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Pathways to Low-Carbon Small and Medium Companies: A Practical Tool for GHG monitoring

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Pathways to Low-Carbon Small and Medium Companies: A Practical Tool for GHG monitoring

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THESIS APPROVAL

I, Salvatore Pappalardo as supervisor of the student Julio Sierra, hereby APPROVE the thesis entitled "Pathways to Low-Carbon Small and Medium Companies: A Practical Tool for GHG monitoring".

Place Padova, Italy, Date August 31st 2025

Signature



Declaration of Mobility

This thesis is the result of the Erasmus Mundus Joint Master's degree in Climate Change and Diversity: Sustainable Territorial Development (CCD-STeDe).

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This program has a duration of 24 months. The course started at UNIPD in Italy, for the first semester. The second semester was spent at Universidad Andina Simón Bolívar in Quito (Ecuador). The third semester was blended with the international Winter School in Kenya. The fourth semester was spent for internship and thesis *in SOGESCA srl (Rubano, Italy)* under the supervision of Università degli Studi di Padova (UNIPD, Italy).

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Abstract

Climate change stands as one of the most urgent and complex challenges of our time, requiring coordinated efforts across all sectors and regions. While the issue is undeniably global, the path to effective mitigation must also include targeted actions within specific geographic contexts and economic sectors. Focusing efforts where emissions are concentrated or where untapped potential for improvement exists can significantly enhance the effectiveness of broader climate strategies.
In this context, a specific potential and importance was identified in the role of Small and Medium Enterprises (SMEs), which make up 99.8% of businesses in Europe.
However, they often face barriers to engaging in climate mitigation, particularly due to limited technical resources, financial constraints, and the lack of tailored tools for tracking GHG emissions. Despite these obstacles, their participation is essential to achieving meaningful and widespread sustainability outcomes.
This thesis presents the development of a simplified, sector-specific GHG emissions calculator designed to support SMEs in the European furniture industry for the concrete adoption of localized mitigation measures. Created within the framework of the DEESME 2050 project, the tool offers a practical means to estimate emissions and identify potential areas for reduction. In parallel with the development of the calculator, a deeper analysis was carried out to examine the logic and structure behind GHG accounting and the broader carbon economy. This involved evaluating the conceptual frameworks, methodologies, and regulatory instruments that underpin emissions calculations. The aim was to critically reflect on the assumptions and limitations embedded in current tools, while also recognizing the strengths of existing standards and legal frameworks. This dual approach seeks not only to enhance the usability and relevance of the proposed tool but also to contribute to ongoing discussions on how climate accounting practices can become more transparent, inclusive, and effective.
The work is driven by the recognition that SMEs, although critical to Europe's economic and environmental future, remain underserved by conventional climate accounting methodologies. By providing a user-friendly and reliable solution aligned with international standards, this tool aims to empower these companies to take the first steps toward emissions monitoring and climate action, bridging a gap that has often left them on the margins of sustainability initiatives.
At the same time, this effort is framed within the broader context of climate responsibility, particularly in regions of the Global North where historical and current emissions are disproportionately high compared to the Global South. Supporting SMEs in these regions with practical tools is not only a matter of inclusion, but also of accountability. Enabling more businesses, regardless of size, to engage in emissions tracking helps ensure that the transition toward climate neutrality is both fair and comprehensive, reinforcing the shared responsibility to act and the need for solutions that reach all layers of the economy.

Resumen

El cambio climático representa uno de los desafíos más urgentes y complejos de nuestra era, requiriendo acciones coordinadas a múltiples niveles. Si bien es un fenómeno global, su mitigación efectiva demanda intervenciones específicas según el contexto geográfico y sectorial. En este marco, las pequeñas y medianas empresas (PYMEs), que constituyen la mayoría del tejido empresarial europeo, tienen un papel clave, aunque enfrentan barreras técnicas, económicas y metodológicas para abordar sus emisiones de gases de efecto invernadero (GEI).

Esta tesis presenta el desarrollo de una herramienta simplificada y sectorial para el cálculo de emisiones de GEI, diseñada para apoyar a las PYMEs del sector del mueble en Europa. Elaborada en el contexto del proyecto DEESME 2050, la calculadora permite estimar emisiones e identificar oportunidades de reducción de forma práctica y accesible. Paralelamente, se llevó a cabo un análisis crítico del marco conceptual, metodológico y regulatorio que sustenta el cálculo de emisiones, con el objetivo de reflexionar sobre sus limitaciones, suposiciones y fortalezas.

El trabajo parte del reconocimiento de que las PYMEs, aunque fundamentales para el futuro económico y ambiental de Europa, han sido tradicionalmente excluidas de las metodologías convencionales de contabilidad climática. La herramienta propuesta busca cerrar esta brecha, ofreciendo una solución confiable, alineada con los estándares internacionales, que facilite su participación en la acción climática.

Finalmente, este esfuerzo se inscribe en un contexto más amplio de responsabilidad climática, especialmente en regiones del Norte Global, donde las emisiones históricas y actuales son considerablemente altas. Apoyar a las PYMEs con instrumentos adecuados no solo promueve la inclusión, sino que responde a un imperativo de justicia climática, fortaleciendo una transición hacia la neutralidad de carbono que sea equitativa, integradora y efectiva.

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1. INTRODUCTION

1.1 Global Context of Climate Change

Human activities, principally through emissions of greenhouse gases (GHG), have unequivocally caused global warming, with global surface temperature reaching 1.1°C above 1850–1900 in 2011–2020 (Lee, 2023). The concentration of GHG, which has been progressively increasing since the Industrial Revolution, has caused a significant rise in the Earth's temperature (Eleftheriadis, 2024). This temperature increase has had a direct negative influence on all natural systems within the planet's atmosphere, and, according to the IPCC Working Group I report (IPCC, 2021), impacts of climate change will intensify even further during this century. The degree of intensification of these changes will depend directly on the mitigation actions taken and the seriousness and effectiveness with which they are implemented.

Although climate change is a global phenomenon that impacts all parts of the planet, contributions to GHG emissions are highly unequal. Historically, countries in the Global North have been the main emitters and, therefore, are largely responsible for the increased concentration of GHGs in the atmosphere by the cumulative historical emission since the Industrial Revolution. This is directly attributed to the development and industrialization model based on fossil fuels that these countries adopted since the beginning of the Industrial Revolution (IPCC, 2021). This disparity presents major challenges in terms of climate justice, as regions with the lowest GHG contributions tend to be the most vulnerable to the effects of climate change. For this reason, it is essential that nations with the greatest historical responsibility for emissions assume an active leadership role in reducing impacts both within their own territories and globally. On one hand, they must actively support the most affected parties through technology transfer, financing, and cooperative policies; on the other hand, which is the focus of this study, they must take concrete and effective actions to directly mitigate their emissions.

Particularly, European Union as part of the "Global North," plays a key role in the historical accumulation and current generation of GHG, contributing significantly to global warming (Figure 1). Although in recent decades it has implemented emission reduction policies and promoted the transition to renewable energies, it still maintains a significant climate footprint. Due to its great economic, political, and technological influence, Europe plays a crucial role in the fight against climate change. Its mitigation actions not only greatly impact the amount of gases in the atmosphere but also set a trend and serve as an example for other regions of the world.

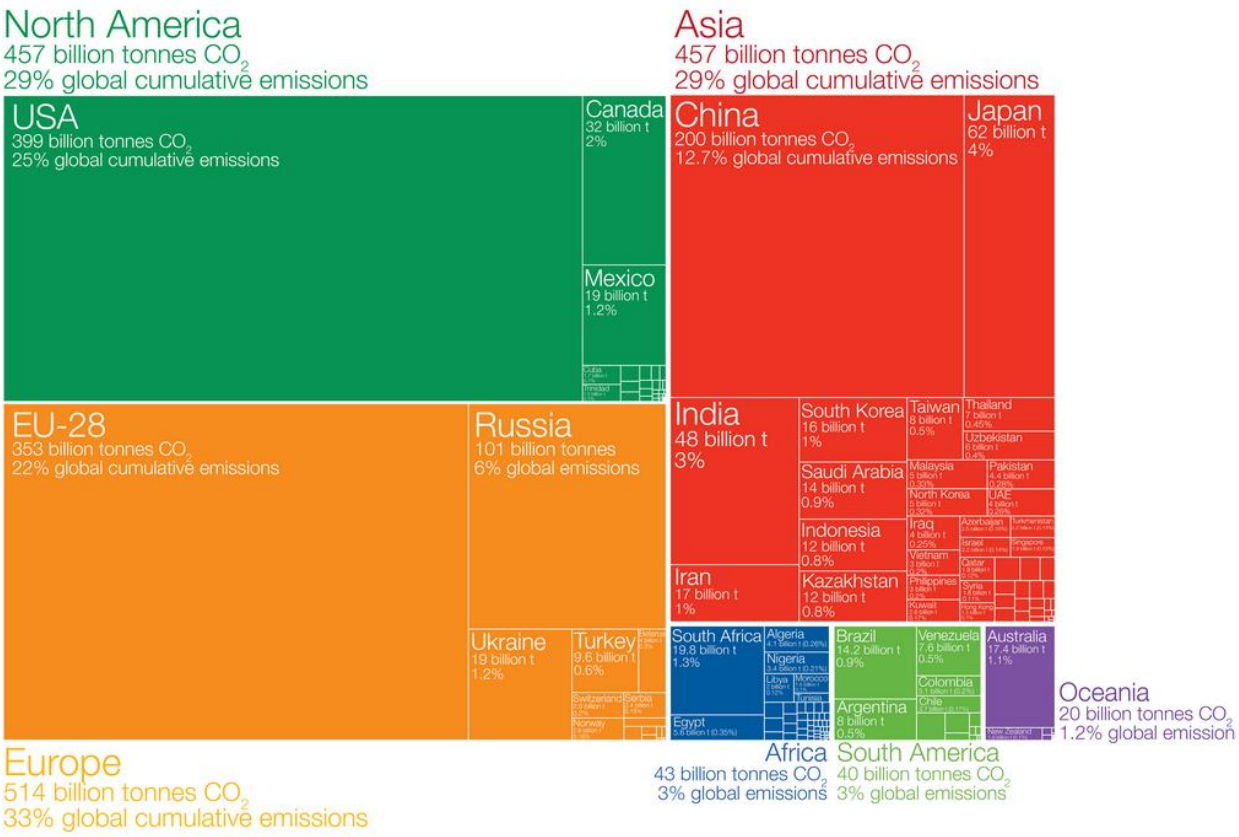


Figure 1. Global cumulative CO_2 emissions in the period 1751-2017 (H. Ritchie 2019)

The figure above clearly shows that the United States has been the largest historical emitter of CO2, contributing around 400 billion tonnes since 1751, which represents 25% of global emissions, twice the amount of China, the second-largest contributor. The EU-28 also stands out as a significant historical emitter, accounting for 22% of total emissions. In contrast, countries like India and Brazil, which are major emitters today, have contributed relatively little historically. This historical imbalance underscores the principle of common but differentiated responsibilities, highlighting that the Global North bears a greater obligation to lead in climate change mitigation.

1.2 Role of the furniture-focused SMEs in Europe

When discussing the major changes that need to be made in Europe, the business sector is one of the most responsible (European Parliament, 2018). While large companies have a greater weight in the generation of GHG, SMEs, generally defined as those with fewer than 250 employees and limited business volume, collectively contribute significantly to GHG emissions. In the European continent, SMEs make up approximately 99.8% of all businesses and generate around 65% of employment in the business economy, making them key actors for success in climate change mitigation at both the European and global levels (Di Bella et al., 2023). Although their individual

impact may be smaller than that of large corporations, their large number and presence across multiple sectors make their participation in emission reduction essential.

Europe remains a global leader in the furniture industry, with a market value of nearly EUR 100 billion, making it the second-largest furniture market in the world and the most integrated, with over 80% of its demand is met by EU production. The DEESME 2050 project is a European Union–funded initiative under the Erasmus+ Programme. It brings together universities, research institutions, and business associations across Europe. It supports SMEs in improving energy efficiency and reducing GHG emissions, has identified the furniture sector as strategically important for achieving EU climate goals. As a result, the project launched its activities in four key European countries within the furniture sector (France, Italy, Poland, and Bulgaria) chosen as reference countries. This focus is justified by the sector's strong economic relevance: over 130,000 companies employing more than one million people, the vast majority of which are SMEs (European Commission, 2022).

While not classified as energy-intensive, the furniture sector, along with related industries like textiles and leather, still accounts for significant energy consumption and GHG emissions. As the most energy-intensive sectors are already subject to legal obligations, the furniture sector presents an ideal next focus for voluntary climate action. Moreover, the European Furniture Industry Confederation has publicly supported the climate-neutrality objectives of the European Green Deal (EGD) and the transition to a circular economy, reinforcing the relevance of DEESME 2050's targeted support in this area. Additionally, these companies face increasing external pressure to become more sustainable, with over 90% of SME associations in Europe reporting that they experience strong or very strong pressure to achieve climate neutrality. This pressure mainly comes from society and the European Union, but also from investors, national governments, customers, and partners in their supply chains (Di Bella et al., 2023).

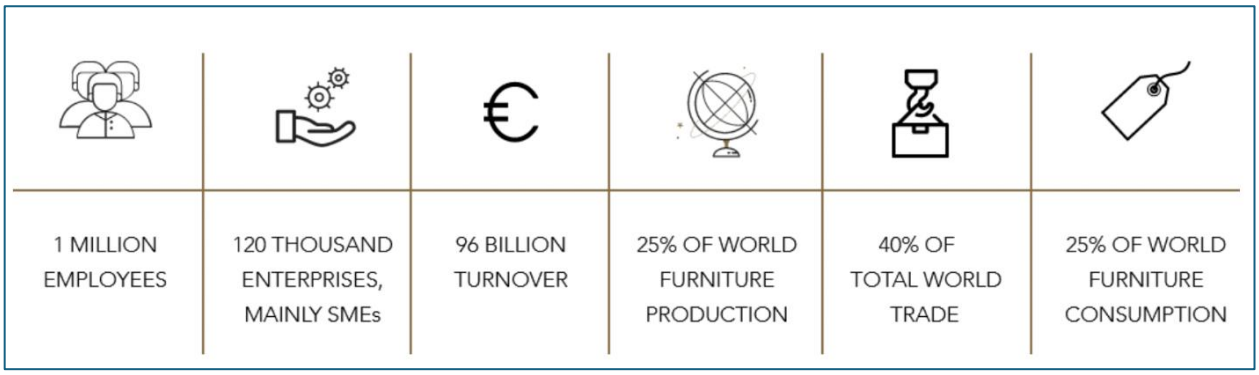


Figure 2. Furniture Based Sector Data (IEECP, 2022)

1.3 Energy Efficiency: A Key Strategy

In July 2021, the European Commission introduced a proposal to revise the Energy Efficiency Directive, aiming to strengthen support measures for SMEs. The International Energy Agency (IEA) has emphasized this point strongly, and the Energy Efficiency Financial Institutions Group (EEFIG), has also been active in promoting investment in energy efficiency for SMEs. All these developments confirm that focused action in industry, especially in SMEs, is essential for meeting Europe's climate and energy goals (IEECP, 2022).

Improving energy efficiency remains the most cost-effective approach to reducing energy-related emissions, enhancing economic competitiveness, and increasing energy security. Within the European Union, various legislative frameworks provide guidance for both states and enterprises, regardless of size, on how to improve energy efficiency. Chief among these is the Energy Efficiency Directive, which establishes a common framework of measures to eliminate market barriers and promote the efficient use of energy in both supply and demand. Article 8 of the Directive plays a key role in this effort, requiring Member States to promote and facilitate the implementation of energy audits and energy management systems. While energy audits are mandatory for large companies, they are also recommended for SMEs, with national authorities expected to encourage implementation of the resulting recommendations. (IEECP, 2022).

1.4 Small and Medium Enterprises Challenges and Relevance

Despite the availability of data and supportive EU policies promoting energy efficiency, most SMEs have not undergone an energy audit in the past five years, do not have an appointed energy manager or an established energy policy, and have not implemented energy efficiency measures.

One of the main challenges of SMEs face in reducing their energy consumption, and, consequently, their GHG emissions, is the difficulty of accurately measuring it. Although emission reduction is a key objective in global climate strategies, many SMEs lack accessible tools and simplified methodologies to effectively quantify their emissions. Accurate measurement requires detailed data on energy use, production processes, supply chains, and other factors that are often not easily traceable for companies with limited technical and financial resources. This lack of reliable data creates a structural barrier: without accurate measurements, it is difficult to set realistic reduction strategies, access financial incentives, or comply with increasingly strict environmental regulations. Moreover, many decarbonization initiatives and sustainability certifications are designed with large enterprises in mind, leaving SMEs at a disadvantage.

In addition to these structural limitations, SMEs also face a lack of awareness, limited capital, and difficulty accessing financing and support from national policies, along with doubts about the actual energy-saving potential and a shortage of technical human resources. Support mechanisms are often unavailable, resources are scarce, and there is limited facilitation to encourage the uptake of energy efficiency measures or awareness of their multiple benefits. Competing business priorities further hinder progress. DEESME 2050 has found that, at the EU level, there are no quantitative targets or mandatory obligations for SMEs, making additional motivation necessary (IEECP, 2022).

At the national level, alignment of policies remains unclear, and support is typically limited to information-sharing, with insufficient financial assistance. Furthermore, DEESME's analysis of the multiple benefits approach to energy auditing reveals that managers often do not prioritize energy management, particularly in SMEs. The strategic value of investing in energy efficiency is not clearly perceived, and there is a general lack of integrated design, systems thinking, reliable data, and tools to quantify the benefits of efficiency measures. Other barriers include a lack of training, absence of energy considerations in appraisals, limited incentives, inconsistent results, and a narrow focus on traditional cost-benefit analyses that overlook broader environmental, social, and economic benefits (IEECP, 2022).

To ensure that all SMEs can actively participate in the fight against climate change, it is essential to create simple, easily accessible tools for emission measurement, supported by technical guidance and, where possible, financial support. These tools must be designed with specific approaches tailored to each type of business, making them easier to use and as accurate as possible. The importance of involving all SMEs in Europe in the transition to sustainability is recognized, given their pivotal role in the economy and their environmental impact. However, it is also understood that addressing all SMEs simultaneously may not be feasible.
For this reason, a more effective strategy is to work sector by sector, developing tools tailored to the unique characteristics of each industry. In this case study, the focus will be on creating and adapting a tool for emission measurement specifically for the furniture sector, with particular attention to those working with wood. This will ensure that the tool is accurate, applicable, and useful in driving effective emission reduction strategies within this sector.
This effort will be specifically targeted at the four countries involved in the DEESME project, France, Italy, Poland, and Bulgaria, ensuring that the tool is designed to meet the unique needs and challenges of SMEs in these regions. By addressing these challenges, the development of a tailored emissions calculator for the furniture sector will offer SMEs in these countries a practical, sector-specific solution, enabling them to actively contribute to climate goals and improve their energy efficiency (IEECP, 2022).

2. AIMS OF THE STUDY

The general aim of the present work is to explore the development of a simplified, sector-specific GHG emissions calculator designed as a strategic instrument for SMEs in the European furniture industry to both quantify emissions accurately and identify opportunities for reduction. Specifically, the study focuses on identifying the most significant and feasible GHG emission scopes to measure for companies participating in the DEESME 2050 project, validating the functionality and accuracy of the calculator through its application to a real case study of an Italian furniture company, and evaluating the advantages and limitations of the proposed GHG accounting approach and its related frameworks.

3. CLIMATE POLICIES FRAMEWORK

3.1 The Evolution of GHG Accounting

United Nations Framework Convention on Climate Change (UNFCCC)

The first major milestone for the formalization and operationalization of GHG accounting was the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force on March 21, 1994. Today, it has an almost universal membership. The 197 countries that have ratified the Convention are known as Parties to the Convention. This Convention established an international framework to address climate change, which involved the need to monitor and reduce countries' GHG emissions.

The UNFCCC is a "Rio Convention," one of the two treaties opened for signature at the 1992 Earth Summit in Rio de Janeiro. This was a remarkable achievement for its time. It is worth noting that in 1994, when the UNFCCC came into effect, there was less scientific evidence than there is today. The UNFCCC incorporated a very important principle from one of the most successful multilateral environmental treaties in history, the Montreal Protocol (1987), which obligated member states to act in the interest of human safety even amid scientific uncertainty (UNFCCC, 1997).

The Kyoto Protocol

Following this framework that begins to lay the foundation for acting, the next key point arises. On December 11, 1997, the Kyoto Protocol was adopted in Kyoto, Japan. Specifically, the Kyoto Protocol operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries to limit and reduce GHG emissions in accordance with individual targets agreed upon. Structured around the principles of the Convention, the Protocol sets binding emission reduction targets for 37 countries and the European Union (EU), implicitly recognizing that, in 1997, they were primarily responsible for the high levels of GHG emissions in the atmosphere (United Nations Framework Convention on Climate Change, n.d.).

The Kyoto Protocol established mechanisms such as the Clean Development Mechanism (CDM). The CDM allows an Annex I Party to implement a project that reduces GHG emissions or, subject to certain limitations, removes GHG through carbon sequestration ("sinks") in the territory of a Non-Annex I Party. The resulting certified emission reductions, known as CERs, can be used by the Annex I Party to help meet its emission reduction targets. CDM projects must be approved by all parties involved, must lead to sustainable development in host countries, and must result in real, measurable, and long-term benefits in terms of climate change mitigation. Furthermore, the reductions must be additional to any that would occur in the absence of the project activity (UNEP Collaborating Centre & Riso National Laboratory, 1999).

It also introduced the concept of emissions trading, which later inspired systems such as the EU ETS. Emissions trading, as set out in Article 17 of the Kyoto Protocol, allows countries that have emission units to spare, emissions permitted to them but not "used", to sell this excess capacity to countries that are over their targets. Thus, a new commodity was created in the form of emission

reductions or removals. Since carbon dioxide is the principal GHG, people speak simply of trading in carbon. Carbon is now tracked and traded like any other commodity. This is known as the "carbon market." (United Nations Framework Convention on Climate Change,1997).

