UNIVERSITY OF PIRAEUS

DEPARTMENT OF INDUSTRIAL MANAGEMENT AND TECHNOLOGY

MSC IN INDUSTRIAL MANAGEMENT AND TECHNOLOGY

SPECIALIZATION

LOGISTICS MANAGEMENT

Reducing waste in warehouse operations through EWM system optimization: A case study of SAP-enabled solutions

IOANNIDIS MINAS

TML 2207

Supervisor: Prof. Dimitrios Emiris

Piraeus, July 2024

ΔΗΛΩΣΗ

«Η εργασία αυτή είναι πρωτότυπη και εκπονήθηκε αποκλειστικά και μόνο για την απόκτηση του συγκεκριμένου μεταπτυχιακού τίτλου».

«Τα πνευματικά δικαιώματα χρήσης του μη πρωτότυπου υλικού ΜΔΕ ανήκουν στον μεταπτυχιακό φοιτητή και στο επιβλέπον μέλος ΔΕΠ εις ολόκληρο, δηλαδή εκάτερος μπορεί να κάνει χρήση αυτών χωρίς τη συναίνεση άλλου. Τα πνευματικά δικαιώματα χρησιμοποίησης του πρωτότυπου μέρους ΜΔΕ ανήκουν στον μεταπτυχιακό φοιτητή και στον επιβλέποντα από κοινού, δηλαδή δεν μπορεί ο ένας από τους δύο να κάνει χρήση αυτού χωρίς τη συναίνεση του άλλου. Κατ' εξαίρεση, επιτρέπεται η δημοσίευση του πρωτότυπου μέρους της διπλωματικής εργασίας σε επιστημονικό περιοδικό ή πρακτικά συνεδρίου από τον ένα εκ των δύο, με την προϋπόθεση ότι αναφέρονται τα ονόματα και των δύο (ή των τριών σε περίπτωση συνεπιβλέποντα ως συν-συγγραφέων. Στην περίπτωση αυτή προηγείται γραπτή ενημέρωση του μη συμμετέχοντα στη συγγραφή του επιστημονικού άρθρου. Δεν επιτρέπεται η κατά οποιοδήποτε τρόπο δημοσιοποίηση υλικού το οποίο έχει δηλωθεί εγγράφως ως απόρρητο».

Ο Φοιτητής — *Οι Επιβλέποντες*

Μηνάς Ιωαννίδης — *Δημήτριος Εμίρης*

Στέλιος Σαράντης

Abstract

In today's era of rising environmental concerns and increasing focus on sustainability, organizations across industries are striving to reduce waste and improve efficiency in their operations. This study explores the potential benefits of implementing SAP Extended Warehouse Management (EWM) software to streamline and optimize warehouse processes, thereby resulting in waste reduction. By leveraging SAP EWM's advanced features, such as inventory management, order fulfillment optimization, and real-time visibility, organizations can effectively eliminate unnecessary inventory holding costs, minimize stockouts, and improve overall warehouse productivity. This abstract discusses the key functionalities of SAP EWM that can be utilized to identify and address various waste types, including excess inventory, obsolete stock, material handling inefficiencies, and operational bottlenecks. More specifically, this study investigates how SAP EWM, a comprehensive warehouse management solution, can assist in streamlining processes and monitoring inventory levels to minimize wastage of machine oil in warehouses. The significance of integrated technology systems in achieving waste reduction goals, emphasizing the potential benefits of using SAP EWM in warehouse operations, is also highlighted in this research. By embracing SAP EWM as a powerful tool for waste reduction, organizations can significantly enhance warehouse operations, reduce ecological footprints, and contribute to a sustainable future. Finally, this study examines an organization responsible for electricity distribution to reveal the structure and efficiency of systems within this domain, with a particular emphasis on electronic waste management. Furthermore, it explores the implementation of SAP Extended Warehouse Management (EWM) to improve the spatial and quantitative management of waste. The research seeks to understand the interaction of these systems and their contribution to a more effective waste management strategy, thereby optimizing processes in both electricity distribution and electronic waste handling.

Key phrases:

1. Rising Environmental Concerns and Increasing Focus on Sustainability
2. Implementing SAP Extended Warehouse Management (EWM) Software
3. Reducing Waste and Improving Operational Efficiency
4. Inventory Management, Order Fulfillment Optimization, and Real-Time Visibility
5. Achieving Waste Reduction Goals and Contributing to a Sustainable Future

Στη σημερινή εποχή των αυξανόμενων περιβαλλοντικών ανησυχιών και της αυξανόμενης εστίασης στη βιωσιμότητα, οι οργανισμοί σε όλους τους κλάδους προσπαθούν να μειώσουν τα απόβλητα και να βελτιώσουν την αποδοτικότητα των λειτουργιών τους. Η παρούσα μελέτη διερευνά τα πιθανά οφέλη από την εφαρμογή του λογισμικού SAP Extended Warehouse Management (EWM) για τον εξορθολογισμό και τη βελτιστοποίηση των διαδικασιών αποθήκευσης, ως αποτέλεσμα τη μείωση των αποβλήτων. Αξιοποιώντας τις προηγμένες λειτουργίες του SAP EWM, όπως η διαχείριση αποθεμάτων, η βελτιστοποίηση της εκτέλεσης παραγγελιών και η ορατότητα σε πραγματικό χρόνο, οι οργανισμοί μπορούν να εξαλείψουν αποτελεσματικά το περιττό κόστος διατήρησης αποθεμάτων, να ελαχιστοποιήσουν τα αποθέματα και να βελτιώσουν τη συνολική παραγωγικότητα της αποθήκης. Η παρούσα έρευνα εξετάζει τις βασικές λειτουργίες του SAP EWM που μπορούν να αξιοποιηθούν για τον εντοπισμό και την αντιμετώπιση διαφόρων τύπων αποβλήτων, συμπεριλαμβανομένων των υπερβολικών αποθεμάτων, των απαρχαιωμένων αποθεμάτων, της αναποτελεσματικότητας του χειρισμού υλικών και των λειτουργικών συμφορήσεων. Πιο συγκεκριμένα, η παρούσα μελέτη διερευνά τον τρόπο με τον οποίο το SAP EWM, μια ολοκληρωμένη λύση διαχείρισης αποθηκών, μπορεί να βοηθήσει στον εξορθολογισμό των διαδικασιών και στην παρακολούθηση των επιπέδων αποθεμάτων για την ελαχιστοποίηση της σπατάλης του μηχανέλαιου στις αποθήκες. Η σημασία των ολοκληρωμένων τεχνολογικών συστημάτων για την επίτευξη των στόχων μείωσης της σπατάλης, τονίζοντας τα πιθανά οφέλη από τη χρήση του SAP EWM στις εργασίες αποθήκης, τονίζεται επίσης σε αυτή την έρευνα. Αγκαλιάζοντας το SAP EWM ως ένα ισχυρό εργαλείο για τη μείωση των αποβλήτων, οι οργανισμοί μπορούν να βελτιώσουν σημαντικά τις λειτουργίες των αποθηκών, να μειώσουν το οικολογικό αποτύπωμα και να συμβάλουν σε ένα βιώσιμο μέλλον. Τέλος, στην παρούσα μελέτη εξετάζεται ένας οργανισμός που είναι υπεύθυνος για τη διανομή ηλεκτρικής ενέργειας με ιδιαίτερη έμφαση στη διαχείριση των ηλεκτρονικών αποβλήτων. Επιπλέον, διερευνά την εφαρμογή του SAP EWM για τη βελτίωση της χωρικής και ποσοτικής διαχείρισης των αποβλήτων. Η έρευνα επιδιώκει να κατανοήσει την αλληλεπίδραση αυτών των συστημάτων και τη συμβολή τους σε μια αποτελεσματικότερη στρατηγική διαχείρισης αποβλήτων, βελτιστοποιώντας έτσι τις διαδικασίες τόσο στη διανομή ηλεκτρικής ενέργειας όσο και στη διαχείριση ηλεκτρονικών αποβλήτων.

Φράσεις-κλειδιά:

1. Αύξηση των περιβαλλοντικών ανησυχιών και αυξανόμενη εστίαση στη βιωσιμότητα
2. Εφαρμογή του λογισμικού SAP Extended Warehouse Management (EWM)
3. Μείωση των αποβλήτων και βελτίωση της επιχειρησιακής αποδοτικότητας
4. Διαχείριση αποθεμάτων, βελτιστοποίηση εκτέλεσης παραγγελιών και ορατότητα σε πραγματικό χρόνο
5. Επίτευξη των στόχων μείωσης των αποβλήτων και συμβολή σε ένα βιώσιμο μέλλον

Acknowledgements

I wish to extend my heartfelt appreciation to the following individuals for their invaluable contributions to this research:

- Mr. Stelios Sarantis, for his guidance throughout the research and for generously sharing his exceptional expertise and knowledge in this field of study
- Prof. Dimitrios Emiris, for his unwavering support and invaluable insights that significantly enriched this study

Contents

List of Figures

List of Tables

Table of abbreviations

ADR	Appropriate Dangerous Goods Road Transport
EWR	Electronic Waste Registry
LoW	List of Waste
IT	Information Technology
EWM	Extended Warehouse Management
PTO	Power Transmission Operator
EWMS	Electronic Waste Management System
EMPA	Basel Convention and the Swiss Federal Laboratories for Materials Science and Technology
SaaS	Software-as-a-Service
ISCC	International Sustainability & Carbon Certification
ESG	Environmental, Social and Governance
EU	European Union
WIF	Waste Identification Form
HWIF	Hazardous Waste Identification Form
F-GASES	Fluorinated Greenhouse Gases
GHG	Greenhouse Gas
ODS	Ozone-Depleting Substances
KPI	Key Performance Indicator
WEEE	Waste Electronic and Electrical Equipment
CSV	Comma-Separated Values
PoCs	Proof-of-Concepts
ETS	Emissions Trading System
IED	Industrial Emissions Directive

1 Introduction

Environmental protection has come to the world's attention in recent years, and scientists have been emphasizing the need to limit planetary warming. As a result, world leaders from 40 countries participated in the "Leaders Summit on Climate" on April 22 and 23, 2021. The summit was hosted by the President of the United States and held at the White House. The Summit has highlighted how these climate ambitions would create jobs with good incomes, accelerate technological innovation, and help countries in need to adopt the effects of climate change [The White House, 2021]. This eco-friendly mindset to nurture the source of the earth has reached peak momentum so that the organizations feel pressured to start thinking critically in building environmentally friendly business practices. Green supply chain practices [GSCP] are believed to have a potential contribution throughout the entire supply chain process, from suppliers, manufacturers, customers, and until the disposal of the product [Yu, Chavez, Feng & Wiengarten, 2014]. According to a recent study, companies need to compete through the implementation of information technology to contribute to the efficiency of the company [Acar, Zaim, Isik & Calisir, 2017].

Warehouse operations are central entities in competitive supply chains for handling and storing materials [Pereira et al., 2020]. They also are essential structures to enable a smooth product flow in supply chains [Sudding, 2021; De Koster et al., 2017]. Previous research has established three main types of warehouses: distribution, production, and contract warehouses [Berg et al., 1999]. While distribution warehouses focus mainly on storing and shipping deliverables from supplier to customer, production warehouses are spaces for different types of products (e.g., raw materials or finished goods). Finally, contracted warehouses perform warehouse activities for a number of customers. More precisely, in this study the phenomenon of interest is the identification and elimination of operational waste occurring in the warehouses. Most warehouses have similar distinct activities, including offloading and sorting of goods, put-away activities, picking, and packaging [Salhieh et al., 2018]. However, despite the importance of warehouses, many do not operate and perform to their potential because they engage in several non-value-adding activities [Pereira et al., 2020]. In this case, non-value-adding activities contribute neither to warehouse performance nor customer satisfaction, resulting in different types of operational waste [Prasetyawan et al., 2020; Panwar et al., 2017]. Consequently, identifying and reducing operational waste in warehouses has become a key challenge in increasing the performance of warehouse operations and supply chains [Dotoli et al.,

2015; Ben Moussa et al., 2019]. Additionally, it is noticed that an underexplored route in the supply chain literature refers to empirically grounded research examining warehouse wastes, including their performance and operations [Tahboub & Salhieh, 2019; Salhieh et al., 2018; Baby et al., 2018; De Koster et al., 2017].

Enterprise Resource Planning (ERP) is one of the information technologies which has a significant influence in enhancing the company's performance [Tarigan, Siagian & Jie, 2021]. Nowadays, electricity production companies face constant pressure to enhance their operations by delivering reliable and high-quality energy at the lowest possible cost and with maximum efficiency.

One of the solutions to this problem is performing supply chains activities using information technology [Salam, 2017]. Then the company seeks to implement business practices while reducing the risk of environmental damage through the company's products, services, and operations in general [Zhang, Zhao Q. & Zhao X., 2019]. As a matter of fact, the company's operational performance can be improved by adopting ERP technology, practicing green purchasing, green production, green plant maintenance and more efficient waste management.

Taking all the above into consideration, the main objective of the study is to reduce industrial waste in warehouse operations through an SAP ERP system optimization. More specifically, this study aims to investigate the benefits and challenges of using SAP's Extended Warehouse Management (EWM) and SAP's Waste Management systems as tools for improving waste management practices in warehouse operations.

In the second chapter, we explore the versatile role a Power Transmission Operator (PTO) in the environmental responsibility, emphasizing their impact on the ecosystem. We dive into current practices and challenges in capturing PTO's waste management information, highlighting the critical necessity for more accurate data in order to enhance sustainability outreach efforts. This chapter is also examining the integration of Enterprise Resource Planning (ERP) systems to both streamline operations and improve the efficiency. Finally, we focus on the key features of SAP Extended Warehouse Management and SAP Waste Management modules, displaying the course these tools are able to optimize waste collection and disposal techniques and contribute to more effective environmental management.

In chapter 3, we are emphasizing in the critical role of sustainability in the framework of synchronous business practices in reforming strategies and fostering economic growth. We explore the significance of ERP systems in promoting sustainable business growth, illustrating the way these systems facilitate initiative-taking decision-making, focusing on waste management. Furthermore, this chapter provides a detailed reference of the European List of Wastes, addressing its classification, implementation and the main challenges associated with the sustainable waste management practices. Overall, the chapter highlights the fundamental interface between sustainability, technology, and regulatory frameworks in the modern business activities.

In chapter 4, we focused on the environmental impacts of electricity production and distribution, emphasizing on pollution caused form air emissions, water contamination and contributions to climate change and global warming. Additionally, we examined how ERP systems can promote sustainable growth and ensure compliance within the electricity distribution sector. Moreover, we embodied the legal requirements for pollutants and dangerous goods, emphasizing in the regulations applicable to EU and the local industries, while chronicling results from recent sustainability reports from electricity distribution companies and promoting significant measurements implemented in order to integrate environmental and waste management operational techniques. Finally, we addressed the detection of waste managed by a warehouse of electricity transportation companies, highlighting the importance of effective waste monitoring and disposal strategies.

In fifth chapter, we developed workflows for waste management in warehouse operations through SAP S/4HANA & SAP EWM. These workflows were enriched with anticipated waste management scenarios for warehouses related to electricity distribution companies. More specifically, there are steps combining the collection of waste material related to electricity distribution activities and the relocation of them by following optimal warehouse practices. In addition, there are scenarios regarding the review and engagement of potential external organizations responsible for the execution of waste management operations (i.e. safe disposal/scrapping/reuse), deemed unfeasible for completion internally. Finally, the definition of accurate documentation of both theoretical and actual waste, leading to comprehensive reports, illustrated in an extensive workflow.

Overall, we have examined how both SAP Waste Management and SAP Extended Warehouse Management modules are able to help organizations manage waste more efficiently and reduce their environmental footprint while optimizing their warehouse

operations. This examination was implemented through the development and customization of specific transactions on the SAP S/4HANA (waste management) and SAP EWM (warehouse management) platforms.

2 Literature Review

2.1 Environmental Impact of a Power Transmission Operator

Power Transmission Operators (PTO) and the environment are seemingly unlikely partners. This is so because all of the high-voltage power transmission lines which emit electromagnetic fields (EMFs), the construction and maintenance of power transmission lines that may require the clearing of land and can disrupt local ecosystems and habitats, and the risk posed to climate change. Pollution is not only caused by these lines but also by substations and the essential cooling and maintenance of autotransformers, which involve significant quantities of lubricants. Environmental issues associated with these Operators include energy consumption, water consumption, wastewater, solid waste and by-products, and emissions to air.

Power Transmission Operators rely on energy to operate and maintain their electrical transmission systems. This energy consumption encompasses the functioning of control centers, equipment, and infrastructure. Additionally, in certain instances, power transmission infrastructure may necessitate water for cooling and other operational purposes. The issue of water consumption is particularly pertinent in regions facing water scarcity challenges. Furthermore, in most cases, transformers are cooled using air conditioners that utilize SF6 gases, which are classified as greenhouse gases.

