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Sustainability in Supply Chain Management

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Sustainability in Supply Chain Management

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Abstract

The increasing need to address climate change has turned sustainability to a prioritized aspect of the global Supply Chains. The complexity of the modern supply chains, the international interconnection of industries and suppliers make the transition to greener supply chains a challenge. Companies are struggling to maintain their transparency about their emissions, so they try to monitor and report their data with the help of either technology, official guidelines from regulatory bodies and initiatives that are formed for this cause.

Supply chains are a huge contributor to Greenhouse Gas Emissions (GHG), so the understanding of the current situation, the tools and strategies that can lead to the minimization of the carbon footprint is of high importance. This thesis highlights the importance of supporting financial mechanisms and environmental framework that shapes the path to less carbon dependent supply chains, with a focus on European Regulatory Framework and green energy initiatives. Flexibility and agility in distribution systems and productions are critical enablers, allowing supply chains to react immediately and adapt to the constant changes of the market, being able to address their sustainability issues and work towards greener solutions throughout their supply chain.

As part of the Renewable Energy necessity in contemporary Supply Chains, we simulated the installation of a PV plant in an online PV system design platform (Huawei's Fusion Solar Smart Design) as part of corporate sustainable practices, to better understand the economic and environmental impacts. Through the case study of Merck Company and their supply chain, this thesis emphasizes a real world example of sustainable supply chain practices, by incorporating their Suppliers Code of Conduct and emissions monitoring.

By combining findings from Literature, Regulations and Simulation, this thesis examines ideas of how to form a framework where sustainability in supply chains can grow and supply chains can transform to a greener version.

Keywords

Sustainability, Flexibility, GHG emissions, European Regulatory Framework, Green energy

Περίληψη

Η αυξανόμενη ανάγκη αντιμετώπισης της κλιματικής αλλαγής έχει μετατρέψει τη βιωσιμότητα σε μια προτεραιότητα για τις παγκόσμιες Εφοδιαστικές Αλυσίδες. Η πολυπλοκότητα των σύγχρονων εφοδιαστικών αλυσίδων, η διεθνής διασύνδεση βιομηχανιών και προμηθευτών καθιστούν πρόκληση τη μετάβαση σε πιο πράσινες αλυσίδες εφοδιασμού. Οι εταιρείες αγωνίζονται να διατηρήσουν την διαφάνεια σχετικά με τις εκπομπές τους, γι' αυτό προσπαθούν να παρακολουθούν και να κάνουν τον απολογισμό των δεδομένων τους με τη βοήθεια της τεχνολογίας, επίσημων οδηγιών από ρυθμιστικούς φορείς και πρωτοβουλιών που έχουν δημιουργηθεί για αυτόν τον σκοπό.

Οι εφοδιαστικές αλυσίδες συμβάλλουν σημαντικά στις Εκπομπές Αερίων Θερμοκηπίου, επομένως η κατανόηση της τρέχουσας κατάστασης, των εργαλείων και των στρατηγικών που μπορούν να οδηγήσουν στην ελαχιστοποίηση του αποτυπώματος άνθρακα είναι μεγάλης σημασίας. Η διατριβή αυτή, υπογραμμίζει τη σημασία της υποστήριξης μέσω χρηματοοικονομικών μηχανισμών και περιβαλλοντικών πλαισίων που διαμορφώνουν την πορεία προς λιγότερο εξαρτώμενες από τον άνθρακα εφοδιαστικές αλυσίδες, με έμφαση στους ευρωπαϊκούς νόμους και κανονισμούς και τις πρωτοβουλίες πράσινης ενέργειας. Η ευελιξία των συστημάτων διανομής και παραγωγής είναι ένας κρίσιμος παράγοντας που επιτρέπει στις εφοδιαστικές αλυσίδες να αντιδρούν άμεσα και να προσαρμόζονται στις συνεχείς αλλαγές της αγοράς, να είναι σε θέση να αντιμετωπίσουν τα ζητήματα βιωσιμότητας και να εργαστούν προς πιο πράσινες λύσεις σε όλα τα κομμάτια της αλυσίδας.

Για να τονίσουμε την ανάγκη για ενσωμάτωση Ανανεώσιμων Πηγών Ενέργειας στις σύγχρονες Εφοδιαστικές Αλυσίδες, προσομοιώσαμε την εγκατάσταση μιας φωτοβολταϊκής εγκατάστασης μέσω μιας διαδικτυακής πλατφόρμας σχεδιασμού φωτοβολταϊκών συστημάτων (Huawei's Fusion Solar Smart Design) ως πρόταση εταιρικής βιώσιμης πρακτικής, καταλήγοντας σε συμπεράσματα για τις σχετικές οικονομικές και περιβαλλοντικές επιπτώσεις της επένδυσης. Μέσα από την μελέτη περίπτωσης της εταιρείας Merck κα της εφοδιαστικής της αλυσίδας, αυτή η διατριβή δίνει έμφαση στα παραδείγματα πρακτικών βιώσιμων εφοδιαστικών αλυσίδων, ενσωματώνοντας τον δικό τους Κώδικα Δεοντολογίας Προμηθευτών και

παρακολουθώντας τις εκπομπές αερίων του θερμοκηπίου που σχετίζονται με τις δραστηριότητες τους.

Συνδυάζοντας ευρήματα από τη βιβλιογραφία, τους κανονισμούς και δεδομένα προσομοίωσης, η διατριβή αυτή εξετάζει ιδέες για το πώς να διαμορφωθεί ένα πλαίσιο όπου η βιωσιμότητα στις αλυσίδες εφοδιασμού μπορεί να αναπτυχθεί και οι αλυσίδες εφοδιασμού να μετατραπούν σε πιο πράσινες.

Λέξεις – Κλειδιά

Βιωσιμότητα, Ευελιξία, Εκπομπές αερίων Θερμοκηπίου, Ευρωπαϊκό Ρυθμιστικό Πλαίσιο, Πράσινη ενέργεια

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List of Abbreviations & Acronyms

Advanced Manufacturing Technologies	AMT
Alternating Current	AC
Automated Machine Learning	Auto ML
Carbon Border Adjustment Mechanism	CBAM
Carbon Dioxide	CO2
Carbon-Aware Control	CAC
Chlorofluorocarbon	CFCs
Commercial and Industrial	C&I
Conference of the Parties	COP
Contracted Remanufacturers	CR
Corporate Sustainability Reporting Directive	CSRD
Data Quality Ratings	DQRs

Day Ahead Market	DAM
Direct Current	DC
Environmental Performance	EP
Environmental Social Governance	ESG
EU Emissions Trading System	EU ETS
European Commission	EC
European Environment Agency	EEA
European Sustainability Reporting Standards	ESRS
European Union	EU
Flexible Manufacturing Systems	FMS
Flexible Production Rate of	FPR
Fluorinated ethers	HFEs
Global Goal on Adaptation	GGA
Global Reporting Initiative	GRI
Global Warming Potential	GWP
Green Distribution	GD
Green Information System	GIS
Green Manufacturing	GM
Green Product Designing	GPD
Green Purchasing	GP
Greenhouse Gas	GHG
Hydrochlorofluorocarbon	HCFCs
Hydrofluorocarbons	HFCs
Independent Remanufacturers	IR
International Financial Reporting Standards - Sustainability disclosure standards 1 / 2	IFRS S1 / S2
Life Cycle Sustainability Assessment	LCSA
Nitrogen triflouride	NF

Nitrous Oxide	N2O
Original Equipment manufacturers/Remanufacturers	OEM/OERs
Perfluorocarbons	PFCs
Perfluoropolyethers	PFPEs
Photovoltaic	PV
Product Carbon Footprint	PCF
Renewable Energy Sources	RES
Responsible Minerals Initiative	RMI
Reverse Logistics	RL
Small and Medium-sized Enterprises	SMEs
Sulphur hexafluoride	SF6
Supplier Code of Conduct	SCoC
Supply Chain Flexibility	SCF
Supply Chain Management	SCM
Sustainable Supply Chain	SSC
Sustainable Supply Chain Management	SSCM
Sustainable Supply Chain Management Practices	SSCMPs
The Partnership for Carbon Transparency	PACT
Primary Data Share	PDS
United Nations Framework Convention on Climate Change	UNFCCC
World Business Council for Sustainable Development	WBCSD

Chapter 1. Introduction

Sustainability is becoming a priority in companies' strategic plans as they try to balance environmental, social and economic issues. Firms focus on Sustainable Supply Chain Management (SSCM), as part of their corporate innovation agenda, by improving awareness of environmental protection and social responsibility. Negative effects of environmental, social and economic matters affect not only the company but also all members of the supply chain. So, SSCM processes shall be implemented not only internally but also for the management of the entire supply chain. Many organizations still struggle to manage their supply chains in such ways that are not only financially sustainable but also environmentally sustainable and socially responsible.

Although, companies are trying to stay informed about latest sustainability regulations, guidelines and practices, keeping up is not an easy task. Therefore, the main purpose of this thesis is to provide the framework and practices that enable sustainability in a supply chain. We will try to better understand the role of sustainability in Supply Chain Management (SCM) by exploring the Environmental, Social and Governance Framework that sets the guidelines, regulations, initiatives and laws on environmental issues. We will focus more on the Environmental European Regulatory Framework. The European Green Deal, The European Climate Law and the Corporate Sustainability Reporting Directive (CSRD) are included in this regulatory framework. We will also discuss the targets set by the UN Framework Convention on Climate Change Conference of Parties (COP29). We will try to highlight the basic areas where companies shall focus their interest to manage a Sustainable Supply Chain (SSC). This thesis, examines how sustainability is being incorporated into SSCM and how the adoption of Sustainable Supply Chain Management Practices (SSCMPs) help companies and their supply chains maintain a low environmental impact. Furthermore, by exploring the case study of Merck, we aim to identify what made Merck's SSCM successful and can be used by other companies as an example to manage their own supply chains by achieving sustainability. Last but not least, we give an example of a company considering installing a solar system by presenting a simulation of the potential investment. The environmental and financial benefits of the investment that we identify through the simulation as much as the investment consideration itself can be beneficial for companies that want to achieve sustainability by incorporating Renewable Energy Sources (RES) in their business.

The main findings of this thesis are the results from the Photovoltaic (PV) system simulation, as it supports the investment in Renewable Energy Sources as a sustainability practice. Moreover, the Merck case study highlighted some successful practices that can lead companies and their supply chains to achieve sustainability. The conclusions from this case study show that sustainability shall be incorporated in such ways that they engage all supply chain parties. One of Merck's main successful steps to sustainability is the adoption of Merck's Supplier Code of Conduct.

One of the limitations of this dissertation is the price assumption regarding selling and buying prices of energy that we used in our simulation. This is something that the potential investor shall know as these prices change every day and are defined by the Day Ahead Market (DAM) which is an electricity market. Another main limitation is that there were not many articles to support the role of flexibility as an enabler of sustainability. We based our bibliographical research on the few available articles that connect flexibility and sustainability.

The dissertation consists of nine chapters, including Introduction. The second chapter discusses SSCM and SSCMPs and the challenges that companies face when trying to adopt them. The third chapter presents the European and International Regulatory Framework for Sustainability and the fourth chapter introduces the Environmental, Social and Governance (ESG) framework with its standards and principles. In the fifth chapter we discuss Greenhouse Gas emissions Greenhouse in order to highlight the role of supply chains in generating emissions and how sustainability can minimize them. In chapter six we examine the role of Renewable Energy Sources (RES) in the sustainability of supply chains as we explore how the deployment of non conventional sources can benefit the supply chain. To support investment in RES, we will present in the same chapter a simulation of installing a Photovoltaic System as a corporate practice to achieve sustainable results, by using Huawei's Fusion Solar simulation program.

Seventh Chapter explores Flexibility as we try to identify what makes flexibility an enabler of sustainability, what the possible challenges of flexibility may be and emphasize processes like manufacturing, remanufacturing and Industry 4.0 technologies. In the eighth chapter we analyze the case of Merck and its approach to sustainability by highlighting the best sustainable practices and how a company can balance environmental and social responsibility without compromising their economic growth. In the last chapter, we discuss the conclusions of this thesis.

Our research is based on literature review in chapters one to seven. To explore the benefits of a company investing in RES, we will use an online program to simulate the installation of a solar system. A case study is presented in the last chapter, to identify the successful practices that Merck adopted to achieve sustainability in its supply chain.

Chapter 2. Sustainable Supply Chain Management

Sustainable Supply Chain Management (SSCM) has grown increasingly important, as governments, businesses and society shift toward greener or more ethical practices, aiming to create positive environmental and social impacts. According to Ortas et al. (2014), SSCM is the set of skills and leverages that allow the company to develop its business processes in such ways that promote sustainable performance. Pagell and Gobeli (2009) refer to SSCM as the set of practices and activities that integrate environmental and social issues into Supply Chain Management (SCM) in order to improve performance on these issues without trading off economic performance (Wang and Dai, 2018). Sustainability has evolved from being perceived as a costly obligation to becoming a strategic driver of competitive advantage, essential for a company's long-term viability and success in today's business landscape. (Mahler and Kearney, 2007). Businesses nowadays promote sustainable practices that emphasize economic development, environmental management and social wellbeing and put in place specific and concise sustainability strategies for internal operations and external relations (Mahler and Kearney, 2007).

Companies operating within the European Union (EU) are increasingly integrating sustainability into their corporate identity, driven by regulatory frameworks and the growing emphasis placed on sustainability by both EU authorities and European society. EU supports sustainability with laws and policies, as it will be discussed thoroughly in the chapter of the European Regulatory Framework about Sustainability and society is always informed and highly aware of any environmental threats, opportunities, latest technologies and search for transparency on these issues. In EU member-states where environmental concerns are prominent, and both society and regulatory authorities exert pressure on companies to adhere to sustainability guidelines, the pursuit of a sustainable corporate identity becomes a top priority (Alzubi and Akkerman, 2022). The market and legislative pressure to adopt SSCMPs shifted businesses' focus on forming relative strategies that can either be compliance strategies or voluntary strategies. By having a compliance strategy the enterprise adopts SSCMPs to follow rules and regulations whereas by having a voluntary strategy they adopt SSCMPs to gain competitive advantage (Alzubi and Akkerman, 2022). The selection of one of the two different strategies is a corporate decision on whether they will react when necessary actions are required or be proactive. As the environmental regulation framework is constantly extending, making it clear that sustainable goals and preservation of the environment are here to stay, being proactive is linked to enhanced competiveness, reputation, improved product quality and reduced energy costs by using renewable energy. Many initiatives or guidelines that are not yet mandatory show the company the way to gain an outstanding position among its competitors and improve their company image. Their early adoption places the company one step ahead by giving them the opportunity to create a well prepared business strategy that incorporates updated SSCMPs and has sustainability as a core value. Moreover, voluntary adaptation of SSCMPs shows the actual engagement to the concept of sustainability that will engage stakeholders and attract possible investors (Alzubi and Akkerman, 2022).

Sustainable Supply Chain Management Practices

Sustainable Supply Chain Management Practices (SSCMPs) shall be integrated into corporate culture in order to minimize the adverse effect of their activities on social and environmental issues while trying to maximize their financial performance and market domination (Mugoni et al., 2024; Acquah et al., 2020; Panigrahi et al., 2018). SSCMPs incorporate environmental thinking from the initial stages of the product design process to the end of life management (Acquah et al., 2020). SSCMPs need to be adopted by the firm, customers and suppliers in order to achieve improved performance and less negative environmental effects. According to Busse et al. (2016), the successful adoption of SSCMPs is a challenge as internal or external individuals through many stages of the supply chain can affect overall performance. The most powerful external member is the supplier, and its sustainability risks are inextricably linked to the company and have a direct negative effect on it. Strategic plans and agendas should extend from just internal management to managing supply partners too. Supply chain partners should be monitored and assessed for not only their performance on financial or quality aspects but also for their environmental and social identity and how this identity can affect the company. In previous years, supply managers were searching for input by considering the lowest market price and a good balance of price and quality. Nowadays, this belief has changed and supply managers are also considering the social and environmental risks that come with the lowest market price. They foster sustainability by ensuring that their suppliers are also following the same sustainable practices and share the same environmental and social goals. They stop focusing solely on achieving the best financially wise supplier deal and they work towards selecting suppliers whose corporate identity on ethical and environmental issues is aligned with the company's values. SSCM has the potential to shape a corporate identity that prioritizes environmental sustainability and social responsibility by adopting new technologies and processes that promote innovation on sustainability and evaluate potential supplier partners on the same issues (Mahler and Kearney, 2007).