One of the main criticisms of the emissions trading system established by this protocol is that it does not guarantee an actual reduction in emissions. Although countries can buy carbon credits to "offset" their emissions, this does not lead to a direct decrease in emissions in the countries purchasing the credits. Instead of investing in local and sustainable solutions to reduce emissions, countries may simply pay others to reduce their emissions on their behalf, allowing them to continue with polluting practices without making substantial changes to their own industrial sectors. This and other shortcomings will be discussed in depth later on.

GHG Protocol

Finally, in 1998, the GHG Protocol Initiative (GHG PI) was created. The GHG PI is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and other entities, convened by the World Resources Institute (WRI), a U.S.-based NGO, and the World Business Council for Sustainable Development (WBCSD), a coalition of 170 international companies headquartered in Geneva, Switzerland (GHG Protocol, 2004). This initiative's mission is to develop internationally accepted accounting and reporting standards for companies' emissions and to promote their widespread adoption. It is worth noting that it was the first global standard for the accounting and reporting of GHG emissions. This protocol introduced a classification of emissions into three "scopes" (GHG Protocol, 2004):

- Scope 1: Direct emissions from sources owned or controlled by the organization.
- Scope 2: Indirect emissions from the generation of purchased electricity.
- Scope 3: Other indirect emissions, such as those from the supply chain and transportation.

The scopes of the GHG Protocol are important because they provide a clear and structured framework for categorizing GHG emissions based on their origin and the organization's responsibility over them. Although this is the intended purpose of the scopes, which in theory should be highly effective, a more critical perspective on this approach will be discussed later on. In the past few years, GHG Protocol standard reporting has been integrated into law in many parts of the world. For example, the European Commission adopted the European Sustainability Reporting Standards (ESRS) for use by all large companies listed in the EU subject to the Corporate Sustainability Reporting Directive (CSRD) in July 2023. The European Sustainability Reporting Standards directly reference GHG Protocol's standards and are expected to impact 50,000 companies across the European Union (World Resources Institute, 2024). It is important to mention that although the GHG Protocol was conceptualized and shared in 1998, it was not officially published and widely implemented until 2001.

ISO Normatives

Following this milestone in GHG accounting, more organizations joined efforts to create frameworks that facilitate and improve the accounting process. In 2006, the ISO 14064 standard was published by the International Organization for Standardization (ISO), an independent non-governmental entity that develops and publishes international standards. ISO brings together

national standardization bodies from various countries with the goal of establishing international standards across a wide range of areas, including environmental management. The ISO 14064 standard aims to provide credibility and assurance for GHG emission reports and for declarations of GHG reduction or removal. This standard includes a set of criteria for the accounting and verification of GHGs and defines international best practices for the management, reporting, and verification of GHG-related data and information (Fronti de García, 2022). This standard is divided into three parts:

- ISO 14064-1: Specification for the quantification, monitoring, and reporting of emissions and removals at the organizational level.
- ISO 14064-2: Specification for the quantification, monitoring, and reporting of emission reductions and enhancement of removals resulting from GHG projects.
- ISO 14064-3: Specification with guidelines for validation and verification.

ISO 14064 has applications for both the private and public sectors. For businesses, the standard provides steps for developing an inventory that is not only easily verifiable but also comparable with inventories from other organizations. By using the standard as a guide, businesses can reduce the cost of conducting and verifying a GHG inventory. Because the standard represents a consensus on technical GHG inventory best practices, companies can have greater confidence in the inventories they produce, which in turn enhances their credibility with stakeholders (Wintergreen & Delaney, 2004).

After the publication of this standard, ISO 14069 was released in 2013. This normative establishes the principles, concepts, and methods related to the quantification and reporting of GHG emissions, both direct and indirect, for an organization. It provides guidance for the application of ISO 14064-1 to GHG inventories at the organizational level, including the quantification and reporting of direct emissions, energy indirect emissions, and other indirect emissions. It outlines the steps that all organizations, including local authorities, should follow to establish organizational boundaries, either through a control approach (financial or operational) or an equity share approach. It also defines operational boundaries by identifying direct emissions and energy indirect emissions that must be quantified and reported, as well as any other indirect emissions the organization chooses to include in its inventory. For each emission category, specific guidance is provided regarding boundaries and methodologies appropriate for the quantification of GHG emissions and removals.

Regarding GHG reporting, ISO 14069 provides guidelines to enhance transparency in defining boundaries, in the methodology used for quantifying GHG emissions and removals, and in assessing the uncertainty of the results. This ensures that organizations can communicate their emissions in a clear and verifiable manner, increasing confidence in the reported information (ISO, 2013).

Paris Agreement

Following this, another major milestone in GHG accounting was the Paris Agreement, a legally binding international treaty on climate change. It was adopted by 196 Parties at COP21 in Paris in December 2015 and entered into force in November 2016. Its goal is to limit global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of GHG emissions as soon as possible to achieve a climate-neutral world by mid-century. To succeed in these ambitious goals, GHG accounting is essential for measuring and reporting GHG emissions at both national and international levels, as it provides the foundation for countries and companies to meet their emission reduction commitments (UNFCCC, 2015).

One of the most important parts of this agreement are the Nationally Determined Contributions (NDCs). NDCs are at the heart of the Paris Agreement and the achievement of its long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions (UNFCCC, 2015).

The Paris Agreement requests each country to outline and communicate their post-2020 climate actions, known as their NDCs. Together, these climate actions determine whether the world achieves the long-term goals of the Paris Agreement and to reach global peaking of GHG emissions as soon as possible and to undertake rapid reductions thereafter in accordance with best available science, to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century. It is understood that the peaking of emissions will take longer for developing country Parties, and that emission reductions are undertaken on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty, which are critical development priorities for many developing countries (UNDP, 2023). While NDCs are established at the national level, their successful implementation relies heavily on action across all sectors of society, including the private sector. Businesses, and particularly SMEs, play a critical role in achieving national emission reduction targets. They are key drivers of innovation, production, and employment, and their operational choices directly impact energy consumption and GHG emissions. Therefore, engaging SMEs in climate action not only contributes to fulfilling NDCs but also helps build a more resilient and sustainable economy.

It is important to mention that the Paris Agreement explicitly acknowledges the importance of traditional knowledge, including the knowledge of Indigenous Peoples, especially in the context of climate adaptation. Article 7.5 of the Agreement emphasizes that adaptation efforts should be "guided by the best available science and, as appropriate, traditional knowledge, knowledge of Indigenous Peoples and local knowledge systems." This recognition reflects a growing understanding of the value that Indigenous Peoples bring through centuries of lived experience, ecological stewardship, and sustainable land-use practices (UNFCCC, 2016).

In practice, however, the extent to which Indigenous knowledge is incorporated into NDCs varies significantly across countries and regions. Some governments have begun to actively include Indigenous Peoples in national climate dialogues, recognizing their rights and contributions. At the international level, the UNFCCC has established the Local Communities and Indigenous Peoples Platform (LCIPP) to facilitate the exchange of experiences and best practices on climate change mitigation and adaptation. The LCIPP serves as a crucial mechanism for incorporating Indigenous knowledge into global climate policy discussions and for promoting the engagement of Indigenous Peoples in the implementation of NDCs (UNFCCC, 2016).

Despite these advancements, significant challenges persist. Indigenous communities continue to face systemic exclusion from national and international climate decision-making processes, often due to political marginalization, lack of legal recognition, and structural inequalities. While the Paris Agreement and some NDCs acknowledge the value of Indigenous knowledge, its integration often remains superficial or symbolic, limited to consultations rather than genuine power-sharing in climate governance. In many cases, Indigenous knowledge is appropriated without proper recognition or benefit-sharing, undermining the very communities it claims to empower.

European Green Deal and the Climate Pact

The EGD is a comprehensive strategy launched by the European Commission in December 2019 with the goal of making the European Union (EU) "climate-neutral" by 2050. It outlines a set of policies, regulations, and initiatives aimed at reducing GHG emissions, improving environmental sustainability, and transforming the economy to achieve long-term ecological goals. The Green Deal encompasses a broad range of areas, including energy, transportation, agriculture, biodiversity, and circular economy, aiming to align economic growth with environmental protection (European Commission, 2019).

The European Climate Pact is an initiative launched by the European Commission as part of the broader European Green Deal. Its primary objective is to engage people, communities, and organizations across Europe to participate in climate action and contribute to achieving the EU's target of climate neutrality by 2050. The Pact provides a platform for citizens and stakeholders to connect, learn, and collaborate on solutions to reduce GHG emissions and enhance environmental protection. It encourages voluntary commitments, whether large or small, like community projects or adopting greener business practices (European Commission, 2020).

The Climate Pact is also intended to support the implementation of national climate policies and the achievement of NDCs under the Paris Agreement. By empowering citizens and local actors, the Pact bridges the gap between high-level policy and grassroots action, helping to ensure that the transition to a low-carbon economy is both inclusive and socially just. The initiative fosters a bottom-up approach, recognizing that real and lasting change often starts with individuals and communities (European Commission, 2020).

The EGD and GHG accounting are deeply interconnected, as the first one provides the framework for achieving climate neutrality and reducing emissions across the EU, while the latter serves as the tool to track progress and ensure transparency. GHG accounting is critical in measuring

emissions across various sectors, such as energy, transportation, and agriculture, to ensure these reduction targets are met. It enables policymakers to monitor progress, verify that emission reductions are being achieved, and guide future actions based on accurate, up-to-date data. (European Commission, 2019).

European Financial Reporting Advisory Group

European Financial Reporting Advisory Group (EFRAG) is an independent organization that advises the European Commission on the development and adoption of financial reporting standards. Founded in 2001, its main role has been to ensure that International Financial Reporting Standards (IFRS) are appropriate for use within the European Union. It acts as a bridge between international standard-setters and the European context, evaluating the relevance, usefulness, and applicability of these standards in EU member states (Arena & Catuogno, 2024).
In recent years, EFRAG has expanded its mandate to include the development of sustainability reporting standards. In this framework, it leads the creation of the European Sustainability Reporting Standards (ESRS) in support of the Corporate Sustainability Reporting Directive (CSRD). These standards aim to ensure that companies report clearly and comparably on environmental, social, and governance (ESG) aspects, aligning their practices with the objectives of the EGD and other climate targets (EFRAG, 2022).
In relation to GHG accounting, EFRAG plays a fundamental role, as the ESRS include specific requirements for companies to report their GHG emissions under all three scopes (Scope 1, 2, and 3), following international standards such as the GHG Protocol. This means that emission accounting methodologies must not only be rigorous but also compatible with the European regulatory framework (Arena & Catuogno, 2024). EFRAG ensures that this integration is technically and operationally feasible, promoting transparency and accountability regarding corporate climate impacts (EFRAG, 2022).

3.2 Methodological Approaches to Carbon Footprint Calculation

Softwares and tools to estimate GHG emissions

The tools presented below are complex and highly specialized platforms designed for use by professionals in the field of Life Cycle Assessment (LCA). These tools offer advanced modeling capabilities, detailed databases, and impact assessment methods, enabling the generation of accurate and reliable results. However, due to their complexity and the high costs associated with their use, they are primarily accessible to large companies or professionals dedicated to environmental analysis and sustainability. Despite their high price, their precision and depth of results make them essential tools for those seeking to carry out thorough and detailed analyses of the environmental impacts of products and processes.
While other tools may exist, the following are considered the most widely used in the LCA field: SimaPro, GaBi, and Umberto.

- SimaPro

SimaPro is a software tool used by professionals and organizations to assess the environmental impacts of products, processes, or services throughout their entire life cycle. Developed by PRé Sustainability, SimaPro is used both in academia and in the corporate world, and is considered one of the most comprehensive and widely used platforms in environmental analysis (PRé Sustainability, n.d.). One of the key features of SimaPro is its comprehensive database, EcoInvent, which contains detailed and up-to-date information on life cycle inventories (LCI) for a wide range of materials, energy sources, and processes. Additionally, it supports several impact assessment methods, such as ReCiPe, CML, and Eco-Indicator 99, which allow for the calculation of environmental impacts such as global warming potential (GWP), acidification, eutrophication, and resource depletion. This detailed modeling capability enables users to carry out accurate and reliable analyses to evaluate the environmental performance of products and processes (PRé Sustainability, 2025).

SimaPro also stands out for its flexibility in modeling, allowing users to create complex models that cover all stages of a product's or service's life cycle, from raw material extraction to final disposal. It also supports sensitivity analyses and scenario analyses, which help identify key variables that influence environmental impact and enable informed decision-making based on different scenarios.
Although SimaPro is known for its precision and reliability, it has some limitations. First, its high cost makes it accessible primarily to large companies, research institutions, and specialized consultants. Furthermore, due to its advanced functionalities, its complexity may require training to fully unlock its potential, which can make it challenging for users unfamiliar with life cycle assessment (Rodrigues et al., 2017).

- GaBi

GaBi is an advanced software tool specialized in Life Cycle Assessment (LCA), which allows for the analysis of the environmental impacts of products, services, and processes across all stages of their life cycle, from raw material extraction to final disposal (Sphera, 2025). Developed by Sphera (formerly thinkstep), GaBi offers an extensive and up-to-date database that covers a wide range of materials, energy sources, and processes. Similar to SimaPro, GaBi is designed for professionals in the field and, therefore, comes at a high cost and is typically acquired by companies specialized in environmental assessment (Sphera, 2025).

- Umberto

Umberto is a software tool specialized in Life Cycle Assessment (LCA), Material Flow Analysis (MFA), and carbon footprint calculation. Developed by ifu Hamburg, Umberto enables users to analyze and visualize environmental impacts, resource consumption, and waste generation throughout the life cycle of products, processes, or services.

The tool is particularly useful for mapping and analyzing material and energy flows within complex systems, helping to identify inefficiencies and areas for improvement in resource use. In addition, Umberto supports the LCA methodology, allowing users to calculate environmental impacts such as global warming potential (GWP), eutrophication, and acidification (iPoint Systems, 2025).

- OpenLCA

OpenLCA is a free, professional Life Cycle Assessment (LCA) and footprint software with a broad range of features and many available databases, developed by GreenDelta. Since 2006 openLCA is completely free, without any license costs. The software is fully transparent. You can freely share both the software and any models you create in openLCA, provided the database licenses allow it.It is also open-source software, which means that users can access its source code and adapt it according to their needs. This makes it a very attractive option for organizations and individuals looking for an economical and flexible solution (GreenDelta GmbH, 2025).
The software aims to foster a collaborative programming community, where developers can contribute to the continuous growth and improvement of the tool. The idea is to create additional modules for the existing framework, allowing users not only to take advantage of the standard functionalities but also to create their own custom modules according to their specific needs. This flexibility and open collaboration strengthen the software's ability to adapt to a wide range of applications in life cycle assessment. It is is compatible with various impact assessment methods, such as ReCiPe, CML, Eco-indicator 99, among others, allowing the calculation of environmental impacts like global warming, eutrophication, and acidification, among others (GreenDelta GmbH, 2025).
Table 1. show results of the qualitative comparison of the LCA software tools. This is based on the results of the study and comparative assesment conducted by the Brazilian Institute of Information in Science and Technology (IBICT) (Silva et al., 2017).

Analysis Criteria	**GaBi**	**openLCA**	**SimaPro**	**Umberto NXT**
Software Origin and Version	Germany, ThinkStep, software version 6.5.	Germany, GreenDelta, software version 1.5.0.	Netherlands, PRé Consultants, software version 8.2.3.0.	Germany, iFu Hamburg GmbH, software version NXT Universal 7.1.13.
Format of Datasets	ILCD, EPD, ecoSpold v1, GPR, gbx.	ILCD, ecoSpold v1, v2, csv, Excel, JSONLD.	ecoSpold, csv, Excel.	ecoSpold, csv, Excel.

User Interface Perception	Uses process modelling and diagrams for each unit process.	Uses process modelling and diagrams for each unit process.	Uses matrices for modelling of unit processes.	Uses Petri nets for LCA modelling.
Presentation of LCA Results	Uses Sankey diagram and bar charts to show LCA results. Tables and automatic flow balances are used for inventory analysis.	Uses Sankey diagram and bar charts to show LCA results, and tables for inventory analysis.	Uses Sankey diagram and bar charts to show LCA results, and tables for inventory analysis.	Uses Sankey diagram to show LCA results and tables for inventory analysis. The results can be exported to Dynamic Excel Pivot Table and Dashboard.

Table 1. LCA Tools Comparison. Author's own elaboration.

Simplified Calculation Tools

The following section presents a simple review of several GHG calculators. The goal is to highlight their strengths and limitations, providing insights into which calculators may be most suitable for various GHG accounting needs and how they can support businesses in measuring and reducing their carbon footprints.

- UNFCC GHG Emissions Calculator

The UNFCC secretariat developed the GHG emissions calculators to provide the general public a free up-to-date methodology for estimating GHG emissions. The UNFCC GHG Emissions Calculator aims to support organizations to estimate their GHG emissions to raise awareness and to promote climate actions. The data and information on the spreadsheet are for reference purpose only and the emission factors are publicly available on third parties' websites. The emission factors used to calculate business travels rated emissions retrieve the data from UK GHG Reporting: Conversion Factors (2021). The spreadsheet should not be used for certification purposes and does not replace a formal, tailored GHG inventory development process nor third-party verified GHG inventories (UNFCCC, 2021).

The tool is a bottom-up spreadsheet that enable companies to calculate their CO_2 equivalent emission related to the organization activities. It is based on the GHG Protocol standard dividing the emission per Scopes. It permits to calculate the GHG emissions also for home office and food.

- Mobilize Your City Emissions Calculator

The Mobilise Your City is a partnership, launched at the COP21 in Paris in 2015, of nearly 100 partners for Sustainable Urban Mobility Plans (SUMPs) and National Urban Mobility Programs (NUMPs). It supports cities and countries to project the GHG impact of their SUMPs and NUMPs. The tool has been developed by the Institute for German Energy and Environmental Research in cooperation with the German and French development agencies (MobiliseYourCity Partnership, 2024). The tool is a spreadsheet model for GHG emission (GHG) calculations in the transport sector at the national and local level. It enables calculating GHG inventories of cities and countries as well as "business as usual" scenarios and climate scenarios. The tool enables governments to calculate potential effects of national and urban transport policies on total GHG emissions, e.g. extension of public transport, subsidies for electric vehicles. The scope of the analysis is based on a territorial principle (all traffic within the city/country must be considered within the defined territory). The emissions factor has been selected from a number of sources ranging from IPCC guidelines 2006, IEA statistics, and EMEP/EEA air pollutant inventories 2016 (MobiliseYourCity Partnership, 2024).

- EPAs Simplified GHG Emissions Calculator

The Simplified GHG Emissions Calculator is a tool developed by the United States Environmental Protection Agency (EPA) to help organizations, especially SMEs, estimate their GHG emissions in a simple and accessible way. Its goal is to facilitate the calculation of the carbon footprint without the need for complex tools that require advanced knowledge and detailed data.
The calculator features an easy-to-use interface and allows for emissions assessment without prior technical experience, covering Scope 1 (direct) emissions, Scope 2 (indirect emissions from electricity), and some key categories of Scope 3 (such as business travel or fuel consumption). Its methodology is based on activity data, such as fuel consumption, electricity usage, and distances traveled, and uses pre-integrated emission factors from official sources like the IPCC and DEFRA. Additionally, it follows the guidelines of the GHG Protocol, ensuring credibility and compatibility with international standards (EPA, 2024). This calculator was the foundation for many aspects of the calculator that was developed, as it offered a clear methodology, a user-friendly design, and suited very well the needs that were present.

- Iordanis Eleftheriadis (University of Macedonia) Simplified GHG Emissions Calculator

The tool's design is based on the Life Cycle Assessment (LCA) methodology, which assesses the environmental impact of a particular service or product over the different stages of its life cycle. The tool was tested in a small cheese factory in northern Greece, an SME representative of the country's average SME. The production process was mapped, a GHG inventory was created, and the total emissions related to the production of a specific product were estimated (Eleftheriadis & Anagnostopoulou, 2024).

The development of the tool contributed to advancing the calculation of CF in SMEs in the following manner. First, it allows for a complete mapping of the LCA stages of a particular product or service according to the structure of their current processes. Second, specialized knowledge regarding the boundaries and the scopes of carbon reporting is not necessary when using the specific tool; its design is more aligned with daily business processes, such as the reception of raw material, production, storage, etc. Finally, it allows for comparisons between different production processes since emissions are allocated to each stage and the equipment used in the particular stage, making it easier for managers to identify energy consumption hotspots. Also, the fact that this is a web application allows for multiple users to have access to the tool. Therefore, each user can record data according to his/her area of expertise (Eleftheriadis & Anagnostopoulou, 2024).

3.3 Critics and points of improvement in GHG Accounting for SMEs

Emission Factors and Their Limitations

Utilizing global or regional average emission factors in GHG inventories can lead to significant inaccuracies when applied to local conditions. This approach can overlook specific variations in technology, fuel types, industrial practices, and environmental regulations, resulting in either overestimation or underestimation of actual emissions.

By relying solely on these generalized emission factors, organizations risk either overestimating or underestimating their true environmental impact. Overestimation may lead to unnecessary costs or excessive mitigation efforts, which can be really harmful specially for SMEs. On the other side, underestimation can result in non-compliance with environmental regulations, reputational damage, and missed opportunities for improvement. To enhance accuracy, it is crucial to use localized data whenever possible, employ region-specific emission factors, or integrate databases that provide more detailed and context-specific information. Because of this, understanding how reliable the data we use is crucial for making informed decisions in GHG inventories and climate action (GHG Protocol, 2004).

