Interreg Programme
Danube Region

Co-funded by the European Union

DANUBE REGION strategy Energy

Energy Efficiency in Industry of the States in the Danube Region

Final version

MINISTRY OF INDUSTRY AND TRADE

GATUM

This study was supported as part of DRP-PAC-PA2 an Interreg Programme project co-funded by the European Union. The content of this study reflects the opinion of their authors and does not in any way represent opinions of the European Union.

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Table of Content

Executive Summary

This study explores industrial energy efficiency within the framework of the EU Strategy for the Danube Region (hereinafter also “EUSDR”). The EUSDR, the EU's second macro-regional strategy, was adopted by the European Commission in 2010. Its purpose is to establish a basis for cooperation in priority areas affecting all participating countries and regions, **aligning policies, sharing best practices, and identifying opportunities for international collaboration**.

Priority Area 2 of the EUSDR: Sustainable Energy (hereinafter also “PA2”) focuses on coordinating regional energy policies across various topics, integrating the energy markets of non-EU countries, and driving the development of advanced technologies to enhance energy efficiency in the region. Over the years, numerous studies have addressed diverse topics, with this one adding a high-level perspective on industrial energy efficiency. **Industry accounts for over 27% of all final energy consumption** (Eurostat, 2021) in the countries of the Danube Region (hereinafter also “DR”), making it a key component of decarbonisation and energy efficiency initiatives alongside transport, households, services, and other sectors.

The analytical part of the study (Chapter 1) highlights the DR's socio-economic diversity, which is even more pronounced in terms of industrial organisation. While industry is a major contributor to GDP in countries such as Austria, Czechia, Hungary, and Slovakia, it plays a smaller role in others like Moldova and certain regions of Bulgaria and Ukraine. In absolute terms, smaller DR countries in the east generally have limited industrial bases compared to north-western countries. Thus, the **main drivers of industrial energy efficiency will naturally be those countries and regions with large industrial sectors** capable of significantly impacting the DR's overall energy intensity.

Chapter 2 examines the energy intensity of specific sectors within each country, highlighting further the diverse industrial bases across the DR. Interestingly, it identifies energy-intensive industries which are common across several countries, such as the chemical and petrochemical sectors in Germany, Hungary, Romania, and Bulgaria, and the food and tobacco sectors in Hungary, Serbia, Croatia, and Montenegro. These sectors represent **potential areas for international cooperation** among major stakeholders and associations to address shared challenges.

The data presented in Chapter 2 also indicate that **greater use of renewable energy sources** (hereinafter also “RES”) **in industry remains largely untapped**, with all countries except Austria showing less than 10% RES use. Notably, while Germany produces a large share of energy from RES, less than 5% is consumed by industry, with most used in other sectors, such as households. Moreover, a significant portion of this energy is lost during transformation, indicating an area for further exploration. Efficient use of RES in industry therefore represents an important development area within the DR.

Chapter 3 assesses the implications and current state of the transposition of various provisions of the EU’s Energy Efficiency Directive (hereinafter also “EED”), based on information from national energy experts across the DR. Once again, **significant heterogeneity emerges in the successful implementation of tools such as energy audits, voluntary industry agreements, and diverse programmes funded from public sources**. Among the factors contributing to these disparities, the general motivation of companies themselves to proactively reduce energy intensity stands out. Therefore, the success of instruments adopted by local governments depends on the industry’s engagement and its sense of inclusion in creating policies and guidelines for energy efficiency. This is clearly demonstrated by the progress of highly motivated companies in Austria and Bavaria, which exhibit strong commitments to protecting natural resources. Strengthening institutional support and trust will be crucial in DR countries facing challenges with the effectiveness of energy audits and in encouraging companies to adopt innovative technologies for enhanced energy efficiency.

Chapter 3 also **highlights the underdeveloped enablers for wider adoption of, not only, AI-powered innovative technologies**, particularly modernised energy networks (Smart Grids), which are essential prerequisites. Thus, the potential for implementing further industrial measures in the DR will increase significantly as networks are modernised in the coming years. Sharing best practice projects will prove even more beneficial, with successful examples of Smart Grid-enabled technologies identified in Baden-Württemberg's food and metal manufacturing industries.

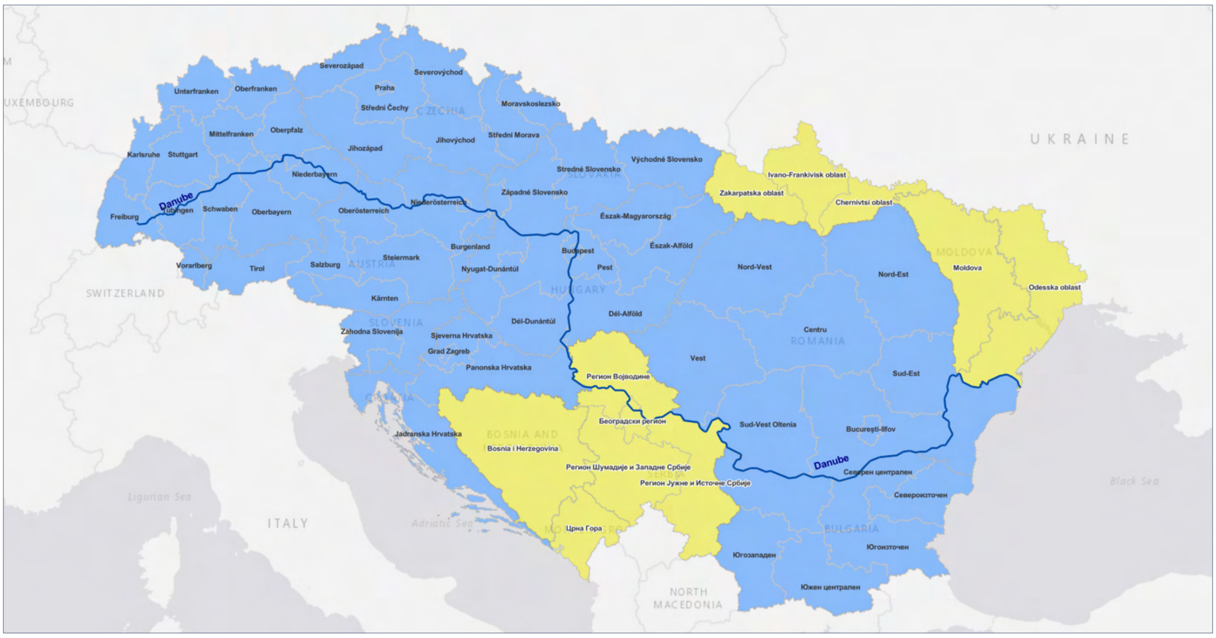
This study reinforces the importance of industrial energy efficiency in reducing the energy intensity of European economies and shows that much progress can still be made. The EU's current legislative framework is beginning to place indirect obligations on Small and Medium-sized Enterprises (hereinafter also "SMEs"), notably through the Corporate Sustainability Reporting Directive (hereinafter also "CSRD"), which will require comprehensive audits and monitoring of supply chains across numerous industrial sectors. As noted in Chapter 4, a balance must be maintained between legislative obligations and what is realistically expected from industry to foster trust between the public and industrial sectors. The potential for EUSDR-enabled cooperation should therefore be maximised by introducing more platforms for sharing best practices and overcoming common challenges in designing national instruments aimed at promoting industrial energy efficiency. The possibility of further linking professional associations should also be explored.

On a technical note, this study draws on multiple sources. Quantitative data were primarily obtained from Eurostat, a trusted source of reliable information, regularly cross-validated with national statistical offices. For non-EU member states, data were often sourced directly from national statistical offices where observations were missing. National energy experts were also consulted on specific topics through questionnaires and a subsequent workshop to gather further insights, which were then supplemented by information from publicly available sources, such as policy briefs, strategies, and other relevant materials. The project team responsible for the study consisted of research staff from the Czech Technical University and the Institute of Regional Development of Charles University, with coordination by Gatum Group, a company specialising in energy and strategy consulting for the public sector.

1. The Danube Region

The Danube is the second-longest river in Europe, stretching over 2,850 km. Flowing through ten countries, it has been a crucial trading route since ancient times. This economic importance led to the development of major cities along its basin, which hosts a variety of industries. **The European Commission defines DR as an area covering 1,083 thousand km^2, spread along 14 countries.** Apart from Germany and Ukraine, all states are part of this macro-region with their entire territory. Altogether, it currently **covers an area of 71 NUTS2 regions**[1].

Map 1 illustrates the DR, highlighting NUTS2 regions within EU member states in blue (Austria, Bulgaria, Croatia, Czechia, Germany, Hungary, Romania, Slovakia, Slovenia) and EU-candidate states in yellow (Bosnia and Herzegovina, Moldova, Montenegro, Serbia, and Ukraine).



__Map 1__: NUTS2 regions within the DR (European Commission, 2022)
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)

[1] In the case of Bosnia and Herzegovina and Moldova, the entire country is considered as one NUTS2 region since there is no final agreement on the division of the countries into Nomenclature of territorial units for statistics (NUTS). The population threshold, which should be considered for statistical division of countries within NUTS regions, Moldova, with its population of 2.5 million, falls within the interval for NUTS2 regions, which recommends a minimum of 800 thousand and a maximum of 3 million inhabitants. Bosnia and Herzegovina, with a population over 3.2 million, is slightly over the standard interval for a NUTS2 region; however, for simplicity, no division of the country was made for the study.

Despite the very diverse history and culture, the nations within this area are currently **sharing several common challenges**, namely:

- **Environmental threats** (water pollution, floods, climate change)
- **Untapped shipping potential** and lack of modern road and rail transport connections
- **Insufficient energy connections**
- **Uneven socio-economic development**
- **Uncoordinated education, research, and innovation systems**
- **Shortcomings in safety and security.**

As a result, the common challenges faced by these regions led to the formation of the **EUSDR,** which was launched in 2011 as an initiative to **promote economic development, environmental protection, and social cohesion in the DR**. The Strategy aimed to address the diverse challenges facing the countries along the Danube River, including environmental degradation, economic disparities, and social exclusion, by fostering cooperation and collaboration among EU member states and neighbouring countries.

1.1 Geography and Climate

A mix of plains, hills, and mountains characterizes the geography of the DR. The Danube River flows through or along the borders of ten countries (see Map 1 in the previous chapter), **traversing a diverse landscape**. It starts in the Black Forest in Germany, passes through the fertile Pannonian Plain in Hungary, and reaches the Danube Delta in Romania, one of the most biodiverse regions in Europe.

The region is also home to other major rivers, such as the Drava, Sava, Tisza, and Morava rivers, which contribute to the region's rich biodiversity and provide important transportation routes and resources for the surrounding communities.

The landscape of the DR also includes various mountain ranges, such as the Carpathian Mountains in Romania and Slovakia, the Balkan Mountains in Bulgaria, and the Austrian Alps in Austria. Besides providing scenic beauty, these mountains also **shaped their region's economies**, which developed different tourism facilities along with traditional industries, attracting people from all over Europe for recreational activities. Similarly, the coastlines of Slovenia, Montenegro, and mainly Croatia along the Adriatic Sea provide the surrounding regions with opportunities within the tourism industry.

Generally, **the region experiences continental, oceanic, and Mediterranean climates**, depending on the location. The **northern and eastern parts** of the DR are **characterized by hot summers and cold winters**, with significant variations in temperature and sunlight between seasons. The **western parts** of the DR are also influenced by the Atlantic Ocean, which results in **milder temperatures and more consistent precipitation throughout the year**.

Mediterranean climate can be observed in **southern parts of the DR**, bringing **more sunlight throughout the year and mild, wet winters**. Lastly, the **Mountain climate** within the macro-region, such as **the Carpathian Mountains or the Alps**, has its own microclimates, with **cooler temperatures and more precipitation**, including snowfall in the winter months.

Altogether, each state within the DR has its geographic and climate characteristics, which significantly impact the formation of settlements and the shaping of economic activities. These **characteristics also provide different levels of opportunities for the transition to energy from renewable resources**.

1.1.1 Natural resources

Mining is generally a crucial sector of the global economy, involving the extraction of valuable minerals, metals, and other geological materials from the Earth. These **resources are essential for manufacturing, construction, and energy production**. However, **each state has different predispositions** for mining, either from the point of view of the type and content of mineral resources occurring on its territory or also from the location of their occurrence. The occurrence of mineral resources on the territory of a given state had mostly **historical effects on the structure of the industrial base of the given country**.

In recent years, also mining was influenced by several challenges such as its negative environmental impact, resource depletion, and regulatory compliance obligations. As the demand for raw materials grows, the mining sector must balance economic benefits with ecological responsibility and social considerations.

Thus, even within **mining, the issue of energy efficiency is addressed**. The industry is undergoing a rebirth, with greater use of previously little-used elements such as rare earth elements, which are key to modern technologies such as smartphones, wind turbines, electric cars, and various electronic devices, or rare metals such as lithium, nickel, manganese or cobalt, which are used for lithium-ion batteries.

Table 1 below presents a comprehensive overview of the significant mineral resources mined in each country within the DR.[2] It connects these resources with the structure of the national industries—illustrating how the presence of certain minerals supports related industrial activities, such as foundries where coal or iron is present, or porcelain production where clay is mined. Furthermore, the table offers a broader perspective on the economic and strategic importance of these materials in the regional context.

***Table 1**: Overview of significant mineral resources mined in each country within the DR*

Overview of significant mineral resources mined in each country within the DR						
Austria	Graphite	Iron	Magnesite	Salt	Tungsten	
Bosnia and Herzegovina	Aluminium	Coal	Iron	Lead	Zinc	
Bulgaria	Coal	Copper	Gold & Silver	Lead	Manganese	Zinc
Croatia	Natural gas	Petroleum	Salt			
Czechia	Coal	Diatomite	Kaolin			
Germany	Coal					
Hungary	Aluminium	Coal	Manganese			
Montenegro	Aluminium	Coal	Lead	Zinc		
Romania	Coal	Copper	Gold & Silver	Manganese	Petroleum	

2 No major source of mineral resources was reported for Moldova and Slovenia. They were therefore not included in the overview presented.

Overview of significant mineral resources mined in each country within the DR						
Serbia	Coal	Copper	Gold & Silver	Lead	Zinc	
Slovakia	Coal	Gold	Magnesite			
Ukraine	Natural gas					

Source: own elaboration based on data from the World mining data of the Austrian Federal Ministry of Finance (2023)

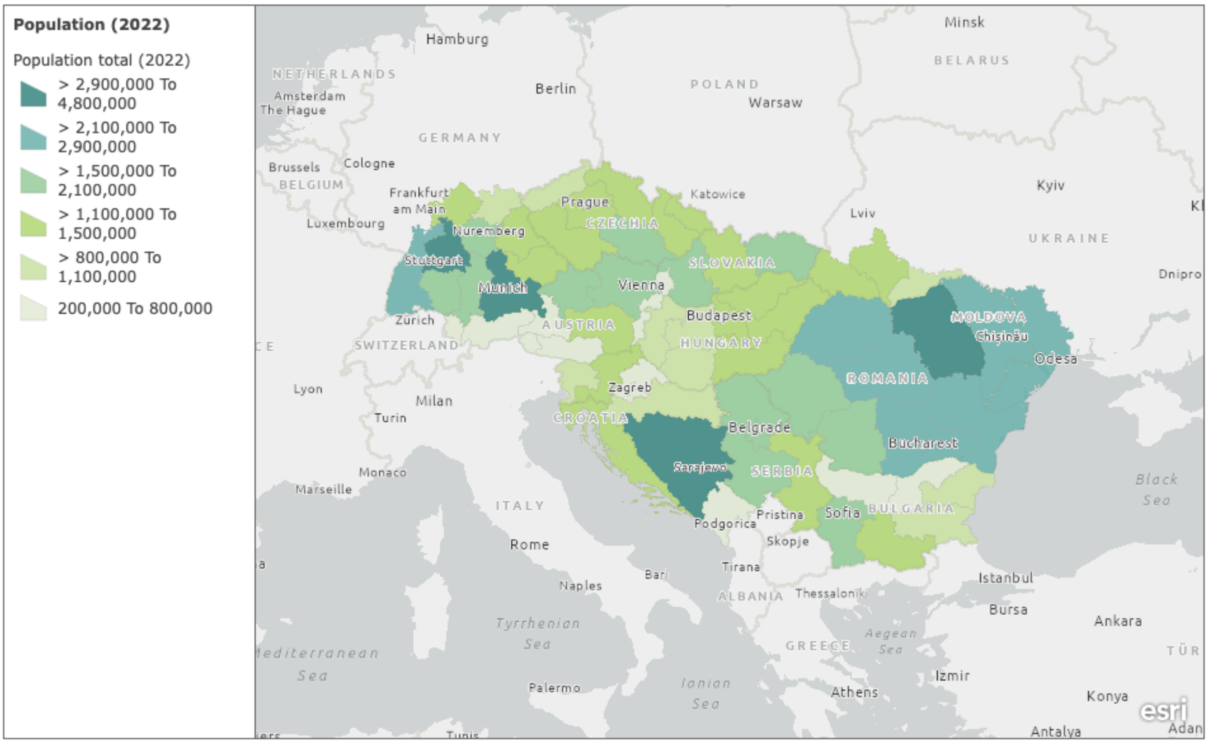
The countries in the DR primarily mine metal ores containing iron, copper, zinc, and lead, as well as rare metals such as gold and silver to a smaller extent, or tungsten from other metals. Additionally, coal extraction is prevalent across most of these nations.

The presence of such diverse mineral resources in the region serves as a strong indicator for the development of heavy industries, particularly in the metallurgical and foundry sectors, as **these industries are closely tied to the mining and processing of coal and metal ores.**

1.2 Population

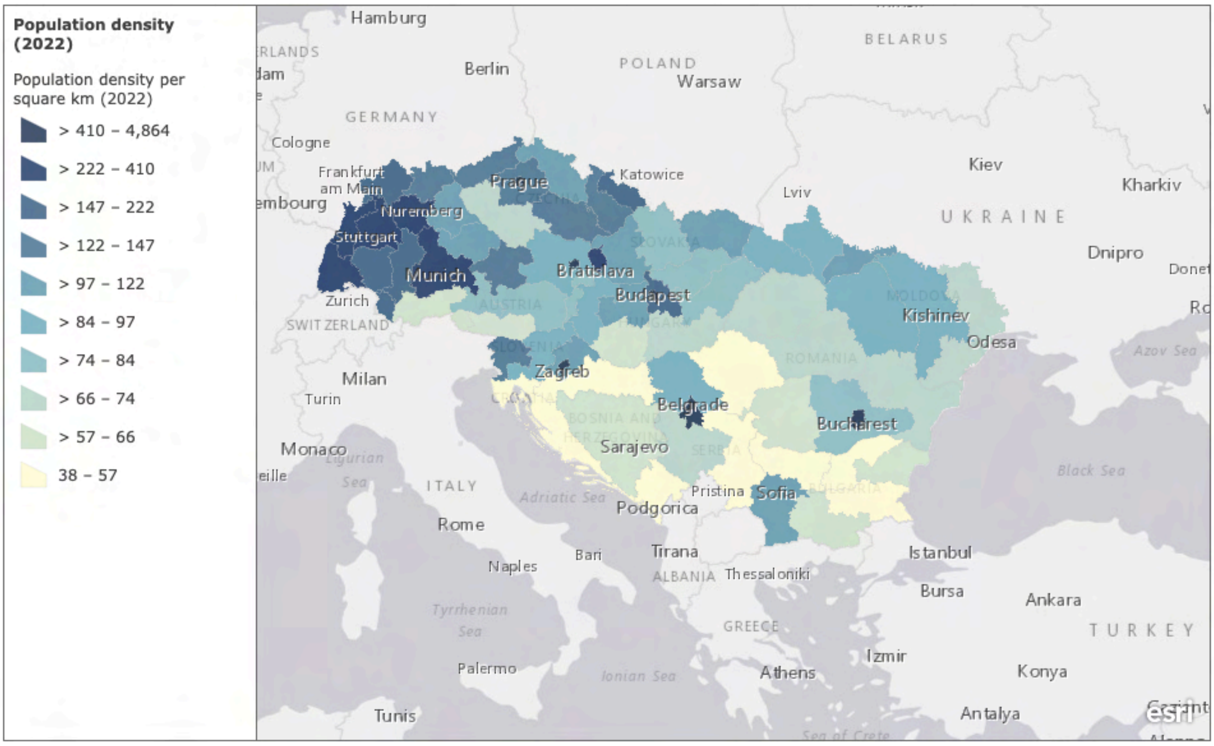
With over **109 million inhabitants** (Eurostat, WorldBank, Derzhstat; 2022), **the DR is home to a large share of the overall population of Europe**. As demonstrated in Map 2, the total population of the regions is diverse, with some surpassing the most populous, having more than 2.9 million inhabitants.

Regions of Stuttgart and Oberbayern are the only two surpassing the threshold of 4 million residents. On the opposite spectrum, 11 regions have less than 800 thousand inhabitants, with Burgenland in Austria being the least populated.



Map 2: *Population range of NUTS2 regions within the DR.*
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)

The population density of the NUTS2 regions (see Map 3) indicates a **significant concentration of people in the capitals of the different countries**, e.g., Vienna, Bratislava, Zagreb, Belgrade, and Bucharest. Above-average population densities can also be observed in the NUTS2 regions of Germany, as well as Austria, Czechia, Slovakia, Slovenia, Northern Hungary, and Croatia, which had generally more favourable socio-economic development in recent decades compared to the southern parts of the DR.



__Map 3:__ Population density in NUTS2 regions of the DR (persons per sq. km, 2022)
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)

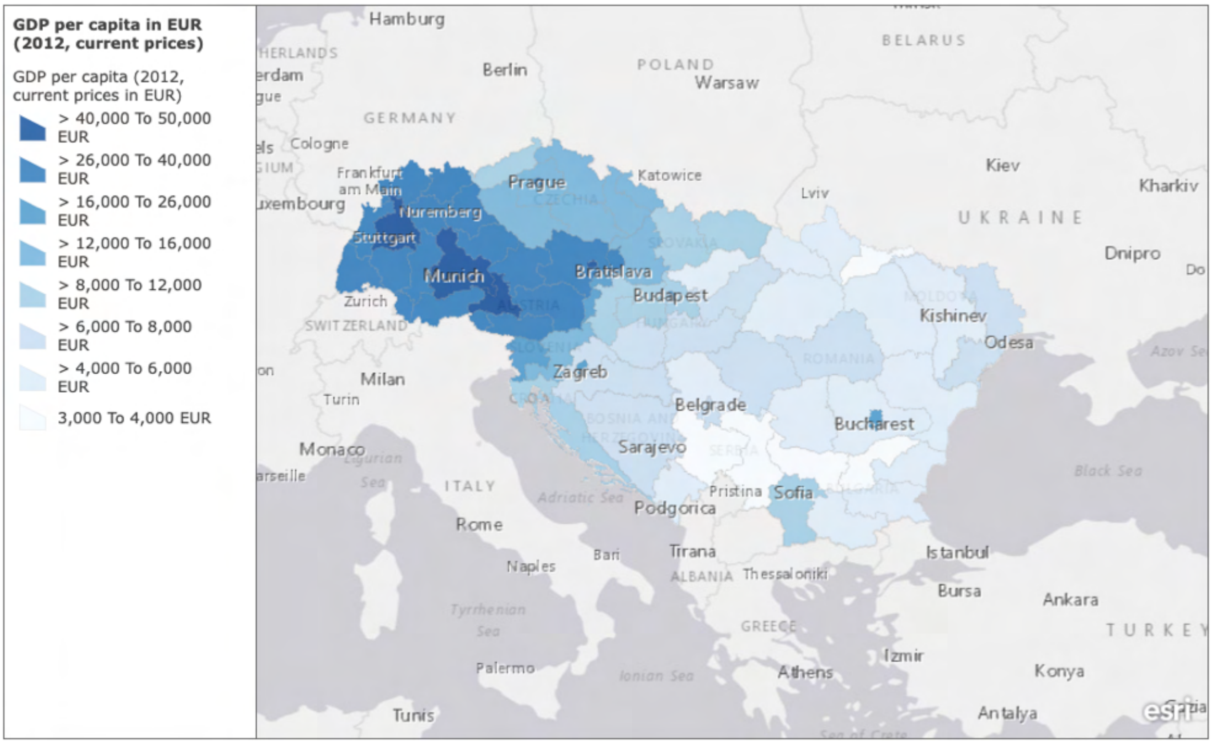
The diverse population distribution naturally impacts overall economic activity, including the distribution of industries. **More urbanised areas are expected to have more human resources needed for industry growth**, which will be analysed in the next sub-chapters. In many countries, the capital city and the surrounding area represent the most industrialized, modern, and socially advanced part of their country, creating significant differences in the living standards of inhabitants of these cities in comparison to those living in remote areas of their country.

1.3 Economic Performance and Activities across the DR

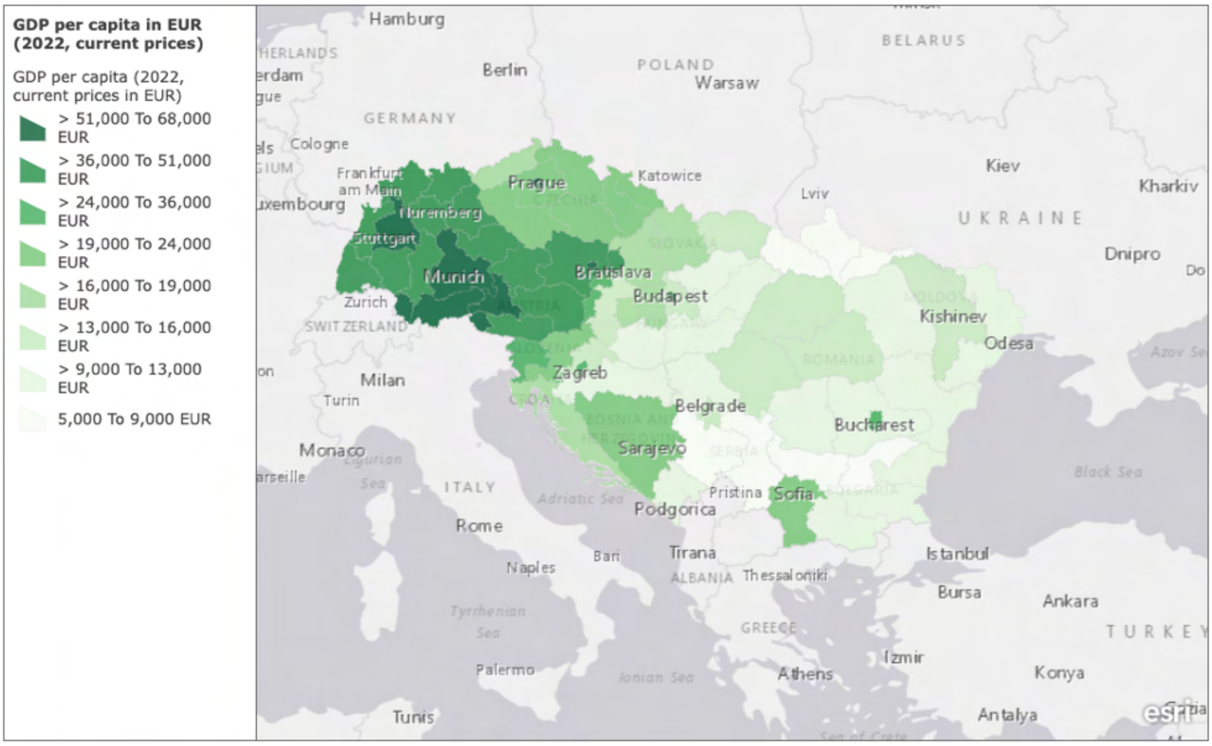
The GDP per capita across the regions of the DR varies significantly, **with western regions having multiple times higher economic output than eastern regions.** The only exceptions in eastern regions are major economic hubs in capital cities.

