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Energy efficiency in the industrial sector in the EU, Slovenia, and Spain

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ABSTRACT

'Energy efficiency first' is one of the key principles of the Energy Union, mainly due to it being the most cost effective way to reduce emissions, improving energy security, enhancing competitiveness and making energy consumption more affordable for all consumers. In light of the revised EU Energy Efficiency Directive, this paper discusses new developments brought by the EU together with the national case studies of Slovenia and Spain. Given that the paper has a specific focus on the industrial sector, it discusses the selected measures of the Energy Efficiency Directive, such as defined in Articles 7, 8, and 14, which are the most relevant to this sector. The paper also explores the newly issued integrated national energy and climate plans together with national measures and policies that support energy efficiency in industry, including the quantification of achieved and forecast energy savings in these two EU Member States.

1. Introduction

The European Commission has a strategic long-term vision to lead the transition towards a climate-neutral economy by 2050 in line with the objectives of the Paris Agreement. Building on the EU's international commitments, in 2009 the EU adopted a wide-ranging package where it located legislation to ensure the EU meets its climate and energy targets for the year 2020. They are the so-called EU's '20-20-20' targets – 20% increase in energy efficiency, 20% cut in greenhouse gas emissions (from 1990 levels), and 20% renewables by 2020. In 2016, in the Clean Energy for all Europeans package [1] the European Commission set tasks to bring EU energy legislation into line with the new 2030 climate and energy targets stressing the 'Energy efficiency first' as one of the key principles of the Energy Union. This is because energy efficiency is the most cost effective way to reduce emissions, improve energy security, enhance competitiveness and make energy consumption more affordable for all consumers. It also presents one of the key factors in achieving the long-term energy and climate goals. With Article 194 of TFEU (Treaty on Functioning of the European Union) the EU promotes energy efficiency and energy saving and the development of new and renewable forms of energy. Specifically, the 2012 Energy Efficiency Directive (EED) [2] is an overarching directive, which introduced a number of measures, policy requirements and tools (i.e. energy efficiency obligations schemes or alternative measures) to enable the EU to reach its 20% energy efficiency target by 2020. The EU Member States are required to use energy more efficiently at all stages of the energy chain, including energy generation, transmission, distribution and end-use consumption. Further revisions were set for long-term trajectories by the amended EED [3] with the energy efficiency target for 2030 set of at least 32.5% (to be achieved collectively across the EU). Within the framework of the Paris Agreement, the European Commission also issued a strategy for a climate neutral economy by 2050 by updating its roadmap towards a systematic decarbonisation of the economy [4] and by providing a cost-efficient trajectory towards the attainment of the target of net-zero emissions. The EU also operates the EU Emissions Trading Systems, which puts a price on greenhouse gas emissions to create financial incentives for industry and businesses to reduce emissions [5].

While the EU is on track to meet its 2020 targets on GHG emission reductions and renewable energy [6], it seems that this is

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Abbreviations

CHP	Combined Heat and Power
DC	District Cooling
DH	District Heating
EE	Energy Efficiency
EED	Energy Efficiency Directive
EEOS	Energy efficiency obligation scheme
EMS	Energy management systems
ESR	Effort Sharing Regulation
EUR	Euros
EUROSTAT	Statistical office of the European Union
FNEE	National Energy Efficiency Fund (*Fondo Nacional de Eficiencia Energética)*
GHG	Greenhouse gas
IDAE	Institute for the Diversification and Saving of Energy (*Instituto para la Diversificación y el Ahorro de Energía)*
Ktoe	Thousand tonnes of oil equivalent
M	Million
MITECO	Ministry for Ecological Transition and Demographic Challenge (*Ministerio de Transición Ecológica y el Reto Demográfico)*
Mtoe	Million tonnes of oil equivalent
NECP	National energy and climate plan
NEEAP	National energy efficiency action plan
RES	Renewable Energy Sources
SME	Small and medium sized enterprise
TJ	Terajoule
TOE	Tonnes of oil equivalent

not the case for energy efficiency, which will be discussed in this paper while exploring the EU recent trends in terms of primary and final energy consumption and noting the gaps in reaching the set targets. The specific emphasis will be placed on the industrial sector, which is one of the largest users of energy (after the transport sector) in the EU and in most Member States, including Slovenia and Spain. This sector requires further attention not only because of the incline of energy consumption in recent years but also because of its potential of energy efficiency. Notably, this article will review the most recent EU updates on energy efficiency in relation to the measures imposed by Articles 7, 8, and 14 revised EED, which are the most relevant to the industrial sector. It will then explore the extent to which the national regulatory frameworks (including the most recent national plans) in the selected jurisdictions, such as Slovenia and Spain, promote energy efficiency and what measures are employed to address that. These will be placed in a broader national context in terms of strategy developments and institutional settings. While embracing a "stick and carrot" approach where regulations are combined with incentivising instruments to ensure that energy-intensive industries implement more advanced technology to save energy, this article will also identify good practices to improve energy efficiency in these countries.

Specifically, the paper is structured as follows. After this introduction (section 1) and the background and methodology (section 2), section 3 outlines the recent EU regulatory framework and policies on energy efficiency (including the updated EED), the EU energy consumption as well as prospects to meet the energy efficiency targets for 2020 and 2030. This will follow by energy efficiency obligation schemes as well as alternative measures (Article 7 EED), mandatory audits and energy management systems (Article 8 EED) and industrial waste heat recovery heating and cooling (Article 14 EED). Given that the EU Member States are obliged to transpose the EU regulatory framework (i.e. the EED) and contribute towards the overall EU target, the paper will also discuss the national measures and policies employed at national level to enhance energy efficiency, namely in two Member States – Slovenia (section 4), and Spain (section 5). Finally, section 6 summarises the discussions presented in the paper, whereas the conclusions and recommendations are singled out in section 7.

2. Background and methodology

Energy efficiency is a highly debated topic mainly due to its significant importance to achieve the sustainability goals. Underpinned by interdisciplinary by its very nature, energy efficiency has been analysed from different perspectives. For instance, there is comprehensive scholarship literature on technological advancements to improve energy efficiency, most importantly, from various renewable energy sources [7–10], including the technologies for industrial waste heat recovery [11,12] with a specific emphasis being placed either on one [13], or several industrial branches, such as the aluminium, ceramic, and steel industries [14]. Some reports focused on the larger scale of EU and beyond in attempt to identify best practices and case studies for industrial energy efficiency improvements [15]. There have also been scientific considerations and suggestions to move away from single-sector thinking to a coherent energy systems in terms of smart energy system demonstrating the benefits from the integration of all sectors and infrastructures [16]. An economic perspective should not be undermined as well, for instance, the improvements of energy efficiency have been discussed within enterprise [17,18], industrial sub-sectors in a selected jurisdiction [19], or the standpoints of whole society [20–22]. There has been a critical view expressed that in order to limit energy consumption, there is a need for energy sufficiency (or conservation) rather than energy efficiency to avoid any the 'rebound' effects [23]. There have been also studies undertaken at the larger scale, such as the EU level, where Connolly, Lund et al. proposed a new heat strategy with the expansion of district heating, along with more heat savings, heat recycling, and the use of more renewable energy resources, which would result in heating and cooling costs being reduced by approximately 15% [24].

Further studies have addressed the EU regulatory frameworks and policies on energy efficiency [25] quite often with an economic connotation, as all European policies and initiatives must be economically justified. For instance, while using the new methodology built on an econometric model Bertoldi and Mosconi [26] evaluated energy efficiency policies in the EU Member States in the period 1990–2013 and discovered the energy savings induced by these policies counted to a remarkable 12%. Some papers have focused on energy efficiency improvements by national measures in one selected Member State, such as Lithuania [27], Slovenia [28], and Spain [29]. There have also been more specialised studies conducted on the EU energy efficiency policies, especially the EED and its separate aspects; for instance, the EU energy efficiency obligation schemes [30], in particular, White Certificate [31,32]; the EED requirements on mandatory energy audits [33], industrial waste heat recovery [34]. Even though the EED has a horizontal application and covers broader themes, the focus of this paper is on the selected measures of the EED which are the most relevant to the industrial sector, such as the measures imposed by Articles 7, 8, and 14 EED. Building on the previous studies, the EU policies on the

selected measures on energy efficiency together with statistical data on EU energy consumption are discussed to provide the foundation of this paper, as the EU is a driving force for change in national Member States. Yet, its objectives and targets cannot be achieved without national contributions. Therefore, Slovenia and Spain have been chosen as case studies in this paper. Given that the 'rebound' effects are less likely in the industrial sector, the common terminology of 'energy efficiency' will be used.

As far as the methodology is concerned, the review process involved analysing the primary sources, such as the EU regulatory framework, policies, and assessment reports published by the European Commission, and the European Environment Agency as well as national government strategy and policy documents, the mandatory reports, such as the National Energy Efficiency Action Plans (NEEAPs), with a specific emphasis being placed on the most recent plan - the Integrated National Energy and Climate Plan (NECP). All Member States of the EU had to submit their draft NECP for the Commission's evaluation to ensure that the countries' national energy efficiency contributions and their proposed measures would collectively achieve the EU target. Therefore, the evaluation of these new plans (which are currently available in national languages) is essential, as they define national measures and policies that support energy efficiency in different sectors, including industry, as well as the quantification of achieved and forecast energy savings. This enables businesses operating in the industrial sector to better understand their government's priorities and future trajectories. A template with specific questions centred on four typologies, such as i) energy consumption (including energy consumption in industry), ii) obligatory energy savings schemes (and alternative measures), iii) audits and energy management systems, and finally, iv) efficiency in heating and cooling (including industrial waste heat recovery) was provided for each national rapporteur for data collection. Qualitative data analysis was then undertaken within each typology, which then facilitated consistency in comparative analysis between the two jurisdictions in attempt to identify any good practices. In addition, comparison took place not only at jurisdictional level, but also within a jurisdiction in terms of the energy efficiency measures and policies introduced by the previous NEEAPs (effective until the end of 2020) and the future orientated NECPs.

3. The EU regulatory framework and policies on energy efficiency and energy consumption

3.1. EU energy consumption

Energy consumption in the EU is assessed in the context of primary energy consumption (gross inland consumption, excluding non-energy uses) [2] and/or final energy consumption (the total energy consumed by end users - all energy supplied to industry, transport, households, services and agriculture, yet, excluding deliveries to the energy transformation sector and the energy industries themselves) as defined in Articles 2 (2) and 2 (3) EED respectively [2]. A 20% EU energy efficiency target by 2020 translates into a primary energy consumption of no more than 1483 Mtoe and a final energy consumption of no more than 1086 Mtoe. Whereas the 2030 energy efficiency target is 32.5%, meaning that a primary energy consumption should not be more than 1273 Mtoe and a final energy consumption -no more than 956 Mtoe. Given that the UK is leaving the EU at the end of 2020, the Union's energy consumption figures have been adjusted accordingly, to the situation of the remaining 27 Member States; with a primary energy consumption of no more than 1312 Mtoe in 2020 and 1128 Mtoe in 2030 and a final energy consumption of no more than 959 Mtoe in 2020 and 846 Mtoe in 2030 [35].