Although specific data may exist for the same region or country, fulfilling the need for more accurate inventories, it is possible that the entities generating this data use different methods. This can lead to discrepancies in estimations, even if the data seems to apply to the same geographical context. Variations in data collection methods, calculation approaches, or the databases used can significantly influence the results of GHG emission estimations. Therefore, it is essential to use the same calculation methods and consistent data sources when making different estimations to ensure valid comparisons and that decisions based on this data are as accurate as possible. This highlights the importance of ensuring methodological consistency when working with emission data, especially when used to assess environmental impact and design effective mitigation strategies (GHG Protocol, 2004).

The need of third-party verification in many corporate GHG inventories

GHG reporting, often voluntary for companies, can suffer from inconsistencies or misreporting without independent oversight. When companies self-report their emissions data, there is an inherent risk of bias or errors, whether intentional or accidental. This lack of independent

verification undermines confidence in the reported data and raises questions about its reliability, making it difficult for stakeholders, to trust that the company's emissions claims are accurate.
Without third-party verification, there is a risk that companies could downplay their emissions or fail to accurately account for certain sources of GHGs, particularly those that may not be immediately visible or easy to quantify, such as supply chain emissions or indirect emissions. The absence of external validation also means that claims of "carbon neutrality" or "net-zero emissions" could be misleading if they are based on self-reported data that hasn't been scrutinized by independent experts. For example, according to a Guardian analysis (O'Brien, 2024), from 2020 to 2022 the real emissions from the "in-house" or company-owned data centers of Google, Microsoft, Meta and Apple are probably about 662%, or 7.62 times higher than officially reported. Even though, most recently, to address these issues, various frameworks and standards, such as the ISO 14064-3 (which provides guidelines for GHG verification), advocate for third-party verification to enhance the credibility and reliability of emissions data. The verification process involves selecting qualified verifiers, establishing appropriate levels of assurance, and conducting thorough assessments of a company's GHG assertions (ISO, 2019).
In the specific case of SMEs, third-party verification of GHG inventories is not mandatory, at least not globally. While it is recommended to enhance the credibility and transparency of emissions data, third-party verification is generally voluntary unless required by specific regulatory frameworks or corporate sustainability reporting standards in certain jurisdictions. This lack of external verification undermines the effectiveness of climate change mitigation efforts.

How data gaps lead to underreporting or selective reporting

Data gaps in GHG inventories can lead to underreporting or selective reporting, significantly affecting the accuracy of climate change mitigation efforts. When comprehensive data is unavailable, organizations may rely on assumptions or modelling, potentially omitting indirect emissions or those from less-monitored sectors. This omission can result in inventories that do not fully capture an organization's emissions, leading to selective reporting that emphasizes certain emissions while downplaying others. The complexity of accounting GHG and the lack of data make necessary simplifications and assumptions in inventorying GHG emissions, but it is important to search for a balance between making the necessary assumptions, based on well-known data, and downplaying the real impact of their activities (Palermo et al., 2024).
To address these challenges, the GHG Protocol suggests utilizing comprehensive life cycle databases, such as Ecoinvent, to provide regional or global average GHG emission factors. These databases can help fill data gaps by offering standardized emission factors, enhancing the accuracy of Scope 3 GHG reporting (GHG Protocol, 2004).The issue with this is that databases like Ecoinvent are typically not open source, and SMEs often cannot afford the necessary investment to access them, which hinders their ability to fill these information gaps with well-curated data. Another challenge is that the information gaps often arise from parts of the inventory that are complex and difficult for regular workers in SMEs to understand. As a result, external professional help is often required, but not all companies have the resources to afford this support. This is one of the key aspects that need to be assessed to understand how different the results can be when

using software with access to a database like Ecoinvent compared to a simplified calculator. Comparing these two approaches can help determine the level of accuracy needed for decision-making and whether SMEs require more advanced tools or external support to ensure reliable emissions assessments and also determine which points can be improved. (GHG Protocol, 2004).

The impacts in the Global South of carbon offset projects

The use of land in the Global South for carbon offsetting projects has generated controversy due to its negative impacts on local communities. These projects, such as reforestation or forest conservation initiatives, are often promoted by countries and companies from the Global North as a solution to reduce their emissions and meet their climate targets. Many studies confirm that forest-dependent communities are not sufficiently involved in current carbon offsetting projects. Furthermore, the current and potential impacts of this type of project often disrupt local peoples' livelihoods and strategies, institutions, and socio-cultural systems in various ways, such as unequal benefit sharing, food insecurity, the introduction of new powerful stakeholders, illegal land acquisition, unfair free, prior and informed consent processes, and the establishment of monoculture plantations.

The following section provides a review and compilation of some of the main issues related to the carbon market, and more specifically, to carbon offsetting projects.

When discussing the impact of carbon offset projects at the governmental level, it is important to consider that, over the past 25 years, forest management systems in many developing countries have undergone decentralization, granting local actors and institutions greater rights, responsibilities, and decision-making authority over the natural resources under their management or control (Phelps, Webb, & Agrawal, 2010). Various authors like Berkes (2017), Ostrom & Nagendra (2006), have pointed out that decentralized forest management and local institutions are crucial for sustainable forest conservation and community livelihood development. At its most extensive, decentralization allows stakeholders to redefine ownership, use, and management of forests. Governments have decentralized forest management for many reasons: to reduce costs and increase efficiency by transferring responsibilities, to respond to local demands for rights and international donor pressures to transfer benefits to users, and in recognition that conservation is possible across diverse tenure regimes (Phelps, Webb, & Agrawal, 2010). However, projects of carbon offsetting, can reverse current trends in the forest governance structures of the countries where these projects take place (Bayrak & Marafa, 2016).

Carbon offsetting projects could potentially exclude forest-dependent communities and recentralize forest governance. Furthermore, it could introduce new powerful parts, like external private and political actors. They can undermine the decentralization of forest management systems in developing countries (Agrawal, Nepstad, & Chhatre, 2011). Governments could be inclined to recentralize their forest management systems, because, normally, carbon offsetting projects require governments to establish national carbon-oriented forest management plans, reliable baseline data, MRV mechanisms, and national institutions for the trading and payment of carbon stocks in the forests (Phelps, Webb, & Agrawal, 2010).

These demands would impose prohibitive costs for small-scale initiatives, but a centralized system would benefit from economies of scale, coordination, and standardization. A national approach to REDD+ could generate greater emissions reductions at a lower cost, however, bureaucracy and corruption could render a national approach inefficient and counter effective. It is therefore important that countries do not only show a willingness to actively involve local stakeholders, such as forest-dependent communities, through a nested approach, but that they will also have to outline clearly in their project readiness plans how they are going to do it (Angelsen, 2008).
A national approach could generate greater emissions reductions at a lower cost; however, bureaucracy and corruption could render a national approach inefficient and counter effective. Centralized forest governance could lead in countries with weak or no safeguards to a greater forest loss and lower forest-related benefits for forest-dependent communities, and the poor (Sandbrook et al., 2010).

From a financial perspective, it is important to note that land designated for carbon markets can restrict local communities' access to forest resources essential for their livelihoods. In many cases, this occurs with little or no compensation, thereby marginalizing local populations or making them dependent on external actors, such as foreign companies or nongovernmental organizations (NGOs).Restrictions may affect most traditional uses and last for long periods, leaving some local populations in a critical situation. This can lead to a loss of employment, income, and even food security for forest-dwelling communities. It would be incorrect to consider all traditional practices as sustainable. However, if forest protection cannot be achieved by suppressing people's livelihoods; alternative livelihoods must be provided rather than simply imposing limitations (Atmadja & Verchot, 2012).
Livelihood constraints should be compensated by payments from carbon sequestration, but local communities may not be the beneficiaries, even suffering the restrictions caused by a lack of land titles or legal use rights, especially in poor communities and women-headed households (Olsen, 2007). Communities that traditionally exercise forest stewardship may be pushed out by local elites, investors, or NGOs. Even when benefit sharing reaches the local population, the distribution is often inequitable, with external actors receiving the lion's share. Social inequality increases when some people have access to benefits and others do not. It is hardly possible to optimize carbon offsetting and alleviate poverty simultaneously (Barton & Lienhoop, 2024).
It's a fact that Carbon offsetting projects provide various opportunities for livelihoods in some communities, but it remains important that trade-offs are realistic, fair, equitable and include all segments of forest-dependent communities, especially poorer households. The benefits of these types of projects have to be well shared so it makes sense for the communities to be part of them. (Barton & Lienhoop, 2024).

Another significant dimension of these impacts is socio-cultural. The monetization and commodification of nature have been shown to harm indigenous and forest-dependent communities. Many organizations representing indigenous peoples have long regarded themselves

as victims of neoliberal and market-driven policies.Carbon offsetting projects could also be considered as a neoliberal approach to forest conservation as its main rationale is that forests should be protected in order to get financial benefits from carbon credits. A fixation on carbon sequestration and monetary benefits could lead to intended and unintended socio-cultural consequences, which could change indigenous and local communities for the worse.

Forests form for many indigenous peoples an integral part of their existence (Carling, 2010). Therefore, restructuring or banning traditional forest management systems because of carbon projects, do not only change local people's forest use practices, but also the ecological, cultural, social, spiritual, political customary, institutional and world-view values which underline and justify it. A fixation on carbon sequestration and monetary benefits could lead to intended and unintended socio-cultural consequences, which could change indigenous and local communities for the worse (Forest Peoples Programme, 2011).

Being amongst the most vulnerable to climate change, forest-dependent and indigenous communities have traditional knowledge and management systems, which could provide effective solutions to climate change mitigation and adaptation. Incorporating indigenous and traditional knowledge in these types of projects can be something useful and important to integrate the community while protecting the forests (Forest Peoples Programme, 2011).

Speaking about food security in communities impacted by these projects, indigenous and local people could be forced to give up swidden agriculture. Implementation of carbon offsetting projects might therefore negatively influence traditional management systems, which could result in the social disruption of communities and a loss of traditional knowledge and practices. There is a valid concern that forest and natural resource-based livelihoods of indigenous minorities, can be identified as drivers of deforestation and therefore, its practice may be curtailed or banned altogether. These forms of livelihoods are linked to their identities and traditional culture. This will therefore have serious implications on the ways of life, food security and traditional knowledge of ethnic minorities (Barton & Lienhoop, 2024).

Greenwashing Through GHG Calculations

Greenwashing can be understood as a strategy by companies to create the illusion of environmental responsibility while maintaining their actual business practices. In the realm of GHG accounting, this becomes evident when organizations use tools like GHG calculators to report emissions reduction goals without implementing meaningful changes to their operations (Kim & Lyon, 2015). While companies may report their objectives and strategies to reduce emissions, this information may not reflect genuine efforts to combat climate change. Instead, it be used to enhance the company's image and legitimacy, without a real reduction in environmental impact. Legitimacy, which is largely shaped by public perception, can be influenced by the way companies disclose information about their environmental efforts. In the specific case of SMEs, the risk of greenwashing is heightened due to their relatively lower impact and limited resources to effectively manage and reduce their environmental footprint. Without proper guidance, regulatory frameworks, or third-party verification, SMEs may unintentionally fall into the trap of

greenwashing, undermining their potential to make meaningful contributions to climate action (Mateo-Márquez et al., 2022).

Net-zero claims often hide continued fossil fuel dependence, and this issue becomes particularly evident when considering GHG accounting and the use of emission calculators. Companies, including SMEs, may announce net-zero commitments, but their continued reliance on fossil fuels is often not fully captured in simplified tools like GHG calculators. (Siano et al., 2017; Yang et al., 2020). For SMEs, which often have fewer resources to conduct detailed emissions tracking, these calculators can be an important tool to get an initial understanding of their environmental impact. However, without more comprehensive accounting, they may unintentionally allow fossil fuel dependence to persist unnoticed. Therefore, while calculators serve as valuable tools, it's crucial for companies to integrate them into broader strategies that address all aspects of their emissions and move beyond just reporting to achieve genuine reductions in fossil fuel use and carbon emissions (Schmidt, 2009).

3.4 Stakeholder Mapping of GHG Accounting

As GHG accounting becomes a fundamental component of climate action strategies, a diverse range of stakeholders are increasingly involved in its implementation, regulation, and verification. Understanding the roles, interests, and influence of these actors is essential for developing effective and transparent emissions reduction pathways. The following table provides a structured overview of the key actors in the GHG accounting ecosystem, highlighting their respective responsibilities, levels of influence, and their overall impact on the process of measuring, reporting, and reducing emissions.This stakeholder mapping sets the foundation for identifying opportunities for collaboration, capacity-building, and targeted interventions in future climate-related initiatives. To conclude, this synthesis completes the state of the art, offering a comprehensive view of the technical, regulatory, and organizational landscape in which GHG accounting practices are currently evolving.

Stakeholder	Role	Interest/Influence	Impact on GHG Accounting
Companies/ Entities	Responsible for measuring, reporting, and reducing GHG emissions	High - Direct responsibility for emissions data and reduction efforts	Core data providers, implementers of emission reduction strategies
GHG Accountants/Consultants	Provide expertise in GHG accounting, calculations, and reporting	High - Essential for ensuring accurate and compliant reporting	Critical for accurate GHG data reporting and advising on reduction measures
Government Bodies/Regulatory Authorities	Set regulations, standards, and policies for GHG emissions	High - Regulatory power to enforce compliance	Influence organizations' strategies and legal requirements
Third-Party Auditors	Verify the accuracy and reliability of GHG reports	Medium - Independent verification ensures credibility	Increase trust and confidence in GHG reports through audits
Standardization Organizations	Develop and maintain standards and frameworks for GHG accounting	High - Define best practices and guidelines	Ensure consistent and standardized accounting practices
Environmental NGOs/Activists	Advocate for transparency, policy change, and emission reductions	Medium - Influence public opinion and policy through advocacy	Press for transparency and stricter environmental standards
Investors/Shareholders	Evaluate companies based on climate disclosures, including GHG emissions	High - Increasing demand for sustainability and climate action	Influence companies' reporting practices and climate action initiatives
Software Providers	Provide tools and platforms for GHG accounting and life cycle assessments	Medium - Enable efficient and accurate tracking and analysis of emissions	Facilitate the tracking, calculation, and reporting of emissions

Table 2. Stakeholder mapping: role, interest/influence, impact on GHG accounting. Author's own elaboration.

4. DATA AND METHODS

The development of the GHG emissions calculator for SMEs took place between March and July, directly in the municipality of Rubano, in the province of Padova, Veneto region, at the offices of SOGESCA. This tool was designed to be used by SMEs participating in the European DEESME2050 project, specifically those in the wooden furniture manufacturing sector across four countries: Italy, France, Poland, and Bulgaria.

Although the specific company to be evaluated as a case study had not been identified during the development of the calculator, it was known that it would be an Italian company, primarily due to considerations of time, availability, and proximity.

4.1 Justification of Methodology

The selection of Italy, Poland, France, and Bulgaria as pilot countries is well justified given their significant and diverse roles within the European furniture sector. These countries represent a mix of leading producers, emerging markets, and a high concentration of SMEs, which aligns with the objectives of the DEESME 2050 initiative. Their inclusion ensures the testing of solutions across a representative spectrum of industrial structures and regional dynamics, allowing for the development of scalable and adaptable approaches to improve sustainability and energy efficiency in the sector. According to official statistics (ISTAT, Eurostat, 2021), in the first four months of 2021 the furniture and furnishings sector was in good recovery in Europe compared to the same period of 2019 (before the crisis due to COVID). In particular in Italy, production grew by 9.4% (€22.7 bln), in Poland by 8.7% (€11.6 bln), in France by 5.5% (€7 bln), in Bulgaria 2.3% (€0.678 bln). The consortium includes three of the main producers (France, Italy and Poland) and, amongst them, the two main ones (Italy and Poland) (IEECP, 2022).

In Italy, there are many districts with specialisations; in the Veneto Region (Italy), where the DEESME 2050 partner SOGESCA is based, there are three important furniture districts: Cerea, Bassano, Treviso. In Poland, the furniture industry is one of the fastest growing industry sectors. On the Polish market, in the furniture sector, the largest share in the total number of companies belongs to micro-enterprises (employing 0–9 people) and small enterprises (employing 10–19 people). The largest number of companies from the furniture industry is located in two voivodeships: Wielkopolskie and Warmińsko-Mazurskie. The furniture industry in Bulgaria is represented by a total of 1,842 companies, predominantly SMEs. Furniture manufacturing is one of the fastest growing industries in the country due to its export orientation as well as its dependability on the construction sector which has been growing in recent years. In the last 10 years companies operating in this sector grew by 32%. In Finally, in France, the furniture industry is scattered all over the country and totals 2,171 companies, mostly SMEs (IEECP, 2022).

For the pilot implementation of the tool, a company was carefully selected based on its operational relevance and availability of data. The chosen firm is an Italian company with expertise in the wood processing sector, making it particularly suitable for testing the tool in a real-world industrial context. Using actual data from this company allowed for a more accurate and meaningful evaluation of the tool's performance and applicability. However, in accordance with data

protection regulations and to safeguard sensitive business information, the name of the company will not be disclosed.

4.2 An integrated approach

A mixed methodology was used in the development of the GHG emissions calculator, combining both quantitative and qualitative approaches. The quantitative approach was essential for formulating the calculation formulas and validating the results obtained, using accurated data on energy consumption and emissions generated by SMEs. This ensured the accuracy and reliability of the tool.

On the other hand, the qualitative approach was employed to understand the specific characteristics of the wooden furniture sector, such as production processes and common sustainability challenges. This perspective allowed the calculator to be tailored to the sector's needs and ensured its suitability for the conditions of the companies, thereby enhancing its applicability and effectiveness in real-world contexts. Specifically, this understanding of the processes enabled an informed selection of the relevant sections within each "scope" to include in the tool.

Additionally, the qualitative methodology was key in the selection process of the databases used for various sections of the calculator, such as fuel densities, emission factors, calorific values, among others. A critical evaluation was conducted based on criteria including accuracy, scientific relevance, and alignment with international standards. This analysis helped identify and prioritize sources offering the highest methodological rigor and recognition within the scientific community, strengthening the calculator's credibility and technical robustness.

Furthermore, efforts were made to ensure that the selected sources were representative of the different territories relevant to the tool, particularly those where the participating SMEs operate. This involved considering both international and regional databases, prioritizing those that most accurately reflected the energy, production, and environmental conditions of these contexts. In this way, a greater consistency was achieved between the data used and the operational reality of the companies, increasing the applicability and relevance of the results generated by the calculator.

It is important to mention that both deductive and inductive approaches were used, but the methodology leans more toward a deductive approach. The development of the GHG emissions calculator followed existing data, formulas, and standards (e.g., energy consumption data, emission factors, calorific values), which were validated and selected based on their scientific rigor and international recognition. This type of process can be classified as a deductive approach. In the other hand, maybe in a not so important degree, the inductive part was also applied while doing the qualitative analysis, because it also involved understanding sector-specific characteristics and adapting existing frameworks to the real-world context of the SMEs.

4.3 Methodology workflow

The development of the GHG emissions calculator began with a thorough review of the DEESME2050 project documents and grants, which helped clarify the specific objectives aimed at SMEs in the wooden furniture sector. A literature review was conducted to analyze existing

methodologies for GHG calculation, focusing on those that were more accessible and adaptable to SMEs. Additionally, technical guidance from project supervisors provided a practical perspective that helped shape the design of the tool. Based on this foundation, the calculator was structured and developed in Microsoft Excel, prioritizing ease of use and clear information flow. The tool was progressively built to include the three scopes of the GHG Protocol, integrating a custom database of emission factors and key variables, and programming the necessary formulas to ensure accurate results.

Once the initial version of the calculator was developed, it was tested using both simulated and real data to validate its functionality. A practical case study was then carried out in an Italian company, where on-site visits were conducted to collect operational data, which was then reviewed and validated with staff before being used to populate the tool. This real-world application revealed limitations and improvement areas in how the tool interacted with actual business data. Based on the feedback received, several adjustments were made input categories were simplified to better reflect the kind of data typically available in SMEs, calculations were refined to enhance accuracy, and the layout and instructions were improved to support non-expert users. These revisions increased the tool's overall usability and made it more applicable for broader adoption by similar businesses.