As shown in Map 4 and Map 5, such regions are Belgrade in Serbia, Sofia in Bulgaria, and Bucharest in Romania. Even though most eastern regions of the Danube area more than doubled their economic output between 2012 and 2022, these had a minimal impact on the overall mitigation of the regional differences.

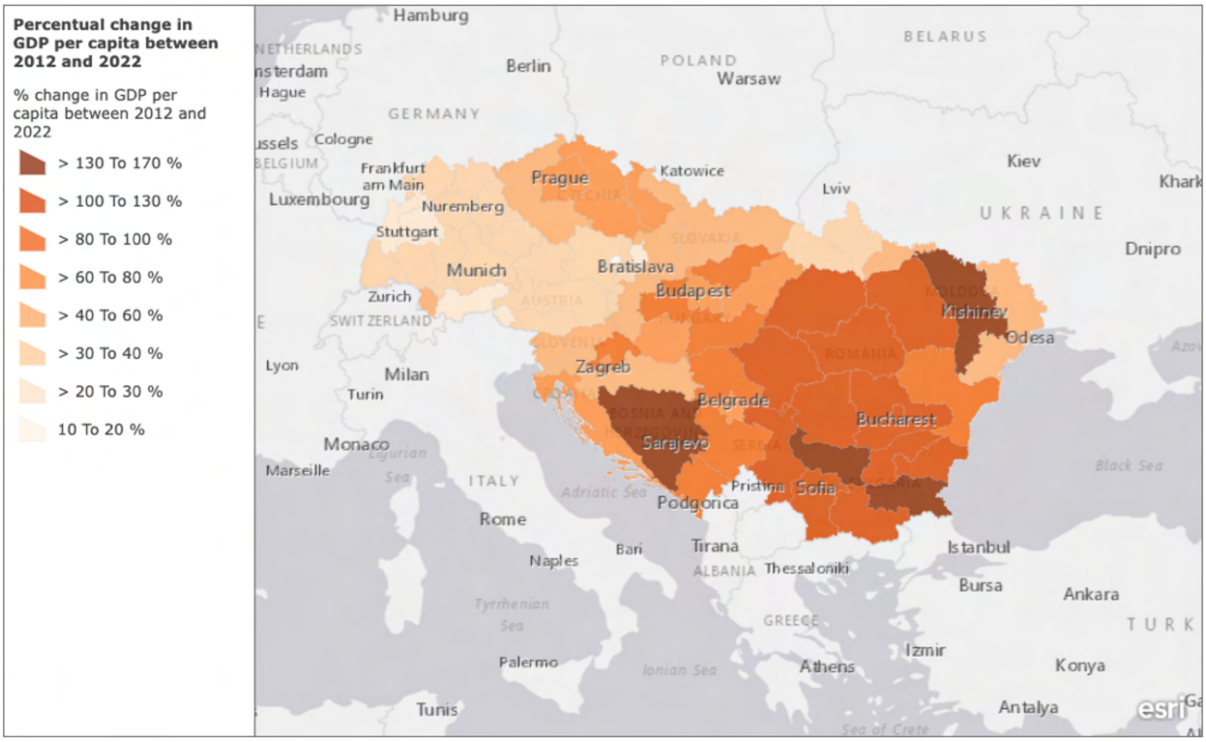
Possible explanations for these economic disparities are different with industrial organization being one of them. The modern organisation of industries in the region was influenced by the different levels of successful transition to a market economy in all post-Soviet countries and subsequent events such as the time of joining the EU or other important trade agreements.



Map 4: *GDP per capita in NUTS2 regions of the DR (2012, current prices)*
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)



Map 5: *GDP per capita in the NUTS2 regions of the DR (2022, current prices)*
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)



Map 6: Percentual change in GDP per capita between 2012 and 2022.
Source: own elaboration based on data from Eurostat, World Bank, and Derzhstat (2022)

1.3.1 The Industrial Organisation in the DR

There are not many parts of the world that have experienced such a **significant economic transformation in recent years as is the case of post-Soviet countries in Europe**. From planned economies, they gradually transitioned to market economies impacting almost all aspects of the organisation and specialisation of their businesses.

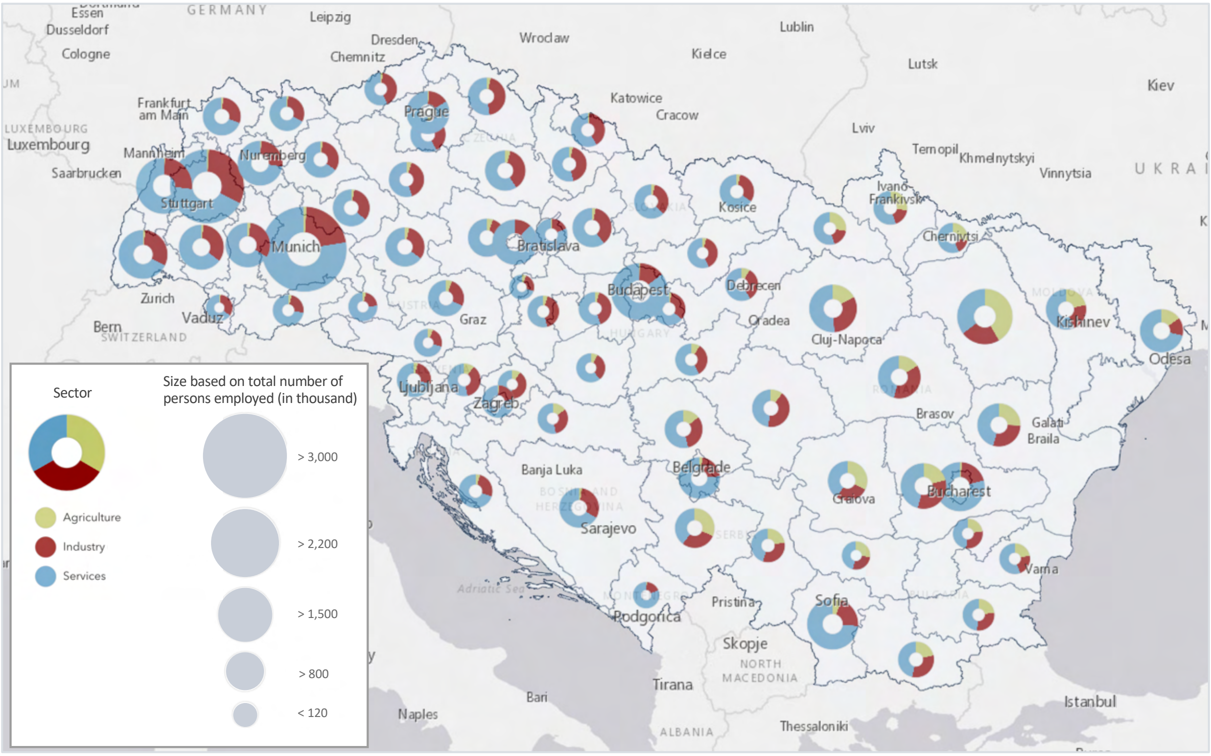
Since 1990s a general shift towards services could be observed all over Europe in highly urbanised areas, while semi-urbanised areas in post-Soviet countries became especially attractive for major foreign industrial companies due to their relatively low labour costs of less-skilled workers (a major example is the current spatial organisation of the automotive industry).

Nevertheless, low labour costs of skilled workers in post-Soviet countries also attracted international corporations, by establishing offices of several international corporations in cities such as Prague and later in Warsaw and Bratislava (e.g., financial, technical or other shared services departments). However, the pre-1990s period should also not be omitted as the way it shaped the industry in most countries is visible up to this date (more details on the topic are provided in Section 2.2).

Map 7 below depicts the distribution of labour force (or economically active population) in three major economic sectors: industry, services and agriculture[3]. The size of the donut charts indicates the absolute number of economically active persons for better comparison.

3 The division is based on employment data as specified by the NACE Rev. 2 methodology of Eurostat. Agriculture represents the NACE sector A, Industry is composed from NACE sectors B to F (incl. construction), and Services aggregate NACE sectors G to U. See Part A in Appendix for a detailed categorisation and list of sectors.

While agriculture employs proportionally only a minor part of economically active population in western regions, it represents an economically important sector especially in most regions of Bulgaria, Romania, Moldova and Ukraine. When it comes to industry, the data suggest that a **large proportion of economically active people work in industries in most regions of Germany, Czechia and Slovakia, with some others also located in Hungary, Romania, Slovenia and Croatia**.



Map 7: Employment structure in NUTS2 regions in 2021
Source: Own elaboration based on data from Eurostat, Derzhstat, Monstat, National Bureau of Statistics of Bosnia and Herzegovina, and Moldova

Figure 1 shows the distribution of employed persons within the five NACE sectors representing industry by country.[4] **In absolute numbers, most persons working in industry are in the selected regions of Germany (Baden-Württemberg and Bayern), followed by Romania and Czechia**.

In the contrary, Montenegro and Moldova - both relatively small non-EU countries - have the lowest number of persons working in the industry. The largest sector by a significant margin is manufacturing, followed by construction. The remaining three sectors employ only a minor proportion of the economically active population. Nevertheless, mining and quarrying appear to be more significant in Romania and Serbia in comparison to other states of the DR.

4 *Based on Eurostat's categorisation, the NACE sectors falling under industry are:* B – Mining and Quarrying, C – Manufacturing, D – Electricity, Gas, Steam, and Air Conditioning Supply, E – Water Supply; Sewage, Waste Management and Remediation Activities and F – Construction.

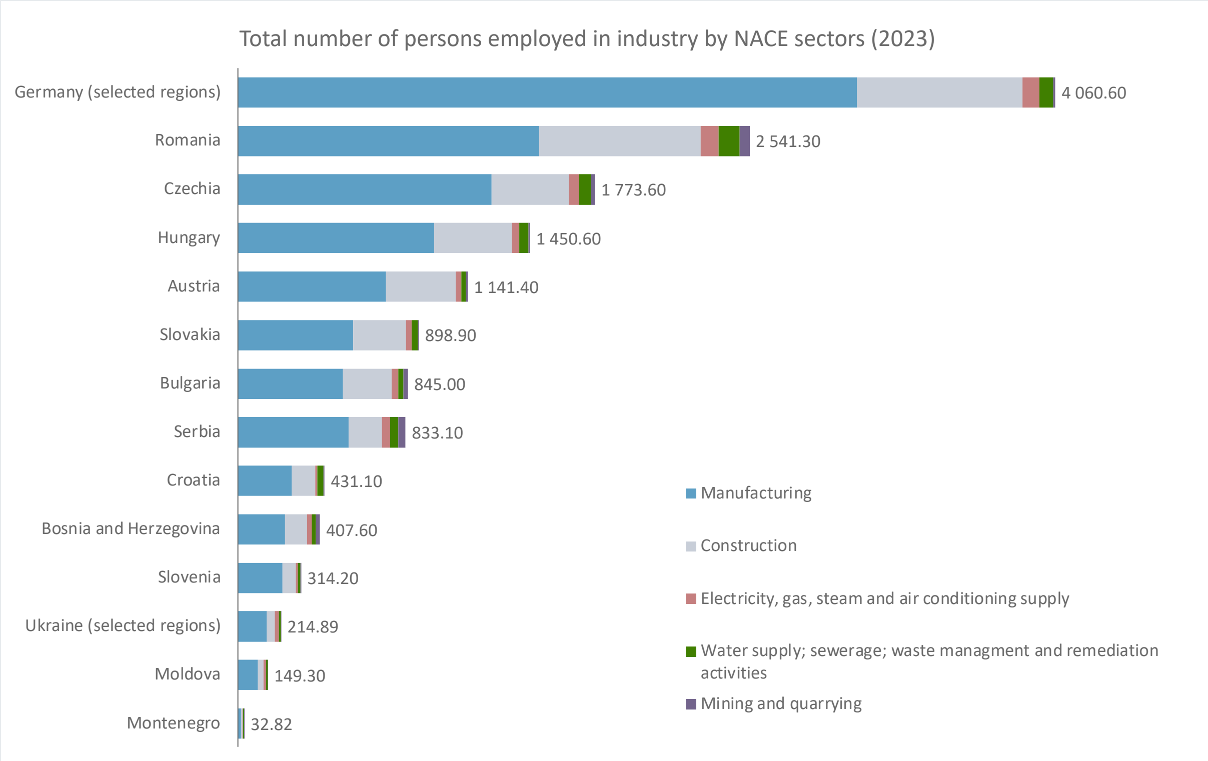


Figure 1: *Breakdown of the number of persons employed (in thousand) by NACE sectors of industry (2023)*
Own elaboration based on data from Eurostat, Derzhstat, Monstat, National Bureau of Statistics of Bosnia and Herzegovina, and Moldova

The two presented visualizations indicate that large industries are generally found in EU member countries, suggesting that energy efficiency measures in industry will be most relevant for these nations.

1.4 Key Takeaways and the Five Categories of Regions in the DR

The major consideration that should be taken away from this chapter is that the **DR is very heterogeneous in terms socio-economic development and its industrial organisation**. This heterogeneity is not only observable among the borders of the 14 countries but there are major differences within the countries themselves. Thus, taking into account these regional differences is also important to avoid a certain level of generality. On the other hand, the different cohesion regions within the DR can be also aggregated into five major categories based on the presented data as follows:

1 **Urbanised regions with an abundance of skill-intensive industries:** regions characterised by a higher proportion of skill-intensive industries, which generate products and services with a high added value. In general, these regions are mostly urbanised with a well-functioning infrastructure. For example, in regions like Niederbayern, Karlsruhe, or Freiburg in Germany. The high level of robotisation of their businesses and overall technological progress hints that the energy needs of the industry in these regions can be significant.

2 **Regions surrounding major capital cities in post-Soviet countries**: these regions differ from standard urbanised regions in Western Europe due to their different economic development in the second half of the 20th century. Home to many high-skilled workers with relatively low salary demands, they attracted in the early 2000s branches of many international corporations to outsource "less interesting" office jobs (e.g., different types of shared services). Their economic transition was therefore significantly quicker in comparison to other regions within their countries. In some cases, they even surpassed the economic performance of most regions in Western Europe. Nevertheless, as shown by the data presented, these regions have only small industries and services are generally the most predominant economic activity.

3 **Populated regions with a significant manufacturing sector:** these regions were significantly re-shaped in the 1990s and 2000s located mostly in post-Soviet countries that became part of the EU. They are characterised by low unemployment rates primarily driven by manufacturing industries employing low-skilled workers. These regions are sometimes referred to as "assembly plants" of corporations from Western Europe, and one could classify most of the NUTS2 regions of Czechia, Slovakia, Poland, Romania, and Hungary into this category. These regions have therefore a significant probability of being home to many energy-intensive sectors.

4 **Specialised regions**: their development and economic activity are shaped mainly by their unique characteristic, which they take advantage of, whether it is location, nature, or both. These regions benefit from their natural attractiveness and can often be linked with high levels of tourism. Examples of such regions are the Adriatic region in Croatia, which became a major tourist hub, and the Odessa region in Ukraine, with its strategic location at the Black Sea with access to world trade routes. Industry in these regions does often not represent a significant type of economic activity.

5 **Rural regions:** regions that usually have a lower population density and agriculture play a significant part in the local economy. These regions also never became targets for industrialisation efforts from their respective governments and often fought with high levels of emigration due to a lack of employment opportunities for high-skilled workers. It is important to note that such regions can be found within all countries of the DR with different levels of wealth depending on factors such as the intensity of government investments and the success of Small and Medium Sized Enterprises (SMEs).

In summary, the **regions with the highest potential to play a significant differentiating role in the efficient use of energy in the industry** are mainly those with large modern industries in Germany and Austria, and the ones which are home to large manufacturing sites in EU-member state countries such as Czechia, Slovakia, Romania and Hungary.

2. Understanding Energy Efficiency

"Reducing energy consumption and energy waste across the energy system – from production to consumption – in all economic sectors is one of the EU's strategic objectives." *(European Environment Agency, 2023)*

To understand energy efficiency from the EU's perspective, various sources can be consulted. Nonetheless, the Directive (EU) 2023/1791 on Energy Efficiency can be currently considered as the most relevant document with cross-border importance.

It defines energy efficiency as a comprehensive approach that involves finding ways to reduce the energy needed to produce the same or even higher amounts of products and services. This aligns with the European Environment Agency's (EEA) definition, which describes energy efficiency as the process of achieving the same output with the same energy input, thereby minimizing waste.

In general, Energy efficiency has **emerged as a critical agenda in contemporary politics and academia** due to its multi-faceted benefits across various domains, notably:

Environmental	**Mitigating environmental degradation linked to fossil fuel extraction, combustion, and waste generation can play a pivotal role in the attempt to reduce energy consumption**. Adopting energy-efficient technologies and practices can also conserve natural resources and ecosystems by reducing the need for resource extraction and habitat destruction.
Economic	**Energy efficiency can yield significant economic benefits by reducing energy costs for businesses and governments.** By using energy more efficiently, businesses can increase their competitiveness and profitability, and governments can save taxpayer money on energy expenditures.
Social	**Energy efficiency measures can help enhance energy access and equity by making energy services more affordable, reliable, and accessible to underserved populations**, including low-income households and rural communities. By reducing energy poverty and increasing energy affordability, energy efficiency measures contribute to social equity and inclusive development.
Public health	**Adopting energy-efficient practices and technologies can enhance public health and well-being by reducing air pollution and indoor exposure to harmful contaminants**. By transitioning to cleaner and more efficient energy sources and technologies, air quality can be improved, leading to the reduction of respiratory diseases and higher levels of quality of life.
Energy security and Economic development	**By diversifying energy sources and promoting energy conservation, countries can reduce their vulnerability to energy supply disruptions, geopolitical conflicts, and price fluctuations in global energy markets.** This can positively impact economic growth and development, create jobs in energy-efficient industries, and spur innovation in clean energy technologies.

Promoting energy efficiency measures in industries can therefore contribute to achieving these benefits, since they represent a significant consumer of energy products.

2.1 Importance of Energy Efficiency

In our modern world, the integration of diverse energy sources has become a global necessity, significantly improving human life and simplifying daily tasks. As countries evolve from agrarian to industrial to service-based economies, the demand and use of energy undergo profound transformations.

Technological progress and economic growth **have significantly increased the global demand for energy and energy-related goods.** However, this rise is not uniform across all nations as it occurs gradually alongside economic development and improving living standards. From 1990 to 2008, **the EU27 saw a substantial increase of about 30% in electricity production**. This growth is due to the strong expansion of the European industrial sector and its economy, which has enabled a gradual shift toward more sustainable, though more expensive, energy technologies.

The example of the EU27 highlights the need for energy-efficient solutions. Many less developed regions are increasing their demand for energy, often relying on environmentally harmful fossil fuels to support their growing industries. To reduce and ideally prevent the negative impacts of using more fossil fuels, the **European industry can set an example by finding new ways to manage energy efficiently**.

2.1.1 Evolution of Consumption and the Flow of Energy: World vs. EU27 and the DR

Since 1965, **primary energy consumption[5] has increased more than three times around the world**. This is shown in Figure 3 below, which compares the evolution in primary energy consumption in the world (left-hand side) and EU27 (right-hand side). The primary energy consumption in the EU27 increased significantly slower in comparison to the world consumption with a decreasing tendency from 2008. The energy mix of the EU27 is also more diverse with a visibly higher share of renewable resources.

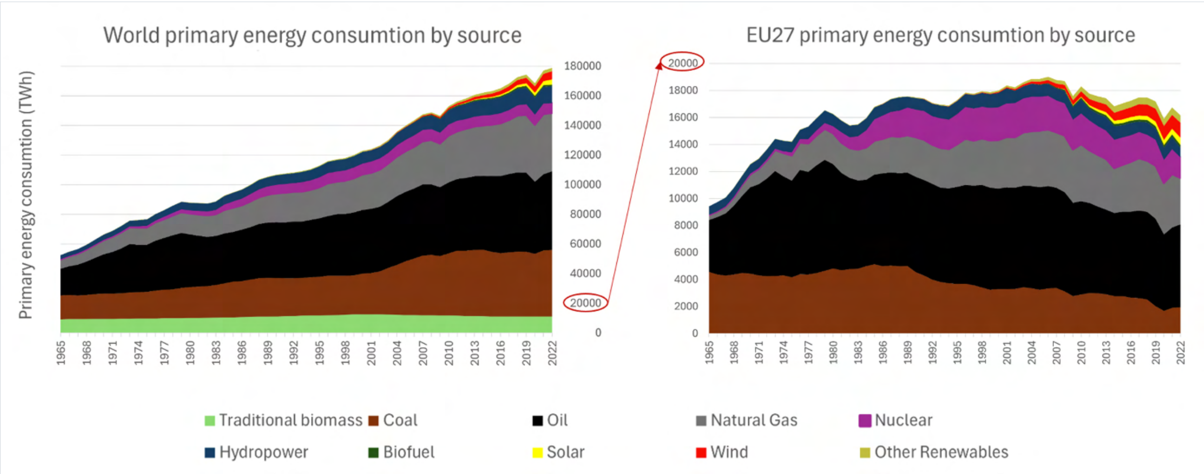


Figure 2: *Comparison of primary energy consumption in the world and the EU27*
Source: own elaboration based on data from Eurostat (2022)

5 Primary energy consumption refers to the total amount of energy consumed by a country, region, or entity before any conversion or transformation into other forms of energy.

Figure 3 also shows that the **primary energy consumption of the EU27 accounts for only 9% of global energy consumption**. One could therefore argue that the overall development in the EU27 is positive, and no more drastic energy efficiency measures are needed across the continent. However, especially the industries of post-Soviet countries demonstrate a potential for further improvement which will be further discussed in the next sections**.**

Two-thirds of the energy input is imported into the EU and the DR, while a mere one-third is produced locally (Eurostat, 2024). This imbalance underscores the heavy reliance of the EU on external sources and the pressing need for increased local production. This is illustrated in the Sankey diagram below (see Figure 3) which visualizes in a simplified way the energy flow from import and production to the final industry consumption.

It highlights major stages of the energy flow based on data from the countries of the DR for 2021 omitting some major flows in the later stages. The diagram confirms that 60% of energy came from imports, while 36% was produced within the countries of the DR. Of the total available energy sources, 36% were used directly, while 64% had to be transformed for further use. Based on data for the DR, 17% were lost in the transformation process. This led to around 83% of energy sources being available after transformation. From the available energy sources, around 1% of the total energy was lost within the distribution and transmission network, and 63% was dedicated to final energy consumption after the transformation stage. Finally, **the total industry energy consumption in the DR was 22%, above the EU27 average of 16%**.

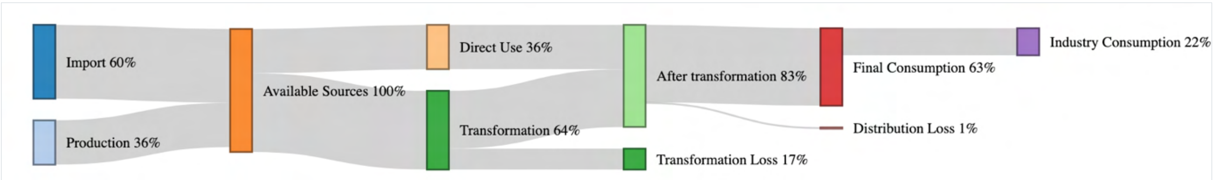


Figure 3: *Sankey diagram of energy flow in countries of the DR (2021)*
Source: own elaboration based on data from Eurostat (2021)

2.1.2 Energy Intensity of the Industry of the DR

Figure 4 compares the share of the industrial sector in the final energy consumption with the EU27 average and the countries of the DR separately. Based on the data, **the industrial sector participates in energy consumption in all EU states in the DR at a comparable rate of around 25%**, except for Croatia, where it contributed roughly to 16% of the final energy consumption.

Since non-EU countries of the DR have smaller industrial bases (e.g., as shown in Figure 1), the energy consumption of their industries participates to a lesser extent in their final energy consumption. The only exception is Ukraine, where energy consumption by the industrial sector exceeded 30%, one of the highest in the entire region.

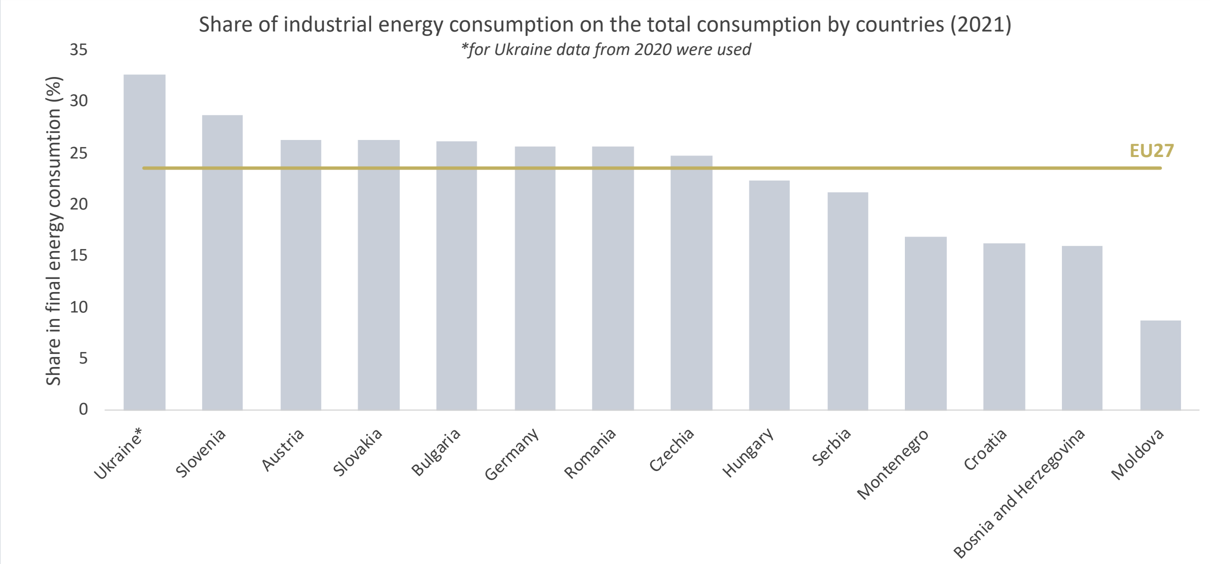


Figure 4: *Share of industrial energy consumption on total energy consumption by countries (2021)*
Source: own elaboration based on data from Eurostat (2021)

Figure 5[6] below shows the total energy consumption of the industry by country. It reveals that Germany's industry is the most energy-intensive compared to other states in the DR. Among countries with similar sizes in terms of population and land area, an **interesting difference in total industrial energy consumption can be observed in case of Austria and Czechia who report similar values, which are significantly higher than those of a comparably large country like Hungary**. On the lower end of the industrial energy consumption are non-EU member states of Montenegro, Moldova and Bosnia and Herzegovina. The presented comparison gives therefore a first indication on the extent to which energy efficiency measures in industries can impact the overall energy consumption in different countries.