Given that energy needs are influenced by a number of factors, including economic developments as well economic/financial/health crises (i.e. the current pandemic of coronavirus), the structural changes in industry, the implementation of energy efficiency measures and also the specific weather situation, the primary energy consumption has fluctuated over the years. While energy consumption in the EU has been gradually decreasing in the 2000s (with some exceptions), this trend has changed in 2014. Between 2014 and 2017 the primary energy consumption has increased by 4% each year, but it decreased by 0.7% in 2018.

Fig. 1 indicates that the gap between the actual level of primary energy consumption and the target level in 2020 was 15.2% in 2006, 1.5% in 2014 and in 2018 it was 4.9% and the distance to the 2030 target was 22.0% in 2018 (in the revised EU-27 Member States). Specifically, primary energy consumption in the EU-28 in 2017 was 1675 Mtoe, which is 1.6% higher than in 2016 [35].

As far as final energy consumption is concerned, final energy consumption in the EU was 5.7% lower in 2017 in comparison to 2005, accounting to an average annual decline of 0.5%. It was lower in all sectors (save the services sector) and the highest decrease was in the industry (14.7%) and households (7.1%) sectors [35]. This overall decrease of final energy consumption since 2005 can be down to the various factors similar to primary energy consumption, including the changes in economic performance (the economic recession), structural changes in various end-use sectors, in particular less energy intensive industrial sectors, improvements in end-use efficiency, and favourable climatic conditions [37]. However, alongside to primary energy consumption, final energy consumption has also been increasing in the EU since 2014. For instance, in 2018 it was 5.5% higher than in 2014.

While in 2014 the final energy consumption was 2.2% below the 2020 target level, in 2018 it was 3.2% above the 2020 target level and the distance to the 2030 target was 17.0% in 2018 (in the revised EU-27 Member States, see Fig. 2) [35]. In 2018, the energy consumption increased in 15 Member States, in comparison to 2017 with the biggest energy-consumption increase being recorded in Poland and Spain, with a rise of 13.7% and 7.5% respectively from 2013 [5].

3.2. EU policies on energy efficiency

3.2.1. Overview

The European Commissioner for Climate Action and Energy in 2016 expressed that "the cheapest energy, the cleanest energy, the most secure energy is the energy that is not used at all" [38]. Therefore, energy efficiency needs to be considered as a source of energy in its own right. To ensure this is the case, the European Commission has set ambitious policies and targets on energy efficiency. The EED [2], adopted in 2012, embraced a set of measures such as: legal obligations to establish energy saving schemes and/or alternative measures in the Member States, the provisions on the setting of energy-efficiency targets, general energy-efficiency policies, energy audits, combined heat and power (CHP), management systems for enterprises, consumer behaviour etc. 2019 marked the completion of the new energy rulebook – so called the Clean Energy for all European package [1]. As part of this package, the revised EED [3] updated the policy framework for 2030 and beyond. It set a binding energy efficiency target of at least 32.5% by 2030 (which can be increased subject to a review in 2023). As stated above, the 2030 binding target is to be achieved collectively across the EU. The EU Member States must set their own national contributions for 2030. Specifically, the Governance Regulation [39] requires the Member States to design integrated 10-year NECPs, which should, *inter alia*, define how they intend to meet their energy efficiency and other targets for 2030 and provide future

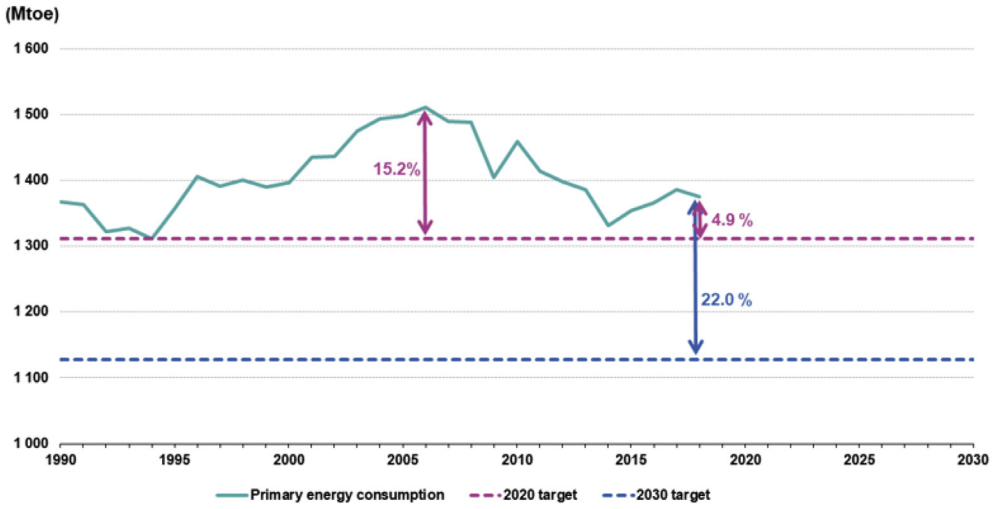

Fig. 1. Distance to 2020 and 2030 targets for primary energy consumption in the EU-27 [36].

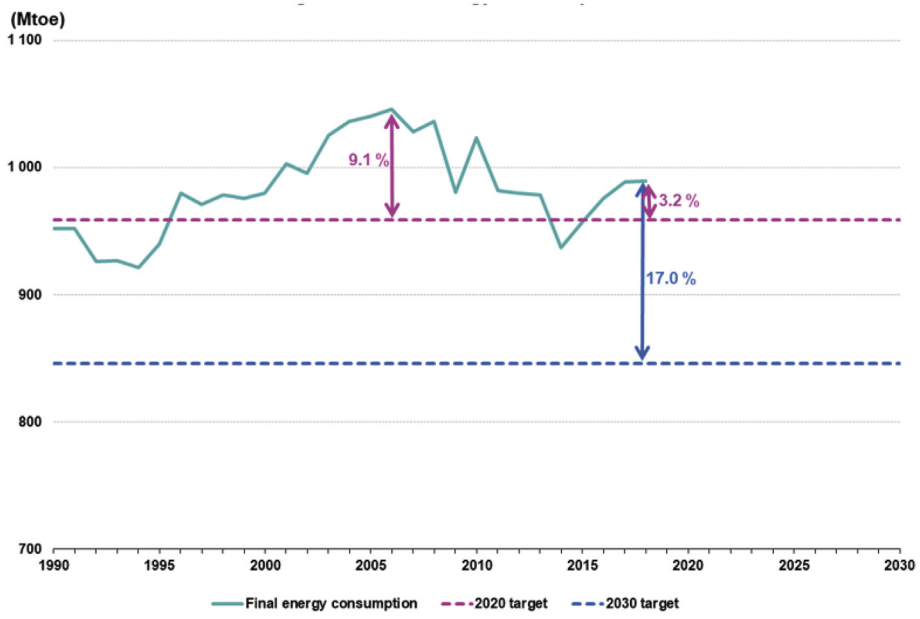

Fig. 2. Distance to 2020 and 2030 targets for final energy consumption in the EU-27 [36].

directions to all, including industries.

3.2.2. Obligatory energy savings schemes and alternative measures

Pursuant to Article 7, the revised EED has extended the Member States' annual energy savings obligations; while from January 2014 to December 2020 they had to ensure savings each year from of 1.5% of annual energy sales to final customers by volume, the new savings each year from January 2021 to December 2030 is 0.8% of annual final energy consumption. The Member States have flexibility on how they achieve their energy savings, such as by introducing energy savings obligation schemes, alternative measures or a combination of the two. Alternative measures embrace CO_2 taxes, financing schemes, fiscal incentives, regulations or voluntary agreements that lead to the application of energy-efficient technology, training and education, energy efficiency standards, norms and labelling to achieve or even go beyond the targets mandated by EU law [2]. For instance, relying on the MURE database, Bertoldi and Mosconi (2020) reported that during the 1990–2013 period the average number of energy policy measures was 66 in the Member States, whereas Spain indicated 139 measures (in comparison to Denmark and its 27 measures). As far as the high impact measures are concerned, Spain reported 91 "high impact" measures while Denmark only 3 [26]. Therefore, the evaluation of the effectiveness of these measures is complex.

Furthermore, the Member States may institute minimum efficiency standards to reduce industrial energy demand, as they address the main obstacles to the take-up of cost-effective energy-efficiency measures in industry (i.e. risk aversion and uncertainty). Yet, these should be designed with an awareness of possible interactions or overlaps with the EU emissions trading scheme [40]. The updated EED clarified that the calculation of the amount of energy savings either as a result of energy efficiency obligations schemes or alternative policy measures are on equal footing. Therefore, due to the flexibility of energy efficiency obligation

schemes the Member States can design them in a variety of ways to meet national needs and to fit within their different policy mixes in order to achieve sustained energy savings and find the system that is best suited to particular circumstances of a Member State [41]. However, the Member States need to take into account energy poverty and other social aspects when they design their energy efficiency schemes and alternative measures. They also should assess and take appropriate measures (where applicable) to minimise the impact of the direct and indirect costs of energy efficiency obligation schemes on the competitiveness of energy-intensive industries exposed to international competition [2]. Notably, countries with energy-intensive, trade-exposed industries (e.g. aluminium smelting), may decide to exclude (or 'carve out') such industries from an energy efficiency obligatory schemes on the grounds that their competitiveness in international markets may be adversely affected [40]. While the EED has a horizontal application, the Member States have the flexibility to target one or more specific sector(s) in order to meet the energy savings obligation, by introducing policy measures, for instance, in the industrial sector [40]. According to the estimations based on the Member States national plans, the biggest proportion of savings will be achieved by measures targeting buildings followed by the second and third biggest proportions coming from industry and transport respectively; and the energy efficiency obligatory scheme (a cross-sector policy) will generate the highest share of savings per policy measure [42].

3.2.3. Audits and energy management systems

Article 8 EED imposes an obligation of independent, cost-effective, high-quality energy audits to all large enterprises, which defined as non-SMEs (small and medium sized enterprises). The EU definition of SMEs is fewer than 250 employees and a turnover of no more than EUR 50 M or a balance sheet of no more than EUR 43 M. These audits must be conducted at least every four years. They are designed to provide individual firms with valuable advice on their energy consumption. Indeed, energy audits and energy management are identified as important instruments to explore economic energy efficiency potentials; to gain knowledge and develop a strategy to improve energy efficiency in businesses [5]. Large businesses are exempted from this audit obligation if they have implemented energy management systems (EMS) (Article 8 (6) EED), where an EMS whereby 'means a set of interrelated or interacting elements of a plan which sets an energy efficiency objective and a strategy to achieve that objective' [2]. An EMS creates a structure to monitor energy consumption and improve energy efficiency in an industrial firm and the use of it in industry is currently increasing [5]. The Member States should also encourage energy audits and EMS to SMEs.