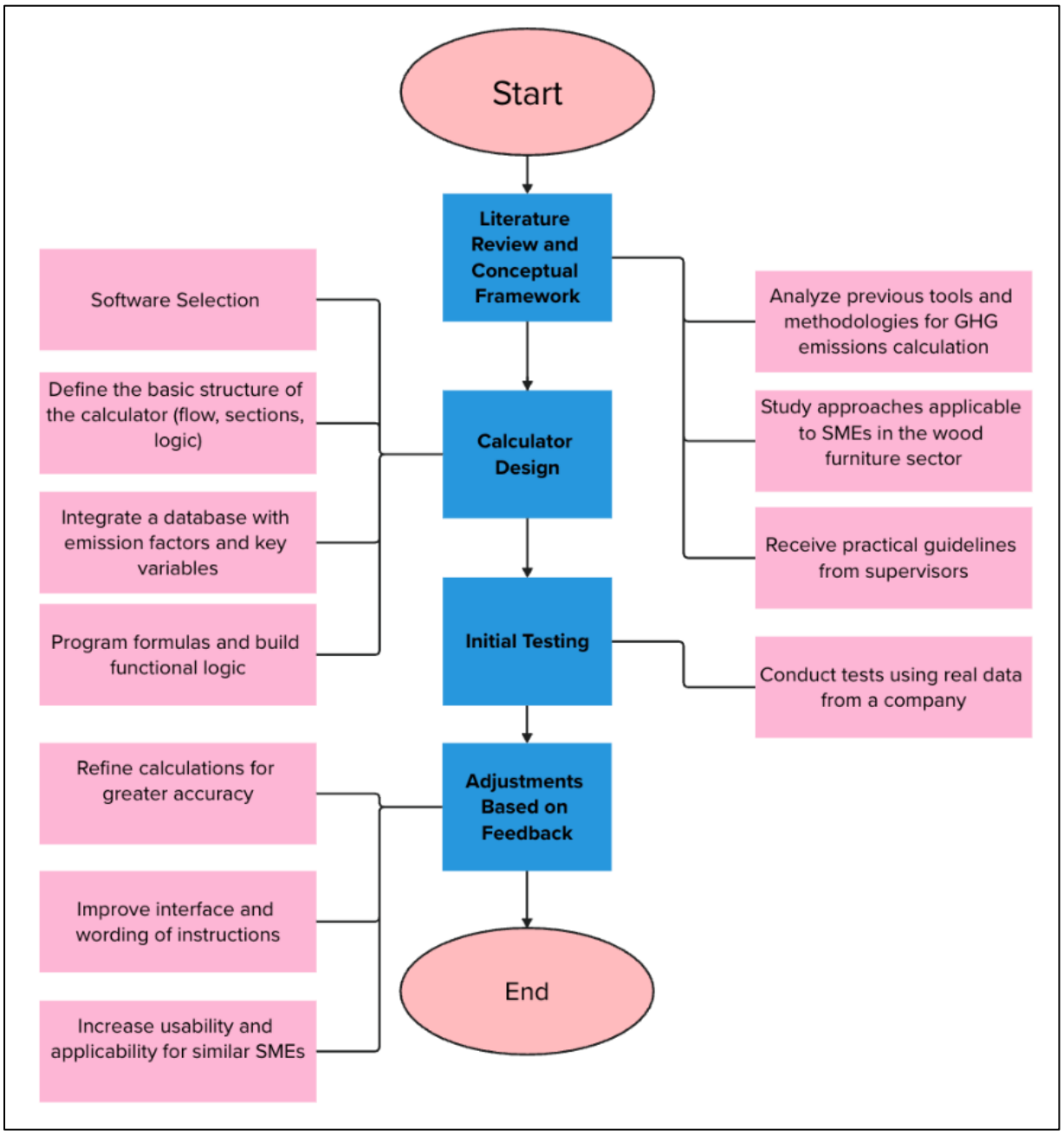


Figure 3. The methodology workflow: phases, data input and output

5. Delimitations, Limitations, Assumptions

During the design and development process of the GHG emissions calculator aimed at SMEs in the wooden furniture sector within the framework of the DEESME2050 project, it was necessary to establish a set of delimitations, acknowledge the limitations present in the process, and work based on certain assumptions. This section summarizes these elements, which were crucial in defining the scope of the work, its constraints, and the conditions assumed during its execution.

5.1 Delimitations

The target audience for the calculator was defined as SMEs in the wooden furniture sector in Europe, primarily those participating as pilot companies in the DEESME2050 project from Italy, France, Poland, and Bulgaria. This focus allowed the content, language, and structure of the tool to be tailored to the typical productive and organizational characteristics of these companies. The emissions analysis was limited to an annual period, considering the most recent fiscal or calendar year for which data was available from each company, which facilitated standardized data input and comparability of results across different organizations.

The development of the calculator began with modules for Scope 1 (direct emissions) and Scope 2 (indirect emissions from electricity consumption), following international practices that prioritize these two types of emissions as the foundation for climate monitoring and reporting. Only after completing these sections was the design of Scope 3 (other indirect emissions) undertaken. Microsoft Excel was chosen as the technical platform due to its widespread use and availability in the European business environment. The methodological approach relied on standardized and internationally recognized data sources, such as emission factors published by the IPCC, DEFRA, or ISPRA, aiming to balance technical accuracy with ease of application.

5.2 Limitations

Although Excel was chosen for its accessibility, this decision imposed certain functional limitations. For instance, it was not possible to implement cloud-connected databases or automate updates, features that could have been achieved using web development tools or more specialized software. Additionally, the development process was not linear, requiring constant consultation of technical literature, methodological manuals, and databases to verify values, adjust formulas, or update references, which demanded intensive use of additional resources.
The project also faced challenges related to user feedback and technical expertise. During the early design phases, there was a lack of direct and continuous input from the pilot companies; although simulated and some real data were used, formal testing with each company was not feasible, limiting the ability to iterate based on user experience. Personal limitations in advanced Excel programming further complicated development, necessitating frequent consultation of manuals,

technical forums, educational videos, and AI assistance tools to design complex formulas, debug errors, and optimize the calculator's functionality.

5.3 Assumptions

Several key assumptions guided the development of the calculator. It was assumed that participating companies already had operational access to Excel, so no additional licensing costs or compatibility issues were considered. Given that SMEs typically lack specialized technical training in carbon accounting, the tool needed to be intuitive, with clear explanations, standardized units, and visible examples. From a methodological standpoint, the use of generic but recognized emission factors was assumed to provide useful, though not necessarily precise, estimates to support initial decision-making. Furthermore, having a functional, even if simplified, tool was considered preferable to having no tool at all, as the project aimed to initiate climate management processes in companies that had not yet measured their carbon footprint.
Operational control was assumed to be the main criterion for emissions consolidation, prioritizing the company's direct emissions (Scope 1) and indirect emissions from purchased electricity (Scope 2). Emissions related to industrial processes in wood and furniture SMEs, as well as emissions from land use, land-use change, and forestry (LULUCF), were assumed to be negligible. Regarding direct fugitive emissions, only the release of refrigerant gases was considered, while gases used for fire suppression were deemed negligible. For Scope 2 emissions associated with purchased electricity, both the location-based and market-based approaches were assumed to be used in the calculation, whereas emissions from purchased steam were considered negligible.

6. CASE STUDY

As previously mentioned, the specific project involved the development of a simplified tool for measuring GHG emissions in SMEs within the countries participating in the DEESME 2050 project. The primary objective of this calculator was to facilitate access to emission quantification methodologies in a way that is understandable and accessible for companies that, in many cases, lack the technical or financial resources to carry out a detailed inventory according to complex standards such as the GHG Protocol or ISO 14064.
From the outset, it was clear that this calculator would play a fundamental role within the project, as it served as the starting point for understanding the current state of GHG emissions in the participating companies. This initial understanding was essential for developing effective strategies aimed at reducing energy consumption, and consequently, emissions, thus aligning with the broader objectives of the DEESME 2050 project to promote sustainability and energy transition in the business sector.

6.1 Description of the calculator sections

The calculator was developed into a Microsoft Excel environment, organized into different sheets corresponding to each of the sections required to perform the necessary calculations for a detailed understanding of companies' GHG emissions.

Below is a detailed description of the various sections that make up the calculator, including their functionality, the development process, the databases used, and the main challenges encountered during its creation. The tool, structured as an Excel file, is divided into eleven sections: an introductory section defining key parameters, a section for determining organizational boundaries, a summary of total emissions, a sheet with conversion factors, another with emission factors, a sheet for estimating reductions for 2030 and 2050, a sheet linking the results to calculate EFRAG indicators, one listing the sources used, and three sections dedicated to data entry for the three scopes of the protocol (Scope 1, Scope 2, and Scope 3).

For Scopes 1 and 3, these sections consist of several individual sheets, each dedicated to a specific emission source within that scope. This structure allows for clearer organization and more detailed analysis of emissions.

Each scope section includes a guidance sheet that explains and illustrates the type of data needed to fill in the tables, followed by the actual data entry sheet. For instance, before the first part of Scope 1, Stationary Combustion, there is a sheet titled “Stationary Combustion Guidance Sheet,” which serves as a guidance and example tool. Its purpose is to provide users with concrete examples of typical emission sources from stationary fossil fuel combustion. The top part of the sheet offers a clear definition of stationary combustion and a brief guide on how to collect the necessary data, pointing to common sources such as utility bills, consumption logs, or supplier reports.

The sheet also includes a sample table illustrating different types of stationary combustion equipment. For each example, it details the type of fuel used, its purpose or function, the associated GHG (CO_2, CH_4, N_2O), suggested methods for data collection, the most appropriate units of measurement, and a final column where the amount of fuel consumed would typically be entered. This sheet is not intended for real data entry, its function is solely to serve as a reference to help users understand how to correctly fill in the corresponding data entry sheet.

Each section follows the same logic, and while there is a guidance sheet for every section, they will not all be described in detail here, as the structure and purpose are consistent throughout.

Before diving into the specific description of each section, the following flowchart illustrates the recommended sequence in which the parts of the calculator should be completed. It is important to note that this is not the order in which the sheets appear in the Excel file, but rather the logical order in which they should be filled out.

Finally, for each section, there is a corresponding image in the annexes that visually represents each part of the calculator.

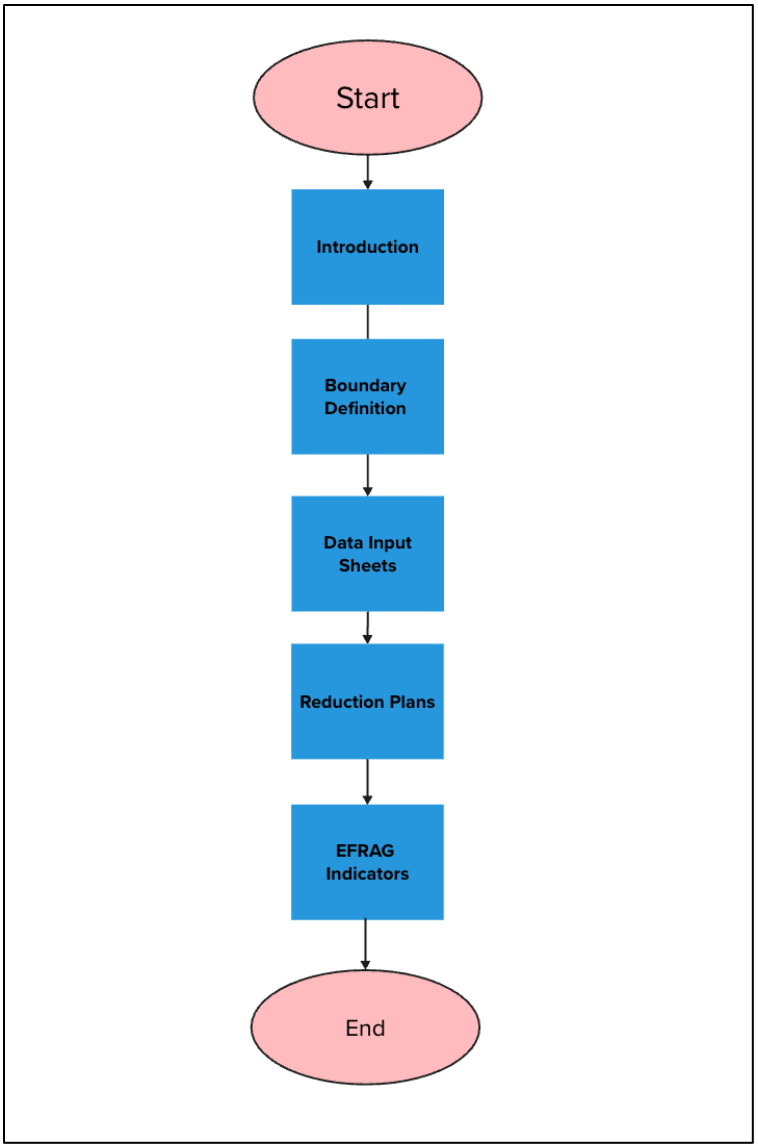


Figure 4. Calculator Process

A. Section 1: introduction

The Introduction section is the first page users see when opening the calculator. It creates the first impression of the tool, so special care was taken to design it with a professional visual appearance that also feels welcoming and easy to use from the beginning. This section provides a clear and concise explanation of what the tool is, with the goal of helping users immediately understand its purpose and overall usefulness.

It also mentions the main methodologies the calculator is based on, including ISO 14069, the GHG Protocol, and other reference calculators. This technical foundation helps build user confidence. However, it is clearly stated that the tool does not fully comply with all the requirements of these frameworks, which is important to set realistic expectations.

Additionally, the section outlines the kind of results users can expect from the calculator, specifically an approximate quantification of both direct and indirect GHG emissions. This prepares the user for the subsequent analysis and decision-making regarding emissions reduction strategies.

Within this section, there is also a subsection called "Steps before entering data." Here, users are guided through several preliminary actions they should complete to ensure proper use of the calculator. These steps help make sure the tool is used accurately and in line with its intended methodology.

The first recommended action is to read the instruction manual. This is essential for understanding how the calculator works, which units are required, what sheets are available, and the overall calculation logic. Next, users are asked to select the country where their organization is located. This is done via a dropdown menu and is particularly important because some emission factors vary depending on the national context, such as each country's energy mix. In this case, the available countries are those participating in the DEESME 2050 project: Italy, Poland, France, and Bulgaria. It is worth noting that if the country is not selected at this stage, the calculator will not allow the user to continue, which is why this step is placed at the very beginning.

After selecting the country, users are prompted to define the evaluation year and to enter the name of the company being assessed. Another key step is to define the organizational boundaries using a specific sheet titled "Boundaries." This involves determining which parts of the organization will be included in the emissions inventory, such as sites, activities, or facilities. This is a critical step in any carbon footprint assessment because it defines the scope of the analysis and ensures the consistency of the data that will be entered.

The final recommended action in this section is to provide the net revenue for the analyzed year. This information is necessary for calculating some of the EFRAG indicators.

B. Section 2: Boundary Definition

The section "Operational Boundary Questions – Emissions Sources to Include" aims to help the user clearly and systematically identify which emission sources should be included in the GHG inventory, based on the specific activities carried out by their organization. This part of the calculator functions as a self-assessment guide, presenting a series of key questions that help define the operational boundaries of the analysis, that is, which emission sources fall within the scope of the inventory based on the control or ownership the organization has over them. It serves as an initial filter to ensure that only necessary and relevant data are collected, facilitating a more focused and manageable inventory, especially useful for SMEs.

The section is organized by emission scopes (Scopes 1, 2, and 3) and presents "Yes or No" questions related to possible emission sources. For Scope 1, questions cover stationary combustion (such as boilers or generators using fossil fuels), mobile sources (vehicles owned or leased by the organization), and the use of refrigeration or air conditioning systems. If the user answers affirmatively, they must collect the corresponding data and use it in the specific spreadsheet for that type of emission.

Regarding Scope 2, questions ask about electricity use in the inventoried facilities, as well as the existence of special energy contracts (such as renewable energy certificates or agreements with providers allowing the application of specific emission factors). Finally, for Scope 3, questions relate to business travel (carried out using transport means not owned by the company) and employees' daily commuting. Unlike the previous scopes, Scope 3 emissions are optional, so the user may decide whether or not to include them in their inventory. If they choose to include them, they must also use the corresponding sheets to input the data.

A hyperlink has been added to each of the titles corresponding to the different scopes (Scope 1, Scope 2, and Scope 3) to facilitate navigation within the file. This way, users can directly access the relevant spreadsheet with a single click on the section title of interest.

C. Section 3: Emission Summary

This section of the report aims to provide a concise, yet comprehensive overview of the GHG emissions generated by the organization. Its structure is designed to facilitate the interpretation and analysis of data, allowing quick identification of the main emission sources, the type of scope to which they belong, and their relative contribution to the organization's total emissions.

The information is organized according to the methodology of the GHG Protocol (GHG Protocol), dividing emissions into three main scopes: Scope 1, Scope 2, and Scope 3. Within each scope, emissions are classified by source category. For Scope 1, emissions from stationary combustion, mobile combustion, and refrigeration and air conditioning systems are included. Scope 2 reports indirect emissions associated with purchased electricity, under both the location-based and market-based approaches. Finally, Scope 3 covers additional indirect emissions related to activities such as business travel and employees' daily commuting, broken down by means of transportation (which in turn are divided by the type of fuel used).

Each category features a summary column for emissions in metric tons of CO_2 equivalent, which updates automatically based on the results obtained in the respective spreadsheets. There is also a column showing the corresponding percentage relative to the overall total (calculated under the location-based approach). This allows for a clear visualization of the relative distribution of each emission source within the overall inventory. Additionally, a specific section at the end of the summary is dedicated to biomass combustion emissions, both stationary and mobile, recognizing the need to report these emissions separately according to methodological recommendations.

The design of this section also includes automatically generated charts based on the input data, intended to complement visual analysis and facilitate communication of results to non-technical users. This tool allows for quick identification of critical emission points and prioritization of interventions to reduce the carbon footprint. In this case, there are four charts: a histogram for the Scope 1 categories, two histograms for each subdivision of Scope 3 (business travel and employee commuting), and a final pie chart representing the weight of each scope in the total emissions (Scopes 1, 2, and 3 represented).

D. Section 4: Reduction Plan

This section allows users to report their reduction plans for 2030–2050, using the same table as the Emission Summary as a baseline. The part of the tool consists of two additional tables where

users must indicate their planned reduction actions for each specific source, the percentage of reduction they aim to achieve, and the tool will automatically calculate the estimated reduction in tonnes of CO_2 equivalent, as well as the total and disaggregated percentage reductions by section and scope.

E. Section 5: EFRAG Indicators

This sheet uses data from the entire calculator to compute the indicators required by EFRAG. Most calculations are performed automatically based on the information entered by the user in the other sheets, while some sections, mainly the narrative parts, require user input. Although this section is not mandatory, as most companies are not required to produce this report, it adds extra value to the calculator and makes it useful for other reporting requirements.

The reported categories include total consumption broken down by fuel type and scope, as well as total reduction targets for the years 2030 and 2050 across different scopes.

F. Section 6: Scope 1

Scope 1 – Stationary Combustion Calculation

This sheet is designed exclusively as a data entry table for the user to input actual data. Unlike the previous sheet, which serves only as an example and explanation, this section is enabled for organizations to enter specific information about their own stationary combustion sources. The sheet includes columns to specify the emission source, fuel type, equipment use or purpose, data collection method, unit of measure, and amount of fuel consumed. Each row can be completed with the corresponding data for a particular installation or piece of equipment within the previously defined organizational boundary.

The table "Total Organization-Wide Fuel Amount Combusted in Stationary Sources by Fuel Type" automatically aggregates the total amount of fuel burned for each fuel type. Fuel quantities are recorded in units such as liters (L), cubic meters (m3), or tonnes (t). This table is automatically filled with the sum of values entered in the initial table, reflecting the total amount of each fuel consumed by the organization during the measurement period. Next, in the table "Organization-Wide Emissions from Stationary Combustion Sources by Fuel Type," the total GHG emissions for each fuel type are automatically calculated based on the fuel quantities provided in the previous table.

Finally, the "Total Emissions" table summarizes the total CO_2 equivalent (CO_2e) emissions generated by all stationary combustion sources within the organization. Additionally, a specific breakdown of biomass emissions (if applicable) is provided to offer a detailed distinction between general emissions and those generated by biological fuels.

Scope 1 – Mobile Combustion Calculation

This worksheet in the spreadsheet is dedicated to the analysis of emissions from mobile sources, that is, vehicles owned or operated under the control of the organization. It is structured to allow

detailed recording and calculation of emissions based on the type of data available, either direct fuel consumption or distance traveled by the vehicles.
The sheet begins with a brief definition of the scope. Mobile sources include all vehicles consuming fuel within the organizational boundary, such as cars or forklifts. It also details the data collection process, which may include fuel invoices, purchase records, odometer readings, or other estimates based on the vehicles' energy performance.
First, two initial tables are presented for data collection. Table 1.A allows entry of information when the exact amount of fuel consumed by each vehicle is known. Each row includes a vehicle identifier, fuel type, data collection method, amount used, and calculated emissions in metric tons of CO_2 equivalent. Parallel to this, Table 1.B, an alternative to Table 1.A, is used if the distance traveled by each vehicle is known, although no data have been entered in this case.
Next, organizational-level aggregation tables are shown. Table 2.A summarizes the total fuel consumed by type, expressed in liters or cubic meters. Then, Table 3.A shows total emissions by fuel type, while Table 3.B displays total emissions by transportation mode, broken down by vehicle type and technology such as diesel, gasoline, hybrid, electric, and so on. Finally, Table 4 provides a summary of CO_2 equivalent emissions from mobile combustion, including a separation of biomass emissions if applicable.
This worksheet enables transparent and traceable calculation of emissions associated with the organization's operational mobility and can be easily integrated into a broader corporate GHG inventory.

Scope 1 – Refrigeration and AC
This worksheet is dedicated to calculating GHG emissions associated with refrigeration and air conditioning (AC) systems used in an organization's facilities or vehicles. The section aims to estimate indirect emissions resulting from refrigerant gas leaks, which typically have a high global warming potential (GWP).

The sheet begins with a conceptual definition explaining how these emissions originate during the use, maintenance, or disposal of the equipment. It is acknowledged that the magnitude of these emissions depends on the type of organization. They may be minimal in offices with basic air conditioning systems but significant in companies with large refrigeration networks such as supermarkets or industrial facilities. Regarding data collection, it is indicated that the necessary information can be obtained from maintenance records, work orders, or invoices from contractors responsible for servicing these systems. The key data to record is the amount of refrigerant gas recharged during the year, which is considered a reasonable estimate of leaks that occurred.

The main section of the worksheet includes a table titled "Organization-Wide Refrigeration Gas CO_2 Eq. Emissions Simplified Material Balance," which details for each piece of equipment the type of refrigerant used, its GWP, the data collection method, the amount recharged in kilograms, and the resulting emissions calculation in metric tons of CO_2 equivalent. Finally, a general total of emissions from refrigerant leaks is included.

G. Section 7: Scope 2

Scope 2 - Purchases of Electricity

This sheet is dedicated to calculate the GHG emissions that result from an organization's consumption of purchased electricity. These emissions fall under Scope 2 of the GHG Protocol, which covers indirect emissions from the generation of purchased energy. The calculations are made taking in consideration that when electricity is drawn from the grid, emissions are produced if that electricity is generated using fossil fuels. In contrast, electricity generated from renewable sources, such as wind, solar, or hydropower, does not contribute to GHG emissions. Likewise, if an organization produces its own electricity on-site using renewable energy systems, these activities are considered emission-free.

