludge from on-site effluent treatment	0	0	0	0	0	0	0	0	0	0	0	0
12 01 03	Non-ferrous metal filings and turnings	0	0	0	0	0	0	0	0	0	0	0	3
14 06 03*	Other solvents and solvent mixtures	0	0	3	0	0	0	0	0	0	0	0	0
15 01 01	Paper and cardboard packaging	1	1	3	1	1	1	1	1	1	1	0	1
15 01 03	Wooden packagin	3	3	1	0	1	1	1	1	1	1	0	0
15 01 06	Mixed packaging	1	1	2	0	3	3	3	3	1	1	0	1
15 01 10*	aging containing residues of or contaminated by ha hazardous substa	0	0	2	0	0	0	0	0	0	0	0	0
15 02 02*	materials, wiping cloths, protective clothing contaminated by hazard	1	1	1	1	1	1	1	1	1	1	1	1
16 02 14	Discharge equipmetn	0	0	0	0	0	0	0	0	0	0	0	0
16 03 06	Organic wastes	0	0	0	0	0	0	0	0	0	0	0	3
17 04 01	Copper, bronze, brass	0	1	0	0	1	1	1	1	1	0	0	3
17 04 05	Iron and steel	3	0	2	2	2	2	2	2	2	2	0	0
20 01 21*	Fluorescent tubes and other mercury-containg waste	1	1	1	1	1	1	1	1	1	1	1	1
20 03 04	Septic tank sludge	0	0	0	0	0	0	0	0	0	0	0	0

Figure 15: *Part of Qualitative A Matrix of Arcevia Plant*

<u>**Quantitative A matrix**</u> – The quantitative A Matrix has the same structure of the Qualitative but with quantity of waste (in kilograms, tons, etc.). To do it the best way is to build an "Allocation" matrix distributing the 100% of each waste among all the processes.

Here below, an extracted part of Arcevia Plant Allocation Matrix is reported:

Allocation MATRIX ARCEVIA plant		COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	RAME
EWC code	**Waste Description**	Forming and cutting steel tube	Copper tube cut	Spiral formation	Solder spiral pins	cr 15	cr 16	cr 17	cr 18	Manual filling	Filling ST3	Offline laminati on	Transfe rt 1
06 03 16	Metallic oxides (MgO)	0%	0%	0%	0%	15%	15%	15%	15%	13%	13%	0%	0%
06 05 02* Liquid	Sludge from on-site effluent treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
06 05 02* Solid	Sludge from on-site effluent treatment	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
12 01 03	Non-ferrous metal filings and turnings	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%
14 06 03*	Other solvents and solvent mixtures	0%	0%	70%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15 01 01	Paper and cardboard packaging	1%	1%	12%	1%	1%	1%	1%	1%	1%	1%	0%	1%
15 01 03	Wooden packagin	16%	16%	3%	0%	2%	2%	2%	2%	2%	2%	0%	0%
15 01 06	Mixed packaging	1%	1%	4%	0%	8%	8%	8%	8%	1%	1%	0%	1%
15 01 10*	aging containing residues of or contaminated by ha hazardous substa	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
15 02 02*	materials, wiping cloths, protective clothing contaminated by hazard	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	5%	1%
16 02 14	Discharge equipmetn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
16 03 06	Organic wastes	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	14%
17 04 01	Copper, bronze, brass	0%	3%	0%	0%	1%	1%	1%	1%	1%	0%	0%	6%
17 04 05	Iron and steel	9%	0%	8%	7%	5%	5%	5%	5%	5%	5%	0%	0%
20 01 21*	Fluorescent tubes and other mercury-containg waste	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
20 03 04	Septic tank sludge	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Figure 16: *Part of Allocation Matrix of Arcevia Plant*

The A Matrix can be obtained simply multiplying the percentages times the total quantity produced over the last 12 months.

When doing the Environmental CD for the first runs, it is possible to decide to deploy in the following matrixes only red and yellow losses.

