energies

MDPI

Review

An Analysis of the Development of the Cogeneration Sector in Spain: A Comprehensive Review of the Period 1980–2020 from a Regulatory Perspective

Angela Adamo [1,2,3], Jordi De la Hoz [2,*], Helena Martín [2], Joan Rubio [3] and Sergio Coronas [2]

[1] University Research Institute for Sustainability Science and Technology, Polytechnic University of Catalonia (UPC), Jordi Girona 1-3, Building K2M, 08034 Barcelona, Spain; angela.adamo@upc.edu s
[2] Electrical Engineering Department, Barcelona East School of Engineering, Polytechnic University of Catalonia (UPC), Av. Eduard Maristany 16, 08019 Barcelona, Spain; m.helena.martin@upc.edu (H.M.); sergio.coronas@upc.edu (S.C.)
[3] SEAT S. A., Autovia A2 km 585, 08760 Martorell, Barcelona, Spain; joan.rubio@seat.es
* Correspondence: jordi.de.la.hoz@upc.edu

Abstract: Combined Heat and Power (CHP) has been identified by the EU as a powerful resource capable of making substantial contributions to energy savings and reducing GHG emissions. Spain's effort to promote CHP has been prolific since the 1980s. In this regard, there have been various Laws, Royal Decrees (RDs) and European Union (EU) Directives addressed to reach the national objectives set for the CHP sector. Despite these attempts, the evolution and growth of installed CHP capacity has been irregular, compared to other technologies. Likewise, the academic treatment of the Spanish CHP evolution has not deserved the same attention as other technologies such as wind, photovoltaic and thermal solar systems. As a result, this article is aimed at providing a comprehensive overview of the regulatory frameworks applied to the Spanish CHP sector and analysing the reasons behind the variable evolution of the installed CHP capacity. The study covers the legislative context from 1980 to 2020, describing the evolution during both the pre-liberalization and liberalization periods, highlighting the modifications in economic policies that affected self-producers and the so-called Special Regime (SR) for CHP, and examining the challenges faced during the cost containment measures that followed. The manuscript finds and explains the connection between the regulatory framework and the evolution of installed CHP capacity in Spain. Likewise, the connection between the industrial situation and the promotion of CHP, as well as the influence of the Spanish Electricity Sector (SES)'s liberalization on the CHP sector are also pointed out. The paper intends to provide valuable insights for CHP experts and policymakers by showcasing the importance of aligning regulatory measures with the objectives of energy efficiency. It also serves as a reference for countries in various stages of promoting CHP, and provides evidence for the importance of stable energy-policy control mechanisms.

Keywords: cogeneration; CHP; self-production; regulatory framework; energy policy; special regime; promotion; Spanish electricity sector; Spain

Citation: Adamo, A.; De la Hoz, J.; Martín, H.; Rubio, J.; Coronas, S. An Analysis of the Development of the Cogeneration Sector in Spain: A Comprehensive Review of the Period 1980–2020 from a Regulatory Perspective. *Energies* **2024**, *17*, 625. https://doi.org/10.3390/en17030625

Academic Editors: Matheus Koengkan and Fernanda Oliveira

Received: 12 December 2023
Revised: 16 January 2024
Accepted: 23 January 2024
Published: 27 January 2024

1. Introduction

Energy efficiency is identified as one of the five "mutually reinforcing" and "closely-interrelated" dimensions of the Energy Union strategy, together with energy security, the integrated European energy market, decarbonization of the economy and research, innovation and competitiveness [1], as well as a fundamental element of the European 2020 Strategy for smart, sustainable and inclusive development [2]. It is considered the "first fuel" [3], and consequently, it assumes a crucial role in the achievement of net-zero emissions in 2050 and the decarbonization process of the industrial sector of the European Union (EU) [4]. Many efforts have been carried out in recent years to increase the energy

efficiency of the EU, requiring Member States to adopt measures that would allow them to increase energy efficiency by 20% by 2020 [5], with this value then updated to 32.5% when compared with projections of the expected energy use in 2030 using the Energy Efficiency Directive 2018/2002 [6].

Combined Heat and Power (CHP), or cogeneration, is an untapped resource that the EU recognizes as a significant contributor to saving primary energy, reducing greenhouse gas emissions (GHGEs), and avoiding network losses. The efficient use of energy by cogeneration positively impacts the energy supply's security and enhances the EU's and its Member States' competitiveness [7]. The Energy Efficiency Directive enables EU countries to conduct a comprehensive cost–benefit analysis of the potential for efficient heating and cooling, including cogeneration assessment [6].

Cogeneration has captured the interest of the academic community. Research on cogeneration has mostly focused on its technical and economic aspects such as the modelling of CHP plants and optimization problems [8–13], energy analysis, and cost–benefit analysis [14–19]. Studies have also explored the use of cogeneration in district heating and cooling [20–27]. However, the impact of regulatory frameworks on the promotion of CHP has received less attention in comparison to renewable energy systems (RES). Although, some relevant exemptions can be found in this field. Moya [28] analyses the influence of the various support measures and barriers on the evolution of cogeneration in Europe, while Colmenar-Santos et al. [29] present possible measures to eliminate the institutional and financial barriers that affect the expansion of cogeneration combined with district heating in the EU-28 landscape. Kavvadias [30] also highlights the main obstacles to the diffusion of combined energy generation and presents some proposals to minimize the exposure to the risk of investments in energy efficiency. Malinauskaite et al. [31] evaluate the measures taken in Spain and Slovenia in terms of energy efficiency in the industrial sector, including those related to the promotion of CHP. Westner et al. [32] present an overview of different support mechanisms for CHP applied in various European countries for a mean-variance portfolio analysis. Another interesting study was made by Uran et al. [33], which presents a method for the correction of the applied Feed-in Tariff (FIT) in Croatia in comparison with EU countries. The study conducted by Rivera-Alvarez et al. [34] is based on the comparison between the different incentives provided for cogeneration with natural gas (NG) in the various countries of South America. Ciarreta et al. [35] analyse the effects of liberalization on the Spanish electricity market and the problems that concern it. Bianco et al. [36] focus on the effects of the massive penetration of renewables, including CHP, on the Spanish electricity generation sector. Similarly, Simoglou et al. [37] carry out a study on the effects of RES integration, including CHP in this group, on the Greek electricity market. Finally, Gelabert et al. [38], on the other hand, conducted a study on the influence of RESs and cogeneration on electricity prices in Spain.

In this regard, Spain has been one of the most prolific EU countries when promoting RESs and CHP. However, to the best of the authors' knowledge, there is no comprehensive analysis of the several economic and regulatory frameworks affecting Spain's CHP sector from the beginning of its promotion to the present moment. Additionally, the evolution of the CHP-installed power in Spain has shown almost negligible variations since the 2000s, despite the various European directives and Royal Decrees (RDs) designed to promote this technology. This trend is decidedly different from that shown by RES technologies, such as Concentrated Solar and Photovoltaic systems, which underwent an evolution consistent with the several regulatory frameworks adopted through the years, as observed by Martín et al. [39], de la Hoz et al. [40] and Coronas et al. [41]. Hereof, this academic work aims to address the two gaps mentioned above. On the one hand, it will provide a comprehensive overview of the several regulatory frameworks to which the CHP sector was subject from 1980 to 2020. And, on the other hand, it will analyse the underlying causes of the apparent decoupling of the CHP deployment in Spain and its regulatory frameworks. In this way, it is intended to provide valuable lessons for experts and policymakers in the CHP sector.

This work is divided into five sections, which follow the introductory section. Section 2 outlines the methodology followed in our study. Section 3 provides the legislative context concerning cogeneration in Spain from 1980 to 2020, including European directives, RDs issued during this time, national energy-saving and efficiency plans, and the results achieved. Section 4 offers a detailed description of the regulatory frameworks identified in Section 3 for the years 1980–2020. In Section 5, there is a critical and detailed analysis of the evolution of the CHP sector in Spain, aimed at understanding the reasons behind the lack of responsiveness to the applied promotion mechanisms. Finally, in Section 5, the conclusions are presented.

2. Methodology

This section briefly outlines the systematic approach employed to investigate and analyse the key aspects of our research topic, aiming to provide a comprehensive understanding of the research process. An outline of all the steps followed in the research method used to write the manuscript is provided in Figure 1.

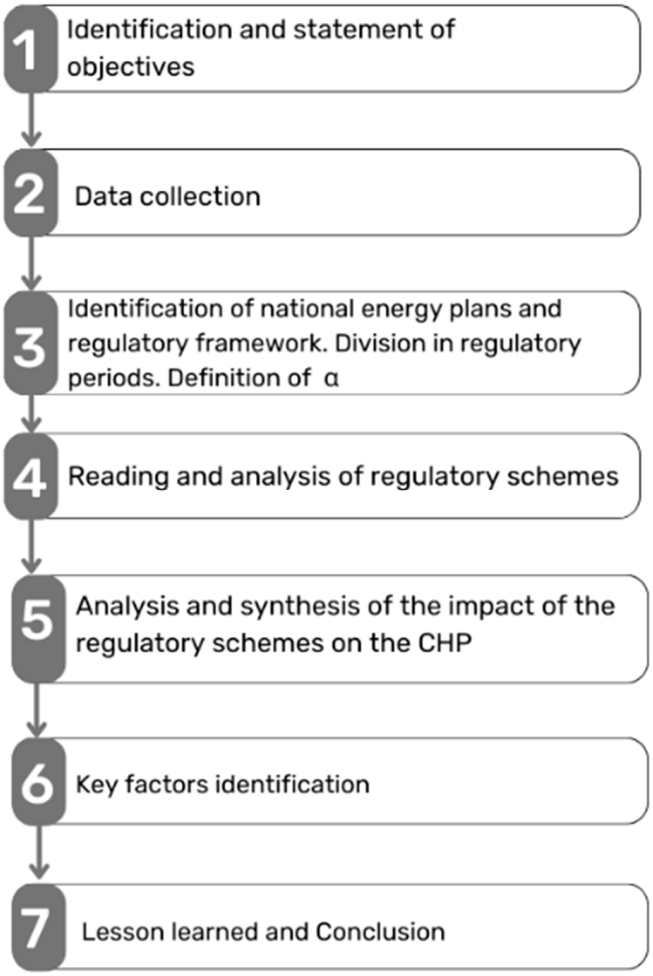

Figure 1. Outline of the methodology used to write the paper. Source: self-elaboration.