To perform the calculations, the organization must gather data on its electricity usage, typically measured in kilowatt-hours (kWh) (if companies have their data in MWh, it can be processed as long as the MWh option is selected). The most reliable source for this information is utility bills or electricity invoices from each facility. Alongside usage data, it is important to collect details on any renewable energy procurement arrangements, such as renewable energy certificates, which can significantly affect how emissions are reported.

The sheet uses two main approaches to calculate and report emissions: the location-based approach and the market-based approach. The location-based approach, which reflects the reality of the grid's energy mix, regardless of any renewable energy purchases the organization may have made. In contrast, the market-based approach accounts for specific electricity sourcing choices. If an organization purchases electricity backed by verified renewable sources, it may report lower, or even zero, emissions under this method. This approach is useful for organizations that actively invest in cleaner energy sources and want to reflect that commitment in their carbon footprint reporting.

At the end of the sheet, a summary table compares total emissions under both approaches. This comparison highlights the difference between the average grid impact (location-based) and the organization's energy procurement strategy (market-based). When properly documented, renewable electricity purchases can lead to significant reductions in reported emissions, supporting transparency and progress toward sustainability goals.

H. Section 8: Scope 3

Scope 3 – Business Travel

This sheet aims to calculate the emissions resulting from business travel activities conducted by employees using transportation not owned or leased by the organization. These emissions fall under Scope 3 of the GHG Protocol, as they represent indirect emissions associated with employee travel in external transport systems such as taxis, buses, trains, airplanes, and personal or rental vehicles used for work-related trips.

To estimate these emissions accurately, the organization must collect data on all relevant business travel carried out during the reporting period. For personal or rental vehicles, it is necessary to

record the distance traveled in kilometers and to identify the vehicle type and fuel type, as emission factors vary depending on that. For public transport modes such as buses, trains, and airplanes, the data should include the estimated passenger kilometers traveled, which allows for the calculation of emissions per individual traveler.
The sheet is divided into different tables, each corresponding to a different mode of transport. Each table shows the distance traveled and the resulting CO_2 equivalent emissions. The first table covers personal vehicles, rental cars, and taxis. In the case of shared taxi rides, it is important to count the trip only once since the emissions factor applies to the vehicle, not to each passenger individually. The second table accounts for bus travel, while the third table addresses air travel, with distinctions based on flight classification such as short haul. The fourth table captures rail travel emissions. Finally, a summary table consolidates the total emissions per transportation mode and provides an overall total for business travel-related emissions.

Scope 3 – Employee Commuting
This sheet aims to calculate the GHG emissions from employee commuting under Scope 3 of the GHG Protocol. It focuses on emissions from the transportation methods that employees use to travel to and from work, which are not owned or controlled by the organization. This includes emissions from personal vehicles, buses, trains, and other forms of public transportation.
Data collection for this calculation involves gathering information on the mode of transportation and the distance traveled by employees during the reporting period. For those using personal vehicles, the organization should identify the vehicle and fuel type (e.g., gasoline, diesel, hybrid) and record the distance traveled in kilometers. For public transport (e.g., buses, trains), the distance should be measured in passenger kilometers to reflect the travel of each individual employee.
The sheet is organized in the same way as the 'Business Travel' sheet, but with the difference that air travel is not taken into consideration.

I. Section 9: Emission Factors

This section constitutes the most important core of the entire document, as it provides all the necessary data to calculate GHG emissions corresponding to the different sections of the calculator. All the spreadsheets are interconnected through formulas that reference this sheet, making it the backbone of most of the calculation processes within the tool.
Precisely for this reason, its development was the most complex and time-consuming. It required thorough research from various bibliographic sources to compile the appropriate technical information and emission factors. Moreover, it was the most iterative part of the project, since data had to be updated, modified, or expanded based on challenges and requirements that arose during the development of other sections of the calculator.
The first section corresponds to emission factors for fuel combustion (Table 1). This includes various types of fuels such as gasoline, diesel, natural gas, biodiesel, ethanol, among others, detailing their density, calorific value, and emission factor expressed in tonnes of CO_2 equivalent

per MWh. This table presents data differentiated by country (Bulgaria, France, Italy, and Poland), allowing the calculations to be adapted to specific national contexts.

Tables 2.A, 2.B, and 2.C present emission factors for electricity under three different approaches. The location-based approach relies on the national average energy mix. The market-based approach considers the residual mix of the electricity market. The life-cycle approach includes all emissions associated throughout the production and distribution cycle of electricity. This triple perspective offers options to apply the most appropriate method depending on the type of analysis or reporting required.

Table 3 contains the Global Warming Potential (GWP) of different refrigerants. This information is essential to calculate indirect GHG emissions in equipment that uses refrigerant gases, such as air conditioning or industrial refrigeration systems. The next section, Table 5, provides integrated emission factors for vehicle use. The values are expressed in kilograms of CO_2 equivalent per kilometer traveled and include a variety of transport modes: gasoline cars, diesel cars, hybrids, electric vehicles, motorcycles, buses, taxis, and air flights. This allows estimating emissions associated with daily or business mobility.

Table 6 offers specific emission factors from tank to wheel for different types of vehicles and fuels. This table focuses solely on direct emissions produced during use, excluding those related to fuel production or distribution. These data are specifically used in the analysis carried out for Scope 1, where emissions are only direct. Finally, Table 7 shows the specific energy consumption of electric trains in Europe, expressed in Wh per passenger-kilometer. This data is useful for comparing the environmental impact of rail transport against other modes. Additionally, this table provides emissions in tonnes of CO_2 equivalent per megawatt-hour for vehicles, based on distance traveled in kilometers. The information is categorized by mode of transport and type of fuel used, allowing for more specific and accurate emission estimates. All distance data must be entered in kilometers. Vehicles with a fully electric engine (plug-in only) have an emission factor of zero.

J. Section 10: Conversion Sheet

This section serves as a key auxiliary tool for converting units of measurement used in calculations of mass, volume, energy, and distance. It is organized in a table format, where each row indicates the type of quantity (mass, volume, energy, or distance), the original unit, the target unit, and the factor by which to multiply to perform the conversion correctly. This structure allows for precise and quick transformations between different unit systems, such as from kilograms to tons, gallons to liters, miles to kilometers, or kilowatt-hours to megajoules.

Its purpose is to facilitate the work of those completing the calculator by enabling them to easily convert their information into the required units of measurement. Since data may come from different contexts or countries with various unit systems, this sheet acts as a practical guide that helps standardize values before entering them into the calculator.

K. Section 11: Information Sources

This sheet compiles various sources of information used to obtain key parameters related to emissions and energy, aiming to provide users with a way to verify and understand the methodologies behind the research that generated the data on which the calculator is based. It is organized into three columns: the type of information, the corresponding institution or source, and a link that directs to the online source. The types of information included are: fuel densities, net calorific value of fuels, emission factors for fuels and electricity, emission factors for refrigerants, and emission factors expressed in kg of CO_2 per kilometer traveled.

The sources include recognized institutions such as the International Energy Agency (IEA), the United Nations Statistics Division, Eurostat, the United States Environmental Protection Agency (EPA), the initiative of the Global Covenant of Mayors for Climate & Energy (JRC - Global Covenant of Mayors), the UK Department of Energy, and the Eco Passenger tool. This table serves as a technical reference to access reliable and standardized data for emission studies, energy analyses, or carbon footprint calculations.

6.2 Case study with an Italian company

To test the emissions calculator, a test was conducted using real data obtained from an Italian company. This test aimed to provide a comprehensive understanding of the practical aspects involved when applying the tool within a real business environment. By engaging directly with the company, the process allowed for a hands-on evaluation of how the calculator operates across its various sections and how effectively it handles authentic data inputs. Additionally, this exercise was essential to uncover potential challenges or limitations that may arise during actual implementation, as well as to highlight opportunities for refinement and improvement of the tool. Furthermore, the test facilitated an initial assessment of the types and quality of data typically available from companies, as well as how these data can be integrated and managed within the calculator. This real-world application is crucial for validating the tool's usability and adaptability in diverse operational contexts. The detailed results and insights derived from this test will be presented and discussed in the following section.

7. RESULTS

7.1 Findings in the process of creation of the calculator

A. Data availability, quality and representativeness

There was no unified database providing all the necessary information to calculate GHG emissions. Due to this lack of centralization, it was necessary to combine different databases from various sources to gather the required data. This process led to the creation of a new unified database specifically designed for the furniture manufacturing sector in the four countries involved in the project. The consolidated database provided a coherent and sector-specific reference, tailored to the particular needs of the sector within those national contexts.

Several challenges were encountered during data collection. Discrepancies were observed among different sources providing the same type of data; for example, emission factors for electricity consumption can vary significantly depending on whether the source is a national government agency, an international organization, or a research institution. Some relevant data had not been updated in recent years, and previously available information was no longer publicly accessible. In certain cases, it was necessary to use data from external sources that do not fully reflect the reality of the target countries, such as emission factors for vehicles in the "business travel" and "employee commuting" sections, which were based on official UK data. While these may be similar to those of other European countries, they are not entirely representative but are considered appropriate for general estimates, especially in optional sections for SMEs where some flexibility is allowed in the accuracy of initial data. Specific difficulties were encountered in finding information related to Poland and Bulgaria due to language barriers, as most databases are published exclusively in national languages. Data related to emissions from electricity consumption also show high variability, reflecting differences in the energy composition of national electricity grids, which can change annually. Some databases are not publicly available but can be requested directly from governmental or technical institutions if greater data accuracy is required.

B. Methodological limitations and technical decisions

There is no official or specific framework for measuring GHG emissions in the furniture manufacturing sector in Europe. As a result, the definition of boundaries and the inclusion or exclusion of activities in the calculation largely depended on the technical judgment of the development team. This selection was made by considering both the relevance of each activity in terms of emissions and the practical feasibility of measuring it, aiming to avoid excluding important elements while also not including overly complex components with marginal impact. Also, knowledge of operations within the furniture sector was enhanced through visits conducted by the SOGESCA team to Italian companies, which are assumed to be representative due to the similarity of industrial processes across countries. Since the calculator relies on a chain of interrelated data, it is sensitive to input errors; incorrect information, such as wrong units of measurement, incorrect fuel types, or inaccurate values, can affect not only the specific sheet in use but also the overall results for each scope and for the company's total emissions.

7.2 Specific Findings of the Pilot Test

A. Methodological Findings from the pilot test

The pilot project was carried out with only one Italian company, mainly due to time constraints, as it was necessary to define the scope of the thesis work to complete it within the academic calendar. However, as part of the development of the European project DEESME 2050, a second, broader validation phase is planned, which will include five pilot tests in each of the four participating countries (Italy, France, Bulgaria, and Poland), making a total of 20 tests.

This approach will allow for the collection of more diverse feedback and further improve the tool based on different productive and organizational contexts. Although only one company was involved in this initial phase, the pilot was very useful for verifying the technical functionality of the calculator, evaluating the clarity of the generated charts, and measuring how easily users can input their data.

At the stage of the pilot test, some of the findings are: it was necessary to increase the number of available rows for data entry, as some companies may have multiple emission sources within the same category, such as different types of fuels, vehicles, or energy suppliers. In some cases, the data provided by companies did not directly match the units required by the calculator. For example, a pilot company only had the total amount of money spent on gasoline rather than the quantity consumed or distance traveled. To estimate emissions, it was necessary to research the average fuel price during the relevant months and calculate an approximate volume of liters used. It was also identified that some companies manage information in an aggregated manner for vehicles or machinery, providing only a single annual cumulative value without monthly breakdowns. The calculator is designed to accept both monthly data and annual totals within the same table, enabling accurate processing of both input formats. Some information is simply not tracked by companies, meaning certain emissions cannot be calculated; this limitation significantly affects the weighting of categories where data is missing. Clear explanations of each required data section must be provided to the personnel responsible for reporting, as misunderstandings about the type of information needed can lead to under- or overestimations of emissions. For instance, in employee commuting data, the company contact initially reported totals that only included one-way trips, which had to be verified to ensure both trips to and from work were considered.

B. Results Obtained

The total GHG emissions, using the location-based approach for electricity, amount to 106.06 tonnes of CO_2 equivalent, while the market-based approach results in a slightly higher total of 111.38 tonnes of CO_2 equivalent. Figure 4 shows the overall results for each scope and its corresponding subcategories, while Figure 5 provides a visual representation of each scope and its contribution to the total emissions.

	Emission Source		GHG Emissions (Tonne CO2 Equivalent)	Percentage of Total Emissions (Location-based Approach for electricity) %
Scope 1	Stationary Combustion		13.41	12.64
	Mobile Combustion		43.62	41.13
	Refrigeration and AC			
	Scope 1. Total		57.03	53.77
	Emission Source		***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 2	Electricity purchased	Location-Based Approach	33.04	31.15
		Market-Based Approach	38.36	Not taken into consideration for the percentage
	Emission Source		***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 3	Business Travel	Personal Vehicle, Rental Car or Taxi	0.20	0.19
		Bus		
		Flight	0.35	0.33
		Train	0.04	0.03
		Total Business Travel	0.59	0.55
	Employee Commuting	Personal Vehicle	15.41	14.53
		Bus		
		Train		
		Total Employee Commuting	15.41	14.53
	Scope 3. Total		15.99	15.08
	Total (Location-based approach for electricity)		106.06	100.00
	Total (Market-based approach for electricity)		111.38	

Figure 5. Emission Summary

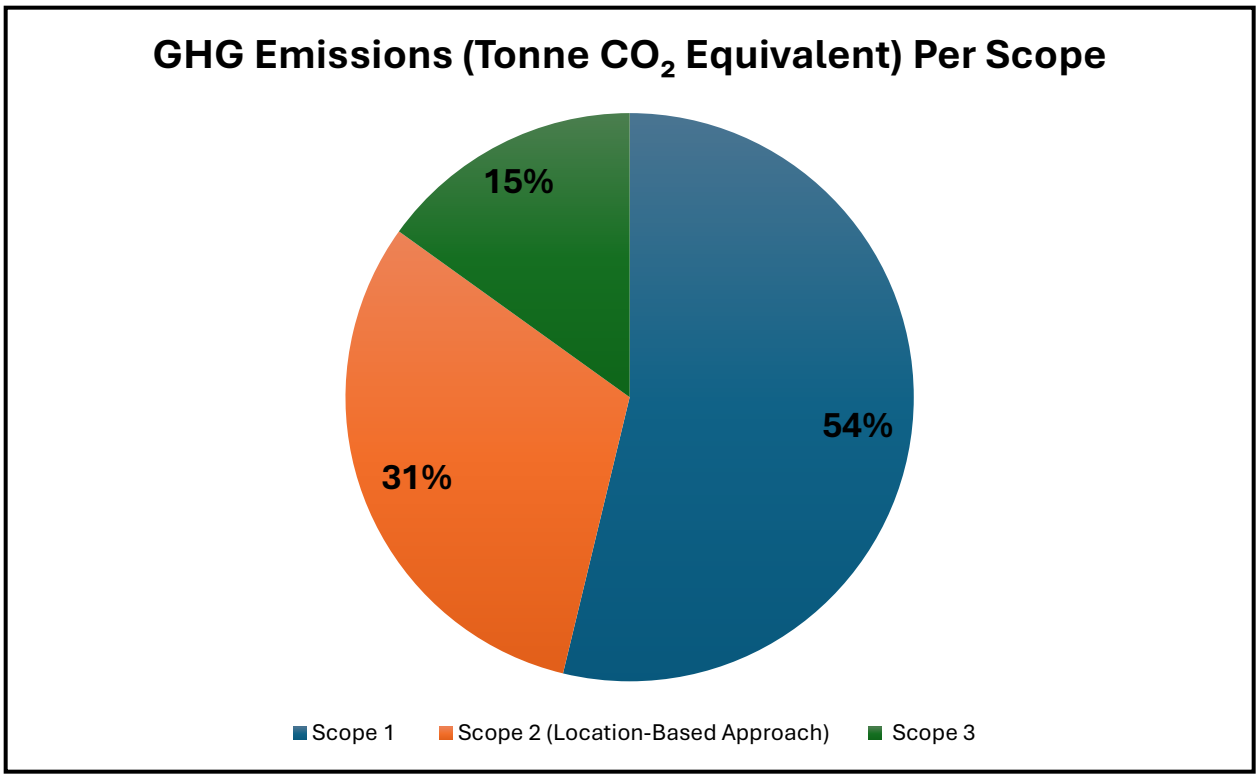


Figure 6. Emissions Per Scope Summary

Scope 1 includes direct emissions from sources that are owned or controlled by the organization. Within this category, stationary combustion accounts for 13.41 tonnes of CO_2 equivalent, representing 12.64% of the total emissions. Mobile combustion is the largest contributor in this scope, with 43.62 tonnes CO_2e, corresponding to 41.13% of total emissions. No emissions are reported under refrigeration and air conditioning. Overall, Scope 1 emissions total 57.03 tonnes CO_2e, making up 53.77% of the total emissions based on the location-based electricity approach.

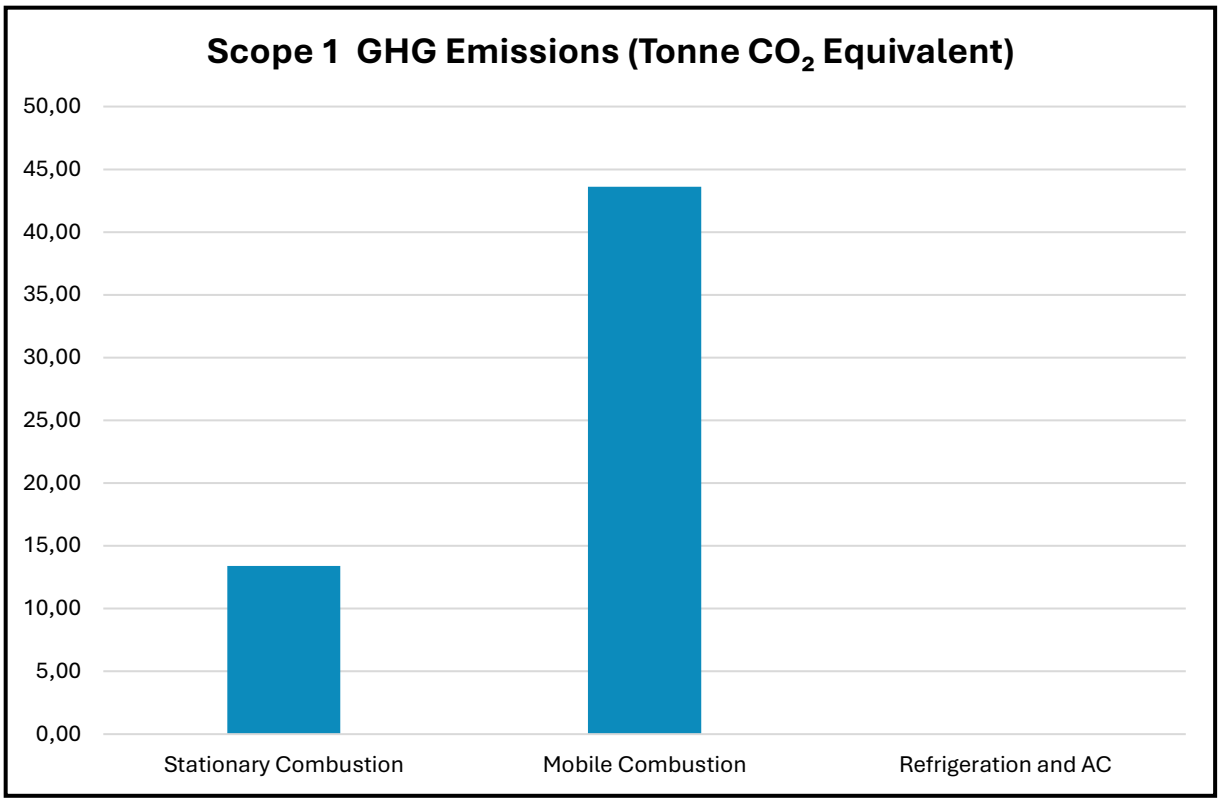


Figure 7. Scope 1 GHG Emissions

Scope 2 covers indirect emissions from the generation of purchased electricity. Under the location-based approach, electricity consumption leads to 33.04 tonnes of CO_2 equivalent, which corresponds to 31.15% of the total emissions. When calculated using the market-based approach, emissions rise to 38.36 tonnes CO_2e. However, this market-based figure is not included in the percentage distribution of total emissions.

Scope 3 includes other indirect emissions occurring in the organization's value chain, specifically from business travel and employee commuting. As seen in the Figure 7, business travel contributes 0.59 tonnes CO_2e (0.55% of total emissions), with air travel accounting for 0.35 tonnes CO_2e (0.33%), personal vehicles, rental cars or taxis contributing 0.20 tonnes CO_2e (0.19%), and train travel adding 0.04 tonnes CO_2e (0.03%), which is represented in the Figure 8. Employee commuting is responsible for 15.41 tonnes CO_2e, entirely attributed to personal vehicle use, which constitutes 14.53% of the total emissions. No emissions are reported for commuting by bus or train. Altogether, Scope 3 emissions amount to 15.99 tonnes CO_2e, representing 15.08% of the total emissions under the location-based approach.