3.2.4. Efficiency in heating and cooling (including industrial waste heat recovery)

There are also requirements addressing efficiency in heating and cooling (as defined in Article 14 EED), requiring the Member States to carry out a comprehensive assessment of the cost effective potential for energy efficiency in heating and cooling, principally through the use of cogeneration, efficient district heating and cooling and the recovery of industrial waste heat. Specifically, the Member States need to identify the technological solutions used to supply heating and cooling, while making distinctions between on-site (i.e. heat-only boilers; high-efficiency heat and power generation; heat pumps; and other on-site technologies) sources and off-site sources (i.e. high-efficiency heat and power generation; waste heat; and other off-site technologies) and between renewable and fossil energy sources. To analyse the economic potential for efficiency in heating and cooling, an assessment should include the identification of suitable technologies for supplying low-carbon and energy-efficient heat and cold on the national territory using a cost-benefit analysis and a baseline and alternative scenarios among other things [43]. The European Commission has also published some soft legislation (non-binding) to help the Member States to fully transpose the different elements of the 2018 amending EED into national law, including the recommendation on transposing the energy savings obligations under the energy efficiency directive and annex [40]; the recommendation on the implementation of the new metering and billing provisions of the energy efficiency directive and annex [44]; and recommendation on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of the energy efficiency directive and annex [45].

4. Energy efficiency: a case study of Slovenia

4.1. Overview

Slovenia is one of the smallest EU Member States (followed by Estonia, Cyprus, Luxembourg and Malta in descending order) with its population of just over 2 million. Given that it is not rich in fossil fuels, it imports all of its oil and natural gas [46], referring to energy dependency at 48% as in 2018 [47]. This dependency results in economic, political, and social vulnerability within the EU [48]. In 2018, domestic energy production in Slovenia was 148 299 TJ (3.542 Mtoe) with nuclear energy accounting for the largest share of 42%, followed by renewable energy sources (including hydro energy) with 32%, coal with 25%, and with less than 0.5% of energy being produced from other sources [49]. Slovenia has a great potential for the sustainable development of energy policy embracing energy efficiency.

As previously discussed, for the EU to meet their 20-20-20 targets, the Member States must deliver on their national targets. While the EU emission target is 20% less compared to 1990 levels, Slovenia's national target is 4% more compared to 2005 levels (for sectors falling outside the EU Emission Trading System) [50]. Meanwhile, the national target for renewables is 25% by 2020 and primary energy consumption 7.125 Mtoe [51], which was revised from the previously stated target of 7.3 Mtoe. In its final integrated NECP [52] published in February 2020, Slovenia indicated that its primary energy consumption will not exceed 6.36 Mtoe by 2030 (see Table 1). The NECP also anticipates 20% GHG emission reduction by 2030 in comparison to 2005 in sectors not included in the Emission Trading scheme. The target of energy efficiency improvement is defined at 35% by 2030 with final energy consumption not exceeding 4.72 ktoe (see Table 1).

The total investment required for the implementation of all the NECP measures is estimated at EUR 22 829 M, of which EUR 6139 M are dedicated to energy efficiency [52].

4.2. Energy consumption

As defined in the Slovenian NEEAP [51], primary energy consumption for Slovenia should not exceed 7.125 Mtoe in 2020 (Fig. 3). This means that it may not exceed the 2012 figure by more than 2%. By the end of 2015, final energy savings of 4949 GWh were achieved, which was 16% above the target for 2016 [51]. More recently, in 2018, the primary energy consumption decreased by 1.8% compared to 2012.6.88 Mtoe of primary energy consumption in 2018 [47] indicates that it is still within the indicative target (Fig. 3).

With regard to final energy consumption, Slovenia's national target should not exceed 5.118 Mtoe in 2020 [51]. With 4.972 Mtoe of final energy consumption in 2018, Slovenia is 3% below the

Table 1
National targets of Slovenia.

National targets and contributions	2020	2030
GHG compared to 2005 under the Effort Sharing Regulation (ESR)	+4%	−20%
Renewable Energy	25%	27%
Energy Efficiency (improvements from 2007):	20%	35%
Primary energy consumption (Mtoe)	7.125	6.36
Final energy consumption (Mtoe)	5.118	4.72

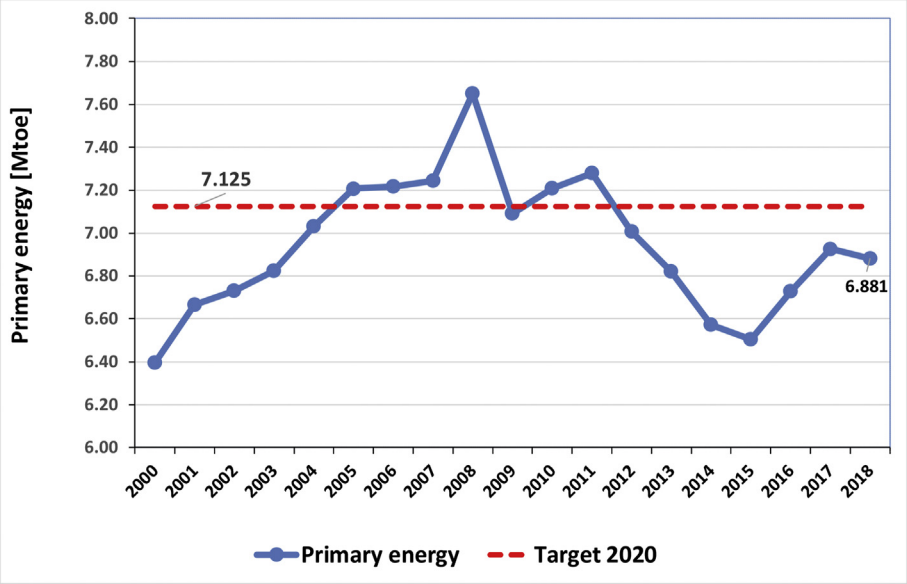

Fig. 3. Primary energy for the period 2000–2018 and the EED target goal for 2020 [47].

indicative target for 2020, as presented in Fig. 4 [47].

During the period from 2014 to 2018, there was an increase in the final energy consumption of all final energy sectors. The largest increase in 2018, in comparison to 2014, can be attributed to the industry sector (12.5%), followed by transport (10.0%), households (4.7%), and other (0.4%). The largest share in the total final energy consumption belongs to the transport sector, namely 40%, followed by industry with 28%, households with 21% and other users with 11%. In the period 2000–2018, the share in final energy consumption decreased the most in industry, namely, by 4% [47]. Final energy consumption in Slovenia slightly increased in 2018 (by 0.5%) in comparison to 2017 [49].

4.2.1. Energy consumption in industry

For the industrial sector, Slovenia has set an indicative target for final energy consumption in 2020, namely that the total energy consumption in this sector will not exceed 1.307 Mtoe [51] by 2020 and 1.283 Mtoe [52] by 2030. Final energy consumption in industry has been increasing since 2013. Notably, from 2013 to 2018 it has increased by 15.6%. Therefore, in 2018, it was about 2% above the target value for 2020, as presented in Fig. 5 [52]. Due to the increasing use of final energy in the industrial sector, the trajectory towards achieving the indicative target in the industry is currently unfavourable. Therefore, energy productivity in this sector has to be improved.

As far as specific industrial branches are concerned, the final energy consumption in basic metal production (C24) has been increasing since 2010. On the contrary, from 2008 to 2018 there have been the significant decrease in energy consumption in the production of non-metallic mineral products (C23 – 40% reduction) and the paper industry (C17 – 27% reduction) (see Fig. 6).

It is important to note that energy-intensive branches in Slovenia account for about 25% of total added value in industry (data for 2018) [53]. The key contribution, almost 12.3% of the total added value of Slovenian industry is generated by pharmaceutical companies (C21) with the remaining energy-intensive sectors contributing as follows: production of chemicals and chemical products (C20) 4.0%, production of metal production (C24) 3.7%, non-metallic mineral products (C23) 3.5% and paper and pulp production (C17) 1.6% [53].

4.3. National policies on energy efficiency

Building on the EU energy policy, the Slovenian energy policy goals also aim to ensure a reliable, safe and competitive energy supply in a sustainable manner by ensuring the transition to a low carbon society [54]. The Ministry of Infrastructure and Spatial Planning, Directorate for Energy is the government body responsible for Slovenian energy policy, which is supported by the Energy Agency (*Agencija za energijo*), the regulatory authority supervising and regulating the energy field that, *inter alia*, is also responsible for promoting efficient use of energy [55]. Additionally, within the ambit of the Ministry of Environment and Spatial Planning, there is also the national public entity Eco Fund (*Eko sklad*), which is the only specialised institution in Slovenia that provides financial supports for environmental projects [56]. The Eco Fund is also responsible for the preparation and implementation of energy efficiency measures at national level and provides financial aids to natural and legal persons (i.e. energy refurbishment of buildings, replacement of old inefficient heating systems, energy advising,

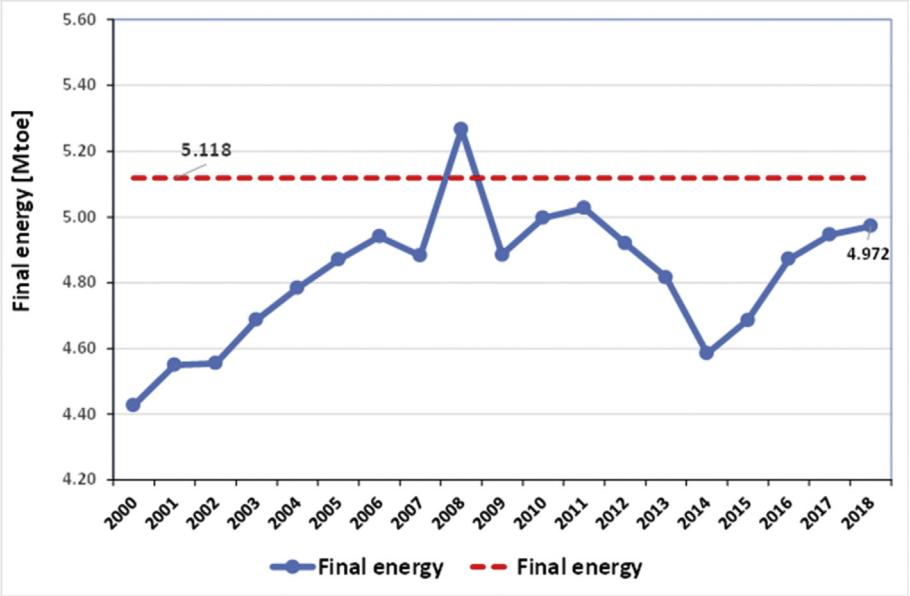

Fig. 4. Final energy consumption for the period 2000–2018 and the indicative goal for 2020 [47].