Here below, an extracted part of Arcevia Plant Quantitative A Matrix is reported:

A MATRIX quantitative		COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	COMUNI	RAME
EWC code	Waste Description	Forming and cutting steel tube	Copper tube cut	Spiral formation	Solder spiral pins	cr 15	cr 16	cr 17	cr 18	Manual filling	Filling ST3	Offline laminatio n	Transfert 1
06 03 16	Metallic oxides (MgO)	-	-	-	-	5.793	5.793	5.793	5.793	5.021	5.021	-	-
06 05 02* Liquid	Sludge from on-site effluent treatment	-	-	-	-	-	-	-	-	-	-	-	-
06 05 02* Solid	Sludge from on-site effluent treatment	-	-	-	-	-	-	-	-	-	-	-	-
12 01 03	Non-ferrous metal filings and turnings	-	-	-	-	-	-	-	-	-	-	-	11.788
14 06 03*	Other solvents and solvent mixtures	-	-	518	-	-	-	-	-	-	-	-	-
15 01 01	Paper and cardboard packaging	817	817	9.809	817	817	817	817	817	817	817	-	817
15 01 03	Wooden packagin	11.141	11.141	2.089	-	1.393	1.393	1.393	1.393	1.393	1.393	-	-
15 01 06	Mixed packaging	571	571	2.283	-	4.566	4.566	4.566	4.566	571	571	-	571
15 01 10*	ing containing residues of or contaminated by ha hazardous subs	-	-	134	-	-	-	-	-	-	-	-	-
15 02 02*	aterials, wiping cloths, protective clothing contaminated by haz	20	20	20	20	20	20	20	20	20	20	99	20
16 02 14	Discharge equipmetn	-	-	-	-	-	-	-	-	-	-	-	-
16 03 06	Organic wastes	-	-	-	-	-	-	-	-	-	-	-	1.100
17 04 01	Copper, bronze, brass	-	3.755	-	-	1.252	1.252	1.252	1.252	1.252	-	-	7.510
17 04 05	Iron and steel	12.526	-	11.134	9.743	6.959	6.959	6.959	6.959	6.959	6.959	-	-
20 01 21*	Fluorescent tubes and other mercury-containg waste	1	1	1	1	1	1	1	1	1	1	1	1
20 03 04	Septic tank sludge	-	-	-	-	-	-	-	-	-	-	-	-

Figure 17: *Real part of Quantitative A Matrix of Arcevia Plant*

4.2.7. “B” Matrix

B Matrix is the tool to investigate and find causal-resultant links between the environmental losses.

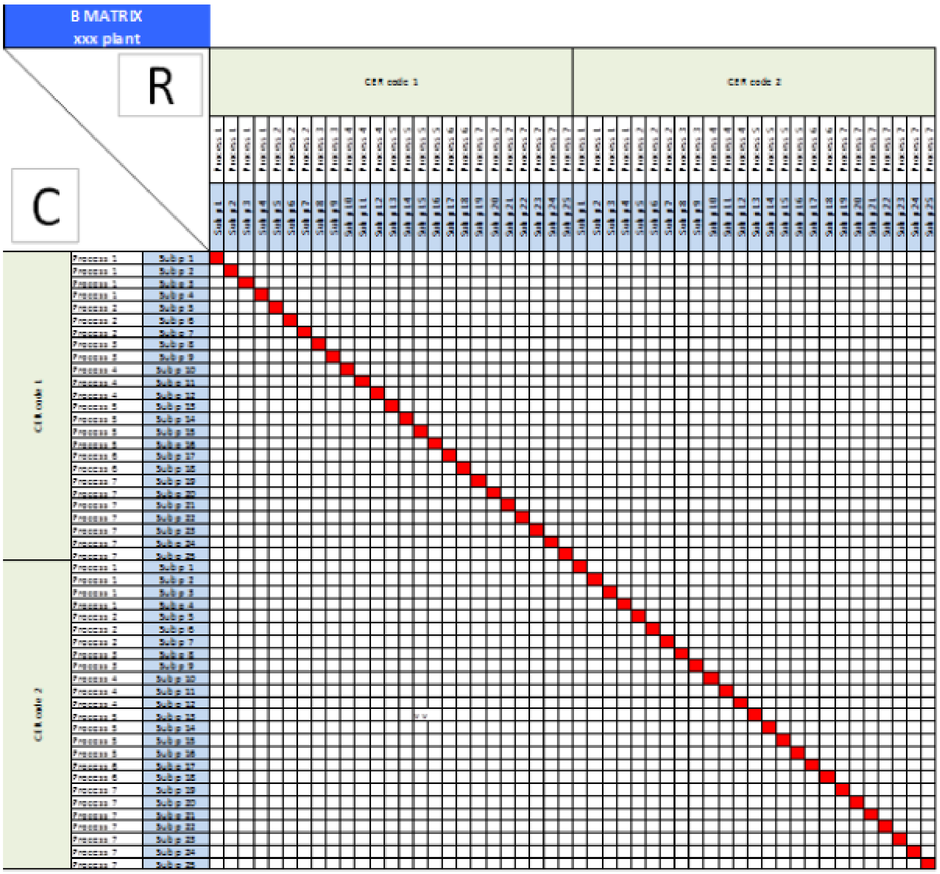


Figure 18: *B Matrix format*

It is a symmetric matrix with rows/columns corresponding to all processes for each environmental loss (waste codes). The assumption is that the environmental losses are all causal and as a result B Matrix is merely a diagonal one.

