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Energy Efficiency Management in Small and Medium-Sized Enterprises: Current Situation, Case Studies and Best Practices

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Abstract: Energy efficiency is a key factor to meet the ambitious climate targets of the European Union (EU) aligned with the international policy directives. On their own, Small and Medium-sized Enterprises (SMEs) do not consume big amounts of energy, but taking into consideration that they represent about 99% of businesses worldwide, their cumulative energy consumption is remarkable. Even though SMEs experience several barriers in their effort to improve their energy efficiency, their contribution to the EU's energy efficiency improvement targets is crucial through the implementation of measures to improve their energy footprint. The purpose of this paper is to present a comprehensive review of SMEs' energy efficiency and energy footprint management, which has been carried out in the context of the "SMEnergy—Energy Footprint Management for SMEs" EU-funded Erasmus+ project. The correlation between energy conversion and consumption processes and energy efficiency, as well as the current situation of energy footprint management and energy management systems in SMEs, are discussed in detail. Moreover, successful case studies of SMEs that have implemented specific measures to improve their energy footprint and achieve energy efficiency targets are also included. It is highlighted that SMEs exhibit a high potential for energy efficiency enhancement that could directly promote climate change mitigation and sustainable development.

Keywords: small and medium-sized enterprises (SMEs); energy efficiency; energy footprint; energy management; energy consumption; international standards

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1. Introduction

The European Union (EU) prioritizes energy efficiency as a key factor to meet 2030 climate targets and become the first climate-neutral continent by 2050 [1]. The EU's Energy Efficiency Directive establishes an ambitious efficiency target that corresponds to 39% and 36% energy reduction compared with the 2020 reference scenario projections for primary and final energy consumption, respectively. The contribution of Small and Medium-sized Enterprises (SMEs) to the energy efficiency improvement targets of the EU is significant. Specifically, the Energy Efficiency Directive introduced the requirement for EU Member States to develop appropriate plans and policies for SMEs that promote energy audits and the implementation of corresponding measures that could improve their energy utilization efficiency [2].

Apart from the EU Energy Efficiency Directive, efficient energy utilization and consumption in each country of the world is secured via the establishment of several policies, which may range from regulations and directives to recommendations and concerted actions. In Table 1, several international policies that are set to promote energy efficiency and a low-carbon economy are summarized.

Table 1. International policies and directives promoting energy efficiency and a low-carbon economy.

Policy	Contextualization
Paris Agreement [3]	It is a worldwide agreement set to promote practices considering the requirement to limit global warming up to 2 °C and (if possible) to 1.5 °C. In the scope to achieve the aims of this agreement, all the involved countries are set to submit comprehensive national climate action plans. Although all these are not sufficient in terms of the establishment of specific measures to be practiced (such as the ones related to the decarbonization of the energy systems), the agreement traces a way for further action.
2012 Energy Efficiency Directive (and 2018 Amendment) [2,4]	It sets a list of rules and obligations that must be followed by EU Member States for the achievement of 2020 and 2030 targets. In relation to energy consumption targets and savings for the reference year of 2030, it is set to promote: • 39% and 36% energy efficiency targets for primary and final energy consumption corresponding to a reduction of 1023 and 787 Mtoe, respectively; • New savings of final energy consumption each year of 1.5% from 2024 to 2030 by EU countries; • Reduction in annual energy consumption by 1.7% for the public sector. In relation to energy poverty and consumers, it is set to promote the following (with the aim of strengthening the requirements on awareness raising): • The establishment of one-stop-shops; • Technical assistance and financial advice for consumers; • The protection of consumers through out-of-court dispute resolution mechanisms.
2030 Climate and Energy Framework [5]	It is set to establish major targets and policy objectives for the 2021–2030 period, namely: • 40% greenhouse gas emission reduction; • 32% renewable energy use share increase; • 32.5% energy efficiency improvement.
European Green Deal [1]	It is a roadmap for the 2019–2024 period set to promote the aims of the 2050 long-term strategy (near-zero GHG emissions in 2050). In relation to energy efficiency improvement and clean energy transition promotion, it is set to accomplish the following: • Develop and promote interconnected energy systems and grids for renewable energy integration support; • Promote the installation of innovative technologies and modern infrastructure; • Promote energy efficiency improvement and product eco-design; • Promote the decarbonization of the gas sector; • Promote intersectoral smart integration; • Take the EU's offshore wind energy to its full potential.
Fit for 55 Package [6]	It is a set of policy proposals to achieve the climate target of reducing EU emissions by at least 55% by 2030 towards the long-term objective of climate-neutral EU. The main objectives of Fit for 55 package are as follows: • Reform of EU's Emissions Trading System (EU ETS) in order to achieve a reduction in the emissions produced by the sectors included in the package on the order of 61% by 2030 compared with that of 2005; • Regarding the sectors that are not covered by the EU ETS, the existing target for the GHG emissions reduction is raised from 29% to 40%; • Complete elimination (100% reduction) of CO_2 emissions produced by cars and vans by 2035, i.e., complete ban of cars and vans powered by internal combustion engines in the marketplace; • Reduction in methane emissions produced by the energy sector. As part of the Global Methane Pledge, the EU has committed itself to a 30% mitigation of its methane emissions by 2030 compared with 2020 levels; • The adoption of a policy package to reduce aircraft emissions; • Promotion of renewable and green fuels in the maritime transportation sector. The EU aims to reduce the carbon intensity of the energy consumed on-board merchant ships by up to 75% by 2050; • The increase in the renewable energy share in the overall energy mix target from at least 32% to 40% by 2030; • The increase in the energy efficiency target from 32.5% to 39% and 36% for primary and final energy consumption, respectively; • The transformation of EU buildings to zero-emission buildings by 2030 and beyond.

Table 1. *Cont.*

Policy	Contextualization
REPowerEU [7]	It is an EU strategy initiated to reduce the dependence on imported fossil fuels and tackle the climate crisis. These specific policies set to be met by 2030: • Increase binding Energy Efficiency Target from 9% to 13%; • Increase the renewable energy share in the overall energy mix target from 40% to 45%; • Reduce the utilization of fossil fuels in industry and transportation, with the objective to decrease the overall natural gas demand of these sectors by 35 bcm.
European Industrial Strategy [8]	It is a policy package for the green and digital transition of the European industrial sector towards global competitiveness. Based on the lessons learned from the COVID-19 pandemic, the EU proposed the following policy actions: • Definition and implementation of appropriate policies that promote sustainability and digitalization of industrial companies, known as twin-transition; • Encouraging the cooperation between different member states to implement specific projects that accelerate the twin-transition of the EU industrial sector; • Focusing on the analysis of the steel production sector in order to identify and overcome the barriers to sustainable transition, ensuring the competitiveness of the sector; • Promoting mixed private and public partnerships that aim toward the financial support of research and development on green and clean technologies; • Addressing the barriers associated with the accelerated adoption of renewable energy sources and the acceleration of investments on power grids.
EU Strategy for Energy System Integration [9]	It is a strategy which was elaborated considering the combination of the aims of both the European Green Deal and the EU long-term strategy until 2050. It is divided into three main pillars, and The 1st Pillar (Energy Efficiency and Circular Economy Nexus) deals with the following: • The "Energy Efficiency-First Principle", according to which energy demand-side solutions are prioritized in relation to energy supply-side measures, if these are more cost-effective; • The promotion of waste heat recovery from industrial facilities as a key measure for the improvement of intraplant energy efficiency and the operation of effective district heating and cooling networks; • Energy recovery from wastewater (mainly through the production of biofuels). The 2nd Pillar (renewable-based electrification) deals with the following: • Utilization of renewable energy resources as the main primary energy form in our effort to meet the expected electricity demand growth; • Industrial processes electrification; • Application of energy storage techniques. The 3rd Pillar (alternative low-carbon fuels) deals with the following: • Sectors that face difficulties towards decarbonization and are encouraged to utilize green hydrogen technologies; • The promotion of Carbon Capture and Storage (CCS) and Carbon Capture and Use (CCU) technologies.

Due to low financial and operational capacity, EU SMEs have relatively lower technical, human, and financial resources. As a result, they have a lot of barriers in their effort to improve their energy efficiency; namely lack of awareness regarding energy efficiency, low capital availability for investments, difficulty to access bank loans, doubts around the effectiveness of energy-saving measures and the lack of specialized and appropriate personnel, etc. [10]. There are national support schemes designed to provide SMEs with appropriate resources (e.g., methodologies, guidelines, technologies inventories, and financial subsidies). Some of them require mandatory actions, e.g., the conduction of energy audits in order to receive financial support.