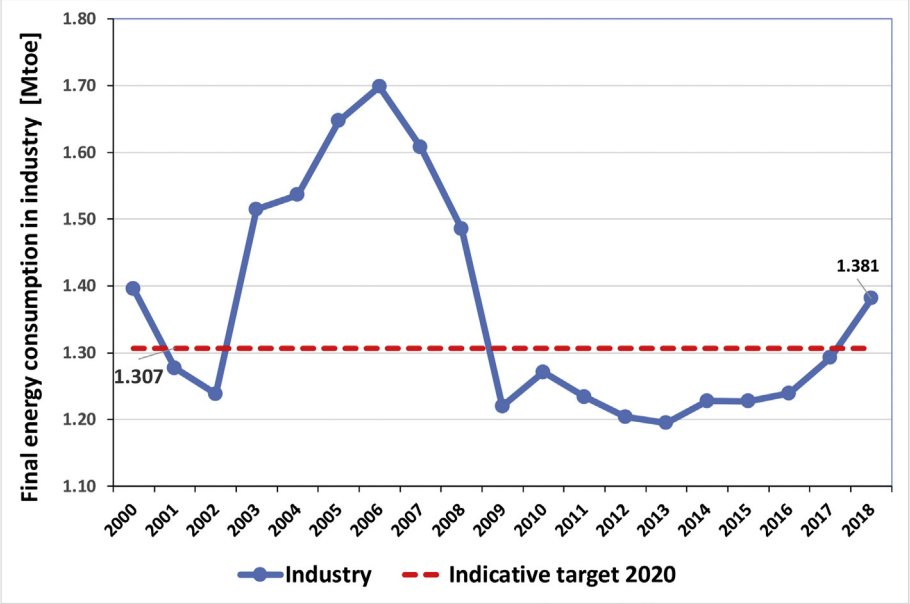

Fig. 5. Final energy consumption in industry for the period 2000–2018 and the indicative goal for 2020 [47].

energy poverty alleviation programmes, co-financing investments in renewable energy sources, subsidies for electric car etc.) [57].

The main legislative framework for the energy sector in Slovenia is postulated in the Energy Act [58], which transposed a number of EU directives concerning electricity and gas markets, energy efficiency and renewable energy sources. It also contains the principles of energy policy, measures ensuring energy security, and measures regulating energy infrastructure and heat distribution. There is also a new long-term development strategy document – the Energy Concept of Slovenia (*Energetski koncept Slovenije*), containing the national energy programme [58]. This document, on the basis of the projections of the country's economic, environmental and social development and the adopted international commitments, defines the objectives of the reliable, sustainable and competitive energy supply for the next 20 years (and tentatively for the next 40 years) [59].

The current measures for achieving the 2020 targets in Slovenia are contained in the NEEAP 2020, which aims to meet the long term climate and energy targets with the highest possible efficiency and the lowest possible costs [51]. Future trajectories are now incorporated in the integrated NECP which sets the overall target to improve energy efficiency by at least 35% in 2030 from the 2007 baseline scenario (in line with the revised EED) [52].

4.4. Obligatory energy savings schemes and alternative measures

Slovenia meets the binding requirements of Article 7 EED through a combination of both energy efficiency obligation scheme

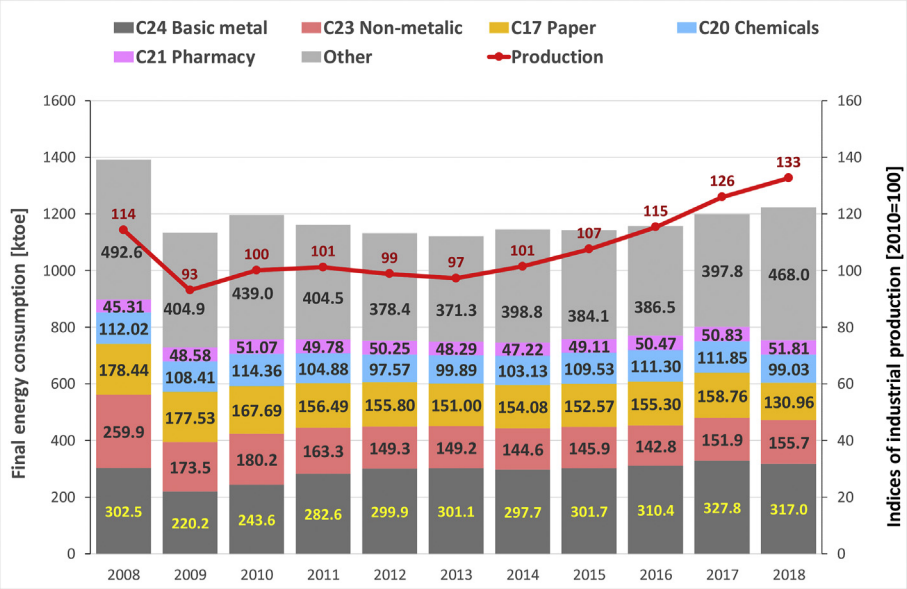

Fig. 6. Final energy consumption in industry per industrial branch in the period 2008–2018 [53].

and alternative measures. The two main measures are the energy efficiency obligation scheme (EEOS) and the Eco Fund, where the obligation is divided as follows: half of the 1.5% energy savings goes to the Eco-Fund and the other half to EEOS. Article 318 of the Energy Act defines that obligated parties are suppliers of electricity and heat and suppliers of solid, liquid or gaseous fuels to final customers irrespective of their size. They should ensure the achievement of energy savings among final customers [58]. The obliged entities may, however, meet their obligations by remitting funds to the Eco Fund in an amount equal to the total savings that should have been achieved by final customers and the additions to the price of heat and fuel prices to increase Eco-Fund's energy efficiency. Furthermore, these measures may be implemented in all sectors, including transport and industry that are included in the emission allowances trading scheme [51]. The Energy Agency is responsible for reporting on and monitoring the achievement of energy savings.

According to the Energy Agency report for 2018 [60], the obliged entities reached 24.4 ktoe of final energy savings, hence, exceeding the 2018 target of 21.5 ktoe. The industrial sector accounted for 37% of all achieved savings because of the main measures being employed, such as the introduction of CHP systems, energy efficient lightning, use of efficient electrical devices (i.e. electrical motors, ventilation systems), introduction of EMS and the use of excess heat. Evaluation of the effectiveness of the NEEAP2020 implementation noted that the overall sectoral comparison for the period 2016–2018 indicates the largest savings being made in the industry sector (i.e. 179 GWh in 2016 and 133.3 GWh in 2017) and the housing sector (163.5 GWh in 2016 and 171.8 GWh in 2017) [61,62].

With regard to alternative measures, Slovenia chose the implementation of the Eco Fund's programme for promoting energy efficiency measures [58]. The obliged parties and their contributions provide funds for Eco Fund, which is supplemented by funds from the Climate Change Fund. The Eco Fund's target in individual years within the 2014–2020 period amounts to 0.75% (22.53 ktoe) of the annual savings target. Therefore, the savings made by the Eco Fund with the help of the measures implemented across the entire 2014–2020 period should reach 157.7 ktoe in 2020, giving cumulative savings of 630.8 ktoe across the entire period [51]. The energy savings provided by the Eco Fund as an alternative measure in 2018 amounted 19.9 ktoe [63]. Even though savings are attained in any given year, Slovenia has not reached the set goals yet, since the surpluses achieved by the obliged entities are transferred to future years, and the objectives set in the framework of alternative measures (22.5 ktoe of final energy savings per year) were not achieved [51]. For the forthcoming period of 2021–2030 Slovenia will continue energy efficiency improvements through a combination of the contributions from the obliged parties and alternative measures, such as the implementation of the energy efficiency measures from the NEEAP 2020, for instance, the Operational Program for reduction of GHG emissions until 2020, the Operational Program for the implementation of European Cohesion Policy Eco Fund programmes and tax mechanisms [52]. A revision of the methods for calculating energy savings is also foreseen, thus, eliminating irregularities that could lead to unrealistically high savings and therefore, low market prices [52].

To conclude, it has been noted that there is a need to improve monitoring of the implementation of the scheme and to ensure the conditions for its stable functioning. This relates primarily to checking the reporting by the obliged entities of the achieved savings (i.e. through the implemented projects), and on-going modification of methods for calculating energy savings. With regard to the implementation of alternative measures, the most important problem remains the effective allocation of funds.

4.5. Audits and energy management systems

The obligations arising from Article 8 EED in Slovenia were also transposed in the Energy Act [58] supported by the Rules on the methodology for the production and the content of energy audits adopted in June 2016, compelling large companies to conduct an energy audit every four years [64]. Given that the target group in this article is large enterprises - defined as "enterprises that are not SMEs" (Article 8 (4) EED), gave the Member States flexibility either to follow the EED verbatim or provide their own definition. Nabitz and Hirzel discovered that different approaches to translating the target groups were taken across the Member States; in some cases, further criteria for a delimitation of large companies were applied which resulted in either an extended or reduced target group regarding the obligation [65]. For instance, Slovenia adjusted and

lowered the financial thresholds for the definition of SMEs, which led to cover businesses that are SMEs. Specifically, the Companies Act (ZGD-I) provides that large companies have to fulfil two conditions: i) have at least 250 employees; ii) an annual income of more than EUR 35 000 000; and the value of assets of more than EUR 17 500 000 [65]. To guarantee compliance with the requirements Slovenia decided to impose the penalty (EUR 10 000) on the management level (i.e. director of the company) [33].

The Energy Agency is responsible for the monitoring of the fulfilment of this obligation. During the 2013–2014 period, 138 energy audits were conducted [51]. According to the Statistical Office of Slovenia, there were 120 large industrial companies in Slovenia in 2018, 30 companies (including non-industrial large companies) had ISO 50001 certificate in 2018 [66]. The measures of management system were also implemented, as businesses with a certified EMS are excluded from the mandatory audit requirement. Slovenia has also introduced a successful education and training program for energy managers (EUREM), which drives future energy efficiency projects [67]. This educational element is largely supported by the European Commission, especially in newer Member States.

In addition, in 2017, the Eco Fund announced a public call for granting of non-refundable financial incentives to carry out an energy audit for SMEs [51]. In 2018, Eco fund has supported by financing (50% of the incurred cost) of energy audits for 10 SMEs [63]. In the area of energy audits and EMS, the continuation of the implementation of existing measures and their upgrading has been planned. The incentive scheme is about to be upgraded with the establishment of a scheme to promote energy governance in SMEs. EMS are also supported with financial incentives to raise energy efficiency and consumption of renewable energy sources (RES) in the industry through Eco Fund [51]. This is reflected in the NECP, which proposes the continuation of the ongoing measures and foresees the expansion of EMS [52].