The reason behind this assumption is that is uncommon to find some wastes which production is due to the production of another waste in the same or in a different process.

4.2.8. “C” Matrix

The Environmental C matrix (Fig. 18) has a structure with the same logic of the manufacturing CD. On the rows has the losses stratified by each process and on the columns all the cost components related to Labor, Materials, Energy and Outsourced Services.

In most of the cases the biggest part in the loss evaluation is played by the disposal cost (**Outsourced Services**) that is the cost paid to the supplier or trucking company to take the waste to their facilities.

With regard to the **Labor** part it is necessary to define the time spent by direct or indirect workers for waste management that is generally speaking the collection and transportation of the wastes/bins/containers inside the plant to the main collecting points. In addition to this it may be also considered the time spent by white collars to manage all the documentation and administrative/legal registrations related to every transportation of wastes outside the plant.

For **Materials** what can be considered as contributing to the loss evaluation are for example:

- Auxiliary Materials: the materials used to collect wastes, like bags, special containers, etc.
- PPE: some special and expensive PPE required to be used for management of special or dangerous wastes (i.e. special breathing mask/filter, special gloves/shoes, etc.), that in worst cases might be also disposable.
- Spare Parts: it may be necessary some planned maintenance on equipment for waste collection, for example on the outdoor press for carton or on the forklifts to move metallic containers.

In **Energy** costs it is possible to consider the energy spent by forklifts for waste movements, or any other energy used for the processing of wastes inside the plant.

Finally, to make all the Pareto and stratifications needed, it is suggested to do a C matrix summary, where on the columns I have the processes and on the rows the wastes. In the crossing you have the total amount of the loss that is the same of labor, materials, energy and outsourced service costs.

C MATRIX ARCEVIA					LABOUR																			
					DIRECT LABOUR					INDIRECT LABOUR										SALARIED PAYROLL				
					24,1					25,7					23,73 (Carico-Scarico) e 31,45 (Qualità)					27,2				
					Direct process					Maintenance					Indirect Labour (Carico-Scarico, Magazzino & Qualità)					Salaried payroll (Caporeparto, impiegato)				
LOSS	support for form	PROCESS	SUB-PROCESS	% prod	KPI - loss [h/year]	cost determinant [€/h]	% manpower loss	nr workers [FTE]	TOTAL [€/year]	KPI - loss [h/year]	cost determinant [€/h]	% manpower loss	nr workers [FTE]	TOTAL [€/year]	KPI - loss [h/year]	cost determinant [€/h]	% manpower loss	nr workers [FTE]	TOTAL [€/year]	KPI - loss [h/year]	cost determinant [€/h]	% manpower loss	nr workers [FTE]	TOTAL [€/year]
06 03 16	2	COMUNI	Forming and cutting steel tube	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	25,37	100%	1	1,5
06 03 16	2	COMUNI	Copper tube cut	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	Spiral formation	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	Solder spiral pins	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	cr 15	15%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	cr 16	15%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	cr 17	15%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	cr 18	15%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	Manual filling	13%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	Filling ST3	13%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	COMUNI	Offline lamination	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6
06 03 16	2	RAME	Transfert 1	0%	0	24,08	100%	0	0	0	25,7	100%	0	0	0	23,73	100%	0	0,00	6,00	27,17	100%	1	1,6

Figure 19: *Real part of C Matrix of Arcevia Plant*

4.2.8 “C” Matrix Graphs

Starting from the C Matrix Summary I can build my final Pareto graphs. The main and most important for a focalized approach is the Pareto of losses (waste codes), where each loss is stratified by process or sub-process. From this analysis it is possible to identify the top losses to be attacked. When starting a specific project, these stratifications inside the identified losses are needed in order to identify the most critical process or sub-process where to start from.