Furthermore, the maintenance and construction of transmission lines can generate solid waste, including materials removed during right-of-way clearing. The responsible management and disposal of these waste materials are areas of concern for operators. It is well-recognized that emissions to the atmosphere can emanate from diverse sources, encompassing vehicles and equipment employed in maintenance and construction activities. Emissions can also arise from the operation of backup generators at substations, particularly during power outages.

These considerations underscore the importance of environmentally responsible practices and technologies within the power transmission sector, as well as adherence to regulatory guidelines and environmental standards to minimize their ecological footprint.

It is encouraging to note that numerous operators are progressively adopting environmentally responsible practices and technologies to diminish their environmental impact. These practices are often guided and enforced by regulatory authorities and

environmental standards to safeguard both the environment and public health [Bamidele Fakoya, Margaretha van der Poll, 2013].

2.2 Current Status of Capturing PTO Waste Management Information

The increasing focus on eco-friendly and sustainable operational processes has significantly escalated their importance for every business, but even more so for Power Transmission Operators worldwide. This is essential for accurately reflecting and accounting for waste management costs, allowing them to efficiently determine these expenditures and assess their effect on overall profits and environmental impact.

As global power transmission operators increasingly prioritize environmental sustainability, it is becoming a common trend for companies worldwide to address their environmental footprint. This shift towards eco-conscious practices is exemplified by the Greek Power Transmission Operator, which has also recognized the importance of mitigating its environmental impact. Amidst growing concerns about climate change and the detrimental effects of traditional energy production methods, such as greenhouse gas emissions and resource depletion, it is imperative for operators like the Greek company to proactively embrace sustainable initiatives. The Greek PTO has initiated a project focused on organizing the management systems and procedures for all waste produced as a result of their operations. More specifically, the operator has been diligently executing all necessary actions to establish and activate an Electronic Waste Recording, Evaluation, and Recycling System. Simultaneously, they are ensuring compliance with legislation and updating the required data in the Electronic Waste Registry (EWR). This proactive approach underscores their commitment to responsible waste management practices and aligns with broader efforts to meet environmental regulations and standards. The aim is to streamline the management procedures for waste generated by the company's operations. By implementing measures to reduce emissions, minimize waste, and promote renewable energy sources, these operators not only contribute to global environmental efforts but also position themselves as leaders in the transition towards a greener energy future.

The PTO responsible of the Greek market is developing an all-encompassing plan to better manage the waste produced through various activities. This plan centers on the implementation of a comprehensive initiative, which underscores the company's commitment to adhering to environmental legislation and standards. It also demonstrates their

broader dedication to responsible waste management practices. This innovative, environmentally conscious move involves a number of well-defined steps, with the ultimate goal of significantly reducing the company's environmental footprint. These steps range from updating census data to creating new sustainability targets.

The following is a comprehensive examination of the nine critical stages in the implementation process:

1. The first step involves a meticulous update of the data and results obtained from the previous year's census. These data were obtained from previous studies on the condition of the waste. From these studies, three primary categories of risk were identified: environmental, financial, and reputational. Environmental risks pertain to incidents such as oil spills, accumulator fluid leaks, asbestos contamination, fires/arson, and the presence of materials containing PCBs and PCTs. Financial risks generally involve legal actions or requests for injunctive relief against the organization, as well as fines, penalties, and theft. Reputational risks are related to deficiencies in waste management, which can damage the organization's image and reputation, heighten local community opposition to network expansion, and undermine the strategy for sustainable development. This critical stage helps set benchmarks for the subsequent strategies and identifies required improvements.
2. Defining the company's Environmental Policy with an emphasis on waste management is the second phase. This stage showcases the company's dedication towards minimizing both direct and indirect effects on the environment resulting from its operations.
3. Next is the creation of dynamic systems and quantifiable goals that focus on recording, monitoring, and efficiently managing all waste streams. This process also includes the establishment of control indicators for separate waste categories to streamline management and monitoring efforts.
4. The fourth step is the detailed preparation of operational and technical specifications required for the electronic waste management system. This platform will buttress the management system and has been designed to comply with the company's interoperability and cybersecurity requirements.

5. Next, we focus on human resources by organizing specialized training for personnel involved in waste registration and management. This training equips them with a thorough understanding of the company's environmental policy, in particular waste management issues, and enables proficient utilization of the waste management information system.
6. The sixth step is the pilot implementation of the designed information system. This involves specific company personnel carrying out operations and data entry checks for each waste category, followed by comprehensive system tests, checks, and adjustments essential for the complete rollout of this system.
7. Subsequently, the system garners results that reflect the company's environmental performance in terms of waste management. These results are derived using the defined control indicators, ensuring their credibility and accuracy.
8. This stage focuses on closely monitoring the management results of all waste quantities within pre-defined priority categories. This process involves the gradual expansion of data (results), aligning with the progress of environmental permit completion for various points or installations. This stage also encompasses data compilation required for the completion of the Electronic Waste Register and the National Waste Register of Producers.
9. Finally, the culmination of this extensive process involves identifying new, ambitious targets committed to further reducing the company's environmental footprint. This reflects the company's ongoing dedication to sustainability and responsible operational practices.

The following flowchart outlines the sequential steps involved in implementing the comprehensive waste management initiative.

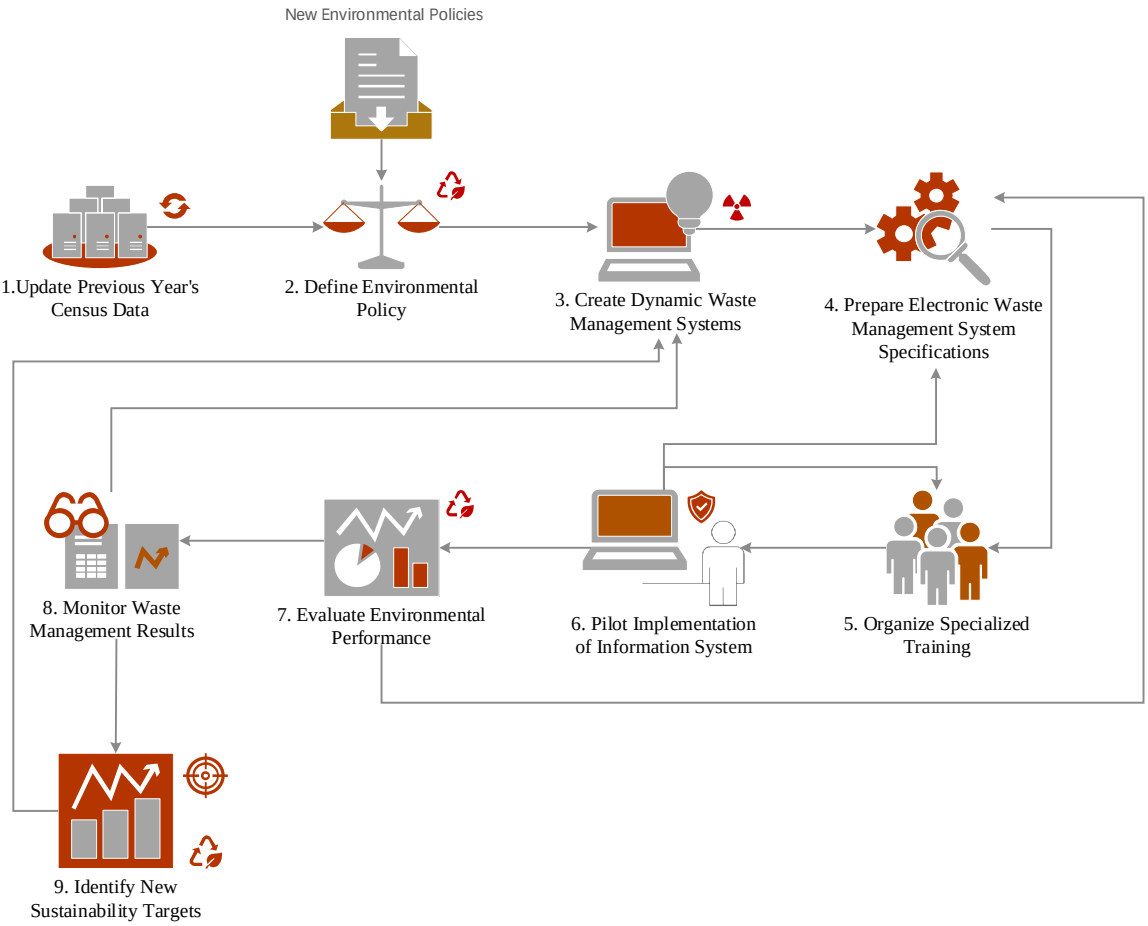

Figure 1. 1 The nine critical stages in the implementation process

The principal goal of the system, currently in the implementation stage, is to ensure the company's adherence with both national and European legislative mandates concerning appropriate waste management. This is to be attained through diligent recording, monitoring, and evaluation of all determined waste flows, assuring their safe, lawful management, regardless of their ultimate disposal resolution, whether that can be reuse, recycling, recovery, or energy recovery.

From a broader perspective, the system aims to create the necessary technical and administrative conditions to contribute to the company's alignment with contemporary environmental management requisites. Given the imperative to quantify, record, and incrementally attenuate its carbon footprint, and to potentially execute strategies for enhancing energy efficiency, this alignment is particularly crucial considering the nature of its activities.

In conclusion, the system under development positions itself as an instrumental tool in the ubiquitous move towards adherence to Environmental, Social, and Governance (ESG) norms. As a precursor to meeting the mandates of ESG compliance, it constitutes an invaluable resource in the constant pursuit of sustainable operational practices.

Incorporating these efforts with an Enterprise Resource Planning (ERP) system propels the initiative to a whole new level of efficacy. By facilitating a centralized data management approach, an ERP system smoothens the execution of operational and waste management procedures. Consequently, the synergy of the Electronic Waste Recording, Evaluation, and Recycling system and an ERP setup, offers an advanced, contemporary approach to achieving sustainable operational practices. The enabling features of the ERP system enhance the functionality of the waste management system, allow for seamless data integration, and robustly support the accomplishment of the predefined sustainability goals.

2.3 ERP System Integration

The integration of an ERP system into waste-reduction decisions will provide a transparent view of resource flow within an organisation and access to good information to reveal where waste are created [Samaranayakea, Laosirihongthongb, Chanc, 2011]. A waste management system can be integrated with an ERP system through two distinct methods. The first method involves incorporating an additional module directly into the ERP system, thereby enhancing its functionality and providing seamless integration. The second method entails implementing a completely independent waste management system that interfaces with the ERP system through various communication protocols and interfaces. Both approaches aim to streamline operations, improve data accuracy, and enhance overall efficiency in waste management practices.

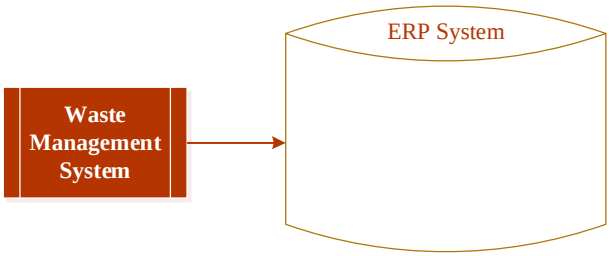

Figure 2. 1 Decentralized Waste Management System

Figure 2. 2 Waste Management System embedded in the ERP

Leveraging a decentralized Waste Management System, fosters a collaborative environment where individual units can tailor their waste management processes to address specific operational needs. This localized approach is facilitated by secure access to critical data housed within a central master database. Through various interfaces, the decentralized system seamlessly interacts with the central repository, ensuring consistent updates for all relevant data points, including waste generation metrics, disposal records, and resource utilization. This shared data foundation empowers comprehensive analysis at both the central and unit levels, enabling informed decision-making across the entire waste management ecosystem.

An ERP system is an integrated suite where individual operating systems, such as the Waste Management system, fit together to serve the particular needs of all units within the organisation [Chen, 2009; Yen & Idrus, 2011]. ERP driven software generates information engineered to work together through a database designed to provide clear and accurate information on raw material input and other resource usage through the system including all transactions data from maintenance and initial installation activities [Samaranayakea, 2009]. Establishing a database system is of paramount importance for making informed decisions. The ERP system's robust data foundation enables administrators to access both historical and current data [Lynch & Zhu, 2011]. This, as a result, proves advantageous in recognizing trends related to process waste and facilitating the prediction of future outcomes. Present systems for waste-reduction decisions in the Power Transmission Operator (PTO) tend to separate economic, social and environmental factors at the planning and management levels. An embedded Waste Management system is a decision-making system that influences actions aimed at reducing waste, thereby impacting efficiency and sustainable development. Hence, a fundamental adaptation or restructuring

of decision-making processes to address organization-specific circumstances is imperative.

2.4 SAP Extended Warehouse Management and SAP Waste Management: Key Features

Reducing waste in a warehouse can be facilitated with the assistance of SAP Extended Warehouse Management (EWM) and its Waste Management process approach . SAP EWM offers a range of features that support waste reduction efforts. For an organization dedicated to electrical power transmission, the responsibility for managing the generation, storage, transportation and disposing of materials deemed to be waste relevant. More information about the key features of this waste management process are provided in the following table [SAP, 2023].

Table 2. 1 SAP Waste Management processes

Process	Use	Prerequisites
Transporters & Disposers	In order to comply with environmental regulations, the organization is responsible for creating and editing business partners as designated transporters and disposers and linking them to specific waste materials.	When creating new transporters and disposers, business partners will only be visible if they have been assigned to a business partner role corresponding to the relevant waste partner type. The waste partner types, such as “Transporter” (01) and “Disposer” (02), are predefined in the system. SAP provides standard business partner roles for transporters (WTRA01) and disposers (WDSP01), which come pre-configured with the necessary mappings. These roles can be assigned to business partners in their master data. It is also necessary, the locations to be defined as waste generators in the “Manage Locations” under the “Environmental Details” tab.
Waste streams	In order to establish waste streams and define the relationship between a waste product and its production and storage locations, the organization needs to follow the be-low steps: 1. Select a product when creating a waste stream. The waste generator field is automatically populated based on the assignment of waste material to a location previously defined as a waste generator in the "My Transports and Disposers - Waste Management" app. 2. Choose from waste storage locations and points of waste generation within the hierarchy of the waste generator. When creating a waste stream with an "Outbound - With Storage Location (OBWS)" type, an internal transfer request is required to move the filled container to a storage location. For a waste stream with an "Outbound - No Storage Location (OBNS)" type, an external transfer request to a disposal facility is initiated, triggering the creation of transport documents.	In order to access and manage waste streams in the “My Waste Streams - Waste Management” app, the following requirements must be taken into consideration: 1. Waste material to the location should be assigned (classified as a waste generator) in the “My Transporters and Disposers - Waste Management” app. 2. Locations (classified as waste generators) and points of generation should be defined using the “Manage Locations” app.

	Storage periods in the app are automatically set with corresponding warnings based on the Customizing activity for waste storage periods. Container data and regulatory information are determined from the validity area of the waste generator. 3. Regulatory codes may be required in some countries/regions for the creation of waste transport documents.	
Waste disposal channels	Creation of a disposal channel to facilitate the ongoing transport and subsequent disposal of waste material.	A new disposal channel could be created by linking it to an active waste stream, which may already be predefined in the “My Waste Streams” app. Additionally, permits can be added to the disposal channel based on the country/region requirements, as defined in the “My Permits” app. In order for the setup to be completed, the packaged product must be ensured that is defined in the “Manage Material Data - Environment Management” app, and the waste generator location be classified in the “Manage Locations” app.
Waste Transfer Request	The disposal process, including waste product documentation, involves recording de-tails such as the waste stream, disposal channel, date of transfer request, and quantity of waste produced (including the unit of measure). Logistics management covers movement from the point of generation to a central or local collection point, followed by transportation to the disposal facility by a designated transporter. If no storage lo-cation is specified, direct transport occurs from the point of generation to the disposal facility	A waste transfer request can be created to a location classified as a waste generator. Waste transfer requests are exclusively available for waste products that have been assigned to waste streams in the “My Waste Streams - Waste Management” app. Additionally, the following prerequisites must be met: 1. The packaged product should be defined in the “Manage Material Data - Environment Management” app. 2. Locations need to be classified as waste storage locations and points of waste generation using the “Manage Locations” app. 3. Activate the waste stream in the “My Waste Streams” app. 4. Disposal channel must be defined in the “Manage Disposal Channel” app. 5. Waste business partners’ information must be provided in the “My Transporters and Disposers” app.

Waste Transportation Documents	To dispose of generated waste, each step in the waste disposal chain needs to be documented in a legally compliant waste transportation document.	In order a new waste transportation document to be created, an active waste stream with a corresponding active disposal channel needs to be predefined in the app “My Waste Streams - Waste Management”. Moreover, the following steps are the requirements in order this process to be successfully completed: 1. Packaged product and waste codes should be defined and entered in respectively, if necessary, in the app “Manage Material Data”. 2. Waste stream and disposal channel should be defined and activated in the app “My Waste Streams - Waste Management”. 3. A disposal channel should be defined and activated in the app “Manage Disposal Channels”. 4. The location must be defined and classified as a waste generator, in the app “Manage Locations” . 5. Waste business partners information must be defined in the app “My Trans-porters and Disposers - Waste Management”.