Improved energy efficiency is a major measure in climate change mitigation, as well as a crucial component for individual companies to maintain and improve competitiveness. High improvement in energy efficiency could be easily achieved via energy services. Perhaps the building sector presents the most prominent example, where energy services measures may be similar for a lot of buildings in a certain area, implicitly implying lower procurement transaction costs for energy service contracts. The industrial sectors, and in particular industrial SMEs, have paid much less attention to energy services.

On their own, SMEs do not have high energy demands. Nevertheless, taking into consideration that they represent almost 99% of businesses worldwide, their collective energy demand has a significant share. It should be also noted that there are SMEs operating in energy-intensive sectors that might consume more energy than bigger enterprises, i.e., non-SMEs, in other sectors. It was estimated that SMEs consumed around 13% of the total global energy demand, i.e., 74 exajoules (EJ), in 2015 [11]. Needless to say, in some countries, the share of SMEs in the energy consumption of industrial and commercial sectors is more than 50% [12]. Collectively SMEs are significant environmental contributors. Although the environmental impact of an individual enterprise is usually low, the overall footprint of its sector may be very high, taking into account the large number of SMEs operating in that sector. Specifically, it is highlighted that SMEs were responsible for approximately 64% of the overall industrial pollution in Europe, with individual sectors variations ranging from 60% to 70% in 2010. These figures are in line with SMEs' share of industrial production and employment, as SMEs contribute around 70% to European employment, while manufacturing and services SMEs produce almost 60% of the overall turnover of these sectors [13].

The application of cost-effective energy efficiency measures could result in a reduction in SMEs' energy demand by 30%. It has been estimated that the adoption of measures, such as the use of energy management software could result in energy savings higher than the annual energy consumption of Japan and Korea. Enhanced energy efficiency could also have a beneficial effect on the SMEs themselves from a financial perspective. Cutting costs and allowing resources to be invested in more productive and profitable activities make the company more competitive, innovative, and resilient. According to the International Energy Agency (IEA) [14], "energy efficiency can deliver a wide range of other growth benefits [. . .] for example by improving productivity and product quality. Energy efficiency in SMEs can also contribute to [. . .] reducing reliance on energy imports and the need for investments in additional generation capacity, and lowering environmental impacts, such as GHG emissions and local air pollution". Considering the large number of SMEs operating all over the world and the associated endless variety of industrial processes involved, it is evident that there would be numerous different measures, applications, and projects to enhance their energy efficiency.

Especially after the global economic crisis that seems to have followed the pandemic era, it is expected that the interest of SMEs to enhance their energy efficiency performance might increase, while authorities and institutions promote energy efficiency as a key factor to deal with the multifaceted challenges that have arisen. The need for studies presenting the fundamentals of energy footprint management for SMEs in a comprehensive, graspable, and concise way is imperative.

In the literature, there are several studies investigating the barriers of implementing energy efficiency measures in SMEs [10,15–23], as well as the benefits resulting from the application of energy management techniques [24–28]. Additionally, some studies present projects promoting energy efficiency in SMEs [11,14], while a few others propose specific measures to improve their energy efficiency [29–31]. The present study explores the concept of energy footprint in SMEs in a comprehensive way towards continuous energy efficiency improvement.

This review paper is structured as follows: The world energy system is briefly presented in Section 2, and the concept of "Energy Footprint" is introduced and explained in Section 3. The current situation of energy footprint management and energy management systems in SMEs are discussed in Section 4. Energy efficiency in relation to energy conversion and consumption is presented in Section 5. Successful examples of energy management implementation, as well as specific energy efficiency improvement measures based on relevant case studies and the corresponding technical literature, are described in Sections 6 and 7, respectively. Concluding remarks and recommendations are included in the last section of the paper.

2. The Big Picture: The World Energy System

In order to promote the most effective and successful policies to enhance SMEs' energy footprint, it is crucial to fully understand the energy conversion chain and appreciate the associated energy conversions losses. The transformation of energy starting from its primary form (extraction and exploitation of natural energy resources, e.g., crude oil, natural gas, wind, sun, etc.) to its useful end (energy-consuming units in industry, transport, buildings, and other sectors) makes up the energy system of a country or a region [32].

The first step in the analysis of an energy-relevant system is to assess its (energy) consumption. While in the context of SMEs the analysis of interest would be in terms of energy relevant services, it is firstly necessary to understand the primary energy supply globally. Figure 1 presents the evolution of primary energy consumption in the world in the timeframe of 1965–2020. Although the renewable energy resources share has been increased in the last years, since the mid-2000s, the energy dependence of the entire world on the burning of fossil fuels is still considerable. Intensifying the utilization of renewable energy resources is of outmost importance in our effort to achieve the decarbonization of energy systems.

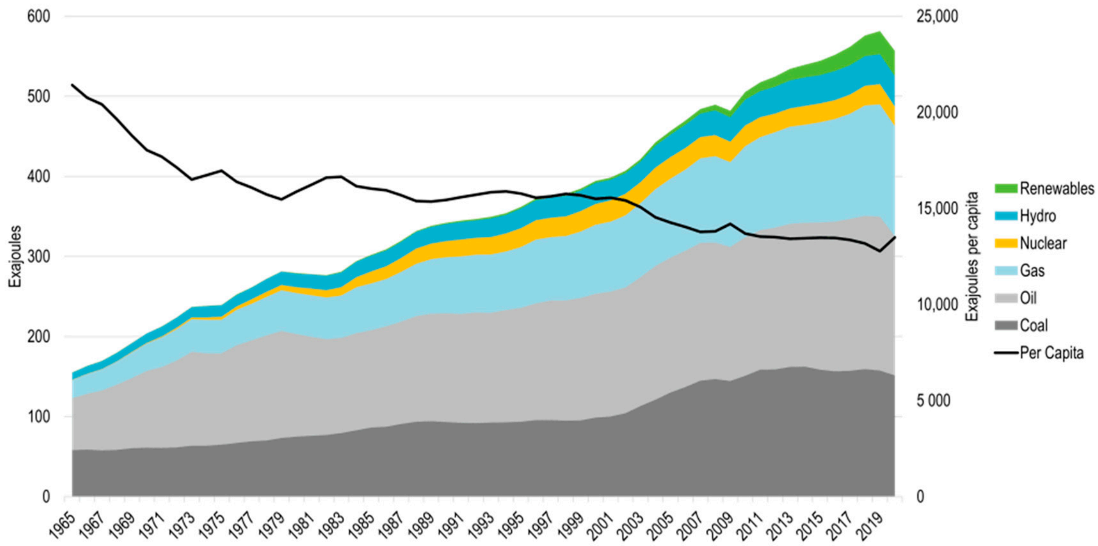

Figure 1. Primary energy consumption in the world in the timeframe of 1965–2020 (adapted from [33]).

The transformation of energy from its various primary forms to different useful forms is presented diagrammatically in Figure 2. Considerable energy losses are observed in the lower part of the diagram, which represents energy services, i.e., useful energy. Apart from the extensive renewable energy integration, either directly promoting supply from RES or indirectly by means of deep electrification, the main instrument for the decarbonization of energy utilization in SMEs is the minimization of these losses. A prerequisite for the latter is the implementation of measures that promote reduced energy footprint, enhanced energy conversion efficiency, and improved energy management for SMEs.

International standards on energy utilization and consumption have been established with the primary aim to decarbonize energy systems, i.e., to reduce the total equivalent to carbon dioxide ($CO_{2,eq}$) emissions. Each one of the different policies specifies its own strategies in order to achieve this, either through actions that enhance the efficiency of energy conversion or more directly via the utilization of primary energy sources associated with lower $CO_{2,eq}$ emissions. In this context, the promotion of more energy-efficient processes and the adoption of energy management techniques would lead to a reduction in total GHG emissions and the associated total energy footprint.