According to Mugoni et al. (2024), environmental performance is highly influenced by six SSCMPs, Green Purchasing (GP), Green Manufacturing (GM), Green Product Designing (GPD), Green Distribution (GD), Green Information System (GIS) and Reverse Logistics (RL).

- Green Purchasing (GP) can be defined as a purchasing practice that aims to reduce sources of waste and recycle procured materials (Narasimhan and Schoenherr, 2012). GP ensures that procurement policies take into consideration environmental matters and comply with environmental standards, to source reusable and harmless components and materials. Suppliers are being assessed internally on environmental criteria for their Environmental Performance (EP). Purchasing activities and environmental objectives shall be aligned in order to have green processes. The green procurement strategy enables the company to provide suppliers with design specifications of the procured materials that meet the environmental criteria. The company can suggest environmental related improvements to the suppliers, which will improve both parties' performance (Mugoni et al., 2024).
- Green Manufacturing (GM) refers to the set of processes that minimize the environmental impact of manufacturing at all of its stages. GM focuses on minimizing resource usage by focusing on green design, green packaging, recycling, redesigning and remanufacturing. Cleaner process technologies are being used and lean production systems are being selected. GM takes into consideration the whole life circle of the product and promotes the green energy like solar energy for environmentally friendlier manufacturing processes with less harmful effects (Mugoni et al., 2024). The five main fields of Sustainable manufacturing are system optimization (for flexible, efficient, utilized manufacturing systems), the use of renewable energy for production processes, energy efficient systems, processes which lower waste and reduce cause of pollution, optimization of production systems using simulation techniques. The main objective of sustainable manufacturing is to create an optimized production cycle and life cycle for the manufacturing systems (Ojstersek and Buchmeister, 2020)
- Green Product Designing (GPD) is defined as the decisions and actions taken when developing a product that aim at reducing the environmental effect of the product during its whole life circle. By considering greener at the initial stage of developing a product, SSCM objectives are clear and strong and ensure that the whole business woks towards this cause and share the same environmental concerns. Green product design can be a challenge as new environmental regulations may create opportunities but also threats especially when the company is in a transitional stage of switching technologies or production lines to better suit the latest

environmental trends or policies. Product development is based on the selection of harmless materials and design processes are optimized to reduce waste and emissions (Mugoni et al., 2024).

- Green Distribution (GD) refers to the movement of goods from the producer to the consumer that has the least negative environmental impact. GD includes warehouse processes, packaging and any means of transformations used to carry and move the goods (Mugoni et al., 2024).
- Green Information System (GIS) refers to the use of information systems and technology to promote sustainability and minimize the emissions from the business operations. From greener software and hardware selection to sustainable data centers and data analytics, GIS are one of the most important strategic initiatives (Mugoni, et al., 2024; Thibodeau ,2007).
- Reverse Logistics (RL) is a catalyst of the circular economy as it promotes sustainable management of product life circles and ensures that products and resources are reused, recycled as long as feasible (Sonar et al., 2024).

Challenges for Sustainable Supply Chain Management

The treatment of complex networks in order to deal with sustainable issues and manage a Sustainable Supply Chain is gaining more and more importance either by the growing society's awareness towards environmental and ethical issues or by the governmental decisions that promote the concept of sustainability by legislating laws and forming regulations and initiatives (Barbosa-Póvoa et al., 2018). Companies are setting high expectations for sustainable supply chains, yet cannot make such progress in the implementation part as they are not able to take the right measure to support the necessary actions. One of the main reasons related to failing implementing sustainability is the complexity of the sustainability concept itself and how it shall be managed amongst the different entities of the organization. Furthermore, the Regulatory Framework regarding sustainability is becoming more and more extensive, with new initiatives, guidelines, laws, with different methods for each sector, adding complexity to the implementation of sustainability. Companies are sometimes unable to identify which is the best practice to use in their case and thus left discouraged (Barbosa-Póvoa et al., 2018). Another significant challenge in implementing sustainability within the Supply Chain is the complexity of global Supply Chains. The framework of gloabalization is linked to several key challenges in SCM, such as the volatility of the external environment, risk management difficulties, a lack of comprehensive managerial expertise and the complexity of supply chain performance evaluation (Li, 2024).

The uncertainty that comes from the external environment can be due to political risks, natural disasters, climate change, pandemics or other international situations that disrupt supply chains, productions and operations of businesses and have an impact on their stability (Li, 2024).

The management of risks can be either internal or external risks. The risks that are within the supply chain are linked to procurement or logistics disruptions, material planning, warehouse management etc. As stated previously, external risks, outside the supply chain can be market uncertainty, political situations, disasters etc. Managing these risks is difficult as these risks are uncontrollable and require the consideration of many factors. Some of these factors are sales, suppliers, inventory etc. (Li, 2024). These risks can have a negative effect on managerial decisions about sustainability and disrupt the sustainable performance of the supply chain.

Supply chain Management requires knowledge and skills in many fields such as production, logistics, planning, quality control, legal frameworks etc. This means that there is a high demand for general management talents. These talents shall also be supported by corporate mechanisms that help them work across departments (Li, 2024). SSCM needs a wholesome perspective of the company and its capabilities in order to form the environmental and social targets.

The Supply Chain Performance Evaluation needs to consider many factors such as quality, on time delivery, costs, customer satisfaction etc. This means that many different departments need to be involved in this evaluation process, adding to the complexity factor. Moreover, the asymmetry of the information and the uncertainty in the supply chain increase this difficulty (Li, 2024). Sustainable performance evaluation is not an easy task as evaluation metrics include information and data coming from different suppliers or different departments.

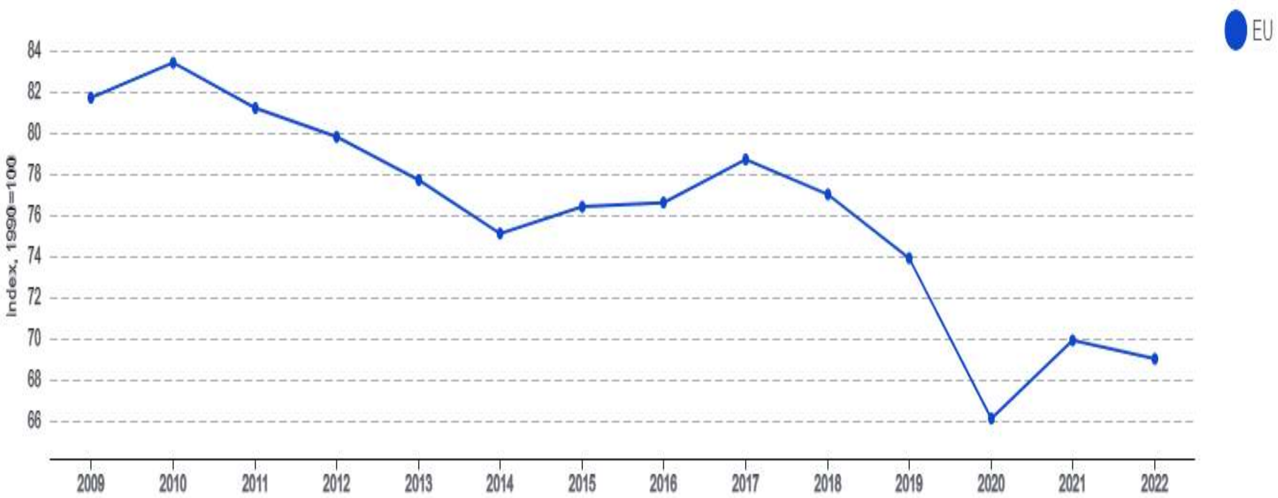
Chapter 3. European and International Regulatory Framework about Sustainability

In order to stay ahead of future needs and true to its incentives and goals for achieving sustainability, the European Union has formed a specific and strict regulatory framework. These regulations aim at promoting sustainability and address challenges regarding climate change, resource efficiency and other aspects of sustainability. Below are some of the most important key European Regulations related to sustainability.

The European Green Deal

The European Green Deal is a growth strategy, set in 2019, that promotes investments related to clean energy and circular economy so that the European Union can face the challenge of climate change and environmental threats. It was one of the six Commission's priorities for 2019-2024. The basic concept of this Deal is to ensure that by 2050, Europe will be the first continent with zero carbon emissions, otherwise known as climate neutral. 2021 was the year that EU adopted its first climate law and set the target of reducing its carbon emissions by 2030 by 55 % compared to 1990. Figure 1 shows the Greenhouse gas emissions reduction from 1990 to 2022 (European Commission, n.d.).

Figure 1: Greenhouse gas emissions (Index, 1990=100)

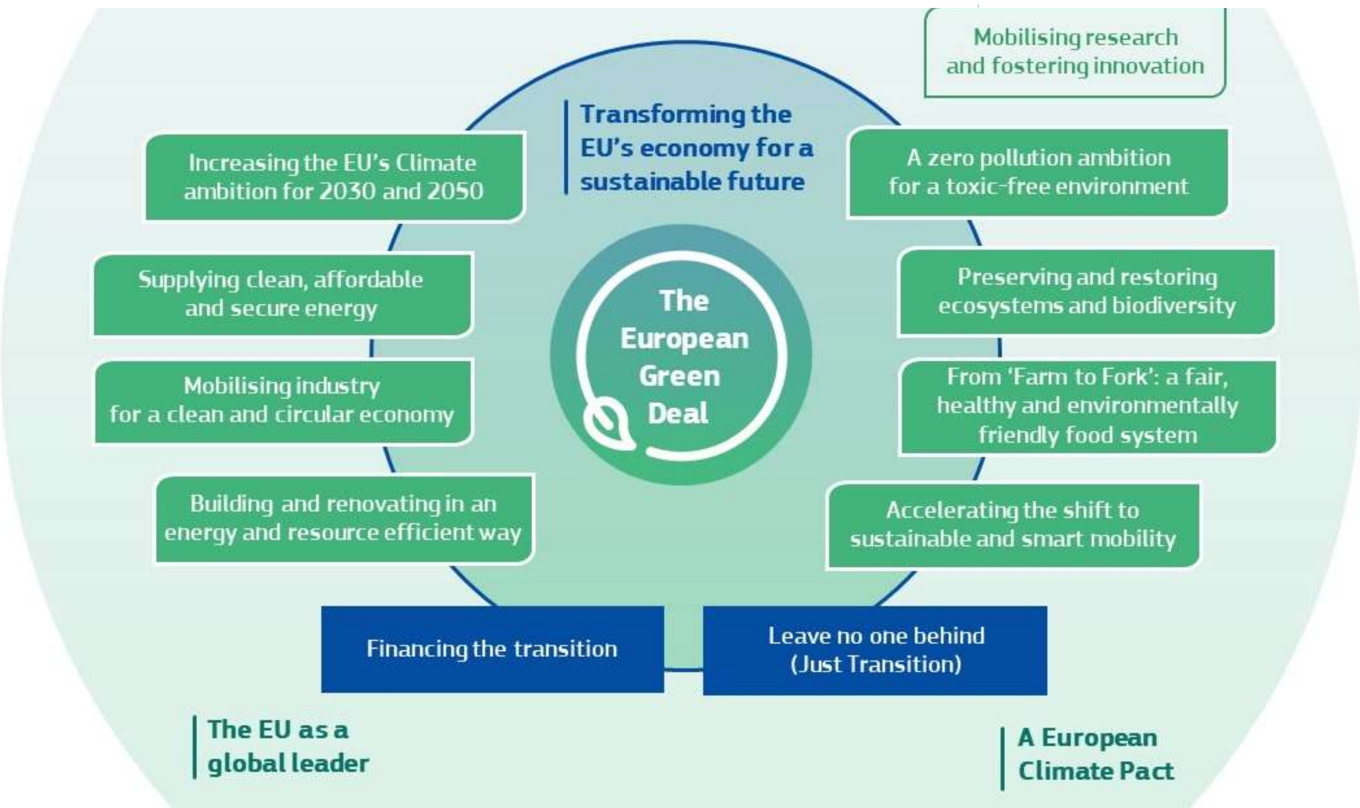


Source: Eurostat, European Environment Agency (EEA)

In 2024 the commission proposed an extra 90% reduction by 2040. The process of working towards a clean transition is accompanied by support funds for fair working and for people affected by climate change, such as the Just Transition Fund and the Social Climate Fund. Funds, such as the NextGenerationEU and REPowerEU secure investments of 275 € billions on green investments and 118 € billions are secured until 2027 by the Cohesion Policy. Climate and economic growth are linked, so EU developed the European Green Deal Industrial Plan, which aims to increase EU's manufacturing capacity for technologies, or products that promote the environmental and climate targets. This industrial plan consists of four pillars that secure innovation with the use of green technologies. The first pillar is the simplification of the regulatory framework so that raw materials are secured and users can actually benefit from renewable energy. There are three initiatives to support this cause, Net Zero Industry Act, Critical Raw Materials Act and Reform of Electricity Market Design. The Net Zero Industry Act will increase the clean energy European manufacturing capacity by 40% of annual deployment by 2030 and will support net zero technologies which will make Europe energy independent. The European Critical Raw Materials Act supports the sustainable supply of Raw Materials (e.g gallium (Ga) used for the production of solar panels, Boron (B) necessary for wind technologies etc.). This act works towards securing that EU will become less dependent on single country import suppliers, will strengthen domestic supply chains and create partnerships with third countries that will equally benefit both parties. Specific targets for domestic capacity that shall be reached by 2030 are: 10% of EU's annual needs for extraction, 40% for processing and 25% for recycling. The Electricity Market Design is developed to secure affordable energy supply across Europe. The energy market rules set for this cause will keep volatility of the energy prices under control and monitor the transparency and efficiency of the energy market needs. The related EU legislation to support the development of the Energy Market Design are the Electricity Directive 2024/1711 and the Electricity Regulation 2024/1747 which focus on and protect the consumer during the energy transition, The ACER Regulation 2019/942, is the Agency for the Cooperation of Energy Regulators, which acts as an independent body that coordinates the actions of European energy regulators, monitor activities to prevent market manipulation advise EU institutions regarding security of supplies or energy infrastructures, REMIT Regulation (EU/1227/2011), is the Wholesale Energy Market Integrity and Transparency Regulation that secures electricity and natural gas markets' integrity and ensures that customers and market participants will not be overcharged with unfair prices drawn by market abuse, the Revised Renewable Energy Directive (EU/2023/2413) to support the flexibility of the energy system, storage systems and secure stable prices. The second pillar of the Industrial Plan aims at speeding up investments and financing for net zero energy across Europe by granting fast track aid to EU state members with new or even existing EU funds which will support the green transition. The third pillar is the enhancement of the necessary skills to make green transition easier. The new technologies developed for clean energy create the need of advanced skilled workers that can support the processes. This means that Commission has to develop Academies and skilling programs, secure public and private funding for skills development and make the EU market accessible to third country national skilled workers. The fourth pillar is facilitating open and fair trade by developing the EU's network of Free Trade Agreements and protects the green energy transition from unfair trade practices (European Commission, n.d.).

Figure 2 below highlights the various elements of the Green Deal (European Comission, n.d.)

Figure 2: The European Green Deal



Source: European Comission (EC)

The European Climate Law

The European Climate Law was established in July 2021 to legally support the European Green Deal goals and make Europe climate neutral by 2050. It ensures that Climate targets are not just political statements but legal binding obligations. It also ensures that all EU policies contribute to achieving net zero green house gas emissions across Europe, by integrating efforts across various economic sectors, including energy, transport industry, agriculture, while promoting investments in clean technologies and environmental protection. Its main objectives are setting a long term direction that will secure and make climate neutrality irreversible, monitor the progress and make adjustments when necessary, provide predictability for all economic participants of the green transition (European Commission, n.d.).