For an organization dedicated to electrical power transmission, the implementation of SAP EWM yields tailored benefits essential for its operational excellence. Initially, SAP EWM provides robust support for the storage of hazardous materials, ensuring strict adherence to safety regulations and mitigating the potential for accidents or environmental incidents. Through precise tracking and monitoring capabilities, SAP EWM enhances safety protocols, effectively managing these critical assets to sustain operational continuity and prevent disruptions.

Furthermore, SAP EWM optimizes the management of maintenance items, subproducts, and waste generation—integral facets of power transmission operations. By streamlining inventory processes, the system ensures the availability of essential maintenance items, minimizing downtime and bolstering equipment reliability. Additionally, it facilitates meticulous tracking and utilization of subproducts, identifying avenues for recycling or repurposing to maximize resource efficiency and reduce waste output, thereby aligning with sustainability imperatives.

Moreover, SAP EWM elevates the handling of waste storage and shipping, tackling the complexities associated with regulatory compliance and environmental stewardship. With its advanced inventory management functionalities, SAP EWM enables organizations to methodically segregate, store, and label various waste types, ensuring secure handling and mitigating environmental risks. By facilitating compliance with legal mandates and industry standards for waste transportation, SAP EWM contributes to environmental responsibility, diminishing the ecological footprint of power transmission endeavors. In essence, SAP EWM empowers electrical power transmission entities to fortify safety measures, optimize resource utilization, and champion environmental sustainability, ultimately bolstering the reliability and efficiency of power distribution endeavors.

Indeed, while the benefits mentioned earlier are indirect outcomes of SAP EWM's impact on waste monitoring within the supply chain, the primary function revolves around the accurate recording of waste generation, either at the point of production or through reverse Bill of Materials (BOM) techniques. Specifically, SAP EWM facilitates the meticulous tracking and documentation of waste occurrences, whether they occur in the field where the waste is generated or through the validation of predictions via reverse BOM methodologies.

For instance, in the context of transformer maintenance, SAP EWM enables precise forecasting of waste generation, such as the production of oil or the release of SF6 and CO2 during the movement of transport equipment. By leveraging advanced predictive analytics and reverse BOM analyses, SAP EWM provides organizations with invaluable insights into anticipated waste outputs, allowing for proactive waste management strategies and resource allocation. This proactive approach not only enhances operational efficiency but also minimizes environmental impact by enabling timely intervention and mitigation measures.

Therefore, while SAP EWM indirectly facilitates broader waste management optimization across the supply chain, its core functionality lies in the accurate recording and prediction of waste generation activities, empowering organizations to proactively address waste-related challenges and uphold environmental sustainability standards throughout their operations.

Finally, SAP EWM optimizes warehouse operations by automating most of its processes. By automating its tasks, human errors and damages can be significantly reduced, leading to less waste. Also, the software enables efficient bin management and space utilization, ensuring that goods are stored and allocated in the most optimal way, minimizing wasted space.

Incorporating SAP EWM into waste management strategies offers a suite of specialized functionalities designed to streamline and optimize waste-related processes. Firstly, the system enables meticulous recording of waste generation directly within its framework, capturing essential data on the types, quantities, and origins of waste produced across operational activities. Leveraging sophisticated reverse Bill of Materials (BOM) techniques, SAP EWM predicts waste generation with precision, facilitating proactive management strategies based on anticipated outputs from planned activities like maintenance or production processes.

Additionally, SAP EWM ensures comprehensive tracking and traceability of waste throughout the supply chain, from its inception to its ultimate disposal or recycling.

One leading technology in this sector is the RFID (Radio Frequency Identification) scanners. SAP EWM can further support the organization in reducing the level of waste through the use of RFID scanners, which can be executed on mobile or handheld devices, enabling real-time tracking and monitoring of waste movement and inventory

levels. This enhanced visibility facilitates proactive decision-making, allowing the organization to identify inefficiencies, minimize waste, and optimize resource utilization throughout the supply chain. Additionally, RFID technology enhances accuracy and efficiency in waste management processes, automating data capture and reducing manual errors associated with traditional inventory management methods [SAP EWM100, 2021].

This end-to-end visibility not only ensures regulatory compliance and adherence to environmental standards but also empowers organizations with insights to enhance operational efficiency and sustainability. Through specialized inventory management features, SAP EWM facilitates proper handling, labeling, and storage of waste materials, minimizing risks of contamination and ensuring safety within storage facilities. Complemented by robust reporting and analytics capabilities, the system empowers organizations to analyze waste generation patterns, identify optimization opportunities, and make informed decisions to drive continuous improvement in waste management practices.

Last but not least, SAP EWM provides comprehensive analytics and reporting capabilities to identify areas of waste and inefficiency in warehouse operations, helping businesses make data-driven decisions for continuous improvement.

In summary, SAP EWM plays a crucial role in reducing waste in a warehouse by enabling accurate inventory management, automating processes, optimizing space utilization, and providing valuable insights for waste reduction initiatives. Through its advanced functionalities, including waste recording, reverse BOM analysis, RFID scanning, and comprehensive analytics and reporting capabilities, SAP EWM empowers organizations to proactively manage waste throughout the supply chain. By leveraging these tools and capabilities, businesses can enhance operational efficiency, minimize environmental impact, and drive continuous improvement in waste management practices, ultimately fostering a more sustainable and resilient warehouse environment.

3 Problem Description

3.1 Sustainability in the Modern Era: Transforming Business Strategies & Fostering Economic Growth

In the modern era, there was a genuine need for the products and services to be increased in this new market. Industries have to uprise their products and goods due to a dramatically increasing demand. In order this aim to be achieved, the industry players are impelled to alter the traditional ways of their production. Globalized workforces and supply chains have raised environmental strains and associated business obligations. The rise of new global powerhouses has escalated the rivalry for natural resources, thereby introducing a geopolitical perspective to the concept of sustainability [Lubin & Esty, 2010]. The notion of sustainability not only pervades the itineraries of governments and organizations, but also the mission and vision of the educational and research programs worldwide [Bettencourt & Kaur, 2011].

Despite the existence of some earlier precursors, these concepts gained formal recognition and began to crystallize in the 1980s. Three interconnected objectives reflect the provided definition of sustainability development: environmental, economic, and social [Elkington, 1994]. This is commonly referred as the Triple Bottom Line [Alhaddi, 2015]. This approach suggests that besides economic performance, corporations require to engage in activities that positively affect the environment and the society. Nowadays, a growing multitude of consumers have demonstrated an inclination towards sustainable products and services and placing dependence on companies that adhere to progressive sustainability practices. Extrinsic resources, including carbon dioxide emissions, waste management procedures, and water utilization, hold a substantial role in influencing a firm's overall performance.

Corporations are implored to enhance their flexibility to promptly adapt and respond to market alterations, owing to the rapidly evolving business strategies and the dynamic global business environment. Among the catalysts instigating changes, the demands for corporate responsibility and sustainability are becoming ever imperative.

In light of a relevant research [Kiron et al., 2012], sustainability adoption drivers consist of internal and external elements to an organization. The internal factors of sustainability drivers are related to operating costs, revenue growth, brand integrity, employee engagement, and leadership. Along with these internal factors, the external factors

include access to new markets, regulation, green score cards, media and nongovernmental organizations, climate change science, resource scarcity, and consumer demand [Chofreh et al., 2014]. Sustainability facilitates the creation of novel opportunities through innovation, thereby providing a competitive edge and propelling cost reduction measures. Beyond the palpable cost-saving derived from reduced energy consumption, further benefits encompass shifting behaviors that bolster productivity, enhance morale, expedite business processes, foster creative innovations and optimize the use of technology. Consequently, numerous organizations are integrating sustainability initiatives into their corporate strategies.

3.2 The Role of Enterprise Resource Planning Systems in Sustainable Business Growth

There is a noticeable upsurge in the number of organizations progressively integrating contemporaneous Information Technology (IT) applications and products into their operational processes. This is possibly sensible as such technologies help organizations to perform business operations effectively, provide strategic advantages and have a potential to lead organizations towards growth and innovation [Anaya & Qutaishat, 2022].

It is well defined that numerous IT solutions are available in the market. Although, during this study, the EWM system was proposed to be implemented to the Greek PTO. This system was selected, among others, to efficiently manage the stock and the waste materials, alongside activating its Waste Management module (EHS-SUS-WA).

For sustainability to thrive, the implementation of sustainable business practices is essential. Information systems serve a pivotal function in propelling an organization's transition towards undertakings of sustainability. The above statement refers to the creation, execution, and maintenance of the information systems that support environmentally friendly business procedures [Boudreau et al., 2008].

The predominant application frequently utilized is the Enterprise Resource Planning (ERP) systems. This progression transpires as ERP systems have been discovered to yield substantial benefits and strategic advantages to organizations. Furthermore, they embody a crucial role in endorsing and implementing best practices, thereby driving operational excellence in business entities. Additionally, ERP systems serve as strategic catalysts, stimulating organizations to achieve success in their development, fostering growth, and promoting long-term sustainability. ERP is found to be associated with many

sustainability indictors in economic, social and environmental dimensions [Anaya & Qutaishat, 2022], boosting the ability to enable data and process integration across multiple business functions.

3.3 ERP Systems in Sustainable Decision-Making for Waste Management

As a business strives for profit growth and new business value creation, it also aspires to achieve sustainability and development. Decision-makers with immediate access to data from an ERP system can efficiently manage and allocate enterprise resources by gaining insights into business profitability and environmental impacts. This is facilitated by KPIs, such as measurements of environmental permitting compliance for projects and activities, adherence to permitting legislation, and compliance with Electronic Waste Register (EWR) requirements.

This advantage facilitates competitiveness, stimulates cost-reduction initiatives and aligns profit generation with societal impacts. It leads to the internalization of societal and environmental factors and institutionalizes sustainability-oriented leadership via the ERP system [Huang et al., 2019].

However, the manner in which businesses approach sustainability becomes a critical aspect of business strategy and operations [Chofreh, Goni & Klemeš, 2018]. Considering the rapid evolution of information technology and its profound impacts on business operations, it is essential for business management models to foster innovation and adaptability for their survival and prosperity.

Enterprise Resource Planning (ERP) systems provide an essential resource for waste management by harmonizing processes for optimal efficiency and sustainability. Key features such as inventory management, supply chain integration, and material requirements planning facilitate the reduction of waste. These systems ensure inventory levels are maintained accurately, materials are procured timely, and appropriate quantities are produced. ERP systems also enhance quality control, demand forecasting, and financial management, reducing waste caused by defects, overproduction, and ineffective resource allocation. Among the features, warehouse management stands out, as it effectively oversees storage organisation, handles hazardous materials, and tracks waste disposal. This leads to a reduction in waste leakage risks, contamination, and mishandling. Additionally, ERP systems also assist with environmental compliance, integrating smoothly with specialized waste management software, providing real-time data access,

and promoting transparency. Therefore, ERP systems essentially enhance waste management, aligning the organization's initiatives with sustainability goals.

Building on the efficacy of Enterprise Resource Planning (ERP) systems in waste management, this type of software dedicated to waste management, offers further benefits. It enhances waste collection and disposal processes, simplifies regulatory compliance [Lachance, 2023], and provides real-time operational visibility, whether for small businesses or large corporations. By centralizing data regarding waste varieties, disposal methods, and associated costs, it optimizes record-keeping and generates accurate reports. Such an overview supports data analysis that drives smart, informed decisions. Cost reduction is another advantage, with software unveiling opportunities to economize resources and streamline operations. Further, it bolsters customer service by offering accurate pickup schedules and real-time notifications. Importantly, efficient waste management software aligns with broader objectives of environmental sustainability and corporate social responsibility. In essence, when combined with ERP systems, waste management software empowers organizations to operate with heightened efficiency, regulatory compliance, and commitment to a sustainable future.

3.4 Classification, Implementation and Challenges of the European List of Wastes in Waste Management

The European List of Wastes (LoW), a substantial compilation consisting of 839 distinct waste types organized into 20 chapters, represents the European Union's official waste classification system. This system primarily functions as an administrative tool in permitting and overseeing waste generation and management sectors [Commission of the European Communities, 2010]. Predominantly, wastes are categorized based on their original source, meaning the specific economic sector or the original process that generated them. Every type of waste is distinctively identified with a unique six-digit code [Government of the United Kingdom, 2021].

- The first two digits are the chapter
- The next two are the sub-chapter
- the last two are the specific to the waste type

Note: Hazardous/special wastes are identified using an asterisk (*).

The Waste Statistics Regulation compels the utilization of the European Waste Catalogue (EWC-Stat) for relaying data to Eurostat, yet it refrains from prescribing any certain classification scheme for data collation. Consequently, countries have the liberty to adopt any waste classification system, given they ensure the delivery of the mandated formats retaining the specified quality.

In order to acquire dependable and comparable data, it is essential to effectively implement both the company's computerized waste management system and the List of Waste (LoW), along with the overall organizational structure. The classification process must align with the procedure described in No. 3 of the introduction to the Commission Decision 2001/118/EC[1]. Should a specific waste require classification, the undermentioned steps [Commission of the European Communities, 2010] should be pursued:

1. Identify the field of activity to which the waste producer belongs, i.e., chapters 1 to 12 or 17 to 20.
2. Identify the sub-chapter within the chapter which best characterizes the source of the waste.
3. Within the sub-chapter, identify the waste category which best characterizes the waste. The specific is always to be identified over the general.
4. If no appropriate waste category can be found in chapters 01 to 12 or 17 to 20, chapters 13, 14 and 15 should be examined as described above in steps 2 and 3 before resorting to waste categories XX YY 99.
5. If only one waste category XX YY 99 comes into question, the waste should be identified with a waste category in chapter 16, in accordance with steps 2 and 3 above.
6. If a suitable waste category cannot be found in chapter 16, then XX YY 99 is to be used in the chapter and sub-chapter corresponding to the most appropriate source producing the waste

Identifying the suitable procedure for the 99-codes in the List of Wastes (xx yy 99 codes) poses a challenge. The 99-codes are exclusively intended for non-hazardous wastes that cannot reasonably be assigned a specific waste code from the list. Ideally, the

[1] 2001/118/EC: Commission Decision of 16 January 2001 amending Decision 2000/532/EC as regards the list of wastes. *Useful link* *Decision - 2001/118 - EN - EUR-Lex (europa.eu)*

use of 99-codes should not be necessary. However, if a particular type of waste is not listed under the specific sector, one is required to browse through all other chapters of the List of Wastes to find the most fitting code.

In the event that countries expand the List of Wastes with supplementary national codes, a national transposition table needs to be implemented to assign these additional codes to the appropriate LoW-code correctly. It is not accurate to assign the supplementary codes to the 99-code of the relevant sector.

The classification process is succinctly summarized and depicted in the decision tree featured below.