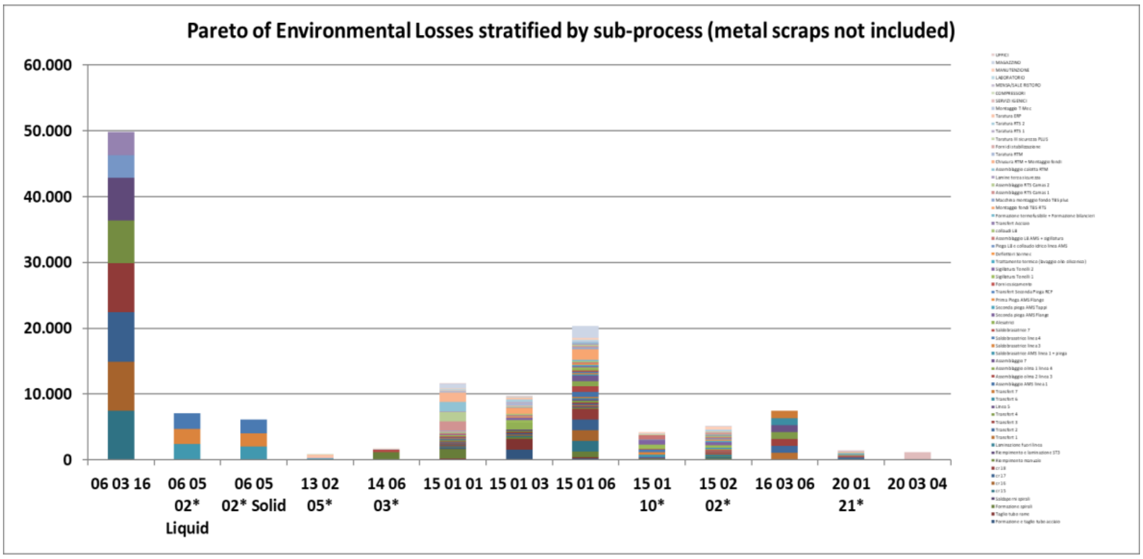


Figure 20: *Real Pareto of Environmental Losses stratified by sub-process*

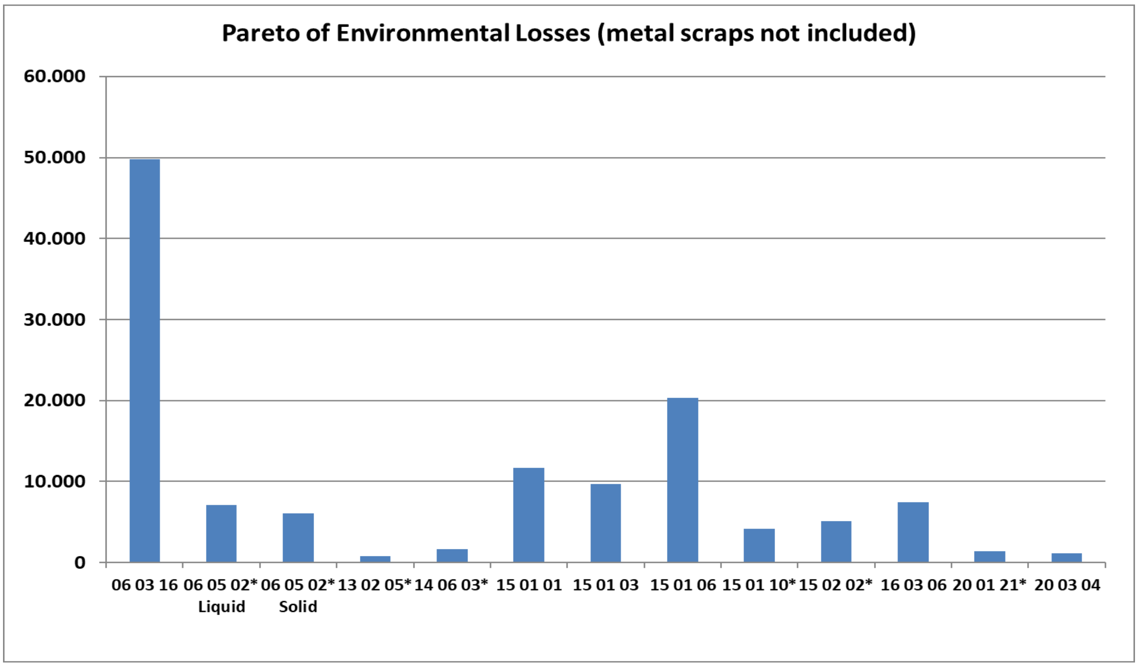


Figure 21: *Real Pareto of Environmental Losses without stratifications*

As we can see here the biggest loss is due to CER 06 03 16, which refers to Magnesium Oxide waste coming from the filling processes of copper and steel heating elements which are the final products of the Thermowatt company. Pure MgO is used to fill the heating elements to guarantee electrical isolation and thermal conduction at the same time. During the filling processes pure MgO, which is a powder, is partly dispersed in the air. This dispersion is avoided by a specific suction system placed close to each single filling process. Once MgO is vacuumed, it becomes a waste (MgO waste) that must be disposed.