Specifically, it sets an intermediate goal of reducing GHG emissions by at least 55% by 2030 in comparison with the levels of 1990. It also introduced a carbon budget that minimizes the GHGs EU can emit until 2050 and boosted the role of the European Environment Agency (EEA) as a monitoring body. The compliance to the Law must be reviewed every 5 years and necessary adjustments shall be proposed in case of non compliance EU member states are obliged to adopt national energy and climate action plans to achieve goals set by the EU. The European Climate Pact was established to engage citizens, businesses and governments in climate action (European Commission, n.d.).

The Renewable Energy Directive

The Renewable Energy Directive was introduced in 2009 (2009/28/EC) to help the development of clean energy across all economic sectors of the EU by providing the necessary legal framework. The consumption of green energy has approximately doubled since the application of the Directive from 12,5% in 2010 to 24,5% in 2023. The initial binding renewable target of the Directive was 20% by 2020 and the Revised Renewable Directive EU/2018/2001 introduces a new higher target of at least 32% by 2030. EU is considered to be a global leader in the Renewable Energy Sector and is mainly independent regarding external suppliers as the green energy can be produced inside EU at a relatively low cost. 2019 was the year that power production from solar and wind surpassed coal, which was a milestone for the EU (European Commission, 2024.). The Fit for 55 package, is a European Commission's (EC) set of proposals that aim to reduce greenhouse gas emissions by at least 55% by 2030. This package's goal is to keep EU legislation updated and create new initiatives that will ensure the alignment of European Policies with legislated climate goals (European Council, 2024.). In 2021, the European Council (EC) proposed the Revision of the Renewable Directive and an even higher target of 40% consumption of green energy. As geopolitical risks escalated in 2022 due to the invasion of Russia in the Ukraine, the dependence of EU on fossil fuels had to be minimized as much as possible, to secure the energy future of Europe. In this context, EC proposed a binding target of at least 42,5% and efforts for even 45%, which was legislated with the 2023 Revises Renewable Directive EU/2023/2413 (European Commission, n.d.).

The Corporate Sustainability Reporting Directive (CSRD)

The Corporate Sustainability Reporting Directive (CSRD) was proposed in 2021 and was officially legislated in 2022, Directive 2022/2464, as a part of the European Green Deal and it promotes transparency and accountability in corporate sustainability practices. Market participants must comply with the obligations of the Directive and report their ESG practices. The Directive updated and strengthened the rules regarding the social and environmental information that shall be reported by companies. Large companies and Small and Medium sized Enterprises (SMEs) (SMEs will start report from 2026) as well as some non EU companies that have profits over € 150 million on EU market have to report on sustainability and provide data about their financial risks and opportunities that emerge from climate change which be helpful for investors and stakeholders and also information on how they impact society and the environment. The first companies will have to publish their 2025 Report by following the rules of the Directive during the financial year of 2024. The reports will be formed according to the European Sustainability Reporting Standards (ESRS). ESRS are mandatory common standards that shall be followed in order to manage and communicate reported information regarding sustainable performance in a comprehensive way that can be conceived, comparable and used by all interested involved parties. Investors need information on which are the social, financial, environmental impacts that the company has, the sustainability risks that they face and the plans they have to deal with them in the future. Companies, as also required by the Accounting Directive, will have to report on a full range of sustainability issues such as: climate, pollution, water and marine resources, biodiversity and ecosystems, resource use and circular economy, own workforce, workers in the value chain, affected communities, consumers and end users and business conducts (European Commission, 2024; European Union, 2022).

The EU Emissions Trading System (EU ETS)

EU ETS established in 2005, consists of four trading phases. We are currently in the fourth phase (2021-2030) and it is supported by an ETS Directive, which aligns the system with its climate targets. ETS requires polluters to pay taxes for emissions and reduces emissions from the electricity and heat generation, manufacturing sector especially steel, cement and chemical industries, aviation and maritime transport. By 2027 it will also include buildings and road transport sectors. It is based on a "cap and trade" principle, setting a limit on the total amount of Greenhouse Gas Emissions (GSG). The cap is reduced per year, following the EU's Climate targets so that the emissions decrease through the years. This resulted in reducing emission from European Manufacturing and energy industries to approximately 47%, in comparison with 2005. Companies shall monitor report and keep their emission under control as they will face penalties and fines if they do not comply (European Commission, n.d.)

The Carbon Border Adjustment Mechanism

Regulation (EU) 2023/956 establishing a Carbon Border Adjustment Mechanism (CBAM) will prevent the risk of importing products from countries with less strict emission rules than EU's, otherwise known as carbon leakage. Set in 2023, the regulation is in its transitional period until the end of 2025. This period will be used as a learning period for all involved parties, such as importers, authorities, producers) so that they are completely aligned with the regulation's requirement until its full implementation by the beginning of 2026. It will initially target high emission industries such as electricity, steel, iron, fertilizers etc. and will later expand to lighter emission sectors. Importers will have to purchase CBAM certificates to state the carbon emissions of their goods and must report the carbon content of the imported products. The benefits are expected to be significant from an environmental, economic and global policy perspective. Specifically, cleaner production policies will be encouraged to achieve less global carbon emissions, protects European industries from unfair competition of cheap and carbon intensive transports and supports countries outside EU to comply with carbon pricing mechanisms and boost their climate commitments (European Commission, n.d.).

UN Framework Convention on Climate Change Conference of Parties (COP29)

COP29 is the 29th Conference of the Parties, the main decision-making body of the United Nations Framework Convention on Climate Change (UNFCCC). COP is an annual event where scientists, world leaders and activists meet to discuss the actions needed to be taken to tackle climate change. These annual COP events help setting environmental targets for specific time horizons, reviewing progress each year or checking the results at the end of the time limit of each target, boost the concept of collaboration between countries and set guidelines that should be followed in order to meet set targets. Moreover, COP events draw public concern on environmental issues, the need for climate action is highlighted by providing scientific data, encourage both private and public sector to work towards innovative and sustainable solutions, countries are accountable for their actions regarding environmental commitments. The COP29 took place in November 2024, in Baku Azerbaijan. One of the main environmental targets of the event were the commitment to 1.5°C Goal of the Paris agreement and the encouragement to countries to stick to stricter emission reduction goals by 2025. Climate Finance was also an important subject of the discussion, which led to setting a new financial goal to aid countries to protect their citizens from natural disasters and share the benefits of the green energy development. Around 200 countries were participants and reached an agreement that will secure USD 300 billion annually by 2035 to developing countries, with projects like renewable energy, forest preservation, climate resilience though infrastructure and finance mechanisms such as carbon taxes on aviation and shipping and private sector support to public funds. A major achievement of COP29 was setting a global framework for carbon credit trading, which was the finalization of Paris Agreement Article 6 on this subject and the creation of a UN regulatory body which will check international carbon markets to ensure transparency and integrity from an environmental aspect. The need to phase out unabated fossil fuels globally was highlighted by emphasizing the importance of renewable energy such as solar, wind and green hydrogen. Climate adaptation of vulnerable regions was set as a priority as was strengthening the global goal on adaptation (GGA) to ensure progress in climate resilience that will be measured. Another environmental target set were nature based solutions to protect ecosystems, preserve biodiversity, enhance reforestation as part of climate action. Loss and Damage fund agreed upon at the previous COP event (COP28) was operationalized to deal with the irreversible impacts of climate change in developing countries by setting an initial pledge of using at least 10 billion USD dollars by 2025 (United Nations, n.d).

Chapter 4. Environmental, Social and Governance (ESG) Framework

The focus on sustainable practices is constantly increasing due the persistent environmental threats, such as climate change, resource use and biodiversity loss and the pressure coming from stakeholders (Truant et al., 2024; Tao et al., 2023). Environmental, Social and Governance (ESG) standards highlight the goals that companies should set, act as decision criteria upon investments and can be used as performance metrics for corporate sustainability (Truant et al., 2024; Dai and Tang, 2022).

ESG Principles

ESG Principles aim to guide businesses in operating responsibly by focusing on the following three areas:

- Environmental area: Corporate management shall include strategies that aim at minimizing the company's carbon footprint, which is linked to direct or indirect GHG emissions. Companies have the responsibility to take measures against climate change and steps that encourage the use of green energy and reduction of waste by managing their operations and supply chain is such ways that they contribute to the preservation of biodiversity and the ecosystem (Tsoulfas, 2024)
- Social: Companies are supposed to promote fair labor, diversity and inclusions and protect human rights. From providing a safe workplace and securing workers' health to contributing to society by volunteering, organizing charity actions, business shall work towards securing not only the company as an economic entity but also their social identity as part of a community (Tsoulfas, 2024).
- Governance: Organizations should follow policies regarding anti-corruption, have ethical conduct and follow any law that applies to their business activity. This way, companies secure and strengthen the processes linked with internal controls, management, executive compensation etc. (Tsoulfas, 2024).

ESG Standards

The framework regarding reporting information on sustainability shall be transparent and standardized. Therefore, there is the need for ESG disclosure standards that will support and strengthen information sharing.

The International Sustainability Standards Board, which is a non-profit foundation of public interest, published two ESG disclosure standards, IFRS S1 and IFRS S2 that have a global application. Their main goal is to create a common ground, with specific guidelines that can be used worldwide, achieve compatibility with other standards so that they can complement each other if needed. This way, sustainability disclosure standards will become less complex for investors and stakeholders (Tsoulfas, 2024). Standards are used as a means to help companies identify and report sustainability issues that are of high importance for the investors. Investors examine the sustainability performance of the company and make decisions according to the financial implications it has and the possible future risks that may arise from sustainability practices. Investors will be able to take the necessary information from the ESG elements and make a decision according to how these elements can transform the value and risk profile of the business. ESG data are easily included in the existing corporate reports as standards are designed in such a way that they complement the financial and accounting ones. This integration and alignment between different standards used inside a company, makes their adaptation easier, quicker, encourages the sustainable transparency and enhances corporate performance (Tsoulfas, 2024).

IFRS S1 sets the framework for the General Requirements for Disclosure of Sustainability-related Financial Information. The standard requires that the business entity discloses information about sustainability related threats and opportunities that could affect the company's cash flows, cost of capital and finance. The company shall provide information about:

- Governance processes are used to monitor and manage sustainability related threats and opportunities. The company shall identify the governance body, that takes decisions upon sustainability matters and can be a board, committee or any other body with governance and disclose information about how sustainability related responsibilities are delegated, how often the governance body is informed, how this information affects the entity's strategy and how they monitor progress.

- Strategy selected to manage sustainability related threats and opportunities. In this way users will understand how the sustainability threats and opportunities affect decision making processes, the entity's business model and value chain, financial position, performance and cash flows. Furthermore, the company shall disclose information that enables the users of financial reports to understand to what extent the company can adjust to uncertainties that are linked to sustainability threats and be resilient (International Financial Reporting Standards (IFRS) Foundation, n.d.)
- Risk management, processes that the company uses to identify, assess, prioritize and monitor sustainability related threats and opportunities. These processes include information about parameters, data sources, scope of operations, scenario analysis, criteria and qualitative and quantitative factors used for assessment (International Financial Reporting Standards (IFRS) Foundation, n.d.)
- Metrics and goals to measure the company's performance regarding its sustainability targets or compliance with relative laws and regulations. The company shall include information about the time period of the target, milestones or intermediate targets, revisions of the set goals, performance over each goal etc. (International Financial Reporting Standards (IFRS) Foundation, n.d.)

IFRS S2 sets the framework for the Climate – related Disclosures. The standard requires that the business entity discloses information about climate- related threats and opportunities that could affect the company's cash flows, cost of capital and finance. The company shall provide information that are similar with IFRS S1 but from climate perspective respectively. The application of both Standards since January 2024 depends on whether government authorities have decided their adoption (International Financial Reporting Standards (IFRS) Foundation, n.d.)

Global Reporting Initiative (GRI), is an independent non-profit organization that acts as a creator of common global language to report on environmental, social and economic impacts. GRI standards are a system of interconnected standards that enable companies to report the impact of their activities and inform the public, staying transparent with stakeholder and any other interested party (Global Reporting Initiative, 2021).

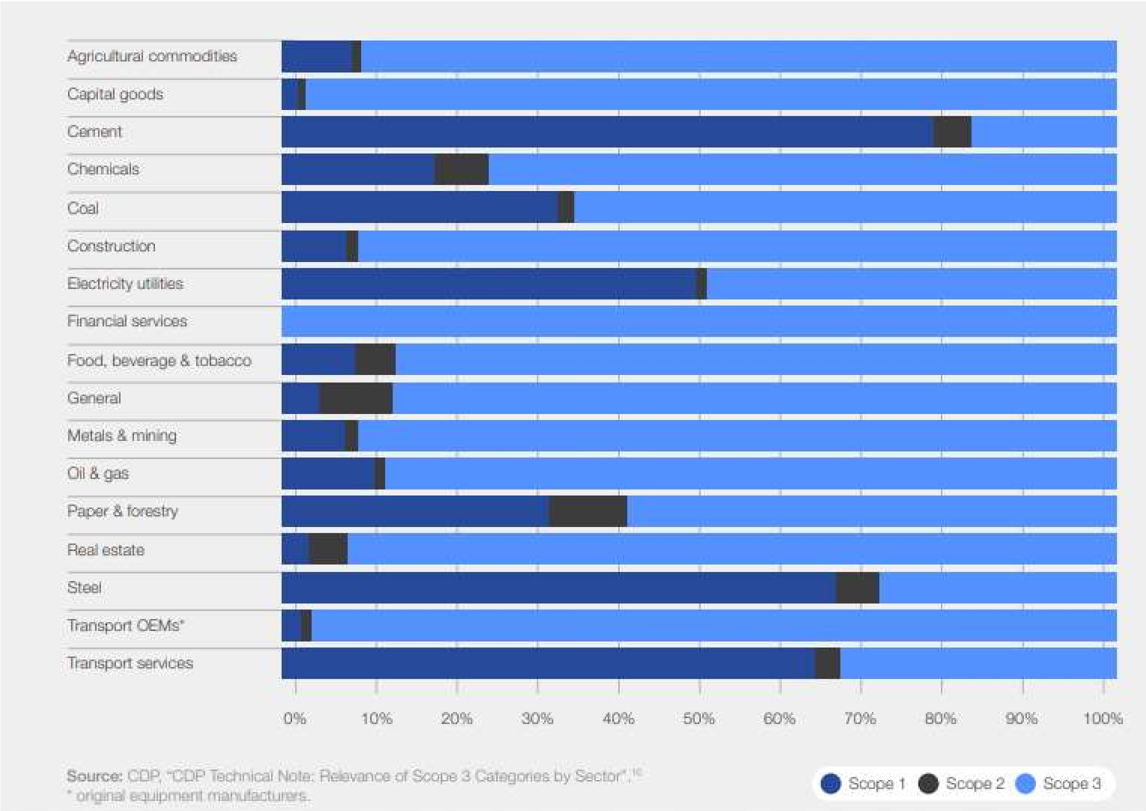
There are three categories of GRI Standards, Universal standards, Sector Standards and Topic Standards.

- Universal Standards apply to all organizations and consist of three subcategories:
    - ✓ GRI 1: Foundation 2021 (GRI 1) that highlights the purpose of the standard, its concept, explains how it should be used, the requirements and principles that shall be followed in order to create high quality reports.
    - ✓ GRI 2: General Disclosures 2021 (GRI 2) that includes information that shows the company's profile such as practices, strategy, policies, stakeholder engagement, governance etc.
    - ✓ GRI 3: Material Topics 2021 (GRI 3) that includes information about the steps taken to determine its material topics, which are the topics most relevant to its impacts and how the Sector Standards can are used.
- Sector Standards that are developed for 40 sectors, beginning with those with the highest impact such as oil, gas, agriculture and fishing. These standards increase the quality of the reports.
- Topic Standards that provide disclosures for specific topics, which help businesses find relevant material to achieve sustainability in their businesses.