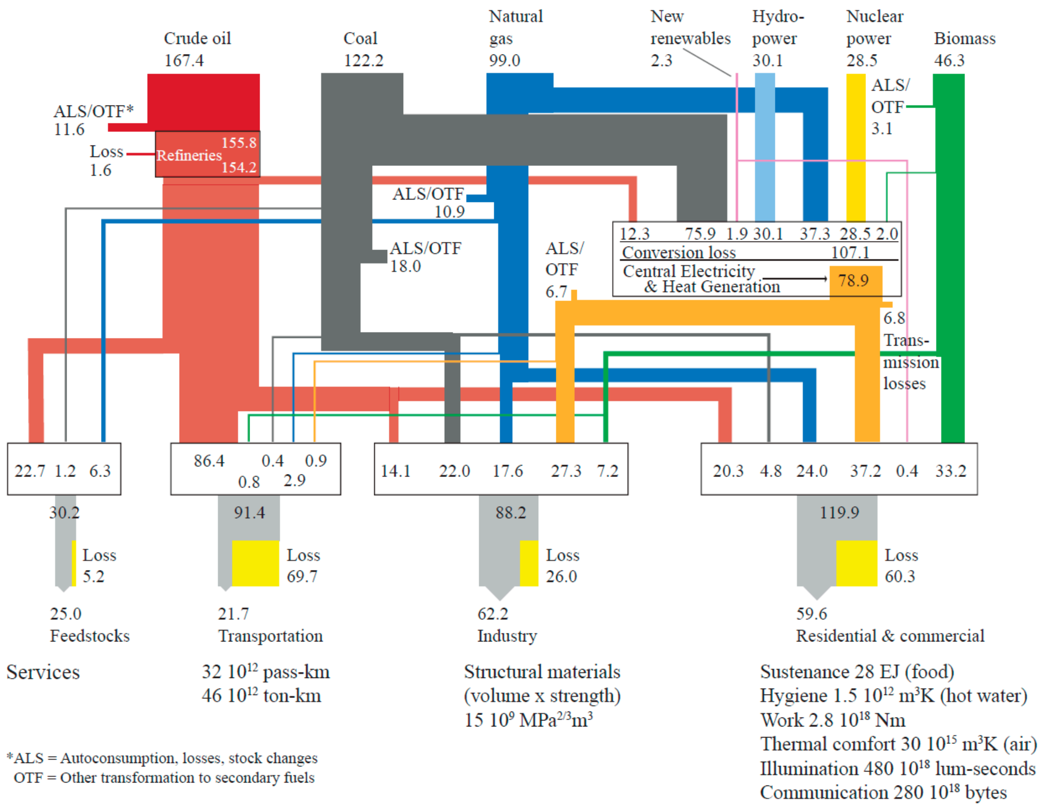

Figure 2. Energy utilization levels (expressed in EJ) in each energy transformation step from primary to useful energy (adapted from [34]).

3. Energy Footprint as a Benchmarking Practice towards Energy Efficiency Targets

The "Energy Footprint" is a subset of the ecological footprint and is defined as "the sum of all (land) area required to absorb the CO_2 emissions from the consumption of non-food and non-feed energy". It is a measure of the equivalent amount of forest land required to absorb CO_2 emissions from fossil fuel combustion and electricity generation processes associated with a product, organization, subnational area, country, region, or the planet over a particular time period. The definition of energy footprint makes it quite difficult to calculate it. Thus, the term is commonly used to indicate the electricity demand for the production of a product or the delivery of a service [35].

The energy footprint allows us to better understand the spatial distribution of energy utilization, as well as to compare energy consumption within different enterprise sectors. Identified areas of significant energy consumption or energy losses could indicate energy-footprint-enhancing opportunities by implementing appropriate energy management practices and energy efficiency guidelines, upgrading energy systems, or applying new technological solutions. Therefore, the energy footprint provides a macroscale benchmark for the evaluation of energy consumption, as well as prioritization and opportunity analysis [36].

"Energy Efficiency" is reversely related to the amount of energy consumed to perform a given task or produce a specified output. Energy-efficient buildings, for instance, consume relatively lower amounts of energy to heat, cool, and run appliances and electronics, while energy-efficient manufacturing facilities consume relatively lower energy to produce goods. Enhancing the energy efficiency of production operations could also contribute significantly to counteract climate change through the reduction in the overall operational energy demand. Therefore, the lower energy consumption of several sectors combined with the development of renewable energy sources would lead to the reduction in fossil fuel consumption and the achievement of net-zero emissions of CO_2 through decarbonization [37]. Additionally, it represents an easy and cost-effective way not only to reduce energy costs but also to improve the competitiveness of a business.

4. Energy Management in SMEs

Energy management includes the plans, processes, and operations related to the production, consumption, distribution, and storage of energy within an organization. The main objectives of Energy Management in SMEs are related to climate protection by optimizing and reducing the consumption of energy, energy costs, and resource conservation, without limiting the access to the amounts of energy required by the user [38]. It is closely associated with environmental management, production management, logistics, and other business operations. Cooremansa and Schönenbergerb [39] highlight that energy management could be a key factor in promoting the required investments to implement energy efficiency policies within SMEs. Several other works tackle different aspects of energy management applied in SMEs [39–42].

Its economic dimension is specified in the following VDI-Guideline 4602 definition: "Energy management is the proactive, organized and systematic coordination of procurement, conversion, distribution and use of energy to meet the requirements, taking into account environmental and economic objectives". Energy management employs engineering solutions and management techniques in order to systematically optimize the energy efficiency of the organization with respect to specific social, environmental, economic and political objectives [43].

Energy management is defined as the process of tracking and optimizing energy consumption from all business processes (including relevant devices and equipment employed to conserve energy in the company/organization premises) [44]. The four key steps for the application of effective and successful energy management plans are as follows:

1. *Measure energy consumption:* A key component in identifying improvement opportunities is to perform a comprehensive energy analysis. The main parts of such an energy analysis include collecting energy consumption data of the equipment employed within the examined facility, as well as examining the most energy-intensive processes and operations so to be able to identify their energy consumption pattern and demand and evaluate their contribution to total energy usage. In this context, the installation of appropriate energy metering and monitoring equipment is crucial in order to track and set up the energy usage baseline of the examined facility.
2. *Fix the basics:* Having carried out an energy audit or a similar energy analysis, organizations usually apply passive measures to improve their energy efficiency, such as implementing high-efficiency technologies and solutions for motors, lighting, and heating, as well as ventilation and air conditioning (HVAC) systems.
3. *Automate:* Apart from taking passive energy efficiency measures, organizations should also adopt active energy management policies in order to further improve their energy efficiency performance and promote continuous energy efficiency enhancement and cost savings over time. A typical example of active energy management measures is the implementation of controllers, timers, sensors, etc. HVAC or lighting systems, for instance, are equipped with such automatic equipment in order to maintain room temperature at an optimum level or to turn on the lights of a room during working hours only or whenever the room is occupied.
4. *Monitor and control:* In addition to the application of energy efficiency measures that help to manage energy-intensive operations and processes within the facility, employees' awareness through training and information, as well as their commitment to a behavior driven by energy efficiency principles, is a decisive factor in the efforts of organizations to continuously improve their energy efficiency and reduce their operational cost. Policies that could definitely contribute to this direction are the installation of monitoring and control systems and the frequent conduction of energy audits and energy efficiency analysis, as well as the implementation of an appropriate and preferably custom-made Energy Management System (EMS).

According to the United Nations Industrial Development Organization [45], EMS is defined as "a framework for energy consumers, including industrial, commercial, and public sector organizations, to manage their energy use". EMS could be used as an opportunity analysis tool to help organizations and companies to identify opportunities for energy efficiency improvement and guide them to adopt specific technologies, including the low capital-intensive ones. Typically, the availability of specialized staff and experts, as well as the training of the company's staff, are required for the successful implementation of EMSs. According to the International Organization for Standardization (ISO) [46], an EMS involves the development of specific energy policies, the definition of measurable and realistic energy consumption targets, the creation of improvement plans to achieve them, and the monitoring of the relevant progress achieved. Measures to improve energy efficiency performance might include the mitigation of energy losses, the implementation of more energy-efficient technologies, or the redesign of current processes in order to achieve energy consumption and cost reductions.