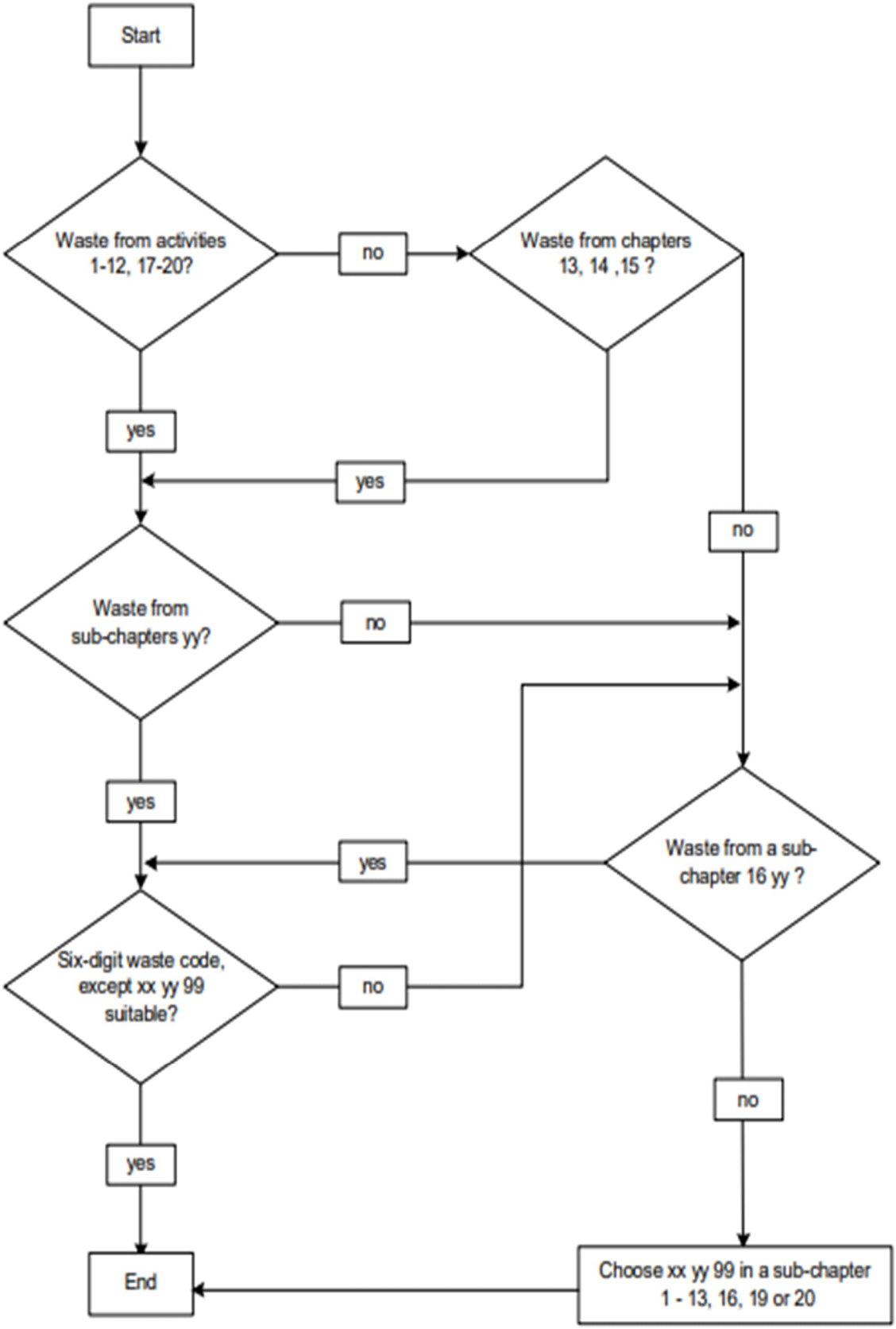

Figure 3. 1 Schematic flow chart on the correct assignment of wastes to LoW codes

Table 3. 1 Waste Electronic and Electrical Equipment (WEEE)

Example	*Waste Electronic and Electrical Equipment (WEEE)*
Scope	*This example provides guidance on the classification of waste electronic and electrical equipment (WEEE) and related components.*

The list of waste contains entries for WEEE in two chapters, 16 and 20.WEEE from domestic households, and items of a similar type from industrial and commercial sources household, is classified in chapter 20. Although, this chapter takes precedence over chapter 16, the example will be focused on waste produced by electricity generation and transmission. More specifically, commercial / industrial-type or sized equipment, that a domestic household would not typically produce, would be classified under chapter 16.

- 16 02 09* transformers and capacitors containing PCBs AH
- 16 02 10* discarded equipment containing or contaminated by PCBs other than those mentioned in 16 02 09 AH
- 16 02 11*discarded equipment containing chlorofluorocarbons, HCFC, HFC AH
- 16 02 12*discarded equipment containing free asbestos AH
- 16 02 13* discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12 AH
- 16 02 14 discarded equipment other than those mentioned in 16 02 09 to 16 02 13 AN

The entry 16 02 13* is an absolute hazardous entry because a 'hazardous component' is not a hazardous substance either specifically or generally. It is the presence or absence of a hazardous component in the equipment that determines code is used. If no hazardous component is present in the equipment, 16 02 14 would be appropriate. A hazardous component is a component either:

- listed in the LoW as hazardous, or
- any other component that would possess a hazardous property if assessed in isolation

The list of waste specifies that hazardous components include hazardous accumulators/batteries (ones coded 16 06 01* to 16 06 03*); mercury switches; glass from cathode ray tubes and other activated glass; mercury containing backlights and other similar items.

Similarly, the entries 16 02 09* to 16 02 12* are also absolute hazardous component entries which contain reference to specific hazardous substances. The component alone is assessed to determine whether it is hazardous due to the presence of the specific hazardous substance. The entry is used if the equipment contains a component assessed to be a hazardous due to that substance (for example asbestos containing components like cables, washers or insulation). If it does not, then the other entries in this sub-chapter (both hazardous and non-hazardous) must be considered.

4 Methodology

4.1 Assess Pollution Impacts of Specific Operations, Illustrated by Electricity Production Facilities and Transfer

Even with significant advances in decreasing pollution from the electric power industry, power plants that use fossil fuels are still major contributors to air, water, and land pollution affecting communities across the globe [US EPA, 2023]. A comprehension of the various elements involved, and their environmental consequences is needed to assess the pollution effect from activities such as power production installations. Electricity generation facilities, particularly those dependent on fossil fuels, have a varied array of environmental implications, contributing to air and water contamination, soil degradation, destruction of habitats, and global warming.

4.1.1 Air Pollution

During the process of electricity generation, the combustion of fossil fuels discharges an array of injurious atmospheric pollutants, such as Particulate Matter (PM), Sulfur Oxides (SOx), Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs) and Cardon Dioxide (CO2) [Fengping & Yongming, 2021]. These pollutants pose a substantial threat to public health, inciting or exacerbating respiratory ailments such as asthma and chronic bronchitis, and inflict damage on the environment by acidifying landscapes and aquatic ecosystems.

Power plants that generate and distribute electricity are recognized as the primary source of substantial Carbon Dioxide (CO2) emissions, a greenhouse gas that exacerbates global warming and climate change. All of these CO2 emissions are generated through various activities involved in the PTOs. These activities include the removal of old infrastructure, the transportation of materials and equipment, the installation of new power lines, and the ongoing maintenance of the electrical grid. Each of these processes requires significant energy consumption, typically involving the use of fossil fuels, which results in the release of CO2 into the atmosphere. Consequently, these operational activities collectively contribute to the overall carbon footprint of power plants.

4.1.2 Water Contamination

The distribution of electricity involves various processes that can have significant environmental impacts on water bodies. While the production of electricity is often highlighted, the distribution network itself also poses several risks to aquatic ecosystems.

One of the primary environmental impacts on water bodies from the distribution of electricity by a Power Transmission Operator (PTO) is chemical contamination from insulating fluids. Transformers and other electrical equipment often use insulating fluids like polychlorinated biphenyls (PCBs) and mineral oils. Leaks or spills of these fluids can contaminate nearby water bodies, harm aquatic life, and potentially enter the human food chain. Another significant source of water pollution is thermal pollution. Electrical distribution equipment generates substantial heat, and cooling systems that use water from nearby sources are sometimes employed to dissipate this heat. The discharge of heated water back into water bodies can raise local temperatures, disrupt ecosystems, and harm temperature-sensitive species. Lastly, the construction and maintenance of PTO assets have a major negative impact on the environment, particularly on water bodies. Building and maintaining power lines often involve extensive ground disturbance, leading to increased erosion and sediment runoff into water bodies. This can smother aquatic habitats, reduce water quality, and disrupt the life cycles of various aquatic species.

4.1.3 Climate Change & Global Warming

Carbon dioxide emissions from power plants contribute to climate change, which affects ecosystems in multiple ways. Climate controls how plants grow, how animals behave, which organisms thrive, and how they all interact with the physical environment. Climate change poses the most notable longstanding environmental threat amplified by power production installations. These installations make the electric power industry the second predominant cause of carbon dioxide pollution, thereby worsening climate change [US EPA, 2023]. As a result, we are seeing damaging ripples on public health and various ecosystems, affecting biological communities, economies, people, and the services the ecosystems offer. Predominantly, the use of fossil fuels discharges substantial volumes of CO2 into the atmosphere. Being a greenhouse gas, CO2 ensnares heat, catalyzing the Earth's average temperature increase, or global warming. Consequences of such change include heightened occurrence and intensity of heatwaves, increased vulnerability to droughts and floods, sea-level rise, alterations in precipitation patterns, and ecosystem disruptions.

To moderate these effects, the focus is shifting towards adopting alternative electricity production methods such as wind and solar power, which generate minimal pollutants and inflict significantly less environmental harm. Nevertheless, the shift towards these renewable energy sources needs to be meticulously steered to alleviate potential

environmental repercussions while maintaining a dependable electricity supply. Although, electricity transmission is unavoidable, capturing and mitigating associated pollution is critical for a cleaner energy grid. PTOs operations can be optimized to minimize their environmental footprint through the implementation of pollution capture technologies and essential reduction strategies.

The fruitful evaluation and governance of these environmental impacts necessitate the amalgamation of technological progress, regulatory initiatives, and societal responses. Technological breakthroughs can augment the efficiency of power generation installations and electricity distribution minimizing their pollution. Meanwhile, policy-based actions can establish standards and implement guidelines to regulate the emission of pollutants. Societally, the transformation of consumption habits towards energy-efficient practices and renewable energy sources can markedly decrease the environmental harm caused by electricity production facilities.

4.2 ERP Systems: Driving Sustainable Growth & Compliance in the Electricity Production Sector

An Enterprise Resource Planning (ERP) system plays a crucial role in promoting the sustainable growth of a company in the electricity production and transportation domain, respecting both legal and business constraints. The following components are particularly pertinent:

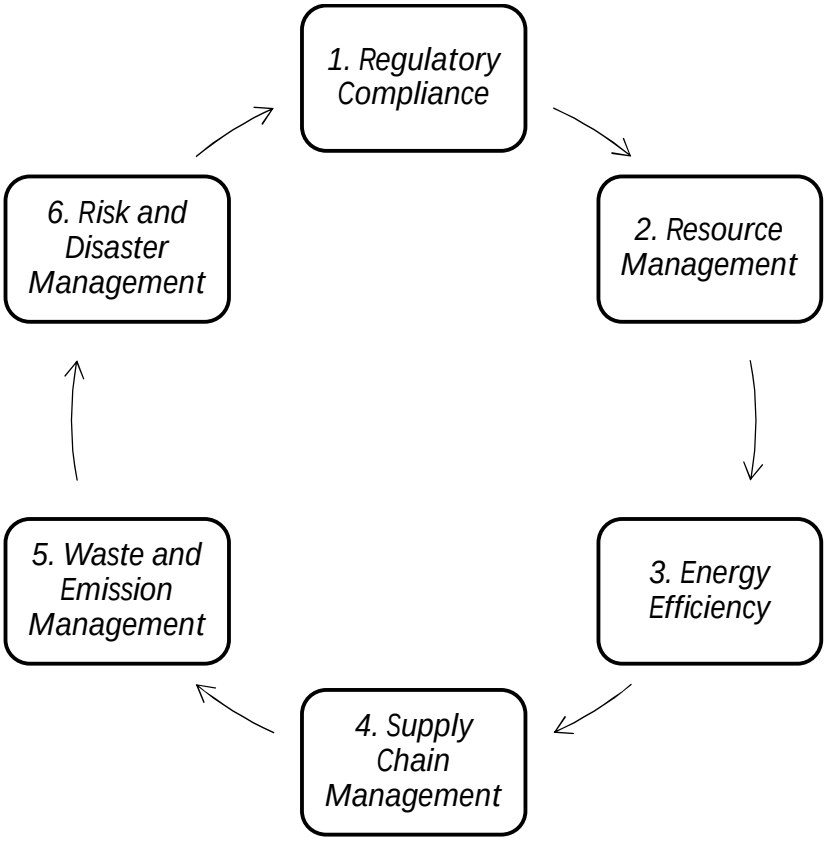

Figure 4. 1 ERP Components that promote sustainable growth

- *Regulatory Compliance:* ERP systems can help track and manage compliance with local, national, and international regulations like environmental laws, safety standards, and industry-specific standards. They also ensure compliance with renewable energy targets and emission reduction goals.
- *Resource Management:* ERP systems can optimize resource allocation and utilization, reducing waste and improving efficiency. For instance, this encompasses everything from the planning of material requirements, such as submarine cables for interconnecting island regions, to the scheduling of equipment and personnel. This approach would reduce the environmental footprint of these interconnections.
- *Energy Efficiency:* An ERP system can track energy usage and identify areas where efficiency can be improved, thus reducing both costs and environmental impact.
- *Supply Chain Management:* ERP systems can manage relationships with suppliers to ensure the use of sustainable and ethically-sourced materials, such as paper and packaging products that are not associated with deforestation

activities, and to optimize delivery and transportation to reduce environmental impact.

- *Waste and Emission Management:* ERP systems can help quantify and manage waste products and emissions, targeting reduction, recycling, and proper disposal, in line with environmental regulations. Moreover, there has been a technological breakthrough in forecasting the pollution generated by preplanned maintenance activites.
- *Risk and Disaster Management:* ERP systems help in better predicting, mitigating, and managing risks including operational, financial, and environmental risks.

Investing in an ERP system that considers these aspects can help an electricity production and distribution company align its business strategy with sustainability objectives, while adhering to all legal and commercial constraints.

4.3 Legal Requirements Valid for EU & Local Industries: Pollutant & Dangerous Goods

Predicated on the tenets of precaution, prevention, pollution mitigation at its genesis, and the 'polluter pays' doctrine, the European environment policy seeks to address an array of multifaceted ecological predicaments. The European Union (EU) grapples with intricate environmental dilemmas that span from climate variations and biodiversity decline to resource scarcity and pollution. Recent developments have seen environmental policy gaining a pivotal role within EU legislation. The Commission has instigated the implementation of the European Green Deal (2019), positioning it as the principal impetus behind the EU's economic augmentation strategy [European Parliament, 2023]. The European Union is competent to act in all areas of environment policy, such as air and water pollution, waste management and climate change.

Since 1973, the Commission has issued multiannual Environment Action Programmes (EAPs) setting out forthcoming legislative proposals and goals for EU environment policy. In May 2022, the 8th EAP entered into force, as the EU’s legally agreed upon common agenda for environment policy until the end of 2030 [European Parliament, 2023].

It reiterates the seventh EAP's vision for 2050: ensuring well-being for all, while staying within planetary boundaries. The new program endorses and builds on the environmental and climate objectives of the European Green Deal along six priority objectives:

- Achieving the 2030 greenhouse gas emission reduction target and climate neutrality by 2050;
- Enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change;
- Advancing towards a regenerative growth model, decoupling economic growth from resource use and environmental degradation, and accelerating the transition to a circular economy;
- Pursuing a zero-pollution ambition, including for air, water and soil and protecting the health and well-being of Europeans;
- Protecting, preserving and restoring biodiversity, and enhancing natural capital (notably air, water, soil, forest, freshwater, wetland and marine ecosystems);
- Reducing environmental and climate pressures related to production and consumption (particularly in the areas of energy, industrial development, buildings and infrastructure, mobility and the food system).

It is worth mentioned that electricity generation and distribution are influenced by nearly all of the aforementioned objectives, as they involve structures on land, sea, and in the air.

Parliament significantly influences the development of environmental regulations within the EU. In its eighth term (2014-2019), it addressed legislative matters related to the circular economy action plan, encompassing areas such as waste management, batteries, end-of-life vehicles, and landfilling. Additionally, the Parliament tackled climate change issues, including the ratification of the Paris Agreement, efforts regarding emissions sharing, accounting for land use changes and forestry in the EU's climate commitments, as well as reforms to the Emissions Trading System (ETS), among other topics.

Industrial activities play a pivotal role in the European economy; however, they concurrently exert notable adverse environmental impacts. Prominent industrial

installations contribute significantly to the overall emissions of key atmospheric pollutants, generate substantial waste, and consume considerable amounts of energy. These emissions detrimentally affect water and soil quality, posing threats to ecosystems, crops, and the built environment. In response to the substantial environmental and health implications associated with industrial installations, comprehensive EU-wide legislation has been enacted. This regulatory framework aligns with the Zero Pollution action plan, emphasizing the imperative to systematically address and mitigate the environmental repercussions of industrial activities [European Commission].

Increasingly, companies responsible for the electricity distribution in their regions, are committing to meet the sustainability goals for 2025 and 2030. These goals focus on forecasting a responsible value chain, which includes promoting biodiversity, leading in the circular economy and driving change among their suppliers. Recent sustainability reports from electricity distribution companies based in countries across European region, such as Spain, Belgium, Norway, Italy and United Kingdom, indicates that these companies are implementing significant measures in order to integrate environmental and waste management techniques into their operations.

The first company in the world exclusively involved in electricity system operation and transport, based in Spain, has already taken significant actions to address its environmental footprint. In 2022, 29.8 million euros earmarked for environmental issues, 681.2 km of lines marked with bird-saving devices in critical priority areas (70.1% of the total), 197 ha of forest were restored and 92.7% of waste were recycled. In 2023, the company made remarkable progress in the implementation of the Zero-Waste Model. Additionally, the Spanish company has already set their objectives for the circular economy roadmap for 2025 and 2030. More specifically, in 2025 their most valuable key targets are: the elimination of waste to landfill to 0%, the implementation of the SF6 reuse procedure and the reduction of hazardous land waste with the strategy of zero accidents and zero contaminated sites. By 2030 the company targets to accomplish 100% of SF6 waste reduction and 100% reduction of soil waste in all their operating assets. In order all the above objectives to be achieved, the company is focusing on establishing three crucial elements for maintaining smooth operations, optimizing the functionality and ensuring safety in their facilities and operational environment:

1. Preventive or corrective maintenance tasks: This includes servicing and inspections, parts replacement, oil renewal, etc.