The first phase of our study, indicated in Figure 1 with point 1, aimed at the identification and formulation of the topic and the objectives of our research. Following this, as highlighted in point 2 of Figure 1, an exhaustive data collection process was undertaken to determine the values of installed CHP capacity and regulatory policy goals. The following part of our research involved the identification of national energy plans and the examination of the evolution of the Spanish regulatory framework. This framework was then subdivided into distinct regulatory periods to establish the correlation between the

regulatory context and the implementation of CHP in the country (point 3, Figure 1). In the same phase, the installation rate, denoted as α, was defined as a tool to quantify and express the link between the Spanish energy policy and the installed CHP capacity. An in-depth analysis of regulatory schemes was conducted to understand their nuances and implications, as reported in point 4 of Figure 1. The impact of these diverse regulatory frameworks on the evolution of installed CHP capacity was then examined and synthesised (point 5 in the scheme in Figure 1). Afterwards, the study proceeded to pinpoint key factors influencing the evolution of installed CHP capacity specifically within the Spanish context, as indicated in point 6, Figure 1. Drawing upon the insights gained, the lessons learned were articulated, culminating in a conclusive summary (point 7, Figure 1).

3. The Spanish Cogeneration Policy—Contextualization, Main Goals and Results

The Energy Conservation Law 82/1980 [42] initiated the impetus for cogeneration in Spain. This law introduced a remuneration system for facilities that utilized renewable energy sources and cogeneration. Its primary objective regarding cogeneration was to harness the residual energy generated by industrial processes and convert it into electricity. The "self-producer" was a regulatory concept employed to achieve this goal. To encourage self-production and develop Law 82/1980, RD 907/1982 [43] was put into effect. This was followed by the National Energy Plan 1991–2000 (NEP 1991–2000) [44] publication, which included measures, actions, and objectives outlined in the Energy Efficiency and Savings Plan Annex (PAEE 1991–2000) [44]. The PAEE 1991–2000 policy goal was to increase the installed capacity of CHP by 1263 MW by the end of 2000, reaching a total of 2222 MW [44].

In 1994, Law 40/1994 was enacted to regulate the Spanish Electricity Sector (SES) [45], partially repealing Law 82/1980. This law distinguished between conventional power plants and new renewable and cogeneration systems, creating a Special Regime (SR) for the latter. This was a positive step towards promoting high-efficiency cogeneration, as the SR benefited from a differentiated economic framework. Later, in 1994, RD 2366/1994 [46] was enacted to produce electricity through pumping, cogeneration, and other systems supplied by renewable energy sources. This developed the economic framework for the SR, which included CHP plants rated up to 100 MW and satisfying specific energy efficiency requirements [46].

Starting from 1997, the SES initiated a process of liberalization that is still ongoing and is regulated by Law 24/2013. Throughout this liberalization period, multiple regulatory frameworks were established to encourage the promotion of RES, such as RD 2818/1998 [47], RD 436/2004 [48], RD 661/2007 [49], and RD 413/2014 [50]. The purpose of these frameworks was to accomplish the energy plans that were in place during those years. In this regard, and following the NEP 1991–2000 [44], Spain approved the Energy Saving and Efficiency Strategy (E4) in November 2003 [51]. The goal was to reach 7100 MW of installed power through cogeneration by 2011 [51]**.** This target was later revised with the Action Plan 2005–2007 and the Action Plan 2008–2012, increasing the objective to 10,851 MW by 2020 [52,53].

In February 2004, Directive 2004/8/EC [7] was approved with the aim of promoting and developing high-efficiency CHP. It required Member States to provide a guarantee of the origin of the electricity to demonstrate that it was produced from high-efficiency cogeneration [7]. In 2006, Directive 2006/32/EC on the efficiency of the final use of energy and energy services was published. It required Member States to reduce their energy consumption by at least 9% and expressly indicated cogeneration as one of the possible tools for improving energy efficiency in the industrial sector [54].

The Energy and Efficiency Action Plan 2011–2020 (EEAP 2011–2020) was published in 2011, in accordance with Directive 2006/32/EC. The plan aimed to install 3751 MW in new cogeneration plants by 2020, out of which 2490 MW were planned to be installed between 2011 and 2016 [55]. The ultimate goal was to reach a total of 9807 MW by 2020. In October 2012, the Energy Efficiency Directive 2012/27/EU came into effect, replacing Directives

2004/8/EC and 2006/32/EC. The new directive established rules and obligations to help the EU achieve its 20% energy efficiency target by 2020 [5].

As part of the 'Clean Energy for all Europeans package' released in 2016 [56], an agreement was reached to update the policy framework until 2030 and beyond through the Directive on Energy Efficiency (2018/2002) [6], which amended Directive 2012/27/EU. The key aim was to set a target of at least a 32.5% improvement in energy efficiency by 2030, based on the 2007 modelling projections for the same year. This target is meant to be attained collectively across the EU [6].

In January 2020, Spain's Integrated National Energy and Climate Plan 2021–2030 (INECP) was published, as stated in the 2016 'Clean Energy for All Europeans package' [56]. According to the INECP, the country set a goal to achieve carbon neutrality by the year 2050 and reduce GHGEs by at least 90%, compared to 1990 levels. It also expected a considerable decrease in the installed power of cogeneration, going from an estimated 4373 MW of installed capacity by 2025 to 3670 MW by 2030 [57].

Figure 1 depicts the growth of cogeneration installed capacity in Spain from 1990 to 2020, along with legislative changes. The left side of the graph, shaded in green, represents the pre-liberalization period, before the liberalization of the SES through the enactment of Law 54/1997 [58]. Similarly, the blue area represents the liberalization period. The orange marks depict the targets set by various energy plans, while the blue line indicates the installed power achieved, allowing for a comparison.

Figure 2 shows that from 1991 to 2004, there was significant growth in the CHP installed power, going from 356 MW in 1991 to 5643 MW in 2004. The objective of 2222 MW for the year 2000 set by the PAEE 1991–2000 was vastly exceeded by reaching 4890 MW, which was more than double the initial goal. The PAEE period coexisted with two different regulatory conceptions, the Pre-liberalization and Liberalization period. In the first phase, under Law 82/1980, RD 907/1982 and RD 2366/1994, the installation of CHP went exceptionally well, consistently exceeding the objectives set by the PAEE. In 1997, near the end of the PAEE period, the Spanish liberalization process started. All the previous frameworks were repealed, being the RD 2818/1998 responsible for promoting renewable energy sources and cogeneration. According to the figures, at the beginning of RD 2818/1998, the growth pace of installed CHP capacity (495.5 MW/year, see Figure 2 caption) remained the same. It might be assumed that this was due to the typical 2–3 years between the investment decision and the commissioning of a CHP plant.

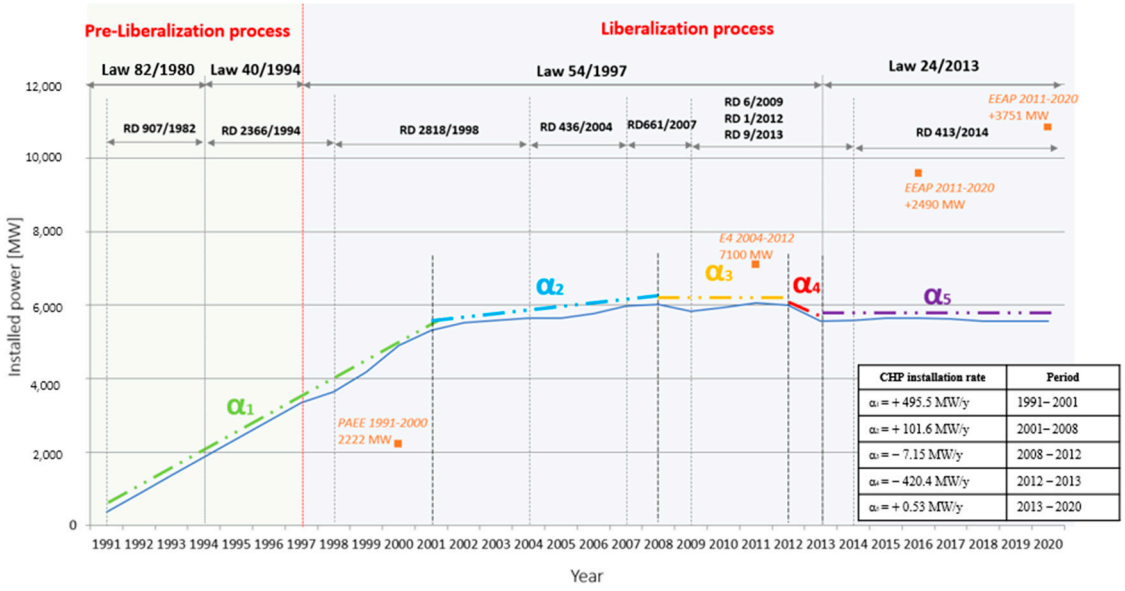

Figure 2. Evolution of the installed CHP in the period 1991–2020. Source: self-elaboration based on [59].

Nevertheless, despite the great variety of RDs addressed to promote CHP plants, from 2001 on, there was a decline in the installed CHP growth speed, changing from 5306 MW in 2001 to only 5989 MW in 2012 (see the lower growth paces at Figure 2 caption). The evolution worsened in 2013 because of a reduction of the installed power, which resulted in a final number of 5568 MW. These numbers more or less remained the same until 2020 with 5572 MW. As a result, the objectives set by E4 and EEAP 2011–2020 of reaching 10,851 MW by 2020 were not fulfilled.

4. A Description of the 1980–2020 Legal–Economic Frameworks for the CHP Plants in Spain

Due to the influence of the regulation on the development of CHP plants in Spain, in the following sections, the main characteristics of the several regulatory frameworks in force in the analysed periods will be described in detail. As a summary, Figure 3 collects the most representative Laws, RDs and directives that influenced the CHP plants through these years. In this regard, Laws are depicted in bold black letters, RDs in black, the energy plans in red and the European directives in blue.