4.6. Efficiency in heating and cooling (including industrial waste heat recovery)

In compliance to Article 14 EED, Slovenia has developed a comprehensive strategy for heating and cooling providing guidelines for the development of efficient DH (District Heating), DC (District Cooling) and the use of CHP [51] According to the Energy Act [58], the ministry responsible for energy, every five years, prepares a comprehensive assessment of the possibilities for the use of CHP and effective DH and DC with the overall assessment, which also includes a cost-benefit analysis. For instance, the first comprehensive assessment of the possibilities for the use of CHP and effective DH and DC has estimated the technical potential for CHP only in DH systems at up to 600 GWh of heat [51]. The Centre for RES/CHP Support provides information, training and awareness-raising brochures to various target groups in relation to the benefits and practical aspects of the development and use of energy efficiency and renewable energy technologies [58].

The support schemes in Slovenia were improved in 2009 which significantly expanded the promotion of CHP to all sectors (primarily in DHs), set more support for the production of electricity from RES (several RES resources and size classes of support) and defined clear methodological starting points for determining the amount of support. As a result, in the period up to 2014, around 140 MWe of new CHP generating plants were built mostly in DH systems, in recent years the number of smaller units in the service sector has also increased significantly [51].

There are financial incentives intended for investments in new DH-RES systems and DH-RES microsystems, as well as the expansion of existing DH-RES systems and construction of new boiler rooms with wood biomass boilers, CHP on wood biomass or solar systems [51], which is implemented under the Operational Programme for the Implementation of the European Cohesion Policy for the period 2014–2020 [68]. Furthermore, the Eco Fund has prepared a comprehensive financial incentive programme for the period from 2018 to 2020 to promote the sustainable development of existing DH systems and increase their competitiveness by implementing various measures [51], where the exploitation of excess heat from the industry is also highlighted. The NECP continues the implementation of all energy efficiency measures from the NEEAP 2020 and provides guidelines and the basis for the improvements of energy efficiency (e.g. 33 ktoe excess heat recovery in industry by 2030 and 61 ktoe by 2040). The NECP plans at least a 30% share of RES in industry, taking into account the use of excess heat, and also anticipates a 1.3% annual increase in the share of RES in heating and cooling in industry, including excess heat and cold [52], which is in accordance with the requirements of Article 23 REDII (Recast Renewable Energy Directive) [69].

In terms of technological developments, the intake of several technologies that are considered in European industrial strategy until 2020 as key technologies were extremely low in the Slovenian manufacturing companies [70]. Slovenia was also named as a traditionalist when it comes to the readiness of the countries towards Industry 4.0 [71]. Nevertheless, empirical evidence undertaken by Hojnik and Ruzzier [72] highlighted that competitive pressure was the most influential driving force of eco-innovation process, followed by managerial environmental concern and customer demand in Slovenia. Slovenia has recently started introducing the new technological developments. Some examples include the ERDF funded project OPERH2, which is designed to deal with the optimisation of energy conversion in order to reduce the share of fossil fuel used with hydrogen in industrial glass melting. There have also been several successful projects in terms of heat waste recovery. For instance, company SIJ (Slovenian Steel Industry with high energy intensive production), implemented a project to capture waste heat from the cooling system of the electrical arc furnace in steel production (in Metal Ravne) for the purpose of district heating. A heat exchanger with heat power of 4.5 MW_{th} was installed for heat recovery. The potential of the heat utilisation for district heating presents about 25% of the heat waste and is estimated at 8000 GWh per year. This was the first project of cooperation between the steel industry, the district heating system operator and local community in Slovenia. As discussed in 4.2.1 section Slovenia is unlikely to meet its energy efficiency target set to the industrial sector. This is mainly due to the perpetually increasing final energy consumption, especially in the basic metal production branch. Therefore, the energy efficiency measures are essential. Most recently, as part of the Horizon 2020 funded project ETEKINA, a heat exchanger prototype will be installed in one of the Slovenian steel company in order to significantly improve the plant's heat management by recovering of at least 40% of the waste heat streams [73]. This in turn will reduce environmental impact and the company's energy bills. Given that traditionally, the Slovenian steel undertakings are producers of special steel products and mainly oriented to export [74], this new technology will further lead to the increase of the company's global competitiveness, will secure local jobs and most importantly, will also contribute in meeting the EU's climate and energy goals [73].

5. Energy efficiency: a case study of Spain

5.1. Overview

Spain, which is divided into seventeen autonomous communities (comunidades autónomas) and two African autonomous

cities with their own parliaments and regional governments, is now the fourth largest EU Member States (after Germany, France and Italy, as the UK is no longer counted as a Member State) with its population of 47.1 million (2019 data) [75,76]. It is a member of 'Union for the Mediterranean', which also has a focus on renewable energies and energy efficiency [77], providing a platform for the regional cooperation. As far as energy is concerned, Spain is one of the largest net importers of energy in absolute numbers alongside Germany, Italy and France, due to its prevalence of fossil fuels in the energy mix [78]. For instance, in 2017 its primary energy consumption was 132 Mtoe, 99 Mtoe of which was fossil fuels (almost all imported) [77]. It is estimated that renewables, efficiency and reduction of imports (mainly coal and oil) will lower the degree of energy dependency from 74% in 2017 to 61% in 2030 [77].

General State Administration as well as Governments of Autonomous Communities have embarked on ambitious policies, have set the programmes, measures and actions falling under ambit of their competence [79–82] in order to comply with the EED. While autonomous communities introduce specific measures for energy efficiency, the strategic energy and climate framework, which includes the NECP 2021–2030, the Law on Climate Change and Energy Transition, and the Just Transition Strategy [83] is set for the whole of Spain. It seems that the mandatory requirement to introduce the NECP has facilitated the long overdue national Climate Change and Energy Transition Law, approved in 2020 alongside the development of long-term and Just Transition strategies [84]. For instance, the new Climate Change and Energy Transition Law embraces some bidding and other market mechanisms as well as mandatory measures such as phase-outs, deadlines, bans and ambitious targets. However, while new fossil fuel subsidies are banned, they are allowed on social grounds, such as to protect Spain's economic interests or to offset for the lack of adequate technological alternatives [85], therefore, leaving a loophole for new subsidies for fossil fuel in the future. The Just Transition strategy, which accompanies the NECP, is designed to anticipate and manage the consequences on the regions and people directly linked to technologies to be progressively displaced as a result of the transition [77].

In terms of the binding national targets, in its NECP Spain has set the targets for renewables, aiming at installing 122.7 GW renewable energy capacity by 2030, primarily wind and solar, leading to renewables making up 42% of the final energy consumption, whereas a 74% share of renewables in the electricity generation and a 28% share of renewables in transport by 2030 [77,85]. In line with the EU's climate-neutral strategy, Spain also aims to achieve a 100% renewables share in the electricity sector by 2050. The plan is also to obtain a 23% reduction in GHG emissions compared to the 1990 levels. Even though initially the target was set at 40% similar to the ambition of most EU countries (Germany (−55%), Ireland (−40%), France (−40%), and Spain's closest neighbour Portugal (−45%), yet, it was scaled down and settled at 23% arguing it was a fair, achievable and balanced goal (see Table 2) [84]. Energy efficiency plays a key role in energy planning policies in Spain due to its strategic importance in the transition towards a more competitive and sustainable economy. The target of primary energy consumption by 2030 in Spain is projected at a 39.5% reduction compared to the baseline, the reduction in primary energy consumption equivalent to an improvement of the primary energy intensity of 3.5% per year until 2030 [77].

The objectives set in the NECP cannot be attained during the period of 2021–2030 without investments, which is estimated to be EUR 241 412 M, most of which being disbursed by the private sector (approximately 80%). The plan will promote accumulated savings in fossil fuel imports of EUR 67 381 M (or 28% of the total budget) [77]. However, those values may alter due to the new economic circumstances generated by the COVID-19 crisis. During the writing of this paper there have not been any modifications confirmed.

5.2. Energy consumption

As far as energy consumption in Spain is concerned, after a long upward trend in energy demand, primary energy consumption followed a downwards trend for consecutive years from 2007 until 2014. This downward trend was reversed in 2015 by a 4.1% increase in consumption, which has been further increasing annually [86]. The years of 2017 [77] and 2018 [87] (see Fig. 7) have also observed continuous energy consumption growth in Spain, mainly boosted by greater economic and industrial activity [77]. In terms of primary energy and energy sources, there was an increase in renewable energy with a 3.4% increase in consumption, ahead of oil (+2.7%), nuclear power (+2.2%) and natural gas (+2%) in 2016 [88].

The trend in final energy demand by energy source is also consistent with primary energy, both demonstrating common peculiarities. For instance, in 2015, final energy consumption (excluding non-energy uses) rose to 80 461 ktoe, an increase of 1.6% over the previous year, which marked a break in the downward trend during the 2007–2014 period (with the exception of the upturn in 2010) [86]. With regard to energy sources, the increase in 2018 is mainly due to the increased consumption of oil products (+2.1%) and natural gas (5.8%), which jointly accounted for 67.4% of overall demand (see Fig. 8) [89].

As previously discussed, Spain set the efficiency target of 39.5% by 2030. The National Energy Efficiency target in Spain has been defined in terms of primary energy consumption and final energy consumption. Specifically, the target of primary energy consumption is 98.5 Mtoe for the 2030 [77].

With regard to the final energy consumption, it is planned to be reduced to 73.5 Mtoe in 2030. The target accumulated energy saving from January 2021 to December 2030 is 36 809 ktoe from which 10 256 ktoe belongs to the industry sector, whereas the target accumulated energy saving from January 2014 to December 2020 was set at 15 979 ktoe [90].

The targets set for 2030 meant that Spain had to review and update its objective of improving energy efficiency by 2020 with respect to the objective in its previous plan - the NEEAP 2017–2020. That plan defined that primary energy consumption should not exceed 122.6 Mtoe by 2020, referring to a 24.7% improvement in energy efficiency. However, in line with the new NECP 2021–2030, the 2020 target had to be formulated as an improvement of 24.2%, which means that 123.4 Mtoe should not be exceeded in terms of primary energy consumption (see Fig. 9) [77].

5.2.1. Energy consumption in industry

In the context of sector-specific demand, similar to Slovenia, Fig. 10 indicates that transport continued to be the highest energy consumption of 40% of total final demand (i.e. 32 531 Ktoe), followed by the industrial sector - 25% (20 219 Ktoe) with the remaining 35% shared by the residential, tertiary and agriculture sectors in 2018. In 2016 approximately 75.6% of energy consumption in the industrial sector was concentrated in five branches - metallurgy, non-metallic minerals, chemistry, food, beverages and tobacco, and pulp and paper [88]. For the industrial sector, Spain has set a target scenario for final energy consumption (excluding non-energetic uses) of 19 771 ktoe [77] in 2020 and 19 570 ktoe [77] in 2030.