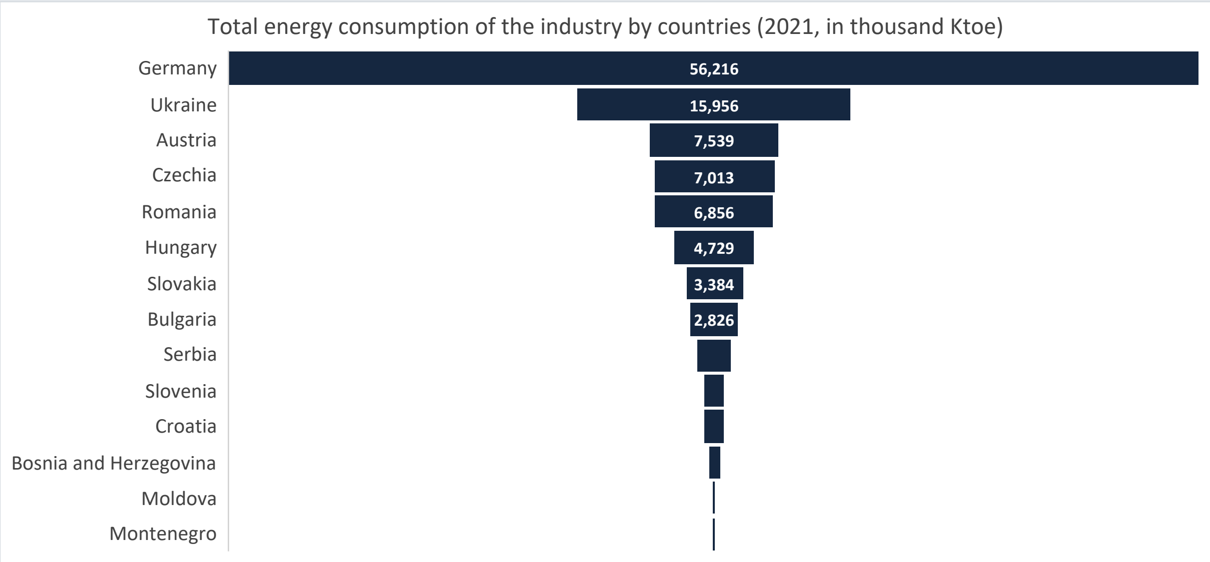


Figure 5: *Total energy consumption of the industry by countries (2021, in thousand Ktoe)*

6 Data for Germany and Ukraine represent the industrial energy consumption for the entire country. Comparable region-specific data were requested, nevertheless, in the case of BW and Bayern, the format of the data is not comparable to those of Eurostat and no information was provided by the Ukrainian representatives.

Source: own elaboration based on data from Eurostat (2021)

Comparing the data on total industrial energy consumption to other country level indicators of their industry can provide further insights. For instance, when contrasting the country level industrial energy consumption to the value added of the industry, a positive linear relationship can be observed as shown in Figure 6 below. In other words, **a greater value added of the industry in a specific country can be associated with a gradually higher total energy consumption**.

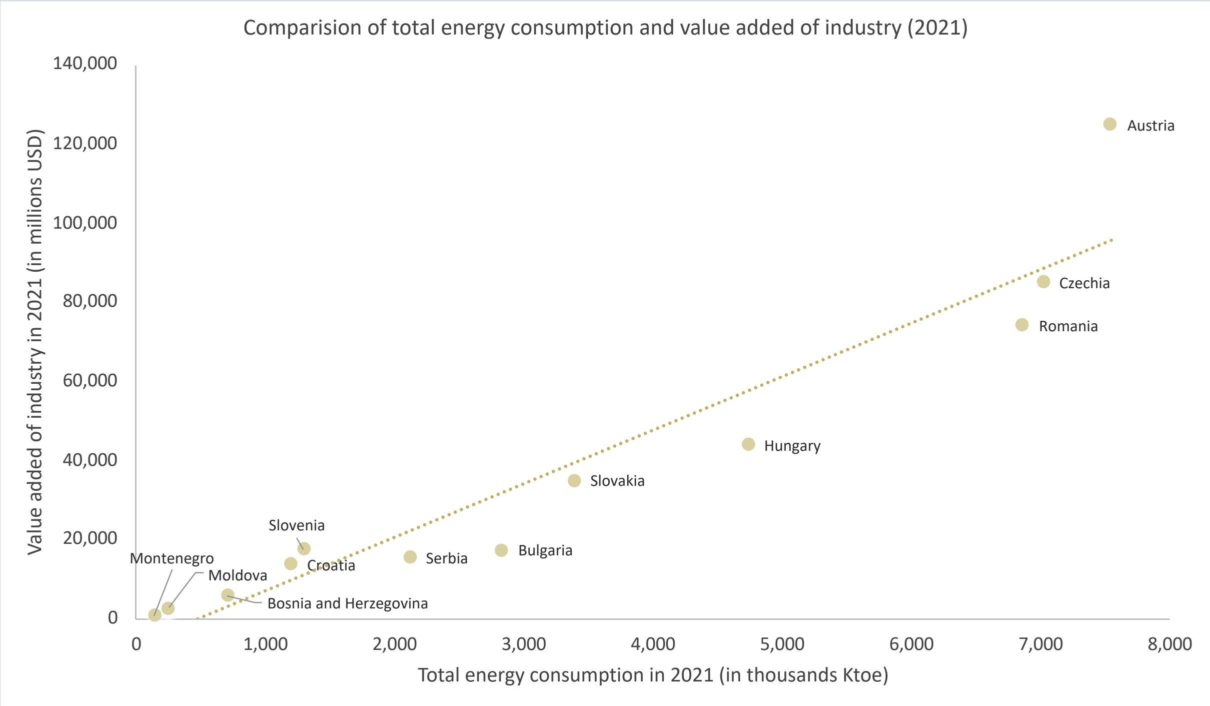


Figure 6: *Comparison of total energy consumption and value added of industry (2021)*
Source: own elaboration based on data from Eurostat and the World Bank (2021)

Interestingly, some potential outliers can be observed among the states of the DR such as the case of the Austrian industry. Based on the data presented it has a proportionally higher added value when compared to other countries in comparison to the total number of energy units consumed by its industry. This contrast is even more visible when comparing the presented data to countries such as Bulgaria or Hungary.

Possible explanations for such variations in the average amount of energy needed to produce the same output of the industry can be linked to the different composition of the industry among the countries, as well as a potential difference in the technological specialisation among them.

In general, **one can expect higher added value from the goods produced by Austrian industry, since it specializes more in the development and producing of technologies of higher order**. On the contrary, **manufacturing of heavy machinery creates a lower added value even though it still requires a significant proportion of energy**.

Another intersecting observation can be drawn from the scatter plot below (Figure 7) which visualises the comparison of total industrial energy consumption and the number of persons working in industry. **Austria and Romania exhibit very different share of the labour force and energy needed to run their industries**.

While the Romanian industry employs twice as many persons as the Austrian one, they both consume a similar amount of energy. This underlines again the potential difference in the industrial organisation of the states of the DR. The lower labour force needed to run the industry in Austria can be associated with a **higher percentage**

of robotisation and automation of processes in companies requiring fewer human resources and more energy input.

Although it is a very simplified interpretation, it underlines an important consideration that **incorporating technologies in companies within industry can lead to an increasing demand for energy needed to run them**.

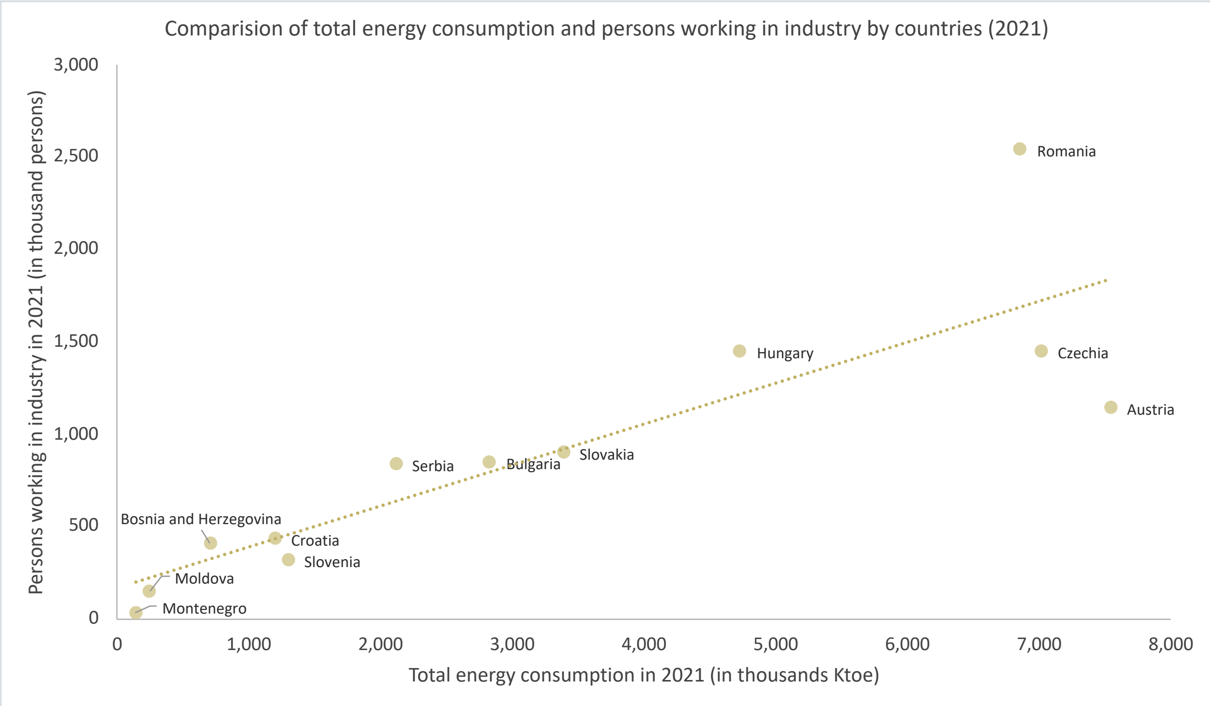


Figure 7: *Comparison of total energy consumption and persons working in industry by countries (2021)*
Source: own elaboration based on data from Eurostat, Derzhstat, Monstat, National Bureau of Statistics of Bosnia and Herzegovina, and Moldova (2021)

The data shown in this sub-chapter can also underline the different stages at which the states of the DR are in their efforts to implement energy efficiency measures within their industries. Even though the industrial energy intensity seems to be linked to its organisation and specialisation in each state, the role of incorporating newer technologies and the approach adopted for energy management cannot be omitted as potential factors in the differences of cross-country industrial energy consumption.

Interesting case studies are therefore states and regions with similar industries, but different levels of energy consumption. These should be targeted to identify which measures in place can have a differentiating impact on total industrial energy consumption.

2.1.3 Energy Flowing through Industry by the Share of Specific Fuels

The data presented in Table 2[7] provide further detail on the share of specific fuels running through industry in each country of the DR. Except for Montenegro **a prevalent energy source is gas, which indicates a high dependence on its import from outside the DR since there are no major natural gas deposits on its territory**.

Another major commodity flowing through the industry of the industry of the DR is electricity transformed from different sources in power plants (e.g., nuclear). In case of renewable energies, their highest share on the total industrial energy consumption can be observed in Austria reaching 16.5%.

Other industries with relatively significant share of consumption of energy from renewable sources (i.e., more than 8%) are the ones in Slovakia, Bulgaria and Serbia. Interestingly, the share of renewable energies consumed by the German industry is among the lowest in comparison to other states in the DR.

Table 2: *Energy flowing through industry by the share of specific fuels (2021)*

Energy flowing to industry by the share of specific fuels (2021)								
Country	**Total energy consumption (in thousands Ktoe)**	**% Share of specific fuels**						
		Solid fuels	Oil and petroleum products	Gas	Renewable energies	Non-renewable waste	Heat	Electricity
Germany	56,216	5.0%	6.3%	40.2%	5.0%	2.3%	7.6%	33.5%
Ukraine	15,956	30.6%	4.0%	17.6%	0.0%	0.6%	22.5%	24.7%
Austria	7,539	4.0%	4.2%	38.1%	16.5%	3.3%	3.2%	30.6%
Czechia	7,013	10.9%	3.1%	36.3%	7.8%	3.8%	8.0%	30.1%
Romania	6,856	10.0%	15.9%	37.8%	3.0%	4.6%	2.3%	26.5%
Hungary	4,729	1.6%	15.3%	31.4%	6.4%	2.9%	8.3%	34.1%
Slovakia	3,384	7.9%	9.3%	36.4%	9.8%	5.1%	2.0%	29.5%
Bulgaria	2,826	8.8%	14.0%	33.2%	8.3%	2.4%	3.7%	29.5%
Serbia	2,113	6.4%	14.7%	23.1%	8.4%	0.0%	9.1%	38.2%
Slovenia	1,294	1.6%	7.7%	36.9%	6.2%	3.5%	3.9%	40.3%
Croatia	1,193	9.0%	19.7%	31.2%	2.7%	3.8%	6.4%	27.3%
Bosnia and Herzegovina	704	26.7%	16.3%	17.2%	1.1%	0.0%	0.1%	38.5%
Moldova	247	11.7%	12.6%	27.5%	1.2%	0.0%	20.6%	26.3%
Montenegro	139	3.6%	47.5%	0.0%	7.2%	0.0%	0.0%	41.7%

Source: own elaboration based on data from Eurostat (2021)

The presented data underline the high dependence of the different industries on imported sources of energy. Most recent country-level energy data from 2023, which are publicly available only for some countries, do not exhibit any significant change in the share of different fuels used by the industry of the respective states. Thus, more energy efficient industries can help in lowering their dependency on imported energy sources and increase the share of renewable energies on the total consumption.

7 Data for Germany and Ukraine represent the industrial energy consumption for the entire country. Comparable region-specific data were requested, nevertheless, in the case of BW and Bayern, the format of the data is not comparable to those of Eurostat and no information was provided by the Ukrainian representatives.

2.1.4 Share of Final Energy Consumption by Country and Industry Type

Another look at industrial energy consumption provides available country-level data on the share of energy consumed by different types of industries. Based on Table 3 below, the following observations can be drawn:

- **Metals manufacturing and casting** emerge as the most energy-intensive sectors in Ukraine, Slovakia, and Bosnia and Herzegovina
- In Germany, Hungary, Romania, and Bulgaria, the **chemical and petrochemical industry** dominates energy consumption
- The **machinery sector** is notably energy-intensive in Czechia, Hungary, and Slovenia
- In Austria, the **paper industry** represents the highest energy-consuming sector
- The **food and tobacco sectors** are major industrial energy consumers in Hungary, Serbia, Croatia, and Montenegro

These observations represent another important input since they allow to target the most energy-intensive sectors in each country and assess the feasibility and potential impact of different energy efficiency measures.

Table 3: *Share of final energy consumption by country and industry type (2021)*

Share of final energy consumption by country and industry type													
Country	**Type of industry**												
	Iron & steel	Chemical and petrochemical	Non-ferrous metal	Non-metallic minerals	Transport equipment	Machinery	Mining and quarrying	Food and tobacco	Paper	Wood and wood products	Construction	Textile and leather	Non-specified
Germany	12.3%	24.8%	4.0%	12.3%	4.8%	8.9%	0.6%	9.3%	9.6%	3.4%	4.4%	0.7%	5.0%
Ukraine	53.3%	8.2%	0.0%	10.4%	1.2%	2.6%	8.2%	9.6%	1.6%	1.3%	1.7%	0.3%	1.6%
Austria	11.7%	14.7%	3.0%	13.0%	1.9%	7.2%	2.5%	7.3%	23.6%	8.0%	3.8%	0.9%	2.5%
Czechia	14.9%	15.7%	1.4%	16.5%	7.5%	10.3%	1.4%	8.3%	10.7%	3.3%	2.5%	2.4%	5.1%
Romania	16.3%	23.1%	6.5%	18.5%	4.2%	5.6%	0.6%	8.3%	2.8%	4.2%	6.3%	2.0%	1.8%
Hungary	4.0%	25.6%	2.2%	12.5%	5.0%	11.2%	0.8%	15.4%	5.3%	3.2%	7.0%	0.8%	7.1%
Slovakia	26.9%	14.2%	7.8%	13.3%	5.2%	6.3%	1.5%	4.3%	12.8%	1.3%	0.9%	0.6%	4.8%
Bulgaria	4.1%	29.3%	6.5%	21.2%	0.7%	4.7%	6.4%	9.8%	6.3%	3.2%	3.0%	1.9%	2.9%
Serbia	16.3%	14.9%	3.3%	16.2%	1.1%	5.7%	4.9%	18.5%	3.9%	1.1%	3.3%	4.0%	6.7%
Slovenia	12.0%	12.8%	9.4%	15.7%	2.2%	14.9%	1.4%	5.4%	10.9%	4.7%	3.2%	1.1%	6.3%
Croatia	2.4%	10.7%	1.8%	32.5%	0.8%	5.5%	0.6%	14.1%	6.7%	8.2%	10.5%	1.8%	4.3%
Bosnia and Herzegovina	29.2%	3.0%	15.3%	17.7%	1.0%	4.5%	3.5%	8.5%	4.0%	3.5%	4.1%	2.4%	3.1%
Moldova	0.0%	2.8%	0.4%	66.9%	0.0%	1.2%	3.6%	16.5%	0.8%	0.4%	5.2%	0.0%	2.0%
Montenegro	3.7%	1.5%	39.0%	2.9%	0.0%	1.5%	8.1%	19.1%	0.0%	12.5%	0.0%	0.0%	11.8%

Source: own elaboration based on data from Eurostat (2021)

2.1.5 The Importance of Energy Efficiency in Industry

Based on the data presented in this chapter, **the importance of energy efficiency in the industry of the states of the DR** can be demonstrated on the following observations:

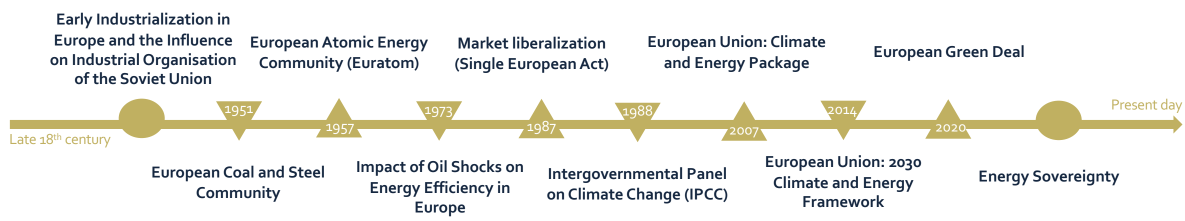
- The EU27 and the DR are heavily **reliant on energy imports, which makes them vulnerable to supply disruptions**. The significant consumption of fossil fuels (oil, natural gas) in the region exacerbates **energy security concerns**.
- Even though the primary energy production of the EU27 comprises **43% of energy transformed from renewable sources**, it is still **crucial to increase their share** to attain higher levels of self-sufficiency by lowering energy imports.
- The **industry of the countries of the DR**, mainly Germany, can **play a crucial role in the energy efficiency efforts** of the EU by implementing new energy efficiency technologies in their production.
- One of the **highest priorities should be reducing energy losses in transformation, transmission, and distribution, which can account for** almost one-fifth of available energy from imports and production.
- Some types of **industries exhibit a high energy-intensity across the different states of the DR** (e.g., metals manufacturing and casting, chemical and petrochemical industry or machinery sector). Thus, identifying the most feasible measures for the respective sectors might have a differentiating impact on the total energy consumption attained through higher efficiency of energy use.

Thus, a balanced approach leading to more efficient energy transmission and use is necessary within the frame of the next years. Initiatives, such as localising energy production can reduce the need for imports to satisfy the energy supply needs of the industry. From the regional perspective, it is also important to carefully evaluate the potential impact of legislative requirements to avoid disruptions of industries in specific parts of the DR.

2.2 Historical Perspective

The industrialisation of Europe in the late 18th century marks the beginning of a gradual increase in energy demand across all sectors. A very remarkable momentum in industrial energy consumption was also the influence of the Soviet Union which largely shaped the industrial organisation of most countries within the DR. However, it was only in recent years that energy efficiency became a topic of discussion, while significant damage to the environment was already done.

In this sub-chapter, a brief historical perspective on the development of the significance of energy efficiency is presented. The **timeline below presents the major historical milestones which gradually shaped our understanding of energy efficiency**. The timeline starts in late 18th century with early industrialization in Europe which significantly increase the demand for energy to keep up with the production growth. It is only in the second half of the 20th century that the effects of heavy industrialization on the environment started to create concerns among scientists while policy makers started to recognize the seriousness of the topic few decades later.



Early Industrialization in Europe and the Influence on Industrial Organisation of the Soviet Union

During the Early Industrialization period in Europe, which spanned from the late 18th century to the mid-19th century, **energy efficiency was not a major priority**. The era was characterized by rapid industrial expansion, largely driven by coal, especially in the late 1700s and early 1800s. Coal was used to power steam engines in factories and transportation systems, with little consideration for efficiency or environmental impact.

The primary objective was to maximize output rather than optimize energy consumption. Nevertheless, technological advancements during this time laid the **groundwork for future advancements in energy efficiency**. Despite initial inefficiencies, progress was eventually made, resulting in more sustainable energy practices as Europe transitioned into the modern era.

The DR, except for Germany and Austria, fell under the **influence of the Union of Soviet Socialist Republics** (hereinafter also "USSR") after World War II. The states in this region, apart from former Yugoslavia, formed the Eastern Bloc and were satellite states of the Soviet Union. The USSR had a significant impact on their socio-economic orientation and the development of their industrial sector.

The Soviet Union's influence on the economies of these countries was mainly through **implementing a centrally planned economic model**, with economic goals set in multi-year plans, such as five-year plans. This approach limited market mechanisms, with the state determining which industries would be developed.

Heavy industry, including metallurgy, engineering, chemical, and energy, **was prioritized** to ensure economic self-sufficiency and support military potential. Investments were focused on heavy industry at the expense of light industry and consumer goods. The construction of mining facilities, smelters, and power plants aimed to supply the domestic market, the Soviet market, and other Eastern Bloc countries' markets.

The **Council for Mutual Economic Assistance** (hereinafter also "COMECON") centrally managed the economies of these countries, coordinating their economic plans and defining their national specializations. This resulted in an industrial structure where **countries became interdependent for specific products**, **increasing their dependence on the Soviet Union**. The adoption and use of Soviet technologies and procedures further deepened this reliance. Additionally, scientific research and development were frequently tailored to meet the needs of the USSR.

European Coal and Steel Community

The inception of the European construction era dates to the **early 1950s when several countries decided to collaborate on coal production**. This decision marked a concerted effort to foster economic cooperation and stability in post-war Europe. **Coal was recognized as the primary energy source** during this period, and it held strategic importance in fuelling industrial growth and rebuilding efforts across the continent in the aftermath of World War II.

As a result, the **European Coal and Steel Community** (hereinafter also "ECSC") **was established as a European organization to integrate Europe's coal and steel industries into a single common market**. The ECSC was based on the principle of supranationalism, which was governed by the creation of a High Authority composed of appointed representatives from the member states who made decisions in the general interests of the Community rather than representing their national interest.

The ECSC was first proposed via the Schuman Declaration by French Foreign Minister Robert Schuman on May 9, 1950 (commemorated in the EU as Europe Day), the day after the fifth anniversary of the end of World War II, to prevent another war between France and Germany.

Formally established in 1951 by the Treaty of Paris, signed by Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany, the ECSC was widely regarded as the first step in the European integration process following the end of the Second World War in Europe. The organization's subsequent enlargement of members and duties ultimately led to the creation of the EU in 1993.

The ECSC had **notable impacts on energy efficiency in Europe**. By promoting the integration of coal and steel industries, the ECSC indirectly encouraged the adoption of more efficient production technologies and practices within these sectors, leading to gradual improvements in energy utilization. As these industries modernized, the shift towards more energy-efficient methods helped reduce overall energy consumption and emissions.

European Atomic Energy Community (Euratom) & European Economic Community (EEC)

The establishment of the **European Atomic Energy Community (Euratom) and the European Economic Community (hereinafter "EEC") on March 25, 1957**, was a significant milestone in European integration, playing unique roles in **shaping energy efficiency policies and practices across the continent**.

Euratom was established alongside the EEC through the Treaty of Rome by the same six countries. It was primarily created to regulate and develop nuclear energy, secure the supply of raw materials, and enhance Europe's energy independence after the Suez Crisis threatened to cut off oil supplies peacefully.

The organization's main objectives included **promoting research and development in the field of atomic energy, establishing common safety standards for nuclear facilities, and facilitating the free movement of nuclear materials and expertise among member states**. Although Euratom contributed to advancements in nuclear technology and energy production, its impact on overall energy efficiency in Europe was indirect, focusing primarily on the safe and responsible use of nuclear power.

On the other hand, the EEC aimed to foster economic integration among its member states. In 1993, it was renamed the European Community, and upon becoming integrated into the first pillar of the newly formed EU, it **played a broader role in shaping energy efficiency policies across various economic sectors**. Through the implementation of common market regulations, environmental standards, and energy efficiency directives, it has sought to promote, for example, energy conservation.

The emphasis on nuclear energy by Euratom offered an alternative to traditional coal energy sources, facilitating a more varied and potentially efficient mix of energy options. In the DR, known for its combination of developing and industrialized nations, this shift helped **promote regional initiatives to improve energy security and efficiency**. Through encouraging economic stability and technological progress, both the ECSC and Euratom paved the way for more sustainable energy approaches, which in turn supported wider efforts towards European integration and cooperation.

Impact of Oil Shocks on Energy Efficiency in Europe

The oil shocks in the 1970s had a profound impact on Europe, including the DR, and influenced energy policies and practices for decades. **The first oil shock in 1973, triggered by geopolitical tensions in the Middle East**, resulted in sudden oil price increases and supply disruptions. This crisis made it clear that Europe heavily depended on imported fossil fuels and underscored the risks of relying on a single energy source. In response, European countries started **focusing on energy efficiency measures to reduce their reliance on oil and lessen the economic impact**. Policies promoting energy conservation, renewable energy development, and technological innovation gained traction, aiming to enhance energy security and resilience.

The second oil shock in 1979, caused by **political instability in Iran and the Iran-Iraq War**, further intensified Europe's efforts to diversify its energy sources and improve efficiency. Governments in the DR and across Europe invested in enhancing industrial processes, transportation systems, and building standards to **minimize energy consumption and reduce dependence on volatile oil markets**. These initiatives were crucial in laying the groundwork for a more sustainable energy future, promoting regional cooperation, and accelerating the adoption of renewable energy sources. Overall, the oil shocks prompted a **shift towards energy efficiency across Europe, resulting in lasting improvements in resource management and economic stability**.

Market liberalization

In recent years, the Euratom and the EU have increasingly acknowledged the significance of energy efficiency in attaining their wider goals of sustainable development, climate action, and energy security. To improve energy efficiency across Europe, **various measures have been taken, including investing in energy-saving technologies, enhancing building insulation and efficiency standards, and introducing initiatives to encourage energy-efficient transportation and industrial practices**.

On July 1, 1987, the Single European Act (SEA), the first significant revision of the 1957 Treaty of Rome leading to the creating a single market, came into effect. By this, Europe began a journey towards market liberalization, significantly impacting energy efficiency policies across the continent. During this period, a shift towards deregulation and market-oriented reforms aimed to foster competition, innovation, and efficiency in the energy sector.

During this time, one of the primary objectives was to **adopt directives and regulations that would liberalize energy markets and promote competition among suppliers**. These measures aimed to dismantle monopolies, promote consumer choice, and incentivize investment in energy infrastructure and technologies that prioritize efficiency.