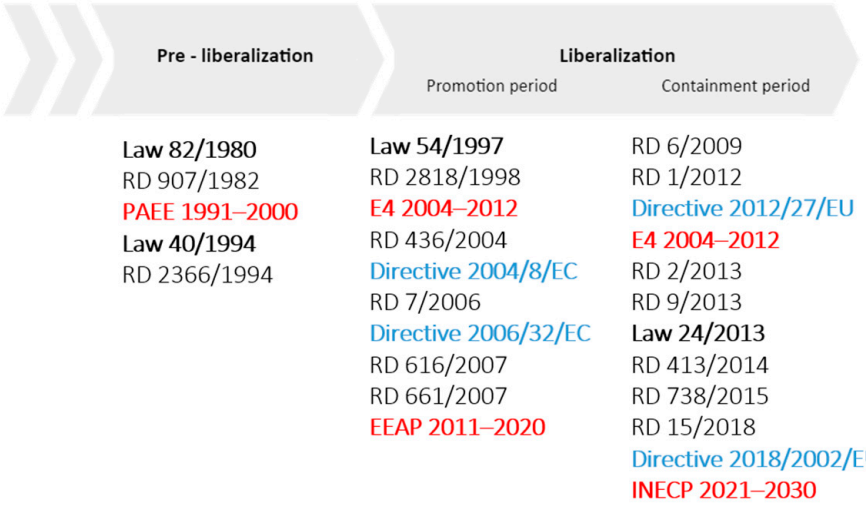

Figure 3. A summary timeline of the regulatory frameworks in Spain in the period 1980–2020. Source: Self-elaboration.

4.1. The Pre-Liberalization Period: 1980–1997

It might be said that the start of the promotion of cogeneration in Spain began with Law 82/1980 on energy conservation. Cogeneration was one of the several technical solutions that could fall within the group of self-producers. As a result, CHP plants were eligible for fiscal benefits defined in the law, as well as for a future and expected economic regime to be developed [42]. This economic regime was lately developed by RD 907/1982 on the promotion of the self-generation (or self-production) of electricity. According to it, the selling prices of the energy of the self-producers to the electricity companies at the point of connection to the network would be established by the Ministry of Industry and Energy [43].The main regulatory characteristics are displayed in Table 1.

In December 1994, Law 40/1994 on the regulation of the national electricity system, which partially modified and repealed Law 82/1980, was enacted. This Law introduced an integrated tariff system for the electrical energy supply, where these tariffs supported all the recognised costs of the different activities of the SES. Energy production was a recognised activity divided into two groups: the ordinary regime and the SR. The SR aimed to back those energy solutions that used renewable energy sources and cogeneration. The Law stated the need for a new economic regime for the SR, which was developed in the same year by RD 2366/1994.

Table 1. Regulatory framework for CHP in the pre-liberalization sub-period 1980–1994. Source: self-elaboration based on [42,43].

Legislation	Main Characteristics
Law 82/1980	
Subject	Established rules, basic principles and incentives to do the following: - Optimize the yields of energy transformation processes; - Strengthen the use of renewable sources; - Promote the use of residual energy from technological processes; - Analyse and control the development of projects for the construction of industrial plants with high energy consumption, according to energy profitability criteria at a national level; - Regulate the relationship between the auto-generators and the electricity distribution companies; - Promote actions to reduce external energy dependence.
Related to CHP installations	The Law defined the self-production or self-generation concept. Those facilities belonging to this concept were described as those whose primary economic purpose was that other than electricity production. Nevertheless, this electricity production was obtained from energy processes using energy excedents. According to it, CHP facilities were embedded into the "*self-producers*" or "*self-generators*" definition.
Key concepts	• Self-generation or self-production; • Surplus of electricity when possible; • Beneficial fiscal framework.
RD 907/1982	
Subject	To promote the self-generation
Related to CHP installations	The RD defined a set of legal conditions to be recognised as a self-producer or self-generator. Among these conditions were those related to facilities whose electricity production was derived from high energy efficiency heat production using conventional fuels or industrial waste heat. Again, according to it, CHP facilities were embedded into the "*self-producers*" or "*self-generators*" definition. Self-producers, or self-generators, were also classified into three categories: off-grid self-generators, grid-connected self-generators and assisted self-generators, which may receive energy from the grid in case of need.
Key concepts	• According to the contractual regime between self-generators and the grid company, the energy surplus was classified as follows: - Guaranteed energy: it required long-term contracts lasting at least two years and included specificities such as maximum and minimum power, day and hour type, etc.; - Scheduled energy: it required a weekly planning program, forecasting the energy throughout the week, including as well maximum and minimum power, day and hour type, etc.; - Eventual energy: it is referred to the non-programmable surpluses that the self-generator might deliver to the grid in case of variations in the electrical demand.

The 1994 new regulatory framework was an inflexion point concerning self-production treatment. Before 1994, the energy conservation approach was based on two great players: renewable energy producers and self-production. The first group was solely formed by hydroelectric power plants equal to or less than 5 MW. It might be inferred that the legislator had no confidence in other renewable energy power plant technologies. The second group was self-production. Those self-producers were energy assets addressed to either energy savings or electricity production through energetic subproducts or waste, which had a specific regulatory framework. After 1994, this clear differentiation was diluted thanks to Law 40/1994 and RD 2366/1994. According to the SR conception, any electricity production under the SR could fall into one of three categories: hydroelectric power plants with a capacity of up to 10 MW, other renewable power plants (including waste) and CHP, as well as electricity producers whose primary economic activity was not electricity production. These categories had a rated power (P) less than or equal to 100 MW.

Nevertheless, although the term "self-generator" or "self-producer" was no longer in the law, its essence was. The new framework allowed both the use of SR-produced energy in their facilities and/or the injection of this energy into the grid. The injected energy into the grid was considered surplus energy, and it was defined as the balance between the injected electricity into the grid and that received from the grid. All interconnection points

between the "producer-consumer" facility were considered for this balance. As a result, the term "self-producer" was replaced by the term "producer-consumer", characterized as the owner of a set of energy assets electrically connected to the grid within a facility that has subscribed to an energy supply contract.

The economic framework provided by RD 2366/1994 defined all income and cost streams for CHP plants regarding energy surpluses and consumed energy. As per the framework, CHP plants received revenues for the delivered energy and power while also facing penalties for non-compliance. In addition, distribution companies were forced to acquire the resulting energy surplus. CHP plants were also incentivized to contribute to reactive power regulation. In this regard, the framework enabled potential investors to predict the economic evolution of such energy assets. In Table 2, the main characteristics of these frameworks have been synthesised.

4.2. Liberalization Period: 1997–Ongoing

The liberalization period began in 1997 and represented a radical change for the SES, introducing the concept of free trading in the electricity market. This period has two parts. The first part was the promotion sub-period from 1997 to 2009. As a consequence of several regulatory frameworks, this period was characterized by the sudden growth in installing energy assets related to the SR [39–41]. Paradoxically, CHP was not among the technologies that suffered this outburst. Nevertheless, the resulting rise caused an economic burden on the SES that required containment regulatory measures. As a result, from 2009 to 2020, there was the so-called containment sub-period. Those periods will be discussed in detail below.

4.2.1. Promotion Sub-Period: 1997–2009

The liberalization period began with Law 54/1997 of the SES, which established the principles of a new operating model of the electricity market based on free competition. This law confirmed and preserved the distinction between the ordinary regime and the SR, establishing, for the later, a new remuneration system through the RD 2818/1998 to adapt the SR to the new regulation foreseen by Law 54/1997 [58].

The term "self-producer" appeared again in Law 54/1997. This term was used to refer to an energy production asset that supplied energy to its premises and used, when available, its surplus of energy to feed it into the grid.

It appeared in Article 25, where the exemptions to the energy market were set. According to it, in the case of energy assets under the SR, it allowed these energy assets to avoid the need for their surpluses to be sold in the energy market and for receiving economic remuneration. Additionally, this term was also used in the 8th Transitory Disposition when referring to those energy assets under the former RD 2366/1994.

In 1998, one year later, the definition of "self-production" was provided by RD 2818/1998. According to it, "self-producer" referred to those legal or natural people who generated electricity primarily for their own use. Facilities up to 25 MW had to self-consume at least, on an annual average, 30 per cent of the electrical energy produced, while for facilities equal to or greater than 25 MW, the percentage was at least 50 per cent. Additionally, according to RD, the self-producers' assets could be either CHPs or thermal electricity production facilities unrelated to "electrical activities".

In the same way, RD 2818/1998 also defined the concept of the electricity surplus introduced by Law 54/1997. In this regard, RD forced the SR assets to inject only the surplus into the grid, while the RESs were allowed to inject all their production.

The economic regime to which CHP was subjected changed again in 2004 with RD 436/2004. The new RD did not affect the definitions and conception of the term self-producer besides developing the definition of the self-consumption term. According to RD 436/2004, self-consumption was the electricity supply delivery from CHP to the company's premises or any of the members of a group that owns the installation. In this RD, electricity producers falling under the SR could choose between receiving FIP or FIT, both calculated considering the average electricity tariff (AET) [48].

Table 2. Regulatory framework for CHP in the pre-liberalization sub-period 1994–1997. Source: self-elaboration based on [45,46].