2. Facility improvements: This involves the replacement of obsolete switchgear, the adaptation of accident prevention systems, etc.
3. Action protocol in the event of accidents: This covers the containment measures used in the event of leaks or spills and the clean-up work can involve a large amount of waste.

The company, in addition to its environmental objectives, has released some metrics & KPIs for year 2023. These include details on the waste management method was applied to each type of waste (hazardous & non-hazardous). More specifically, regarding the total hazardous waste generated by the company, 90.08% was recycled, 1.10% was removed, 8.80% was regenerated and 0.02& was reused. For the non-hazardous waste, 76.46% of the total waste produced was recycled, 4.83% was removed, 1.51% was regenerated and 17.20% was reused [Redeia, 2024].

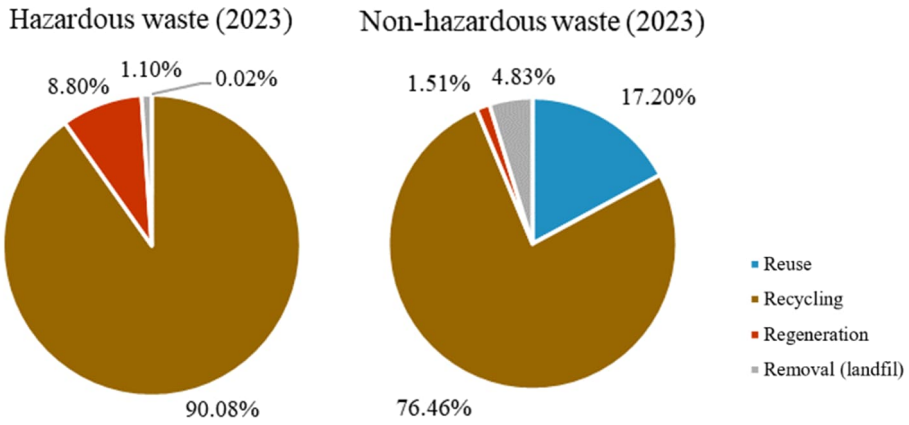

Figure 4. 2 Waste management methods for hazardous and non-hazardous waste

Moreover, an electricity transmission company from Belgium has released its sustainability report for the year 2023 and it is mentioned that the company has established a waste management policy for its administrative and local technical sites (service centers), which includes contracts with authorized collectors who specialize in the collection, transport and recycling of hazardous and non-hazardous waste. The company acquire asset management policies that prioritise avoidance/minimization of waste over waste treatment (reuse, repair, refurbish). More specifically, regarding waste from its own operations and the upstream value chain, the company comply with all national and federal laws and regulations. On its construction sites (value chain upstream), contractors must apply the waste hierarchy and comply with the applicable environmental legislation to remove and sort the waste generated on site and have it collected by a registered waste

collector. Waste management companies provide information about the way our waste is disposed of (and necessary certificates). On the other hand, regarding the waste produced by the company's own sites (own operations), waste is removed by authorized waste management companies, which collect, transport and recycle hazardous and non-hazardous waste.

Additionally, the Belgian company has released some metrics about their waste management activities for 2023. More specifically, the company generated approximately 1,101 tonnes of waste, form which 726 tonnes waw hazardous waste and 376 tonnes was non-hazardous waste. All the waste generated form company's activities was fully recycled (recycling rate: 100%). It is worth to mention that all recovery and disposal operations happened offsite [Elia Group, 2024].

Furthermore, a company from Norway that represents the system operator of the Norwegian power system that owns and operates the transmission grid and maintains the balance between consumption and production, has published its annual and sustainability report for 2023. The Norwegian company plays a key role in Norway’s transition to a low-emission society and manages waste so that it does not harm people or the environment. The waste is appropriately managed and sorted so that materials can either be reused, recycled, or used for energy recovery. More specifically, the waste that company produced, diverted from disposal for waste handled by a Norwegian waste collector, covering 727 metric tons of waste, for which the split was 53.9% recycled materials (392 mt), 37.6% recycled as energy (273 mt) and 8.7% disposed to landfill (62 mt) [Statnett, 2024].

In addition, the largest independent electricity transmission system operator in Italy & Europe is engaged in driving and enabling the ecological transition. Their goal is to establish a new development model based on renewable sources and respect for the environment. Sustainability, innovation and distinctive competencies drive all aspects of the company’s operations, with the aim of providing the generations to come with a clean, accessible and emission-free energy future.

Based on the sustainability analysis for the waste type and management methodology practiced by the company, the materials used in the electricity infrastructure are recovered for reuse in operations, at the end of their normal life cycle. Only a residual portion is sent to landfill, thereby impacting on the environment. The percentage of waste

recovered amounted to 87% (91% in 2022 and 86% in 2021). More specifically, the total waste that was produced in 2023 estimated to 7,672 tonnes. From the total waste generated, 6,685 tonnes (87%) were sent for recovery and 1,064 tonnes (13%) were sent for disposal, of which 770 tonnes (72%) and 294 tonnes (28%) were hazardous and non-hazardous waste respectively. The total non-hazardous special waste produced from activities related to machinery, equipment, pylons, conductors, cables, packing was 2,971 tonnes, of which 2,728 tonnes (92%) was sent for recovery. Additionally, the total hazardous special waste produced from activities related to machinery, equipment, pylons, conductors, cables, oils, waste comprising material containing asbestos, was 4,701 tonnes, of which 3,956 tonnes (84%) was sent for recovery.

Last but not least, the English company, which is the United Kingdom's largest electricity distribution network and serves nearly 8 million customers in the East and West Midlands, South West and Wales, is committed to achieve net-zero by 2050, according to its latest sustainability report of 2023. The company, in its sustainability report, sets environmental commitments for the next stage of its operation. More specifically, the enterprise will reduce greenhouse gas (GHG) emissions 80% by 2030, 90% by 2040, and to net zero by 2050 from a 1990 baseline. Moreover, the company aims to reduce SF6 emissions from its operations 50% by 2030 and reduce energy consumption in its offices 20% by 2030 from a 2019 baseline. Following these targets, the results are promising. Notably, the company aims to eliminate all SF6 gas from all company's assets by 2050 and to successfully operate a zero-carbon system by 2025 [National Grid, 2022].

The company undertakes various projects that produce waste, including cleaning up former gas plant sites, retiring old fossil assets and leak-prone equipment, building out grid infrastructure and supporting various renewable energy projects. Despite the ongoing generation of waste, the company aims to continue ensuring that all waste is properly disposed of with appropriate environmental permits and compliant with regulatory standards. The total waste generated in the period 2023/24 was 331,612 tonnes of which 311,504 tonnes (94%) and 20,108 tonnes (6%) was non-hazardous and hazardous waste respectively. Also, from the total waste produced, 259,224 tonnes (78%) was reused and recycled. In more detail, approximately 22% of hazardous waste is recycled and 45% is sent to landfill. Moreover, approximately 10% of non-hazardous waste is sent to landfill, with 43% been reused and 39% been recycled. For the remaining 8% the company uses

disposal methods which include thermal processing and incineration [National Grid, 2024].

4.4 Detection of the Waste Generated by a Warehouse of Electricity Transportation Company

The effective management of waste within warehouse facilities of electricity transportation accompany plays a pivotal role in upholding environmental sustainability and regulatory adherence. With a multitude of contributors, spanning from maintenance tasks on plant machinery to the disposal of office and facility waste, a comprehensive strategy is indispensable for handling diverse waste streams efficiently. From waste oils and hazardous material spills to electronic waste and municipal refuse, each category presents unique challenges that require specialized management techniques. Understanding these distinct waste types and implementing appropriate disposal methods are imperative for maintaining operational efficiency and mitigating environmental impact. Herein lies an exploration of the primary waste streams identified within the specific warehouse environments:

- Waste oils resulting from maintenance activities on the plant's equipment, including production machinery and motorized equipment, are directed to an authorized management entity engaged in an alternative lubricating oil waste management system.
- Liquid waste spills originating from waste storage areas are gathered in containment basins and subsequently forwarded to a suitable hazardous waste management facility.
- Used batteries extracted from the plant's motorized equipment, such as forklifts, are collected by a designated management body contracted for an alternative battery management system.
- Used tires from the plant's motorized equipment, for instance, forklifts, are retrieved by a management entity contracted for an alternative waste tire management system.
- Waste originating from Electronical and Electronic Equipment (WEEE), found in office premises and electrical equipment, is gathered by a contracted management body specialized in an alternative WEEE management system.

Based on the European Waste Catalogue (EWC) as detailed in Section 3.4 of this paper, the aforementioned wastes have been categorized and are presented in the table below according to their respective types:

Table 4. 1 Categorization of Waste types produced by a warehouse

Waste code by EWC	Waste type by EWC	Waste category
13 02 05*	Non-chlorinated engine, gearbox and mineral-based lubricating oils	Waste Lubricating Oils (WLO)
13 02 08*	Other engine, transmission and lubricating oils	WLO
13 02 16*	Synthetic engine, transmission and lubricating oils	WLO
16 01 03*	Tires at the end of their life cycle	Tires
16 02 13*	Discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 12	WEEE
16 02 14*	Discarded equipment containing hazardous components other than those mentioned in 16 02 09 to 16 02 13	WEEE
16 02 16*	Components removed from discarded equipment other than those mentioned in 16 02 15	WEEE
16 10 01*	Aqueous liquid waste containing hazardous substances	A tank to collect any effluent
16 06 02*	Ni/Cd batteries	Waste Electric Batteries & Accumulators (WEBA)
16 06 03*	Batteries containing mercury	Waste batteries and accumulators (WBA)
15 02 02*	Absorbent materials, filter materials (including oil filters not otherwise specified), wiping cloths, protective clothing contaminated with dangerous substances	Contaminated materials to deal with spills of hazardous substances
15 01 10*	Packaging containing residues of or contaminated with dangerous substances	Plastic or metal or composite packaging
20 01 33*	Batteries & accumulators included in 16 06 01, 16 06 02 or 16 06 03 and mixed batteries & accumulators containing these batteries	WEBA
20 01 34*	Batteries & accumulators other than those mentioned in 20 01 33	WEBA
20 01 35*	Discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components	WEEE

5 Implementation

5.1 Registration Steps of Waste by the Responsible Teams in the ERP System

The subsequent chapters will delve into the examination of the registration steps involved in waste management within a warehouse setting in an SAP ERP environment. Each of these steps encompasses a distinct methodology that is consistently implemented by the responsible team.

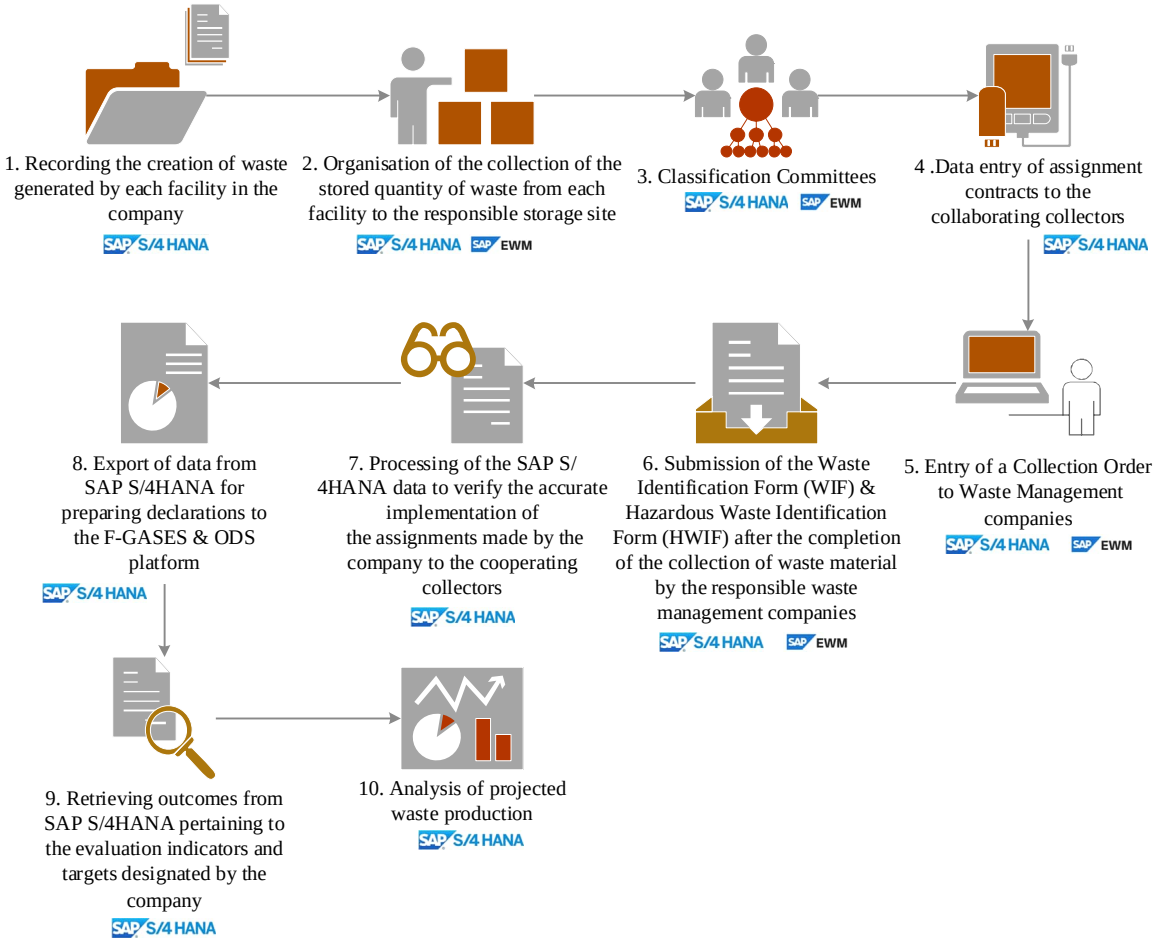

Figure 5. 1 High-Level Overview Workflow

5.1.1 Recording the creation of waste generated by each facility in the company

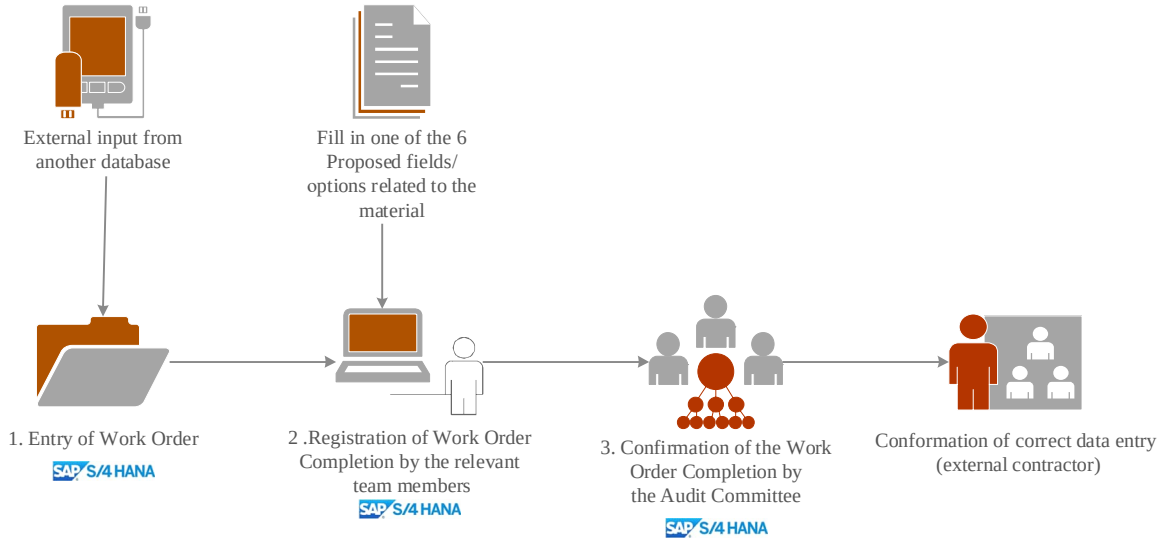

Figure 5. 2 Workflow No.1

Following the utilization of the aforementioned visual aid (Flowchart No. 1), the primary objective is to accurately record the generation of waste from each facility. This initiative is undertaken alongside enhancements to Work Order management, ensuring a seamless progression from task inception to finalization. Further clarification regarding the components of each stage is elaborated upon in the subsequent paragraphs.

1. Entry of Work Order

The Work Order must be entered in SAP S/4HANA, consider transferring the specific data from another application already running to track Work Orders.

The external data input to be entered from the merged database includes:

- The data of the crew that will implement the job
- The identity/name of the installation (in the coding that will be done there will be a provision to make it clear to the crews whether it is a licensed or unlicensed installation)
- The type of work, among the following categories:
  - work without the use of a spare part/production of waste
  - work with the use of a spare part / waste production

- maintenance of Fluorinated Greenhouse Gases[2] (FGASES) equipment
- maintenance of Sulfur hexafluoride[3] (SF_6) equipment

- The consumable, spare part or equipment to be received by the workshop and the identity of the storage area from which it will receive it.
- Instruction on whether to leave the material produced at the facility or to transfer it to a Warehouse and to which Warehouse in case it is identified by the crew as reusable or unusable.
- The key number (F-GASES & ODS platform code) of the machine in case the work involves FGASES & SF_6.