Spanish policy of financial support for industrial investment has provided the framework to promote industrial competitiveness. Consequently, the measures implemented by the previous NEEAP 2017-2020 and its predecessor contributed to an improvement in

Table 2
National targets of Spain.

National targets and contributions	2020	2030
GHG compared to 2005 under the Effort Sharing Regulation (ESR)[a]	−27%	−49%
GHG compared to 1990 under the ESR	−11%	−23%
Renewable Energy over final energy consumption	20%	42%
Energy Efficiency improvement:	24,2%	39,5%
Primary energy consumption (Mtoe)	123,4	98,5
Final energy consumption (Mtoe)	86,3	73,6

[a] The emissions in 2005 were higher than in 1990 (54%) and the projections of GHG emission in 2020 are also higher than in 1990 (11%). This explains the reason behind the high percentage figure of GHG reduction in 2030 referred to 2005. The GHG reduction plan by 2030 compared to the 1990 is set at a 23%.

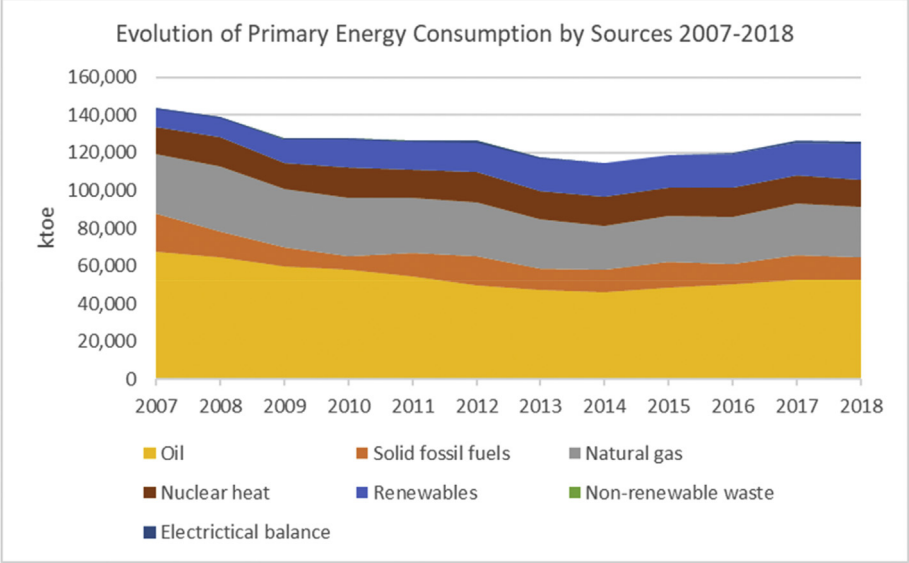

Fig. 7. Evolution of Primary Energy Consumption by sources in Spain, 2007–2018 [87].

energy efficiency. For instance, during the period 2004–2016 it was quantified an annual decrease of 2% in final energy intensity in the industry sector [77]. Final energy consumption in the industry sector had slightly increased in 2017 but stabilised in 2018 (see Fig. 11). This suggests that further investments in this sector are essential.

5.3. National policies on energy efficiency

The EED was transposed in different national regulations in Spain. For instance, the Law 18/2014 of 15 October established the system of energy saving obligations, whereas Royal Decree 56/2016 transposed the EED regarding energy audits, accreditation of service providers and energy auditors and promotion of efficiency of energy supply [91].

As per institutions, the Ministry for Ecological Transition and Demographic Challenge (*Ministerio de Transición Ecológica y el Reto Demográfico, MITECO*); Institute for the Diversification and Saving of Energy (*Instituto para la Diversificación y el Ahorro de Energía, IDAE*), which is responsible for the objectives and commitments regarding improvements in energy efficiency, renewable energy and other low carbon cost technologies; Autonomous Communities and local institutions work together in the implementation and monitoring of targets and measures defined in the NECP. The Climate Change Policy Coordination Commission was created in 2005 to coordinate the collaboration between the General State Administration and Autonomous Communities with regard to all climate change policies [92].

The National Energy Efficiency Fund (*Fondo Nacional de Eficiencia Energética, FNEE*), established by Law 18/2014 of October 15, 2014, introduced urgent measures for growth, competitiveness and efficiency. This Fund falls under auspice of the MITECO and is an instrument of the implementation mechanisms for financial and economic support, technical assistance, training and information or other measures in order to increase energy efficiency across all energy-intensive sectors. The FNEE consists of the financial contributions from the European Structural Funds, contributions of the obligated parties required by the EEOS, other contributions from the State budget as well as any other resources intended to finance actions of energy savings and efficiency [90]. Specifically, the financial contributions from the obligated parties for 2014 was EUR 103 M, which has increased significantly for the two consequent years of 2015 and 2016 at EUR 207 M, followed by the other consequent years of 2017 and 2018 set at EUR 205 M with the most recent years of 2019 and 2020 reaching EUR 203 and EUR 207 M respectively [93–99]. The total amount of the aid program for 2020 is EUR 307 M [100]. The FNEE is supervised and monitored by Supervision and Monitoring Committee and managed by the IDAE.

5.4. Obligatory energy savings schemes and alternative measures

The cumulative savings target in Spain are reached by implementing the national EEOS and by applying a combination of alternative measures of a regulatory, fiscal or economic nature.

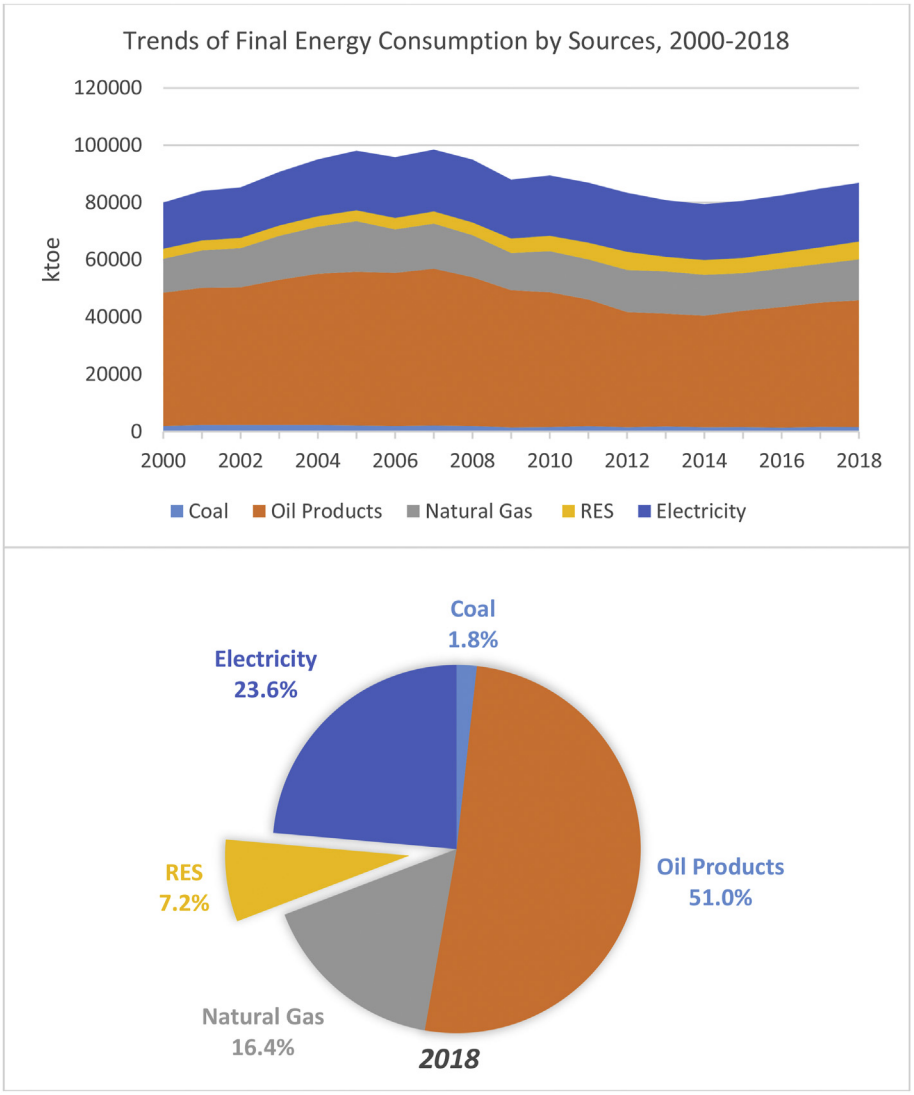

Fig. 8. Trends of final energy consumption by sources, 2000–2018 [77,89].

EEOS in Spain are identified within the FNEE, which has now been extended until December 31, 2030 as defined by the updated EED [3]. In terms of saving obligation, pursuant to the respective laws [101–104], the obligated parties (i.e. the energy distributors and retail energy sales companies, namely, gas and electricity retailers, petroleum product wholesalers and liquified petroleum gas wholesalers) are obliged each year to contribute to the FNEE an amount which is calculated by taking into account the investments required to achieve their respective obligation (i.e. assigned annual energy savings quota). Additionally, Article 7 EED and the updated EED require the Member States to demonstrate the achievement of cumulative energy savings in the two main periods: January 1, 2014–December 31, 2020 and January 1, 2021–December 31, 2030 ensuring that new savings are attained each year. It is estimated that Spain for the first period would achieve 15 979 ktoe, whereas for the second period it would be equivalent of 36 809 ktoe. This in turn means that new and additional energy savings would be equivalent to 669 ktoe each year from January 2021 to December 2030 [77], demonstrating the importance of the EEOS in terms of generating new savings in Spain. The distribution by sectors of the planned 36 809 ktoe accumulative savings is shown in Fig. 12.

The NECP incorporates the ten principal energy efficiency measures designed to meet the obligation arising from the application of Article 7 EED by taking a sectoral approach. One of the measures (No. 2.5 funded by the FNEE) is to facilitate improvements in the technology and management systems of industrial processes for SMEs and large enterprises (particularly to those not included in the EU ETS) [86]. Specifically, this measure promotes:

i) the investments for replacing low energy efficient equipment or installations by high energy-efficient technologies or by best available technologies or for replacing the auxiliary energy consuming systems.
ii) the investments in the implementation of energy management systems in industry [77] which will be further discussed in the following section.