Chapter 5. GHG emissions in Supply Chains

As the need for carbon transparency in global supply chains is constantly increasing, companies shall measure and keep track of the emissions in their supply chains. Understanding supply chain emissions can help minimize climate change. Figure 3 shows the estimated shares of emissions scopes per sector. Customers, suppliers, business partners and regulators set specific expectations or targets to minimize these emissions. According to Ouassou et al. (2024) large companies show greater interest in defining their GHG emissions as they are more likely to face reputational risks, social and economic pressure than small businesses. Despite the fact that these big companies may be engaged in reporting their carbon footprint, subcontracting which I really common in big industries creates a challenge. Supply Chains generate approximately 60% of the total global carbon emissions worldwide, making it a sector that shall be monitored and make a turn to more sustainable practices in order to tackle rapid climate change. This necessity requires partnerships and collaborations between plenty industries in order to collect the essential data linked to carbon emissions at different stages of the supply chain and its activities (Timmermans, 2023; Burchardt, 2021; Ouassou et al., 2024). Environmental accountability is enhanced by policies that are implemented in Europe or worldwide by governments and institutions and by the technological advances.

Figure 3: Estimated shares of emissions scopes per sector



Source: CDP, "CDP Technical Note: Relevance of Scope 3 Categories by Sector".10 * original equipment manufacturers & WORL Economic Forum (WEF)

The Partnership for Carbon Transparency

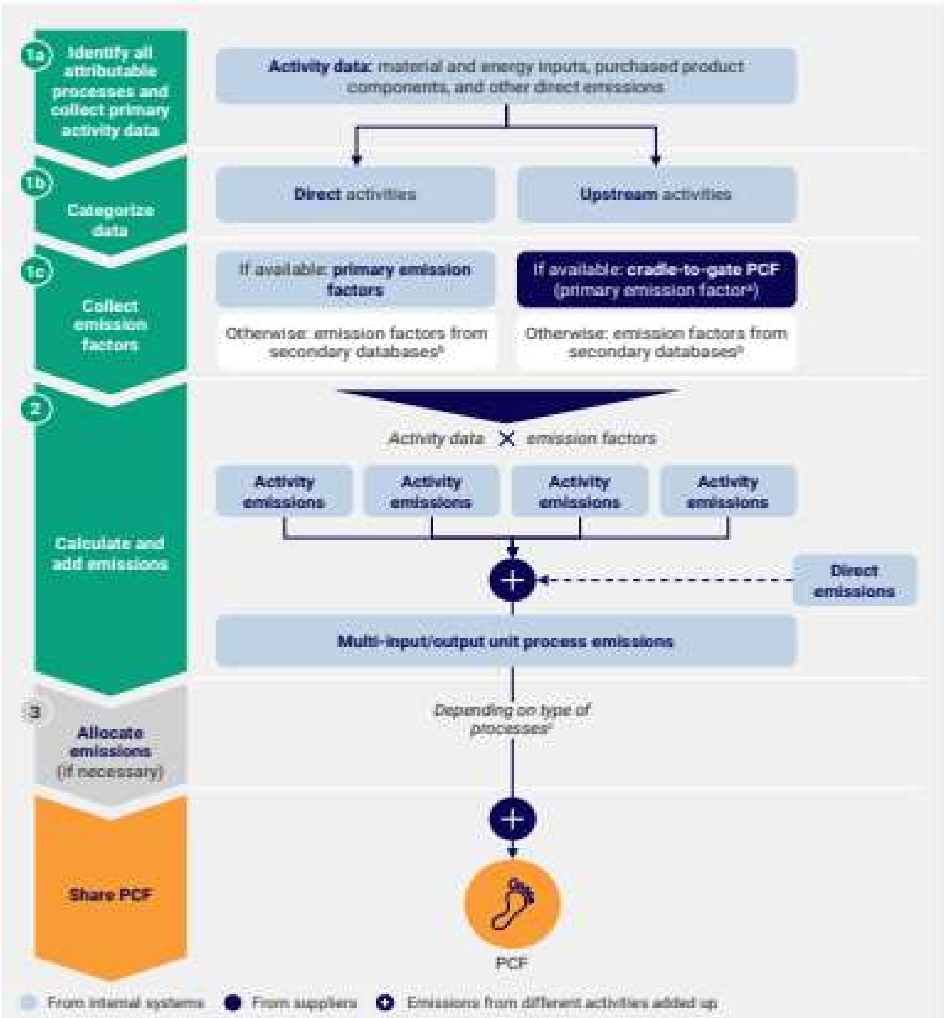
The Partnership for Carbon Transparency (PACT) is an initiative that created a methodology that calculates and exchanges carbon footprint and aims at minimizing Scope 3 emissions, which are indirect emissions though the company's value chain from the good they purchase to the disposal of these goods as defined by the Greenhouse Gas Protocol. Greenhouse Gases (GHGs) are atmospheric gases that absorb and emit radiation and contribute to the Greenhouse effect, leading to adverse climate changes (World Resources Institute, 2013). Emissions can be produced through many stages of the supply chain and are classified as direct and indirect ones by GHG Protocol. GHG Protocol introduced the concept of 3 scopes (scope 1, scope 2, scope 3) used for accounting and reporting causes (World Resources Institute, 2014). Scope 1 emissions are direct GHG emissions that are produced by the company and its processes. Activities that are included in scope 1 are generation of energy, chemical processing and transportations of materials or goods with vehicles owned by the company. Scope 2 emissions are mainly emissions from the generation of purchased electricity that is consumed within the company but it is produced at the facilities were electricity is generated. Scope 3 is an optional reporting category that includes all the other indirect emissions, such as production of purchased materials, the use of sold products, transport related activities like transportation of purchased material or goods, sold products and waste with vehicles that are not equity of the company. The extraction of raw materials such as in mining and agriculture produces significant amounts of Co2 emissions. For example cement, steel and chemicals are the materials with the most carbon emissions. Manufacturing processes usually make use of electricity and fossil fuels. As factories and their machinery are not always updated, they lead to excessive emissions. The indirect emissions that are linked to the consumption of purchased energy, as the emissions occur at the power plant and not at the company, are defined as scope 2 emissions. Packaging is the next step of the production process. Usually plastic materials used for the packaging or other non recyclable packaging materials contribute to greater emissions. This activity can be defined as scope 1 if packaging materials are processed inside the company's facilities or as scope 3 if the packaging materials are sourced by suppliers. Finished goods should be transport to either stores or directly to the final customer. This movement of goods via airplanes, trucks, trains and ships adds up to the emissions. If the finished goods are not immediately sent to the buyer, they shall be stored. Warehouses used by companies are mainly large buildings that use energy for lighting, cooling, heating and operating equipment that handles stored goods until they are delivered, which makes this step of the supply chain an also carbon intensive one (Ouassou et al., 2024). Defining Scope 3 emissions is a challenge as there is not always transparency through companies' value chains. This led the European Commission's Corporate Reporting Sustainability Directive (CSRD) to require that scope 3 emission disclosure. Therefore, the

World Business Council for Sustainable Development (WBCSD) has formed, in cooperation with 50 well known companies, such as Microsoft, Siemens, P&G, Nestle, Deloitte, IBM, McKinsey etc. and regulators, the PACT Methodology (previously known as Pathfinder Framework) that helps companies decarbonize by reporting and exchanging carbon footprint data across their value chains. The GHG emissions that are studied and companies shall be kept accountable for are listed in the GHG Protocol Required with the title of "Greenhouse Gases in Inventories; Accounting and Reporting Standard Amendment." and includes: Carbon dioxide (CO2), Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorinated compounds, Sulphur hexafluoride (SF6), Nitrogen triflouride (NF3), Perfluorocarbons (PFCs), Fluorinated ethers (HFEs), Perfluoropolyethers (e.g., PFPEs), Chlorofluorocarbon (CFCs), Hydrochlorofluorocarbon (HCFCs) (World Business Council for Sustainable Development, 2023).

The PACT methodology consists of 4 pillars, Emissions and accounting, Data integrity, Assurance and Verification and Data exchange.

To calculate the Product Carbon Footprint (PCF) companies shall follow the guidance of the WBCSD that is presented in the following Figure 4 (World Business Council for Sustainable Development, 2023).

Figure 4: Product Carbon Footprint (PCF) calculation steps



Source: World Business Council for Sustainable Development (WBCSD)

The first step is data identification. All company activities that are linked to scope 3 emission category shall be identified by collecting primary (available directly from suppliers or internal processes) or secondary emission factors (the data are not directly available and the company shall consult and comply with set safeguards and make the most suitable emission factor selection), calculate the total amount of emissions per activity and allocate if necessary in case of emissions among multiple outputs. The calculation of GHG emissions is determined by multiplying the activity data with the emission factor that is related to the activity. In case the activity involves more than one greenhouse gases, e.g CO2, CH4 etc., then the equation shall also take into account the GWP multiplier, which is the Global Warming Potential (GWP) that reflects the relative warming effect of each gas compared to CO2 over a specific time period.

So, the equation to calculate GHG emissions (CO2e) for the activity data is:

Kg CO2e = Activity data (amount of activity) × Emission factor (kg GHG/ unit of activity) × GWP (kg CO2e/ kg GHG)

Data sources shall be prioritized and companies shall seek for secondary data only when primary data is unavailable. Companies are encouraged to measure GHG emissions directly or by calculating them using the activity data and relative emission factor. In order to improve data quality, the PACT Framework had introduced metrics, such as the Primary Data Share (PDS) and the Data Quality Ratings (DQRs) and indicators such as Technological representativeness, Geographical representativeness, Temporal representativeness, Completeness and Reliability which must be reported by companies from 2025 to ensure their alignment with the PACT guidelines. Reported emissions data shall be accurate, transparent, have credibility and be comparable in order to ensure that PCF calculations are harmonized among different industries. Collaboration across the supply chain makes data exchange essential. Sharing activity data, emissions factors and other relative metrics are essential as companies have to deal with suppliers, stakeholders and other third parties that play a role in their supply chain (World Business Council for Sustainable Development, 2023).

Carbon Pricing

Carbon pricing boosts green technology investments as robust carbon pricing mechanisms such as USD 85 per ton by 2030, is a financial disincentive to those who want to stay fully carbon dependent (Ouassou et al., 2024 ; Black et al., 2023). Carbon transparency is also promoted by the European Union Green Deal and European Climate Law, which are thoroughly examined at the chapter of the European Regulatory Framework about Sustainability. Not only European Union, but also other nations outside EU form policies, regulator or initiatives that serve the need for decarbonization. Such examples are the Australian Government's Clean Energy Regulator, the Argentinian Congress Passed Climate Change Law, Swedish Pigouvian Tax Mechanisms and the Global Carbon Pricing Initiatives.

Technological Innovations

Technological Innovations can also promote carbon transparency and lead to clean energy investments. Pathfinder Framework and Network, as explained previously, provide guidance for calculating emissions and exchange the emissions data with other industries by forming a standardized approach. The data exchange technologies are using updated technical specification and fixed technical language that serve the unobstructed sharing of reported information. Cloud computing can also help work towards minimizing carbon footprint. Companies that transfer their application on the cloud do not maintain onsite servers. There are approaches linked to the decarbonization and are related to geo-distributed cloud services. An example of such an approach is the Carbon-Aware Control (CAC) Framework that is designed to optimize energy usage and reduce carbon emissions by adapting operations based on geographical load balancing, capacity and server speed scaling (Ouassou et al., 2024; Panch and Sharma, 2023). Furthermore, blockchain technology enhances traceability and transparency by offering secure and decentralized ways to report carbon emissions. Artificial Intelligence (AI)-powered Solutions can help companies form automated processes that handle complex carbon emission data, make thorough reports and eventually help them optimize their carbon management strategy. Automated Machine Learning (Auto ML) makes the use of machine learning systems a lot easier by deploying AI capabilities in energy management systems (Ouassou et al., 2024; Moraliyage et al., 2023). Internet of Things (IoT) Devices such as IoT sensors and equipment that help the company gather real time data on issues like energy usage, waste etc. that eventually lead to less corporate carbon emissions (Ouassou et al., 2024; Tsokov and Petrova-Antonova, 2017).

Chapter 6. Renewable Energy Sources (RES) in the Supply Chain

Countries and their economies work towards decarbonizing their electricity system by turning to a renewable based one. Renewable energy incorporation or even domination (e.g solar, wind, geothermal, biomass) is one of the top priorities in most countries, as they are in dire need of clean energy and independence from fossil fuels. Renewable energy can foster innovation in the context of Supply Chains and assist in achieving Supply Chains' sustainability goals.

There is the need to secure energy supply by conditions that can threaten its adequacy. The international electricity interconnection exposes countries to more threats other that national ones. Price volatility, supply chain disruptions and geopolitical risks, such as wars or tensions are threats to those depending solely on one source of energy. In addition, system stress events such as extreme heat or cold, natural disasters increase electricity demand or lead to the unavailability of energy generation (European Investment Bank, 2024).

The Ukraine war and high energy prices pushed Europe to make a quicker transition to green energy (European Investment Bank, 2024). Renewable Energy Sources can be a reliable part of the grid if technologies that promote grid stability are used in order to counterbalance the volatile production due to weather patterns. One of the top technologies used for this cause is batteries in solar systems, which provide a short term, yet with lots of benefits flexibility. Photovoltaic systems produce at daylight time as they transform the solar energy into electric and they stay inactive during night. A solar system with battery technology saves the excessive energy produced during the day and can be used at night (for self consumption or to feed the grid).

Furthermore, Renewable Energy Sources can lower the price of electricity in the electricity market as there is oversupply of energy compared to a scenario where electricity is only produced by conventional sources. Greece's electricity price is determined by a national Energy Market, aligned to the European Electricity Markets guidelines, by introducing the Day Ahead Market (DAM). DAM sets the electricity price for the next day, by taking into account bids of energy producers (companies that produce energy of all kinds) that state how much energy they are able to sell and the price every hour).

Design of a PV plant as a sustainability enabler

In order to explore the concept of Renewable Energy as a tool that benefits Supply Chains, we will present the case of a company that considers the possibility of installing a Photovoltaic (PV) System. PV systems generate electricity form sunlight that it is collected in photovoltaic solar modules. A PV system consists of these PV solar panels that collect the solar energy and generate Direct Current (DC) electricity through photoelectric effect, inverters that convert Direct Current (DC) electricity to Alternating Current (AC) electricity, mounting systems, wiring meter tracks, monitoring systems etc. We will use a solar system simulation program (Huawei's Fusion Solar) to create a solar system and extract all the conclusions in case of installing such a system.

The company is a data center provider, with three data center facilities. The company has almost continuous consumption all day long and without major differences between weekdays and weekends. The annual energy consumption of all three facilities is 1.227.291, 97 kWh. The company considers the idea of installing a 350 kWp PV system, which will be used for self consumption of the produced energy or to feed the grid with the remaining energy. Their main purpose is to reduce electricity cost and adopt green technologies aligned with their environmental goals.

The company considers installing a PV system as part of virtual net billing technology, of maximum power 350 kWp, at a field owned by the company, different than the consumption facilities, which energy production will be synchronized virtually with the consumption facilities. The contract demand of the facilities is 350 KVA in total, which is the upper limit for the power of the PV system. The simulation requires the location of the selected area of installation and the electricity consumption profile of the consumption facility.

The steps to Design a PV System Using Huawei FusionSolar

Huawei's FusionSolarSmartDesign, is a free online PV system design platform that allows users to create different PV plant scenarios and export economic and environmental results. The European domain name of the tool is https://eu5.smartdesign.huawei.com

Users shall create a personal account and login in by setting a username and a password.

The steps of designing a PV plant to meet your desired scenario's goals are described below (Huawei, n.d.):

1. Selection of the standard design of a large-scale C&I (Commercial and Industrial) scenario. The system allows simulations up to 1.5 MW of installed capacity.

2. Enter basic information, such as location of the PV, grid parameters and weather station. Feed-in Power Upper Limit shall also be stated (kW).

3. Define the electricity price settings. Feed in tariff (€/ kWh), electricity purchase price (€/ kWh) and consumption settings are the basic requested details. An .xlsx template must be filled in, with the electricity consumption (kWh) every hour for a year period. The company has to download a load curve file with these consumptions by its electricity supplier.