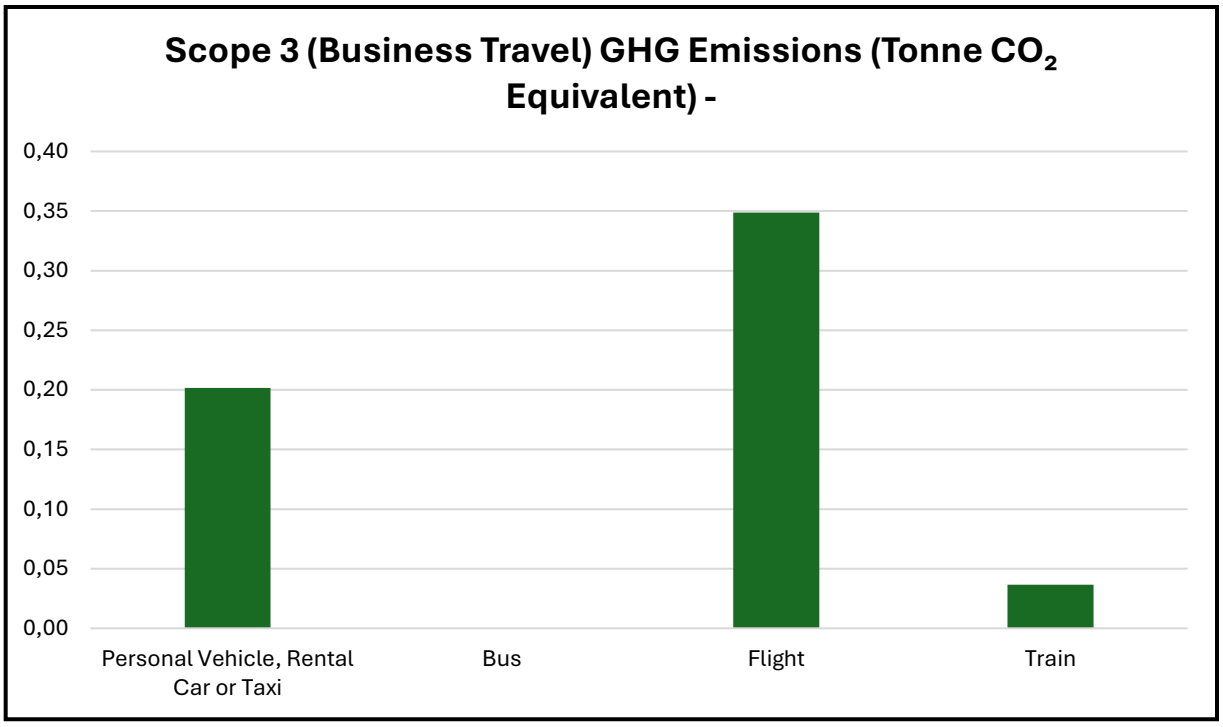


Figure 8. Scope 3 (Business Travel) GHG Emissions

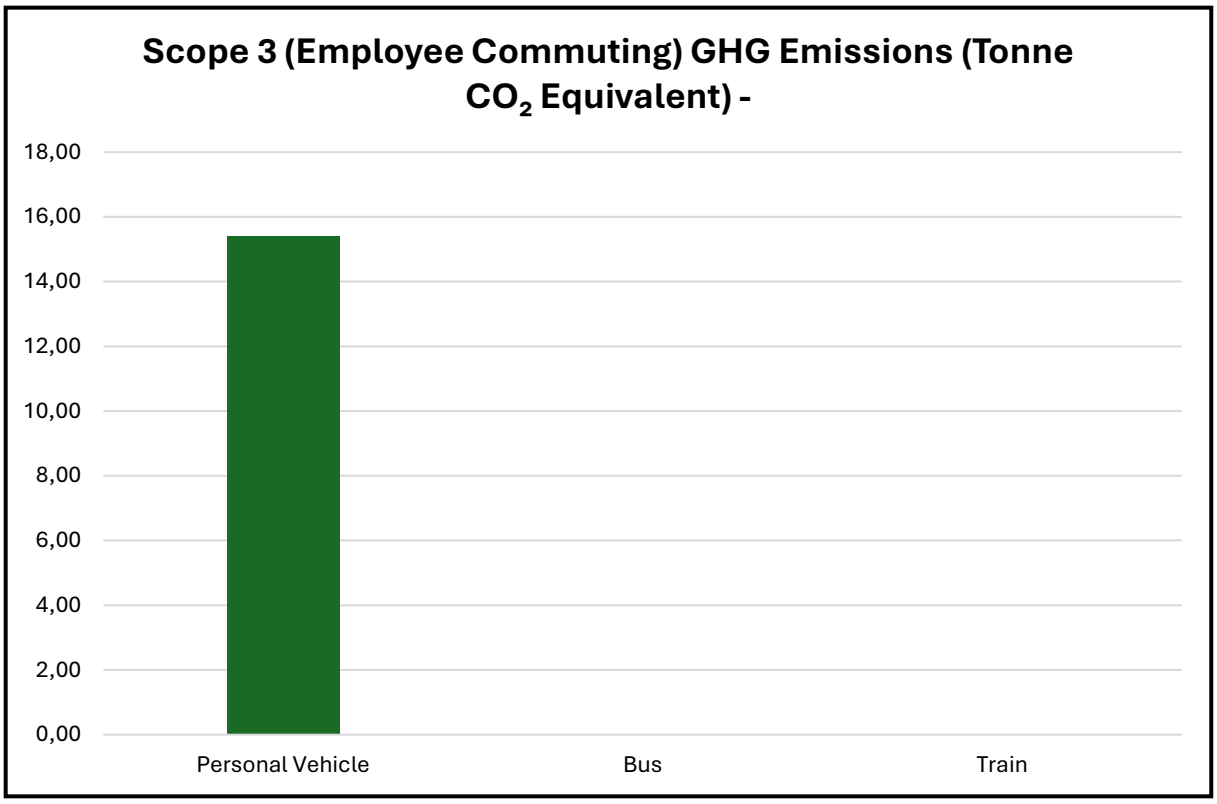


Figure 9. Scope 3 (Employee Commuting) GHG Emissions

8. DISCUSSION

8.1 DEESME GHG Emissions Calculator

The findings emerging from both the development of the emissions calculator and the pilot test offer valuable insights into the broader challenges and opportunities involved in implementing simplified GHG accounting tools for SMEs in the furniture manufacturing sector across Europe, not only for the DEESME 2050 project but also for future projects with another sector as priority. These findings reflect not only technical limitations and practical considerations, but also underline the importance of context-specific data availability and user-centered design for the success of such initiatives.

As mention above, a key challenge encountered was the lack of a centralized database for emission factors and activity data relevant to the sector. This necessitated the integration of diverse data sources and the creation of a unified dataset tailored to the project countries. This fragmentation is an issue in environmental accounting and highlights the need for coordinated data infrastructure at the European level, particularly for sectors like furniture manufacturing (but not only) that are often overlooked in standard methodologies.

The observed variability and outdated nature of certain emission factors, along with inconsistencies among sources, further emphasize the need for regular updates and validation of

databases to maintain the accuracy of GHG inventories. One of the clearest examples of inconsistency between sources was found in the data on fuel densities, where multiple sources provided varying values for each type of fuel. In this case, the approach was to rely primarily on a single official source for most values, ensuring its credibility and comparing it with other references to assess the degree of variability and ensure the data used was within a reasonable range.
Then, the reliance on foreign data sources, such as UK-based emission factors for transport-related activities, introduces a degree of approximation, which is acceptable for optional or less critical sections of the tool. However, this also suggests the importance of regionalized emission factors and improved access to national datasets, especially in countries like Poland and Bulgaria, where language barriers and limited publication formats hinder data acquisition. In the long term, this points to a need for multilingual and publicly accessible databases to support harmonized climate action efforts across the EU. This tool is a good starting point for this type of database and tool development, which will hopefully continue to evolve in the future.

From a methodological view, the absence of sector-specific guidelines for GHG accounting in the furniture industry required SOGESCA's team to define system boundaries and activity scopes based on technical judgment. While this approach allowed for flexibility, it also implies a degree of subjectivity and potential variability if the tool were applied by different actors. Nevertheless, the choice to balance relevance with practical feasibility appears justified, especially given the diversity in operational contexts among SMEs. An important technical consideration is the sensitivity of the tool to input errors, which underscores the critical role of user training and interface design. Even small mistakes in data entry can propagate through the interlinked sheets and significantly alter the results. This risk highlights the importance of embedding validation checks and user guidance features to ensure data integrity and reliability of the outputs. An example of this is the selection of the country in the introduction section. An incorrect choice would result in a completely different database being used for the calculations, as some data is country-specific.

Regarding user experience, several aspects proved essential to facilitate tool adoption: the visual clarity of the spreadsheet, the integration of graphs, and the availability of example sheets all contributed to user engagement and understanding. Aesthetics, simplicity, and support materials are key drivers of usability, particularly for non-expert users. Technical robustness must be accompanied by intuitive design in order to foster widespread application among SMEs.
The pilot test, although limited to a single Italian company, served as a proof of concept to validate the calculator's functionality and data processing capabilities. It also revealed practical issues such as incompatibility between company data formats and tool requirements, and the need for more flexible data input structures, which were addressed by expanding input capacity and allowing both annual and monthly data formats. These adaptations reflect an iterative design approach and suggest that feedback from real users is critical to refining such tools.

Based on all this, it is safe to conclude that the development of a GHG emissions calculator tailored to the needs of the DEESME 2050 project was successfully achieved, with a specific focus on SMEs in the European furniture sector. The calculator demonstrated its ability to automatically compute GHG emissions based on the data entered by users, delivering a clear and practical summary of emissions categorized by scope. Moreover, it offers a graphical representation of the results for Scopes 1, 2, and 3, making it easier for users to visualize and interpret their environmental impact.

8.2 GHG Calculators and GHG accounting in general

A. Making accessible GHG Accounting

GHG accounting tools designed specifically for SMEs are essential for broadening the scope of climate action beyond large corporations. While the development of user-friendly calculators and frameworks tailored to SMEs represents significant progress, questions remain regarding their actual accessibility and scalability. Although this tool was explicitly created to assist SMEs in calculating and managing their GHG emissions, it is essential that efforts are made to ensure its broader accessibility beyond the initial group of partner organizations. Making the tool available to a wider range of companies, especially those that lack internal resources or technical expertise, is a key step toward promoting equity in climate action. To this end, establishing clear mechanisms for dissemination, support, and long-term availability should be a priority. Ensuring that tools like this one are open, adaptable, and easy to implement is fundamental to avoiding new barriers and enabling fair participation in GHG accounting across diverse business contexts.

The development of this tool was made possible largely through the funding and support of the European Union, underscoring the vital role that public investment plays in enabling innovation in environmental management. EU funding has accelerated the creation of tailored, low-barrier, and easy-to-use GHG accounting instruments, which are indispensable for encouraging voluntary climate action across diverse economic actors. However, this reliance on substantial European resources highlights a significant challenge: many countries outside the EU lack comparable financial capacity and infrastructure to support similar initiatives. This disparity calls for an international dialogue and strategic allocation of funds beyond Europe to foster the global adoption of accessible GHG accounting tools. International cooperation and financial support mechanisms are crucial to bridge these gaps, enabling businesses worldwide, especially in developing economies, to participate in transparent and standardized climate reporting.
The DESMEE calculator itself exemplifies this trend, as it was designed and implemented within a European framework. In practice, nearly all the GHG calculators identified during this research were developed and applied in the Global North, clearly illustrating the urgent need to design, adapt, and scale these tools within Global South contexts to ensure broader and more equitable climate action.

B. GHG Accounting and Just transition

By quantifying emissions, identifying areas of high energy consumption, and providing a simple way to communicate emission reductions based on concrete actions, GHG accounting can support evidence-based policymaking and corporate climate action. However, for GHG accounting to truly serve the goals of a just transition, it must be designed and implemented in a way that is accessible, practical, and sensitive to the varying capacities and needs of diverse stakeholders. The GHG calculator developed within the DEESME 2050 project contributes directly to the vision of making climate action more equitable by supporting the inclusion of SMEs in emissions monitoring and reduction efforts.

While the calculator represents a significant step toward enabling SMEs to engage in climate action, the existence of such a tool alone is not sufficient to achieve a just transition. To maximize its impact, it must be supported by broader structural measures, including training, technical assistance, and long-term strategies for accessibility and dissemination. Although the tool's initial deployment was limited to a select group of partner organizations, future efforts should focus on expanding its reach to a wider range of enterprises and regions. This calls for frameworks that ensure the tool is adaptable and usable across diverse contexts, especially in the global south where climate finance and institutional capacity are limited. Addressing these disparities will require targeted funding, international cooperation, and knowledge sharing to ensure that all businesses, regardless of size or geography, can participate in global climate efforts.

It is also important to recognize that outside of Europe, the priorities and challenges faced by SMEs in the context of GHG transition may differ significantly. In many regions, especially in the global south, the availability of a GHG calculator might not be the most urgent or impactful intervention. Instead, foundational issues such as access to reliable data, capacity building, awareness, and basic infrastructure might take precedence. Therefore, the implementation of GHG accounting tools in these contexts must be approached with openness and humility, avoiding a one-size-fits-all or top-down imposition of solutions developed primarily for the European context.

To ensure meaningful and effective support, there is a pressing need for further research focused on understanding the specific needs, constraints, and cultural contexts of SMEs in the Global South. This research should guide the development of tailored approaches that may extend beyond digital tools to include hands-on processes, training programs, and participatory methodologies that work directly with businesses and communities on the ground. By prioritizing co-creation and local engagement, climate initiatives can foster ownership and relevance, ensuring that interventions truly support equitable and sustainable transitions rather than simply transferring external models that may not fit local realities.

At the same time, it is important to recognize that a just transition cannot be framed solely through carbon metrics. While carbon accounting tools are essential for quantifying emissions and informing climate strategies, the broader challenge of sustainability demands a more holistic approach, one that integrates social, ecological, and territorial considerations. Businesses should be encouraged to assess their operations not only in terms of emissions but also in relation to ecosystem impacts, labour conditions, and contributions to local development. Particularly for

SMEs operating within specific regional contexts, aligning climate action with goals such as environmental justice, community resilience, and inclusive growth is essential. Carbon reduction, therefore, should be viewed as one element within a multidimensional strategy that fosters systemic and equitable transformation.

C. Italian Company Test

The following section presents an analysis of the results obtained from the Italian company used as a test case for the GHG calculator. The aim is to interpret the findings by exploring potential reasons behind the emission levels observed across the different scopes. Particular attention will be given to identifying the main sources of emissions and discussing the factors that may have contributed to their magnitude. Based on this analysis, the section will also outline possible mitigation actions that the company could undertake, especially in areas where higher GHG generation was identified, in order to support more effective and targeted emission reduction strategies.

Scope 1 Analysis:

Scope 1 emissions, totaling 57.03 T CO_2 equivalent, represent the largest share of total emissions when applying the location-based approach (accounting for 53.77% of the total footprint). These emissions are direct and result from sources that are owned or controlled by the organization, specifically:

- Mobile Combustion (43.62 T CO_2 equivalent - 41.13%):
  This is the dominant contributor within Scope 1 and across all scopes. It includes emissions from vehicles owned or controlled by the company, which are likely used for operational transport, deliveries, or staff mobility. The high proportion is due to the heavy reliance on fossil-fuel-powered vehicles, likely gasoline or diesel. This indicates a key intervention area where transitioning to low-emission vehicles (electric or hybrid), improving route optimization, and implementing travel reduction strategies could significantly reduce the organization's carbon footprint.
- Stationary Combustion (13.41 T CO_2 equivalent - 12.64%):
  These emissions stem from the combustion of fuels in stationary equipment such as boilers, furnaces, or generators, often used for heating or industrial processes. While smaller in comparison to mobile combustion, this source still reflects a reliance on fossil fuels for fixed infrastructure. Opportunities here include improving energy efficiency, retrofitting heating systems, or switching to renewable thermal energy sources (e.g., biomass or solar thermal).
- Refrigeration and Air Conditioning: Not quantified
  The absence of reported emissions by the company suggest either negligible emissions, a lack of tracking, or unaccounted sources. Including these emissions in future inventories would improve accuracy and comprehensiveness.

Given that Scope 1 emissions account for over half the total footprint, the organization would benefit from focused mitigation strategies in this area. Electrification of the fleet, maintenance of combustion systems, and proper refrigerant management can significantly reduce these direct emissions. Moreover, these actions are within the organization's operational control, making implementation feasible in the short to medium term.

Scope 2 Analysis:

For this scope, emissions were calculated using both the location-based and market-based approaches, as recommended by the GHG Protocol Corporate Standard.

Using the location-based method, which relies on the average emissions intensity of the regional or national electricity grid, the organization reported emissions totalling 33.04 T CO_2 equivalent This represents 31.15% of total emissions when using the location-based electricity approach. This proportion indicates a moderate dependence on electricity for operational activities and suggests that the energy mix of the local grid includes a significant share of fossil fuels. The market-based approach, in contrast, produced a higher emission estimate of 38.36 T CO_2 equivalent. This methodology reflects the specific emissions associated with the electricity actually purchased, based on contractual instruments such as Guarantees of Origin (GOs) or Renewable Energy Certificates (RECs).

It is important to mention that this is just the part of the electricity that was purchased, as the company autoproduces electricity from solar panels, but it is not taken in consideration in this calculation. From a strategic standpoint, several opportunities emerge. Switching to electricity suppliers that offer 100% renewable energy could yield immediate reductions in Scope 2 emissions. Installing onsite renewable energy systems, such as solar photovoltaic panels, could further reduce dependency on external suppliers while enhancing energy autonomy. Complementary to this, implementing energy efficiency measures, like retrofitting lighting systems, improving HVAC operations, and optimizing equipment usage, can further lower electricity demand and operational costs. Addressing Scope 2 emissions is especially advantageous because it can be achieved relatively quickly and with minimal disruption to daily operations. Scope 2 mitigation actions can be implemented internally through procurement decisions and infrastructure improvements. Moreover, aligning such actions with national and European decarbonization goals enhances regulatory compliance and positions the organization as a proactive actor in climate mitigation.

Scope 3 Analysis:

In this inventory, two categories were considered under Scope 3: business travel and employee commuting, which together accounted for a total of 15.99 T CO_2 equivalent, representing 15.08% of total emissions (based on the location-based approach for electricity). While Scope 3 emissions are smaller in absolute terms compared to Scope 1 and 2, they are highly relevant from a sustainability perspective, as they reflect behavioral patterns and operational choices that can be improved with well-designed policies and incentives.

- Business travel (0.59 T CO_2 equivalent - 12.64%):
  Within this category, air travel was the most significant source, contributing 0.35 T CO_2 equivalent (0.33%). This indicates that, despite the potentially low number of flights, the carbon intensity of air travel remains high, particularly when compared to other forms of transportation. Travel by personal vehicle, rental car, or taxi contributed an additional 0.20 T CO_2 equivalent (0.19%), while train travel accounted for just 0.04 T CO_2 equivalent (0.03%), highlighting its relatively low emissions footprint. No data was reported for bus. This category reveals opportunities for emissions reduction through encouraging low-carbon transport modes such as rail or bus travel for national trips, implementing virtual meeting policies where appropriate, and promoting internal guidelines that favor sustainable business travel.
- Employee commuting (15.41 T CO_2 equivalent - 14.53%):
  All of these emissions came from the use of personal vehicles, underscoring a high dependence on private cars for daily commuting. No emissions were reported for public transport options such as buses or trains, which could indicate a low adoption rate or a data gap in reporting. This result highlights a critical area for intervention. The organization can promote the use of public transport, cycling, walking, or carpooling through awareness campaigns, incentives, or mobility benefits. Additionally, offering hybrid or remote work options could reduce commuting-related emissions significantly. Conducting periodic mobility surveys could also help refine commuting data and support better-targeted sustainability strategies.

  Although Scope 3 emissions represent a smaller fraction of the organization’s carbon footprint, they are closely tied to employee behaviors and management decisions. As such, they offer valuable opportunities for engagement, awareness-raising, and emissions reduction through relatively accessible actions. Addressing Scope 3 effectively not only contributes to climate goals but also enhances the organization's sustainability culture and social responsibility profile.

9. CONCLUSIONS

9.1 Simplified GHG Calculator

This research work aimed to design and validate a simplified GHG emissions calculator aimed at SMEs in the furniture sector in Europe, within the framework of the DEESME2050 project. The calculator, developed in Microsoft Excel for its accessibility and familiarity to most companies, proved effective in automatically calculating emissions for scopes 1, 2, and 3. The calculator includes intuitive inputs, automatic results, and graphical summaries that allow for clear interpretation even for users with no prior experience in carbon accounting or environmental sustainability.

The tool was tested using real data from an Italian company in the sector, which allowed its functionality to be evaluated in a specific operational context. The results showed that the calculator is able to provide consistent estimates of emissions, while also being easy to apply in business practice. From this test, important adjustments were made to the data entry structure, user instructions, and integration of updated emission factors. The success of this validation supports the conclusion that it is possible to develop accessible and functional GHG accounting tools, which respond to the real needs of SMEs.

However, to ensure the long-term utility and reliability of the tool, it is essential to continuously update the emission factors and data sources used in the calculator. GHG accounting relies heavily on the accuracy and timeliness of data, and outdated information could lead to significant miscalculations. Therefore, periodic revision and validation of the underlying databases should be considered a core element of the tool's maintenance.

Additionally, as SMEs evolve and their operations become more complex, the calculator must be further expanded and refined to reflect these changes. Different companies may have varying levels of emissions, specific materials or processes, or additional reporting needs. This highlights the necessity of developing a modular and flexible system that can grow with the demands of the users, whether by integrating sector-specific emission factors, supporting new types of inputs, or connecting with external data management systems.

9.2 Italian Company Test and Results

The assessment carried out in this project revealed that most of the organization’s GHG emissions originate from Scope 1 and Scope 2 activities, particularly mobile combustion (41.13%), electricity consumption (31.15%), and stationary combustion (12.64%). Scope 3 emissions, although comparatively lower (15.08%), are still significant, especially in relation to employee commuting. These results highlight the importance of addressing both direct and indirect emissions to build a comprehensive climate strategy.

It is important to underline that the primary objective of this investigative work and the development of the simplified GHG accounting tool was not to offer a complete or highly complex set of mitigation strategies, but the development of the tool itself. That aspect belongs to a broader phase of the project that requires its own focused attention and multidisciplinary analysis.