Furthermore, the focus on market liberalization led policymakers to **recognize the critical role of energy efficiency** in achieving sustainable and competitive energy systems. Governments and regulatory bodies began implementing **measures to incentivize energy savings**, such as energy efficiency standards for appliances, buildings, and industrial processes. These steps stimulated technological advancements and innovations in energy efficiency as companies competed to offer more cost-effective and sustainable solutions. Investments in renewable energy sources, energy-efficient technologies, and smart grid systems gained momentum, driving energy productivity and resource utilization improvements.

Intergovernmental Panel on Climate Change (IPCC)

In the late 19th and early 20th centuries, **industrialization increased, and fossil fuels became the primary energy source**. This led to concerns about the environmental impact of carbon dioxide emissions. However, **it wasn't until the mid-20th century that the importance of energy efficiency in mitigating climate change gained widespread recognition**. The realization that improving energy efficiency could reduce emissions, save money, and enhance energy security spurred efforts to promote more efficient technologies and practices.

One of the significant milestones in the history of combating climate change by means of energy efficiency was the formation of the Intergovernmental Panel on Climate Change (IPCC) on November 20, 1988, which was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The IPCC's reports have consistently highlighted the significance of energy efficiency as a cost-effective strategy for reducing emissions across various sectors, including industry, transportation, and buildings.

The **Kyoto Protocol** was adopted on December 11, 1997, as a significant addition to the 1992 United Nations Framework Convention on Climate Change (UNFCCC), **marking a pivotal step in the global effort to combat climate change**. The protocol **set legally binding targets as well as for countries in DR** to reduce their greenhouse gas (GHG) emissions, considering carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), and nitrogen trifluoride (NF_3), which was added for the second compliance period during the Doha Round, conducted under the auspices of the World Trade Organization (WTO). Energy efficiency measures played a pivotal role in meeting these targets.

The efforts not only helped to reduce greenhouse gas emissions but also led to **lower energy costs and improved economic stability in the region**. The collaborative approach fostered by European integration and international agreements, such as the Kyoto Protocol, was crucial in advancing these energy efficiency initiatives. This demonstrates the region's commitment to sustainable development and climate change mitigation.

European Union: Climate and Energy Package

On 8 and 9 March 2007, **the European Council established new environmental targets** that were even more ambitious than the Kyoto Protocol. This plan included the "20-20-20 targets," covering four proposals:

- **Reduce GHG emissions** by 20% by 2020, based on 1990 emissions.
- **Increase energy efficiency** to save 20% of EU energy consumption by 2020.
- **Increase renewable energy** to 20% of total energy consumption in the EU by 2020.
- **Increase the use of biofuels** to 10% of total vehicle consumption by 2020.

On December 11-18, 2008, **the EU made a significant commitment to enhance energy efficiency**, combat climate change, reduce GHG emissions, and promote renewable energy sources by adopting the modified initial measured by the "Climate and Energy Package" as follows:

Greenhouse Gas Emissions Reduction Target	Energy Efficiency Target	Renewable Energy Target
The proposed and adopted versions of the package included a **binding target for the EU to reduce GHG emissions by 20% compared to 1990 levels by 2020**. This target remained unchanged from the initial proposal to the final adoption.	The proposed package included a **non-binding target to improve energy efficiency by 20% by 2020** compared to projected levels. However, during the negotiation process, this target was strengthened to become binding, meaning that EU member states were legally obligated to achieve a 20% improvement in energy efficiency by 2020. This adjustment reflected the EU's increased emphasis on energy efficiency as a critical component of its climate and energy policy. It underscored the importance of concrete actions to reduce energy consumption and promote energy-saving measures.	The proposed package version set a **target for the EU to increase the share of renewable energy in its overall energy consumption to 20% by 2020**. However, during the negotiation process, this target was refined to specify that the 20% target would apply to the EU's final energy consumption rather than its gross energy consumption, as initially proposed. This adjustment ensured consistency with international energy statistics and clarified the scope of the target.

The package was designed to drive **significant enhancements in energy efficiency** and the adoption of renewable energy sources. It fostered regional collaboration and innovation, resulting in economic growth, decreased energy expenditures, and reduced GHG emissions. These efforts collectively fostered a more sustainable and secure energy landscape for the DR.

European Union: 2030 Climate and Energy Framework

On October 14, 2014, the EU made a significant move by setting new objectives for the period beyond 2020. **The 2030 Climate and Energy Framework**, which **includes three primary goals**, aims to build upon past successes and learn from previous targets.

Greenhouse Gas Emissions Reduction Target	Energy Efficiency Target	Renewable Energy Target
The EU committed to **reducing its GHG emissions by at least 40% by 2030** compared to 1990 levels. This target represented a significant increase in ambition compared to the 20% reduction target for 2020 and reflected the EU's commitment to more ambitious climate action in line with international efforts to limit global warming.	The EU established a binding energy efficiency target to **improve energy efficiency by at least 32.5% by 2030** compared to projected levels. This target built upon the 20% improvement target for 2020 and reflected the EU's recognition of the central role of energy efficiency in achieving its climate and energy objectives.	The EU set a binding **target for renewable energy to represent at least 32% of the EU's final energy consumption by 2030**. This target aimed to drive further the deployment of renewable energy sources across various sectors and contribute to reducing the EU's dependence on fossil fuels.

In addition to the primary energy efficiency target set for 2030, the **EU's 2030 Climate and Energy Framework incorporated measures aimed at fostering innovation, stimulating investment, and fostering job growth within the realm of energy efficiency technologies**. These initiatives were designed to bolster the adoption and advancement of energy-efficient practices and solutions across various sectors.

European Green Deal

The European Green Deal **builds upon the Paris Agreement adopted in 2015**, representing a landmark international accord to address climate change globally. The Paris Agreement is a framework that was agreed upon by 195 members of the UNFCCC until February 2023. **The goal is to keep the global temperature rise below 2 °C from pre-industrial levels, with the efforts to limit it even further to 1.5 °C**. The plan is to improve our ability to adapt to the negative effects of climate change and to promote climate resilience and low greenhouse gas emissions development without compromising food production. Furthermore, the aim is to ensure that financial flows support the transition towards low greenhouse gas emissions and climate-resilient development.

In 2020, the European Commission approved the European Green Deal - **a forward-thinking vision that aims to position the EU as the world's first climate-neutral continent by 2050 through the reduction of GHG emissions**. To achieve this ambitious goal, the Green Deal proposes a wide-ranging set of policies and initiatives intended to promote greater environmental sustainability, placing a special emphasis on optimizing energy efficiency in multiple sectors.

Key elements of the Green Deal include:

Greenhouse Gas Emissions Emission Reduction Targets	It **commits the EU to cut its GHG emissions by at least 55% by 2030** compared to 1990 levels. This target represents a significant increase in ambition compared to previous targets and underscores the EU's commitment to accelerating the decarbonization of its economy.
Renewable Energy Expansion	It **prioritizes expanding renewable energy sources such as wind, solar, and hydroelectric power** to increase the share of renewable energy in the EU's energy mix to at least 32% by 2030, with a particular emphasis on supporting the development and deployment of renewable energy technologies.
Energy Efficiency Improvements	Energy efficiency lies at the heart of the European Green Deal, as improving energy efficiency is considered one of the most cost-effective ways to reduce emissions and enhance energy security. The Green Deal sets ambitious targets to improve energy efficiency across various sectors, including buildings, industry, transportation, and agriculture.
Fit for 55 Package	Building on the momentum of the European Green Deal, the European Commission introduced the Fit for 55 package on July 14, 2021. This **comprehensive legislative package includes a wide range of proposals aimed at aligning EU policies and regulations with the goal of reducing GHG emissions by at least 55% by 2030**. Key elements of the Fit for 55 package include revisions to the EU Emissions Trading System (ETS), the introduction of a carbon border adjustment mechanism (CBAM), and the tightening of vehicle emission standards.

The European Green Deal has brought about a **significant shift in the approach to energy efficiency in the EU** and has **fundamentally reshaped the approach to energy efficiency in the DR**. It has placed energy efficiency at the core of its climate and energy strategy by setting ambitious targets and implementing supportive policies and measures.

The deal promotes the rapid expansion of renewable energy sources such as wind, solar, and hydroelectric power, while advocating for a Building Renovation Wave to improve the energy performance of existing buildings. Additionally, the Green Deal emphasizes a circular economy, encouraging resource efficiency and sustainable practices across industries.

It provides substantial funding and support for green projects, fostering technological innovation and regional cooperation to drive energy efficiency solutions. Furthermore, the initiative ensures a just transition, supporting regions reliant on fossil fuels with green investments to spur economic growth and job creation.

Energy Sovereignty

The events that unfolded in February 2022, with Russia's invasion of Ukraine, have led to **significant shifts in the European Union's approach to energy policy**. This situation has prompted the **EU to prioritize the concept of 'energy sovereignty,'** which involves reducing dependence on external energy sources.

Before the conflict, the EU had a strong reliance on Russia for fossil fuel imports, with oil supplies accounting for 16.5% of imports, natural gas supplies accounting for 37%, and coal supplies accounting for 44%. However, following the outbreak of the war, the EU had to find alternative suppliers to replace Russian fossil fuels, resulting in a diversification of energy trade patterns, including purchases from the United States and other countries.

This situation has prompted the EU to re-evaluate its energy policies and explore ways to achieve energy independence. It is essential for the EU to reduce energy consumption, increase the use of renewable sources and local raw materials, and improve energy efficiency. Moreover, the EU should recognize the importance of maintaining positive relationships with energy partners while pursuing its goals of achieving energy independence.

2.3 Main Drivers of Energy Efficiency in Europe

Regulatory measures, technological advancements, economic incentives, and societal awareness drive energy efficiency in the European Union. This chapter, therefore, provides an overview of the identified drivers for energy efficiency within the EU and the DR and discusses in more depth the relevant legislation.

In general, there are **several types of drivers of energy efficiency within the European Union**. The drivers could be **split into two major categories**. At the same time, one could consider **external incentives for energy efficiency**, capturing factors such as general societal sentiment towards a need to address climate change, and second, **internal factors**, which represent the motivation for implementing new technologies and processes based on actions taken by the EU institutions and the governments of the Member states (e.g., drivers such as changes in legislation, the focus of public funding on low-carbon technologies or education on the topics of prevention of climate change).

2.3.1 External drivers of energy efficiency

Recent events, such as abnormally high temperatures in most EU countries and the related media coverage, impacted society's perception of climate change. **The rising awareness among people results in their interest in checking with their governments about the actions taken towards more sustainable economies**. Its share of the rising awareness on the topic also has academia from all around the world since it regularly increases the number of science papers underlying concrete evidence and consequences of the industrialised world on the dramatic changes.

United Nations, which represents a renowned institution and "has the attention" of people worldwide, **could be considered a driving force that popularised the term "sustainable development"**. Most societies are aware of the 2030 Agenda for Sustainable Development. Consisting of 17 ambitious goals, among others, it sets basic milestones that should be achieved to address climate change.

Within the DR, several external drivers motivate its inhabitants to be more interested in climate change. In recent years, the notoriously cold winters have become milder, and summer temperatures are hitting new peaks. However, **the topic was not as popular among people as it became after the invasion of Ukraine by Russia in 2022**, as it started a chain of reactions that underlined the need to find any possible ways of becoming less dependent on gas imported outside the EU. All **fractions of society were suddenly stimulated to evaluate their energy needs and how they manage them**. Since there is significant room for improvement in energy efficiency across the economy, it became one of the objectives of many companies and households to seek efficient technologies to lower their increasing electricity and gas bills. These recent events heavily impacted the DR since its economies heavily rely on gas imports from outside the EU.

In summary, the following factors can be considered as the **main external drivers** for the implementation of energy efficiency measures:

- **Rising awareness of society** on the consequences of inefficient use of energy,
- **Volatile and rising prices of energy** in response to current events,
- **Uncertainty regarding energy supply**.

All these factors have contributed to making energy efficiency an important and historically popular subject, such as increasing energy production from renewable sources.

2.3.2 Internal drivers for energy efficiency

Since measures to mitigate the impact of human activity on the climate are part of several initiatives, for clarity, this sub-chapter will focus solely on the EU actions and legislation that are the most relevant for energy efficiency, focusing on the implications for industry.

It is worth noting that most directives, regulations, and communications of the European Commission and European Parliament were reviewed in 2023, and some directly supplement older legislation in place. The timing of the significant revision and introduction of new documents is no coincidence.

It acts as a structured response to the above-mentioned external factors, notably the geopolitical situation in Europe since 2022, the drastic climate changes observed in past years, and significant technological transformation from the past decade.

The EU institutions use the following tools to foster the introduction of energy efficiency measures:

- **Directives, regulations, and communications** with different levels of legislative implications for its Member States.
- **Funding schemes** are provided by the EU in the form of grants, loans, and subsidies to support energy-efficient initiatives.
- **Rising public awareness and education** is also an activity that EU institutions execute on top of the ones done by international organisations, such as the United Nations.
- **Energy performance standards** require certain sectors, such as data centres, to collect and report data relevant to their energy performance.
- **Carbon pricing and emission trading** represent instruments that capture the external costs of greenhouse gas (GHG) emissions and allow industries with low emissions to sell their extra allowances to larger emitters.
- **Energy audits and monitoring** mean that industries are required to conduct regular energy audits and implement energy management systems to identify and realize energy savings opportunities.

The above-listed tools are not limited but can be considered the most visible. It is also important to note that they are heavily interconnected since funding schemes often act as a catalyst for implementing the measures set by the different directives.

2.3.3 Recent legislations

The **year 2023 marked an important year for the energy-related legislation of the European Union**. As a reaction to the geopolitical situation in Europe, the European Commission reviewed several EU directives, regulations, and communications, tackling the topic of energy efficiency. The most notable ones also significantly impact the already mentioned Directive on Energy Efficiency, A Green Deal Industrial Plan for the Net-Zero Age, and Directive on the Sustainability Reporting Standards.

Directive on Energy Efficiency *(Directive (EU) 2023/1791)*	Among others, the directive sets the ground for the **first energy efficiency principle**, which can be viewed as an overarching policy framework that integrates into all levels of decision-making across sectors beyond the energy sector itself, including financial, industrial, and infrastructure planning. In practice, energy efficiency should be prioritized when deciding on new investments, and it should be thoroughly examined in all phases, from generation, transmission, distribution, and end-use. Member States are encouraged to **implement the "Energy Efficiency First Principle" in national policies**, regulations, and practices, guided by recommendations and guidelines provided by the European Commission.
A Green Deal Industrial Plan for the Net-Zero Age *(Communication 2023/62 final)*	This communication outlines a **strategic approach for transforming European industry** to achieve climate neutrality by fostering innovation, sustainability, and competitiveness in a global market. The key goals highlighted in the document are: ▼ Increase technological development and installation of net-zero products and energy supply. ▼ Creation of new economic opportunities presented by the transition to a net-zero age. ▼ Strategic use of public funding to enhance competitiveness and resilience. ▼ Maintaining fair-trade practices. ▼ Upskilling and reskilling of the workforce. ▼ Simplification of the regulatory environment to facilitate investments and innovation in net-zero technologies.
Directive on the Sustainability Reporting Standards *(Delegated Regulation (EU) 2023/2772)*	The directive **establishes standards for companies to report on their sustainability**. It represents a complex directive that incorporates ESG principles and adapts them to the context of the European Union and its economy. As of 2025, large companies are required to begin tracking sustainability indicators, making the European Sustainability Reporting Standards (ESRS) a significant topic of interest among all industry sectors. Since the directive also applies to major companies and the entire supply chain, even from 3rd countries, it might represent a powerful tool to motivate industries in non-EU member states in the DR to implement energy-efficient technologies.

Many additional EU directives are partially relevant to the subject of energy efficiency, e.g., sector-specific directives such as the Energy Performance of Buildings Directive and Renewable Energy Directive. As outlined in Chapter 2.1, the energy efficiency efforts take back to the 1980s, and thus, many already functioning initiatives are already in place.

Worth mentioning is also the 2030 Climate target plan, which calls for urgent modernisation of the EU's industry, taking into consideration the impact of measures aiming at the transition to low-carbon economies, such as energy affordability and connectivity for the middle-class, vulnerable households and for people living in peripheral areas. This plan also promotes the need for policy updates by June 2021 to ensure overall inter-coherence. In particular, the following directives and regulations are mentioned:

- Emission Trading System Directive,
- Effort Sharing Regulation,
- The Land Use, Land Use Change and Forestry Regulation,
- CO_2 Emissions Performance Standards for Cars and Vans,
- Energy Efficiency Directive,
- Renewable Energy Directive (Directive 2018/2001)[8],
- Energy Taxation Directive.

[8] Directives 2010/31/EU – amended by Directive 2018/844/EU.

2.3.4 Implications of the Directive on Energy Efficiency for the Industry

The **practicality of the Energy Efficiency directive is that it refers to many other EU directives and regulations** and, thus, covers the implications for the industry in a complex way. The major activities industries should be conducted based on the directive are, among others, the following ones:

Conduct regular energy audits and implement energy management systems	Industries are required to conduct regular energy audits and implement energy management systems to identify and realize energy savings opportunities. These audits should comply with European or international standards, such as EN ISO 50001 (Energy Management Systems) or EN 16247-1 (Energy Audits).
Follow national energy-saving obligations	Industries may be affected by national energy savings obligations, which could include specific requirements for industrial sectors to achieve energy savings through various means, such as process improvements, equipment upgrades, or changes in operational practices.
Implications of the Directive on Energy Efficiency for the Industry	The directive encourages the adoption of innovative and sustainable technologies to improve energy efficiency. Industries should invest in advanced technologies and processes that reduce energy consumption and enhance efficiency.
Participate in energy efficiency obligation schemes	Industries can participate in energy efficiency obligation schemes, alternative policy measures, or both to contribute to the national energy savings targets. This participation may involve implementing energy-saving measures directly or contributing to national energy efficiency funds.
Implement special measures in case of industries with high energy consumption	The directive emphasizes the importance of energy efficiency measures in enterprises with high energy consumption. Industries falling within this category should prioritize energy efficiency improvements to comply with the directive's requirements.
Implement so called Best Available Techniques (BAT)	Industries should consider the implementation of BAT for energy efficiency, which can help reduce energy consumption and environmental impact. This approach aligns with the directive's goal of promoting efficient energy use across all sectors.
Comply with relevant reporting requirements	Certain sectors, such as data centres, are required to collect and report data relevant to their energy performance. While this specific requirement may not apply to all industries, the directive encourages transparency and regular reporting on energy efficiency efforts.
Compliance with environmental and climate standards	When designing energy efficiency measures, industries should ensure compliance with the Union's environmental and climate standards, aligning with the principle of 'do no significant harm' within the meaning of Regulation (EU) 2020/852.

It is worth mentioning that the **directive recognizes the financial burden of the transition to a low-carbon economy for EU industries**. In response, the **EU made available numerous funding schemes** to financially support all types of enterprises in their efforts for the green transition. Notable funding schemes for the gradual implementation of green measures represent the EUR 250 billion **Recovery and Resilience Facility** (centrepiece of **NextGenerationEU**) and numerous **Cohesion policies** worth EUR 100 billion for the green transition, such as the just **Transition Fund, European Structural and Investment Funds and Modernization Fund**. Given the complexity of funding for energy efficiency measures, a separate chapter is dedicated to the topic later in the study.

2.3.5 Energy Efficiency in Legislations of the countries of the DR

As outlined in previous chapters, **new energy efficiency measures were incorporated in the amended versions of existing EU directives and regulations, mainly in 2023**. Thus, their transposition in national legislation will take some time and can be expected throughout 2024 and 2024.

In general, **the countries of the DR take different approaches to incorporating energy efficiency measures into their legislation and other initiatives**. Some of them handle energy efficiency within Smart City strategies (Austria, Hungary), introduced or revised existing legislation (Bulgaria, Romania), or prepared elaborated strategies for energy transformation (Germany). Most countries focus on energy efficiency measures in diverse buildings (government buildings, public buildings such as schools or hospitals, factories, etc.) to support energy efficiency measures in the industry

The list below provides a very brief overview of the selected country-level measures aiming to enforce energy efficiency as mapped within the 12th edition of the European Energy Handbook for 2023 and 2024.

Table 4: *Selected country-level measures aiming to enforce energy efficiency in 2023 and 2024*

Country	Major country-level measures enforcing energy efficiency
Austria	Austria enforces energy efficiency through **comprehensive legislation** and **various smart city initiatives** focusing on energy efficiency in buildings and public utilities.
Bosnia and Herzegovina	Bosnia and Herzegovina **adopted the Law on energy efficiency in 2017,** which sets rules for making implementing plans to energy efficiency measures. In 2023, the legislation was harmonised by a set of reforms, targeting, among others, the achievement of energy efficiency across various sectors.
Bulgaria	Bulgaria's 2021 **Energy Efficiency Act** amendments implement alternative policy measures for energy efficiency targets, including Energy Efficiency Obligation Schemes (EEOS) for energy suppliers to achieve energy savings goals
Croatia	Croatia implements energy efficiency through **incentives and support schemes for high-efficiency cogeneration plants**. These schemes include support quotas and public tenders to encourage energy-efficient operations.
Czechia	Energy efficiency should be primarily enforced by implementing **projects financed from the Modernisation Fund**, established under the EU ETS Directive. In case of industry, special focus should be given to modernizing heat supply systems and energy-efficient installations.
Germany	The German Roadmap Energy Efficiency 2050 outlines various measures, including **tax breaks and subsidies for energy-efficient buildings**, to halve primary energy consumption by 2050 compared to 2008.
Hungary	Hungary has embraced **smart city strategies**, with major cities focusing on **refurbishing existing buildings to reduce energy use** and **setting up smart grids** to support public transport and utilities. Hungary also encourages green investments through **subsidised loan schemes**.
Moldova	Moldova's National Program aims to improve energy efficiency, with a target of increasing global energy consumption efficiency by 20% by 2020 and increasing the share of biofuels in total energy consumption.

Country	Major country-level measures enforcing energy efficiency
Montenegro	Montenegro has introduced various incentives to improve energy efficiency, including the **Green Economy Financing Facility**, which provides incentives to households that install green technologies. The government has also introduced a "cap and trade" system to limit CO_2 emissions.
Romania	Romania promotes energy efficiency by implementing the **Renewable Energy Act**, setting **targets for renewable sources in transport and encouraging biofuels**, with specific targets for energy reduction and efficient energy use.
Serbia	Serbia is focusing on renewable energy and energy efficiency, with incentives for **solar panels in homes**, supporting the energy transition to green energy sources, and **coordinated regional strategies to finance green energy projects**.
Slovakia	Energy efficiency measures of Slovakia include **promoting biofuels in transportation** and **adopting the Climate Change Package** with energy efficiency targets and mechanisms for energy-efficient initiatives
Slovenia	The **National Energy and Climate Plan** of Slovenia aims to improve energy efficiency with various targets and measures to **promote smart cities**, reduce fossil fuel incentives, and phase out coal by 2030.
Ukraine	Ukraine **adopted a new Law on Energy Efficiency** which introduces state policies for **energy efficiency, smart metering, and energy audits**. It also introduces Energy Service Company (ESCO) contracts, which encourage private investments in energy efficiency, with specific targets for energy reduction and fines for non-compliance.

Source: own elaboration based on data retrieved from the 12th edition of the European Energy Handbook for 2023 and 2024

In the next chapters, the role of regional governments will be discussed in greater detail, as many energy efficiency initiatives are also supported by RIS3 and other innovation or energy-related regional strategies. For some countries (e.g., Czechia), the quality of the governance of SME innovation activity of specific regions plays a vital role in the different levels of successful implementation of, among others, green technologies in the industry.

3. Energy Efficiency in the Industrial Sector

The data presented in the previous chapters highlight significant differences in the energy intensity of industrial bases across countries in the DR, with Austria, Czechia, and Romania identified as having the highest levels of industrial energy consumption. As automation and digitalisation of industrial processes continue to advance, combined with potential disruptions in energy supply, industrial energy efficiency becomes a critical issue for policymakers and businesses. Moreover, the sharp increases in energy prices have amplified the need to use energy more efficiently to minimise production costs.

While industrial energy efficiency measures need to be primarily implemented by the companies themselves, public institutions can support this process by offering various incentives. However, as this chapter will demonstrate, the **motivation of companies remains the key factor for success**. If companies do not perceive energy-efficient initiatives as beneficial, **government interventions can be seen as restrictive, inflexible, and imposed**—an outcome that should be avoided at all costs. Instead, a balanced approach is required, combining regulation with attractive public funding and other incentives.

Although the role of national governments is somewhat limited, this chapter discusses six relevant topics in promoting energy efficiency in industry. These topics represent a blend of **regulatory and cooperative measures with the government**, including implementation of the "Energy Efficiency First Principle", energy audits, and voluntary agreements between government and industry. The other set of topics focuses on **practical opportunities for increased investment to enhance energy efficiency**, such as the integration of advanced energy management technologies aligned with the Industry 4.0 strategy, the use of waste heat in industry, and innovations in energy accumulation, flexibility, and aggregation.

3.1 Implementation of Measures and Policies Arising from the "Energy Efficiency First Principle"

The Energy Efficiency First Principle (hereinafter as "EE1st") is a crucial strategy adopted by the European Union to prioritize energy efficiency in all energy-related decisions. It encourages stakeholders, from policymakers to industry leaders, to exhaust all energy-saving avenues before investing in new energy generation or supply infrastructure. This approach offers a multitude of benefits, including cost reduction, greenhouse gas emission mitigation, and enhanced energy security.

EE1st requires a fundamental shift in how we approach energy planning, investment, and operations. By integrating energy efficiency considerations at every stage, we can ensure the most cost-effective and environmentally sustainable solutions are prioritized. This often translates to adopting energy-efficient technologies, optimizing industrial processes, and implementing robust energy management systems. Crucially, aligning policies and regulations with EE1st is essential to drive long-term energy savings.

Recent Trends and Implementation

The European Union is actively strengthening its commitment to EE1st through policy initiatives like the European Green Deal and the updated Energy Efficiency Directive (EED). These initiatives mandate that member states implement measures to support EE1st, such as stricter energy performance standards, mandatory energy audits, and the integration of energy efficiency into national energy and climate plans.

Particularly **Germany** and **Austria** are leading the way in EE1st implementation. Germany's National Action Plan on Energy Efficiency (hereinafter as "NAPE") prioritizes **energy-saving measures**, including building renovations, industrial equipment upgrades, and the adoption of energy management systems compliant with the ISO 50001 standard. Austria has introduced **mandatory energy audits** for large companies and implemented energy performance standards for buildings.

Impact and Future Outlook

The European Commission estimates that widespread adoption of EE1st could lead to energy savings of up to 30% by 2030, significantly contributing to the EU's climate and energy goals. Further research from the European Council for an Energy-Efficient Economy (ECEEE) suggests that applying EE1st in key industrial sectors could reduce CO_2 emissions by up to 40% by 2040. Furthermore, industries already implementing EE1st have reported operating cost reductions of up to 20% and increased competitiveness.

Technological advancements are playing a key role in accelerating EE1st adoption. Digital technologies like advanced data analytics, IoT devices, and smart energy management systems enable real-time energy monitoring and optimization. This digitalization trend is vital for scaling EE1st, allowing industries to identify inefficiencies, predict energy needs, and dynamically adjust operations to minimize waste.

3.1.1 Implementation of the "Energy Efficiency First" principle in the DR

Further analysis examines the implementation of the **EE1st** in the DR, drawing on data collected from a questionnaire survey and an online workshop. The principle, which **prioritizes energy efficiency improvements** before **considering increases in energy supply**, is a **key component** of the **European Union's energy policy** and a crucial step towards achieving a sustainable energy future.