4. Draw the PV model (3D or 2D). 2D PV module layout design facilitates panel arrangement. PV module settings allow the selection of panels from a list of top manufacturers and panel models. Additional settings, such as direction of your panels (landscape or portrait), row space, column space, PV azimuth[1], relative tilt, distance to field boundaries etc. can result in a more realistic simulation. Orientation of the PV plant shall be south for maximum efficiency and better radiation pattern.

5. Electrical Design. The system proceeds to an automated selection of inverters and optimizers according to the number of panels, their arrangement and the capacity of the system. Modifications can be made manually to better facilitate your desired scenario and create your

[1] PV Azimuth is the direction towards which the PV panels face. Greece is in the Northern hemisphere with 0° azimuth.

ideal design scheme. The connection is successful when all panels are grouped per string to match the inverter's DC input voltage.

6. Report that includes the project's basic info, project overview, economic benefits, electricity bill analysis, energy management, power curve, ESS benefits, PV model layout, electrical connection, system loss diagram, first year environmental benefits and simulation parameters.

7. Economic Analysis. After completing the whole PV system design, you can analyze the benefits of the PV system. Required data such as the installation cost of the PV system (€/ W) and annual operational costs shall be filled in. There is also data such as investment and loan settings and subsidies (if applicable) that can also be filled in, to better support your scenario's results.

To successfully fill in the consumption template of the system, you shall choose the correct time interval option (60, 30 or 15 minutes) and a horizontal or vertical template (day -time row-column arrangement) which corresponds to your available consumption input.

The electricity purchase price's volumetric charge type can be set as fixed (which is an assumption as prices are defined every day by DAM) and an up-to-date Volumetric Charge Rate (€/ kWh) can be assumed for this cause.

The parameters and results of the PV System Design

The simulation requires defining the location of the PV system installation. We selected the field by navigating through the available map of the program and the simulation parameters of weather, grid type etc are automatically generated by the system. The selling and buying prices considered for the calculation were 0,04 EUR/kWh and 0,15 EUR/kWh accordingly. We filled and imported the consumption template (15 minutes template). We also considered the conservative scenario of a feed in upper limit 250 kW, as the Distribution Network Operator limits the max produced energy at approximately 73% of the installed system capacity.

Basic parameters of the simulation are the selected equipment. We selected Jinko Solar/JKM585N-72HL4-V PV modules, landscape – Free Field mounting system (support) and two inverters (Huawei SUN2000-150K-MG0 and SUN2000-115KTL-M2). Relative tilt is 30 °, and Azimuth Angle 0°.

By using auto design and adjusting it to achieve the desired power we used 598 PV modules in total. The system has DC Power 349.83 kWp.

We used auto electrical design that proposed 1 x Huawei SUN2000-150K-MG0 and 1 x

Huawei SUN2000-115KTL-M2, which meet our project requirements. We considered Initial Installation Cost PV System Price as 0,68 EUR/W and that the investment will be solely funded by the company (no loans, external investors, government subsidies etc.). We did not include the annual system operation and maintenance costs as we want to focus on primary costs linked to capital expenditure and energy production.

The exported report shows results such as environmental benefits, economic benefits, energy demand comparison etc.

The initial investment cost will be approximately 238,000 EUR. It reduces annual electricity bills by 58.159,73 € as in table 1 and creates profits of approximately € 1.3 million in 25 years. Payback period is less than 4 years (3,72 years) with IRR 26,6% NPV is approximately 760,000 € as in table 2.

Table 1: Electricity Bills analysis

Description	Before(EUR)	After(EUR)
Annual Bill Savings	0	58,159.73
Annual Volumetric Charges	184,093.8	125,934.07

Source: Huawei Fusion Solar Simulation

Table 2: ROI overview

Accumulated Net Profits of 25 years	1,298,465.42 €
Initial Investment Cost	237,884.4 €
Own Funds	237,884.4 €
NPV	759,985.74 €
IRR	26.6 %
Payback Period	3,72 years

Source: Huawei Fusion Solar Simulation

The results show that the installation of the PV system will enhance the company's sustainability goals by reducing CO2 emissions by 234 tons in the first year, which is equivalent to 320 trees planted and 197 tons coal saved.

NPV result shows that the investment will be profitable and that it is expected to generate a net benefit of 759,985.74 € through its lifespan, after calculating the difference between present cash inflows (revenues) and present value of cash outflows (initial installation cost). IRR 26.6 % means that the investment will have a return of 26.6 % per year, suggesting an attractive and profitable investment.

The economic as much as the environmental benefits are aligned with the company's goals so it can be a strategic investment that will create profits and increase sustainability for the company.

The detailed report of the simulation is provided in the Appendix A.

Benefits of Renewable Energy Sources

According to Deloitte's report (n.d.) the use of renewable energy can lead to innovation across the supply chain. By producing clean energy, supply chains can be electrical independent and be secure from price increases or volatility in the energy market. Annual electricity bills will be reduced, and long-term revenues will start after the payback period. These revenues can be used for designing new products, technologies, strategies, gain new assets etc., which can reshape the supply chain. Moreover, the company will be aligned with international and national regulations which shift to clean energy. This protects the company from potential future risks or penalties caused by not complying with current legislation. Furthermore, sustainability goals will be met, and corporate sustainability identity will be enhanced. This can lead to employee engagement (e.g solar carparks for employees at the company's facilities) and increase the company's reputation as sustainable initiatives are appreciated by customers, suppliers and partners and keep up with the competitors' pace. In some cases, companies financially support society's renewable energy initiatives (e.g. schools, voluntary organizations and other causes). This may not create direct corporate financial benefits but will boost the company's sustainability responsibility and profile, which may lead to financial earnings. This can also place the company as a sustainability leader.

To better benefit from renewable energy usage, companies shall consider some factors that will shape energy procurement strategy. The energy profile of the company is one of the most important factors that should be taken into account as the renewable energy produced should be used as much as possible by own loads to minimize annual electricity bills. Selected Technology and capacity of the system shall be decided carefully and according to company energy needs. In case of future facility expansion, future energy needs should also be calculated when deciding the renewable energy project's specifications. So, production, supply chain and all energy related company needs will shape the decision of what renewable energy plan should be adopted. The company size and its revenues must form the size of the renewable energy investment and future maintenance and operational costs should be taken into account too. Companies should also consider if they own the property where the renewable plant will be installed, or they lease it, as such a huge and long-term investment that shall be secured from external threats. Another important factor is what the national or international regulations are and how can the company take advantage by following them. For example, specific renewable energy technology alignment is subsidized by governments. This reduces costs, payback period and makes the investment a lot more affordable. Visibility of the renewable energy initiative shall also be taken into consideration. Such investments are highly expected and supported by customers as they are considered environmental actions. So, securing the visibility of the project will maximize corporate reputation and related financial benefits. This can be achieved by also selecting the most appropriate location for the renewable plant. For instance, installing the energy plant near the company's premises can increase visibility more than placing it away. However, this decision is most of the time based on capacity and available space needed to support this capacity.

Chapter 7. The role of flexibility in the supply chain

The growing competitiveness creates many challenges for the supply chain networks all around the world. Supply chains need to be more flexible than ever, as uncertainties and diversifications can cause many disruptions to the stability and the smooth operation of logistic systems (Shoja et. al, 2019).

According to Roser (2000), uncertainty is described as the level of lack of knowledge for the design process. The level of uncertainty can range from maximum (complete lack of knowledge) to even zero (complete knowledge).

Optimization under uncertainty is the problem of modern supply chain networks. The process of building adaptive and flexible systems should take into consideration the uncertainty factors as well as the whole range of the company's functions (sourcing, planning, product design, manufacturing, supply chain and logistics) (Ponce-Rocha et al., 2022).

Demand uncertainties are the main risk to which manufacturing companies should respond as quickly as possible in order to maintain their control over the market. Fluctuations of demand and forecast errors can create serious threats to the production systems and supply chain networks (Chod and Rudy, 2006). Therefore, manufacturing companies are focusing on designing flexible systems that can adapt and respond faster to the new demands (Hariharan et al., 2020).

Zhang et al., 2022 suggest that modern mass production manufacturing models and the complexity of the production systems create the need for a flexible and adaptive manufacturing system. These smart flexible production systems enhance the company's quick response to the ever changing and dynamic needs of the market, increasing its autonomy over the uncertainties and contribute to the prompt adjustment of the production lines and distribution networks as per the current industrial trends.

Therefore, it is suggested that flexibility of the manufacturing systems shall be considered as a valuable practice that will mitigate the negative effects of the current unstable market environment (Chryssolouris et al, 2012). Georgoulias et al. (2009) stress the importance of flexibility of industrial systems as an attribute that ensures delivery reliability. The purpose of production flexibility is not to minimize robustness caused by uncertainty but to reduce the design costs caused by the negative effects of uncertainty (Roser and Kazmer, 2000).

According to Roser (2000), flexible design methodology aims at minimal cost design that is adjusted to the possible future uncertainties. Uncertainties lead to necessary changes in the design process which can cause extra costs, negatively affect performance and increase the time needed for product development and production. The flexible design allows the company to adjust quickly to the changes with minimal extra costs.

The concept of flexible design as part of the engineering design method is introduced due to inaccuracies, uncertainties or errors caused by the design predictions. These differentiations may have a minor or even a significant effect on the design process. It is therefore of high importance to find the right balance between a less sensitive to uncertainty design scheme that might cost more in the initial design process and the cost of changes caused by the typical uncertainty prone design model. With flexible design, companies seek to avoid expensive design changes rather than inexpensive ones. The inexpensive design changes increase the freedom rate in the design process, as it can be transformed and adjusted economically and fast enough.

The value of information during the product development phase is also crucial as it can help in the selection of the appropriate model and eventually reduce the product development time. Flexible design method evaluates the errors of a design and suggests changes in the design beforehand and aims at keeping the overall expected cost low. Some of the reasons that led to the need for flexibility are:

- Growing competitiveness among companies of the same industry, create the need for a more flexible production system and supply chain which will keep up with the market's growing needs and the competitor's fast response.
- Customization era for products, in which we are living, leads to many complicated production processes. These processes are hard to change, if needed in case of errors, wrong forecasts etc, creating extra costs and delays in production and delivery.
- Technology changes rapidly and systems that used to be state of the art become obsolete in a very short period of time. Production lines that are based on those technologies will inevitably face disruptions if they are not flexible. Unexpected changes in technology that happen rapidly, create opportunities and risks and each company will have to respond immediately. The response to these unpredictable changes will determine whether there will be gain or loss for the company (Neufville and Scholtes, 2011).
- Unpredictable economic, social, environmental and other events can cause changes in demand. COVID-19 caused a bullwhip effect in many production lines, stressing the adverse effects of societal risks. Many industries were unprepared for the unpredictable change of demand and the need for a more flexible design became more obvious than ever. Moreover, the political instabilities and geopolitical risks, with the war between Russia and Ukraine being the most glaring example, disrupted the supply chains and production of many products worldwide. The reconsideration of the production system design is necessary in order to meet new higher demand or even adjust the production to lower demand. Lead times for many products shall be shortened (e.g. pharma products). The disruptions caused by the Pandemic, created the need for

accelerated design phases, production processes and logistic systems in order to meet the new unexpected demand.

Flexibility and Sustainable Supply Chain Performance

Supply Chain Flexibility (SCF) is considered a dynamic capability that is a key enabler of modern logistics and operations (Singh, 2024). It allows the supply chain to react immediately to supply chain disruptions by focusing on flexible production, efficient resources etc. Immediate response leads to minimized waste through the supply chain. According to Singh and Mathiyazhagan (2024) SSCF accelerates strategies that promote corporate sustainability targets such as emissions reduction, resource efficiency and responsiveness that eventually lead to more sustainable and resilient supply chains. Efficient resources lead to the minimization of waste and excessive usage of materials and energy, which maximizes environmental performance (Singh, 2024). Flexibility of the production systems helps reduce waste and inventory holding costs as products are made fast and with variability. Flexibility is linked to physical and technological infrastructure that enables smooth operation, communication and leads to optimized operations that promote sustainability. Flexible supply chains are ready to comply with new environmental regulations or standards related to social or ethical issues at any point by changing their production line, design, materials and make easier transitions to new processes. By meeting new requirements immediately, they enhance their sustainable performance (Singh, 2024).

Flexibility of production systems and distribution systems are linked and considered to be a successful strategy against the competitiveness of the market (Gunasekaran et al., 2016). As suggested by Chan et al. (2017), supply chain agility depends on production flexibility and on the responsiveness of the production and logistic systems towards the constant challenges of the competitive market environment. A flexible production rate (FPR) ensures sustainable industrial development and can help the company deal with plenty unavoidable situations that could threaten its reputation or performance (Sarkar and Bhuniya, 2022; Taleizadeh et al., 2018; Sarkar et a., 2021).

Flexibility in the production systems leads to quicker production pace, reduced inventory costs and ensures that materials and energy are not over used through the supply chain processes.

Manufacturing Flexibility has a direct impact on sustainable production and therefore on the whole firm's sustainable environment (Ojstersek and Buchmeister, 2020). The complexity rate of the modern production systems creates the need for production processes that are time wise and economically efficient, increasing the company's growth and competitiveness. By optimizing the manufacturing processes industries can achieve improved production system performance and increased quality of the products or services.

The evaluation of such production systems that promote sustainability can be achieved by defining the activities, costs, orders, environmental impact they have. Sustainable manufacturing can be described as the set of energies that save energy (logistic systems, shorter lead times, utilization of human resources and machinery) as well as natural resources (raw materials and material handling etc.) (Haapala et al., 2013; Rosen and Kishawy, 2012)

According to Peukert et al. (2015), staying competitive during unpredictable market demand requires the development of Flexible Manufacturing Systems (FMS). Flexibility of the technical performance of plants should be accompanied by sustainability (social and environmental) in order to keep up with the current market environment. The production processes should take into consideration both technological aspects that will support the flexibility framework and sustainability performance. Manufacturing systems that are oriented towards sustainable value creation are measured with Life Cycle Sustainability Assessment (LCSA), for their performance in aspects such as environmental, social and economic ones.

Manufacturing flexibility can be described as a proactive approach to meet dynamic customer demands by dealing with unpredicted changes. In the sustainability framework, it should be characterized by customer driven meet of demands. Ojstersek and Buchmeister (2020) suggest that the current trend of providing personalized products to the customers lead eventually to a high degree of manufacturing flexibility and stress the importance of sustainable production systems. Personalized products allow material optimization leading to less material waste compared to mass produced items' production. Sustainable manufacturing is a major competitive advantage for industries as it results in the production of goods that last long, with sustainable production processes that save energy, resources, materials thus negative environmental impacts are minimized.

Remanufacturing

As stated by Sarkar and Bhuniya (2022) and the Remanufacturing Associations, Remanufacturing is an industrial process of restoring used components to same-as new or with even better condition and performance. This process adds value to the sustainability pillars promoting environmental, social and economic benefits. Environmentally wise, remanufacturing helps preserve raw materials, energy and reduce carbon emissions. Socially and economically wise, remanufacturing reduces costs, creates opportunities for jobs and enhances corporate reputation (Sarkar and Bhuniya, 2022). By incorporating remanufacturing processes in the industrial processes, environmental waste is reduced as the disposal of defective products is eliminated (Dey et al., 2021; Sarkar and Bhuniya, 2022). Remanufacturing can be considered as an opportunity to handle less and safer toxic substances and chemicals, minimize resource depletion and work towards reducing global warming effects. Lower costs, less downtime and more resale value of equipment are also some of the benefits (Sarkar and Bhuniya, 2022). The recyclable materials of this process are usually waste, worn out and defective products or components, returns etc. that are collected from various origins, from customers or from the market though service facility, as depicted in Figure 4. (Sarkar and Bhuniya, 2022, Liu et al., 2019). This is a challenge for the company, as the quality and the quantity of these materials is uncertain and increases the level of complexity when it comes to production decisions (Liu et al., 2019). Moreover, remanufacturing companies face various challenges that differ from one company to another depending on their type of product, production volume, the legislation, competition etc. (European Remanufacturing Network, n.d.)
According to Lund (1983), Jacobsson (2000) and Sundin (2004) companies perform remanufacturing according to their type of business, as described below:

- Original Equipment Manufacturers/Remanufacturers (OEM/OERs) make business by remanufacturing their own products that are delivered to them by service centers, retailers etc. They have spare parts, know how to design the product and the service process. The process of remanufacturing can either be integrated with the manufacturing process or be a completely different part of the production line (European Remanufacturing Network, n.d.).
- Contracted Remanufacturers (CR) are contracted to remanufacture for other companies In the case of contracted remanufacturers, the manufacturing company still owns the product but does not perform the process of remanufacturing. CR can consult the OEM for information about the product design, testing, tooling etc. (European Remanufacturing Network, n.d.)
- Independent Remanufacturers (IR). They buy remanufacturable parts and components for their processes and they do not have any experience from the OEM shared with them. The OEM does not have much contact with the product (European Remanufacturing Network, n.d.)