Legislation	Main Characteristics		
Law 40/1994			
Subject	To regulate activities to guarantee the electricity supply at the lowest cost possible. Definition of the SR economic framework is to promote RESs and CHP. It is the first time that the definition and recognition of the CHP were stated in the Law.		
Related to CHP installations	Facilities that produced electricity through high energy efficiency, including CHP facilities and other non-electric activities with a rated power up to 100 MW, were subjected to the SR under the Law.		
Key concepts	• Two different organizational and regulatory systems for the generation and distribution of electricity: integrated system and independent system; • SR; • Cogeneration.		
RD 2366/1994			
Subject	On the production of electricity through hydraulic, cogeneration and other installations powered by renewable sources or resources with P$\leq$ 100 MW.		
Related to CHP installations	Definition of the economic regime for CHP with P $\leq$ 100 MW, which falls into group d (Article 2). Definition of the necessary requirements for a CHP installation to fall under the SR.		
Key concepts	• SR; • To be registered in the "General Registry of Production Facilities of IDAE Regime (SR) in the General Directorate of Energy of the Ministry of Industry and Energy "; • Definition of cogeneration.		
Classification	Group d		
Economic regime	Equation for the calculation of the incomes of the CHP: $FT = (PF \cdot Tp + Ec \cdot Te \pm DH \pm ER) \cdot Kf - AI$ where: - FT is the income of the CHP; - PF is the power to bill; - Tp is the economic term related to the power; - Ec is the transferred energy; - Te is the economic term related to the energy; - DH is a revenue time discrimination; - ER is a revenue due to the reactive energy; - Kf is a coefficient specified within the RD 2366/1994; - AI is a payment for failure to perform.		
	Rated Power	Tp [EUR/kW]	Te [EUR/kWh]
	P $\leq$ 15 MW	10.6	0.0478
	15 MW < P $\leq$ 30 MW	10.2	0.0462
	30 MW < P $\leq$ 100 MW	9.9	0.0448
Further requirements	Compliance with the effective electric efficiency (EEE) in accordance with Annex of this Royal Decree. Compliance with the efficiency required for the specific installation.		
Update	Tp and Te annually updated		
Energy supply limits	Only electrical energy in excess of that produced by the facilities under examination may be incorporated into the system.		

In May 2007, the RD 616/2007 [60] was published in response to Directive 2004/8/EC, on the promotion of the cogeneration. In the same year, RD 661/2007 was enacted to regulate the activity of electricity production in the SR while repealing former RD 436/2004. The RD 661/2007 stated an objective method to determine the amount of electricity production from CHP assets and its energy efficiency [49]. This RD incorporated the modifications of the Royal Decree-Law (RDL) 7/2006 [49] concerning abolishing the "self-producer" term

in the SES for CHP technologies. In addition, the economic regime of the installations belonging to the SR was again modified.

Table 3 shows the characteristics of the RDs and Laws of the promotion sub-period, while Table 4 provides an outline of the different economic regimes in force for the CHP systems in Spain in the period 1997–2009.

Table 3. Regulatory framework for CHP in the promotion sub-period 1997–2009. Source: self-elaboration based on [47–49,58,60,61].

Legislation	Main Characteristics
Law 54/1997	
Subject	Law that regulated the SES and its activities involved in the electricity supply, i.e., generation, transport, distribution, marketing, and intra-community and international interchanges, as well as the economic and technical management of the electricity system. The production of electrical energy was developed in a regime of free competition. Initially, this regime was based on a system where energy demand and production were fit according to an incipient day-ahead energy market. Later, this incipient market developed into the current electricity market production. The regulatory body of the electricity system was the National Electricity System Commission. This referred to the regulation of the remuneration system of the activities that participated in the supply of electricity. There were also defined in the following ways: - Market operator: responsible for the economic management of the energy market; - System operator: responsible for the technical management of the transport network of the SES; - Definitions of transition costs to competition (TCC).
Related to CHP installations	The Law stated the existence of the SR, defined the technical characteristics of the energy assets under its regime and recognised CHP as one of the technical solutions among them (Article 27). In the initial text, CHP was related to the self-production term, addressed to those that use cogeneration or other forms of electricity production associated with non-electric activities as long as they involve a high energy efficiency with $P \leq 50$ MW. Nevertheless, in 2006, the self-production term was erased from the Law, being the CHP defined as just electricity production energy assets. It also contemplated the maintenance of the former economic scheme for those facilities with rated powers equal to or less than 50 MW, which were installed previously to Law 54/1997 and were under RD 2366/1994.
Key concepts	• Liberalization and free competition; • National Commission of the Electricity System; • Self-producers and electricity producers; • TCC.
RD 2818/1998	
Subject	Promotion of the production of electricity through installations powered by renewable resources, cogeneration or waste. Regulatory development of the SR that was established in Law 54/1997. Establishment of a transitory regime for facilities that, on the date of entry into force of the SES Law, were under RD 2366/1994. Derogation of RD 2366/1994.
Related to CHP installations	Classification of CHP that falls under the SR into groups and subgroups. In particular, CHP plants were included in Group *a*, provided that they had high energy performance and met the requirements of Annex I. They were classified into two groups: - **Subgroup a.1**: Facilities including a cogeneration plant. This refers to systems that combine the production of electricity with the production of useful heat for the subsequent use of non-electric energy; - **Subgroup a.2**: Installations that include a plant using residual energy from any installation, machine or industrial process whose purpose was not the production of electrical energy.

Table 3. *Cont.*

Legislation	Main Characteristics
Key concepts	• SR; • Self-producer plant; • Surplus of electricity; • FIP and FIT.
RD 436/2004	
Subject	Updating, systematization and rewriting of the regulatory regime of the electricity production activity under the SR included in Law 54/1997 of the SES. Establishment of an economic regime for installations covered by the SR based on the AET, regulated by RD 1432/2002. Establishment of two transitory economic regimes: for the installations covered by RD 2366/1994 and for those covered by RD 2818/1998. Derogation of RD 2818/1998.
Related to CHP installations	In particular, CHP was included in category *a* and category *d*: • **Category a**: Self-generating plants using cogeneration or other forms of thermal electricity production related to non-electrical activities with high energy performance and meeting the requirements of Annex I. They were classified into two groups: (a) *Group a.1*: Installations that include a CHP plant. This group was divided into two subgroups: - **Subgroup a.1.1**: CHP that uses NG as a fuel, if it represents at least 95% of the primary energy used, measured by the lower calorific value; - **Subgroup a.1.2**: Rest of CHPs. (b) *Group a.2*: Installations with a plant that uses residual energy from any installation, device or industrial process whose purpose is not the production of electrical energy. • **Category d** *: Installations that use CHP for the treatment and reduction of waste from the agricultural, livestock and service sectors, provided that they entail high energy performance and meet the requirements determined in Annex I, with a maximum installed power of 25 MW. It was divided into three groups: (a) *Group d.1*: Manure treatment and reduction facilities from pig farms in surplus areas; (b) *Group d.2*: Sludge treatment and reduction facilities; (c) *Group d.3*: Other waste treatment and reduction facilities, other than those listed above.
Key concepts	• SR; • Definition of CHP; • Self-producer and self-consumption; • AET; • Electricity Surplus.
RD 7/2006	
Subject	It presented urgent measures in the energy sector. It partially modified Law 54/1997.
Related to CHP installations	Abolition of Sixth (on TCC) and Eighth (on former RD 2366/1994 regulatory framework) transitional provisions of Law 54/1997. The existence of the TCC was a sine qua non condition for the former CHPs to remain adhered to the RD 2366/1994. Subject to the TCC's existence, RD 2818/1998 and RD 436/2004 contemplated in their transitory dispositions the right to preserve the former economic regime for those facilities under RD 2366/1994, with rated powers up to 50 MW. The abolishment of those TCC provisions resulted in the loss of a presumably favourable economic framework into a new framework to come. Nevertheless, some of these changes, such as the abolishment of the former economic framework, were planned to be applied after the revision of the economic framework of the SR, which was undertaken in May of 2007 by RD 661/2007. RD Law 7/2006 also finally erased the self-production term in relation to CHP, being then just considered electricity production assets. This new concept came into force as well, after the revision of RD 661/2007. By Directive 2004/8/EU, it is necessary to adequately remunerate all cogenerated electricity, regardless of the size of the installations.

Table 3. *Cont.*

Legislation	Main Characteristics
Key concepts	• TCC; • Cogenerated energy.
RD 616/2007	
Subject	Creation of a regulatory framework for the promotion of CHP, in accordance with Directive 2004/8/EU. Analysis and evaluation of the national potential for high-efficiency CHP, of the barriers that hinder its development and of the necessary measures to facilitate access to the network of CHP units and small-scale micro-CHP and CHP plants, while defining methods for determining energy savings for high-efficiency CHP units.
Related to CHP installations	Analysis of the application potential of high-efficiency CHP, including high-efficiency micro-CHP, carried out by the Ministry of Industry, Tourism and Trade. List of types of considered high efficiency CHP (Annex I). It is established that the calculation of electricity from CHP must be based on the real relationship between electricity and heat.
Key concepts	• High efficiency electricity
RD 661/2007	
Subject	Establishment of a legal and economic regime for the electricity production activity under a SR that replaced RD 436/2004. Establishment of a temporary economic regime for facilities included in categories (a), (b), (c) and (d) of RD 436/2004. The determination of a premium to complement the remuneration regime for biomass and/or biogas co-combustion facilities in ordinary regime thermal power plants, regardless of their power, in accordance with the provisions of article 30.5 of Law 54/1997. Derogation of RD 436/2004
Related to CHP installations	Classification of CHP plants into categories, groups and subgroups. In particular, cogeneration plants are included in category a. • **Category a**: Producers that use CHP or other forms of electricity production from residual energy. They were classified into two groups: (a) *Group a.1*: Installations including a CHP plant with a high energy efficiency and satisfying the requirements determined in Annex I. This group was divided into four subgroups: - **Subgroup a.1.1**: CHP using NG, representing at least 95% of the primary energy used, or at least 65% of the primary energy used when the rest comes from biomass and/or biogas under the terms provided for in Annex II; - **Subgroup a.1.2**: CHP that used diesel, fuel oil or Liquefied Petroleum Gases (LPG) as fuel (at least 95% of the primary energy used); - **Subgroup a.1.3**: CHP that used biomass and/or biogas as the main fuel, under the terms that appear in Annex II, and provided that this represents at least 90% of the primary energy used, measured by the lower calorific value. The economic regime for this subgroup was defined according to Annex II of this RD and it is based on the fuel used in the plant; - **Subgroup a.1.4**: Rest of CHP that included, as possible fuels to be used, refinery waste gases, coke oven, process fuels, coal and others not contemplated in the previous subgroups. (b) *Group a.2*: Installations using residual energy with no purpose of producing electrical energy.
Key concepts	• SR; • Definition of CHP; • Suppression of the concept of surplus of electricity; • Hourly discrimination regime; • Efficiency Complement.

* For the first time in the regulatory framework of the SR, waste treatment was linked only to CHP technologies to receive its economic benefits. Later, the RD 661/2007 modified this requirement, allowing a wider range of technological solutions.