The findings reveal a **diverse landscape across the region**, with **varying levels of awareness, implementation, and integration** of the principle into national policies. While some countries like Bavaria and Austria demonstrate a proactive and comprehensive approach, others like Czechia and Slovakia are still in the early stages of transposition and implementation.

Key trends observed in the analysis include several factors that play a pivotal role in the implementation of the "Energy Efficiency First Principle" across countries in the DR. One major trend is the **significant implementation gap**. While the principle is widely acknowledged, its actual implementation varies considerably. For instance, in countries like Bavaria and Austria, energy efficiency measures are strongly integrated into national policies, supported by robust legal frameworks. However, countries such as Czechia and Slovenia are still in the process of transposing the relevant EU directives into national law, leading to gaps in implementation.

The importance of a solid legal framework is another key observation. A **strong legal framework is essential for driving the adoption of energy efficiency measures**, as it provides the necessary support and structure for implementation. Countries like Austria, Bavaria, and Moldova have developed comprehensive legal frameworks that help support energy efficiency initiatives, while others are still working on strengthening theirs.

Public procurement has emerged as a key driver of energy efficiency adoption. Integrating energy efficiency criteria into public procurement processes can stimulate market demand and drive innovation. For example, Baden-Württemberg has effectively integrated energy efficiency into its public procurement processes, setting a strong example for other regions to follow. This approach not only boosts demand for energy-efficient products but also encourages the development of innovative solutions in the market.

Financial incentives also play a crucial role in promoting energy efficiency investments. Countries like Austria and Slovakia demonstrate the effectiveness of subsidies and preferential loan rates in encouraging businesses to invest in energy efficiency. These financial incentives help reduce the upfront costs of energy-efficient technologies, making them more accessible to a broader range of companies, including SMEs.

There is also a clear **need for capacity building and support**, particularly for SMEs. Clear guidance and support are essential for helping businesses navigate the complexities of implementing energy efficiency measures. Czechia, for instance, has identified the need for such support, particularly for smaller companies, to help them overcome challenges related to the adoption of energy efficiency practices.

The analysis also highlights the **importance of regional cooperation** and knowledge sharing to accelerate progress towards a more energy-efficient DR. Best practices, such as those seen in Bavaria and Austria, offer valuable lessons that can be adapted and applied in other countries within the region. This could help bridge the gaps in implementation and foster a more coordinated approach to energy efficiency.

Selected country-specific observations are summarised in the overview below. The weaknesses presented by countries all point to the lack of strong national legal frameworks in which the EE1st would be well transposed. Nevertheless, it is expected that these will be addressed in the remaining years.

Country	Strengths	Weaknesses
Czechia	Actively working on transposition of the relevant EU Directive into its national energy laws	Lack of legal obligation and established practices
Baden-Württemberg	Strong legal framework, integrated into public procurement	
Slovenia	Proactively transposing the EU Directive by adding new obligations	
Slovakia	Incentivizing complex renovations in the building sector	Limited information on achievements and evolution within other sectors (incl. industry)
Bavaria	Proactive approach, dedicated programs and funding, integrated into public procurement	
Austria	Comprehensive legal framework, various support mechanisms in place	
Moldova	Comprehensive legal framework (Law No. 139/2018)	Limited information on practical implementation and impact

3.1.2 Good Practice Example in More Detail: Bavaria

In Bavaria, the transposition of the EE1st principle is more advanced compared to many other countries in the DR, making it an insightful case for examining current developments. The principle is already well integrated into several key areas, including public procurement, tailored funding schemes for industries, and investment projects led by the public sector.

The Public Sector Taking a Lead

Although the primary focus of this study is the industrial sector, the role of the public sector as a driver of ambitious change should not be overlooked. For example, when a municipality, such as the city of Munich, sets a strong example for other actors in the local economy, it can encourage similar actions within the industry. A recent case from Munich demonstrated that integrating smart controls and upgrading to LED streetlights resulted in energy consumption reductions of up to 50%. This showcases a compelling cost-cutting opportunity for local companies, which often face similar challenges, such as addressing energy inefficiencies in their facilities.

In many countries within the DR, large state-owned industrial enterprises present a significant opportunity to drive change. The strong influence of the state in these companies can be leveraged to integrate the EE1st principle into their transformation processes, setting a clear example for other private enterprises. Additionally, privately-owned corporations with transnational influence, such as the automotive group Volkswagen, offer another avenue for fostering change. Influenced by Germany's strong focus on sustainability, Volkswagen collaborates with governments in other countries, such as Slovakia, on various initiatives. This demonstrates that **robust cooperation between governments and leading companies can provide a solid foundation for implementing practical and impactful energy-efficient measures**.

Bayerisches Energieprogramm

While most regions and countries within the DR have developed strategies to meet the EU's energy transformation and efficiency objectives in their specific contexts, Bavaria's *Bayerisches Energieprogramm* stands out by outlining clear priorities and providing concrete examples of how energy efficiency measures should be implemented across all sectors. The strategy identifies key targets for the industrial sector, including:

- Promoting the development and implementation of innovative technologies to enhance energy efficiency in industrial processes.
- Investing in applied energy research to maintain Bavaria's technological leadership.
- Encouraging industries to leverage digital technologies to optimise energy management.
- Supporting industries in adopting renewable energy sources and improving energy flexibility.
- Modernising conventional power plants, particularly gas plants, to ensure flexible and low-emission energy supply.
- Advocating for reforms to stabilise energy costs for businesses, ensuring that industries remain competitive while transitioning to sustainable practices.

The practical implementation of this strategy is closely linked to funding schemes. For instance, in a large-scale project within the chemical industry, companies were required to demonstrate energy-saving measures before becoming eligible for support in adopting new energy technologies.

Developing region-specific energy efficiency strategies that are directly linked to public funding for companies is an effective way to allocate resources to areas where they are most needed at the regional level. Without a clear analysis of the actual needs of businesses, funding schemes often fail to attract interest, resulting in underutilisation. Initiatives like Bavaria's *Bayerisches Energieprogramm* demonstrate how such strategies can be successfully implemented, providing valuable inspiration for similar efforts in other regions.

Transposition of the EE1st into Public Procurement

A powerful tool for influencing the industrial sector is the integration of EE1st principles into national public procurement rules, as demonstrated at both the federal and state levels in Germany. The *Regulation of the State Government on the Awarding of Public Contracts in Baden-Württemberg* requires a detailed cost-benefit analysis that considers factors such as climate impact, energy consumption, and greenhouse gas emissions throughout the entire lifecycle of the service. This regulation mandates prioritising bids with the lowest environmental and climate impact over the lifecycle of products or services, with a strong focus on energy efficiency and environmental protection.

To ensure compliance, the procurement process can reference recognised quality standards, such as the European energy label, "Blue Angel," or equivalent certifications, and may require proof of environmental management systems like EMAS or ISO 14001 for contracts involving environmentally sensitive areas.

As demonstrated in Bavaria, changes to public procurement practices can significantly influence market demand for energy-efficient products and services. The **provisions outlined in the public procurement regulations of German states serve as valuable inspiration for incorporating EE1st principles into the national procurement frameworks** of other countries in the DR. Special provisions should be included, particularly for services and supplies with a substantial environmental impact, to ensure alignment with energy efficiency and sustainability goals.

3.1.3 General Observations and Recommendations

The analysis highlights a **notable disparity between EU and non-EU members**. While some EU countries like Bavaria and Austria have fully embraced the principle, integrating it into their legal frameworks and actively promoting it through various programs, others like the Czechia appear to be lagging, despite being bound by EU directives. This disparity suggests that **EU membership** alone **doesn't guarantee swift and effective implementation**. Interestingly, Moldova, a non-EU country, has demonstrated a proactive stance by establishing a comprehensive legal framework for energy efficiency, aligning itself with EU energy policies. However, the lack of concrete examples and reported results raises questions about the effectiveness of implementation on the ground. This contrast highlights the **crucial role** of **not only establishing policies** but also **actively enforcing** them and providing necessary support for successful implementation across all countries in the region, regardless of their EU membership status. It underscores the **need for regional cooperation and knowledge** sharing to bridge the gap and ensure a more unified and effective approach towards energy efficiency in the DR.

It's crucial to recognize the **varying levels of engagement** observed among the countries in this analysis, with some providing detailed responses and actively participating in the workshop, while others offered minimal information or did not respond at all. This difference in engagement itself is a valuable insight and should be considered when **developing strategies for promoting the EE1st principle** in the DR. Here are some further considerations and recommendations based on this observation:

1. **Tailored engagement strategies:** It's crucial to recognize that countries are at different stages in their energy efficiency journeys. Therefore, a one-size-fits-all approach may not be effective. Tailored engagement strategies should be developed, taking into account each country's specific context, capacity, and level of commitment.
2. **Capacity building and technical assistance:** For countries with limited capacity or engagement, providing targeted capacity building and technical assistance can be instrumental in driving progress. This could include training programs, workshops, and knowledge sharing platforms to enhance understanding of the "Energy Efficiency First Principle" and its implementation.
3. **Peer-to-peer learning and best practice sharing:** Facilitating peer-to-peer learning and best practice sharing between countries in the region can be a powerful way to encourage knowledge transfer and inspire action. Countries like Bavaria and Austria, which have demonstrated strong leadership in energy efficiency, can play a crucial role in mentoring and supporting others.
4. **Targeted outreach to non-responsive countries:** For countries that did not respond to the questionnaire or participate in the workshop, it's important to proactively reach out and understand the reasons for their lack of engagement. This can help identify potential barriers and develop strategies to address them.
5. **Incentivizing participation:** Exploring ways to incentivize participation in future initiatives, such as providing financial support or recognition for best practices, can encourage greater engagement and commitment.
6. **Leveraging regional platforms:** Platforms like the EUSDR can be leveraged to foster collaboration, knowledge sharing, and capacity building on energy efficiency.
7. **Public awareness campaigns:** Raising public awareness about the benefits of energy efficiency can create broader support for policy implementation and encourage individual action.
8. **Monitoring and evaluation:** Establishing a robust monitoring and evaluation framework can help track progress, identify challenges, and inform future policy development.

By addressing the varying levels of engagement and tailoring strategies accordingly, the DR can move towards a **more cohesive and effective approach to implementing the "Energy Efficiency First Principle"** and achieving its **energy efficiency goals.**

3.2 Efficiency of Energy Audits in Industry

The EED represents a significant milestone in establishing a legal framework for energy audits across the EU. It mandates regular energy audits for large enterprises, encouraging the industrial sector to assess energy use and identify areas for improvement. The subsequent amendment to the Directive introduced additional obligations and recommendations, particularly emphasizing the adoption of certified energy management systems, such as ISO 50001. For industries with energy consumption exceeding 7.5 gigawatt hours (GWh) per year—typically highly energy-intensive sectors like steel and metal production, the chemical and petrochemical industry, automotive manufacturing, heavy industry, or data centres—these systems are now mandatory.

Although energy audits became compulsory for most large enterprises in 2015, public authorities have noted inconsistencies in both the quality of audits and the enforceability of their findings. Despite the robust legislative framework established by the EED, the implementation of energy audits varies considerably across EU Member States and industries.

Several factors contribute to this uneven landscape:

- **Variable expertise and audit depth:** Countries such as Germany and Denmark have established strong frameworks for energy audits, with well-trained professionals, standardized procedures, and detailed reports. In contrast, some countries face a shortage of experienced auditors and lack rigorous national standards. In these cases, energy audits are often seen as a mere compliance exercise rather than an opportunity to improve energy efficiency. This "box-ticking" approach results in audits that meet legal requirements but offer little depth or actionable insight.
- **Resource limitations:** Large enterprises typically allocate sufficient resources to establish effective energy management systems and conduct high-quality energy audits, which identify further opportunities for improvement. Small and medium-sized enterprises (SMEs), however, often lack the resources and motivation to conduct thorough audits, instead focusing on fulfilling minimum legal requirements, sometimes for marketing purposes rather than environmental or energy-saving goals.
- **Failure to implement recommendations:** Companies frequently delay or fail to act on audit recommendations, especially when significant investments are required. National public authorities across Europe must consider the varying financial capacities of companies and strike a balance to avoid overly restrictive regulations. While some countries impose fines or penalties for non-compliance, others take a more lenient approach and have weaker systems for ensuring adherence to audit findings.
- **Sectoral differences:** Energy-intensive sectors tend to take energy audits more seriously because the potential benefits of improved energy efficiency far outweigh the costs. Consequently, the quality and enforceability of energy audits vary significantly across industries, depending on the cost-benefit ratio.

These differentiating factors contribute to the different levels of quality and enforceability of energy audits across the DR.

3.2.1 How do Governments of the States of the DR Enforce Energy Audits?

In most countries within the DR, **energy audits have become mandatory for large companies**, including non-EU member states such as Serbia and Moldova, as part of efforts to align national legislation with the Energy Efficiency Directive (EED). Typically, energy auditors are required to be certified and registered with the relevant national authority to ensure consistency in audits and to regularly verify the competency of auditors. However, based on observations gathered from energy experts across several countries in the region, this has proven insufficient in guaranteeing the consistent quality of energy audits. Instead, **audits are often perceived as a compulsory activity** rather than a genuine opportunity to enhance energy management systems. It has been noted that companies generally do not engage significantly with government authorities to facilitate the monitoring of the implementation of recommendations related to their energy management systems.

The **Austrian government addressed the issue of standardisation and enforceability of energy audits in 2017**, organising dialogues involving responsible ministries and industry stakeholders to discuss possible amendments to the Federal Energy Efficiency Act. The national energy regulator, E-Control, which oversees the enforcement of the Act, introduced detailed provisions on the format, structure, and layout of standardised short reports. These reports form a minimum requirement for regular audits and management systems every four years. While the implementation of audit recommendations is not legally mandated, each subsequent report includes an **evaluation of the implementation of prior recommendations**, with unsatisfactory assessments potentially resulting in an administrative penalty of up to 20,000 EUR by the competent district authority.

To improve the quality of energy audits, **Slovenia has also recently amended its relevant legislation**, introducing a requirement for companies to p**resent a concrete action plan based on audit recommendations alongside the audit report**. This action plan must ensure technical and economic feasibility, and it will be incorporated into companies' annual public reports. The national energy agency will maintain records of companies required to implement energy audits and management systems, submitting an annual report to the relevant ministry to highlight cases of non-compliance. This approach not only emphasises regular oversight but also aims to continuously improve the quality of energy management systems.

In Bavaria, the government has sought to incentivise small and medium-sized enterprises (SMEs) to voluntarily conduct energy audits by offering financial support. **The Bavarian Energy Programme provides additional financial incentives for the implementation of energy-saving measures**, with a focus on follow-up and execution, particularly when government involvement is present. Energy audits and the implementation of their recommendations are also highlighted as key elements of Bavaria's broader energy and climate objectives, as outlined in the Bavarian Climate Programme 2050.

These examples from Austria, Slovenia, and Bavaria offer potential insights for national governments that currently do not monitor the implementation of audit recommendations (e.g., Slovakia) or face challenges in engaging with companies (e.g., Czechia). A particularly **interesting case is Moldova**, which, in its efforts to align with EU legislation, has strengthened its National Centre for Sustainable Energy. This institution manages a pool of energy auditors specialising in buildings, industry, and transport. While energy audits are less frequently requested by industry due to Moldova's smaller industrial base, the government's proactive approach, including the introduction of a national support mechanism with banks offering favourable financial products for companies implementing energy efficiency measures, sets a valuable example.

In summary, **energy audits have the potential to serve as a powerful tool for governments to promote energy efficiency measures**. However, the "ideal" implementation model is still evolving, and governments must navigate varying levels of corporate motivation towards decarbonisation. Realistic expectations and sufficient incentives, particularly for SMEs that often lack the necessary financial resources, are crucial for encouraging investment in energy-saving technologies.

It is worth noting that a potentially significant driver for increased interest from SMEs in energy audits and energy management systems could be the new EU Corporate Sustainability Reporting Directive (CSRD), as referenced in Chapter 2.3.3. In addition to large enterprises, listed SMEs will also be required to comply with the Directive. Indirectly, all companies within many supply chains will be affected, as the Directive mandates that large companies report on the environmental performance of their suppliers, including those outside the EU. As such, this new regulation can be seen as a powerful tool for governments to encourage more transparent reporting on selected indicators related to energy efficiency.

Governments could also leverage these new requirements to promote the voluntary adoption of energy audits in 2025 and 2026, positioning them as a valuable tool for pre-assessing compliance with future regulations that may be applied to a broader range of companies than those currently targeted by the CSRD.

3.2.2 Good Practice Example in More Detail: Austria

In Austria, energy audits are governed by the Austrian Federal Energy Efficiency Act (see § 41–43 and Annex 1 of the Bundes-Energieeffizienzgesetz), which transposes EU directives into national law. Obliged entities are primarily large enterprises, in other words, all companies that meet the EU criteria for SMEs[9]. Such enterprises must conduct an energy audit at least every four years or implement an equivalent energy or environmental management system that aligns with recognized European or international standards.

Key Requirements of Energy Audits

Energy audits in Austria must comply with the **minimum specifications** set out in Annex 1 of the Federal Energy Efficiency Act. These include:

- **General Company Overview:** A description of the enterprise and its activities.
- **Identification of Major Energy Uses:** Analysis of key energy-consuming areas such as buildings, production processes, and transportation. This includes identifying main energy conversion systems, consumption drivers, and performance indicators while considering waste heat potential.
- **Proposed Measures:** Recommendations for reducing energy consumption, improving energy efficiency, and adopting renewable energy sources, supported by detailed calculations and potential savings.
- **Monitoring Systems:** Evaluation of existing or proposed systems for energy monitoring.

Audits must use current, verifiable data and, where feasible, include dynamic profitability calculations. They should be proportionate and representative, offering a reliable overview of the company's energy performance and opportunities for improvement.

A learning opportunity from the Austrian example is to **define a clear list of minimum requirements for energy audits**. Other countries, where this is not the case, should consider following such an approach to increase transparency and clarity of what is expected from the companies to regularly monitor and report. For this purpose, Annex I to the Austrian Federal Energy Efficiency Law can be consulted.

Standards and Auditors

Energy audits must adhere to relevant European or international standards. Only qualified energy auditors, verified by E-Control (Austria’s national energy regulator), may conduct these audits. E-Control maintains a registry of certified auditors, who must requalify every five years to ensure compliance with updated standards. The practice appears to be followed by most other countries of the DR which also have their authorities responsible for certifying and regularly updating a list of energy auditors (e.g., Moldova). A potential topic for further investigation is to analyse what are the measures in place to ensure that the certified energy auditors adhere to high-quality standards during the certification process. However, **it does not seem that Austria would impose stricter rules on energy auditors than other** countries which call for a tailored approach respecting the local culture and business practices.

9 Fewer than 250 employees, and either an annual turnover under €50 million or a balance sheet total under €43 million.

Short Reports on Energy Audits

Along with the execution of complex energy audits, the Austrian government developed a standardised "Short Report" which has to be submitted within the four-year cycle to E-control - the relevant regulatory authority. These reports were designed to reduce bureaucratic effort and detail compliance with statutory requirements. E-Control generally specifies the format and structure of these submissions focusing on key findings, compliance and legal requirements. If an energy audit is not conducted or reported, penalties of up to €50,000 may apply.

The development of the standardised Short Report, now **implemented through an online web tool**, serves as an **exemplary approach** to efficiently gather critical information from a complex process such as an energy audit. This tool facilitates the collection of data on selected energy performance indicators, enabling the monitoring of specific quantitative metrics from a high-level perspective and allowing comparisons across companies.

The creation of such monitoring tools represents a **valuable opportunity to enhance data collection and oversight**. However, it is important to note that not all countries demonstrate the same level of efficiency in digitising their administrative processes within the EU framework. For example, some nations, such as Czechia, lag behind other European countries in this regard. Consequently, the development of similar tools may not always be prioritised politically.

Implementation and Monitoring

While there is no direct obligation to implement audit recommendations under the Federal Energy Efficiency Act, enterprises must explain non-implementation if measures were not adopted, **particularly if prior audits indicated cost-effective solutions**. In addition, compliance is often required as a condition to participate in diverse public funding schemes.

An interesting aspect of the Austrian approach is the integration of evaluations on the implementation of recommendations from previous energy audits, which form a mandatory part of each audit conducted every four years. Significant shortcomings identified during these evaluations can indirectly result in financial penalties, as a successful audit requires a credible assessment of efforts made during the previous cycle to improve energy efficiency.

While many countries where energy audits are mandatory for large companies likely include an evaluation of the implementation of recommendations from previous audits, the Austrian example underscores the **importance of conducting such ex-post assessments rigorously**. These evaluations provide valuable insights into whether companies take audits seriously and implement the recommended measures. Other DR States could consider reviewing and, if necessary, enhancing their current evaluation practices. Additionally, responsible authorities, such as E-Control in Austria, could place greater emphasis on **reviewing the findings of these evaluations to gain a more comprehensive understanding of the effectiveness of energy audits in their country**.

Austria's energy audit framework prioritizes standardization, compliance with EU directives, and efficient reporting. This ensures effective energy performance monitoring while balancing regulatory oversight with reduced administrative burdens.

3.2.3 Key Take-Aways

On a more generalised level, the following set of recommendations should be considered on top of the concrete practices presented for Austria in the previous chapter:

- **Strengthen the institutional background:** Improve the quality of institutions responsible for implementing national legislation that requires energy audits.
- **Standardise the reporting process:** Ensure audit reports contain a minimum set of standardised information about the checks conducted, making it easier to compare results. Introduce a platform for entering monitoring data to better supervise the progress of implementing recommendations from energy audits.
- **Increase focus on evaluating implemented measures:** Following Austria's example, energy audits should critically assess the state of recommendation implementation. Financial consequences should be tied to negative evaluations where recommendations are not properly implemented.
- **Enhance educational activities for companies:** Increase awareness about the benefits of conducting energy audits. Develop a strategy to rebrand energy audits to highlight their importance and potential benefits.
- **Improve auditor training and certification standards:** Ensure higher-quality assessments by strengthening auditor training. Provide opportunities for cross-national collaboration and training and promote success stories to motivate engagement.
- **Link public financial support to energy audits or Energy Management Systems (EMS):** Public funding should be tied to the requirement of conducting energy audits or maintaining a functioning EMS.

3.3 Voluntary Agreements with Industry

Voluntary agreements are a mechanism used to promote energy efficiency, particularly in industrial sectors. These agreements are typically established between the government and companies or industry associations, aiming to encourage participants to reduce energy consumption and improve efficiency without the imposition of mandatory regulations. In EU member states, voluntary agreements complement mandatory policies such as those arising from the Energy Efficiency Directive (EED), which, as previously mentioned, primarily applies to large enterprises.

Voluntary agreements offer a more flexible and less rigid approach to energy audits, as discussed in Chapter 3.2, allowing businesses to choose the most cost-effective methods for meeting their energy-saving commitments. To incentivise enterprises to participate in these agreements, governments often offer various benefits in return.

The strongest motivational tools available to governments are financial incentives, particularly tax benefits, public grants, and other financial instruments that support business investments. National governments can also play a more active role by fostering a network of participating companies and organizing conferences, workshops, low-carbon technology fairs, and other networking events that may generate valuable business opportunities.

The following paragraphs describe the current state across several states in the DR, their practices and recommendations for the next period to increase the popularity of voluntary agreements among SMEs.

3.3.1 Voluntary Agreements with Industry in the DR

Based on collected data, **voluntary agreements are predominantly promoted by governments of EU member states within the DR**, as a result of following the applicable recommendations of the EED. Remarkable success has been observed in the German states of Baden-Württemberg and Bavaria, where hundreds of agreements have already been signed across a diverse range of companies. These include enterprises widely recognized for their active commitment to sustainable business practices, often the recipients of multiple awards in this field. A **key driver of this success may be the strong culture among German companies of understanding their social and environmental impact**, coupled with a motivation to engage positively with both. As a result, minimal effort is required to encourage companies to approach government bodies to enter into voluntary agreements.

In contrast, **other countries have not yet achieved comparable success**. In Czechia, only a limited number of voluntary agreements have been signed, primarily with large, publicly owned or energy companies. Similarly, in Slovakia, voluntary agreements are frequently established with subsidiaries of foreign-owned firms, such as Volkswagen Slovakia, with which the government has established a cooperative framework to support the implementation of energy efficiency measures. As in Czechia, the majority of participating companies are energy-sector entities.

These observations suggest that most countries in the DR face challenges in concluding voluntary agreements with a broader range of companies, thus limiting the potential of this instrument. A contributing factor may be the general perception across the region of decarbonization activities as mandatory obligations required to meet national and EU regulations. Additionally, many companies view such agreements as an additional administrative burden they prefer to avoid.

3.3.2 Good Practice Examples in More Detail: Bavaria and Baden-Württemberg

Within the DR, Bavaria and Baden-Württemberg serve as exemplary cases, reporting hundreds of voluntary agreements concluded with companies of all sizes, from SMEs to large corporations. While the motivation and awareness of companies regarding their environmental impact are generally higher compared to firms in other states of the DR, the ongoing **efforts of the respective local governments and public institutions should not be overlooked**. These should be regarded as potential sources of inspiration for reconsidering approaches to fostering voluntary agreements with industry.

Adoption of a Tailored Approach

A distinctive approach observed in Baden-Württemberg is the effort to **tailor objectives and targets to each company**, taking into account its financial capacity and level of experience in implementing energy-efficient measures. In other words, companies with little or no experience are not expected to demonstrate the same level of proactivity as those that have already developed such expertise. To prevent stagnation within a specific company, objectives are regularly reviewed, with new targets consistently set to be slightly ambitious.

Adopting a more tailored approach to collaborating with a broader range of companies and defining company-specific energy efficiency targets could help engage more sceptical firms, as the objectives outlined in a voluntary agreement would align with their current capacities. For SMEs, it is particularly crucial to maintain realistic expectations regarding what can be achieved and to offset the additional costs they may incur from implementing measures they might otherwise avoid. This could be achieved through grants or low-interest loans provided by national development banks.

WIN-Charta / KLIMAWIN in Baden- Württemberg vs. Voluntary Agreements in Czechia

Introduced in 2014, the WIN-Charta served as a structured sustainability framework for businesses in Baden-Württemberg. Unlike the traditional “voluntary agreements” seen in Czechia, the State does not have a directly comparable mechanism. Instead, the WIN-Charta, now replaced by KLIMAWIN to better align with the updated requirements of the CSR Directive, operates as a voluntary platform for companies committed to advancing sustainability and climate action within the private sector.

KLIMAWIN represents a more structured and transparent approach compared, for example, to the Czech version of voluntary arrangements, which tend to be more general, with companies committing to broad environmental or economic goals without detailed frameworks. In contrast, KLIMAWIN provides clear guidelines and a reporting system for implementing climate protection and sustainable practices. While participation remains voluntary, it involves specific commitments, such as adhering to predefined sustainability principles, submitting annual progress reports, and supporting local non-profit projects.

The platform, which differs from energy audits by being based on a voluntary decision for each company to join, offers a valuable opportunity to provide a supportive space for businesses to begin their journey towards greater sustainability. By aligning its reporting principles with the latest versions of the EU's CSR Directive, it also helps prepare large companies for the mandatory reporting requirements set to take effect in 2025. For SMEs, the platform offers a concrete and more flexible approach compared to energy audits, along with the benefits of joining a network of environmentally and socially responsible companies. Therefore, **KLIMAWIN serves as both an excellent source of inspiration and a viable alternative to the more traditional method of signing broad voluntary agreements.** However, it does require significantly more effort from the managing institutions, as establishing such a platform necessitates a dedicated team of experts.