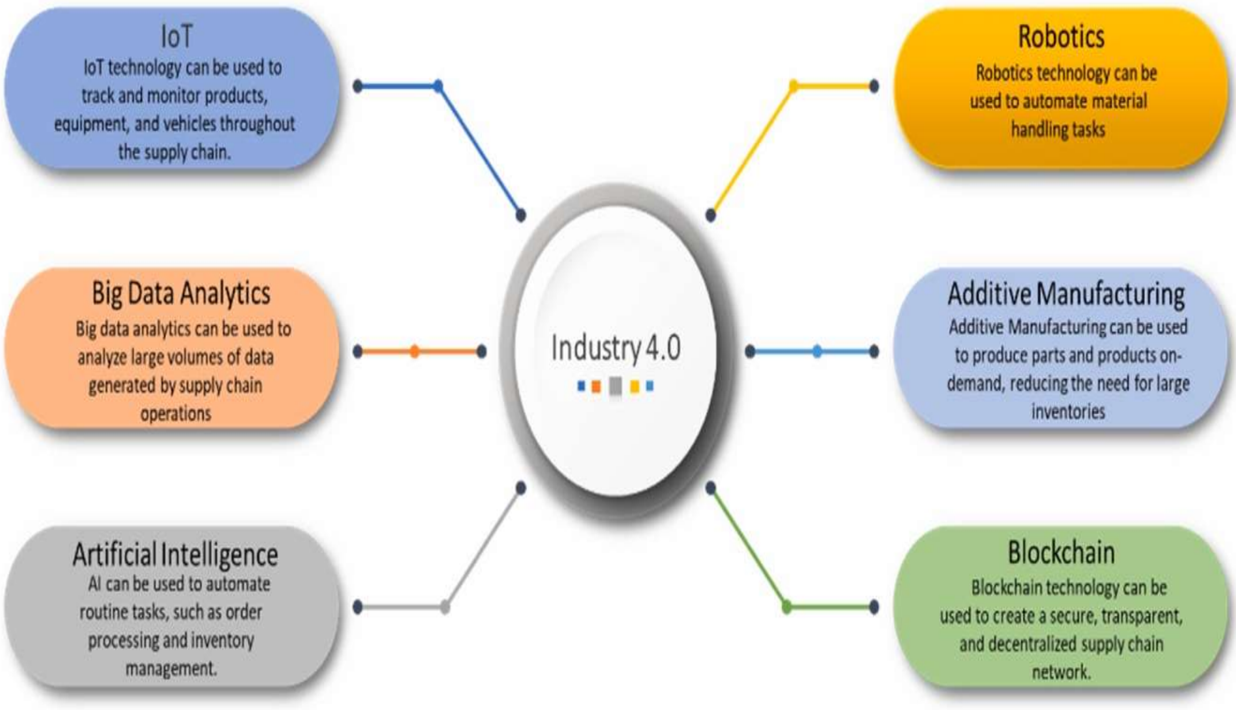
Figure 5: Single-manufacturer multiretailer manufacturing–remanufacturing

Source: Sarkar and Bhuniya, 2022, Liu et al., 2024

Industry 4.0 Technologies

Industry 4.0 is considered as the 4th industrial revolution and it is used as a strategy to acquire competitive advantage by implementing technological breakthroughs. Intelligent production systems and automation are widely used by companies all around the world to maximize efficiency (Gania et al., 2018). Industry 4.0 technologies, as shown in Figure 6 (Karmaker et al., 2023) and sustainable supply chain practices became more important due to the worldwide instability caused by the COVID-19 pandemic and the Russia-Ukraine war as the need for new technologies to support performance grew (Karmaker et al., 2023).

Figure 6: Industry 4.0 Technologies



Source: Karmaker et al. (2023).

The 3 main principles of Industry 4.0 are vertical integration, horizontal integration and end-to-end engineering integration.

Vertical integration refers to the process of combining information from different parts of the company (shop floor to corporate) in order to connect machines, materials and all production's activities (Tabim et al., 2021; Bueno et al., 2020; Enrique et al., 2022). Horizontal integration considers the use of those digital technologies as a tool to create a cooperation ecosystem of companies, suppliers and customers, increasing production and supply chain flexibility (Dos Santos et al., 2020; Benitez et al., 2020; Enrique et al., 2022). The end-to-end engineering integration refers to the incorporation and of all activities, design decisions and elements in the design and production processes through the visibility the digital technologies offer (Wang et al., 2016; Dalenogare et al., 2018; Enrique et al., 2022).

Economically wise, Industry 4.0 technologies enable real time information transfer to the shop floor, decrease set up times, eventually leading to more flexible shop floors. These technologies also contribute to the production's vertical integration, connectivity of machines, shared information and product identification (Enrique et al., 2022)

Environmentally wise, the ongoing and rapid growth of digital technologies such as the Internet of Things (IoT), support Industry 4.0 (Meindl et al., 2021; Dalenogare et al., 2018) by monitoring the production processes and combining workers, machinery and cyber technology (Zhong et al., 2017). The Industry 4.0 application transforms the traditional production environment (Brettel et al. 2014) and therefore is considered a major determinant of production flexibility (Fragapane et al., 2020). Karmaker et al., 2023 states that IoT can help in minimizing waste (Jabbour et al., 2020), 3D printing leads to reduced materials and energy consumption (Despeisse et al., 2017), cloud computing makes carbon footprint assessment easier (Xing et al., 2016) and transparency can be achieved by deploying Block Chain Technology (BCT) (Khan et al., 2022).

Furthermore, Industry 4.0 technologies can help with social challenges that companies may face, such as workplace accidents, health and safety issues and dissatisfied employees. New technologies create new job vacancies in fields like information technology, cyber security etc.

Automations help reducing workplace accidents and increase worker safety. In addition, the use of Robotics, aim at completing routine tasks, allowing humans to focus solely on value- added activities which improve their work experience (Karmaker et al., 2023).

The processes and technologies linked to the Industry 4.0 concept are more complex and sophisticated than the traditional technologies that companies used to use for years. These technologies require an investment in order to acquire them and they need to be incorporated in the company's systems. People involved in the process of introducing these advanced technologies should be trained and familiar with the use of such technologies in order to communicate the know how to all involved parties (workers, engineers, designers, production planners etc.) (Enrique et al., 2022).

Chapter 8. Sustainable Supply Chain Management at Merck KGaA

Merck KGaA is a global leading company in science and technology and operates across healthcare, life science and electronics. As the company procures many materials, components and packaging from around the world, they have to check that their suppliers also comply with the social or ethical standards set. Sustainability is of high importance for the company and it is at the core of its supply chain management strategy (Merck Group, 2023).

The company has incorporated a risk management process in order to ensure the security of the supply. Suppliers are selected upon country, material and supplier risk. The risk management approach has the following four basic pillars:

- Supplier Risk Assessments, in order to understand the risks at a supplier level
- Alert System, in order to inform the Procurement team about the potential threats with the company's suppliers
- Material Risk Assessments, to check and minimize the risks of materials used in the finished goods. For example, in 2023 there were more than 2.500 assessments of materials in order to identify any material related threat.

- Risk Response Tracker, which is a system that plans, resources, controls and monitors actions that shall be taken to minimize the risks.

Merck sources products that contain minerals, otherwise known as "3GT" or tin, tungsten and tantalum, which are linked to risks of being extracted and traded by areas where unethical tactics are used and human rights are not respected. The complexity of the supply chain due to the large number of suppliers led Merck to be part of the Responsible Minerals Initiative (RMI) that provides all the necessary tools and data in order to make informative decisions on selecting responsible suppliers of minerals. They have formed a due diligence program through all their business sectors and considers international laws, standards or guidelines that shall be met. To be on the safe side and verify their compliance with EU Conflict Material Regulation (EU) 2017/821, they have hired an external auditing firm which conducts independent assessments on this matter and make recommendations that can lead to possible redefinition of procedures (Merck Group, 2023).

Merck's procurement team is responsible for incorporating sustainability requirements into sourcing and supplier management. They have formed a Center of Excellence for Sustainability that decides all the new initiatives and measures that they shall take and Category Sourcing teams that deal with all the parameters that shall be taken into account when selecting suppliers, making contract (Merck Group, 2023).

Merck reached a milestone in 2019 when decided to transition 80% of their medicine shipments from air to ocean freight. They achieved a remarkable reduction of their carbon footprint related to logistics by 10,600 tons, lowered costs while maintaining their reliability. To further improve their environmental impact, Merck cooperated with DHL Logistics Company to minimize their carbon emissions. The two companies launched together the Green Lotus pilot project. This was a two month trial for testing DHL's Go Green Plus Service, which ensures shipments with sustainable aviation or marine fuels instead of fossil fuels. They tested it on all shipments from Europe to destinations in the Asia Pacific region. This collaboration led to 65% reduction in carbon emissions while delivering 50 tons of medicines by sea and air and highlighted that biofuels can be effective and easy to integrate without requiring a complete supply chain redesign (DHL, n.d)

They have a strong commitment to sustainability, which they also transfer to their suppliers. They expect their suppliers to comply with the company's environmental and social standards and to ensure that their subcontractors also do follow the same guidelines. In order to engage its suppliers in following its sustainability strategy, Merck send them a letter with the basic guidelines they should follow in order to contribute to Merck's sustainable and transparent supply chain, as described below:

- The supply Chain Act. As a German company, Merck has to comply with the German Supply Chain Due Diligence Act, taking effect in January 2023, which sets some specific regulations regarding protection of the environment and human rights. This shall be followed by all involved in Merck's supply chain parties such as suppliers, sales intermediates and affects all the company's subsidiaries worldwide. In case of not conforming to the law's requirements, the company faces potential financial and social penalties, like fines, exclusion from tenders and the risk of harming their corporate image.
- They have formed a new Supplier Code of Conduct (SCoC) in January 2023 to replace their Responsible Sourcing Principles with all their expectations on environmental and ethical issues they are invested in. They assess their suppliers based on information acquired during audits or by an independent rating agency. (Merck Group, 2023). In order to fully incorporate the Supplier Code of Conduct in their business, Merck decided to integrate it in their General Terms and Conditions of Purchase. Furthermore, Merck has formed a grievance mechanism for employees inside the company or their suppliers' employees that can report any concern or violation of the Supplier Code of Conduct.
- Merck has also a Supplier Decarbonization Program with which they encourage their suppliers to calculate their carbon footprint and they provide them the appropriate training material to do so. Moreover, they offer their suppliers a Renewable Electricity Supplier Toolkit with tips and knowledge on renewable electricity. This toolkit provides

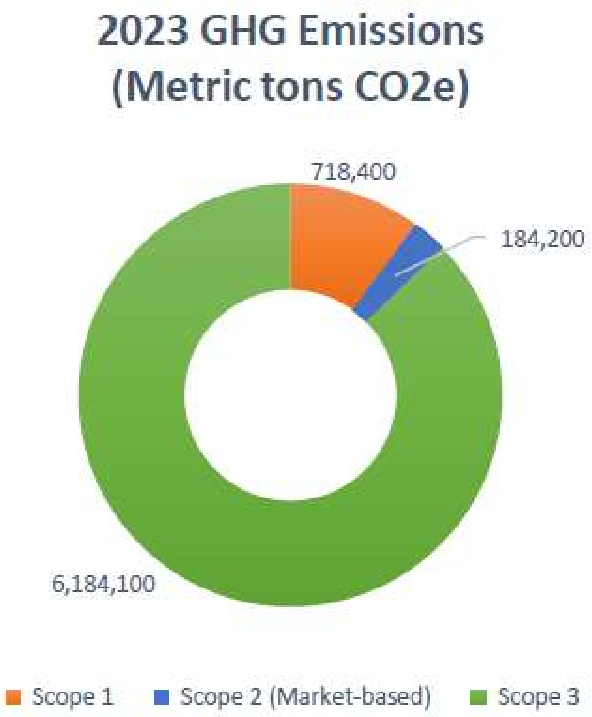
suppliers with information such as energy attribute certificates, on-site and off-site energy generation, targets they shall set when evaluating their energy strategy etc.

As previously stated, Merck's Supplier Code of Conduct is one of the company's milestones in managing sustainability in its supply chain. In 2023 Merck purchased goods and services from 55,000 suppliers in more than 140 countries. The Supplier Code of Conduct shall be followed by all parties providing goods or services to the company and sales intermediates such as agents, resellers, wholesalers, dealers etc. This code of Conduct sets the minimum requirements that suppliers shall meet to align with Merck's sustainability plan, without being an obstacle to extra requirements proposed either by Merck or its suppliers that may have their own Code of Conduct. They also state that in case of supplier's stricter than Merck's Code of Conduct rules or laws are applicable in the countries they operate, then the stricter rule shall be applied. Merck's Supplier Code of Conduct consists of seven basic areas as described below:

- Ethics and General Business Integrity. This area includes requirements such as anti-corruption or anti-bribery commitments, fair competition, bioethics, conflict of interest etc.
- Business Integrity in the Pharma Sector which refers to product quality and supply chain integrity requirements, clinical trials, pharmacovigilance, interaction with healthcare stakeholders etc.
- Protection of the Environment that focuses on environmental authorizations, handling of mercury, chemical related regulations biodiversity, palm oil and waste of materials or water and emissions.
- Human and Labour Rights
- Occupational Health and Safety
- Security and Protection of Assets.
- Commitments, continuous Improvement and Management Systems.

To respond to climate change related public health risks and opportunities Merck conducted a qualitative assessment of their practices for governance, strategy, risk management, metrics and targets and issued a report using the Task Force on Climate-Related Financial Disclosure (TCFD) framework. In this report, Merck includes in the Metrics and Targets section their emissions performance, as in below figure 7 below.

Figure 7: Merck's 2023 GHG emissions



Source: Merck (2024)

Merck has set targets approved by the Science Based Targets Initiative (SBTI) for their scope 1, 2, 3 emissions and the progress they have made achieving these goals. SBTI is a global body that helps companies align their targets with the Paris Agreement and set their GHG emission reduction goals (Merck, 2024). The goals are:

- Reduce their operational (scope 1 and 2) emissions 46% by 2023 compared to 2019. Till now they have made a 12% reduction.
- Reduce their value chain (scope 3) emissions by 30% by 2030, compared to 2019. So far they have achieved a 4% reduction.
- 2024 was the year that Merck made a commitment to neutralize their emissions (net zero targets), by aiming to minimize their GHG emissions across their worldwide operations.
- Source 100 % of their purchased electricity from RES by 2025. Their progress in 2023 was achieving 57% of this goal.

Chapter 9. Conclusions

This thesis aims to explore literature to define the framework of sustainability in Supply Chain Management by using qualitative research method. The society's concerns alongside the governmental pressure to follow guidelines and take initiatives lead to sustainable results in the supply chain. The European Regulatory Framework is extending with Directives, Laws and initiatives that have sustainability in their core.

Supply Chains are the main contributors to GHG emissions. Therefore, this thesis highlights the need for GHG emissions' minimization and the initiatives to achieve this. Some of these initiatives are Carbon Pricing, Technological Innovation and PACT to calculate the carbon footprint and achieve transparency. Reporting information is really important when trying to measure, be transparent and assess the progress of the sustainability processes. Specific ESG standards have been formed to aid information sharing regarding sustainability and ESG principles can be metrics of sustainable results.