2. Registration of Work Order Completion by the relevant team members

After completing the required work, the maintenance teams will access SAP S/4HANA to automatically log their code, the date, and the installation or serial number of the machine.

At this stage, the maintenance teams should choose to select one of the following 6 cases:

i. The material produced has been identified as scrap material but could not be weighed

ii. The material is suitable for reuse, so it will be recorded in pieces in the category designated for materials destined for reuse

[2] Fluorinated greenhouse gases play a significant role in exacerbating global warming, with their warming potential often thousands of times greater than that of carbon dioxide (CO_2). Initially introduced as substitutes for ozone-depleting substances (ODS), F-gases were discovered to effectively trap heat from the sun, accelerating the planet's warming process. These gases, which are anthropogenic in origin, encompass hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and other fluorinated compounds. Among these, hydrofluorocarbons (HFCs) account for approximately 90% of all F-gases. [European Commission, 2024]
[3] Sulfur hexafluoride is a synthetic fluorinated compound with an extremely stable molecular structure. Because of its unique dielectric properties, electric utilities rely heavily on SF6 in electric power systems for voltage electrical insulation, current interruption, and arc quenching in the transmission and distribution of electricity. Yet, it is also the most potent greenhouse gas known to-date. [US EPA, 2024]

iii. The material cannot be identified by the maintenance team, so it will be recorded in pieces in the category identified for these materials

iv. The materials will be received by the external contractor responsible for the activities, pending declaration of quantities, waste categories, and their appropriate disposal methods. This category will be selected to indicate that it is pending, enabling the supervising agency to monitor the completion of data entry

v. The resulting material is classified as waste, weighed, and either retained within the facility or, if deemed non-hazardous and transferable, it is relocated to the warehouse

vi. The assignment relates to the maintenance of a machine containing F-GASES or SF_6 or a leak detection system

These records will form the dataset for submitting declarations to the FGASES Platform [Ministry of Environment and Energy of Greece, 2024], including ODS categorized by equipment serial number.

3. Confirmation of the Work Order Completion by the Audit Committee

With the data recorded by the maintenance team through SAP S/4HANA, the Audit Committee, utilizing the software, will be able to:

- Conduct mass or individual checks to verify the execution of work orders and confirm the completion of data entry. Additionally, they will have the capability to identify orders that have not yet been confirmed.
- Monitor the "pending" orders recorded under cases 1, 3, 4. This oversight will enable efficient tracking and management of pending tasks.

The impact of these steps is evident in the monitoring of waste quantities stored per facility to streamline waste collection planning. The application may incorporate

guidelines for setting maximum storage limits for each type of waste at each facility. If these quantities exceed the specified limits, an alert is generated.

5.1.2 Organisation of the collection of the stored quantity of waste from each facility to the responsible storage site

In this process, within SAP S/4HANA, predefined thresholds will be set for the quantity of waste per category and materials earmarked for inspection. Upon surpassing these thresholds, it becomes incumbent upon the Administration to commence the transfer procedure from the pertinent facility to the responsible storage facilities, using the SAP EWM. In accordance with software specifications, an alarm will be activated upon reaching these predefined thresholds, thereby indicating the necessity for immediate action.

The detailed flowchart illustrating this process is presented below:

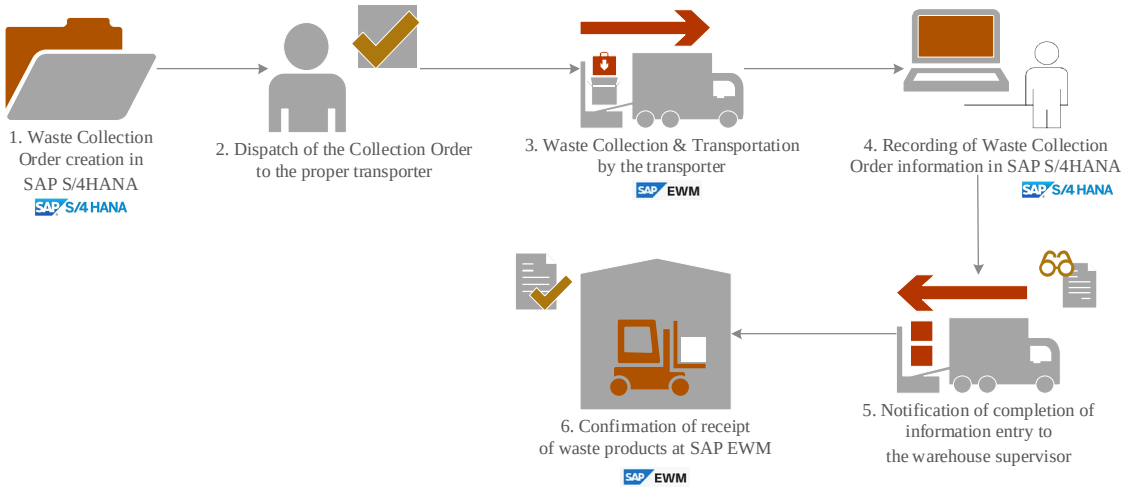

Figure 5. 3 Workflow No.2

1. **Waste Collection Order creation in SAP S/4HANA**

In this step, the creation of the Waste Collection Order is underway from SAP S/4HANA.

2. **Dispatch of a Waste Collection Order to the proper transporter**

Following the creation of the specific Order, a notification is dispatched to the designated transporter. These notifications correspond to three distinct types of waste “collections”, which are indicated in the initial cases of the preceding flowchart:

i. Collection of waste materials from a licensed facility (Case V) or the scrap material has emerged from a licensed facility but has not been weighed (Case I).

In this collection type, the transporter receives the Order in which is stated:

- The identity/name of the receiving facility
- The category of material
- The EWC code of the waste
- The quantity pieces/weight of the material
- Warehouse details where the delivery will be made

ii. Collection of waste materials from an unlicensed facility entails transporting the material as material for inspection rather than as waste.

In this collection type, the transporter receives the Order in which is stated:

- The identity/name of the receiving facility
- The category of material
- The quantity pieces/weight of the material
- Warehouse details where the delivery will be made

i. Collection for material that has been classified as usable (Case II) or has not been characterized by the workshop and is either in a licensed or unlicensed facility (Case III).

In this collection type, the transporter receives the Order in which is stated:

- The identity/name of the receiving facility
- The category of material
- The quantity pieces of the material

- Warehouse details where the delivery will be made

3. Waste Collection & Transportation by the transporter

In this step, subsequent to the dispatch of a Waste Collection Order, the designated transporter retrieves the waste material from the facility and conveys it to the specified, by the Collection Order, warehouse in SAP EWM.

4. Recording of Waste Collection Order information in SAP S/4HANA

Following the collection process, the driver accesses SAP S/4AHANA and initiates the Collection Order, correlating it with their unique identification code. This code, specific to the transporter's data, is provided to them beforehand. Subsequently, the information pertaining to the command for each case is automatically recorded, as previously described. If the entered data does not align with the actual data, the transporter is required to make the necessary adjustments within SAP S/4HANA.

5. Notification of completion of information entry to the warehouse supervisor

Upon completion of the transporter's registration into the SAP EWM, a notification will be sent to the respective warehouse supervisor to confirm the information entry of the waste material.

By entering the above data, we have information regarding:

- the transportation of waste generated per facility
- the transportation of materials that are either usable or require evaluation
- the transportation of waste from unlicensed facilities, which cannot be declared in the Electronic Waste Registry (EWR)

6. Confirmation of receipt of waste products at SAP EWM

Within the SAP EWM system, the last step confirms that incoming waste products have been received and documented, ensuring accurate inventory management.

5.1.3 Classification Committee

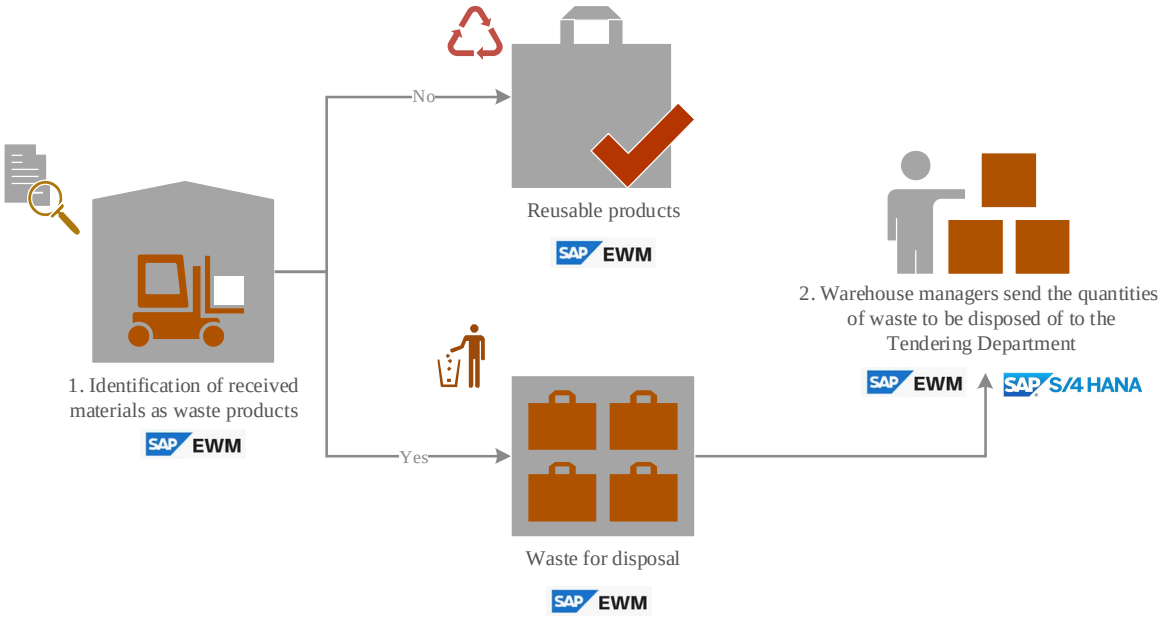

Figure 5. 4 Workflow No.3

1. **Identification of received materials as waste products**

When the materials are collected in the warehouse, then the Classification Committees characterize the materials produced by the maintenance and replacement operations to classify them into 2 categories, with the assistance of SAP EWM:

- Reusable products or
- Waste for disposal

2. **The warehouse managers send the quantities of waste to be disposed of to the Tendering Department**

This identification process serves to reduce errors in distinguishing between materials designated for disposal as waste and those suitable for reuse as usable products. Furthermore, it aids in determining the quantity slated for disposal, thereby facilitating the organization of recycling efforts by companies and enabling forecasts regarding the volume of waste expected within a specific timeframe. As a result, with the assistance of SAP

EWM, Classification Committees wield the authority to categorize materials as waste for disposal or as candidates for reuse, thus integrating them back into operational processes.

5.1.4 Data entry of assignment contracts to the collaborating collectors

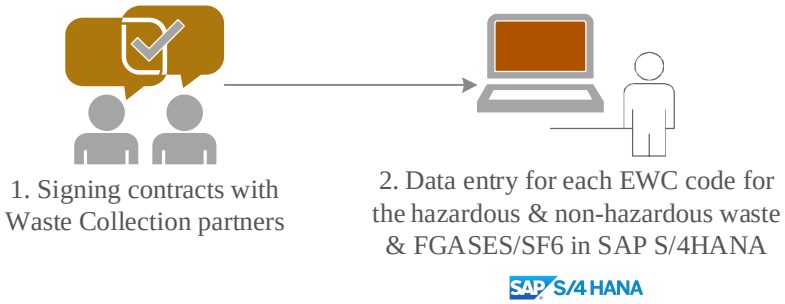

Figure 5. 5 Workflow No.4

1. **Signing contracts with Waste Collection partners**

Expanding upon the flowchart provided above, the Department responsible for tendering evaluates the EWC codes and associated waste quantities for each project. Once the tendering process concludes and contracts are signed by the designated collectors, they are then transferred to the Department tasked with entering contract data into the ERP system.

2. **Data entry for each EWC code for the hazardous & non-hazardous waste & FGASES/SF6 in SAP S/4HANA**

In this phase, the user accountable for data entry, which process is facilitated within the SAP S/4HANA, must provide the following inputs for each EWC code pertaining to hazardous waste, non-hazardous waste, and F-GASES/SF6:

- For hazardous waste:

    1. Contract number with the PTO & its expiration date
    2. The code of the company managing the waste disposal
    3. Code of the company managing the waste disposal from the EWR

4. Quantity of waste to be disposed of in case it is based on a tender for a specific quantity. If it is a framework contract, there will be another provision.
5. Expiration date of the responsible Collector's license
6. Collector's ADR4 driver names & licenses
7. Expiration date of Collector's Intermediary Liability Policy
8. Fee/unit of weight or Charge/unit of weight (optional)

- For non-hazardous waste:

1. Contract number with the PTO & its expiration date
2. The code of the company managing the waste disposal
3. Code of the company managing the waste disposal from the EWR
4. Quantity of waste to be disposed of (in case it is based on a tender for a specific quantity)
5. Expiration date of Collector's Intermediary Liability Policy
6. Fee/unit of weight or Charge/unit of weight (optional)

- For the maintenance of a machine containing F-GASES or SF6:

1. Maintenance license number & certification authority
2. Taxpayer Identification Number (TIN) & name of the responsible organisation for the maintenance activities
3. Maintenance license number

[4] ADR is a French acronym for the "European Agreement concerning the International Carriage of Dangerous Goods by Road" which is a treaty signed in Geneva dating back to 1957 from the United Nations regarding the governance of international transport of Dangerous Goods. The original French name for this Treaty was: *"Accord européen relatif au transport international des marchandises Dangereuses par Route"* [UNECE, 2023]

4. Authentication Key number (related to the TIN, for tax purposes), type of controlled substance added, type of controlled substance recovered per equipment

5.1.5 Entry of a Collection Order to Waste Management companies

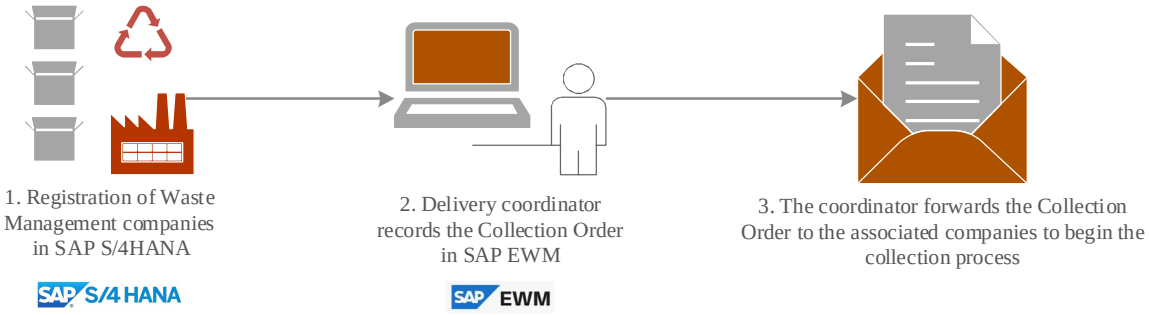

Figure 5. 6 Workflow No.5

Following the utilization of the aforementioned flowchart, the primary objective is to notify the companies responsible for the collection and disposal of the waste.

1. **Registration of Waste companies in SAP S/4HANA**

This action was undertaken during the initial stages of customizing and installing SAP S/4HANA. Specifically, the designated user registered all companies/organizations involved in waste disposal and management. These entities have entered into contracts with the waste-producing company, signifying their agreement to handle waste disposal.

2. **Delivery coordinator records the Collection Order in SAP EWM**

At this juncture, the waste management companies designated for each waste code have been meticulously recorded within the SAP EWM. It is now incumbent upon the delivery coordinator to promptly transmit the Order to the associated entities.

3. **The coordinator forwards the Collection Order to the associated companies to begin the collection process**

The procedure for this step will be as follows:

The company will receive the Collection Order (with a specific code) for the loading in which it will be declared:

- The EWC code of the waste
- The quantity/weight of the waste
- The identity of the facility where the waste is temporarily stored

5.1.6 *Submission of the Waste Identification Form (WIF) & Hazardous Waste Identification Form (HWIF) after the completion of the collection of waste material by the responsible waste management companies*

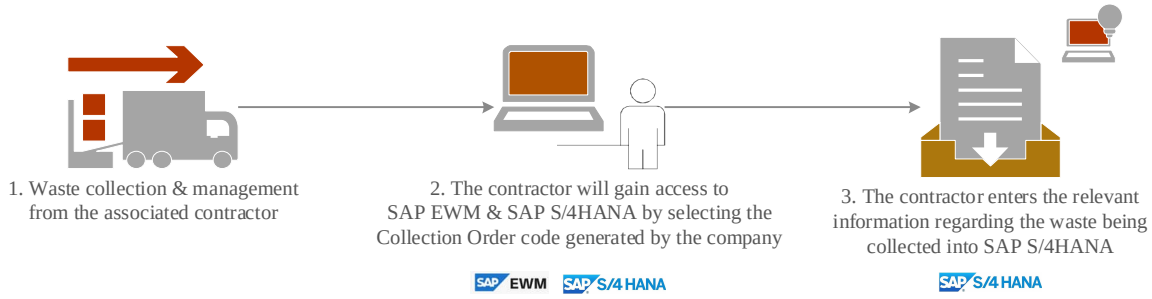

Figure 5. 7 Workflow No.6

Following the depiction of the related flowchart, the main objective of this step is to systematically submit information concerning the disposal of waste, by the contractor, immediately after the collection of this type of material.