Since MgO waste represented the main loss, this specific waste had to be attacked first. Analysing the high cost of this waste it was seen that it came mainly from its landfill disposal cost (1,25 €/kg).

Following the 5R approach (chapter 4.2.4), for how the filling processes are designed, the only way to go is that of recycling the MgO waste. Neither Refuse nor Reduce nor Reuse can be applied.

For this purpose, a specific project was carried out during the year 2020 and it consisted in characterizing of MgO waste itself first, by specific analysis, in order to understand if its possible reuse could be realized or not. Analysis showed that MgO waste was mainly pure MgO without therefore any relevant contaminations from other materials. This result is something reasonable since MgO waste, as I said before, comes actually from the collection of pure magnesium powder dispersed in air and collected by a suction system.

Once the waste was classified, some companies specialized in recycling have been contacted to understand if our characterized waste could really be recycled. After a careful research, a company specializing in the recycling of waste was identified, which name is Trezzi Refrattari,

Trezzi Refrattari deals with the recovery of refractory materials deriving from industrial production processes. Thanks to the grinding, mixing and packaging systems, it carries out the enhancement of the aggregates and their reintegration into the market. These materials can be used to replace basic and aluminous raw material.

Recycled refractories are classified as non-hazardous and can be used for reuse in total or partial replacement of homologous raw materials without using natural resources for the benefit of greater environmental protection.

The company has all the legal authorizations to carry out the recovery, transport and treatment of refractory materials.

For all of these reasons Trezzi Refrattary company has been entrusted with the recycling of our MgO waste. This means that Thermowatt no longer has costs related to landfill disposal, the only costs that Thermowatt will have to bear, from now on, are the cost of transporting MgO waste to the Trezzi Refrattari headquartes and the Labor costs.

The **economic saving** that will be obtained annually is equal to **48.274,99 €** (Table 24).

This cost saving comes from comparing the costs incurred in 2019 without the implemented project to the same year 2019 with the implemented project. This to have a reliable evaluation since the quantity of the waste is always the same.

	CER 06 03 16
YEAR 2019 PRE-PROJECT	€ 49.800,20
YEAR 2019 POST-PROJECT	€ 1.525,21

Table 24: *Economic saving*

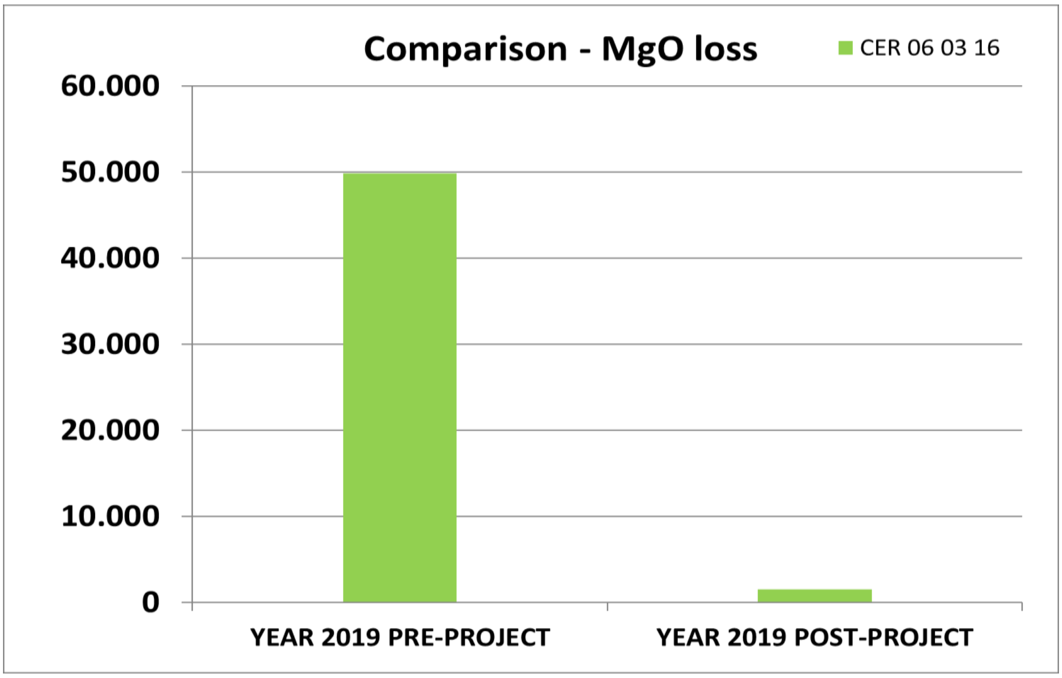
49800,20 € takes into account the Labor, Materials, Energy and Outsourced Services (disposal and transportation) costs.
1525,21 € takes into account the Labor, Materials, Energy and Outsourced Services (only transportation) costs.