In the past, there were some successful alternative measures. For instance, the Energy Diversification and Saving Investment Fund which is part of JESSICA (Joint European Support for Sustainable Investment in City Areas) with a budget of EUR 123 million financed, *inter alia*, urban energy-efficiency and energy management projects, falling within one of the eligible sectors (construction, industry, transport and energy-related public service

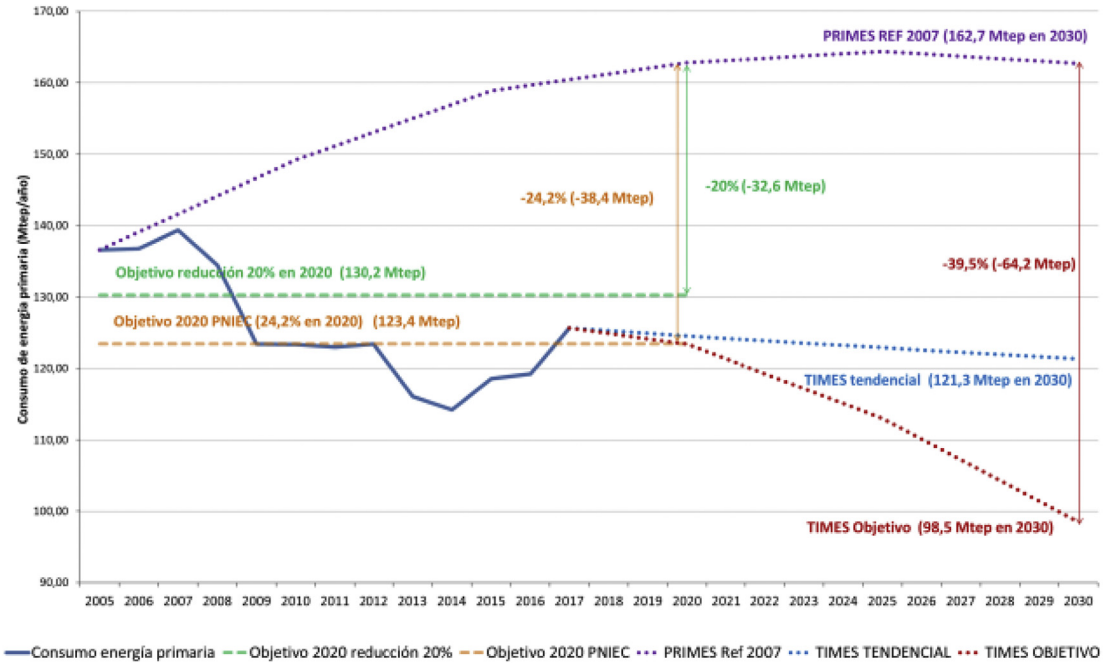

Fig. 9. Reduction objective for the consumption of primary energy (Mtoe/year) [77].

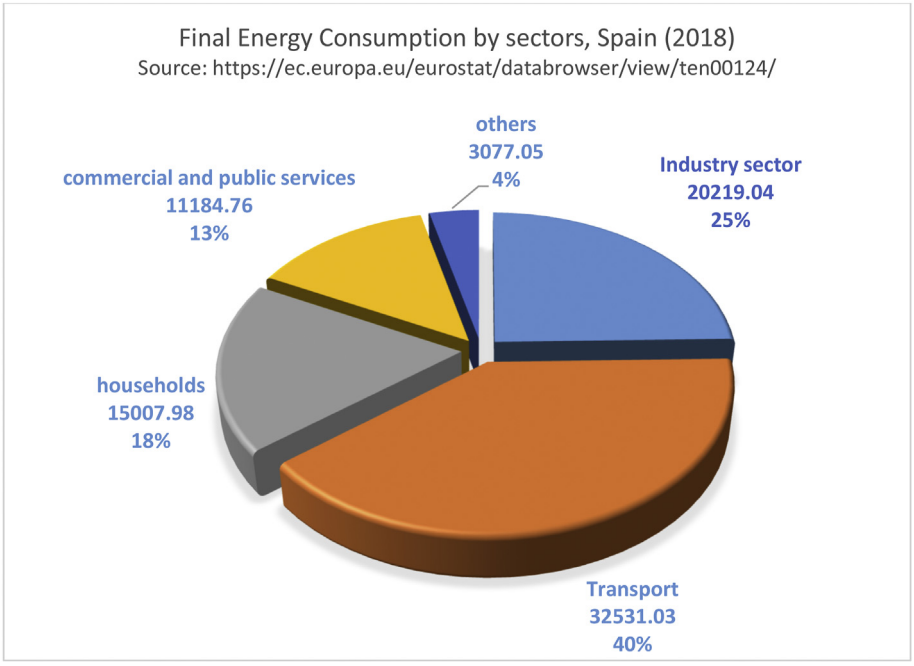

Fig. 10. Final energy consumption by sectors in Spain in 2018 [77].

infrastructure). CLIMA projects financed by Spanish FES-CO2 (Carbon Fund for a Sustainable Economy) also applicable to industry aimed at reorienting the Spanish production system towards a low-carbon model. Order IET/274/2015 of February 13, 2015 introduced the Industrial competitiveness incentive program to stimulate investments that contribute significantly towards generating added value in the industrial sector. Specifically, it aimed to help companies shift towards newer production models which were more advanced, efficient and environmentally friendly, and to manufacture products with greater added value, intended to have a significant impact on businesses' competitiveness therefore, enabling them to gain access to and increase their presence in international markets [86]. There are also initiatives at local level to promote energy efficiency. For instance, in Basque Autonomous Community jurisdiction, Basque Energy Cluster regularly organises events to promote the energy efficiency in industry where companies show their experiences of different energy efficiency measures applications (i.e. fumes heat recovery for air combustion preheating, water for cooling moulds, use of frequency variable devices in injection machines, using of advanced sensors and monitoring in

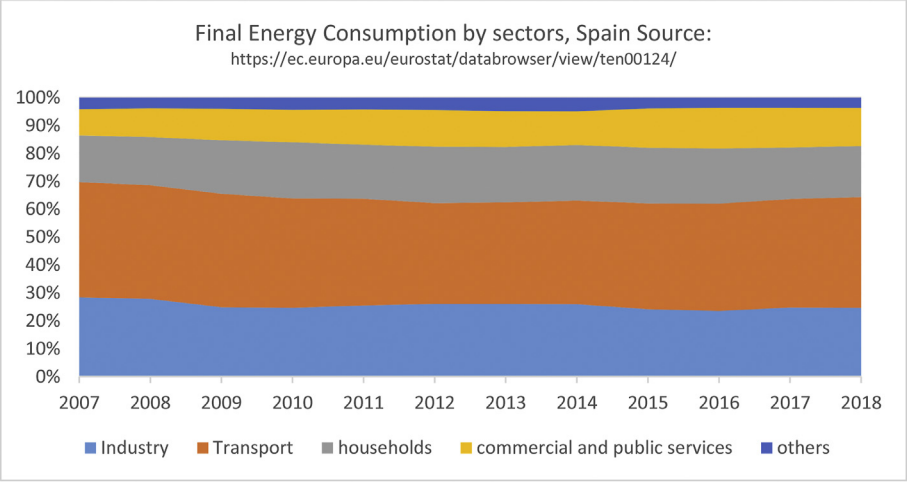

Fig. 11. Final energy consumption by sectors in Spain 2007–2018 [77].

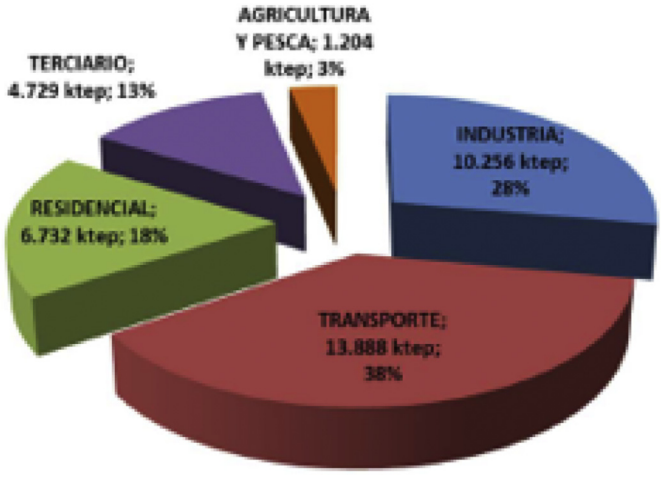

Fig. 12. Distribution by sectors of the planed 36 809 ktoe savings [77].

forging processes, TIC technology integration for energy efficiency in Industry 4.0, etc.) [105].

Building on the most recent measures as defined in the NECP, the industrial sector is expected to achieve 10 256 ktoe of cumulative final energy savings during the 2021–2030 period [77]. These planned energy-saving targets should be attained through a) public support programmes (i.e. aid through grants or repayable low-interest loans in compliance with the EU State Aid regulations); or b) voluntary agreements [77]. The authorities responsible of this measure is MITECO and IDAE (coordinated with other Ministry Departments having competencies in industry policy) and the Governments of Autonomous Communities under their respective jurisdiction.

5.5. Audits and energy management systems

Article 8 EED was implemented in Spain by the adoption of Royal Decree 18/2014 and Royal Decree 56/2016 of February 12 on energy efficiency concerning energy audits, accreditation of providers of energy services and auditors, and promotion of the efficiency of energy supply. For instance, audits must be conducted by properly qualified energy auditors [106]. The Energy Audit Register was created in the MINETAD based on the information provided by the regional authorities [107].

As discussed above, only large companies have the obligation to perform an audit every four years under Article 8 EED. Spain adopted a similar approach to the EU by using the same employee and financial thresholds. Yet, it defines large companies with at least 250 employees and a turnover of more than EUR 50 million or a balance sheet of more than EUR 43 million [106]. Furthermore, an audit is applicable to corporate groups which, taking into account the aggregate size of the corporations from that consolidated group, meet the large enterprise criteria. They must undergo an energy audit every four years, which covers a least 85% of the total final energy consumption of the group of facilities located within national territory [106]. The penalties can be imposed on large companies in case of non-compliance. Spain has a two-fold test: i) up to EUR 60 000; or ii) up to 10% of the company's turnover, therefore, linking with a profitability criterion [33]. To ensure compliance, the Member States must have a mechanism in place of continuous monitoring. Most EU Member States, including Spain, conduct random checks on spot and large companies must provide the relevant documents on request. In addition, these obligated companies also proactively submit the information about their energy audit [33]. By December 2018 there have been around 35 000 energy audits listed [108].

In compliance with the EED, the implementation of an energy or environmental management system is considered equivalent to the above obligation, provided that the management system includes an energy audit in accordance with the minimum energy audit criteria [86]. As discussed above, there is also an aid programme available for SMEs and large industrial enterprises, financed by the FNEE, which can facilitate the implementation of the energy saving and efficiency measures proposed by energy audits to reduce energy consumption in industrial processes.