There is a specific International Standard for Energy Management, namely ISO 50001, that presents an acceptable systematic framework for the design of a successful EMS that can be followed by any organization [47]. ISO 50001 has been developed in order to guide an organization to enhance its energy efficiency performance by improving the management of its energy-intensive activities, assets or processes. ISO 50001 may be implemented globally by any organization regardless of its size. Its benefits could vary from reducing the overall environmental impact and enhancing the organization's reputation up to cutting costs and improving its competitiveness. Finally, an organization following ISO 50001 could verify its legal and internal compliance, identify the assets and/or processes with higher impact on the overall energy demand, and gain a better perception of its energy use and consumption via internal communication.

Similarly to other ISO management system standards, ISO 50001 is designed following the "Plan-Do-Check-Act" principle for continual improvement [48]. This approach helps organizations to integrate energy management policies successfully and, as a consequence, to enhance other operational aspects, such as quality and environmental management. Specifically, ISO 50001 provides a systematic framework of standards that help to create a policy for more energy-efficient operation; define measurable targets to meet the policy; monitor and process the available data in order to understand and manage their energy consumption; implement specific measures and techniques to achieve these targets; measure their results; evaluate the applied action plans and take appropriate decisions based on available measurements; and improve their energy use and costs over time.

5. Energy Consumption for Various SME Sectors

The industrial sector is the most important energy consumer relative to any other end-use economic sector. This is because energy is widely used within an industrial enterprise for the operation of manufacturing equipment, steam production, process heating and cooling, cogeneration applications, lighting, heating, air conditioning in buildings, etc. Additionally, basic chemical feedstocks contribute to the overall energy consumption of the industrial sector. Specifically, the production of agricultural chemicals is based on natural gas feedstocks, while organic chemicals and plastics are manufactured using natural gas liquids and petroleum products [49].

Although the industrial sector is the most energy-intensive, it should be noted that SMEs operating in the tertiary sector, such as transportation or hospitality companies, could have significant energy consumption and consequently the potential for energy savings [50]. For instance, intermediate-sized hotels could have considerable energy demand, not only because of the variety of the services they offer but also because of their continuous operation and the uncontrolled nature of their energy requirements. Thus, they might have the opportunity for significant energy savings, namely in the range of 10–30% [51].

The International Energy Outlook of the U.S. Energy Information Administration [49] suggests three distinct types for categorizing the industrial sector, namely energy-intensive manufacturing, non-energy-intensive manufacturing, and nonmanufacturing, as shown in Table 2.

Table 2. Major groupings and representative industries of the industrial sector; source: U.S. Energy Information Administration (May 2016) [49].

Industry Grouping	Representative Industries
Energy-intensive manufacturing	
Food	Food, beverage, and tobacco manufacturing
Pulp and paper	Paper manufacturing, printing, and related support activities
Basic chemicals	Inorganic chemicals, organic chemicals (e.g., ethylene propylene), resins, and agricultural chemicals; includes chemical feedstocks
Refining	Petroleum refineries and cola products manufacturing, including coal and natural gas used as feedstocks
Iron and steel	Iron and steel manufacturing, including coke ovens
Nonferrous metals	Primarily aluminum and other nonferrous metals, such as copper, zinc, and tin
Nonmetallic minerals	Primarily cement and other nonmetallic minerals such as glass, lime, gypsum, and clay products
Nonenergy-intensive manufacturing	
Other chemicals	Pharmaceuticals (medicinal and botanical), paint and coatings, adhesives, detergents, and other miscellaneous chemical products, including chemical feedstocks
Other industrials	All other industrial manufacturing, including metal-based durables (fabricated metal products, machinery, computer and electronic products, transportation equipment, and electrical equipment)
Nonmanufacturing	
Agriculture, forestry, and fishing	Agriculture, forestry, and fishing
Mining	Coal mining, oil and natural gas extraction, and mining of metallic and nonmetallic minerals
Construction	Construction of buildings (residential and commercial), heavy and civil engineering construction, industrial construction, and specialty trade contractors.

The classification of manufacturing industries to energy-intensive and non-energy-intensive is quite useful because it implicitly identifies the industry sectors that should be prioritized in improving their energy efficiency. The industrial sectors which are considered to be energy-intensive are food, pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (primarily aluminum), and nonmetallic minerals (primarily cement). The share of these sectors to the overall energy consumption of the industrial sector is about 50%. It should be emphasized that the above industrial sectors considered are in line with the ones identified by the Department for Economic, Scientific and Quality of Life Policies of the European Parliament [52], which focuses on the industrial sectors that are included in the EU ETS and have the highest share of CO_2 emissions. Specifically, the European Parliament considers the following industries as energy intensive: iron and steel, aluminum, cement, refineries, petrochemicals, fertilizer, lime and plaster, paper and pulp, hollow glass, and inorganic chemicals.

However, this classification refers in general to all enterprises without considering their scale. Focusing on SMEs, the main sectors with considerable energy consumption and impact are the following:

- Food, Beverage, and Tobacco [53];
- Chemical and Metal Production [14];
- Construction [54];
- Agriculture and Forestry [55];
- Transport, Storage, and Communication [56].

In our effort to characterize the identified SME sectors in terms of relative levels of energy-use-related key performance indicators, the following aspects were considered [13,57]:

- Number of SMEs in each one the different sectors considered;
- Size of individual SMEs in the sector;
- Overall energy consumption in the sector;
- Corresponding energy efficiency;
- Potential for energy efficiency improvements in the sector.

The relevant indicators are shown in Table 3.

Table 3. Characterization of SME sectors by energy-related indicators.

Sector	Level of Energy Consumption per Enterprise	Level of Energy Efficiency	Energy Efficiency Improvement Potential
Food, Beverage, and Tobacco	Medium	High	Medium
Chemical and Metal Production	High	High	High
Construction	Low	Medium	High
Agriculture and Forestry	Low	Low	High
Transport, Storage, and Communication	High	Low	High

In order to identify the energy-intensive SME sectors which should be prioritized in improving their energy efficiency, it is crucial to have an indication of the final energy amounts they consume. In the context of the present work, we evaluated the final energy consumption levels per number of enterprises using Eurostat's data [58,59]. Corresponding levels are presented graphically in Figure 3. It is noteworthy that our values compare favorably with the ones given in [49].

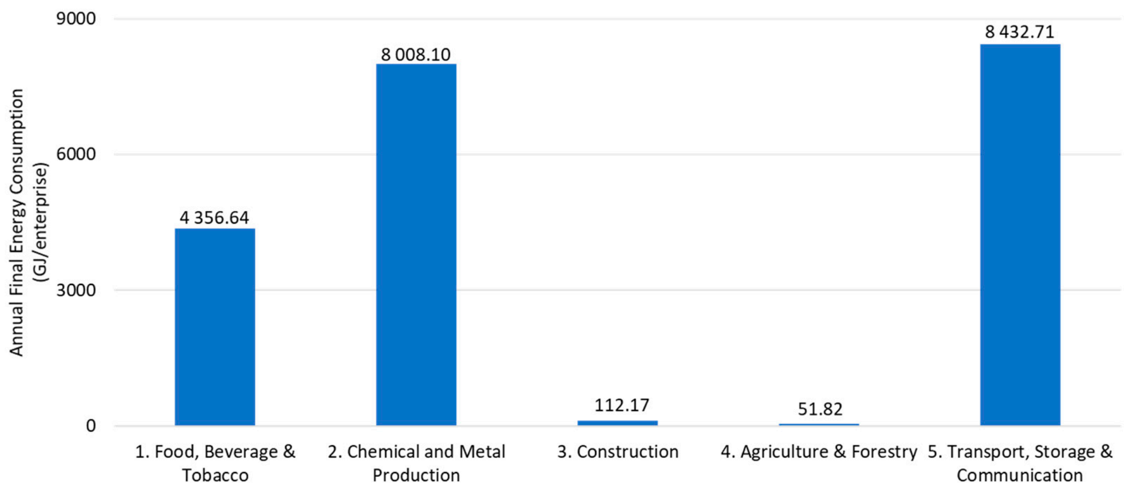

Figure 3. Final energy consumption levels for various SME sectors per number of enterprises.

6. Case Studies of SMEs That Improved Their Energy Efficiency

It is well known that energy efficiency is not of high priority within SMEs, and energy management tools are scarcely applied [57]. Energy efficiency improvement investments in SMEs are quite small. This is mainly due to the limited available relevant economic and time resources, as well as to the low awareness of the multiple possible potential benefits to be achieved. Additionally, SME owners, managers or decisionmakers prioritize other investments instead of the ones that could enhance the energy efficiency performance of their organization, while SMEs do not have the appropriate and specialized technical staff to monitor, evaluate, and improve their energy efficiency performance. Particularly, in the COVID-19 pandemic period, where quite a few SMEs struggled for survival, adopting energy efficiency measures might not be affordable [11].