Creation of a Strong Network of Signatory Companies

The examples of Bavaria and Baden-Württemberg also underline the importance of building a strong network of companies with similar targets. Linking the signing of a voluntary agreement as an opener to a network of other interesting companies adds the dimension of acquiring new contacts for business development which is in the interest of most small companies. E.g., small manufacturers could even benefit from their increased visibility as environmentally conscious potential suppliers for larger companies which will need to ensure compliance with the EU's CSR.

Organising of venues and workshops for companies joining the different versions of voluntary initiatives to foster energy efficiency therefore represents an opportunity also in the context of other countries of the DR. The ones, struggling to get more signatory companies should even consider organising workshops and presentations to ease the "onboarding" of new firms. The practices of the respective managing institutions in Bavaria and Baden-Württemberg represent a good inspiration for potential realisation of similar activities.

Promoting Good Practices of Exemplary Companies

It is also worth noting the initiatives aimed at promoting best practices among companies in both states. While not directly organised by the respective platforms, the increased visibility of companies through sustainability awards can help motivate those seeking to enhance their overall visibility. However, such activities should be carefully planned to avoid the risk of creating a platform enabling "greenwashing" practices for companies.

A more viable option would be for the managing institutions to support, and ideally oversee, the creation of brochures promoting concrete examples of good practices. For example, in Baden-Württemberg, a brochure is produced each year featuring a hundred successful projects, often selected from a pool of companies that have received public funding to support such initiatives (see the latest version here). Disseminating these brochures among companies can help reach a broader audience, including those who are particularly sceptical about industrial sustainability. Since many countries within the DR have their own programmes to support SMEs in implementing "green" technologies, these programmes should facilitate the regular monitoring and identification of good practices worth sharing. In cases where sufficient examples are not available within one country across multiple sectors, cases from other states can be sourced. To the best knowledge of the authors of this study, such initiatives are already being carried out at the Interreg DR level, with expected results in the coming years (for more information, see the SMEenergy project's websites). An important consideration for such materials is to ensure that these documents are provided in the national language of the respective country.

In summary, the examples of strong commitment to creating useful and practical voluntary platforms, benefiting both the government and the private sector, as demonstrated in Bavaria and Baden-Württemberg, appear to be a key differentiating factor. This approach should be explored by the managing institutions of other countries in the DR as well.

3.3.3 Key Take-Aways

National governments could enhance voluntary agreements through several targeted actions:

1. **Greater emphasis on flexibility:** Emphasizing the flexible nature of voluntary agreements can attract more sceptical companies. However, it is crucial to ensure true flexibility, allowing for contract modifications as needed. For instance, the Bavarian government collaborates with relevant associations to ensure agreements are practical and industry-aligned.
2. **Revised benefit packages:** Reviewing the benefits offered to companies when entering into voluntary agreements is key. These benefits could include access to additional funding for energy efficiency measures, specialized know-how, or other incentives tailored to each country's circumstances. In Slovenia, for example, the availability of supplementary funding is a significant motivator for companies to participate in voluntary agreements.
3. **Strengthening the network of signatories**: Building a robust network of signatories through events, conferences, and workshops fosters knowledge-sharing and best practices. Bavaria has demonstrated success in this regard, offering opportunities for companies to learn from peers who have successfully implemented voluntary agreements.

To achieve these improvements, governments will need to allocate dedicated human resources to promote the attractiveness of voluntary agreements and establish working groups with representatives from relevant ministries, support institutions, and business associations to create tailored, country-specific strategies. As with energy audits, strengthening the institutions responsible for facilitating voluntary agreements will be key to expanding this initiative.

An enhancement to the current approach among DR states could be to form voluntary agreements with specific industrial sectors, represented by their respective associations, rather than setting targets with individual companies. This would enable sector-specific tailoring of agreements to match industry capacities and establish realistic measures and targets. Each country should prioritize sectors with high energy consumption, as discussed in Chapter 2.1.4. Greater collaboration with unions and industry associations could also allow governments to reach a wider range of companies, particularly those affiliated with such organizations.

For non-EU countries, voluntary agreements with industry represent an attractive opportunity to align their vision on industrial energy efficiency with the business sector. The EUSDR network offers valuable opportunities to gain insights and learn from the practices of other regions and countries within the Danube Area.

3.4 Development of Smart Grids and Use of Advanced Technologies in View of the Industry 4.0 Strategy

The core impact of the Industry 4.0 strategy on industrial energy efficiency lies in leveraging modern technologies powered by AI and IoT to optimise energy resource use. However, in many countries within the DR, the essential prerequisites for implementing such advanced technologies—particularly the modernisation of energy networks through the introduction of intelligent components—have yet to be fully established. Since the 2010s, EU member states have made varying progress in deploying smarter grids and meters, resulting in different levels of advanced technology adoption for energy management.

Smart grids are **modernized electricity networks that utilize two-way communication** and control capabilities to optimize energy transmission, distribution, and consumption. In the European Union, smart grids are viewed as a critical component of the transition to a sustainable and secure energy system. The EU's approach to smart grids is shaped by several factors, including its commitment to decarbonization, the need for enhanced energy security, and the desire to increase energy efficiency and empower consumers.

Key objectives of smart grids in the EU include:

- Integrating large shares of renewable energy sources, such as wind and solar power, into the electricity grid.
- Improving grid flexibility and resilience to mitigate the impact of potential disruptions and reduce dependence on energy imports.
- Optimizing grid operations to reduce energy losses and improve overall system efficiency.
- Empowering consumers to actively participate in the energy market by providing them with real-time information on energy consumption and pricing.

To facilitate the development and deployment of smart grids, the EU has adopted several legislative measures, including the Third Energy Package and the Energy Efficiency Directive. These measures provide a framework for the modernization of electricity infrastructure, the integration of renewable energy sources, and the promotion of demand-side management and smart metering systems.

However, the implementation of smart grids in the EU also faces several challenges, including the need for significant investments, the complexity of integrating diverse technologies and systems, and the importance of addressing cybersecurity and data privacy concerns. Overcoming these challenges will require continued efforts from policymakers, industry stakeholders, and consumers alike.

The global push towards smart grids reflects a growing recognition of their potential to enhance energy efficiency, integrate renewable energy sources, and improve grid reliability. However, the specific drivers and approaches to smart grid implementation vary significantly across different regions. In the European Union, a unique set of factors shapes the development and deployment of these advanced energy networks.

Unlike the fragmented approach often observed in the United States, the European Union benefits from a highly interconnected electricity grid, renowned for its robustness and reliability. This interconnectedness, facilitated by extensive cross-border transmission infrastructure, allows for efficient balancing of supply and demand across the continent. This system, due to its interconnection of individual countries' energy systems, is one of the most robust in the world and is characterized by its extreme reliability. This inherent strength of the European grid influences the priorities and strategies for smart grid implementation.

While microgrids, particularly those incorporating battery storage, have gained traction in other regions as a means to enhance local resilience and address grid reliability concerns, their role in the European context is less pronounced. The European grid's ability to compensate for fluctuations in renewable energy generation through cross-border electricity flows and diverse generation sources reduces the urgency for widespread microgrid deployment. For these reasons, community microgrids are not as widespread in Europe as elsewhere in the world and, in terms of installed capacity, occupy a minority share on a global scale.

Nevertheless, the European Union recognizes the critical role of smart grids in achieving its ambitious climate and energy goals. The European Commission actively promotes smart grid development through legislative frameworks, financial support, and research initiatives. Key drivers for smart grid implementation in the EU include:

- **Decarbonization:** Smart grids are essential for integrating large shares of renewable energy sources, such as wind and solar power, which are inherently intermittent. They enable efficient management of variable generation, balancing supply and demand, and reducing reliance on fossil fuels.
- **Energy security:** By enhancing grid flexibility and resilience, smart grids contribute to energy security by reducing dependence on energy imports and mitigating the impact of potential disruptions.
- **Increased efficiency:** Smart grids optimize grid operations, reduce energy losses, and improve overall system efficiency, leading to cost savings and environmental benefits.
- **Consumer empowerment:** Smart grids enable active consumer participation in the energy market by providing real-time information on energy consumption and pricing, facilitating demand response programs, and enabling the integration of distributed energy resources.

While the interconnected nature of the European grid may reduce the immediate need for widespread microgrid deployment, the EU recognizes the value of energy storage, including battery storage, in supporting the transition to a low-carbon energy system. Within the framework of the EU's long-term climate policy, energy storage is one of the key elements for securing electricity supplies as part of the transition to a carbon-free economy. Battery storage, particularly lithium-ion batteries, is expected to play an increasingly important role in balancing renewable energy generation, providing grid stability, and ensuring energy security.

While the European grid is robust, the shift towards renewable energy sources necessitates a greater emphasis on energy storage to maintain grid stability. The intermittent nature of renewable generation, such as solar and wind power, requires robust energy storage solutions to ensure a continuous and reliable energy supply. This need is further amplified by the EU's ambitious decarbonization targets, which entail a significant increase in renewable energy penetration. As the share of renewable energy grows, so too will the importance of energy storage in managing fluctuations in generation and maintaining grid balance.

3.4.1 Smart Grids in the DR

A key indicator for quickly assessing the current state is the extent of smart metering deployment, which is essential for gathering data across all end-user types. According to the DSO Observatory 2022 study (Meletiou et al., 2022), Denmark, Estonia, Finland, Italy, Spain, and Sweden are pioneers in smart metering, achieving nearly 100% coverage. In the DR, Austria and Slovenia stand out as EU member states with notable progress. Additionally, the data presented for countries across the DR indicate significant advancements in smart meter adoption in Montenegro.

Table 5: Share of Smart Electricity Meter Adoption Across the States of the DR

Share of Smart Electricity Meter Adoption Across the States of the DR		
Country	**% share of smart meters installed**	**Target year, when 80% of the consumers will be equipped with smart meters**
Germany	0-10%	*No information provided*
Ukraine	11-20%	*No information provided*
Austria	51-60%	Expected by 2024
Czechia	0-10%	Expected by 2029
Romania	21-30%	Expected after 2024
Hungary	0-10%	*No information provided*
Slovakia	21-30%	Initially expected by 2020
Bulgaria	0-10%	Negative Cost-Benefit Analysis
Serbia	11-20%	Expected by 2026
Slovenia	91-100%	Target already met by 2020
Croatia	11-20%	Negative Cost-Benefit Analysis
Bosnia and Herzegovina	No concrete data are publicly available	*No information provided*
Moldova	Pilot programmes to install smart meters are carried out	Expected by 2029
Montenegro	91-100%	Target already met

Source: own elaboration based on various sources (DSO observatory 2022 and national strategies)

The comparatively low rate of smart meter adoption in the DR is largely due to a historically reduced need for such infrastructure to maintain the stability of distribution networks, unlike in other global regions. The demand for smart grids has only emerged in recent years, driven by the rise of community energy initiatives, increased use of renewable energy sources, and advancements in AI and IoT that simplify energy management.

As illustrated in the table above, projects focused on modernizing transmission networks are already underway. A notable example of cross-country collaboration in this area is the ACON Smart Grids project, co-financed by the EU, which involves cooperation among Czechia, Slovakia, and partially Hungary. This cross-border initiative between Slovakia and Czechia aims to modernize and integrate electricity grids, enhancing energy efficiency and reliability. By implementing smart grid technologies, the project seeks to improve energy transmission, reduce operational costs, and foster a sustainable, interconnected energy network across these countries.

Another key factor will be the establishment of data centres, which are essential for processing, analysing, and managing the vast amounts of real-time data generated by smart grids. This integration enables more adaptive grid operations, enhancing the management of renewable energy sources, reducing outages, and supporting consumer demand through insights and predictive maintenance strategies.

The development of Smart Grids across the DR will bring another opportunity for further implementation of energy efficiency measures in industry which cannot be currently fully explored due to the lack of the enabling infrastructure.

3.4.2 Good Practice Examples in More Detail: Use of Advanced Technologies in Industry

The following examples highlight how even traditional sectors in Baden-Württemberg, Germany, are incorporating modern technologies and principles aligned with the goals of smart grids. These initiatives focus on decentralizing energy production, managing energy flows efficiently, and optimizing consumption, all of which contribute to a sustainable and flexible energy system.

Food industry – Diefenbach Bakery

This project focuses on a traditional bakery that has taken a comprehensive approach to energy efficiency. By implementing a range of measures, they aim to reduce their environmental impact while improving productivity and product quality.

	Goals	Reduce CO_2 emissions, energy costs, and increase product quality
	Implemented measures	▼ Vacuum conditioning for baking (reduces energy consumption and baking time). ▼ Utilization of waste heat from ovens, steam, and compressors for water heating and space heating. ▼ Replacement of an old dishwasher with a new, more energy-efficient one. ▼ Peak load management system (time shifting of consumption).
	Planned measures	▼ Installation of a rooftop photovoltaic system with a capacity of 84 kWp for maximum self-consumption (98.8%). ▼ Ultrasonic fogging (reduces energy consumption compared to conventional fogging).
	Estimated savings	▼ <u>Total Energy Savings:</u> 372 MWh/year reduction in electricity consumption and 137 MWh/year reduction in natural gas consumption. ▼ <u>Breakdown of Savings:</u> Vacuum conditioning contributes 273 MWh/year of electricity savings and 89 MWh/year of natural gas savings. The photovoltaic system, dishwasher replacement, ultrasonic nebulizer, and waste heat utilization account for the remaining 99 MWh/year of electricity and 48 MWh/year of natural gas savings. ▼ <u>Additional Benefits:</u> Lower energy costs, potential CO2 emissions reduction by 185 tons/year, increased productivity through efficient processes, and maintained or improved product quality.
	Alignment with Smart grid principles	▼ Decentralized energy production (photovoltaics). ▼ Efficient energy management (waste heat utilization, consumption optimization). ▼ Awareness of efficient grid utilization (peak load management).
	Proposed additions	▼ Smart meters for real-time monitoring of energy consumption and production. ▼ System for dynamic consumption control depending on the current grid situation. ▼ Two-way communication with the distribution grid.

Metalworking industry (foundry) – MEGU Metallguss Obermeier GmbH

This project showcases a small foundry that has embraced modern technology to improve its energy efficiency and reduce its environmental footprint. By integrating solar energy and optimizing its processes, the company aims to become a model for sustainable manufacturing.

	Goals	Build an energy-efficient foundry
	Implemented measures	▼ Installation of a photovoltaic power plant to power an electric melting furnace. ▼ Optimization of the melting process according to the availability of solar energy (shifting melting by 2-3 hours). ▼ Recovery of waste heat from melting furnaces for heating and water heating. ▼ Frequency-controlled compressor and other energy-saving measures.
	Planned measures	▼ Installation of a battery storage system to store excess energy from photovoltaics.
	Estimated savings	▼ Energy Savings: 50 MWh of electricity and 377 MWh of heating oil annually. ▼ Emissions Reduction: 146 tons of CO2 equivalent per year. ▼ Additional Benefits: Lower operating costs, increased self-generated electricity, reduced reliance on external energy suppliers, enhanced employee awareness of energy efficiency, and an improved working environment (e.g., LED lighting).
	Alignment with Smart grid principles	▼ Decentralized energy production (photovoltaics). ▼ Flexibility of consumption (shifting melting). ▼ Efficient energy management (heat recovery).
	Proposed additions	▼ Energy storage (battery storage). ▼ Intelligent process control (linking photovoltaics, melting furnace and battery storage).

Metalworking industry (precision tool manufacturing) – Walter AG

This project highlights a manufacturing company that utilizes combined heat and power (CHP) and adsorption chillers to optimize its energy consumption and reduce its reliance on external energy sources.

	Goals	Increase the utilization of the combined heat and power unit and reduce energy consumption for cooling
	Implemented measures	▼ Integration of three adsorption chillers into the existing cooling system. ▼ Use of waste heat from CHP for cooling in the summer months. ▼ Monitoring and optimization of energy consumption of cooling systems.
	Planned measures	▼ Expansion of the capacity of thermal storage tanks for optimized use of waste heat from CHP and adsorption chillers.
	Estimated savings	▼ Energy Savings: 180 MWh of electricity per year, representing a 30% reduction. ▼ Emissions Reduction: 104 tons of CO2 annually. ▼ Additional Benefits: Greater CHP system utilization, more efficient fuel use, increased self-generated electricity, and potential scalability to other production sites.
	Alignment with Smart grid principles	▼ Combined heat and power. ▼ Waste heat utilization. ▼ Consumption optimization
	Proposed additions	▼ Intelligent CHP control. ▼ Accumulation of heat and cold.

These examples illustrate that modern technologies and the underlying principles of smart grids are being adopted across diverse industrial sectors. Businesses are actively pursuing strategies to optimize energy consumption, reduce their carbon footprint, and enhance efficiency. While these initiatives represent significant steps towards sustainability, it's important to acknowledge that they often constitute a partial implementation of smart grid concepts.

To fully realize the transformative potential of smart grids, these successful implementations should be complemented with further projects that deepen the integration of these technologies. This includes:

- **Smart metering:** Implementing smart meters enables real-time monitoring of energy consumption and production, providing valuable data for optimizing energy use and grid management.
- **Dynamic consumption control systems:** Integrating systems that allow for dynamic control of energy consumption based on real-time grid conditions enables greater flexibility and responsiveness to fluctuations in energy supply and demand. This contributes to grid stability and facilitates the integration of renewable energy sources.

By embracing these additional elements, businesses can move beyond partial alignment and achieve comprehensive integration with smart grids, unlocking the full range of benefits associated with this advanced energy infrastructure. This approach will be crucial in creating a more sustainable and resilient energy future.

3.4.3 Learning from Leaders: Exemplary SME Practices in Renewable Energy Integration

This chapter explores how energy-intensive SMEs can leverage modern technologies to transition to renewable energy sources. By addressing challenges such as supplier reliability and adoption complexities, it presents real-world examples of SMEs successfully integrating renewable energy into their operations. These case studies highlight best practices and demonstrate how technology enables decarbonization, enhances efficiency, and strengthens competitiveness in a sustainable energy landscape.

Mineral Processing – Axis Bentonit Ltd. (Hungary)

Axis Bentonit Ltd., based in Pétervására, Hungary, produces various bentonite-based products, including pet litter, animal feed additives, and cosmetics.

	Energy efficiency measures	To combat rising energy costs and reduce their environmental impact, Axis Bentonit implemented several energy-saving measures: ▼ Transitioned from gas-powered to electric and solar-powered drying systems: This significantly reduced their reliance on natural gas, which had become increasingly expensive. ▼ Introduced microwave drying technology: This new technology consumes significantly less energy (29%) than the old gas-powered systems. ▼ Installed a 100-kW solar power system: This allows them to generate renewable energy for their operations and feed excess power back into the grid. ▼ Implemented passive drying methods, heat pumps, and LED lighting: These further optimized energy use across the company. ▼ Utilized an energy management system: This system helps monitor and control energy consumption.
	Resources and implementation	The transition was supported by an EU grant, which helped finance the microwave drying technology and the solar power system.

	Outcomes and impact	▼ <u>36% reduction in energy consumption:</u> This translates to an annual saving of 748 MWh. ▼ <u>16% reduction in overall utility costs:</u> Energy costs, which previously accounted for 32% of production costs, have been reduced to 22%. ▼ <u>Reduced reliance on natural gas:</u> This minimizes the company's vulnerability to fluctuating gas prices. ▼ <u>Increased energy independence:</u> The company can now shift entirely to electricity if gas supply becomes an issue.
	Challenges, risks and transferability	▼ <u>Technological challenges:</u> Microwave drying technology is expensive and can malfunction, potentially leading to financial losses. Outdated electrical infrastructure and limited energy storage also pose challenges. ▼ <u>Financial risks:</u> The initial investment in green technologies can be substantial for SMEs. Volatile energy prices can also impact financial stability. ▼ <u>Regulatory and market risks:</u> Changes in energy regulations and slow regulatory processes can hinder the adoption of efficient solutions. ▼ <u>Knowledge gaps:</u> Lack of expert advice and free energy consultancy can make it difficult for companies to choose the best technologies.
	Key takeaways	Axis Bentonit's success demonstrates the potential of combining various green energy technologies to achieve both economic and environmental benefits. Other companies can learn from their approach by: ▼ Investing in renewable energy sources. ▼ Utilizing grants and government support. ▼ Implementing energy management systems.

Food production – Wolf Nudeln GmbH (Austria)

Wolf Nudeln GmbH, located in Güssing, Austria, is a pasta producer with approximately 100 employees. They are unique in their commitment to energy self-sufficiency and CO2-neutral production. They utilize resources from their own farm and regional partners to create a closed-loop system.

	Energy efficiency measures	Wolf Nudeln GmbH has implemented a range of sustainable practices, including: ▼ <u>Biogas plant:</u> This plant converts chicken manure and grass cuttings into electricity and heat, fulfilling the company's energy needs and achieving carbon neutrality. Excess electricity is fed back into the grid. ▼ <u>Circular economy approach:</u> They utilize waste products and optimize resource efficiency, minimizing their environmental impact. ▼ <u>Regional sourcing:</u> By sourcing ingredients locally, they reduce transportation distances and support local agriculture. ▼ <u>Sustainable packaging:</u> They have replaced plastic packaging with recyclable paper packaging.
	Resources and implementation	The biogas plant, a core component of their energy strategy, was implemented between 2008 and 2010. With an electrical capacity of 500 kW, it generates approximately 1,000,000 kWh of renewable methane annually. The company invested €2.5 million in implementing their energy-efficient measures.
	Outcomes and impact	▼ <u>Energy self-sufficiency and CO2 neutrality:</u> The biogas plant covers all of the company's energy needs for pasta production, building operations, and transport. ▼ <u>Reduced reliance on external energy sources:</u> This protects the company from energy price fluctuations and supply disruptions. ▼ <u>Reduced environmental impact:</u> Their closed-loop system minimizes waste and reduces their carbon footprint.

	Challenges, risks and transferability	▼ Technical challenges: Integrating the biogas plant and managing peak energy loads was technically demanding. ▼ Financial risks: The initial investment was substantial, and there were ongoing costs associated with maintenance and fluctuating energy prices. ▼ Regulatory challenges: Obtaining permits and complying with environmental standards required time and resources.
	Key takeaways	Wolf Nudeln GmbH's success demonstrates the viability of biogas technology for achieving energy self-sufficiency and carbon neutrality in the food industry. Companies considering similar solutions should: ▼ Carefully evaluate their energy needs and available resources ▼ Partner with experts to overcome technical and financial challenges. ▼ Explore available subsidies and incentives

Food Production/Delivery – Biobäckerei Wagner (Germany)

Biobäckerei Wagner is a bakery in Zugsberg, Germany, with 150 employees. They produce and deliver baked goods to restaurants, supermarkets, and their own retail outlets. They are committed to sustainable practices and reducing their environmental impact.

	Energy efficiency measures	To reduce costs and their carbon footprint, Biobäckerei Wagner transitioned their fleet of 11 delivery vans from diesel to electric vehicles (EVs). ▼ Solar-powered charging: A key aspect of their strategy is the use of their own 328kWp rooftop solar system to charge the EVs. This allows them to utilize renewable energy for their transportation needs. ▼ Delivery schedule aligned with solar generation: Deliveries are made between 3 a.m. and 10 a.m., allowing the EVs to be charged during peak sunlight hours, eliminating the need for energy storage. ▼ Gradual implementation: The company started with one EV on a shorter route and gradually replaced its entire fleet. ▼ Expansion to sales vans: Two of their six sales vans are already electric, with plans to replace the remaining four soon.
	Resources and implementation	The €1.2 million project was self-financed through a local bank. Key components include the solar panels, EV charging points, and the electric vans. The bakery prioritized maximizing electricity generation from their solar panels and reducing their energy bill.
	Outcomes and impact	▼ Significant cost savings: The switch to EVs has resulted in monthly savings of approximately €7,000 on fuel and a significant reduction in maintenance costs. ▼ Reduced CO_2 emissions: The bakery has reduced its carbon emissions by 260 tonnes in 10 months. ▼ Enhanced reputation: Their commitment to sustainability has garnered positive media attention and strengthened customer relationships.
	Challenges, risks and transferability	▼ Technology: Initial concerns about vehicle reliability and driver acceptance were addressed by keeping a backup diesel vehicle and through driver training. ▼ Range anxiety: Longer routes require a short charging stop, which is integrated into drivers' break times.
	Key takeaways	Biobäckerei Wagner's success highlights the feasibility and benefits of combining electric vehicles with solar power for businesses with suitable operating hours and delivery routes. Their experience offers valuable lessons for other companies: ▼ Test the concept: Start with a single EV to gain experience and evaluate practicality. ▼ Start small and scale gradually: Expand the fleet as confidence and knowledge grow. By strategically aligning their delivery schedule with solar energy generation, Biobäckerei Wagner demonstrates an innovative and effective approach to sustainable transportation.

Engineering and Automation – Robotehnika d.o.o. (Slovenia)

Robotehnika d.o.o., located in Markovci, Slovenia, is an engineering company with 50 employees specializing in CNC production, hydraulic systems, and product automation. They are known for their technical expertise and innovative solutions for industrial projects.

	Energy efficiency measures	To address high energy demands and costs, Robotehnika d.o.o. implemented the following: ▼ Solar power plant: Installed in 2019, this plant significantly reduces its reliance on the external grid and generates renewable energy. Excess energy is sold back to the grid, creating a new revenue stream. ▼ Energy-efficient machinery: It was invested in new, energy-efficient CNC machines and other production equipment that operate with optimized energy cycles, consuming less electricity. ▼ Climate control systems: They upgraded their heating and cooling systems to improve energy efficiency in their facility.
	Resources and implementation	The solar power plant project was financed with 80% internal capital and a 20% subsidy from SPIRIT, a Slovenian public agency. They worked with qualified contractors to ensure high-quality installation.
	Outcomes and impact	▼ Reduced reliance on the grid: A 45% reduction in electricity demand from the grid was achieved ▼ Renewable energy generation: The solar power plant produces around 100,000 kWh of renewable energy annually. ▼ Cost savings: The solar power plant generates significant cost savings and potential revenue from energy sales. ▼ Reduced CO2 emissions: They estimate an annual reduction of 40-50 tons of CO_2 emissions.
	Challenges, risks and transferability	Robotehnika d.o.o. reported a smooth and successful implementation of their energy efficiency measures without major obstacles, thanks to careful planning and experienced contractors.
	Key takeaways	Robotehnika d.o.o.'s experience demonstrates the effectiveness of combining solar power with investments in energy-efficient machinery and climate control systems to achieve significant energy and cost savings. Their success highlights the importance of: ▼ Careful planning and utilizing qualified contractors: This ensures a smooth implementation and optimal performance of renewable energy systems. ▼ Exploring available subsidies: Public funding can help offset the initial investment costs. ▼ Considering the long-term benefits: Renewable energy solutions can lead to significant cost savings, reduced environmental impact, and increased energy independence.

Brewery – Plzeňský Prazdroj (Czechia)

Plzeňský Prazdroj, located in Plzeň, Czechia, is a major brewery known for its commitment to sustainability. They were recently recognized for their efforts with a first-place award in the TOP Odpovědná firma 2023 (TOP Responsible Enterprise 2023).