Nonetheless, based on the experience of the team and existing literature, a set of general recommendations has been outlined throughout the report. These serve as a preliminary guide for identifying priority areas of action and promoting internal reflection within organizations about their environmental impact. Moreover, it must be emphasized that this analysis focuses exclusively on CO_2 equivalent emissions, which limits the scope of the results. The recommendations and interpretations provided should therefore be understood within the specific framework of carbon accounting. Other critical dimensions, such as social implications, ecological impacts, or effects on biodiversity and ecosystem services, are not included in this phase of the analysis. A truly holistic sustainability assessment would require the integration of these aspects through complementary tools and indicators.Another crucial point is that the quality and accuracy of data heavily depend on each company's internal reporting practices and whether proper audits have been conducted. Incomplete or poorly structured data can lead to underestimations or misleading results. Therefore, it is essential to offer support and guidance to companies, especially SMEs, to help them carry out this process correctly, through standardized tools, staff training, and technical assistance. Finally, it is worth noting that the tool developed in this project will be tested with additional companies in the near future, which will allow for a more robust evaluation of its usability, adaptability, and overall functionality. This next phase will be key to refining the tool, understanding its limitations, and identifying ways to improve its effectiveness across different organizational contexts.

9.3 Theoretical and Practical Positioning

From a theoretical point of view, this research was situated at the intersection between applied environmental accounting, transitions towards sustainability in Europe and innovation in SMEs, specifically SMEs in the furniture sector. It is mainly based on internationally recognized methodologies such as ISO Standards and the GHG Protocol, but also tests to overcome the barriers faced by small companies to join decarbonization processes, making it more accessible to companies with fewer resources and capacities to perform these accounting analyses. By developing a tool that reduces both costs and technical complexity, this work contributes concretely to the implementation of these theoretical principles from an inclusive and effective approach. From a practical perspective, the research aligns with the European Union's current push to include SMEs in climate reporting and green transformation processes. Faced with a scenario where many tools are designed for large corporations, this work shows that SMEs can also be an active part of the energy transition, if they are provided with adapted solutions. In this sense, the thesis also represents a critical response to the excess of technification in environmental tools, demonstrating that simplicity does not necessarily imply a loss of technical rigor.

9.4 External Influences on Research

The development of the tool and its conceptual framework was influenced by various external factors that complemented the theoretical foundations. Firstly, the project guidelines provided DEESME2050 with a clear operational framework, prioritising the creation of a practical, simple

and easily replicable tool for SMEs in the furniture sector in Europe. This specific guidance not only narrowed down the type of target company, but also the acceptable level of complexity, the sources of information allowed, and the type of expected outcomes. The experience and support of the SOGESCA team, with extensive knowledge in environmental consulting and European projects, enriched the process by providing technical and realistic criteria on how to make a calculation tool operational in real business environments. Likewise, the direct interaction with the pilot company during the tests made it possible to collect specific needs of the productive sector, which were key to adjusting the language, the design of the interface and the data entry structure.

On the other hand, the current regulatory and political context of the European Union played a decisive role. Increasing regulatory pressure for companies to measure and reduce their carbon footprint, through directives such as the Corporate Sustainability Reporting Directive (CSRD), or initiatives such as the Green Deal, has driven an urgent demand for environmental assessment tools. This policy environment favoured the project's approach, ensuring that the tool not only responded to a current need, but also anticipated future legal obligations. Consequently, care was taken to ensure that the calculator was aligned with frameworks such as the GHG Protocol and with good practices promoted by bodies such as the European Environment Agency. These external influences, both from the institutional sphere and from the economic and social context, helped the research to have a balanced approach between the technical, the operational and the political, thus strengthening its applicability in the real world.

9.5 Perspectives for future research

While this research has successfully demonstrated the feasibility and practicality of a simplified GHG calculator tailored for SMEs in the European furniture sector, several areas remain open for further exploration and development. Future research could build upon the current work to enhance both its theoretical depth and its practical relevance in broader contexts.

One key recommendation is to explore more deeply the integration of Scope 3 emissions, particularly those related to upstream and downstream supply chain activities. While the current tool addresses Scope 1 and 2 emissions in a simplified and accessible manner, the complexity and variability of Scope 3 emissions (such as purchased goods, logistics, product use, and end-of-life treatment) present both a challenge and an opportunity. Research could focus on methods for estimating Scope 3 emissions with greater accuracy while maintaining usability for non-expert users. This may include exploring secondary databases and proxy indicators.

Another promising direction involves evaluating the long-term behavioural and organizational impact of using such a calculator in SMEs. Future studies could investigate how access to simplified carbon accounting tools affects company practices, decision-making processes, employee awareness, and investment in sustainability initiatives over time. This could involve longer case studies and interviews with firms that have used the tool for multiple reporting cycles.

In addition, there is room to study sectoral adaptability of the calculator across different industries beyond furniture manufacturing. Adapting and validating the tool for other sectors, such as textiles,

food processing, or small-scale construction, would test its versatility and reveal sector-specific needs. Comparative research could identify what core features should be maintained and what elements must be modified for successful cross-sector deployment.
From a technological standpoint, research could investigate the digitalization and automation of the calculator, possibly transitioning from Excel to web-based platforms or integrating with enterprise resource planning systems. This could facilitate automatic data retrieval and real-time emissions monitoring, opening new avenues for scalability and remote audits. Furthermore, future research could benefit from a more robust integration with climate justice frameworks, assessing how carbon accounting tools can be designed to account for social and equity dimensions. This may include exploring participatory approaches to data collection, accessibility for businesses in marginalized regions, and potential incentives or policy supports for inclusive climate action.

Finally, collaborative research with policymakers and business networks (such as chambers of commerce or trade associations) could deepen the exploration of how such tools can be institutionalized or mainstreamed as part of standard ESG (Environmental, Social and Governance) reporting obligations. This would strengthen the role of SMEs in national and European climate goals while ensuring they are supported through practical, scalable, and inclusive tools.

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Annexes

DEESME 2050 Simplified GHG Emissions Calculator and Sustainability Tool

DEESME 2050
Developing Energy Efficiency Projects in SMEs for European 2050 targets

General Information

This Simplified GHG Emissions Calculator and Sustainability Tool (Calculator) is a streamlined tool designed to assist organizations in inventorying their emission sources and estimating their annual greenhouse gas (GHG) emissions within the context of Europe-based operations, with a particular emphasis on the territories of France, Italy, Bulgaria, and Poland.

The methodology used in the Calculator is based on ISO 14064-1:2018 and the GHG Protocol Corporate Accountig and Reporting Standards. While it is grounded in these frameworks, the tool does not fully comply with all of their requirements.

The Calculator incorporates emission factors and other essential data, which have been sourced from officially verified and acknowledged sources. These sources are carefully cited in the Information Sources section to ensure transparency and reliability. By inputting activity data for a specified annual period, the Calculator quantifies both direct and indirect emissions across a range of organizational sources, facilitating accurate GHG accounting and supporting the development of robust emission reduction strategies.

Preliminary Steps

1. Read the User's Manual

Go to the User's Manual provided with the Calculator

2. Indicate the country in which your organization is located (use drop down menu)

Country	

3. Specify the reporting year under consideration

Year	

4. Indicate the name of the company

Name	

5. Define the boundries of the organization in the boundaries sheet (next to this one)

Go to boundaries sheet

6. Insert company net revenue for the reporting year in euros (if possible)

Net revenue	

Annex 1: Introduction

Organizational Boundaries Definition - Emission Sources to Include

Emission Source Definition
A SME in the wood-based industry typically generates Scope 1 and Scope 2 emissions from the following sources. Some Scope 3 emission sources are included in this tool as optional. The list of the organization GHG sources is also called inventory and inventorying means compiling a full list of a company GHG emissions sources.
Combustion
Refrigeration and Air Conditiong (AC)
Purchased Electricity
Business Travel (optional)
Employee Commuting (optional)

If you answer '**yes**' to any of the following questions, the corresponding emission sources must be included in your inventory. For each facility within the established organizational boundary, collect the necessary data for the relevant time period and use the appropriate Excel sheet to calculate the associated emissions

Scope 1 Emissions

Stationary Combustion	Yes or No?
Do you have facilities that burn fuels on-site (e.g., natural gas, coal, fuel oil for heating, diesel fuel for backup generators, biomass fuels)?	?
MobileCombustion	
Do any vehicles fall within your organizational boundary? This can include cars, trucks and forklifts your organization owns or leases.	?
Refrigeration and Air Conditioning	
Do your facilities include refrigeration or AC equipment?	?

Scope 2 Emissions

Electricity Purchase	Yes or No?
Does your company draw electricity from the grid for any of its facilities?	?
Market-Based Emission Factors	
Do you purchase electricity with guarantee of origin? Do you purchase electricity entirely from renewable sources? Do you purchase electricity through a power purchase agreement?	?

The questions below refer to Scope 3 emission sources and offsets. If you answer "yes" you may choose whether or not to include these emission sources in your inventory. Use the corresponding sheet to enter data.

Scope 3 Emissions

Business Travel	Yes or No?
Do employees travel for business using transportation other than the vehicles your organization own or lease (e.g. commercial airline flights, rental cars, trains)?	?
Employee Commuting	
Do employees commute to work in personal vehicles or use public transportation?	?

Annex 2: Boundary Definition

Emission Summary

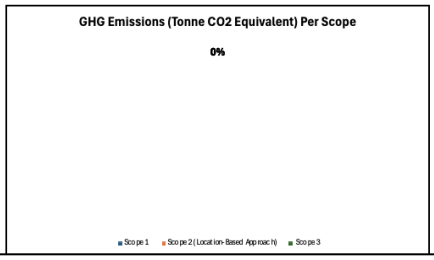
Description: this section provides a clear overview of the total GHG emissions for the organization in the reference year, by scope. The same data are graphically represented in the charts on the right. Additionally, a specific table about anthropobigenic biogenic emissions can be found on the bottom.

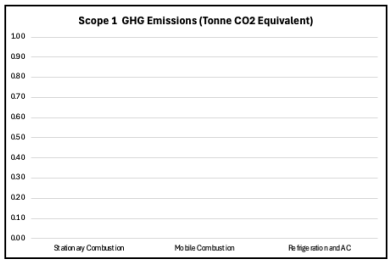
Objective: offer a concise yet comprehensive summary that allows users to easily assess a company overall emissions, understand their distribution across various sources, and identify key areas where emissions reduction or mitigation actions can be implemented.

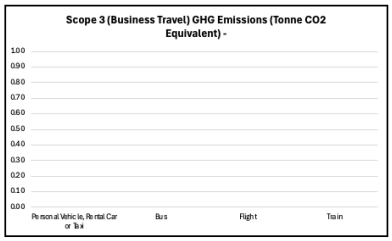
DEESME 2050

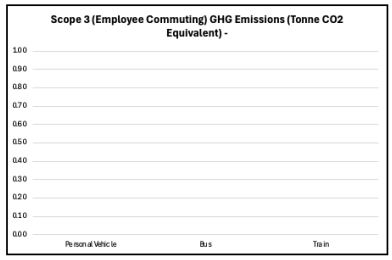
	Emission Source		GHG Emissions (Tonne CO2 Equivalent)	Percentage of Total Emissions (Location-based Approach for electricity) %
Scope 1	Stationary Combustion			
	Mobile Combustion			
	Refrigeration and AC			
	Scope 1. Total			
	Emission Source		***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 2	Electricity purchased	Location-Based Approach		
		Market-Based Approach		Not taken into consideration for the percentage
	Emission Source		***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 3	Business Travel	Personal Vehicle, Rental Car or Taxi		
		Bus		
		Flight		
		Train		
		Total Business Travel		
	Employee Commuting	Personal Vehicle		
		Bus		
		Train		
		Total Employee Commuting		
	Scope 3. Total			
	Total (Location-based approach for electricity)		0.00	
	Total (Market-based approach for electricity)		0.00	

Biogenic Anthropogenic Emissions - Emission Source	*GHG Emissions (Tonne CO2 Equivalent)*
Stationary Combustion	
Mobile Combustion	

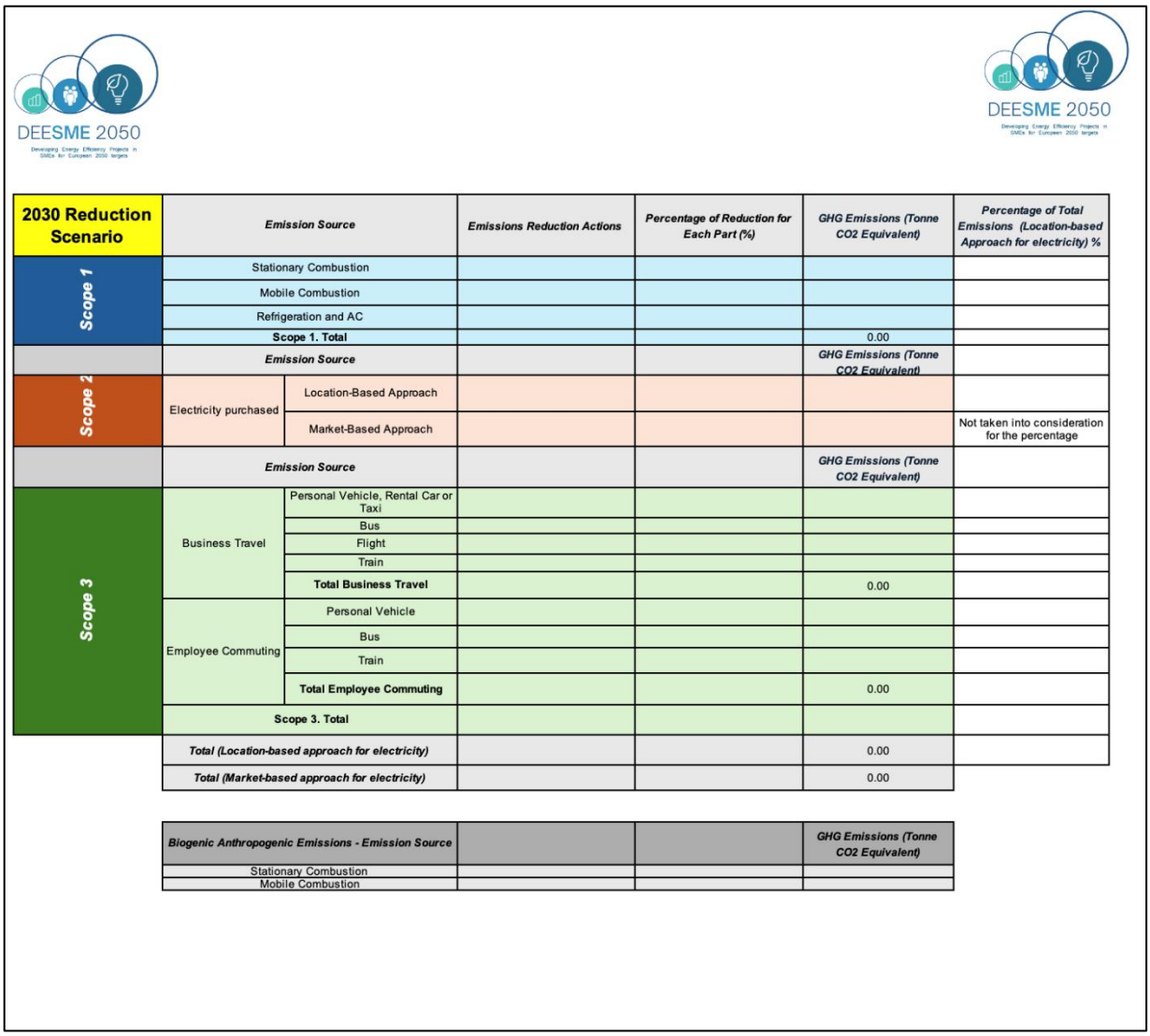








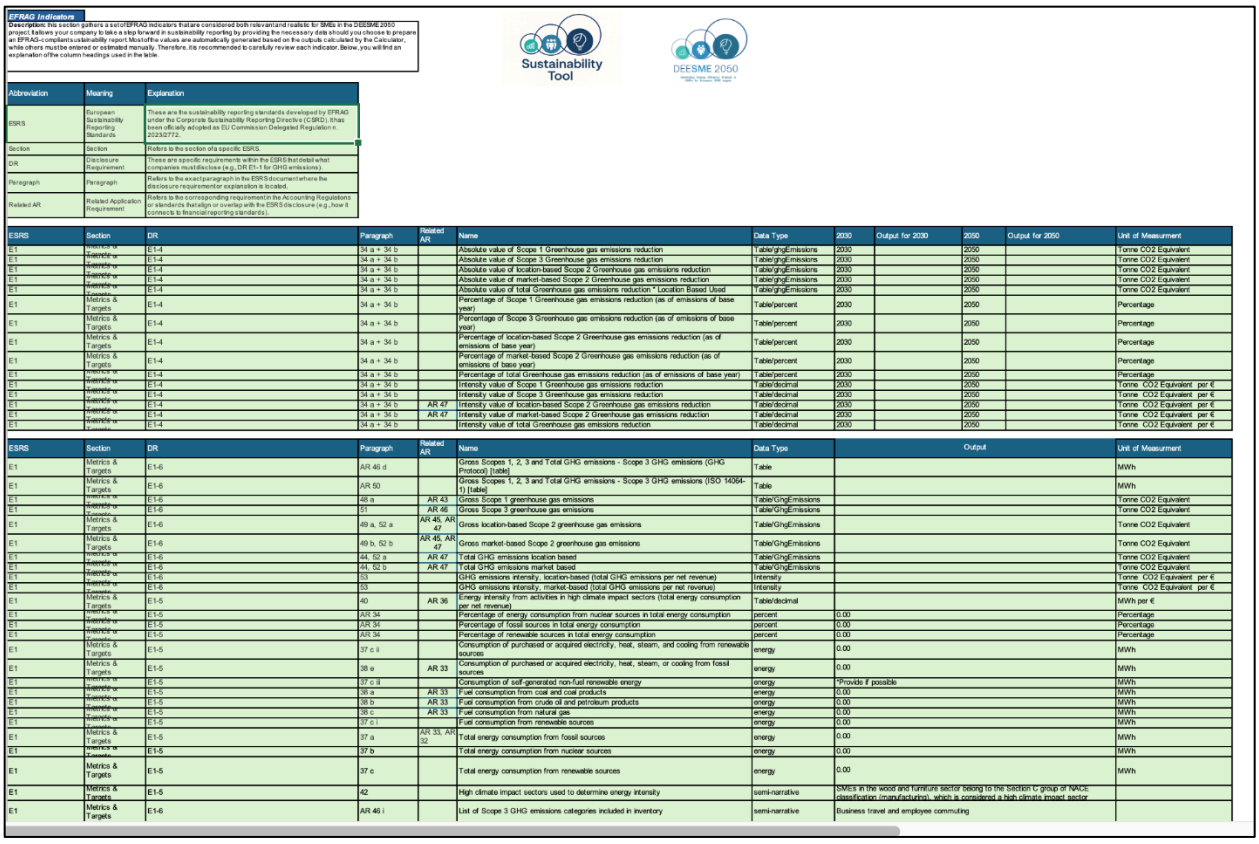
Annex 3: Emission Summary



2030 Reduction Scenario	Emission Source		Emissions Reduction Actions	Percentage of Reduction for Each Part (%)	GHG Emissions (Tonne CO2 Equivalent)	Percentage of Total Emissions (Location-based Approach for electricity) %
Scope 1	Stationary Combustion					
	Mobile Combustion					
	Refrigeration and AC					
	Scope 1. Total				0.00	
	Emission Source				***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 2	Electricity purchased	Location-Based Approach				
		Market-Based Approach				Not taken into consideration for the percentage
	Emission Source				***GHG Emissions (Tonne CO2 Equivalent)***	
Scope 3	Business Travel	Personal Vehicle, Rental Car or Taxi				
		Bus				
		Flight				
		Train				
		Total Business Travel			0.00	
	Employee Commuting	Personal Vehicle				
		Bus				
		Train				
		Total Employee Commuting			0.00	
	Scope 3. Total					
	Total (Location-based approach for electricity)				0.00	
	Total (Market-based approach for electricity)				0.00	

Biogenic Anthropogenic Emissions - Emission Source			***GHG Emissions (Tonne CO2 Equivalent)***
Stationary Combustion			
Mobile Combustion			

Annex 4: Reduction Plan Sheet



EFRAG Indicators

Description: this section gathers a set of EFRAG indicators that are considered both relevant and realistic for SMEs in the DEESME 2050 project. It allows your company to take a step forward in sustainability reporting by providing the necessary data should you choose to prepare an EFRAG-compliant sustainability report. Most of the values are automatically generated based on the outputs calculated by the Calculator, while others must be entered or estimated manually. Therefore, it is recommended to carefully review each indicator. Below, you will find an explanation of the column headings used in the table.

Sustainability Tool

DEESME 2050

Abbreviation	Meaning	Explanation
ESRS	European Sustainability Reporting Standards	These are the sustainability reporting standards developed by EFRAG under the Corporate Sustainability Reporting Directive (CSRD). It has been officially adopted as EU Commission Delegated Regulation n. 2023/2772.
Section	Section	Refers to the section of a specific ESRS.
DR	Disclosure Requirement	These are specific requirements within the ESRS that detail what companies must disclose (e.g., DR E1-1 for GHG emissions).
Paragraph	Paragraph	Refers to the exact paragraph in the ESRS document where the disclosure requirement or explanation is located.
Related AR	Related Application Requirement	Refers to the corresponding requirement in the Accounting Regulations or standards that align or overlap with the ESRS disclosure (e.g., how it connects to financial reporting standards).