It means to have a **cost reduction of 97%** with respect to year 2019 pre-project.

	% COST REDUCTION	COST SAVING
YEAR 2019 POST-PROJECT	97%	€ 48.274,99

Table 25: *Economic saving*

The graph below still shows this economic saving result.



Graph 1: *Comparison*

4.3. FINAL RESULTS RECAP

From VAIA analysis it emerges that Waste Generation is a significant impact for Arcevia plant (Fig. 11). As already explained in 4.1.8., a project to eliminate the disposal cost of MgO was developed with clear economic benefits (Table 25).

Economic benefits are not the only benefits obtained through this project as changing the final destination of MgO waste from landfill disposal to recycling the significance of Waste Generation impact passes from AA to A thanks to the lower Sn value obtained (Table 26).

Waste Generation Significance	Sa	Ira	Is	L	Cpi	E	R	I	Sn 0,30*Is + 0,40*L + 0,10*Cpi + 0,20*I	
YEAR 2019 PRE-PROJECT	2	2	2	3	1	1	2	1	2,1	AA
YEAR 2019 POST-PROJECT	1	2	1	3	1	1	2	1	1,8	A

***Table 26**: Comparison*

The significance reduction comes from the reduction of Is index since Sa index decreases too. Sa index depends on the percentage of total waste sent from the Arcevia Plant to landfill disposal operations (Table 8). As the final destination of MgO waste has changed (it is now recycled and no longer sent to landfill), this percentage decreases passing from 10% to 4% (Table 27).

	Year 2019 PRE-PROJECT	Year 2019 POST-PROJECT
Tot waste sent to landfil disposal [kg]	65000	26380
Tot waste produced in the plant [kg]	630162	630162
% waste sent to landfill disposal	10%	4%
% recycled waste	90%	96%

***Table 27:** % waste sent to landfill disposal comparison*

Therefore, by removing the disposal cost of magnesium oxide, it was possible to obtain economic benefits and at the same time reduce the environmental impact of the Arcevia Plant. All this was possible thanks to the 5R approach (chapter 4.1.4.) and by highlighting the importance of the circular economy.

I recall that the project was implemented in 2020 but to understand its real advantage I took the same year 2019 once considering the implemented project and the other without the implemented one. In this way I could obtain a good comparison since based on the same data.

CONCLUSION

Having reached the conclusion of this thesis work, I can draw the final outcomes regarding the issues addressed in the individual chapters.

First of all, it emerges that ISO 14001, although it appears to be a voluntary certification for companies, is fundamental for setting and achieving environmental and economic objectives through a well-structured and effective Environmental Management System. VAIA analysis is an essential support procedure for the companies aimed at identifying, describing and assessing the environmental impacts of their activities.

We have seen, through the VAIA analysis, which were the most significant environmental impacts of Thermowatt Arcevia Plant. Since Waste Generation impact resulted one of the most significant impact for the plant, it was attacked first by a specific project to eliminate landfill disposal operations of magnesium oxide waste. The project led to an important reduction of **Waste Generation impact** which passed from “AA” significance to **“A”** one.

Secondly, we have seen how WCM system integrates well with environmental sustainability of the plant by locating the greatest environmental losses and also quantifying them economically. In fact, the exact cost related to the magnesium oxide waste has been well-identified and this has allowed me to quantify the economic benefit got by the MgO project. Arcevia Plant is now **saving 48.274,99€ annually**.

All of this gets along with the **Circular Economy thinking**, magnesium oxide has acquired value as new material by its recycle.

Embracing a sustainable approach is now necessary. All companies, not just the largest ones, should embark on a path for their own sustainable development. As we have seen, even simple targeted projects can go in that direction.

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