	Energy efficiency measures	To reduce its carbon footprint and increase energy efficiency, Plzeňský Prazdroj is implementing a large-scale solar panel installation program across its breweries. ▼ Rooftop solar panels: Solar panels are being installed on the roofs of operational buildings. ▼ Phased implementation: The project started with a solar power plant in Velké Popovice, covering 12% of the wastewater treatment plant's energy needs. Further installations are planned, including on the bottling line. ▼ Large-scale deployment: The company aims to install a total of 3,400 solar panels, covering an area equivalent to four football fields.
	Resources and implementation	The solar energy initiative requires significant investment in renewable energy technology. It is likely funded through a combination of company revenues and potential external funding or incentives. Technical teams are responsible for the installation, maintenance, and integration of the solar technology.
	Outcomes and impact	▼ Reduced CO2 emissions: The initiative is expected to reduce CO2 emissions by up to 500 tons annually. ▼ Progress towards carbon neutrality: The project contributes to the brewery's goal of achieving carbon neutrality by 2030. ▼ Increased energy independence: The solar installations reduce reliance on traditional energy sources.
	Challenges, risks and transferability	▼ Technical challenges: Installing solar technology on existing structures and ensuring reliable energy generation presented technical hurdles. ▼ Financial risks: Fluctuating energy prices and the initial investment costs posed financial risks.
	Key takeaways	Plzeňský Prazdroj's solar energy initiative demonstrates a successful model for integrating renewable energy in industrial processes. Companies considering similar projects should: ▼ Conduct a thorough feasibility study: This helps assess the technical and financial viability of the project. ▼ Seek partnerships for funding: External funding and incentives can help support the investment. ▼ Integrate sustainability goals: Aligning renewable energy projects with broader sustainability strategies can enhance their impact. This initiative can be adapted and replicated in various industries, particularly in the manufacturing and processing sectors, with large facilities suitable for solar panel installations.

Agriculture and Livestock – Gold-MG Ltd. (Bosnia and Herzegovina)

Gold-MG Ltd., located in Donji Žabar, Bosnia and Herzegovina, is an agricultural and livestock company with 23 employees. They specialize in sustainable and organic products, including pelletized fertilizers, wood pellets, animal feed, and livestock.

	Energy efficiency measures	Gold-MG Ltd. has implemented a biogas plant as a key energy efficiency measure: ▼ Biogas cogeneration plant: This 1MW plant utilizes silage, manure, and agricultural by-products to generate biogas, which is then used to produce renewable energy. ▼ Waste-to-energy conversion: The plant effectively addresses waste management and renewable energy production, contributing to a circular economy. ▼ Electricity generation and sales: The generated electricity is sold to the domestic and regional markets, creating a new revenue stream.
	Resources and implementation	The biogas plant, a self-sustained pilot project engineered in-house, required a €5.1 million investment. Funding was secured through the "Challenge to Change" project (SIDA) and EU4Agri programs.
	Outcomes and impact	▼ Sustainable income generation: The biogas plant generates revenue through electricity sales. ▼ Reduced environmental impact: The plant significantly reduces carbon emissions and promotes sustainable agricultural practices. ▼ Regional leadership: Gold-MG Ltd. serves as a role model for environmental responsibility in the region.
	Challenges, risks and transferability	▼ High initial costs: The investment required for the biogas plant was substantial. ▼ Specialized skills: The project relied on internal engineering expertise to overcome the need for specialized skills. ▼ Financial risk mitigation: Regulatory and market support helped mitigate the financial risks associated with the project.
	Key takeaways	Gold-MG Ltd.'s biogas plant demonstrates the potential of utilizing agricultural by-products for renewable energy generation in the agricultural sector. Their experience highlights the importance of: ▼ Securing funding and support: External funding and programs can be crucial for financing such projects. ▼ Leveraging internal expertise: Utilizing existing resources and skills can help overcome challenges. ▼ Considering scalability: The modular design of the biogas plant allows for future expansion and potential collaboration with local farmers. This model can be replicated in other agriculturally rich regions with access to waste resources and supportive regulatory frameworks.

Plastic Packaging Manufacturing – Corplex Hurbanovo (Slovakia)

Corplex Hurbanovo, located in Slovakia, is one of six plants in the CORPLEX Group. The company manufacture returnable plastic packaging solutions, with a focus on sustainability and recycling. They employ 150 people and have an annual turnover of €20 million.

Energy efficiency measures	Corplex Hurbanovo has been impacted by rising electricity prices, forcing production cuts and line shutdowns. They have taken several steps to address energy efficiency: ▼ <u>LED lighting and sensors:</u> Installation of LED lights and motion sensors to optimize lighting conditions. ▼ <u>Thermal insulation:</u> Improved insulation in the power plant and offices. ▼ <u>Photovoltaic power plant:</u> A 600 kWp PV power plant was planned for installation on their land to diversify power generation and reduce reliance on external suppliers.
Resources and implementation	The PV power plant project was financed entirely through internal sources. However, implementation has faced significant delays and challenges: ▼ <u>Lengthy implementation:</u> The project has been ongoing for three years due to administrative burdens and authorization processes. ▼ <u>Land installation issues:</u> The roof was not designed for solar panels, necessitating land installation, which led to extra legislative burdens and delays. ▼ <u>Bureaucracy and legal challenges:</u> Bureaucracy, including a lengthy archaeological assessment and a change in the company's legal status, has further hindered the process. ▼ <u>Project status:</u> Despite the efforts and investment, the PV array is not yet connected and producing electricity.
Outcomes and impact	▼ <u>Expected savings:</u> Once operational, the PV plant is expected to generate annual savings of €80,000 to €150,000. ▼ <u>Potential for scaling up:</u> The company plans to explore energy storage solutions in the future to further increase self-sufficiency.
Challenges, risks and transferability	▼ <u>Administrative and regulatory hurdles:</u> The project highlights the significant challenges posed by bureaucracy, authorization processes, and legal complexities in renewable energy projects. ▼ <u>Implementation delays:</u> The lengthy implementation time can lead to cost overruns and lost potential savings. ▼ <u>Uncertainty of outcomes:</u> The project's success remains uncertain due to the ongoing delays and lack of connection to the grid.
Key takeaways	Corplex Hurbanovo's experience serves as a cautionary tale, emphasizing the potential difficulties and risks associated with renewable energy projects. Companies considering similar initiatives should: ▼ <u>Carefully assess regulatory and administrative requirements:</u> Thorough planning and preparation are crucial to navigate potential hurdles. ▼ <u>Factor in potential delays:</u> Implementation timelines may be longer than anticipated due to unforeseen challenges. ▼ <u>Ensure clear communication with authorities:</u> Maintaining open communication with relevant authorities can help streamline the approval process. Despite the challenges, Corplex Hurbanovo's commitment to renewable energy demonstrates their dedication to sustainability. Their experience provides valuable lessons for other companies navigating the complexities of renewable energy implementation.

3.5 Use of Waste Heat in Industry

The **use of waste heat in industry** involves **capturing excess thermal energy** produced during industrial processes and **repurposing it to improve overall energy efficiency**. This waste heat can originate from machinery, high-temperature processes like smelting or combustion, and even exhaust gases. Instead of being released into the environment, this heat can be reused within the same process, converted into electricity, or supplied to external systems, such as district heating networks. This approach helps **reduce energy consumption** and **lowers greenhouse gas emissions**, supporting sustainable industrial practices, which are **encouraged by EU policies** such as the Energy Efficiency Directive (2012/27/EU).

Recent developments in the use of waste heat are focused on improving the efficiency of heat recovery systems and **expanding their application across** a **broader range of industrial sectors**. Advances in heat exchangers, thermoelectric generators, and organic Rankine cycle (ORC) technologies have enabled industries to convert low-grade waste heat into usable energy more effectively. For instance, ORC systems can now convert waste heat as low as 100 °C into electricity, making it accessible for more sectors beyond heavy industry, such as food processing and chemical manufacturing. According to the CE HEAT project funded by the Interreg Central Europe Programme, around **20 %-50 %** of industrial energy consumption is disposed of as **waste heat**, and **18%-30 %** of this **could be reused**. A 2022 European study estimated that if waste heat recovery were fully implemented, it could reduce industrial energy consumption by up to 15%, significantly contributing to the EU's energy efficiency targets.

3.5.1 Waste Heat Utilization in the DR: Unlocking Efficiency and Sustainability

This analysis examines the **utilization of waste heat in industry** within the DR, drawing on data collected from a questionnaire survey and an online workshop. Waste heat, which is generated as a **byproduct of industrial processes** and often released into the environment, represents a significant opportunity to **enhance energy efficiency and reduce emissions**. Utilizing this waste heat plays a vital role in supporting the sustainability of European industry and contributes to achieving climate and energy goals.

The study specifically focuses on identifying **best practices, policies, and programs that promote waste heat recovery** in different countries across the region. It also explores the **challenges and barriers faced by businesses** in implementing these technologies and highlights the **potential for regional cooperation** and knowledge sharing to accelerate progress in this area.

This analysis focuses on several key areas to understand the current state of waste heat utilization in the DR. These include the level of awareness and prioritization of waste heat in national energy policies, the types of financial and legislative support mechanisms available, the role of EU funding programs in promoting waste heat recovery projects, the importance of practical expertise and guidance for companies, and emerging opportunities and challenges such as the increasing need for cooling and the potential of heat pump technology. By examining these aspects, the analysis aims to provide insights into the current state of waste heat utilization and identify opportunities for improvement and collaboration.

Several key takeaways emerged from the analysis. Firstly, while all responding countries acknowledge the importance of waste heat utilization, the level of prioritization and support varies, with Baden-Württemberg appearing to be a leader in this area. Secondly, most countries offer some form of financial or legislative support for waste heat utilization projects, but the extent and effectiveness of these measures differ. Thirdly, EU funding programs contribute to supporting waste heat recovery projects in countries like Bavaria. Fourthly, there is a need for increased awareness and capacity in some countries, like Czechia, where waste heat utilization is not yet fully integrated into energy policies. Fifthly, the importance of practical expertise is highlighted by Baden-Württemberg's competence centre, which provides guidance to companies and connects them with specialists.

Finally, the increasing need for cooling in industries presents a significant opportunity for waste heat utilization through innovative solutions like heat pumps.

Country-specific observations reveal varying approaches to waste heat utilization. In Czechia, waste heat utilization is not a primary focus in energy policy, and while some support is available, there is a need for greater integration into national strategies and increased awareness among industries. Baden-Württemberg demonstrates a proactive and comprehensive approach with a dedicated waste heat strategy, competence centre, and funding scheme, with a strong focus on practical support. Bavaria supports waste heat utilization through financial incentives, tax benefits, legislative measures, and EU funding programs. Austria also demonstrates commitment by providing federal funding programs for waste heat utilization projects.

A more detailed overview of the strengths and weaknesses identified in the country-specific observations regarding waste heat utilization can be found in the table below.

Country	Strengths	Weaknesses
Czechia	Some support through OP TAC program	Lack of integration into energy policy, limited awareness
Baden-Württemberg	Dedicated strategy, competence centre, funding scheme, practical support	
Bavaria	Financial incentives, tax benefits, legislative support, EU co-financing	
Austria	Federal funding programs for waste heat utilization	Limited information on specific programs and impact

3.5.2 Good Practice Examples in More Details: Baden-Württemberg

A Working Competence Centre

The <u>Competence Centre Umwelttechnik Baden-Württemberg</u> (hereinafter "Umwelttechnik BW") empowers businesses, municipalities, and other organizations in Baden-Württemberg to embrace sustainability while driving economic success. By promoting efficient energy use and reducing heat loss in industrial processes, the centre helps organizations lower costs and minimize their environmental impact. Umwelttechnik BW effectively links climate protection with economic development, demonstrating that sustainable practices can enhance competitiveness and contribute to a greener future.

	Purpose and focus of the centre	▼ <u>Identifying waste heat potential:</u> The centre helps organizations identify where and how much waste heat is generated and provides analysis on how it can be reused. ▼ <u>Supporting Technical Solutions:</u> It offers assistance in implementing technologies for the recovery and reuse of waste heat, such as heat recovery systems, heat exchangers, or systems that use waste heat for heating or electricity production. ▼ <u>Education and consulting:</u> The centre provides training, workshops, and consulting services for professionals and the general public to raise awareness of waste heat utilization opportunities. ▼ <u>Innovation projects:</u> It serves as a platform for the development of new technologies and innovative approaches to energy efficiency.

	Financing and support	▼ The competence centre is likely funded through a combination of public funds, particularly regional funds from Baden-Württemberg, and possibly European programs aimed at supporting energy efficiency. ▼ It collaborates with industrial companies, universities, and research institutions
	Target groups and benefits	▼ <u>Industrial companies:</u> Can optimize their processes, achieve significant financial savings, and improve efficiency. ▼ <u>Municipalities and cities:</u> Can use waste heat for district heating, reducing costs and emissions. ▼ <u>Energy companies:</u> Can implement solutions to generate additional energy. ▼ <u>General public:</u> Benefits from improved air quality and increased energy sustainability.
	Forms of help provided	▼ Practical support: Provides facility audits, technology recommendations, and potential financial support for projects. ▼ Networking: Connects businesses and research institutions to share knowledge and develop innovations. ▼ Regulatory and technical assistance: Helps organizations understand legal requirements and optimize processes in line with regulations.

Similar competence centres in Baden-Württemberg also arise in other DR countries. Another interesting case to watch is the Energy Centre of the Ústecký Region in Czechia which was established as a regional (NUTS3 level) energy competence centre in one of the most industrial regions in the country. The aim of the competence centre is to act as a trustworthy local agent of change by providing a helping hand in implementing realistic and needed projects within the region.

It is generally advisable to use part of the available public funding (incl. from the EU) to **establish a functioning regional energy competence centre** which can provide a helping hand to all actors in the local economy. This can boost interest for a priority area, such as energy efficiency and ensure that projects funded by public funds are well implemented with appropriate expert guidance. Observations from the Ústí nad Labe Region suggest that the established competence centres (side note: not only for energy but also the competitiveness of SMEs or digitalisation) increased the number of initiatives taken by local economy agents since they positively responded to the additional expert guidance available.

Wastewater Heat Recovery

The utilization of wastewater heat from sewage treatment plants is emerging as a promising and innovative solution for reducing greenhouse gas emissions and promoting sustainable development. Heat from wastewater, which would otherwise be released into the environment without being used, becomes a valuable source of energy for heating homes and buildings.

A study conducted in Baden-Württemberg confirms that this solution is technically and economically feasible and has the potential to cover a significant portion of the region's heat demand. Analysis of data from 258 wastewater treatment plants showed that using heat pumps could achieve a capacity of 537 MW and supply up to 3.74 TWh of heat per year. This represents approximately 11% of the heat supplied to heating networks and 4.3% of the total heat consumption in buildings in Baden-Württemberg. Pilot projects at wastewater treatment plants in Weinstadt, Tübingen and Altensteig demonstrate the practical implementation of this technology and offer concrete examples for other towns and cities.

Case Study: Tübingen Wastewater Treatment Plant

The Tübingen wastewater treatment plant is located in the eastern part of the city, near the existing "Alte Weberei" district heating network. This plant treats wastewater from 110,000 residents, as well as from local industry, the university, and hospitals. The project aims to integrate wastewater heat recovery into the city's heating system, which currently relies heavily on natural gas. By 2030, the goal is to generate 70% of the heat from renewable sources.

Project Stages and Implementation

The project is divided into two phases:

- **Phase 1:** Scheduled for implementation in 2025, this phase will involve the construction of a multi-stage wastewater heat pump system. This system will extract heat from the purified wastewater and feed it into the "Alte Weberei" district heating network.
- **Phase 2:** Planned for 2028, this phase will expand the heat pump system's capacity, allowing it to contribute even more renewable energy to the heating network.

Benefits of the Project

- **Environmental:** By utilizing wastewater as a renewable energy source, the project will contribute to decarbonizing the city's heating supply and reducing reliance on fossil fuels. This will lead to lower greenhouse gas emissions and improved air quality.
- **Energy:** The project will diversify the city's energy mix, increasing energy security and reducing dependence on fluctuating natural gas prices.
- **Economic:** The project is expected to create jobs and stimulate local economic development. Additionally, utilizing wastewater heat can lead to lower energy costs for consumers in the long run.

Investment and Funding

The project has received significant funding from the BEW (Bundesministerium für Wirtschaft und Energie), a German federal ministry promoting energy efficiency and renewable energy sources.

- **Phase 1:** Total investment costs are €16,288,000, with €9,773,000 coming from BEW funding.
- **Phase 2:** Total investment costs are €4,514,000, with €2,708,000 covered by BEW funding.

Project Status and Outlook

The Tübingen wastewater heat recovery project is currently in the advanced planning stage, with detailed technical concepts and implementation plans in place. The project's phased approach allows for flexibility and adaptability, ensuring its successful integration into the city's existing heating infrastructure. By 2030, Tübingen aims to have a heating system that predominantly relies on renewable energy sources, with wastewater heat playing a crucial role in achieving this goal.

3.5.3 Example projects Funded by the EU

The EU actively supports projects focused on waste heat recovery, recognizing its critical role in enhancing energy efficiency and reducing greenhouse gas emissions. Key initiatives include **CE-HEAT**, which emphasizes mapping and utilizing waste heat in Central Europe; ReUseHeat, showcasing innovative low-temperature waste heat recovery in urban areas; and **HEATLEAP**, promoting advanced technologies for industrial and other applications. Also, there are other EU-funded projects focusing on waste heat recovery in the industrial sector that can serve as case studies for implementing and promoting new technologies such as **SUSPIRE**, **DryFiciency** and **I-ThERM**.

These projects demonstrate practical applications and provide valuable tools like waste heat mapping platforms and methodologies for feasibility studies. Gaining a deeper understanding of these initiatives and establishing connections with them offers EU member states an excellent opportunity to share experiences, adopt best practices, and accelerate the deployment of waste heat recovery solutions. This approach supports both industrial innovation and urban sustainability, aligning with the EU's Green Deal goals for decarbonization and sustainable development

HEATLEAP

The HEATLEAP project, funded by the EU's LIFE program for environment and climate action, aims to demonstrate the potential of waste heat recovery to boost energy efficiency and reduce emissions. Focusing on low-grade waste heat (around 70°C) often found in energy-intensive industries, the project will test innovative technologies like large heat pumps and gas expanders in real-world settings. By showcasing the economic and environmental benefits of these systems, HEATLEAP seeks to increase the competitiveness of the industrial and utility sectors while contributing to decarbonization efforts.

ReUseHeat

The ReUseHeat project, funded by the European Union’s Horizon 2020 program, focused on utilizing excess heat in urban areas. The goal was to demonstrate systems for recovering and reusing heat from data centres, sewage systems, cooling systems, and metro stations. The project aimed to overcome technical and non-technical barriers hindering investment in excess heat utilization through the development of innovative technologies, business models, and contractual agreements. The project resulted in a handbook for investors and developers, which includes information on technical solutions, investment risks, and permitting procedures.

CE-HEAT

Waste heat utilisation is crucial in reducing energy consumption and CO_2 emissions. The **www.waste-heat.eu** website is a key outcome of the European project CE-HEAT, funded by the Interreg CENTRAL EUROPE Programme, which promotes cooperation on shared challenges in Central Europe.

The website provides information for businesses, project developers, energy suppliers and service providers, consultants, municipalities, and policymakers. It includes an overview of waste heat sources and utilisation methods, a methodology for identifying regional waste heat potential, and its connection to action plans.

Furthermore, it is possible to find regional waste heat cadastres with GIS maps, instructions for their creation, and data sources. For a better understanding of the topic, a toolbox is available, including a calculator for assessing project feasibility.

The project proposes a methodology for estimating regional waste heat potential using official energy statistics for industry sectors and specific conversion factors derived from leading studies. Industry sector categorization is standardized across European countries, and each country should have a report on energy consumption by sector. To estimate the potential in a given sector, a specific conversion factor is multiplied by the total energy consumption figure for that sector. The waste heat estimation for Thuringia demonstrates this methodology. In Thuringia, with a total energy consumption of 55 601 TJ in the industrial sector, the estimated waste heat potential is 11 640 TJ.

3.5.4 Key Take-Aways and Recommendations

- **Proactive approach for support:** Given that Czechia is just beginning to integrate waste heat utilization into its energy policies, a proactive approach is essential. This could include:

  - Establishing a dedicated competence centre, similar to Baden-Württemberg's model, to provide advice and support to businesses.
  - Raising awareness of the benefits of waste heat utilization through targeted information campaigns and workshops.
  - Implementing clear policies and incentives to motivate businesses to invest in waste heat recovery technologies.

- **Focus on industry-specific needs:** Consider sector-specific challenges, with targeted programs and incentives for energy-intensive industries.
- **Monitoring and evaluation:** To track the progress and effectiveness of waste heat utilization policies, it is essential to establish a monitoring and evaluation system. This will allow for the identification of areas that require improvement and the optimization of strategies for future development.
- **Leverage energy audits:** Following Austria's example, integrate mandatory waste heat potential assessments into energy audits for large companies. This standardized process will elevate waste heat recovery to a national priority, driving widespread implementation and promoting efficient energy use.
- **Regional cooperation:** Utilizing platforms such as the EUSDR to strengthen regional cooperation and knowledge sharing on waste heat utilization.
- **Private sector engagement:** Actively involving the private sector in the development and implementation of waste heat utilization technologies is key to success. This can be achieved through public-private partnerships and support for innovation.
- **Consider the growing need for cooling:** As highlighted in the analysis, the increasing need for cooling in the industry presents a significant opportunity for waste heat utilization, particularly through heat pumps. This should be considered when developing future strategies and policies.

3.6 Accumulation, Aggregation and Flexibility

The concepts of accumulation, aggregation, and flexibility are critical to **enhancing energy efficiency** in the industrial sector. **Accumulation** refers to the ability to store excess energy, **aggregation** involves combining smaller, distributed energy resources into a single operational entity, and **flexibility** encompasses the adaptability of energy systems to respond to changing demands and supply conditions. These mechanisms are essential for optimizing energy use, reducing peak loads, and integrating renewable energy sources, particularly as industries strive to lower their carbon footprints.

In alignment with these energy efficiency goals, the fourth **European energy package**, "**Clean Energy for All Europeans**," approved in 2019, plays a vital role. It aims to transform the EU energy system into a more sustainable, competitive, and consumer oriented. This package provides the foundation for achieving the goals of energy security, climate protection, and decarbonization as part of the European strategy to achieve carbon neutrality by 2050. The main components of the package are:

1. **Renewable Energy Directive (2018/2001)**, also known as **RED II**, which promotes the use of energy from renewable sources.
2. **Regulation on the Governance of the Energy Union (2018/1999)**, which establishes planning and reporting frameworks for energy and climate policies.
3. **Electricity Market Regulation (2019/943) and Electricity Market Directive (2019/944)**, which define rules for an open and integrated electricity market.
4. **Energy Efficiency Directive (2018/2002)**, which sets new targets for improving energy efficiency across the EU.

The package aims to achieve various goals through regulations and directives, including reducing greenhouse gas emissions, increasing the use of renewable energy sources, improving energy efficiency, and strengthening consumer rights. The key areas and measures of the package involve establishing the necessary legislative framework to meet these objectives, as well as promoting innovation and the adoption of new technologies.

Overall, in the development of the European energy sector, Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU aimed at creating a competitive, a more efficient and consumer-oriented electricity market. The Directive primarily concerns consumer rights and protections, as well as regulations governing the supply of electricity. It specifically focuses on the following areas:

- **Consumer Protection and Empowerment**: Ensuring that consumers are informed and able to make decisions regarding their electricity usage through transparent billing, access to data, and the use of **smart metering systems**. It emphasizes flexibility in billing frequency and payment methods, promoting transparency and consumer-friendly policies.
- **Deployment of Smart Metering Systems**: The Directive encourages Member States to deploy smart metering systems, aimed at giving consumers better control over their electricity consumption. This includes offering **real-time consumption data** and facilitating **demand-response services**, helping consumers optimize their energy use.
- **Electricity Market Flexibility**: Encouraging the participation of all consumer categories, including households, in electricity markets, promoting flexibility in distribution systems. This includes policies allowing for **citizen energy communities** and **active customer participation** in energy production and consumption.

- **Energy Transition and Innovation**: The Directive supports the **decarbonization of energy systems**, encouraging market participants to integrate renewable energy sources, adopt **smart grids**, and leverage **energy storage systems**. It also encourages investment in **electromobility** infrastructure.
- **Public Service Obligations**: It grants Member States the discretion to impose **public service obligations** related to security of supply and environmental protection, ensuring that these obligations are clear, transparent, and non-discriminatory.

The Clean Energy for All Europeans package and Directive 2019/944 aim to facilitate the revival and transformation of the European energy sector. It shifts the focus from a centralized energy model centred around fossil fuel combustion to a decentralized model prioritizing energy generation from renewable sources.

As the **European energy market** evolves with the integration of renewable sources, flexibility becomes a critical component. The Directive emphasizes the need for adaptable electricity networks that can respond to fluctuations in production and demand. By enabling mechanisms such as aggregation and demand response, the market can efficiently incorporate small-scale producers and consumers, fostering a more decentralized and resilient energy system. This approach ensures that the growing reliance on intermittent renewable energy sources can be managed effectively while minimizing infrastructure costs and enhancing overall grid stability.

This directive provides a legislative anchoring and **definition of topics such as aggregation, accumulation of electrical energy, and flexibility**. Most of the directive's provisions were supposed to be **transposed into national legal systems by 31 December 2020**, and **full implementation** is expected by the **end of 2024**. However, in some countries, there has been a delay in the transposition of partial parts of the directive, highlighting the need for timely action to meet the expected full implementation date.

3.6.1 Accumulation, Aggregation, and Flexibility in the DR: Integrating Renewables in Industry

This analysis examines how industrial enterprises in the DR are **implementing renewable energy sources, storage, and grid flexibility measures**. It draws on data from a questionnaire survey, though it's important to note that only Moldova and Bavaria responded to this topic. This limited participation highlights the need for increased engagement and information sharing on this crucial aspect of the energy transition.

The study specifically focuses on how industries are **integrating renewable energy sources like solar, wind, and biomass**, and how they are **utilizing storage and flexibility solutions to contribute to grid stability**. It also explores the **legislative and economic tools** available to support these efforts.

This analysis focuses on several key areas to understand the current state of renewable energy integration, storage, and flexibility in the DR. These areas include the level of awareness and prioritization of these technologies in national energy policies, the types of financial and legislative support mechanisms available to businesses, the role of EU funding programs, the importance of practical expertise and guidance for companies, and emerging opportunities and challenges such as the increasing need for cooling and the potential of heat pump technology.

Some key takeaways emerged from this analysis. First, there is a growing recognition of the importance of renewable energy sources in industry, with both **Moldova** and **Bavaria** actively promoting their adoption.

Second, energy storage and flexibility measures are crucial for maximizing the benefits of renewable energy and ensuring grid stability. Third, a supportive policy landscape is essential, and both Moldova and Bavaria have **implemented policies** and **programs** to encourage the use of these technologies. Finally, there is a need for increased awareness and capacity, particularly in Moldova, to address the challenges faced by the industrial sector in adopting renewable energy and flexibility solutions.

The analysis also highlights some country-specific observations. In Moldova, while the industrial sector accounts for only 15% of electricity consumption, efforts are underway to promote renewable energy sources through various projects and **international collaborations**. However, challenges and barriers to wider adoption remain. Moldova **benefits** from substantial i**nternational support**, including funding, technical assistance, and capacity-building initiatives. In Bavaria, industries are actively implementing renewable energy sources, storage, and grid regulation mechanisms. The government provides **strong support** through **incentives**, **regulations**, and **co-financing** from the EU.