The three pillars of Sustainability are all important, yet this thesis focuses more on the environmental aspect. The need for green supply chains is prominent and is most of the time linked to decarbonization. One of the most successful practices to achieve sustainability is by turning to Renewable Energy Sources, such as solar etc. To better understand the benefits of investing in Renewable Energy Sources in the Supply Chain, we made a simulation of a 350 kWp Photovoltaic System that will reduce the CO_2 emissions generated by the company's Supply Chain operations by also promoting financial growth with long term profits.

The role of the Flexibility concept in Sustainable Supply Chains is mainly based on the impact of Manufacturing Flexibility, Remanufacturing and Industry 4.0 technologies on Sustainable Performance.

Finally, in order to have a real case of a company implementing sustainability in its supply chain, we presented the Merck paradigm. This way, we gained insight into the practices that they adopt to achieve sustainability and be environmentally and ethically responsible without compromising their financial success. One of our main findings from this case is that Merck has incorporated sustainability in its core business. It is not just a target that they try to meet by taking some steps. By forming their own strict Supplier Code of Conduct to collaborating with companies like DHL and taking the decision to turn completely to Renewable Energy Sources, Merck has shown Merck has shown tremendous commitment to its sustainability goals.

The main contribution of this research is to provide insight into the concept of Sustainability in Supply Chain Management and give managers the necessary material that can help them integrate sustainability in their business strategy. All Supply Chain Members can work towards sustainability by not focusing solely on financial success but also on environmentally friendly and ethical decisions. Furthermore, by investing in green technologies and using the latest technologies they can transform their Supply Chains and achieve sustainable results such as reduced waste and lower carbon footprint. As the Regulatory Framework regarding Sustainability is extending, managers should educate their teams on the importance of Sustainability and matters like Reporting, Metrics, Supplier Code of Conduct, Carbon footprint calculation, RES etc. By fostering a culture of Sustainability within the company, across all departments, form production to management, they can achieve Sustainable Performance alongside financial success.

Future research in the Sustainable Supply Chain Management Field could extend the findings of this research by exploring practices that have been adopted for a long time to check their long term impact. Further theoretical research could focus on how flexible systems affect SSCM and case studies of different industries with different regulatory framework regarding sustainability shall be incorporated in future researches. Natural disasters, pandemics and wars create the need of exploring the effect of Sustainability on Supply Chain Resilience. Conducting interviews with not only with Supply Chain Managers but also with production line workers, logistics personnel etc can provide insight into possible obstacles that they face when implementing sustainable practices proposed by the company's SCM team. Last but not least, there is interest in exploring the investment on RES projects as a corporate sustainable practice, by studying cases of companies that have already made such an investment to measure the benefits of RES in their sustainability and financial resilience over the years.

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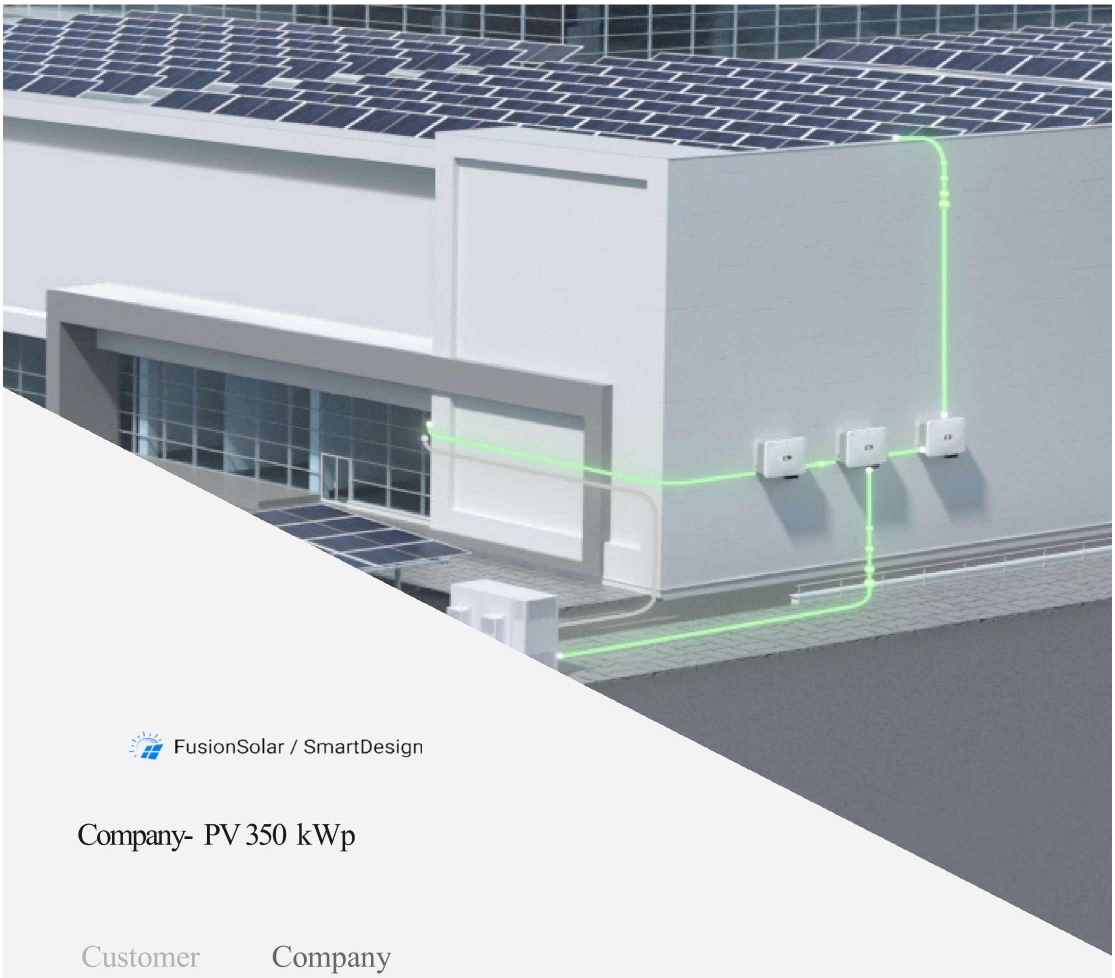
Appendix A. Simulation Report



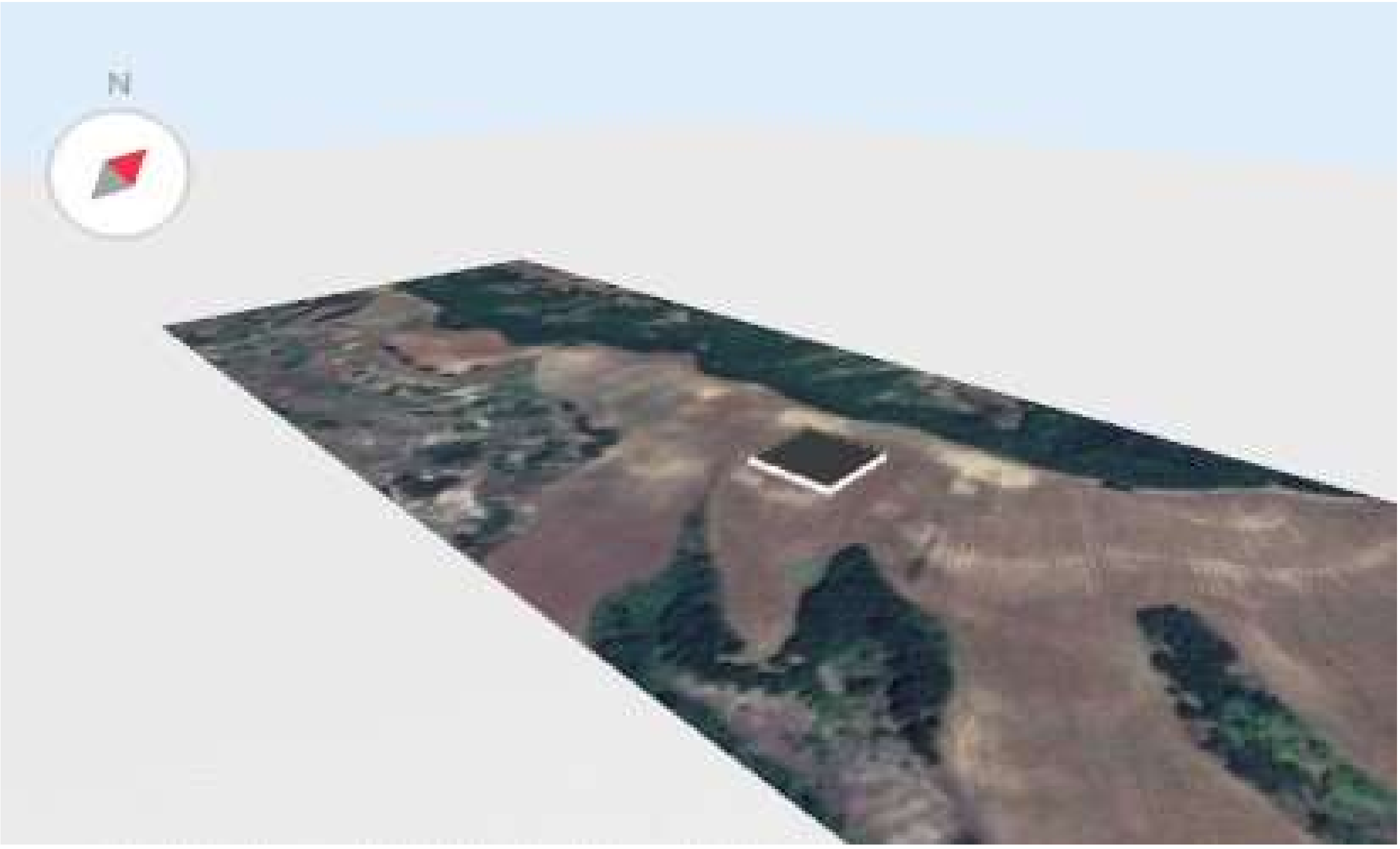
FusionSolar / SmartDesign

Company- PV 350 kWp

Customer Company

Address Grevena 51100, Greece


N


N

Project Overview

System Capacity

PV System 349.83 kWp
AC Power 265 kW
Oversizing Ratio 132.01%

Devices

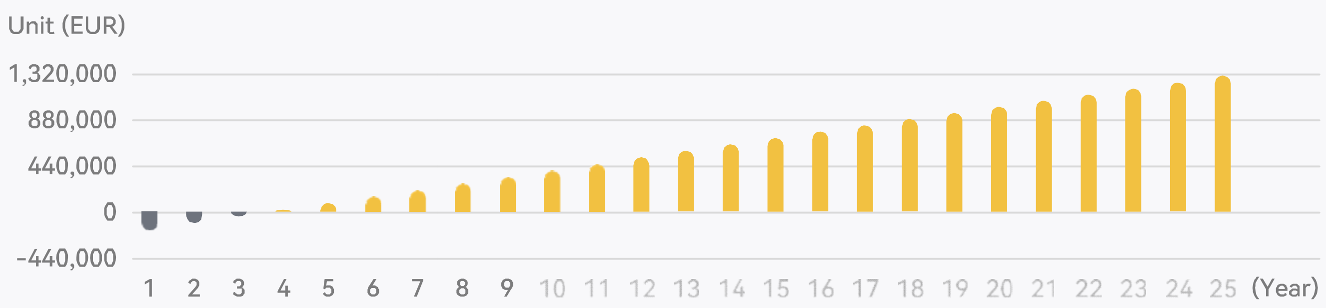
Device Name	Manufacturer/Model	Quantity
PV Module	 JinkoSolar/JKM585N-72HL4-V	598
Inverter	 SUN2000-150K-MG0	1
Inverter	 SUN2000-115KTL-M2	1

Economic Benefits

Accumulated Net Profits of 25 Years: 1,298,465.42 EUR

ROI Overview

237,884.4EUR Initial Investment Cost	237,884.4 EUR Own Funds	0 EUR O&M Cost	759,985.74 EUR NPV
26.6 % IRR	3.72 years Payback Period	0.03EUR/kWh LCOE	



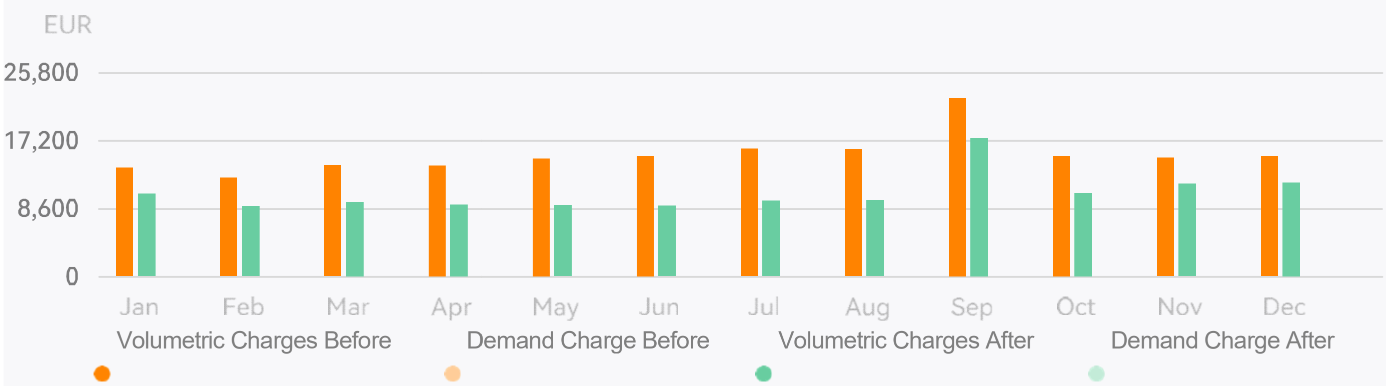
Electricity Bills Analysis

Total Electricity Fees Saved in the First Year 58,159.73 EUR

Annual Electricity Bills

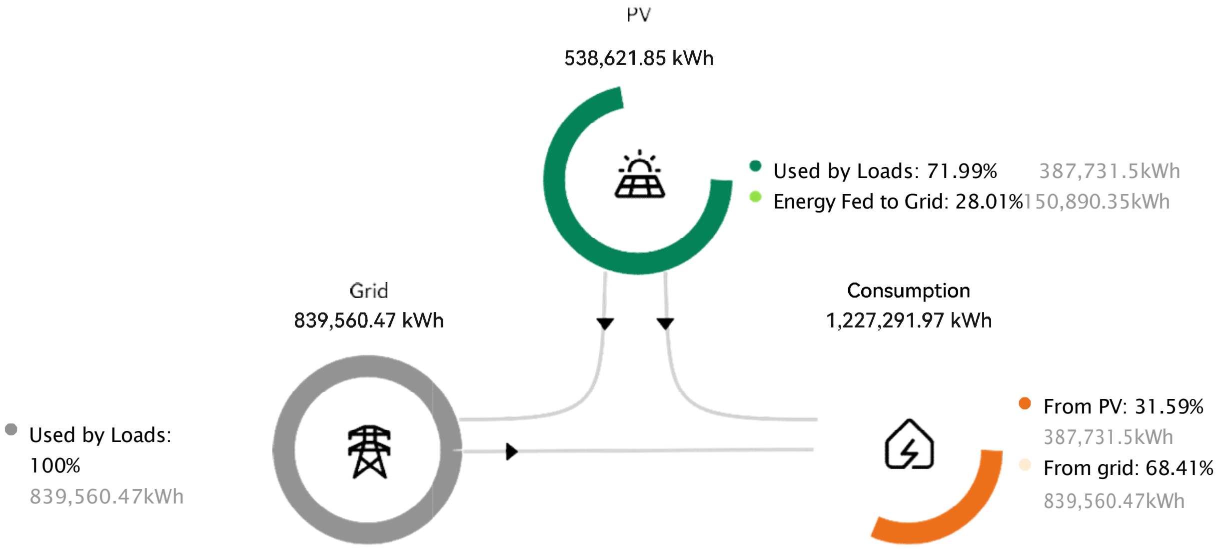
Description	Before(EUR)	After(EUR)
Annual Bill Savings	0	58,159.73
Annual Volumetric Charges	184,093.8	125,934.07
Annual Demand Charge	0	0