In this section, case studies of the successful implementation of measures to enhance the energy efficiency of SMEs operating in different sectors both from Europe and the rest of the world are presented.

6.1. Chemicals Industry Sector

SATECMA, a chemical producer with quite a few production lines, has implemented several measures to improve its energy utilization. More efficient climate control systems were used and Light-Emitting Diode (LED) lamps in conjunction with better exploitation of natural light strategies were adopted, while a photovoltaic (PV) solar energy generation plant was installed. The adoption of these measures resulted in a 20% reduction in the company's overall energy consumption. This led to not only significant cost savings but also to the image improvement of the company among customers, public institutions, and suppliers [60].

In the process of achieving an ISO 14001 certification, a UK chemicals company managed to decrease its energy consumption by more than 30%. The identification and elimination of leakages also helped to improve the thermal efficiency of its boilers, resulting in considerably lower gas and steam bills [13].

Wacker Chemie AG decided to employ a highly efficient gas and steam turbine power plant in a combined heat and power generation mode. Thermal energy is distributed in the form of steam at different pressure levels. The heat released by the chemical reactions, in various production phases of the company, sometimes exceeds its own thermal energy needs. This energy surplus is utilized to cover the heat requirements of other companies. The company initially identified the relevant heat sources and heat sinks at the Burghausen site in Germany. Then, it integrated the heat generation of the central waste gas and residue incineration plants into existing steam networks. It also connected the surplus heat sources with heat sinks via local heating networks. Namely, thermal energy produced at the company's site covers the thermal energy needs of a public swimming pool, an indoor tennis court, and a gymnasium. The implemented changes resulted in significant energy savings. A saving of 421,000 MWh comes from the steam processes, while another 44,000 MWh of saving comes from facility heating and hot water preparation [61].

6.2. Food and Beverage Sector

The world-leading producer of Scotland's national dish haggis conducted environmental and energy audits in 2008, which helped the company to identify the key cost-saving measures to be implemented. Regarding the energy efficiency measures, more efficient cooking methods were introduced, resulting in gas bill reductions on the order of 15% from 2006 to 2008. The company also implemented several other measures such as staff training, installation of technologies to use waste heat of refrigerators, active, schedule-based control of heating, cooling, and lighting, and replacement of the lighting systems with more energy-efficient ones. The adoption of these measures led to the reduction in energy consumption and the associated carbon emissions. Additionally, the company participates in the Bright Green Placements (BEP), a placement program where a student from an environmental field of study works for eight weeks on a particular environmental management problem, helping the company to achieve some of its main environmental management targets [13].

A brewery located in the city of Aying, Germany is using a combined heat and power (CHP) system to cover its energy requirements. The company decided to redesign its CHP system to improve its efficiency. Specifically, the brewing and industrial hot water preparation units, as well as two other heating circuits, were connected to the cooling circuit of the CHP system. An insulated tank with a water content of approximately 30,000 litters was also installed in order to store the thermal energy that is readily available and cannot be "consumed" within the production processes. The installed CHP system has a nominal electrical capacity of 200 kW and a nominal thermal output of 230 kW. Most of the electricity generated is used directly to cover the brewery's energy needs. Excess electricity is fed to the public electricity grid and remunerated. Compared with the generation of heat via a gas-fired boiler and a separate electricity supply from the public grid, the CHP system which was installed resulted in a reduction in production-related CO_2 emissions by more than 100 tons per year. The corresponding electricity consumption was also reduced by 20% [62].

Another German brewery, Krones A, developed an innovative process called Equi-Therm, with which primary energy requirements are reduced via the recovery of waste heat from the brewing process itself, employing a specifically designed heat exchanger. At the same time, cooling energy and, implicitly, the associated electricity are saved, while freshwater requirements are drastically reduced. The developed system extracts energy from the brewing process itself at a particular point and it feeds it back at another point. As a result, savings of about 30% and 20% in thermal energy and in electricity requirements, respectively, are achieved [63].

Rager bakery located in the city of Ansbach, Germany is another example of a small company with less than 10 employees that has been motivated by environmental awareness and rising energy costs to find creative solutions for potential savings. The company optimized their baking processes and oven utilization, reduced to the minimum their utilization of refrigerators, improved their insulation of cold rooms, recovered waste heat from their refrigeration system in order to prepare hot water, adopted LED lighting technology, reduced the duration of their dishwasher's short program from 2.5 to 1.5 min, and employed a hybrid transportation vehicle. The achieved energy savings resulted in an annual approximate saving of EUR 2500 [64].

Regarding another bakery in Germany, it was estimated that it could achieve an annual reduction of about 6.5% in the total energy bill (≈EUR 4000), as well as a lower energy consumption per kg of processed flour from 1.36 kWh/kg to 1.28 kWh/kg, by implementing simple energy management measures. Such measures include frequent maintenance of bake ovens, introduction of LED lighting, enhancement of hot water utilization, improvement of pipe insulation, and process thermostat recalibration [65]. This particular case represents a very good example of the non-energy benefits that could be achieved in small enterprises through the implementation of energy-saving measures. It is reasonable to assume that the proposed changes could have the following positive effects: improved product quality and reliability (which could be attributed to better heating conditions in the ovens and to better lighting), increased productivity (due to lower heating time of the ovens), and improved workplace comfort and safety conditions (due to oven and pipe insulation). Obviously, improved comfort leads to employee's higher productivity and loyalty. Moreover, enhanced safety work conditions reduce the risk of accidents, which in turn leads to a reduction in insurance premiums [66].

Cupcakes of Westdale Village in Canada is another very small company that looked for ways to increase its energy efficiency and reduce the operating costs through the improvement of its lighting equipment. The shop took advantage of a government program and upgraded its lighting equipment. Improved lighting conditions did not only result in an annual saving of almost CAD 400 in the shop's electricity bill, but it also made its products more attractive to customers [67].

6.3. Metal Manufacturing Industry Sector

In the steel rerolling subsector in India, the adoption of new technologies led to significant energy costs savings. Coal demand was reduced by almost 30 kg per ton of product. Moreover, the new technologies introduced helped to improve the overall productivity of relevant processes through the reduction in metal losses because of scaling and oxidation. This case of the Indian SME steel rerolling subsector indicates the significance of non-energy benefits achieved by the adoption of energy-efficient technologies [68].

AMB Alloys Ltd. is a ferroalloys producer and supplier located in the industrial city of Rustavi, Georgia. The company planned a capital-intensive investment in a new production plant. Nevertheless, the company was looking for a relatively short payback period in order to proceed with the investment for the new plant. AMB Alloys took advantage of a technical and financial support program. The company analyzed the expected energy and cost savings, as well as the technoeconomic aspects and the associated risks of the investment. The proposal was for an EUR 842,000 investment that could lead to a reduction in its energy requirements by about 4.3 MWh per year, which is equivalent to an annual saving of EUR 220,000. Thus, the repay period of the investment through just the associated reduction in energy consumption is almost four years, a time period which is acceptable and meets the company's targets. The new facility will also have lower CO_2 emissions, namely 1.7 tons per year lower [27].

6.4. Construction Sector

Lagodekhautogza Ltd. is a Georgian construction company which specializes in road construction and the production of asphalt concrete and cement concrete. The company had to increase its asphalt concrete production capabilities in 2020. However, the available production machinery was quite old and could not provide the required production volume. The company was also looking to find a way to decrease its manufacturing cost. The company received a free-of-charge technical assessment for the project through a government-administered technical and financial support program and made an investment of EUR 254,000, which was directed to the upgrade of its outdated machinery. The new equipment, with the higher production capabilities, was more energy efficient. The volume of production was increased by 55%. An annual energy saving of 160 MWh (equivalent to EUR 10,000) was also achieved [27].