3.6.2 Learning from Leaders: Finland

Although, the DR consists of many countries, and valuable learning opportunities can also be found beyond its borders. In Finland, several innovative initiatives are emerging as examples of **integrating distributed energy resources** and **virtual power plants** (VPPs) into the energy system. These initiatives, spearheaded by companies like St1 Lähienergia Oy, Lassila & Tikanoja, and TietoEVRY, demonstrate the potential for enhancing energy flexibility and supporting sustainable national grid operations. The motivation for adopting these solutions is to address the increasing volatility in energy production due to the growing reliance on renewable sources, such as wind and solar power, which are weather-dependent and decentralized. These efforts should be regarded as sources of inspiration for expanding the adoption of distributed energy solutions and VPPs to support the green transition.

Adoption of a Data-Driven, Flexible Energy System

One of the key strategies observed in Finland is adopting **data-driven solutions** to manage the **increasing decentralization of energy production**. TietoEVRY's Distributed Energy Solution (DES) and St1 Lähienergia's Virtual Power Plant (VPP) are examples of how digital platforms can aggregate and manage distributed energy resources such as heat pumps, buildings, and electric vehicles, participating in the flexibility market. These systems allow for balancing energy supply and demand, helping stabilize the grid and providing new income streams for energy providers. The flexibility to adjust energy consumption based on weather conditions and grid demand is becoming increasingly vital for maintaining energy system stability.

Adopting a tailored approach is **crucial to maximize the potential** of such systems. By customizing energy management solutions to individual needs—whether for industrial facilities, buildings, or residential users—energy companies can better integrate their operations into the broader energy market. For example, Lassila & Tikanoja's pilot project, which combines DES with smart building management systems, illustrates how automated energy controls can reduce manual work, optimize energy consumption, and improve indoor climate conditions. Such systems enable participation in demand response programs, which shift energy use to more affordable hours or balance supply and demand, benefiting both energy providers and consumers.

Supporting Decarbonization through Collaboration

TietoEVRY's role in the Veturi programme further **emphasizes the importance of collaboration** in the energy sector. TietoEVRY is developing new data-driven solutions with research partners and energy companies to better manage distributed energy resources, improve network planning, and enhance market adaptability as part of its efforts to support Finland's decarbonization goals. The programme focuses on creating digital services that address the growing need for flexible energy use, including solutions for wind power operators, e-mobility, and real-time data collection. By integrating AI and cloud platforms, these innovations aim to support the green transition, increase energy efficiency, and contribute to a sustainable, decarbonized energy system.

Adopting these flexible, data-driven approaches at various scales—from individual buildings to large industrial operations—can help **address renewable energy integration challenges** and ensure a more resilient energy system.

3.6.3 Key-Take-Aways

Advancing renewable energy and grid flexibility in industry **requires learning from successful models like Bavaria's**, sharing best practices, and collaborating on research and development. Overcoming adoption barriers through awareness campaigns, technical assistance, and financial support is essential. Simultaneously, promoting innovation in technologies like energy storage and smart grids, alongside modernizing and expanding grid infrastructure, will enable greater renewable integration while maintaining stability and efficiency.

To **address the lack of participation**, proactive outreach to non-responding countries is key to understanding barriers and tailoring engagement strategies. Capacity-building initiatives like training programs, workshops, and knowledge-sharing platforms can help countries with limited awareness or resources, while incentives, such as financial support or recognition of best practices, can encourage greater involvement.

In terms of EU and non-EU dynamics, EU member states can leverage funding programs and policy frameworks to accelerate renewable energy and grid flexibility adoption. Supporting non-EU countries in aligning with EU energy policies and accessing funding opportunities fosters regional unity. Sharing best practices across EU and non-EU countries can further enhance progress throughout the DR.

3.7 Financing

3.7.1 Modernisation funds

The EU Modernization Fund is a financial instrument established by the European Union to support investments proposed by Member States. Its goal is to finance projects that contribute to the modernization of energy systems and improve energy efficiency. This fund is intended for the period from 2021 to 2030. Generally, projects eligible for funding must align with the European climate and energy objectives.

The fund is financed by revenues generated from auctioning emission allowances within the framework of the European Emissions Trading System (EU ETS). The member states receiving funds include Bulgaria, Croatia, the Czechia, Estonia, Greece, Hungary, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia, and Slovenia. In total, 13 countries benefit from the modernization fund, with seven of them located in the DR. This fund complements other EU financing instruments and enables member states to finance projects, particularly those outlined in the Fit for 55 packages.

Responsibilities of Member States:

- Implementing the Modernisation Fund in their territory
- Selecting the investment proposals they would like to support from their Modernisation Fund share
- Submitting an indicative overview of their planned investments to the Commission, the EIB and the Investment Committee
- Submitting the investment proposals for confirmation to the EIB and the Investment Committee, and providing the information needed for their assessment
- Paying off the support to the project proponents or scheme managing authority(ies) upon the disbursement decision of the Commission
- Participating in the Investment Committee
- Monitoring and submitting annual reports on the implementation of the Modernisation Fund investments, including notifying the Commission of any discontinued investments and recovered funds as appropriate
- Auditing the project proponents or scheme managing authorities, submitting the results of these audits to the EIB and the Commission
- Taking appropriate measures to ensure that the financial interests of the Modernisation Fund are protected, including recovery actions.

Financing opportunities

Under the modernization fund, projects aligning with the European Union's climate-neutral goals and the Paris Agreement are eligible for support. At least **80%** of the fund's resources must be allocated to priority areas defined in Article 10d(2) of the ETS Regulation. Investments in these areas are referred to as **priority investments**.

Priority areas:

- The generation and use of electricity from renewable sources, including renewable hydrogen,
- Heating and cooling from renewable sources,
- The reduction of overall energy use through energy efficiency, including in industry, transport, buildings, agriculture and waste,
- Energy storage and modernisation of energy networks, including demand-side management, district heating pipelines, grids for electricity transmission, the increase of interconnections between Member States and infrastructure for zero-emission mobility,

- Support for low-income households, including in rural and remote areas, to address energy poverty and to modernise their heating systems,
- A just transition in carbon-dependent regions in the beneficiary Member States, so as to support the redeployment, reskilling and up-skilling of workers, education, job-seeking initiatives and start-ups, in dialogue with civil society and social partners, in a manner that is consistent with and contributes to the relevant actions included by the Member States in their territorial just transition plans in accordance with Article 8(2), first subparagraph, point (k), of Regulation (EU) 2021/1056, where relevant.

Examples of country level approach

While all DANUBE countries utilize the Modernisation Fund to achieve similar goals of decarbonization and energy efficiency, their specific approaches and priorities reflect their unique national contexts, energy mixes, and administrative structures. Here's a general overview:

Czechia

The State Environmental Fund of the Czech Republic (hereinafter "SFŽP ČR") administers the Modernisation Fund, managing individual subsidy programs and acting as an intermediary for this financial resource. Funds are allocated through specific programs and sub-programs, each with its own application process and conditions for support. To meet European climate and energy goals, the Czechia prioritizes investments in electricity and heat production, and industry, particularly focusing on:

- **Construction of renewable energy sources:** This includes support for solar, wind, and biomass energy projects.
- **Increasing energy efficiency across sectors:** This encompasses the modernisation of thermal energy supply systems, building renovations, and industrial energy efficiency measures.
- **Decarbonizing industry:** Support for projects that reduce greenhouse gas emissions from industrial processes.
- **Fostering community energy:** Encouraging local energy production and consumption.

Slovakia

The Slovak Innovation and Energy Agency (SIEA) is responsible for implementing the Modernisation Fund. It manages calls for proposals, evaluates projects, and provides financial support. Slovakia focuses on:

- **Renewable energy sources:** Supporting the deployment of various renewable technologies.
- **Energy efficiency:** Promoting energy savings in buildings, industry, and transport.
- **Modernising energy infrastructure:** Upgrading electricity grids and district heating systems.

Hungary

The Hungarian Development Bank (MFB) manages the Modernisation Fund, overseeing its administration, calls for proposals, project evaluation, and financial support. Hungary prioritizes:

- **Energy efficiency in industry:** Improving energy efficiency in energy-intensive industries.

- **Renewable energy sources:** Supporting the development of renewable energy projects.
- **Modernizing energy infrastructure:** Investing in grid modernization and smart energy solutions.

Bulgaria

The Ministry of Energy is responsible for managing and implementing the Modernisation Fund. The Sustainable Energy Development Fund (SEDF) serves as the implementing agency. Bulgaria focuses on:

- **Renewable energy sources:** Promoting the uptake of renewable energy technologies.
- **Modernizing energy infrastructure:** Upgrading power plants and electricity grids.
- **Increasing energy efficiency:** Improving energy efficiency in buildings and industry.

Romania

The Ministry of European Funds manages the Modernisation Fund, while the Romanian Environmental Fund Administration (AFM) acts as the implementing agency. Romania prioritizes:

- **Modernization of district heating systems:** Improving the efficiency and sustainability of heat production.
- **Development of smart grids:** Investing in modernizing electricity grids.
- **Increasing energy efficiency:** Promoting energy savings in buildings and industry.

Croatia

The Ministry of Economy and Sustainable Development is responsible for the strategic direction and coordination of the Modernisation Fund. The Environmental Protection and Energy Efficiency Fund (FZOEU) acts as the implementing agency. Croatia focuses on:

- **Renewable energy sources:** Supporting the deployment of renewable energy technologies.
- **Increasing energy efficiency:** Promoting energy savings in buildings, industry, and transport.
- **Modernizing energy infrastructure:** Upgrading energy networks and promoting smart energy solutions.

Despite these variations, some common themes emerge:

- **Dedicated agencies or funds:** Each country has a designated agency or fund responsible for implementing the Modernisation Fund.
- **Ministry oversight:** A relevant ministry, typically responsible for energy, environment, or economy, oversees the fund and sets its strategic direction.
- **Focus on key areas:** All countries prioritize investments in renewable energy, energy efficiency, and modernizing energy infrastructure to align with national and European climate and energy goals.

It's important to note that specific approaches and priorities may evolve over time due to changing national circumstances, policy adjustments, and technological advancements.

Accessing Information on Modernisation Fund Projects

The Modernisation Fund is a crucial instrument for supporting the energy transition in ten lower-income EU Member States, including several in the DR. While the fund has clear objectives and guidelines, accessing detailed information about specific projects can be challenging. This lack of readily available information hinders transparency, knowledge sharing, and the identification of best practices within and across countries.

Current Challenges:

- **Fragmented information:** Project information is spread across various websites, including those of national implementing agencies, ministries, and the EU. This fragmentation makes it time-consuming to locate comprehensive project details.
- **Varying levels of detail:** The level of information provided varies significantly between countries and projects. Some websites offer only basic data like project titles and funding amounts, while others may include more detailed descriptions, results, and even photos.
- **Lack of a centralized database:** There is no single, easily accessible database where stakeholders can search for and compare Modernisation Fund projects across all participating countries.
- **Limited information on project impacts:** While basic project data is often available, information on the actual impacts of completed projects, such as emission reductions or energy efficiency gains, can be scarce.
- **Difficulty in identifying best practices:** Without a centralized platform and consistent reporting standards, it is difficult to identify and share best practices and lessons learned from successful projects.

3.7.2 Selected Good Practice Projects Financed from the Modernisation Fund

C-Energy Planá: Switching from Coal to Biomass

Project goals	To phase out coal and transition to 100% biomass fuel at the C-Energy Planá power plant in the Czechia, reducing CO_2 emissions and improving air quality.
Key actions	▼ <u>Conversion of coal boilers:</u> Existing brown coal boilers were retrofitted to burn wood chips, a renewable and locally sourced fuel. ▼ <u>Infrastructure upgrades:</u> Coal bunkers were dismantled and replaced with a new biomass storage facility. Fuel conveyors were upgraded to handle larger volumes of biomass. ▼ <u>Turbine modifications:</u> Adjustments were made to the turbine to optimize its operation with biomass fuel. ▼ <u>Emission control systems:</u> The project likely included measures to control emissions associated with biomass combustion.
Expected outcomes	▼ <u>Significant CO_2 emission reduction:</u> Replacing coal with biomass will substantially decrease greenhouse gas emissions from the power plant. ▼ <u>Improved air quality:</u> Reduced emissions of pollutants associated with coal combustion will contribute to cleaner air in the region. ▼ <u>Increased use of renewable energy</u>: The project promotes the utilization of locally sourced renewable energy, supporting regional sustainability.

ORLEN Unipetrol Kralupy Refinery: Waste Heat Recovery

	Project goals	To reduce energy consumption and CO_2 emissions at the ORLEN Unipetrol Kralupy refinery by utilizing waste heat from flue gases.
	Key actions	▼ Installation of a heat recovery unit: A new unit will capture waste heat from flue gases generated in the refinery's fluid catalytic cracking (FCC) unit. ▼ Innovative polymer heat exchangers: The project will utilize special polymer heat exchangers resistant to acid corrosion, allowing for efficient heat recovery even below the dew point of the flue gas. ▼ Production of boiler feed water: The recovered heat will be used to preheat boiler feed water for the FCC unit, reducing the energy required for steam production.
	Expected outcomes	▼ Reduced CO_2 emissions: By increasing energy efficiency and reducing fuel consumption, the project is expected to reduce CO_2 emissions by up to 15,000 tons per year. ▼ Improved energy efficiency: The project will optimize energy use within the refinery, contributing to cost savings and reduced environmental impact. ▼ Enhanced refinery flexibility and self-sufficiency: The project will improve the refinery's operational flexibility and reduce its reliance on external energy sources. ▼ Technological innovation: The use of innovative polymer heat exchangers represents a pioneering solution in the refinery industry, showcasing the potential for advanced technologies to improve energy efficiency.

The SFŽP ČR showcases both completed and ongoing projects in its "Gallery of Successful Projects." This includes the finished "C-Energy Planá: Switching from Coal to Biomass" project, where a heating plant transitioned from coal to 100% biomass, and the "ORLEN Unipetrol Kralupy Refinery: Waste Heat Recovery" project, which aims to capture waste heat in an industrial setting and is scheduled for completion in 2025. This approach highlights diverse technologies and applications of the Modernisation Fund across different sectors of the economy.

However, the inclusion of projects still in the implementation phase raises questions about the criteria for "success." How can a project be deemed successful before its completion and the realization of its intended outcomes? It is possible that the SFŽP ČR prioritizes showcasing a variety of approaches and technologies or that projects undergo a thorough evaluation process before funding is approved. Nonetheless, clearer communication about the selection criteria for the gallery and the specific achievements of ongoing projects would enhance transparency and public understanding.

3.7.3 Enhancing the Reach and Effectiveness of Grant Programs

National and supranational grant programs, such as the Modernisation Fund, play a crucial role in supporting businesses in their efforts to transition to a low-carbon economy. However, to maximize their impact and ensure that funding reaches the most impactful projects, a more targeted and needs-based approach is essential.

This involves moving beyond simply offering a broad range of eligible activities and instead actively identifying the specific needs and challenges faced by companies on the ground. This can be achieved through comprehensive, sector-specific audits that analyse energy consumption patterns, emission profiles, and potential areas for improvement. By establishing a benchmark and understanding the key opportunities and obstacles, policymakers can design more tailored grant calls and programs that directly address the specific needs and priorities of businesses.

Key steps for a needs-based approach:

- **Conduct sector-specific audits:** Carry out in-depth audits of companies across different sectors, focusing on their energy consumption patterns, emission profiles, and potential for improvement.
- **Develop a needs-based benchmark:** Analyse the audit data to establish a clear benchmark of the sector's needs and potential for improvement in relation to energy efficiency and decarbonization.
- **Design targeted grant programs:** Develop grant programs with specific eligibility criteria and funding priorities that directly address the identified needs and challenges.
- **Prioritize impactful projects:** Encourage applications for projects that demonstrate the greatest potential for CO_2 emission reduction, energy efficiency gains, and overall contribution to climate goals.
- **Provide tailored support:** Offer technical assistance and guidance to companies to help them develop and implement impactful projects that align with the program's objectives.
- **Monitor and evaluate:** Continuously monitor and evaluate the effectiveness of grant programs, making adjustments as needed to ensure they remain relevant and impactful.

Further Strategies for Refinement:

To further enhance the effectiveness of grant programs, consider these additional strategies:

- **Leveraging data and advanced analytics:** Utilize digital platforms for data sharing, encourage automated data collection, and employ advanced analytics to gain deeper insights into industry needs and potential solutions.
- **Fostering collaboration and knowledge exchange:** Establish collaborative partnerships, implement mentorship programs, and create open-access databases to facilitate knowledge sharing and best practice dissemination.
- **Embracing flexibility and adaptability:** Offer modular grant programs, ensure continuous evaluation and adjustment, and support pilot projects to adapt to evolving needs and technological advancements.
- **Prioritizing long-term sustainability:** Focus funding on essential infrastructure investments, promote education and awareness-raising initiatives and strengthen international collaboration to drive long-term progress towards a sustainable future.

By implementing these strategies, grant programs like the Modernisation Fund can play a more effective role in driving the energy transition, supporting sustainable development, and ensuring that funding reaches the projects with the greatest potential for positive impact.

4. Key Findings, Guidelines and Final Thoughts

The analyses presented in this study pointed out that there is significant heterogeneity in the level of implementation of functioning measures driving industrial energy efficiency, whether those are relevant support policies and legislation or the extent to which modern energy-efficient technologies are used by the industries of the countries of the DR. In this regard, one of the most viable recommendations for the future is to increase the intensity of sharing of best practices and information across the countries in the DR, since the potential of getting inspired from recent experience is not maximised and provides a large cost-efficient opportunity to design functioning government-led measures.

4.1 Key Findings and Observations

Key Challenges

1. **Varying levels of implementation of backbone legislation and instruments promoting industrial energy efficiency**

   Across all topics, there is a clear disparity in the level of implementation and prioritisation among the countries in the DR. Some of them, particularly EU members like Bavaria and Austria, have robust legal frameworks and actively promote industrial energy efficiency and renewable energy initiatives. In contrast, others, including some EU members and non-EU countries, often lack clear policies, dedicated funding, or technical expertise.

2. **An insufficiently tailored approach based on the characteristics of a specific region or country**

   The industrial organisation of the DRs' countries and regions calls for a differentiating approach which respects unique challenges in implementing industrial energy efficiency measures. EU-wide strategies must be adapted to each location's specifics and consider local businesses' capacities. Different levels of wealth across companies depending on their operating countries cannot be ignored, as demonstrated by a certain level of backlash from the business sector in many European countries leading to greater popularity of extreme political views questioning the mere essence of the need for energy-saving measures.

3. **Limited engagement and information sharing among the countries of the DR**

   Some countries are only at the beginning of shaping future measures fostering industrial energy efficiency, while the transfer of knowledge and information appears to be limited on a transnational scale. Even though not all policies can be exactly copied from one country to another, it must be noted that some challenges are common in more countries, e.g., negative publicity of green initiatives, low motivation of the industry to invest in innovative technologies or low awareness about the possibilities and benefits of introducing energy saving measures.

Key Opportunities

1. Stronger regional cooperation and knowledge sharing

The DR has a significant opportunity to enhance regional cooperation and knowledge sharing. The study demonstrated that there are multiple common topics among the countries, among others: making energy audits more efficient and traceable, increasing the motivation of SMEs to participate in energy-saving initiatives or understanding the possibilities of modernised energy networks (SmartGrids) in introducing new technologies supporting efficient use of energy sources. Countries can learn from each other's experiences, best practices, and policy approaches. Platforms like the EUSDR can be instrumental in facilitating this collaboration.

2. Leveraging EU membership and support

EU member states can leverage their access to EU funding programs, policy frameworks, and technical assistance to accelerate their progress. Non-EU countries like Moldova can benefit from aligning with EU energy policies and seeking opportunities for collaboration and support. The Interreg Danube programme can be used to finance pilot projects promoting industrial energy efficiency, and based on the outputs, the projects can then be replicated by new programmes financed by larger EU and national funding schemes such as the Modernisation Fund, Recovery and Resilience Facility, LIFE, Horizon and many others.

3. Public awareness and engagement

Raising public awareness about the benefits of energy efficiency and renewable energy can create broader support for policy implementation and encourage individual and community action. Especially in the DR, there are multiple countries with very a sceptical public view on EU green initiatives often caused by a lack of suitable communication.

Positive Aspects

1. Proactive approaches in leading countries

Countries like Bavaria and Austria demonstrate strong leadership with comprehensive policies, dedicated funding programs, and active promotion of industrial energy efficiency. They both understand the importance of quality communication towards the industry and invest time into mapping successful energy-saving projects in the industry. The strength of the local governments lies in their ability to maintain trust towards the private sector thanks to their investment in building strong relationships with all types of companies. The institutions responsible for the implementation of industrial energy efficiency instruments, such as energy audits, actively seek feedback from the industry itself and encourage the participation of different associations in the creation of policies and guidelines.

2. Commitment of non-EU member states

Despite being a non-EU member, Moldova shows a commitment to align its national legislation with EU energy policies and actively seeks international support for its initiatives. This proactive approach can inspire both EU and non-EU countries, which often lack the necessary motivation to progress with their initiatives. Such commitment towards

3. Emerging opportunities with new technologies

Advancements in technologies like heat pumps and smart grids offer new opportunities to optimise energy use, integrate renewable energy sources, and enhance grid flexibility. Even though some innovative technologies cannot be yet implemented in the industry due to the lack of the corresponding enables (Smart Grids), these will not be the case in the next years, and thus, new opportunities will emerge. Since the DR lacks modernised energy networks, inspiration for future application of innovative technologies, including AI-powered solutions, can be drawn from other countries, mainly in Northern Europe (Finland, Sweden or Denmark).

4.2 Guidelines for Promoting Energy Efficiency in Industry

1	**Strengthen regional cooperation** Enhance collaboration and knowledge sharing among similar regions in the DR, leveraging platforms like the EUSDR and promoting peer-to-peer learning. Widen the network by including also stakeholders representing the private sector, such as representatives of major industrial associations and connect them to their peers in other countries of the DR.
2	**Tailor strategies to specific needs** Support the development and implementation of tailored strategies that address the unique challenges and opportunities faced by each country, respecting their level of development, capacity, and EU membership status. Facilitate the understanding and adoption of relevant provisions of EU legislation into national legislation.
3	**Promote proactive engagement** Encourage proactive engagement from all countries in the region, including those that have been less active in recent initiatives. Provide capacity building and technical assistance to support their efforts. Create a strong knowledge-sharing ecosystem which benefits all stakeholders.
4	**Invest in innovation and technology transfer** Support research and development, promote innovation, and facilitate technology transfer to accelerate the adoption of advanced industrial energy efficiency and renewable energy solutions. Maximise the potential the EUSDR network provides and identify research, development and innovation opportunities, which can be then transformed into concrete projects co-financed by other EU programmes or national resources.
5	**Raise public awareness** Conduct public awareness campaigns to highlight the benefits of energy efficiency and renewable energy and encourage individual and community action. Motivate SMEs to voluntarily implement energy efficiency measures through different incentives and facilitate the formation of networks of large companies and SMEs to streamline practices within similar sub-sectors.

4.3 Final Thoughts

This study observed that the **network's full potential enabled by the Interreg Danube Programme remains underutilised**. Energy efficiency is a priority for all countries and regions within the DR, and thus, the established network of national energy experts and policymakers provides a valuable platform for sharing best practices. While the group convenes regularly, there is further potential for enhanced information sharing through interactive workshops, seminars, expert panels, and similar activities. Chapter 3 identifies several promising opportunities for collaboration, recommending the formation of topic-specific working groups to facilitate smoother information exchange.

Insights from national energy experts reveal that companies prioritising sustainable development exhibit greater interest in areas like green transition and the preservation of natural resources and heritage. For example, observations from Austria and Germany show that **highly motivated companies often take a proactive approach to implementing energy efficiency measures**, thereby fostering an ecosystem of businesses introducing various innovative technologies. **Raising awareness of how businesses contribute to achieving the EU's low- to zero-carbon targets will be critical** in encouraging companies from other DR countries and regions to participate. Governments will need to strengthen their communication strategies with businesses and continue offering support in cases where initial costs for energy-efficient technologies may be prohibitive, especially when financial benefits are realised over longer periods (e.g., reduced operational costs).

Nevertheless, recent developments have already heightened awareness of energy efficiency across European industries, even in countries where green interventions were previously met with scepticism. This shift presents an **opportunity for governments to enhance collaboration with industries** actively seeking ways to offset rising production costs. Building trust between government bodies and the private sector will be essential to increase the efficacy of various energy-saving measures and may positively change how energy audits are perceived by more hesitant businesses.

Introducing smart grids offers further potential, enabling advanced technologies and practices to support efficient energy management. As outlined in Chapter 3.2, these advancements require national government oversight to ensure proper implementation. In cooperation with large energy companies, governments in the DR must invest in and modernise transmission networks—an effort currently underway in most countries within the region. These developments will create additional opportunities for implementing innovative energy efficiency measures in the industrial sector.

Finally, the new EU Directive on Corporate Sustainability Reporting provides a framework for increased cooperation between the industrial sector and government institutions. **Public agencies will need to support companies struggling to implement energy-saving measures** to ensure that all industries across the DR are included in the transition towards a sustainable economy.

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List of Tables, Figures and Maps

List of Tables

List of Figures

List of Maps

Appendix

Part A: List of Abbreviations

Abbreviation	Meaning
CBAM	Carbon border adjustment mechanism
CSRD	Corporate Sustainability Reporting Directive
COMECON	Council for Mutual Economic Assistance
DR	Danube Region
EEA	European Environment Agency
EEC	European Economic Community
EU ETS	European Emissions Trading System
EED	Energy Efficiency Directive
EE1st	Energy Efficiency First Principle
ETS	EU Emissions Trading System
EU	European Union
ECSC	European Coal and Steel Community
ESCO	Energy Service Company
ESRS	European Sustainability Reporting Standards
Euratom	European Atomic Energy Community
EUSDR	European Union Strategy for the Danube Region
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
NACE	Nomenclature générale des Activités économiques dans les Communautés Européennes
NAPE	National Action Plan on Energy Efficiency
NUTS2	Nomenclature of Territorial Units for Statistics level 2
PA2	Priority Area 2 of the EUSDR: Sustainable Energy
RES	Renewable Energy Sources
RIS3	Regional Innovation Strategy 3
SEA	Single European Act
SFŽP ČR	State Environmental Fund of the Czech Republic
SMEs	Small and Medium Sized Enterprises
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
USSR	Union of Soviet Socialist Republics
VPP	Virtual Power Plant
WMO	World Meteorological Organisation

Abbreviation	Meaning
WTO	World Trade Organisation

Part B: List and Categorisation of NACE Codes into Agriculture, Industry and Services

List and Categorisation of NACE Codes into Industry, Services and Agriculture		
Major sector	**NACE code (Level 1)**	**Full name (Level 1)**
Agriculture	A	Agriculture, Forestry and Fishing
Industry	B	Mining and Quarrying
	C	Manufacturing
	D	Electricity, Gas, Steam and Air Conditioning Supply
	E	Water Supply; Sewerage, Waste Management and Remediation Activities
	F	Construction
Services	G	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
	H	Transportation and Storage
	I	Accommodation and Food Service Activities
	J	Information and Communication
	K	Financial and Insurance Activities
	L	Real Estate Activities
	M	Professional, Scientific and Technical Activities
	N	Administrative and Support Service Activities
	O	Public Administration and Defence; Compulsory Social Security
	P	Education
	Q	Human Health and Social Work Activities
	R	Arts, Entertainment and Recreation
	S	Other Service Activities
	T	Activities of Households as Employers; Undifferentiated Goods and Services Producing Activities of Households for Own Use
	U	Activities of Extraterritorial Organisations and Bodies