5.6. Efficiency in heating and cooling (including industrial waste heat recovery)

Royal Decree 56/2016 of February 12, 2016 also transposed Article 14 EED to promote energy efficiency in the production and in the use of heating and cooling energy. Based on the statistics provided by IDAE the co-generated installed capacity in Spain at the end of 2016 was 5618 MW with cogeneration having a strong presence in the industrial sector, with an installed capacity of 5197,1 MW [109] (i.e. approximately 92% of the installed capacity, followed by the remaining 8% in the service and residential sectors).

The fuel mainly consumed by co-generation plants is natural gas, which represents 84% of electricity production and 86% of heat production [108].

Given that approximately 2400 MW of co-generated capacity will have exceeded its regulatory life span by 2030, Spain is planning to transform ageing CHP units into high efficiency CHP units. Additionally, Royal Decree 15/2018 introduced measures for the energy transition and consumer protection, which should in turn drive the return to electricity self-consumption from renewable sources or from co-generation facilities connected to the network. A measure has been proposed aimed at the transition of co-generation to high efficiency in a total of 1200 MW of co-generation facilities using natural gas with an optimised design based on: useful heat, electrical self-consumption, flexibility of operation with regard to the electricity system and high efficiency. The mechanism is based on the competitive tendering procedure with a multi-annual schedule of tenders, to ensure a cost-effective remuneration scheme for the application of public funding, supported by the necessary administrative measures to take advantage of the existing infrastructure. It is estimated that savings associated with this measure will be 1471 ktoe of cumulative primary energy during the 2021–2030 period.

Spain also has some initiatives to promote technology for heating and cooling (such as novel thermal insulations and passive strategies [110], geothermal closed-loop heat exchange [111], district heating/cooling [112], trigeneration systems [113], retrofitting strategies in manufacturing processes and devices [114] etc.). For instance, IDAE offers a Series of Technical Guidelines with the objective of increasing energy efficiency of the thermal installations in buildings [109]. There are also guides prepared by the Autonomous Communities, such as Basic Guide to Heating and Cooling networks, prepared by Catalan Institute of Energy and COFELY AG [115], which promote and disseminate the technology of district heating and/or cooling networks, as well as advise the potential promoters of this type of installations from a methodology that establishes the criteria that should be considered when designing a district network [116]. The EU-funded projects, such as the Horizon 2020 also facilitates the promotion of new technologies. For instance, the I-Therm project has been identified by the European Commission as one of good practices in terms of industrial waste heat recovery [38], which developed technologies and processes for the efficient and cost effective heat recovery in industrial facilities, including in a company in Spain active in steel production [12,117]. In the most recent project ETEKINA, the heat exchanger technology using heat pipes for thermal recovery will be installed in one aluminium automotive parts producer in Spain enabling it to recover the lost heat (of approximately 40%), therefore, increasing the overall energy efficiency and reducing the energy costs, which especially for primary aluminium producers are significant -representing between 22% and 29% of the production costs [73].

6. Summary of the discussions

EU level. 2019 marked the completion of the Clean Energy for all European package (also known as the Winter package) [1] with the final regulations and directives being issued. As part of this package is one of the key principles of “Putting energy efficiency first” embedded in the revised EED, which has expanded the obligatory measures defined in Article 7 EED up to 2030, yet, with the reduced target of 0.8% (for the forthcoming 2021–2030 period) rather than 1.5% as in the previous period of 2014–2020. This way the European Commission forces obliged parties to achieve new energy savings each year. Given that the Member States have flexibility on how they achieve their energy savings, such as by introducing energy savings obligation schemes, alternative measures or a combination of the two, there is a vast variation of these measures across the Member States. In the context of the industrial sector, while the Member States may incorporate some alternative measures (i.e. through tax reduction) to incentive energy-intensive industries to implement energy efficiency measures, the EED has more coercive measures, such as audit obligations on all large enterprises (including businesses operating in the industrial sector). Large businesses are only exempted from this audit obligation if they have implemented an energy management systems, which create a structure to monitor energy consumption and improve energy efficiency in an industrial firm and the use of it in industry is currently increasing [118]. Finally, there are also provisions to address efficiency in heating and cooling requiring the Member States to conduct a comprehensive assessment of the cost effective potential for energy efficiency in heating and cooling, principally through the use of cogeneration, efficient district heating and cooling and the recovery of industrial waste heat [119].

There is an expectation that all these measures will contribute (or continue to contribute) in achieving national energy efficiency targets, which in turn will lead to the accomplishment of the EU overall energy efficiency target of 32.5% by 2030. To ensure this is the case, all the Member States had to present their integrated NECP, *inter alia*, outlining how they intend to meet the energy efficiency targets for 2030 and what measures will be in place. Statistically speaking, it seems the EU may fall short of meeting its targets, as the final energy consumption was 2.2% below the 2020 target level in 2014, in 2018 it was 3.2% above the 2020 target level and the distance to the 2030 target was 17.0% based on 2018 data.

National level. While Slovenia and Spain differ in size, they both have large energy dependency set at 48% and 79% respectively with a great potential for the sustainable energy development, including energy efficiency. Spain aims to reduce its dependency to 61% by 2030. In both countries industry is the second biggest energy consumer, with the transport sector taking the first place. Therefore, both Slovenia and Spain set their more energy efficiency targets to be achieved by 2030, 35% and 39.5% respectively (see Table 3).

Both Slovenia and Spain meet their binding requirements of Article 7 EED through a combination of energy efficiency obligation schemes and alternative measures. Slovenia noted that it has problems in monitoring of the implementation of the scheme (i.e. checking the reporting by the obliged entities of the achievement of energy savings from their implemented projects), as well as the implementation of alternative measures, in the context of the effective allocation of funds to those which have the greatest potential to increase energy efficiency [51]. Spain has a clear sectorial approach, as the measures designed to meet the obligations arising of Article 7 EED are set for each sector (i.e. No 2.5 is applicable for the industrial sector). Interestingly, neither of these countries has white energy certificates (employed in other EU Member States, such as Italy, France, etc) [5], even though the Spanish Law 18/2014 provides a possibility for the establishment of an accreditation mechanism for achieving of energy saving – Energy Saving Certificates.

With regard to the audit obligation, Slovenia has modified the EU definition of SMEs. While Slovenia has expanded the obligation scope by lowering the financial thresholds for the definition of SMEs therefore, covering firms that SMEs, Spain on the other hand, adopted a similar to the EU approach, by defining large companies instead. Most likely Slovenia made these adjustments to reflect its small size of its economy and that most businesses in Slovenia belongs to the SMEs category. Given that the Member States are allowed to lay down national rules on penalties to guarantee compliance with the requirements of Article 8 EED, both Slovenia and Spain can impose fines. While Spain places penalties on

Table 3
Summary of the main provisions discussed in Slovenia and Spain.

	Measure	Description and evaluation
Slovenia	EE targets	More ambitious targets to be achieved by 2030: for its primary (6.36 Mtoe) and final (4.72 Mtoe) energy consumptions; and overall improvement by 35% in comparison to only 20% by 2020.
	EEOS/alternative measures	A combination of energy efficiency obligation schemes and alternative measures; Need of the improvement of the monitoring of the scheme; Utilisation of Eco Funds.
	Audits/Management systems	Expanded definition of large companies to ensure wider coverage of the Audit obligation; Support mechanism to conduct Audits to SMEs.
	Efficiency in Cooling & Heating	Developed a comprehensive strategy for heating and cooling providing guidelines for the development of efficient DH, DC, and the use of CHP; Various financial incentives intended for investments in new (or expansion) of DH-RES systems/microsystems, construction of CHP etc.
Spain	EE targets	More ambitious targets to be achieved by 2030; for its primary (98.5 Mtoe) and final (73.6 Mtoe) energy consumptions; and overall improvement by 39.5% in comparison to its revised target of 24.2% by 2020.
	EEOS/alternative measures	A combination of energy efficiency obligation schemes and alternative measures; A sectorial approach; Utilisation of the FNEE, including the investments to replace low energy equipment/to implement energy management systems.
	Audits/Management systems	Relies the EU definition of SMEs, to define its large companies for the Audit obligation.
	Efficiency in Cooling & Heating	Essential focus on transforming ageing CHP units into high efficiency CHP units; Support mechanism based on the competitive tendering procedure which incorporates more market-based principles.

businesses themselves and links its fine up to EUR 60 000 with a profitability value (not exceeding 10% of the company's turnover), whereas Slovenia imposes fines (EUR 10 000) on the directors (or other senior person at managerial level).

As indicated by Table 3 both countries contain measures to promote energy efficiency in the production and in the use of heating and cooling energy as required by the EED. It seems that the co-generated installed capacity in Spain is most visible in the industrial sector (i.e. approximately 92% of the installed capacity).

7. Conclusions

The EU has a clear long-term strategy towards carbon-neutral economy. To achieve this, the Clean Energy for all Europeans package [4] was issued and set tasks to bring EU energy legislation into line with the new more ambitious 2030 climate and energy targets stressing the 'Energy efficiency first' as one of the key principles of the Energy Union. This is because energy efficiency is the most cost effective way to reduce emissions, improve energy security, enhance competitiveness, therefore, enabling to achieve the long-term energy and climate goals. Given that the Member States come in different shape and size of the economies and their development level, they present different national contributions to the EU energy efficiency target of 32.5% by 2030. To ensure that the EU energy efficiency target will be achieved, all the Member States had to present their integrated NECPs, which, *inter alia*, must outline how they intend to meet the energy efficiency targets for 2030 and what measures will be employed to secure them. Specifically, this paper has focused on two EU Member States, namely, Slovenia and Spain. Both countries analysed in this paper have high domestic dependence on imported energy sources, therefore, showing a great potential for energy efficiency. To address this, Slovenia and Spain have set more ambitious national energy efficiency contributions of 35% and 39.5% respectively for 2030 in comparison to their 2020 targets. They also committed to continue their national measures and schemes (including obligatory energy efficiency schemes) imposed on the obliged parties from their NEEAP 2020 as well energy efficiency support mechanisms, therefore, embracing a 'carrot and stick' approach. The paper has also identified some good practices to improve energy efficiency in the industrial sector, especially through the EU-funded projects, therefore, outlining the importance of funding initiatives. Additionally, the EU requirement to submit the integrated NECP have had a broader impact, inspiring additional national developments in both countries. For instance, the Energy Concept of Slovenia was introduced in Slovenia, whereas in Spain it facilitated the launch of the national Climate Change and Energy Transition Law as well as the development of long-term and Just Transition strategies.

Finally, both Slovenia and Spain have energy efficiency incentive programmes, which may be affected by the COVID-19 crisis. Given that during the writing of this paper there have not been any adjustments confirmed by the governments in both countries, the near future will demonstrate the extent to which the developments of energy efficiency have been impact by this crisis.

Authorship statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in Energy.

Authorship contributions

Please indicate the specific contributions made by each author (list the authors' initials followed by their surnames, e.g., Y.L. Cheung). The name of each author must appear at least once in each of the three categories below.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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