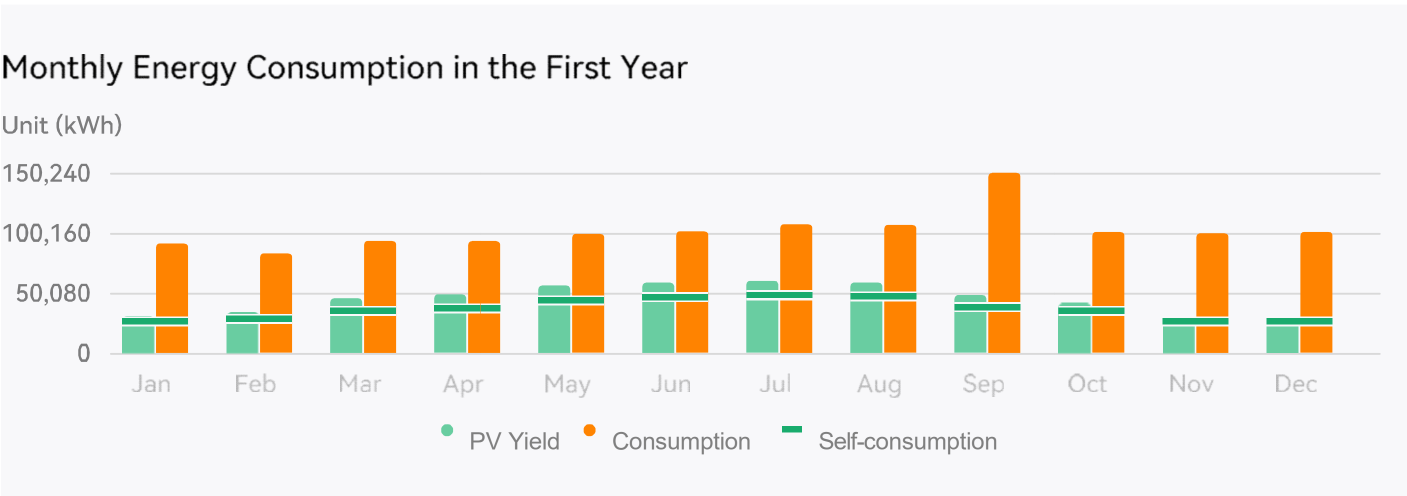
Monthly Electricity Bills



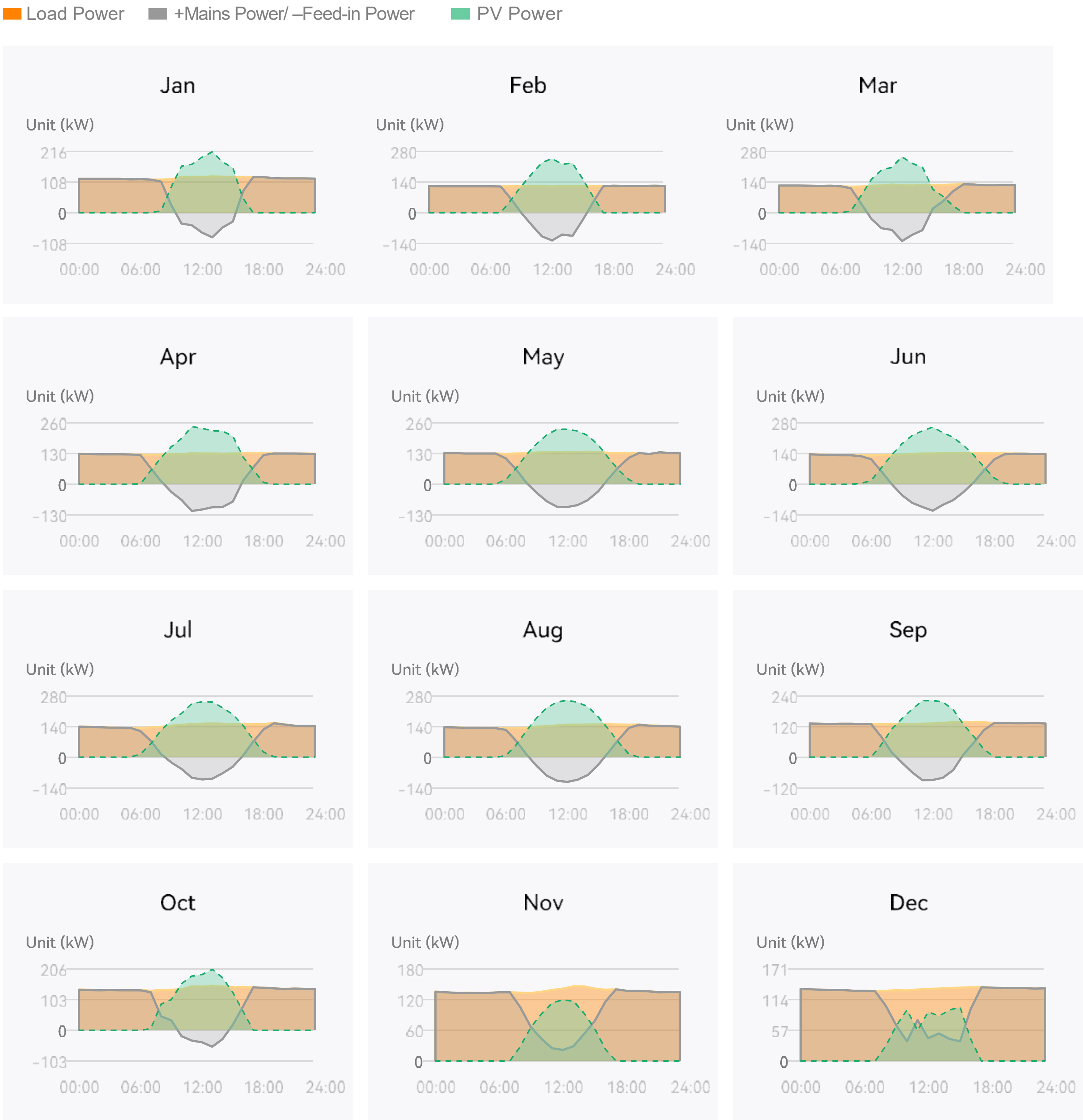
Energy Management

First-Year Data

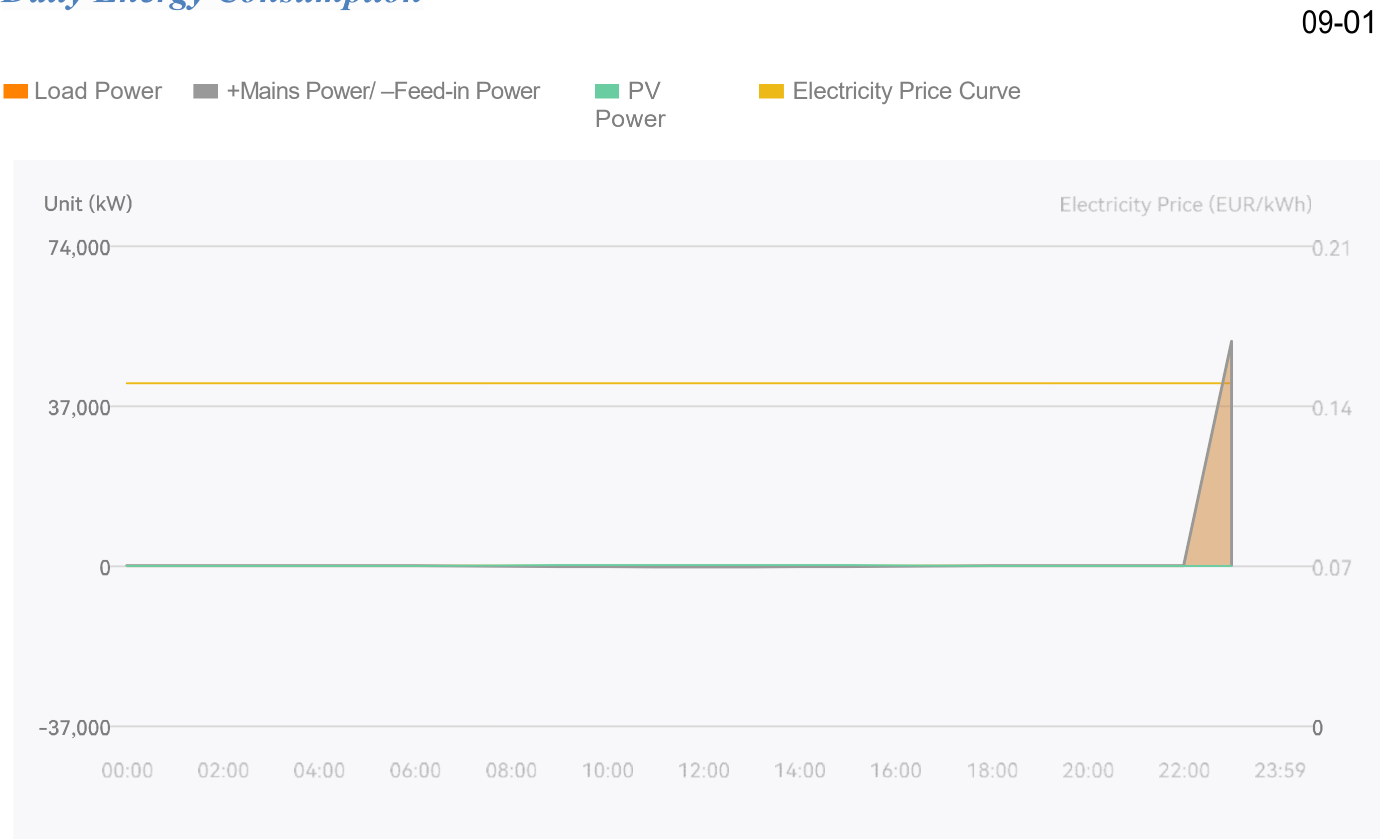




Power Curve

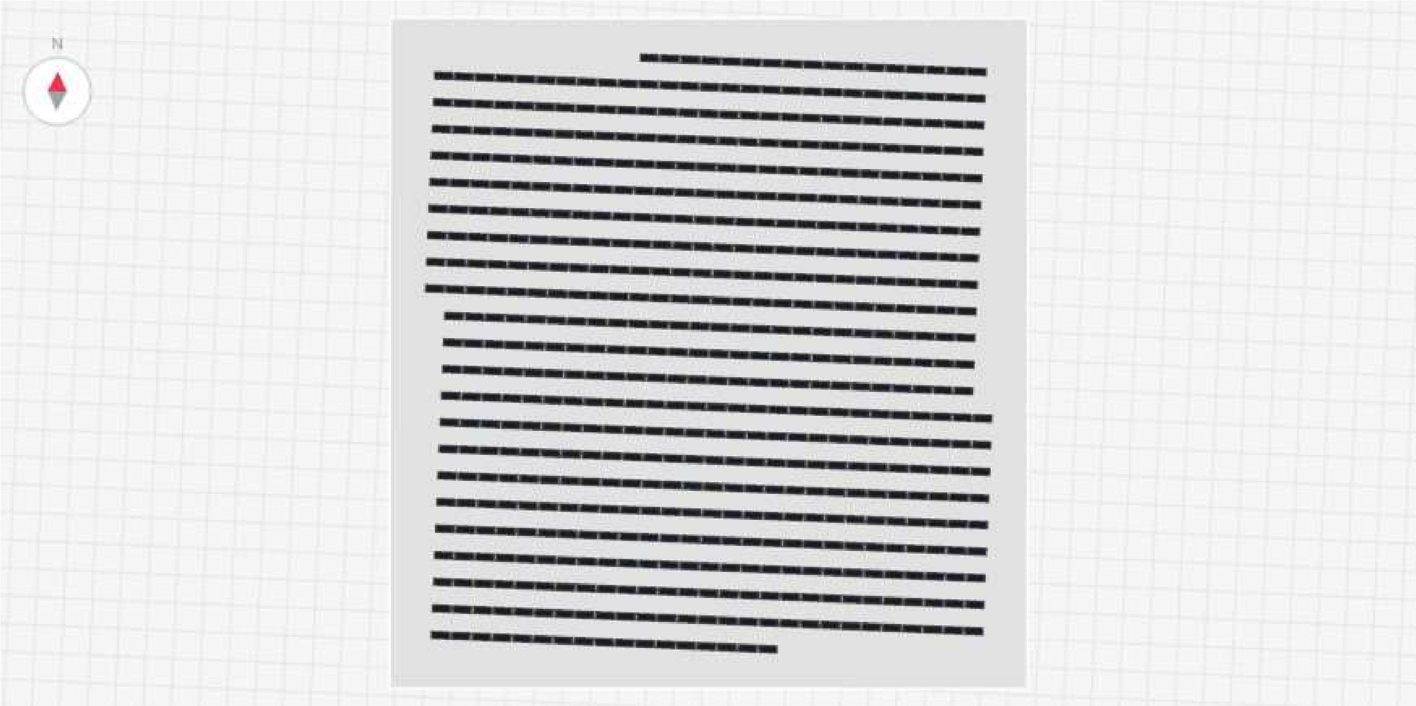

Load Power
+Mains Power/ –Feed-in Power
PV Power
Jan
Unit (kW)
216
108
0
-108
00:00 06:00 12:00 18:00 24:00
Feb
Unit (kW)
280
140
0
-140
00:00 06:00 12:00 18:00 24:00
Mar
Unit (kW)
280
140
0
-140
00:00 06:00 12:00 18:00 24:00
Apr
Unit (kW)
260
130
0
-130
00:00 06:00 12:00 18:00 24:00
May
Unit (kW)
260
130
0
-130
00:00 06:00 12:00 18:00 24:00
Jun
Unit (kW)
280
140
0
-140
00:00 06:00 12:00 18:00 24:00
Jul
Unit (kW)
280
140
0
-140
00:00 06:00 12:00 18:00 24:00
Aug
Unit (kW)
280
140
0
-140
00:00 06:00 12:00 18:00 24:00
Sep
Unit (kW)
240
120
0
-120
00:00 06:00 12:00 18:00 24:00
Oct
Unit (kW)
206
103
0
-103
00:00 06:00 12:00 18:00 24:00
Nov
Unit (kW)
180
120
60
0
00:00 06:00 12:00 18:00 24:00
Dec
Unit (kW)
171
114
57
0
00:00 06:00 12:00 18:00 24:00

Daily Energy Consumption



PV Module Layout

Building1



Manufacturer/Model	Quantity	Azimuth	AbsoluteTilt
JinkoSolar/JKM585N-72HL4-V	598	0°	30°

Electrical Connection

Inverter	MPPT	String	PV Module
#1 SUN2000-150K-MG0	MPPT1	String1	17
		String2	17
		String3	17
	MPPT2	String4	17
		String5	17
		String6	17
	MPPT3	String7	17
		String8	17
		String9	17
	MPPT4	String10	17
		String11	17
		String12	17
	MPPT5	String13	17
		String14	17
		String15	17
	MPPT6	String16	17
		String17	17

Electrical Connection

Inverter	MPPT	String	PV Module
#1 SUN2000-150K-MG0	MPPT6	String18	17
	MPPT7	String19	17
		String20	17
#2 SUN2000-115KTL-M2	MPPT1	String1	16
		String2	16
	MPPT2	String3	16
		String4	16
	MPPT3	String5	16
		String6	16
	MPPT4	String7	16
		String8	16
	MPPT5	String9	16
		String10	16
	MPPT6	String11	16
		String12	16
	MPPT7	String13	16
	MPPT8	String14	16
	MPPT9	String15	17

Electrical Connection

Inverter	MPPT	String	PV Module
#2 SUN2000-115KTL-M2	MPPT10	String16	17

First-Year Environmental Benefits

234 tons
CO2 Reduced

320
Equivalent Trees Planted

197 tons Standard
Coal Saved

Simulation Parameters

Time Zone	UTC+2:00
Weather Station	Kozani (CIV/MIL)
Meteorological Data	Meteonorm
Grid Type	230V/400V
Plant Altitude	627m