4.2.2. Containment Sub-Period: 2009–2020

In 2009, the deviation between the income and the regulated costs of the SES was a matter of concern. As a result, containment policies began to be enacted to restrain the regulated costs of the SES. To this end, RDL 6/2009 [62], RDL 1/2012 [63], RDL 2/2013 [64] and RDL 9/2013 [65] were approved. The latter, in particular, clarified the new bases of the economic framework that were yet to come and would affect SR installations [65]. Considering the deficiencies of Law 54/1997 that led to the financial burden of the SES, it was decided to modify the framework of the SES. In light of the above, in December 2013, Law 24/2013 of the SES was approved [66]. This law erased the two economic regimes system, forcing electricity power plants to negotiate in the electricity market. Nevertheless, a specific remuneration regime was applied to those installations that produced electricity through renewable sources, high-efficiency cogeneration and residues [65].

Table 4. Scheme of the different CHP economic regimes in the promotion sub-period 1997–2009. Source: self-elaboration based on [47–49].

Legislation	Main Characteristics			
RD 2818/1998				
Economic regime	Injected electricity price: $Price_{i,d,h} = Pm_{i,d,h} + FIP_i \pm ER_i$ $Price_{i,d,h}$: electricity price to be paid in cEUR/kWh in a particular year I, for a day d, whithin an hour h. $Pm_{i,d,h}$: electricity market price to be paid in cEUR/kWh in a particular year i, for a day d, within an hour h. FIP_i: FIP to be paid in cEUR/kWh for the electricity produced in a particular year i. ER_i: reactive energy power complement, stated according to the yearly tariffs, which could be positive if the facility's power factor was 0.9 or higher. Otherwise, it was considered negative.			
	Rated Power	FIP [cEUR/kWh] Premium (Pr)	FIT [cEUR/kWh]	Time limit
	P ≤ 10 MW	1.92	-	10 years
	10 MW < P ≤ 25 MW	FIP10 × (40 − P)/30	-	Subjected to the existence of the TCC
Further requirements	For both rated powers: • Justification of the surplus energy given to the electricity grid; • Compliance with EEE.			
Update	Annual update.			
Review	Every 4 years.			
Energy supply limits	Only electricity surplus could be incorporated into the system.			
Facilities under former economic regimes	CHPs with rated powers higher than 50 MW were forced to go to the energy market to sell their energy surplues. Additionally, there was an additional remuneration of 0.9 cEUR/kWh as a capacity payment concept.			
	CHPs with rated powers equal or up to 50 MW saw their former economic regime granted.			
RD 436/2004				
	Injected electricity price: According to RD 436/2004, there were two options for being remunerated. In the first option, the income was based on the injection of the energy produced at a specific FIT. $Revenue_{i,d,h} = E_{i,d,h} \times FIT_i + \pm ER_{i,d,h} \times Cer_i$ $Revenue_{i,d,h}$: obtained income according to FIT scheme to be received in a particular year i, for a day d, within an hour h. $E_{i,d,h}$: produced electricity injected into the grid in a particular year I, for a day d, within an hour h. $ER_{i,d,h}$: produced reactive energy injected into the grid in a particular year i, for a day d, within an hour h. FIT_i: electricity price to be paid in cEUR/kWh in a particular year i. Cer_i: reactive energy complement in a particular year i. In the second option, the income was based on the injection of the energy produced at a specific FIP and the electricity market price: $Revenue_{i,d,h} = E_{i,d,h} \times Pm_{i,d,h} + E_{i,d,h} \times FIP_i + E_{i,d,h} \times Inc_i \pm ER_{i,d,h} * Cer_i$ $Pm_{i,d,h}$: electricity market price to be paid in cEUR/kWh in a particular year I, for a day d, within an hour h. FIP_i: FIP to be paid in cEUR/kWh for the electricity produced in a particular year i. Inc_i: incentive price offered to participate in the day-ahead energy market to be paid in cEUR/kWh for the electricity produced in a particular year i.			

Table 4. *Cont.*

Legislation	Main Characteristics						
Economic regime	**Subgroup a.1.1**						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
		Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
	P ≤ 1 MW	-	-	-	-	90% AET	First 10 years
						50% AET	Thereafter
	1 MW < P≤ 10 MW	10% AET	First 10 years	30% AET	First 10 years	80% AET	First 10 years
		20% AET	Thereafter	-	Thereafter	50% AET	Thereafter
	10 MW < P ≤ 25 MW	20% AET	First 15 years	5% AET *	Period I according to the Law 54/1997	55% AET *	Period I according to the Law 54/1997
		15% AET	Thereafter	-	Thereafter	50% AET	Thereafter
	25 MW < P ≤ 50 MW	25% AET	First 20 years	-	-	50% AET	-
		15% AET	Thereafter				
	Subgroup a.1.2						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
		Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
	P ≤ 1 MW	-	-	-	-	90% AET	First 10 years
						50% AET	Thereafter
	1 MW < P ≤ 10 MW	10% AET	-	30% AET	First 10 years	80% AET	First 10 years
				-	Thereafter	50% AET	Thereafter
	10 MW < P ≤ 25 MW	10% AET	-	5% AET *	Period I according to the Law 54/1997	55% AET *	Period I according to the Law 54/1997
				-	Thereafter	50% AET	Thereafter
	25 MW < P ≤ 50 MW	10% AET	-	-	-	50% AET	-

Table 4. *Cont.*

Legislation	Main Characteristics						
	Group a.2						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
	P ≤ 10 MW	Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
		5% AET	First 10 years	10% AET	First 10 years	60% AET	First 10 years
		10% AET	Thereafter	-	Thereafter	50% AET	Thereafter
	10 MW < P ≤ 25 MW	5% AET	First 10 years	5% AET *	Period I according to the Law 54/1997	55% AET *	Period I according to the Law 54/1997
		10% AET	Thereafter	-	Thereafter	50% AET	Thereafter
	25 MW < P ≤ 50 MW	5% AET	First 10 years	-	-	50% AET	-
		10% AET	Thereafter				
	Group d.1						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
		Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
	-	10% AET	-	20% AET	First 15 years	70% AET	First 15 years
				10% AET	Thereafter	50% AET	Thereafter
	Group d.2						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
		Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
	-	10% AET	-	20% AET	First 15 years	70% AET	First 15 years
				10% AET	Thereafter	50% AET	Thereafter
	Group d.3						
	Rated Power	Incentive [cEUR/kWh]		FIP [cEUR/kWh]		FIT [cEUR/kWh]	
		Incentive	Time limit	Premium	Time limit	Regulated Tariff	Time limit
	-	10% AET	-	10% AET	-	60% AET	First 10 years
						50% AET	Thereafter
	* Subjected to the existence of the TCC						

Table 4. *Cont.*

Legislation	Main Characteristics
Further requirements	For all rated powers and groups, the following is required: • Justification of the surplus energy given to the electricity grid; • Compliance with EEE in accordance with Annex I of this Royal Decree. According to the fuel used, this value might vary from 49% to 59%. Only for group d.1: • Installations must be submitted annually to the Autonomous Community an environmental audit in which it is explicitly stated the collected amount of pig slurry treated by the facility in the previous year; • The annual treatment of at least 50% of the amount of pig manure for which the plant was designed must be fulfilled. Only for group d.2: • Sludge would be that waste that has the following characteristics: - Total solids concentration of at least 10,000 parts per million; - Moisture content between 40% and 99%; - It can be circulated or pumped, and it can have thixotropic properties.
Update	Annual update for both FIT and FIP and for all rated powers.
Review	For FIT, FIP and incentives of all rated powers and groups, the first revision was expected in 2006. Next, after that, it would be every four years. Nevertheless, when reaching 7100 MW of installed power of group a, these energy assets would see their FIT, FIP and incentives reviewed. For group d, the limit was set at 750 MW of installed power, but the revision would only apply to FIT and FIP.
Energy supply limits	Only electrical energy in excess of that produced by the facilities under examination may be incorporated into the system.
RD 661/2007	
Economic regime	Injected electricity price: According to RD 661/2007, there were two options for being remunerated. In the first option, the income was based on the injection of the energy produced at a specific FIT. $$Revenue_{i,d,h} = E_{i,d,h} \times FIT_i + E_{i,d,h} \times 1.1 \times \left[\frac{1}{\mu_{min}} - \frac{1}{\mu_{elec_i}}\right] Cmp_i \pm ER_{i,d,h} \times Cer_i$$ $Revenue_{i,d,h}$: obtained income according to FIT scheme to be received in a particular year i, for a day d, within an hour h. $E_{i,d,h}$: produced electricity injected into the grid in a particular year i, for a day d, within an hour h. $ER_{i,d,h}$: produced reactive energy injected into the grid in a particular year i, for a day d, within an hour h.μ_{min}: required minimum electric equivalent efficiency for CHP energy assets.μ_{elec_i}: electric equivalent efficiency for CHP energy assets in a particular year i. FIT_i: electricity price to be paid in cEUR/kWh in a particular year i. Cmp_i: efficiency complement indexed to the NG unitary cost, the required minimum electric equivalent efficiency in a particular year i.Cer_i: reactive energy complement in a particular year i. In the second option, the income was based on the injection of the energy produced at a specific FIP and the electricity market price: $$Revenue_{i,d,h} = E_{i,d,h} \times Pm_{i,d,h} + E_{i,d,h} \times FIP_i \pm ER_{i,d,h} \times Cer_i$$ $Pm_{i,d,h}$: electricity market price to be paid in cEUR/kWh in a particular year i, for a day d, within an hour h. FIP_i: FIP to be paid in cEUR/kWh for the electricity produced in a particular year i.