1. **Waste collection & management form the associated contractor**

In this action, the contractor (associate collector) has already collected the waste and transferred it to the designated area where the disposal procedure takes place.

2. **The contractor will gain access to SAP EWM & SAP S/4HANA by selecting the Collection Order code generated by the company**

Immediately after loading and transporting the waste material, the contractor accesses the SAP EWM using the unique Collection Order code generated by the company during the collection process. Automatically, the following data pertaining to the waste material are recorded in the system:

- The EWR code and its details
- Field where the drivers and ADRs declared will be shown to select who made the collection. If a new driver has been used there will be a field to fill in his name and ADR license number and expiration date (in case, he/she is carrying hazardous waste)
- The facility from which the collection is being made

3. The contractor enters the relevant information regarding the waste being collected into SAP S/4HANA

At this point, the contractor should enter the following data regarding the waste:

- The quantity/weight of waste without packaging
- The details (EWR code) of the facility where the waste was delivered (secondary storage depot of the collector or recycling facility)
- Waste management operation (R & D)

These records will constitute the data for the submission of the report of each warehouse to the EWR.

5.1.7 Processing of the SAP S/4HANA data to verify the accurate implementation of the assignments determined by the company to the cooperating collectors

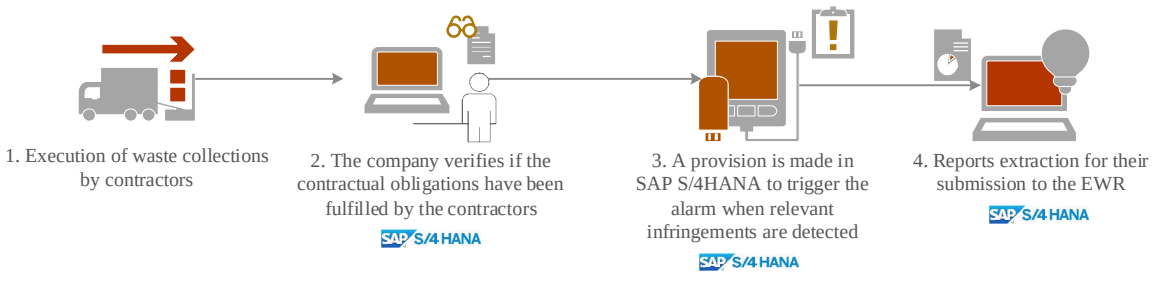

Figure 5. 8 Workflow No.7

The primary objective of the above stage is to confirm the accuracy of data entry conducted within SAP S/4AHNA by the designated contractor responsible for waste material collection. Additionally, it emphasizes the system's capability to issue notifications

& alarms in case any oversight of predetermined waste management rules occur. Lastly, it underscores the ERP system's proficiency in generating relevant reports for uploading to the EWR, inclusive of all necessary specific information.

1. **Execution of waste collections by contractors**

During this phase, the designated collector, typically a contracted entity, has completed the collection of waste from the company's warehouse and subsequently transported the material to their own premises for disposal.

2. **The company verifies if the contractors have fulfilled the contractual obligations**

Throughout the waste collection process conducted by contractors, SAP S/4AHANA empowers the company to verify the fulfillment of contractual obligations, ensuring adherence to specified standards and requirements.

3. **A provision is made in SAP S/4HANA to trigger the alarm when relevant infringements are detected**

The System will include provisions to trigger alarms in the following scenarios:

- Utilization of a driver with an expired ADR certification, especially relevant in hazardous waste management.
- Expiration of the liability insurance policy.
- Expiration of the collection license for the partner collector.
- Delivery to a facility or final recipient (such as secondary storage or recycling company) not registered in the EWR.

4. **Reports extraction for their submission to the EWR**

The system will facilitate report exports for submission to the EWR, encompassing the following data per installation, per year, and per EWC code:

- Quantity of waste managed or still stored at the facility

- Timestamp of waste generation (current year or preceding period)
- Nature of recovery or storage management activity
- Details of the management company and collection company
- Information regarding the final recipient facility

The described process provides several advantages. Initially, it guarantees data precision by validating the input of waste material collection details, thus decreasing inaccuracies in waste management procedures. Secondly, it enables proactive adherence monitoring by highlighting any deviations from preset regulations, minimizing the possibility of regulatory breaches. Thirdly, the notification and alarm system promptly notifies relevant personnel of any oversights, allowing for immediate corrective actions and preventing potential issues from escalating. Lastly, the ERP system's streamlined reporting capabilities simplify the compilation and submission of comprehensive reports to the EWR, facilitating compliance with regulatory standards and ensuring transparency in waste management operations.

5.1.8 Export of data from SAP S/4HANA for preparing declarations to the F-GASES & ODS platform

Figure 5. 9 Workflow No.8

1. **Reports extraction from SAP S/4HANA**
2. In this step, the ERP system generates the reports that are intended for submission to the F-GASES & ODS[5] platform by the company. These reports will contain specific data for each machine key number per year, including:

    - Maintenance date
    - Type and frequency of operations
    - Detection of leaks
    - VAT, company name, license number, certificate number, and certifying agency of the maintainer
    - Work Order number

3. Reports submission to the F-GASES & ODS platform

During this phase, the reports are submitted to the F-GASES & ODS platform, marking a pivotal step in the process. The primary objective is not only to transmit the reports but also to meticulously fill out all essential fields within the platform. This meticulous approach ensures the accurate and comprehensive submission of data, aligning with regulatory standards and organizational protocols.

The advantage of producing these reports via SAP S/4HANA is the optimization of the declaration submission process to the F-GASES & ODS platform for the company. By centralizing all pertinent data within the ERP system, the company can ensure precision, thoroughness, and punctuality in their submissions. This not only aids in adhering to regulatory obligations but also enhances operational efficiency by diminishing manual labor and potential inaccuracies linked to manual data input. Furthermore, the availability

[5] The F-GASES & ODS database serves as a centralized electronic platform for collecting and organizing information and data related to the utilization of fluorinated greenhouse gases and ozone-depleting substances. In addition to storing legal, economic, and scientific information and documents, it also records annual submissions from facility owners using controlled substances, as well as from professionals and businesses involved in the import, trade, distribution, and management of these substances.

of comprehensive reports supports improved monitoring, analysis, and decision-making concerning machine maintenance and compliance with environmental regulations.

5.1.9 Retrieving outcomes from SAP S/4HANA pertaining to the evaluation indicators and targets designated by the company

The extraction of results from SAP S/4HANA involves retrieving data related to the evaluation indicators and targets chosen by the company. This process entails accessing pertinent information within the System, focusing on the specific metrics and objectives set by the company for evaluation purposes. By extracting these results, the company gains insights into its performance against predetermined benchmarks, facilitating informed decision-making and strategic planning.

5.1.10 Analysis of projected waste production in the SAP S/4HANA environment

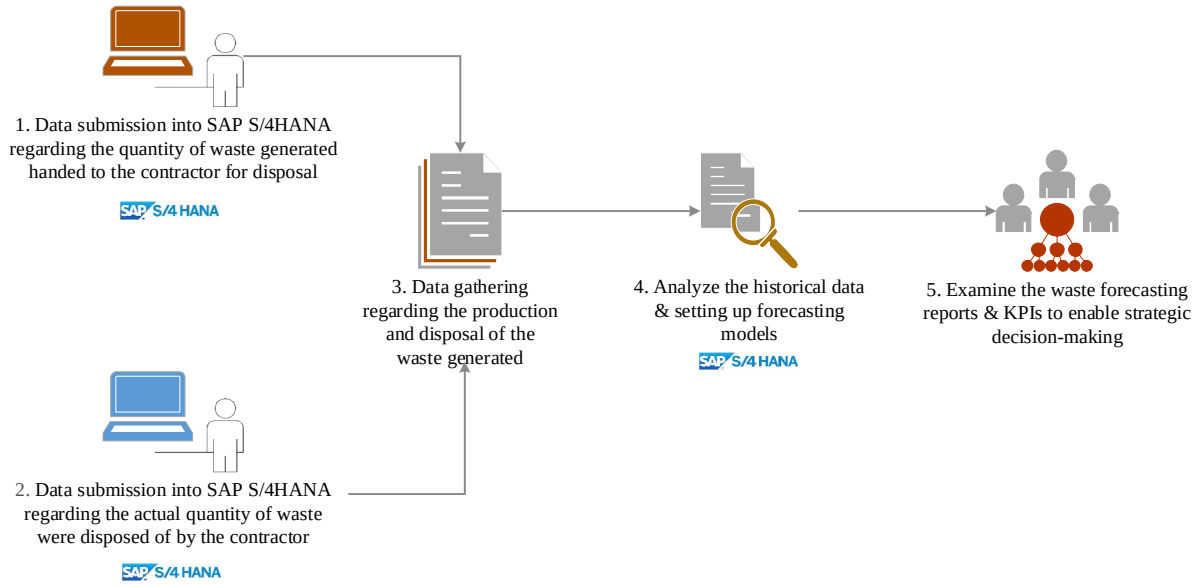

Figure 5. 10 Workflow No.9

Analyzing projected waste production not only aids in maintaining regulatory compliance but also enhances operational efficiency and supports sustainable practices. This process involves a meticulous five-step approach to ensure accurate forecasting and strategic decision-making. The following steps detail the comprehensive methodology for analyzing projected waste production, from data submission and extraction to historical analysis and strategic forecasting.

1. **Data submission into SAP S/4HANA regarding the quantity of waste generated and handed to the contractor for disposal**

The first step involves accurately recording the amount of waste that has been transferred by the contractor. This data entry is crucial as it serves as the foundational dataset for the entire analysis. Ensuring precision at this stage helps in maintaining data integrity and reliability throughout the subsequent steps.

2. **Data submission into SAP S/4HANA regarding the actual quantity of waste were disposed of by the contractor**

In this step, the contractor provides detailed records of the waste they have finally disposed of. This information is crucial for comparing the initial waste quantities with the disposed amounts, enabling a thorough tracking of waste management practices. It helps in identifying any discrepancies or inefficiencies in the disposal process.

3. **Data gathering regarding the production and disposal history of the waste generated**

Once the data on waste handover and disposal is submitted, the next step is to extract historical data on waste production and disposal. This historical data provides a comprehensive view of past waste management activities, highlighting trends, patterns, and any irregularities in waste production and disposal practices over time.

4. **Analyze the historical data & setting up forecasting models**

With the historical data in hand, the analysis phase takes place, utilizing specific SAP functionalities and tools. This involves using statistical methods and modeling techniques to analyze past data and project future waste production and disposal rates. Moreover, the company could develop & schedule custom annually and monthly reports in order monitor waste generation trends and review projected waste against actual waste generated. Additionally, the company could set up a variety of key performance indicators (KPIs) and dashboards in order to track waste generation and projection accuracy. The main goal is to identify patterns that can predict the future waste generation and measure the efficiency of its disposal.

5. Examine the waste forecasting reports & KPIs to enable strategic decision-making

The final step involves leveraging the insights gained from the waste production forecasts to inform strategic decision-making. By understanding potential future waste trends, companies can develop more effective waste management strategies, optimize resource allocation, and implement proactive measures to reduce waste generation. This step is critical for aligning waste management practices with sustainability goals and regulatory requirements.

By following τhis structured approach analyzing projected waste production ensures that companies can effectively manage their waste, enhance sustainability, and make informed decisions that support long-term environmental and operational goals, based on a forecasting analysis and reports in SAP Waste Management. As a result, this could lead to a more efficient waste handling and better environmental compliance.

6 Recommendations & Conclusion

6.1 Recommendations

In order to further impulse the discerning and challenging management activities of waste, in a warehouse environment, the following two recommendations are proposed. Firstly, the proper extraction and the appropriate use of ERP metrics and Key Performance Indicators (KPIs) related for environmental policies and waste management could be very crucial to businesses, such as PTOs, by offering a structured pathway to more successful achievements. More specifically, these KPIs and metrics enable businesses to monitor progress toward strategic objectives and milestones, foster transparency and facilitate alignment at all different scales of the waste management process. As a result, these indicators further assist organizations to maintain focus on their prime goals, confidently formulate evidence-based strategic decisions and adapt to rapid market conditions by pivoting leveraging unexpected progress. Secondly, the adoption of the new extension of SAP Waste Management module, SAP Green Token, could assist supply chain networks in achieving traceability and transparency, regarding the waste management activities. Especially for the management of the waste activites of PTOs, SAP Green Token could enhance their performance by leveraging innovative solutions of managing and tracking waste, thereby aligning with sustainability goals and regulatory requirements.

6.1.1 ERP System Metrics & KPIs for Environmental Policy & Waste Management

The ensuing chapter sheds light on an extensive collection of metrics, crafted to establish a benchmark and the requisite assessment methodologies necessary for a structured approach. The paramount objective of these Key Performance Indicators is to foster coherent execution and unvarying evaluation across a broad spectrum of environmental aspects, particularly emphasizing waste management. The systematic assessment and monitoring indicators, amplified with relevant and detailed content analysis, are predestined to have an influential role in molding environmental policy formulation while concurrently acting as a fundamental touchstone during the derivation of ideal principles for their deployment. Additionally, it is essential to highlight some of the proposed indicators for this undertaking, encompassing principles such as environmental permitting adherence, compliance with the Electronic Waste Register, and the tactical management of alternative waste streams.

This refers to a collection of indicators that establish a general guideline and pinpoint the assessment methodologies required. There is a need to disperse this assessment process throughout all actions concerning environmental waste management elements. Further enriched with relevant and thorough analysis, these diverse indicators for monitoring and evaluation become a crucial component in steering the creation of environmental policy. It also serves as a fundamental source when identifying the best practices for implementing these indicators. Specifically, the proposed indicators for this purpose include:

- A measure of environmental permitting compliance for projects and activities
- A measure of adherence to permitting legislation
- A measure of compliance with Electronic Waste Register (EWR) requirements
- A measure of adherence to the Electronic Waste Management System (EWMS) requirements
- A measure of Public Procurement's adherence to EMPA requirements
- A performance measure of alternative management goals in selected waste streams such as:
    - Paper packaging
    - Plastic packaging
    - Glass packaging
    - Plastic bottles
    - Batteries
    - White goods and Electronic Infrastructure Devices
    - Waste tires
- An index to track the withdrawal and alternative recovery of historically stored waste (such as scrap metal and used spare parts).
- A measure to compare the management of waste quantities generated in the facilities.
- Key performance indicators regarding SF6 emissions:
    - Measure SF6 leaks as a percentage of total installed
    - Measure the SF6 amount
    - Detect the SF6 emissions
- KPIs related to reduction of emissions thanks to circular economy projects and green transformers:

- % of recycled waste
- Number of green transformers sold
- Energy and fuel consumption

6.1.2 SAP Green Token: A Novel Mass Balance Method for Sustainability, Traceability & Transparency

In today's landscape, the absence of visibility beyond tier-1 supply chain partners, alongside the ongoing mixing and processing of raw materials and components, poses a challenge for organizations and supply chain networks in achieving traceability and transparency. Consequently, this impedes the acceleration of this transition. To credibly assert the utilization of bio-based and circular materials in products, there is a critical need for a method to effectively track and trace verified raw materials throughout the supply chain life cycle, from processing through to sale to downstream members [SAP, 2023].

This practical implementation of SAP Green Token, a Software-as-a-Service (SaaS) solution designed for mass balance material traceability and transparency. This platform specifically targets commingled and difficult-to-trace raw materials. Leveraging innovative principles such as mass balance, tokenization, and blockchain for chain of custody, SAP Green Token demonstrates its efficacy through an extensive pilot program. This pilot focuses on certified sustainable chemicals and products sourced from bio-circular waste streams, which are indistinguishable from conventionally produced materials and utilized throughout the supply chain. The adoption of bio-circular and certified sustainable materials in place of conventional ones offers the potential to redirect waste currently not reintegrated into the supply chain [SAP, 2023].

6.1.3 Main key findings & outcomes from SAP Green Token pilot

The transformative impact of SAP Green Token is explored through a rigorous pilot program. The key findings and outcomes of this pilot are mainly focused in the pivotal role of SAP Green Token fostering a sustainable and responsible approach to material sourcing and utilization, ultimately driving positive environmental impact and industry-wide transformation of the organizations.