"Mshenebeli 2019", an asphalt-producing company located in Khashuri, Georgia, implemented measures to improve energy efficiency. A solid-fuel heat generator, prepared by the Technical University of Georgia, replaced the existing natural gas burner of a rotating furnace. The nominal capacity of the natural gas burner was 3000 kW. The new heat generator uses agricultural waste—grape cake—as a (solid) fuel. The operation of the heat generator requires 600 kg of grape cake/h, which is equivalent to 300 m^3/h of natural gas. The objective of the company is to be able to substitute the natural gas burner (requiring 480,000 m^3 of natural gas/year) with the solid biomass-fueled heat generator. Grape cake is the waste product of wine making and is currently quite happily provided by the wineries free of charge. The only cost associated with the grape cake, therefore, refers to the cost of transporting the grape cake from the wineries to the asphalt production site. The annual expenditure for the transportation of biomass fuel to the production site is about USD 33,600, while the annual expenditure of the natural gas consumed in the gas burner is about USD 160,000. The installation of the proposed heat generator, which uses renewable biomass as a fuel instead of imported natural gas, results in an annual saving of USD 126,400. The difficulties that arose during the COVID-19 pandemic, especially the ones related to the increased tariffs for energy carriers, highlight the importance of implementing the specific project. Apart from the economic savings to be achieved, one has also to take into account various other aspects, such as jobs preservation and the enhanced competitiveness and image of the company in the market of construction materials [27].

6.5. Miscellaneous Sectors

A company in Denmark dealing with the production of liquid gases decided to carry out a project aiming at reducing its energy consumption. A technology combining an ozone unit and a sand filter was implemented, allowing the company to decrease the temperature of the required cooling water. As a result, the company achieved a reduction in energy consumption of 153 MWh/year, which is equivalent to an annual saving of USD 12,000. The implemented energy efficiency improvements led to additional benefits. In particular, there was a reduction in the amount of required process chemicals and the need for corrosion inhibitors and corrosion damage, implying additional annual cost savings of USD 50,000, USD 12,000, and USD 20,000, respectively. The company also reported further (non-energy-related) benefits, such as lower labor cost, less down time, lower negative environmental impacts, and enhanced working environment [31].

Firozabad, a cluster of SMEs of the glass sector in India, implemented a simple waste heat recovery system exploiting the high furnace and exhaust gas temperatures that characterize glass manufacturing processes. Almost all the cluster units have installed a counterflow metallic recuperator made up of five stainless steel modules, which could result in an annual energy saving of 25–30%, corresponding to a payback period of six months [68].

Druckerei Senser, a printing company in Germany, achieved a 30% reduction in its power consumption by installing specifically designed energy-saving printing machines. In addition, it installed a new solar power system, which produces almost 25% of its own electricity requirements. The roof of the entire production area was insulated before the installation of the solar power system in order to minimize heat losses. The company also decided to implement a system to extract the machines' waste heat generated during printing and to use it as a heating source for neighboring rooms. The implementation of these measures, and in particular the waste heat recovery, resulted in a reduction in heating energy requirements on the order of 20% [69].

Reunion Island Coffee Roasters, a company located in Oakville, Canada, looked for ways to make its roastery, shipping, and distribution facility more energy efficient. In late 2015, the company updated the lighting in the plant, which was taking up to almost half an hour to reach full brightness, with new energy-efficient LED lighting panels. Additionally, the company installed six motion-activated occupancy sensors which control the operation of the lighting system. Lights are turned on in the different areas of the facility only when the employees are working or passing through the corresponding plant sections. Thus, the number of hours the lights are on is reduced, leading to substantial energy savings. It is noteworthy that the electricity cost associated with lighting was reduced by almost 25%. The company also installed five smart thermostats in order to manage the indoor facility temperature in a more efficient way, i.e., to maintain a lower heating level when there is no one working in the building. Reunion Island also applied simpler solutions, such as the use of reflective tint to the windows of working spaces, allowing the company to reduce its air conditioning requirements, especially during warmer months. The company also upgraded the coffee roasting procedure itself by investing in an energy-efficient roasting machine for all its whole-bean specialty coffee. This machine operates with 80% less energy than larger machines [70].

For the sake of clarity, these case studies are summarized in Table 4.

Table 4. Summary of selected SME case studies.

Sector	Case Study	Implemented Measures	Savings
Chemical industry	SATECMA plant [60]	• Implementation of more efficient climate control systems • LED lamps and better exploitation of natural light strategies were adopted • Implementation of PV solar energy generation plant	20% in total energy
	Chemical plant in UK [13]	Elimination of leakages associated with the supply of gas in boilers	30% in total energy
	Wacker Chemie AG plant [61]	• Adoption of waste heat recovery strategies • Installation of CHP systems • Connection of surplus heat sources to heat sinks via local heating networks	421 GWh/year in steam processes 44 GWh/year in facility heating and hot water preparation
Food and beverage industry	World-leading producer of Scotland's national dish haggis [13]	• Implementation of more efficient cooking methods • Staff training • Installation of technologies to recover waste heat from refrigerators • Improved control of heating, cooling, and lighting was adopted • Replacement of lighting systems with more energy-efficient ones	15% in gas bills in 2006–2008
	Brewery in Aying, Germany [62]	• Installation of CHP system; 200 kW electrical capacity and 230 kW thermal output • "In-house" generated electricity resulted in electric energy savings; electricity is also supplied to public power grid	20% in electricity 100 tons/year in CO_2 emissions
	"Krones A" brewery [63]	Innovative "EquiTherm" process was developed; energy used for heating and cooling purposes was reduced via waste heat recovery, as well as freshwater	20% in electricity 30% in thermal energy
	Rager bakery [64]	• Optimization of baking processes and oven utilization • Reduced utilization of refrigerators and insulation improvement of cold rooms • Waste heat recovery from refrigeration system for hot water preparation • Adoption of LED lighting technology • Reduction in dishwasher's short program duration • Employment of a hybrid transportation vehicle	2.5 k EUR/year

Table 4. *Cont.*

Sector	Case Study	Implemented Measures	Savings
	Bakery in Germany [65,66]	• Inclusion of frequent maintenance of bake ovens • Introduction of LED lighting • Enhancement of hot water utilization • Improvement of pipe insulation and process thermostat recalibration	
	Cupcakes of Westdale Village company [67]	Improvement of lighting equipment	USD 400/year in electricity bills
Metal manufacturing industry	AMB Alloys Ltd. [27]	Energy efficiency improvements included a completely new production plant	4.3 MWh/year in total energy 1.7 CO_2 tons/year
Construction	Lagodekhautogza Ltd. [27]	This cement producing company upgraded old machinery to the most recent one Volume of production was increased by 55%	160 MWh/year in total energy
	"Mshenebeli 2019" [27]	This asphalt producing company substituted a natural-gas-based heat generator with a biomass-based solid-fuel heat generator	USD 126,400/year in fuel bills
Miscellaneous sectors	Liquid gases company in Denmark [31]	Implementation of a technology combining an ozone unit and a sand filter which can reduce the temperature of the required cooling water	153 MWh/year in total energy 50, 12, 20 k USD/year in process chemicals, corrosion inhibitors, and corrosion, respectively
	Firozabad heat recovery system [68]	It is a cluster of SMEs of the glass sector in India which implemented a simple waste heat recovery system	25–30% in total energy
	Druckerei Senser [69]	• Installation of new printing machines • Installation of a new solar power system • Application of roof thermal insulation • Waste heat recovery from printing process to neighboring rooms	30% in total power 25% in total electricity 20% in heating
	Reunion Island Coffee Roasters company [70]	• Installation of new LED lightning panels and six motion-activated room occupancy sensors which control the lighting system • Installation of five thermostats to manage indoor facility temperature • Use of reflective tint on windows to reduce air conditioning requirements • Installation of a new energy-efficient coffee roasting machine	25% in electricity bills

7. Best Practices for Energy Efficiency Improvement

It is estimated that the average SME could reduce its energy bills by 18–25% by adopting energy efficiency improvement measures, with an average payback period of less than 1.5 years. It is also estimated that 40% of these savings do not require any capital investment [29]. This section presents some best practices and guidelines for SMEs' energy efficiency improvement, which are based on the aforementioned case studies and the available technical literature. The proposed measures might be simple and cheap (or even free-of-charge) or more complex and costlier. They could refer to different sections or aspects of the enterprise operation. It is needless to emphasize that the adoption of simple measures towards more efficient energy footprint management, as well as the actual involvement of the enterprise employees themselves in the corresponding actions, contributes to their awareness regarding energy savings, which is of outmost importance.