Subgroup a.1.1

Fuel	Rated Power	FIP* [cEUR/kWh]	FIT* [cEUR/kWh]	Time Limit
NG	P ≤ 0.5 MW	-	12.0400	-
	0.5 MW < P ≤ 1 MW	-	9.8800	-
	1 MW < P ≤ 10 MW	2.7844	7.7200	-
	10 MW < P ≤ 25 MW	2.2122	7.3100	-
	25 MW < P ≤ 50 MW	1.9147	6.9200	-

Subgroup a.1.2

Fuel	Rated Power	FIP* [cEUR/kWh]	FIT* [cEUR/kWh]	Time Limit
Diesel/LPG/Fuel	P ≤ 0.5 MW	-	13.2900	-
Diesel/LPG	0.5 MW < P ≤ 1 MW	-	11.3100	-
	1 MW < P ≤ 10 MW	4.6644	9.5900	-
	10 MW < P ≤ 25 MW	4.2222	9.3200	-
	25 MW < P ≤ 50 MW	3.8242	8.9900	-
Fuel	0.5 MW < P ≤ 1 MW	-	10.4100	-
	1 MW < P ≤ 10 MW	3.8344	8.7600	-
	10 MW < P ≤ 25 MW	3.3822	8.4800	-
	25 MW < P ≤ 50 MW	2.9942	8.1500	-

Table 4. *Cont.*

Legislation	Main Characteristics				
	Subgroup a.1.3				
	Fuel	Rated Power	FIP* [cEUR/kWh]	FIT* [cEUR/kWh]	Time Limit
	b.6.1: (Agricultural and forest energy crops)	P ≤ 2 MW	11.6608	16.0113	First 15 years
			-	11.8839	Thereafter
		P > 2 MW	10.0964	14.6590	First 15 years
			-	12.3470	Thereafter
	b.6.2: (Waste from agricultural and gardening activities)	P ≤ 2 MW	8.4643	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	6.1914	10.7540	First 15 years
			-	8.0660	Thereafter
	b.6.3: (Residues from forest use and forestry operations. Residual biomass produced in any type of treatment or silvicultural use in forest masses)	P ≤ 2 MW	8.4643	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	7.2674	11.8294	First 15 years
			-	8.0660	Thereafter
	b.7.1: (Landfill biogas)	-	4.0788	8.2302	First 15 years
			-	6.7040	Thereafter
	b.7.2: (Biogas from anaerobic digestion in a digester of any waste to which anaerobic digestion is applicable)	P ≤ 500 kW	10.0842	13.3474	First 15 years
			-	6.6487	Thereafter
		P > 500 kW	6.1009	9.9598	First 15 years
			-	6.6981	Thereafter
	b.7.3: (Manure by combustion. Liquid biofuels and related by-products)	-	3.0844	5.3600	First 15 years
			-	5.3600	Thereafter
	b.8.1: (Biomass from industrial facilities in the agricultural sector)	P ≤ 2 MW	8.4643	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	6.3821	10.9497	First 15 years
			-	8.2128	Thereafter
	b.8.2: (Biomass from industrial facilities in the forestry sector)	P ≤ 2 MW	5.1591	9.4804	First 15 years
			-	6.6506	Thereafter
		P > 2 MW	2.9959	7.1347	First 15 years
			-	7.1347	Thereafter
	b.8.3: (Waste liquids from the paper industry)	P ≤ 2 MW	5.419	9.4804	First 15 years
			-	6.6506	Thereafter
		P > 2 MW	4.9586	9.3000	First 15 years
			-	7.5656	Thereafter

Table 4. *Cont.*

Legislation	Main Characteristics				
	Subgroup a.1.4				
	Fuel	Rated Power	FIP * [cEUR/kWh]	FIT * [cEUR/kWh]	Time Limit
	Coal	P ≤ 10 MW	3.8479	6.1270	-
		10 MW < P ≤ 25 MW	1.5410	4.2123	-
		25 MW < P ≤ 50 MW	0.9901	3.8294	-
	Others	P ≤ 10 MW	1.9332	4.5953	-
		10 MW < P ≤ 25 MW	1.1581	4.2123	-
		25 MW < P ≤ 50 MW	0.6071	3.8294	-
	Group a.2				
	Fuel	Rated Power	FIP * [cEUR/kWh]	FIT * [cEUR/kWh]	Time Limit
	-	P ≤ 10 MW	1.9344	4.6000	-
		10 MW < P ≤ 25 MW	1.1622	4.2100	-
		25 MW < P ≤ 50 MW	0.6142	3.8300	-
	* The values of the different depicted FITs and FIPs were modified in 2008 and 2013 by RD 222/2008 and RD-L 2/2013. In 2008, some FITs for a.1.3 and a.1.4 were increased, while in 2013, all FIPs were dismissed. Nevertheless, all the FITs in place saw their values increase. To provide clarity to the text, the authors have restrained the depiction of their values.				
Further requirements:	For the group a.1: • Compliance with the EEE in accordance with Annex I of this RD. For those installations with P ≤ 1 MW, the minimum EEE required will be 10% lower than that which appears in the table in Annex I, by type of technology and fuel. For the subgroup a.1.3: • Justify the energy that is transferred to the grid by means of each of the fuels used, specifying what is reported in Article 6 of this RD; • Compliance with the EEE in accordance with Annex I of this RD.				
Update	For the subgroup a.1.1: • Quarterly update according to the consumer price index (CPI) and the fuel price index (FPI) (Annex VII); • After a 10-year operating period, an aging correction factor is applied. This factor is not applied to those installations already in operation at the entry in force of this RD. For the subgroup a.1.2: • Quarterly update according to the Annex VII of this RD and the evolution of the CPI and FPI. For the subgroup a.1.3: • Annual update according to the CPI (Article 44). For the subgroup a.1.4: • Annual update according to the evolution of carbon price and/or the CPI, as reported in the Annex VII. For the group a.2: • Annual update according to the CPI.				
Review	Review in 2010 and thereafter every 4 years, for all the groups and subgroups.				
Additional remuneration for SR installations	For installations of the SR, which are required to comply with the EEE: • Efficiency Complement.				

The principles settled in the RDL 9/2013 and in Law 24/2013 would be later developed through the RD 413/2014 [50] to regulate the activity of electricity production through renewable sources, cogeneration and residues. To assign the specific remuneration regime, a standard installation type was associated with each power plant based on its physical and economic characteristics. The legislator performed the classification of those standard installations. It was based on a set of representative parameters calculated in compliance with the principle of an "efficient and well-managed power plant" [64,65]. RD 413/2014 would be partially modified first by RDL 15/2018 and then by RDL 17/2019, due to the simultaneous increase in the cost of emission rights established by the EU and to update the value of reasonable profitability [67,68], respectively.

The regulatory frameworks in force since 2009 are schematically described in Table 5 while in Table 6 the outline of different CHP economic regimes in the cost-containment sub-period is provided.

Table 5. Regulatory framework for CHP in the cost containment sub-period since 2009. Source: self-elaboration based on [50,61–67].

Legislation	Main Characteristics
RDL 6/2009	
Subject	The social bonus is approved, and measures are adopted in the energy sector to do the following: • Establish limits to restrict the increase in the deficit, and define a path for the progressive adequacy of access tolls, also addressing a financing mechanism for the tariff deficit; • Establish additional protection mechanisms for vulnerable groups; • Address the need to free the electricity tariff, as soon as possible, from the burden of financing the activities of the General Radioactive Waste Plan; • Establish a Remuneration Pre-Assignment Register (RPAR) to opt for the remuneration conceived in RD 661/2007 to obtain knowledge on the evolution of SR and gain control of the regulated costs of the SES.
Related to CHP installations	Registration in the RPAR was required to guarantee access to the remuneration established in RD 661/2007. To be enrolled, there must be respected some requirements such as an access point to the grid, construction permit, etc. The facilities registered in the RPAR had a maximum period of thirty-six months from the date of their notification, to be registered definitively in the Administrative Registry of production facilities under the SR. Otherwise, the economic right associated with the inclusion in RPAR would be revoked. They had a period of 30 calendar days from the date of entry into force of this RD to submit their request to the General Directorate for Energy Policy and Mines (GDEPM). Likewise, they had an additional 30 calendar days to deposit the required guarantee and to send the supporting receipt to the GDEPM. Once compliance with the prerequisites of the installation projects was verified, they were registered in the RPAR. The remuneration scheme of RD 661/2007 was subjected to obtaining the power objectives for each one of the technologies under this RD. In case the objectives of one of the technologies were surpassed by the registered power in the RPAR, a new legal-economic framework for these technologies had to be approved.
Key concepts	• Social bonus; • RPAR; • Tariff deficit.
RDL 1/2012	
Subject	Suspension of remuneration pre-allocation procedures and of the economic incentives for new electricity production facilities from cogeneration, renewable energy sources and waste.
Related to CHP installations	The values of the regulated tariffs, premiums and limits provided in RD 661/2007 for new facilities that could be within the scope of the application of this RD were suppressed. The efficiency supplement and the reactive energy supplement, regulated in articles 28 and 29, respectively, of RD 661/2007, were abolished. The government could establish specific economic regimes for certain SR facilities, as well as the right to receive a specific economic regime for those SR facilities with $P \leq 50$ MW. The owners of SR facilities registered in the RPAR who chose not to carry out the execution of the installation, within a maximum period of two months from the entry into force of this RDL, provided that the term for the final registration and sale of energy was not expired, could waive their registration in RPAR, without this implying the execution of the guarantees they had deposited.
Key concepts	Suppression of economic incentives for new facilities under the scope of RD 661/2007.
RDL 2/2013	
Subject	Urgent measures in the electrical system and in the financial sector.
Related to CHP installations	The premiums for cogeneration recognized in RD 661/2007 were cancelled. The tariff applied to subgroup a.1.3 of article 2 of RD 661/2007 was modified, becoming 14.6773 centEUR/kWh, instead of that discussed in article 35 of RD 661/2007, to be received for a maximum period of 15 years from its launch. A new economic index was established to replace the CPI for all of those methodologies that used it for updating the remuneration.