ESRS	Section	DR	Paragraph	Related AR	Name	Data Type	2030	Output for 2030	2050	Output for 2050	Unit of Measurment
E1	Metrics & Targets	E1-4	34 a + 34 b		Absolute value of Scope 1 Greenhouse gas emissions reduction	Table/ghgEmissions	2030		2050		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-4	34 a + 34 b		Absolute value of Scope 3 Greenhouse gas emissions reduction	Table/ghgEmissions	2030		2050		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-4	34 a + 34 b		Absolute value of location-based Scope 2 Greenhouse gas emissions reduction	Table/ghgEmissions	2030		2050		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-4	34 a + 34 b		Absolute value of market-based Scope 2 Greenhouse gas emissions reduction	Table/ghgEmissions	2030		2050		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-4	34 a + 34 b		Absolute value of total Greenhouse gas emissions reduction * Location Based Used	Table/ghgEmissions	2030		2050		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-4	34 a + 34 b		Percentage of Scope 1 Greenhouse gas emissions reduction (as of emissions of base year)	Table/percent	2030		2050		Percentage
E1	Metrics & Targets	E1-4	34 a + 34 b		Percentage of Scope 3 Greenhouse gas emissions reduction (as of emissions of base year)	Table/percent	2030		2050		Percentage
E1	Metrics & Targets	E1-4	34 a + 34 b		Percentage of location-based Scope 2 Greenhouse gas emissions reduction (as of emissions of base year)	Table/percent	2030		2050		Percentage
E1	Metrics & Targets	E1-4	34 a + 34 b		Percentage of market-based Scope 2 Greenhouse gas emissions reduction (as of emissions of base year)	Table/percent	2030		2050		Percentage
E1	Metrics & Targets	E1-4	34 a + 34 b		Percentage of total Greenhouse gas emissions reduction (as of emissions of base year)	Table/percent	2030		2050		Percentage
E1	Metrics & Targets	E1-4	34 a + 34 b		Intensity value of Scope 1 Greenhouse gas emissions reduction	Table/decimal	2030		2050		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-4	34 a + 34 b		Intensity value of Scope 3 Greenhouse gas emissions reduction	Table/decimal	2030		2050		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-4	34 a + 34 b	AR 47	Intensity value of location-based Scope 2 Greenhouse gas emissions reduction	Table/decimal	2030		2050		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-4	34 a + 34 b	AR 47	Intensity value of market-based Scope 2 Greenhouse gas emissions reduction	Table/decimal	2030		2050		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-4	34 a + 34 b		Intensity value of total Greenhouse gas emissions reduction	Table/decimal	2030		2050		Tonne CO2 Equivalent per €

ESRS	Section	DR	Paragraph	Related AR	Name	Data Type	Output	Unit of Measurment
E1	Metrics & Targets	E1-6	AR 46 d		Gross Scopes 1, 2, 3 and Total GHG emissions - Scope 3 GHG emissions (GHG Protocol) [table]	Table		MWh
E1	Metrics & Targets	E1-6	AR 50		Gross Scopes 1, 2, 3 and Total GHG emissions - Scope 3 GHG emissions (ISO 14064-1) [table]	Table		MWh
E1	Metrics & Targets	E1-6	48 a	AR 43	Gross Scope 1 greenhouse gas emissions	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	51	AR 46	Gross Scope 3 greenhouse gas emissions	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	49 a, 52 a	AR 45, AR 47	Gross location-based Scope 2 greenhouse gas emissions	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	49 b, 52 b	AR 45, AR 47	Gross market-based Scope 2 greenhouse gas emissions	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	44, 52 a	AR 47	Total GHG emissions location based	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	44, 52 b	AR 47	Total GHG emissions market based	Table/GhgEmissions		Tonne CO2 Equivalent
E1	Metrics & Targets	E1-6	53		GHG emissions intensity, location-based (total GHG emissions per net revenue)	Intensity		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-6	53		GHG emissions intensity, market-based (total GHG emissions per net revenue)	Intensity		Tonne CO2 Equivalent per €
E1	Metrics & Targets	E1-5	40	AR 36	Energy intensity from activities in high climate impact sectors (total energy consumption per net revenue)	Table/decimal		MWh per €
E1	Metrics & Targets	E1-5	AR 34		Percentage of energy consumption from nuclear sources in total energy consumption	percent	0.00	Percentage
E1	Metrics & Targets	E1-5	AR 34		Percentage of fossil sources in total energy consumption	percent	0.00	Percentage
E1	Metrics & Targets	E1-5	AR 34		Percentage of renewable sources in total energy consumption	percent	0.00	Percentage
E1	Metrics & Targets	E1-5	37 c ii		Consumption of purchased or acquired electricity, heat, steam, and cooling from renewable sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	38 e	AR 33	Consumption of purchased or acquired electricity, heat, steam, or cooling from fossil sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	37 c iii		Consumption of self-generated non-fuel renewable energy	energy	*Provide if possible	MWh
E1	Metrics & Targets	E1-5	38 a	AR 33	Fuel consumption from coal and coal products	energy	0.00	MWh
E1	Metrics & Targets	E1-5	38 b	AR 33	Fuel consumption from crude oil and petroleum products	energy	0.00	MWh
E1	Metrics & Targets	E1-5	38 c	AR 33	Fuel consumption from natural gas	energy	0.00	MWh
E1	Metrics & Targets	E1-5	37 c i		Fuel consumption from renewable sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	37 a	AR 33, AR 32	Total energy consumption from fossil sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	37 b		Total energy consumption from nuclear sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	37 c		Total energy consumption from renewable sources	energy	0.00	MWh
E1	Metrics & Targets	E1-5	42		High climate impact sectors used to determine energy intensity	semi-narrative	SMEs in the wood and furniture sector belong to the Section C group of NACE classification (manufacturing), which is considered a high climate impact sector	
E1	Metrics & Targets	E1-6	AR 46 i		List of Scope 3 GHG emissions categories included in inventory	semi-narrative	Business travel and employee commuting	

Annex 5: EFRAG Indicators Sheet

A. Stationary Combustion

Definition: stationary combustion sources comprise static pieces of equipment where a fossil fuel is burnt. Examples are natural gas water heaters for office buildings or oil burning steam generators for industrial applications. Emissions result from the actual combustion of the fuels to produce heated transfer media.

Data collection: To account for these sources, collect information about the type and amount of fuel combusted at each facility. Identify sources of data, which can vary, but are often provided by the supplier or the utility company that delivers natural gas through the grid. Use a monthly natural gas bill, for example, to determine the amount of natural gas purchased during the relevant billing cycle.

Stationary Combustion Source	*Fuel Type*	*Purpose/use*	*Data Collection Method*	*Unit of Measurement*	*Input number*
Wood-Fired Boiler	Wood scraps, Biomass	Provides heat for drying wood and workshop heating	Fuel purchase records, Boiler fuel records	Tons	Quantity combusted
Natural Gas Heater	Natural gas	Heats the office, showroom, or finishing areas	Monthly utility bills, Meter readings	Sm3	Quantity combusted
Diesel or Oil-Fired Boiler	Diesel, Kerosene	Provides heat for production processes or drying chambers	Fuel purchase invoices, Supplier reports	Liters	Quantity combusted
Backup Generator	Diesel, Gasoline, Natural gas	Provides emergency power for machinery and lighting	Fuel records, Generator runtime records	Liters (Diesel/Gasoline), Sm3 (Gas)	Quantity combusted
Paint Drying Oven	Gasoline, Natural gas	Dries paint and coatings applied to furniture pieces	Energy bills, Equipment records	Liters (Gasoline), Sm3 (Gas)	Quantity combusted

Annex 6: Stationary Combustion Example (Scope 1)

A. Stationary Combustion

Definition: stationary combustion sources comprise static pieces of equipment where a fossil fuel is burnt. Examples are natural gas water heaters for office buildings or oil burning steam generators for industrial applications. Emissions result from the actual combustion of the fuels to produce heated transfer media.

Data collection: To account for these sources, collect information about the type and amount of fuel combusted at each facility. Identify sources of data, which can vary, but are often provided by the supplier or the utility company that delivers natural gas through the grid. Use a monthly natural gas bill, for example, to determine the amount of natural gas purchased during the relevant billing cycle.

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Table 1. Stationary Combustion Source

Stationary Combustion Source/ID	Data Collection Method	Fuel Type	Quantity Combusted	Unit of Measurement

Table 2. Total Organization-Wide Fuel Amount Combusted in Stationary Sources, by Fuel Type

Fuel Type	Quantity	Unit of Measurement
Gasoline	0	Liter (l)
Natural Gas	0	Cubic Meter (Sm3)
Diesel	0	Liter (l)
Liquified Petroleum Gas (LPG)	0	Liter (l)
Biodiesel (100%)	0	Liter (l)
Ethanol	0	Liter (l)
Kerosene	0	Liter (l)
Anthracite	0	Tonne (t)
Wood and Wood Residuals	0	Tonne (t)

Annex 7: Stationary Combustion (Scope 1)

B. Mobile Source Emissions

Definition: Mobile sources, like organization-owned cars and heavy-duty vehicles, generate emissions by burning fuel. The fuel usage for any vehicle owned or leased by the organization should be reported in this section.

Data collection: Determine the type of vehicles, type and amount of fuel, and the distance traveled for each vehicle or vehicle type. You can use various data sources: determine fuel usage from fuel receipts or purchase records, or determine mileage from vehicle odometer readings. Estimate distance or fuel use based on vehicle fuel economy from the manufacturer if other data sources are not readily available.

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*Use this table if detailed information regarding the quantity of fuel purchased is available.

Table 1.A Mobile Combustion Source - With Fuel Amount Data

Vehicle ID	Data Collection Method	Vehicle Type	Fuel Type	Quantity Combusted	Unit of Measurement	GHG Emissions (Tonne CO2 Equivalent)

Table 2.A Organization-Wide Fuel Amount Combusted in Mobile Sources, by Fuel Type

Fuel Type	Quantity	Unit of Measurement
Gasoline	0.00	Liter (l)
Diesel	0.00	Liter (l)
Liquified Petroleum Gas (LPG)	0.00	Liter (l)
Biodiesel (100%)	0.00	Liter (l)
Natural Gas	0.00	Cubic Meter (Sm3)

Table 3.A Organization-Wide GHG Emissions from Mobile Sources by Fuel Type

Fuel Type	GHG Emissions (Tonne CO2 Equivalent)	Energy produced by Fuel Combustion (MWh)
Gasoline	0.00	0.00
Diesel	0.00	0.00
Liquified Petroleum Gases (LPG)	0.00	0.00
Biodiesel (100%)	0.00	0.00
Natural Gas	0.00	0.00

Table 4. Total GHG Emissions

Total GHG Emissions (Tonne CO2 Equivalent) - Mobile Combustion	0.00
Total Biogenic Anthropogenic Emissions (Tonne CO2 Equivalent) - Mobile Combustion	0.00

Annex 8: Mobile Combustion (Scope 1)

C. Refrigeration and AC

Definition: Refrigeration and AC Equipment sources can vary in size based on the organization field of activity. Emissions from refrigeration and AC devices are caused by the leakage of refrigerant gases with global warming impact during use, maintenance, and/or disposal of equipment. Gas leakeges are often less important for office-based organizations, where AC equipment can consist of just a rooftop unit. A large organised distribution retail system may have several air conditioning units per store as well as a multitude of other refrigeration equipment. Every refrigerant gas GHG potential contribution is quantified through its Global Warming Potential (GWP), which represents its ability to trap heat in the atmosphere over a specific period of time, compared to CO2 (which has a GWP equal to 1).

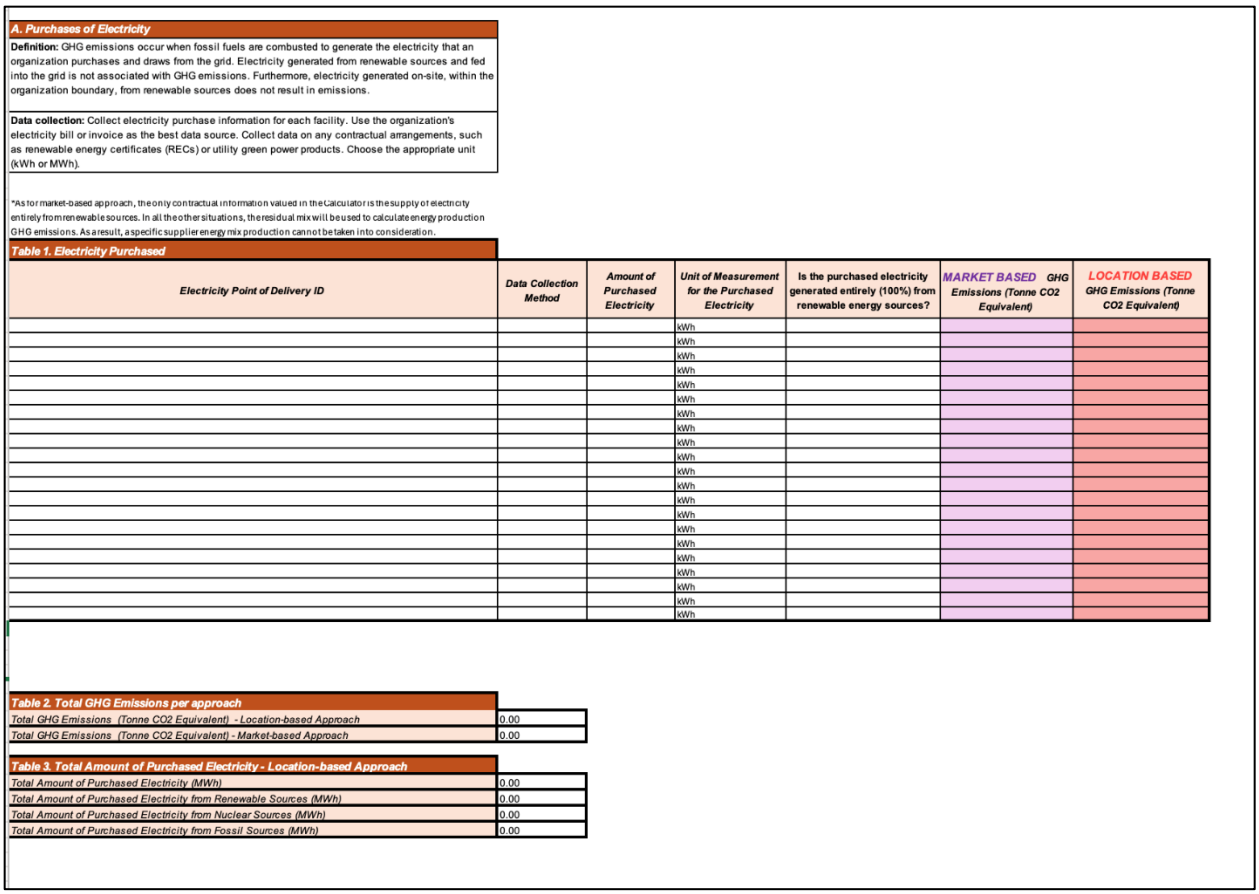
Data collection: Collect data for these sources from maintenance and inspection records, work orders, or invoices from contractors responsible for equipment maintenance. Report the amount of refrigerant gas refilled during these activities.

Table 1. Organization-Wide Refrigeration and AC GHG Emissions

Equipment ID	*Refrigerant*	*Gas GWP*	*Data Collection Method*	Recharge (kg)	GHG Emissions (Tonne CO2 Equivalent)

Total GHG Emissions (Tonne CO2 Equivalent) - Refrigeration and AC	0

Annex 8: Refrigeration and AC



A. Purchases of Electricity

Definition: GHG emissions occur when fossil fuels are combusted to generate the electricity that an organization purchases and draws from the grid. Electricity generated from renewable sources and fed into the grid is not associated with GHG emissions. Furthermore, electricity generated on-site, within the organization boundary, from renewable sources does not result in emissions.

Data collection: Collect electricity purchase information for each facility. Use the organization's electricity bill or invoice as the best data source. Collect data on any contractual arrangements, such as renewable energy certificates (RECs) or utility green power products. Choose the appropriate unit (kWh or MWh).

*As for market-based approach, the only contractual information valued in the Calculator is the supply of electricity entirely from renewable sources. In all the other situations, the residual mix will be used to calculate energy production GHG emissions. As a result, a specific supplier energy mix production cannot be taken into consideration.

Table 1. Electricity Purchased

Electricity Point of Delivery ID	Data Collection Method	Amount of Purchased Electricity	Unit of Measurement for the Purchased Electricity	Is the purchased electricity generated entirely (100%) from renewable energy sources?	MARKET BASED GHG Emissions (Tonne CO2 Equivalent)	LOCATION BASED GHG Emissions (Tonne CO2 Equivalent)
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			
			kWh			

Table 2. Total GHG Emissions per approach

Total GHG Emissions (Tonne CO2 Equivalent) - Location-based Approach	0.00
Total GHG Emissions (Tonne CO2 Equivalent) - Market-based Approach	0.00

Table 3. Total Amount of Purchased Electricity - Location-based Approach

Total Amount of Purchased Electricity (MWh)	0.00
Total Amount of Purchased Electricity from Renewable Sources (MWh)	0.00
Total Amount of Purchased Electricity from Nuclear Sources (MWh)	0.00
Total Amount of Purchased Electricity from Fossil Sources (MWh)	0.00

Annex 9: Purchases of Electricity (Scope 2)

A. Business Travel

Definition: Business travel emissions differ from mobile sources emissions because they account for business travels with vehicles not owned or leased by the organization, such as taxis, trains, airplanes, and personal vehicles when used for business trips.

Data collection: Collect information about employees' business trips. For travelers that use a personal vehicle, choose the vehicle type from the Calculator and collect data about distance travelled during the reporting period. For rail, bus, and air travels, estimate the passenger mileage.

*If a personal vehicle, rental car or taxi was shared, enter the trip only for one employee. The emission factor applies to the whole vehicle, not to each person.

Table 1. Distance Travelled by Personal Vehicle, Rental Car or Taxi

Departure and Arrival Points - Date	Vehicle Type	Distance Travelled (km)	GHG Emissions (Tonne CO2 Equivalent)

B. Employee

Definition: Employee commuting emissions account for employees travel between their home and their workplace in vehicles not owned or leased by the organization, including personal vehicles, buses, and trains.

Data Collection: Collect information about each employee's commuting preferences. For commuters using a personal vehicle, select the appropriate vehicle type from the Calculator and collect data on vehicle distance travelled during the reporting period. For rail, bus, and air travel, select the mode of transport from the Calculator options and provide an estimate of passenger distance travelled for each mode.

Table 1. Distance Travelled by Personal Vehicle

Name of the Employee	*Vehicle Type*	*Distance Travelled (km)*	*GHG Emissions (Tonne CO2 Equivalent)*
Total Distance Travelled by Personal Vehicle			0

Annex 11: Employee Commuting (Scope 3)

Table 1. Fuel Combustion Emission Factors				
Fuel Type	*Density (kg/m3)*	*Country*	*Net Calorific Power (MJ/Tonne) or KJ/m3 for Gases*	*Emission Factor (Tonne CO2 Equivalent/MWh)*
Gasoline	740.7	Bulgaria	42,945.00	0.250
		France	42,005.35	
		Italy	43,944.52	
		Poland	42,030.25	
Natural Gas	Not necessary	Bulgaria	34,832.71	0.202
		France	37,157.87	
		Italy	34,288.48	
		Poland	33,005.58	
Diesel	843.9	Bulgaria	42,300.00	0.268
		France	42,601.00	
		Italy	42,600.00	
		Poland	43,000.00	
Liquified Petroleum Gases (LPG)	522.2	Bulgaria	46,000.00	0.227
		France	46,000.00	
		Italy	46,000.00	
		Poland	46,000.00	
Biodisel (100%)	880	Bulgaria	37,795.00	0.256
		France	37,443.87	
		Italy	37,000.00	
		Poland	37,000.00	
Ethanol	789	Bulgaria	27,000.00	0.234
		France	27,000.00	
		Italy	27,000.00	
		Poland	27,000.00	
Kerosene	802.6	Bulgaria	43,000.00	0.264
		France	42,998.00	
		Italy	43,000.00	
		Poland	43,000.00	
Anthracite	Not necessary	Bulgaria	29,650.00	0.355
		France	29,650.00	
		Italy	29,650.00	
		Poland	29,650.00	
Wood and Wood Residuals	Not necessary	Bulgaria	19,000.00	0.410
		France	19,000.00	
		Italy	19,000.00	
		Poland	19,000.00	
Road diesel	843.9	Bulgaria	41,999.00	0.268
		France	42,154.50	
		Italy	42,259.00	
		Poland	42,609.93	

Annex 12: Emission Factors Sheet

Unit Conversion Sheet

Type	Convert From	Convert To	Multiply By
Mass	Kilograms	Tonnes (t)	0.001
Mass	Tonnes (t)	Kilograms	1000
Mass	Pounds (lb)	Kilograms	0.453592
Volume	Gallons (US)	Liters	3.78541
Volume	Gallons (UK)	Liters	4.54609
Volume	Liters	m3	0.001
Volume	m3	Liters	1000
Energy	kWh	MJ	3.6
Energy	MJ	kWh	0.277778
Energy	Therms (UK)	kWh	29.3071
Energy	MWh	kWh	1000
Distance	Miles	Kilometers	1.60934
Distance	Kilometers	Miles	0.621371

Annex 13: Unit Conversion Sheet

Information Sources

Type of information	Institution / Source	Link
Fuel Densities	International Energy Agency	Link
	United Nations Statistics Division	Link
	VIKAS	Link
Fuel Net Calorific Power	Eurostat Data Base	Link
	International Energy Agency	Link
	Concerted Action Renewable Energy Sources Directive	Link
Fuel Emission Factor	JRC - Global Covenant of Mayors for Climate and Energy	Link
	The Environmental Protection Agency (EPA)	Link
Electricity Emission Factors	JRC - Global Covenant of Mayors for Climate and Energy	Link
	Association of Issuing Bodies (AIB)	Link
Refrigerant GWPs	SINTECO	Link
km/CO2 per km Emission Factors	Department for Energy Security and Net Zero, Department for Science, Innovation and Technology	Link
	Eco Passenger	Link

Annex 14: Information Sources