7.1. Awareness of Energy Savings and Energy Efficiency Improvements

Increased awareness regarding energy efficiency, energy savings potential, and their corresponding benefits can be a key driver for the successful implementation of energy management techniques in SMEs. The appropriate training of SMEs' employees would promote their awareness on these matters and the creation of an energy efficiency and/or energy-saving culture within the organization. Developing such a culture is a decisive factor for the inclusive adoption of energy efficiency policies from SMEs [71,72].

7.2. Measures Related to Operational Processes and Maintenance

There are various simple measures related to operational and maintenance activities that can be implemented within SMEs to improve their energy efficiency [31,73]:

- Maintenance activities should be carried out by specialized and experienced technical staff. There should be sufficient time to complete the relevant maintenance work according to relevant quality standards. Following a maintenance routine and a mid-term schedule is of outmost importance. In the case of replacement activities, the spare parts to be used should be the most modern and efficient ones.
- In the case of recurring plant failures, it should be ensured that the root causes are identified. For this purpose, experiments and tests should be conducted, and everyone must contribute to uncover them. It is very important to ensure that any root cause should be addressed effectively without causing another failure elsewhere in the facility.
- During the installation of new equipment or machinery, it must be ensured that all the relevant parts and components are installed properly following the guidelines of the manual(s) provided by the manufacturer. Additionally, the actual installation should be reviewed carefully before handover in order to ensure that it is as per design.
- Regarding equipment size, it should be ensured that equipment specifications meet the operational requirements and match the actual demand without excess capacity.
- Regarding equipment operation, it should be verified that the relevant machinery can be turned off easily and safely when it is not being used. Facility and equipment safety rules should be strictly followed. There should be safety valves and appropriate protective devices that "guarantee" the safety of the facility and the installed machinery. The ability to also restart the facility's operation at short notice is very important for achieving improved energy efficiency.
- If there is a variety of available machines, one should choose to use the ones that exhibit the highest efficiency. It is evident, therefore, that production managers, supervisors, and/or staff should be aware and have good knowledge of the minimum, normal, and maximum operating conditions of all the available equipment.
- Production processes should be designed in such a way so as to minimize idle time of machinery. Moreover, there should be an effort to stop machines' operation as soon as possible and start them as late as possible. Production processes should be carefully monitored and reviewed, aiming at identifying potential for efficiency improvement.

- It should be ensured that all thermal and electrical insulation is in good condition, minimizing heat losses and eliminating electricity leakages.

7.3. Measures Related to the Thermal Insulation of Buildings

There may be significant energy saving potential for enterprises in the buildings they occupy. The importance of monitoring in the energy management of buildings has already been analyzed. Improving the building fabric via the application of appropriate thermal insulation leads to a reduction in heat losses, thus helping to achieve considerable energy (and operational cost) savings. Such a solution could be sometimes quite costly and labor-intensive. Nevertheless, there are various simple and low-cost measures that can enhance the energy efficiency of existing buildings [31,69]:

- Windows present a common source of heat losses in buildings. For that reason, their frames should be regularly checked and maintained in good condition in order to ensure that they can be closed tightly and are draught-proof. Single-glazed windows should be replaced with double- or, if it is possible, with triple-glazed ones. The application of proper shading systems could also prevent building spaces from overheating.
- Like windows, doors could also be tested in order to ensure that they are draught-proof and can be closed tightly. The replacement of the existing doors with thicker ones and the implementation of self-closing mechanisms could also help to control the temperature of internal spaces consuming less energy.
- Walls and roofs should be regularly checked in order to spot existing gaps or holes which should be repaired/closed by applying appropriate filling materials. Additionally, dedicated audits could be carried out in order to explore the potential of reducing thermal losses through the application of proper thermal insulation.

7.4. Measures Related to the Heating and Cooling of Facilities

Improving and/or modifying HVAC systems could contribute significantly to achieving energy efficiency in office buildings, production plants, and other facilities of SMEs. HVAC systems should be properly regulated in order to not only ensure appropriate comfort and healthy living conditions for the staff of the organization but also to minimize its energy consumption. The main parameters that should be monitored and controlled are humidity, temperature, and air quality. Some simple and practical measures that ensure good and efficient operating conditions of HVAC systems include the following [29,31]:

- Appropriate control systems that regulate room temperature should be employed. Office temperature, for instance, during winter months (heating operation) is recommended to be set to 19 °C. Obviously, it could be set lower than 19 °C in corridors, storerooms, and areas of higher physical activity. In the summer (cooling operation), the corresponding air temperature is recommended not be lower than 24 °C. Regarding cooling temperatures, there is an empirical rule according to which an increase in the set cooling air temperature by 1 °C will result in an increase in energy consumption on the order of 3% by the chiller.
- Cooling systems release/reject heat to the environment, namely to ambient air. It is evident, therefore, that in order for cooling systems to operate efficiently, they should have good and unobstructed access to ambient air. Thus, the positioning of cooling units with respect to existing furniture, equipment, and/or machinery is very important. Space restrictions and/or poor engineering judgment might result in positioning cooling units close to hot air exhausts or in a way that they have restricted ambient air flow, inevitably lowering the overall efficiency of the system. Facility space arrangement should cater to cooling systems to have unobstructed access to the coolest possible ambient air.

7.5. Measures Related to the Lighting of Facilities

Simple measures, techniques, and technologies could be applied in order to reduce the energy consumed by lighting systems. The most common and efficient measures are presented and discussed below [29,31,74]:

- There are sensors and automatic devices that can identify human presence in a room/space of a building or a facility. Such devices could be deployed to turn on the lights of the corresponding room/space only when the room/space is occupied.
- There are standards and norms that specify the lighting level in a room/space according to the activity that is being carried out in the room/space. In order to achieve energy savings, overlamping should be avoided.
- All incandescent lightbulbs should be replaced by more energy-efficient LED lighting in order to save energy.
- It is often highlighted that company spaces do not exploit natural lighting to its full potential. Designing spaces in such a way so as to use natural light from windows and/or skylights at its maximum has almost no cost, mitigating at the same time electricity demand for artificial lighting. This is why objects that block windows, e.g., filing cabinets, should be relocated, while the space arrangement should always aim at maximizing the use of natural light, e.g., working desks should be positioned near windows.

7.6. Optimal Water Chemistry as a Measure for Energy Efficiency Improvement

Improving water quality in industrial SMEs is very important. Water in liquid state or in its gaseous state, i.e., steam, is commonly employed to carry and transfer heat within a plant, equipment, thermal devices, etc. Water is not pure; it contains various elements such as mineral salts, dissolved organic matter, and microbiological organisms. Although the quantities of these elements in water are minute, they adversely affect water properties and the operational efficiency of thermal equipment and devices of a production plant. It is imperative, therefore, to control and monitor water quality closely. Including regular water testing in maintenance schedules of SMEs could ensure improved quality of feed water into boilers and a reduction in energy consumption, as well as in water purchase and treatment bills [31,75].

7.7. Measures Related to Process Design and Energy Supply

Various simple and affordable measures/actions to achieve energy savings have already been presented. Nevertheless, the highest energy efficiency improvements could be achieved through extensive changes related to process design and/or energy supply. Compared with simpler measures, extensive changes are always associated with high (investment) cost and the corresponding high business/financial risk. Such changes might include the implementation of appropriate CHP plants, the redesign of production lines and/or procedures, the application of sophisticated prediction, simulation, and control techniques, and the connection of the facility to the local heating or cooling network to channel waste energy or heat [76,77].

7.8. Renewable Sources and Energy Storage

SMEs have a high potential for the installation of on-site rooftop solar PV systems. Both for the manufacturing and services sectors, as much of the relevant processes are electrified, it is expected that their energy load demand could be matched with periods of high solar generation. Solar water heating could also be adopted as an alternative for heating or preheating. This allows water to be heated well above 80 °C. Additionally, onsite battery storage might also be worth considering as battery prices decline. Batteries enable not only a greater on-site exploitation of solar PV systems throughout the day, but they also provide a backup option in the event of grid failure. For the food and beverage sector in particular, energy could also be stored thermally in water, phase-changing materials, or in the bulk mass of food products in refrigeration [78–80].