Table 5. *Cont.*

Legislation	Main Characteristics				
	Subgroup a.1.1				
	Fuel	Rated Power	FIP [cEUR/kWh]	FIT [cEUR/kWh]	Time Limit
	NG	P ≤ 0.5 MW	-	12.0400	-
		0.5 MW < P ≤ 1 MW	-	9.8800	-
		1 MW < P ≤ 10 MW	-	7.7200	-
		10 MW < P ≤ 25 MW	-	7.3100	-
		25 MW < P ≤ 50 MW	-	6.9200	-
	Subgroup a.1.2				
	Fuel	Rated Power	FIP [cEUR/kWh]	FIT [cEUR/kWh]	Time Limit
	Diesel/LPG/Fuel	P ≤ 0.5 MW	-	13.2900	-
	Diesel/LPG	0.5 MW < P ≤ 1 MW	-	11.3100	-
		1 MW < P ≤ 10 MW	-	9.5900	-
		10 MW < P ≤ 25 MW	-	9.3200	-
		25 MW < P ≤ 50 MW	-	8.9900	-
	Fuel	0.5 MW < P ≤ 1 MW	-	10.4100	-
		1 MW < P ≤ 10 MW	-	8.7600	-
		10 MW < P ≤ 25 MW	-	8.4800	-
		25 MW < P ≤ 50 MW	-	8.1500	-
	Subgroup a.1.3				
	Fuel	Rated Power	FIP [cEUR/kWh]	FIT [cEUR/kWh]	Time Limit
Economic regime	b.6.1: (Agricultural and forest energy crops)	P ≤ 2 MW	-	16.0113	First 15 years
			-	11.8839	Thereafter
		P > 2 MW	-	14.6590	First 15 years
			-	12.3470	Thereafter
	b.6.2: (Waste from agricultural and gardening activities)	P ≤ 2 MW	-	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	-	10.7540	First 15 years
			-	8.0660	Thereafter
	b.6.3: (Residues from forest use and forestry operations. Residual biomass produced in any type of treatment or silvicultural use in forest masses)	P ≤ 2 MW	-	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	-	11.8294	First 15 years
			-	8.0660	Thereafter
	b.7.1: (Landfill biogas)	-	-	8.2302	First 15 years
			-	6.7040	Thereafter
	b.7.2: (Biogas from anaerobic digestion in a digester of any waste to which anaerobic digestion is applicable)	P ≤ 500 kW	-	13.3474	First 15 years
			-	6.6487	Thereafter
		P > 500 kW	-	9.9598	First 15 years
			-	6.6981	Thereafter
	b.7.3: (Manure by combustion. Liquid biofuels and related by-products)	-	-	5.3600	First 15 years
			-	5.3600	Thereafter

Table 5. *Cont.*

Legislation	Main Characteristics				
	b.8.1: (Biomass from industrial facilities in the agricultural sector)	P ≤ 2 MW	-	12.7998	First 15 years
			-	8.6294	Thereafter
		P > 2 MW	-	10.9497	First 15 years
			-	8.2128	Thereafter
	b.8.2: (Biomass from industrial facilities in the forestry sector)	P ≤ 2 MW	-	9.4804	First 15 years
			-	6.6506	Thereafter
		P > 2 MW	-	7.1347	First 15 years
			-	7.1347	Thereafter
	b.8.3: (Waste liquids from the paper industry)	P ≤ 2 MW	-	9.4804	First 15 years
			-	6.6506	Thereafter
		P > 2 MW	-	9.3000	First 15 years
			-	7.5656	Thereafter
	Subgroup a.1.4				
	Fuel	Rated Power	FIP [cEUR/kWh]	FIT [cEUR/kWh]	Time Limit
	Coal	P ≤ 10 MW	-	6.1270	-
		10 MW < P ≤ 25 MW	-	4.2123	-
		25 MW < P ≤ 50 MW	-	3.8294	-
	Others	P ≤ 10 MW	-	4.5953	-
		10 MW < P ≤ 25 MW	-	4.2123	-
		25 MW < P ≤ 50 MW	-	3.8294	-
	Group a.2				
	Fuel	Rated Power	FIP [cEUR/kWh]	FIT [cEUR/kWh]	Time Limit
	-	P ≤ 10 MW	-	4.6000	-
		10 MW < P ≤ 25 MW	-	4.2100	-
		25 MW < P ≤ 50 MW	-	3.8300	-
Key concepts	Abolition of FIPs. CPI.				
RDL 9/2013					
Subject	Urgent measures to guarantee the financial stability of the electricity system.				
Related to CHP installations	This RDL empowered the legislator to develop a new economic framework for the former SR facilities under R 661/2007. The new economic framework, or Specific Remuneration framework (SRF), was based on three pillars; namely, the standard value of the initial investment, the standard operating costs and the standard revenues related to the day-ahead energy market. These parameters were set out based on what was called an efficient and well-managed power plant (or installation type), with its specific standard parameters. The value of these parameters was set by the legislator. Repeal of RD 661/2007 and RDL 6/2009. Modification of the Law 54/1997. The Registry of the SRF was created for the granting and adequate follow-up of the SRF. In the registry, there included the remuneration parameters of those facilities, and it was aimed to be a sine qua non condition for being remunerated.				
Key concepts	• SRF; • Installation type.				
Law 24/2013					
Subject	Law that regulates the SES, guaranteeing the electricity supply with the necessary levels of quality and at the lowest possible cost, ensuring the economic and financial sustainability of the system and allowing a level of effective competition in the SES, all within the principles of environmental protection of a modern society.				

Table 5. *Cont.*

Legislation	Main Characteristics
Related to CHP installations	A standard facility was considered, throughout its regulatory useful life and considering an efficient and well-managed company, to determine the investment and exploitation costs of the electrical energy production activity. An SRF was established for electricity production from RESs, high-efficiency cogeneration and waste. CHP facilities were forced to participate in the market, complementing their incomes with a specific regulated remuneration that would allow these technologies to compete on an equal level with the rest of the technologies in the market. This complementary specific remuneration had to be sufficient to reach the minimum level necessary to cover the costs that could not be recovered in the market. It had to allow them to obtain an adequate return concerning the typical installation in each applicable case. The following criteria would modify the remuneration parameters: • In each regulatory period, all the remuneration parameters could be modified, but the regulatory useful life and the standard value of the initial investment; • Every three years, the estimates of income from the sale of generated energy, valued at the production market price, had to be reviewed for the rest of the regulatory period based on the evolution of market prices and forecast of operation hours. Likewise, the remuneration parameters might be adjusted based on the deviations of the market price concerning the estimates made for the previous three-year period. The adjustment method had to be established by regulation and be applicable for the remainder of the useful life of the facility; • At least annually, the values of remuneration for the operation had to be updated for those technologies whose operating costs depend essentially on fuel price. The granting of the SRF had to be established through competitive bidding procedures. The remuneration was based on the criteria that each CHP had their counterpart in a standard facility. For each standard facility, there was a set of remuneration terms, such as: • The remuneration for the electricity sold to the market; • A per unit term of installed power that would cover, when applicable, the investment costs for each standard facility that could not be recovered from the participation in the market; • A remuneration term related to the operation that would cover, if applicable, the difference between the standard operating costs and the income from participation in the production market of said standard facility. The legislator would keep the register of the SRF, which included the remuneration parameters applicable to said facilities. In the regulatory framework that was in charge of the system of energy efficiency obligations derived from the application of Directive 2012/27/UE, programs for the renewal of cogeneration and waste facilities were developed.
Key concepts	• SRF; • Standard facility.
RD 413/2014	
Subject	About the regulation of the legal and economic regime of the activity of electrical energy production from renewable energy sources, cogeneration and waste.
Related to CHP installations	Classification of CHP facilities that fall under RD 413/2014 into categories, groups and subgroups. In particular, CHP falls into category "*a*"; that is, producers that use cogeneration or other forms of electricity production from residual energy. This category was classified in turn into two groups: *Group a.1*: Installations that include a CHP plant. This group is divided into the following subgroups: • **Subgroup a.1.1**: CHPs that use NG as fuel, provided that this accounts for at least 95 percent of the primary energy used, or at least 65 percent of the primary energy used when the rest comes from biomass or biogas from groups b. 6, b.7 and b.8 of Article 2 of RD 413/2014; • **Subgroup a.1.2**: CHPs using petroleum products or coal as the main fuel, provided that it accounts for at least 95 per cent of the primary energy used, measured by the lower calorific value; • **Subgroup a.1.3**: Other CHPs that use NG or derivatives of oil or coal, and do not comply with the consumption limits established for subgroups a.1.1 or a.1.2. *Group a.2*: Installations that include a plant that uses residual energy from any installation, machine or industrial process whose purpose is not the production of electrical energy. CHP plants were also included in groups b.6, b.7 and b.8 of group b, which includes those installations that use as primary energy some non-fossil renewable energies. For the determination of the specific remuneration applicable in each case, each facility, depending on its characteristics, was assigned a standard facility.
Key concepts	• SRF; • Standard facility.
RDL 15/2018	
Subject	Urgent measures for the energy transition and consumer protection.

Table 5. *Cont.*

Legislation	Main Characteristics
Related to CHP installations	It introduced an exemption on the tax imposition of some hydrocarbons used for electricity production in CPH. It introduced the exemption on fees and grid charges for the CHP electricity produced under a self-consumption scheme. It modified the equivalent number of hours of the CHP under the RD 413/2014.
Key concepts	• Energy transition
RDL 17/2019	
Subject	Urgent measures for the necessary adaptation of the remuneration parameters of the electrical system.
Related to CHP installations	It stated the reasonable profitability (7.09%) applicable in the remainder of the regulatory useful life of the standard facilities, which was used to review and update the remuneration parameters during the second regulatory period. It granted the value of the reasonable profitability stated in the first regulatory period for the following two periods. It applied to all CHPs under RD 661/2007 before the appearance of RDL 9/2013.
Key concepts	• Reasonable profitability

Table 6. Scheme of the different CHP economic regimes in the cost-containment sub-period. Source: self-elaboration based on [50].