The primary key findings and outcomes derived from the SAP Green Token pilot phase encompassed:

1. Related to mass balance accounting

- SAP Green Token allowed for managing certifications, credits transfer, and other relevant information from a single place in a continuous, automated and secure manner.
- The solution provided validated enforcement of mass balance material accounting rules across the supply chain ensuring claims of sustainable deliveries/inventory were directly tied to tokenized volumes preventing "double counting".
- It ensured that ownership and delivery of sustainable volumes were maintained in an unbroken chain of custody which can be audited at each level of the supply chain.
- SAP Green Token provided automatic generation and transferring of ISCC declarations[6].
- The combination of mass balance accounting and tokenization in the solution is considered a unique value proposition.

2. Related to Traceability and Transparency
    - SAP Green Token successfully handled a complex supply chain network with 7 participating business partners , 9 active sites and multi-sites (online members), and 18 representative tier-1 business partners (offline members).
    - The flexibility of working with online and offline members was proven.
    - The solution proved to be agnostic & run on any operating system to handling different types of materials throughout the supply chain network.
    - The solution ensures reliable supply chain transparency information that can be leveraged to ensure sustainable sourcing; and shared with various types of stakeholders.
    - With the chain of custody backed by the blockchain ledger, the stakeholders had a high degree of confidence and trust in the resulting chain of custody.
    - The SAP Green Token platform offered a secure way to pass ESG information along the supply chain so that only the business partners who needed to see the information had a clear text copy.

[6] The ISCC system documents are the guidelines and instructions for certifications and their requirements. They define the obligations and responsibilities that companies and certification bodies must abide by and lay out the different types of certifications that can be applied for. [ISCC, 2024]

- SAP Green Token leverages a ‘green’ blockchain that uses a similar amount of energy compared to other standard cloud databases and runs on 93 percent of energy from green sources with a low carbon impact.

Once more, the above findings underscore SAP Green Token's capacity to expedite the extended chemical industry's transition towards circular and certified sustainable material utilization. Its status as an industry-agnostic solution signifies its potential applicability across a multitude of raw material supply chains. By leveraging the principles of tokenization, mass balance, and blockchain for chain of custody, SAP Green Token enables visibility of any one or more unique attributes (such as origin, circularity status or carbon footprint) of materials across global supply chain networks.

6.1.4 The two main approaches of SAP Green Token

There are two primary approaches utilized by SAP Green Token:

1. Stand-alone internal solution

SAP Green Token can function independently as an internal solution for managing mass balance accounting and certification compliance. It tracks sustainability data and credits across raw materials, components, and products. The inbound, processing and/or conversion, and outbound flow and data are captured through CSV upload or integration with the ERP system. Tier-1 supply chain partners can be represented in SAP Green Token even if they do not actively participate on the platform (offline members) [SAP, 2023].

2. End-to-End Sustainability & Traceability solution

SAP Green Token can be leveraged as an end-to-end traceability and transparency solution for sustainability data across the supply chain network. By harnessing the power of this solution, organizations can seamlessly track and manage sustainability-related information at every stage of the supply chain journey. This robust platform empowers stakeholders with real-time insights into the origin, composition, and environmental impact of materials, fostering greater accountability and informed decision-making.

Overall, SAP Green Token provides full visibility at all stages on a mass balance level of the materials and their sustainability attributes related to their origin as well as the supply chain flow [SAP, 2023].

6.2 Conclusion

Organizations are progressively realizing the importance of information systems to support sustainability initiatives. They are trying to design and reengineering their business processes so that their activities, products and services are environmentally friendly. In this case, organizations need to align between their sustainability strategy and information system strategy. PTOs are focusing on effective practices, adopting related techniques and establishing information systems that provide comprehensive solutions for waste management. By aligning waste management with their broader sustainability goals, these companies promote a holistic approach to environmental sustainability resource efficiency. In more detail, waste management in electricity distribution is a necessary practice for the protection of the environment and the sustainable development of energy companies. However, organizations still have problems in collecting, integrating and reporting sustainability information. The lack of integration affects the sustainability productivity and effectiveness. To solve this problem, the organizations need to have an integrated information system, such as SAP ERP system. Therefore, SAP ERP system potentially becomes a focus area in solving the integration issues for organizations through sustainability practices.

SAP ERP systems assist an organization to provide complete sustainability data and integrate all sustainability information and processes across business functions. It can be seen as a holistic, integrative and complete solution for industry to solve sustainability business issues. The implementation of SAP Waste Management (WM) and Extended Warehouse Management (EWM) systems offers integrated solutions for waste management. The first one integrates all waste management processes into a single system, providing tools for monitoring and generating compliance reports, while the second one offers solutions for efficient waste management in warehouses, facilitating optimal material flow and inventory management.

By implementing these SAP ERP systems, these companies can automate processes, reduce human error, increase efficiency, ensure compliance with regulations, export related reports and measure useful KPIs to leverage strategy decisions and save resources by optimizing their use and reducing operating costs.

7 Bibliography

- The White House (2021) *Whitehouse President Biden Invites 40 World Leaders to Leaders Summit on Climate*. The White House. Washington, DC, USA. Available at: President Biden Invites 40 World Leaders to Leaders Summit on Climate | The White House [Accessed 3 September 2023]
- Yu, W., Chavez, R., Feng, M. & Wiengarten, F. (2014*) Integrated green supply chain management and operational performance, Supply Chain Management*, Vol. 19, pp. 683–696. Available at: Integrated green supply chain management and operational performance [Accessed 3 September 2023]
- Acar, M.F., Zaim, S., Isik, M. & Calisir, F. (2017) *Relationships among ERP, supply chain orientation and operational performance: an analysis of structural equation modeling. Benchmarking*, Vol. 24, pp. 1291–1308. Available at: Relationships among ERP, supply chain orientation and operational performance: An analysis of structural equation modeling [Accessed 3 September 2023]
- Tarigan, Z.J.H., Siagian, H. & Jie, F. (2021) *Impact of Enhanced Enterprise Resource Planning (ERP) on Firm Performance through Green Supply Chain Management. Sustainability*, Vol. 13, pp. 4358. Available at: Impact of Enhanced Enterprise Resource Planning (ERP) on Firm Performance through Green Supply Chain Management [Accessed 3 September 2023]
- Salam, M.A. (2017) *The mediating role of supply chain collaboration on the relationship between technology, trust and operational performance: an empirical investigation*, Vol. 24, pp. 298–317. Available at: The mediating role of supply chain collaboration on the relationship between technology, trust and operational performance: An empirical investigation [Accessed 3 September 2023]
- Zhang, Q., Zhao, Q. & Zhao, X. (2019) *Manufacturer's product choice in the presence of environment-conscious consumers: Brown product or green product.* Int. J. Prod. Res., China, Vol. 57, pp. 7423–7438. Available at: Manufacturer's product choice in the presence of environment-conscious consumers: brown product or green product: International Journal of Production Research [Accessed 3 September 2023]
- Michael Bamidele Fakoya, Huibrecht Margaretha van der Poll (2013) *Integrating ERP and MFCA systems for improved waste-reduction decisions in a brewery in South Africa*, Journal of Cleaner Production Vol. 40, pp. 136-140. Available at: https://doi.org/10.1016/j.jclepro.2012.09.013 [Accessed 15 October 2023]
- Samaranayakea, P., Laosirihongthongb, T., Chanc, F.T.S. (2011). *Integration of manufacturing and distribution networks in a global car company-network models and numerical simulation.* International Journal of Production Research 49 (11), 3127-3149 [Accessed 15 October 2023]
- Chetty, S. (1996). *The case study method for research in small-and medium-sized firms*. International Small Business Journal 15 (1), 73-85. [Accessed 15 October 2023]
- Samaranayakea, P. (2009). *Business process integration, automation, and optimization in ERP: integrated approach using enhanced process models.* Business Process Management Journal 15 (4), 504-526. [Accessed 15 October 2023]
- Lynch, A.L., Zhu, X. (2011). *Electronic conferencing: understanding computer-mediated systems*. Journal of Corporate Accounting & Finance 22 (4), 77-81. [Accessed 15 October 2023]

- Oikokiklios.gr. *Ευρωπαϊκός Κατάλογος Αποβλήτων Ε.Κ.Α. – Περιγραφή αποβλήτων*. Available at: www.oikokiklios.gr [Accessed 8 December 2023]
- Commission of the European Communities (2010) *Guidance on classification of waste according to EWC-Stat categories.* Supplement to the Manual for the Implementation of the Regulation (EC) No 2150/2002 on Waste Statistics, Version 2. Available at: Table 1: List of waste categories (europa.eu) [Accessed 10 December 2023]
- European Union Law (2001). *Commission Decision: 2001/118/EC.* Available at: Decision - 2001/118 - EN - EUR-Lex (europa.eu). [Accessed 10 December 2023]
- NetRegs. *European Waste Catalogue (EWC) - waste codes.* Environmental guidance for your business in Northern Ireland & Scotland. Available at: European Waste Catalogue (EWC) - waste codes | NetRegs | Environmental guidance for your business in Northern Ireland & Scotland [Accessed 10 December 2023]
- Government of the United Kingdom (2021). *Waste classification technical guidance WM3*. Available at: Waste classification technical guidance WM3.pdf (publishing.service.gov.uk) [Accessed 10 December 2023].
- Luay Anaya, Fadi Qutaishat (2022). *ERP systems drive businesses towards growth and sustainability*. International Conference on Industry Sciences and Computer Science Innovation. Procedia Computer Science 204 (2022) 854–861. Available at: https://doi.org/10.1016/j.procs.2022.08.103 [Accessed 3 January 2024]
- A. G. Chofreh, F. A. Goni, A. M. Shaharoun, S. Ismail, J.J. Klemes (2014). *Sustainable enterprise resource planning: imperatives and research directions.* Journal of Cleaner Production, vol. 71, pp. 139-147. Available at: https://doi.org/10.1016/j.jclepro.2014.01.010 [Accessed 4 January 2024]
- Lubin D.A. & Esty D.C. (2010). *The sustainability imperative*. Harvard Bus. Rev. 88, 42-50. Available at: http://refhub.elsevier.com/S0959-6526(14)00019-5/sref83 [Accessed 4 January 2024]
- Bettencourt L.M.A., Kaur J. (2011). *Evolution and structure of sustainability science*. Proc. Natl. Acad. Sci. U. S. A. 108, 19540e19545. Available at: Evolution and structure of sustainability science | PNAS [Accessed 4 January 2024]
- Elkington J. (1994). *Towards the suitable corporation: win-win-win business strategies for sustainable development*. Calif. Manage. Rev. 36, 90-100. Available at: https://journals.sagepub.com/doi/10.2307/41165746 [Accessed 4 January 2024]
- H. Alhaddi (2015). *Triple Bottom Line and Sustainability: A Literature Review*. RedFame. Available at: Triple Bottom Line and Sustainability: A Literature Review | Alhaddi | Business and Management Studies [Accessed 4 January 2024]
- D. Kiron, N. Kruschwitz, K. Haanaes, I. Von Streng Velken (2012). *Sustainability Nears a Tipping Point*. MIT Sloan Management Review, Vol. 53, Issue 2, Pages 69-74.
  Available at: https://www.scopus.com/record/display.uri?eid=2-s2.0-84856880212&origin=inward [Accessed 4 January 2024]
- M.C Boudreau, A. Chen, M. Huber (2008). *Green IS: Building Sustainable Business Practices*. R.T. Watson (Ed.), Information Systems. A Global Text, pp. 1-17. Available at: Green IS: Building Sustainable Business Practices [Accessed 4 January 2024]

- A.R. Al-Ali, A. El-Hag, M. Bahadiri, M. Harbaji, Y. Ali El Haj (2011). *Smart home renewable energy management system*. Energy Procedia. Vol. 12, pp. 120-126. Available at: https://doi.org/10.1016/j.egypro.2011.10.017 [Accessed 4 January 2024]
- M.D. Ahmed, D. Sundaram (2012). *Sustainability modelling and reporting: from roadmap to implementation.* Decision Support Systems. Vol. 53, Issue 3, pp. 611-624.
  Available at: https://doi.org/10.1016/j.dss.2012.02.004 [Accessed 4 January 2024]
- D.S. Markovic, D. Zivkovic, I. Branovic, R. Popovic, D. Cvetkovic (2013). *Smart power grid and cloud computing*. Renewable and Sustainable Energy Reviews. Vol. 24, pp. 566-577. Available at: https://doi.org/10.1016/j.rser.2013.03.068 [Accessed 4 January 2024]
- S. Brooks, X. Wang, S. Sarker (2012). *Unpacking green IS: a review of the existing literature and directions for the future.* Green Business Process Management, pp. 15-37.
  Available at: Unpacking Green IS: A Review of the Existing Literature and Directions for the Future [Accessed 4 January 2024]
- L. L. Chuma (2020). *The Role of Information Systems in Business Firms Competitiveness: Integrated Review Paper from Business Perspective.* International Research Journal of Nature Science and Technology, Vol. 2 Issue 4. Available at: The Role of Information Systems in Business Firms Competitiveness: Integrated Review Paper from Business Perspective [Accessed 10 February 2024]
- A. G. Chofreh, F.A Goni, J. J. Klemeš (2018). *Sustainable enterprise resource planning systems implementation: A framework development.* Journal of Cleaner Production, Vol. 198, pp. 1345–1354. Available at: Sustainable enterprise resource planning systems implementation: A framework development - ScienceDirect [Accessed 10 February 2024]
- M. Lachance (2023). *How Software Can Make Managing Waste Easier*. Cority. Available at: How Software Can Make Managing Waste Easier [Accessed 12 February 2024]
- US EPA | United States Environmental Protection Agency (2023). *Human Health & Environmental Impacts of the Electric Power Sector*. Available at: Human Health & Environmental Impacts of the Electric Power Sector | US EPA [Accessed 2 March 2024]
- H. Fengping & G. Yongming (2021). *Impacts of electricity generation on air pollution: evidence from data on air quality index and six criteria pollutants.* Discover Applied Sciences, Vol. 3, Article number 4. Available at: Impacts of electricity generation on air pollution: evidence from data on air quality index and six criteria pollutants | Discover Applied Sciences [Accessed 2 March 2024]
- M. M. Curmei & C. Kurrer (2023). *Environment policy: general principles and basic framework.* European Parliament. Available at: Environment policy: general principles and basic framework | Fact Sheets on the European Union | European Parliament [Accessed 6 March 2024]
- European Commission. *Industrial emissions and safety.* Available at: Industrial emissions and safety - European Commission [Accessed 6 March 2024]
- European Commission. *Industrial Emissions Directive.* Available at: Industrial Emissions Directive - European Commission (europa.eu) [Accessed 6 March 2024]

- United States environmental Protection Agency. *Sulfur Hexafluoride (SF6) Basics.* Available at: Sulfur Hexafluoride (SF6) Basics | US EPA [Accessed 7 April 2024]
- European Commission. *About F-gases.* Available at: About F-gases - European Commission (europa.eu) [Accessed 7 April 2024]
- UNECE | Sustainable Development Goals. *About the ADR.* Available at: About the ADR | UNECE [Accessed 10 April 2024]
- SAP (2023). *The Power of Tokenization. A new mass balance approach to accelerate sustainability, traceability, and transparency in chemical & plastics supply chain networks.* White paper.
- ISCC (2024). *ISCC System and Guidance Documents.* Available at: ISCC Documents – ISCC System (iscc-system.org) [Accessed 14 April 2024]
- SAP (2023). *Material Traceability for Increased Circularity in the Chemical Industry. A blockchain-based mass balance approach using SAP Green Token.* White paper.
- SAP (2023). *Waste Management (EHS-SUS-WA).* Available at: Waste Transportation Documents | SAP Help Portal [Accessed 6 June 2024]
- SAP EWM100 (2021). *Processes in SAP Extended Warehouse Management*. Official Training Handbook
- Ministry of Environment and Energy of Greece (2024). *F-GASES & ODS Monitoring Information System.* Available at: Πληροφοριακό Σύστημα Παρακολούθησης F-GASES & ODS - (ypen.gov.gr) [Accessed 18 June 2024]
- Redeia (2024). *Sustainability Report 2023.* Available at: Sustainability Report 2023 | Redeia [Accessed 30 June 2024]
- Elia Group (2024). *Integrated annual report 2023: Fully charged for change. Electrifying the net-zero movement.* Available at Elia Group's 'Integrated annual report 2023 by Elia Group - Issuu [Accessed 30 June 2024]
- Statnett (2024). *Annual and Sustainability Report 2023. Accelerating the green transition.* Available at: Annual and Sustainability Report 2023 (statnett.no) [Accessed 30 June 2024]
- Terna (2024). *Annual Report – Integrated Report 2023.* Available at: Annual Report – Integrated Report 2023 (terna.it) [Accessed 30 June 2024]
- National Grid (2024). *Delivering the energy transition now. Responsible Business Report.* Available at: NG_RBR_2023_2024.pdf (ournationalgrid.com) [Accessed 30 June 2024]
- National Grid (2020). *Responsible Business Charter 2020*. Available at: National Grid Responsible Business Charter 2020 US (nationalgridus.com) [Accessed 30 June 2024]