7.9. Combined Heat and Power (CHP)

Conventional (thermo-electric) power generation technologies exhibit relatively low fuel-to-power efficiencies, simply because considerable amounts of high-temperature heat are lost to the environment through the stack. This is the reason why common conventional (thermal) engines exhibit energy efficiency rates which do not normally exceed 38–40%. Specifically, energy efficiency rates for reciprocating engines are in the range of 28–38%. Energy efficiency rates of small gas turbines (nominal power up to 5 MW) vary between 20% to 25%, while the corresponding efficiency figures for bigger gas turbines (nominal power between 5 MW and 500 MW) are in the range of 25% to 35%. Modern gas turbine power plants with a nominal power higher than 500 MW might reach efficiency rates close to 50%. CHP technology captures and utilizes the thermal energy (heat) which is released (lost) to the environment. The captured thermal energy can be used to produce steam, which in turn can drive a steam turbine to generate electricity. At a smaller scale, CHP systems, industrial gas turbines, or reciprocating engines fueled by gas or oil are employed. Apart from electricity generation, the captured heat can be used in other thermal processes, such as steam generation or water heating. Typically, the overall efficiency of CHP plants is much higher than the one exhibited by conventional power plants, namely on the order of 75–85% [31]. However, the overall CHP efficiency of small-scale CHP systems, which are typically installed in SMEs, varies between 62–75% [81].

7.10. Heat Recovery

It is estimated that waste heat represents about 20–50% of the overall industrial energy consumption. This is because waste heat can be generated in several forms within an industrial SME, e.g., as hot exhaust gases, cooling water, or heat loss from equipment surfaces and heated components. All thermal industrial processes may reduce their heat demand by utilizing part of these heat losses, appropriately termed as recovered (waste) heat, by employing heat (recovery) exchangers. The captured heat is commonly used to preheat the inputs to heat chambers, reducing the overall energy demand of the relevant process. Recovered heat may be used by a neighboring industrial facility. Currently, there are various heat recovery technologies available that can be implemented in industrial plants. In order for this technological option to be successful, there should be an easily accessible source of waste heat and a relevant industrial or commercial heat demand to be satisfied, as well as the appropriate recovery technology. SMEs that intend to implement waste heat recovery technologies should carry out special audits by appropriate staff and/or advisors in order to determine the requirements of their industrial facility and evaluate the technoeconomic feasibility of this solution [31,82].

7.11. Waste Heat to Power

The temperatures involved in production processes of certain industrial sectors might be above 1000 °C. Typical examples of such industrial sectors are steel and cement industries. Their corresponding waste heat generated is associated with temperatures reaching 750 °C. In some other processes, such as CHP plants and boilers, waste heat might be available at considerably lower temperatures, ranging between 160 °C and 180 °C. The generated waste heat can be converted to power, following the approach that is commonly known as Waste Heat to Power (WHP) technology. Different WHP technologies can be implemented depending on the temperature of the available waste heat. Waste heat available at high temperatures, for instance, is appropriate for the preparation of steam, which may be used for electricity generation employing a steam turbine. On the other hand, waste heat available at relatively lower temperatures may also be used to generate electricity with a technology quite similar to the one of steam turbines. In this latter case, however, the working fluids to be used should have a boiling point much lower than that of water. It is evident, therefore, that industrial SMEs that generate high-temperature waste heat should certainly investigate WHP options in their effort to enhance their energy efficiency and reduce their energy footprint [31,83,84].

For the sake of clarity, the best practices for energy efficiency improvement discussed in this section are summarized and presented concisely in Table 5.

Table 5. Characterization of best practices for SME's.

Category	Characterization	Ref.
Awareness of energy efficiency improvement potential and opportunities	Measures related to the appropriate training of SMEs' employees in order to promote their awareness of these matters and to create an energy efficiency and/or energy-saving culture within the organization	[71,72]
Measures related to operational processes and maintenance	• Maintenance activities should be carried out by specialized staff • Root causes of failure should be identified and appropriately rectified to avoid recurrence • Handling and assembling of equipment as per design following manufacturer's guidelines • Specifications and operational requirements should be met during the equipment sizing phase • Availability of control equipment, e.g., safety valves for automatic activation/shutdown, etc. • Selecting machinery exhibiting the highest energy efficiency potential • Planning of production processes aiming at minimum machinery idle time • Applying appropriate thermal and electric insulation	[31,73]
Buildings' energy efficiency measures	**Thermal-insulation-related** • Windows: check window frames regularly and maintain them in good condition, replace single-glazed windows with double- or triple-glazed ones, and apply proper shading systems • Doors: replace existing doors with thicker ones and implement self-closing mechanisms • Walls and roofs: check for existing gaps or holes and apply appropriate filling materials **HVAC Systems-related** • Implementation of automatic devices that regulate room temperature; potential for 3% energy use reduction in chillers • Specific facility space arrangement that allows for the most efficient placement of cooling systems; cooling units should be placed far away from heat sources and have unobstructed access to ambient fresh air **Lightning-systems-related** • Installation of sensors/automatic devices that identify human presence in a room • Overlamping should be avoided • Replacement of incandescent lightbulbs with more energy-efficient LED lighting • Specific design of facility spaces that caters to more effective exploitation of natural lighting	[29,31,69,74]
Measures related to process design and energy supply	• Implementation of appropriate CHP units/plants • Redesign of production lines and/or procedures • Application and integration of sophisticated prediction, simulation, and control techniques • Connection of existing facilities to local district heating or cooling networks	[76,77]

Table 5. *Cont.*

Category	Characterization	Ref.
Renewable energy and energy storage	• Installation of on-site rooftop PV systems (for the case of electricity-intensive sectors) • Installation of solar heating systems (presenting a convenient alternative heat source for heating or preheating units) • Installation of on-site battery storage (to store electricity generated via PV systems) • Installation of thermal energy storage systems (such as units containing a phase-changing material)	[78–80]
Combined heat and power (CHP)	• Appropriate technology to capture thermal energy lost to the environment through the stack, and use it to produce steam, which in turn could drive a steam turbine to generate electricity • Captured heat might be used for steam generation and/or water heating thermal processes • Small-scale CHP systems installed in SMEs are associated with 62% –75% efficiencies	[81]
Heat recovery	The aim of implementing heat recovery measures is to reduce the amount of fuel or thermal energy utilized; prerequisites for the implementation of these measures: • Waste heat sources (such as hot exhaust gases, hot water or heat loss from equipment and heated components) • Heat demands (combustion-based processes in the actual or a neighboring plant) • Appropriate technologies (such as heat exchangers)	[31,82]
Waste heat to power	It is a subset of heat-recovery-related measures set to be implemented to generated electricity, namely: • High-temperature waste heat is used to prepare steam which could drive a steam turbine to generate electricity • Relatively lower temperature waste heat could be used to generate electricity with a technology quite similar to the one of steam turbines, employing working fluids with a boiling point much lower than that of water	[31,83,84]
Measures related to water quality	Water, which is the most common working fluid in thermal processes equipment such as boilers, heat exchangers, etc., contains impurities, mineral salts, dissolved organic matter, and microbiological organisms that adversely affect the operational efficiency of equipment. Water quality should be closely monitored and controlled in order to achieve equipment operation with low energy consumption.	[31,75]

8. Conclusions

SMEs represent around 99% of all businesses worldwide and contribute approximately 13% of the global final energy consumption, indicating that their contribution to the energy efficiency improvement targets of the EU is crucial. The present review work, which was carried out in the context of the "SMEnergy—Energy Footprint Management for SMEs" EU-funded Erasmus+ project, reveals that energy efficiency is not a high priority for SMEs. This may be attributed to the high investment costs implied, lack of profitability, lack of awareness, and lack of time and resources. The concise literature review presented also indicates that there are quite a few case studies of successful implementations of measures towards the enhancement of the energy efficiency of SMEs from different sectors, which implies that the barriers to energy efficiency improvement could very well be overcome. Additionally, there are several measures related to heating, cooling, lighting, production equipment, and processes that could be implemented to reduce the energy footprint of businesses. Many of these measures are simple, require zero or low capital cost, and might result in other benefits, such as business staff satisfaction, productivity increase, and companies' public image improvement. Nevertheless, there are step changes related to processes design and energy supply that could be implemented, resulting in significant energy and carbon footprint reduction. The latter changes require considerable investments from SMEs, but they have relatively small payback periods due to considerable relevant energy and cost savings. It is evident, therefore, that there is a high potential for improving the energy utilization performance of SMEs, directly contributing to climate change mitigation and sustainable development.

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