Legislation	Main Characteristics
RD 413/2014	
Economic regime:	By means of a Ministerial Order (MO), a classification of standard facilities was established based on technology, installed power, age, electrical system, as well as any other segmentations deemed necessary for the former facilities. A code was set for each standard facility defined for this purpose. Each standard facility had a set of remuneration parameters that were calculated assuming an activity carried out by an efficient and well-managed company. The most relevant remuneration parameters necessary for the application of the SRF were, when appropriate, the following: • Investment remuneration by unit power (Rinv); • Operation Remuneration by unit of energy (Ro); • Regulatory life period; • Minimum number of operating hours; • Operating threshold; • Maximum number of operating hours; • Annual upper and lower limits of the market price; • Average annual price of the daily and intraday market. In the lines below, in brief, the revenues concerning the SRF are depicted, avoiding the inherent complexity of this framework. For more details, some recent articles can be checked [39,40]. In this regard, the revenues could be defined as follows: $$Revenue_i = Market\_Revenue_i + SRF\_Revenue_i$$ $$Market\_Revenue_i = \sum_d \sum_h E_{i,d,h} \times Pm_{i,d,h}$$ $$SRF\_Revenue_i = OP\_R_i + Inv\_R_i$$ $$E_i = \sum_d \sum_h E_{i,d,h}$$ $$OP\_R_i = E_i \times Ro_i$$ $$Inv\_R_i = P_N \times Rinv_i$$ $Revenue_i$: obtained revenue according to the SRF to be received within a particular year i. $Market\_Revenue_i$: obtained revenue derived from the participation in the electricity market within a particular year i. $SRF\_Revenue_i$: obtained revenue related to the specific regime remuneration to be received within a particular year i. OP_R_i: operation revenue obtained according to the yearly energy produced within a particular year i and the yearly regulatory parameter Ro. Inv_R_i: yearly investment revenue obtained according to the rated power (P_N) of the facility and the yearly regulatory parameter $Rinv$; $E_{i,d,h}$: produced electricity injected into the grid in a particular year i, for a day d, within an hour h. $Pm_{i,d,h}$: market price in a particular year i, for a day d, within an hour h

Table 6. *Cont.*

Legislation	Main Characteristics			
	Classification	Standard facility type	Reasonable return	Regulatory useful life
	Subgroup a.1.1 Subgroup a.1.2 Subgroup a.1.4 Group a.2	Standard installations ranging from IT-01039 to IT-01456	For the first regulatory period it is foreseen: • 7.398% for existing facilities. • Average yield +300 basis points for new facilities for their first 3 months.	25 years
	Subgroup a.1.3	Standard installations ranging from IT-00825 to IT-00935		

5. An Assessment of the 1980–2020 Energy Policy for the CHP Plants in Spain

During the pre-liberalization period, the Spanish government actively promoted the CHP sector to improve energy efficiency and reduce GHGEs using an asset of policies, including tax incentives, grants and favourable tariff structures to encourage its adoption. Consequently, CHP went through significant growth and diffusion in Spain.

The PAEE 1991–2000 targeted an installed power in CHP plants of 2222 MW by 2000 [44]. This goal was overcome with more than 5522 MW installed capacity in 2000, representing a 125% surplus of installed power compared to the expected target.

Among the most significant characteristics of the RDs that defined the economic regime of cogeneration in the pre-liberalization period, the following must be highlighted:

- Energy was rewarded at the consumption price, not the production price, generating favourable sales conditions for self-generators;
- The energy that self-generators could sell to electricity companies was not limited to excess energy alone, as would happen with RD 2818/2018 and RD 436/2004;
- The remunerated energy was paid at a price corresponding to 80% of the average high-voltage tariff;
- The nominal power of the plant was not restricted to specific values to receive benefits from the system, as it would happen with liberalization limiting the rated power up to 50 MW;
- Very advantageous tax and financial incentives boosted the development of the Spanish CHP into the industrial base, such as the chemical, food processing and paper industries.

State institutions played a highly active role in fostering and financing the development and dissemination of CHP in the country during the pre-liberalization period, creating exceptionally favourable conditions for CHP plant installations. Notably, the Institute for the Diversification and Saving of Energy (Instituto para la Diversificación y Ahorro de la Energía, (IDAE)), a public entity attached to the State Secretariat for Energy, exemplified this commitment by supporting industries conducive to CHP installation. This support encompassed the execution of pre-feasibility studies and the supervision of viability studies conducted by specialized engineering teams. The scope of assistance extended to technical and administrative realms, encompassing the management of the inclusion process for the SR [69]. Of note was the significant financial aid extended to businesses for investment, covering up to a substantial 90% of the total investment cost. This robust support framework underscored the proactive engagement of state institutions in catalysing the successful implementation of CHP technologies [70]. As a result, at the end of the pre-liberalization period, many industries decided to take advantage of these conditions, contributing to the successful deployment of CHP in the pre-liberalisation period with installation rates of about 500 MW/year (see Figure 1).

Furthermore, it cannot be ignored that CHP represented a novelty from the point of view of the industrial sector and the State. First, CHP allowed industries to achieve

higher energy efficiency and cost savings. Concerning the State's point of view, CHP was a technology that had a set of advantages that allowed the system to do the following:

- Obtain the energy savings objectives;
- Apply these measures within a sector, the industrial sector, that was well known and was used to collaborate with the institutions and manage the required investment funds.

In contrast, the liberalization period was characterized by a clear setback in the spread of CHP, as shown by the set of its different installation rates. Excluding the first $\alpha 1$ installation rate, which is derived from the inertia momentum concerning the former period, the rest of the installation rates were lower (even negative) when compared to the initial one (see Figure 1). The reasons for such a slowdown are varied, and can be found partly in the intrinsic characteristics of this technology and in the developed regulatory framework over the years.

First, in the liberalization period of the SES, CHP had become well established within the industrial sector. Namely, a significant part of the potential user base had already adopted CHP or other alternative technologies, which might have resulted in fewer opportunities for rapid growth than an emerging market.

Second, it is worth highlighting that the liberalization of the SES under Law 54/1997 introduced the electricity market as a new reference element of the SES. The electricity market would be responsible for setting the value of the remuneration for power plants, as well as one of the relevant energy costs for Spanish consumers. In this regard, in terms of the revenue of CHP related to the electricity market prices, the uncertainty concerning the evolution of these prices might have hampered the predictability of the economics of the projects. Additionally, the regulatory scenario led to a new paradigm where the focus on sustainable electricity production included technologies other than CHP, redirecting policies and incentives towards RESs and drawing attention and investment away from CHP. Furthermore, RD 2818/1998 introduced a restriction on the rated power of CHP, limiting its value up to 50 MW. The relevance of this restriction was that it also affected those CHPs that had been installed under the former pre-liberalization regulatory frameworks. This retroactive measure might have affected the risk perception of future investments.

Consequently, all the factors mentioned above might have impacted the resulting value of the $\alpha 2$ installation rate, which, with 101.6 MW/year, was significantly lower than before (see Figure 1).

In 2008, the regulated costs of the SES were higher than expected. The sharp evolution of the installed capacity of some RES technologies resulted in surpassing the power objectives and, consequently, an increase in the scheduled remuneration to be applied to those technologies. Additionally, by this year, the real-estate economic crisis already hit the Spanish economy, worsening the evolution of the SES due to the reduction in the energy demand. In this context, a downward evolution of the parameter $\alpha 3$ took place (see Figure 1). In this period, retroactive regulatory incentives were addressed to contain the regulated costs, mostly applied to photovoltaic systems. In this regard, it is not surprising that in this period, RD 661/2007 was not able to sustain the moderate rate of installation of CHP, as it happened during 2001–2008. Instead, from 2008 to 2012, the rate of installation of CHP ($\alpha 3 = -7.15$ MW/year) was negative, and a set of former CHPs decided to shut down their facilities and end their activity in the SES. As a result, the strategy plan E4 2004–2012 CHP objectives were not achieved by approximately 1000 MW.

In 2012, through RDL 1/2012, the need for a new regulatory scheme in terms of a new electricity law and a new way to remunerate and regulate the RES and CHP was announced. The sole announcement induced a shutdown of 61 CHP facilities, resulting in an installation rate value ($\alpha 4$) of -420.4 MW/year (see Figure 1).

In 2013, the new electricity Law 24/2013 was enacted, along with the regulatory framework to promote RES, CHP and waste RD 413/2014. This brought a new mechanism to remunerate CHP and was applied to new and existing CHP facilities as well. The former CHPs saw a significant impact on their revenue determination. The new remuneration scheme, however, failed to attract the necessary investment into CHP facilities, resulting in

an installed capacity of 5616 MW by the end of 2020 (α5 of 0.53 MW/year, see Figure 1). This was far below the 9500 MW capacity objectives set by the E4 2012–2020 energy strategy for CHP.

6. Conclusions

This paper provides an in-depth analysis of the evolution of the CHP policy in Spain from 1980 to 2020, where it can be seen that the development trajectory of CHP in Spain can be segmented into distinct phases, each characterised by changes in regulatory frameworks and economic paradigms.

The first phase, from 1998 to 2008, saw a proactive approach by the Spanish legislator in promoting CHP, creating a stable and favourable regulatory environment. According to this regulatory environment, positive installation rates were achieved for CHP.

The next phase, from 2009 to 2020, was characterised by a completely different approach aimed at containing the SES's costs, which were higher than predicted, mainly due to the unexpected evolution of RESs in the SES. These retroactive measures had a significant impact on the profitability of existing power plants and also on the development of new CHP facilities. As a result, the evolution of the installation of CHPs did not fulfil the Spanish energy objectives.

The research has underlined the importance of the support schemes on the evolution of CHP in Spain. It has also highlighted the impact of the retroactive measures implemented during the cost containment phase on the installation rates.

The analysis reveals a substantial influence of both energy and industrial policies on the CHP sector during the examined period. In the pre-liberalization era, the drive to industrialize the country created an environment conducive to the widespread adoption of CHP. This technology, with its primary application in industrial settings, efficiently met the heat demands of heat-intensive industries, and it yielded numerous benefits, including enhanced efficiency compared to separate production processes, leading to primary energy savings, reduced greenhouse gas emissions, and subsequent cost reductions. The favourable historical–economic conditions were further complemented by a regulatory framework explicitly designed to promote the proliferation of CHP, including generous state incentives and a highly advantageous remuneration system for the electricity generated and sold.

Subsequent observations reveal a shift in the energy policy focus after liberalization, accompanied by corresponding changes in subsequent Laws and Royal Decrees. It is accurate to assert that the emphasis has pivoted towards electricity production systems employing renewable sources. This shift can be attributed, in part, to the influence of European directives and the evolving industrial landscape. Notably, the potential for expanding the installed capacity of CHP systems is more pronounced in environments undergoing industrialization and enhancing energy efficiency in industrial processes than in countries with already established industrial sectors.

Furthermore, the decrease in government investment in the CHP sector and the persistent legislative modifications have heightened uncertainties about the viability of these plants, and this, in turn, has contributed to stagnation in terms of installed CHP, reflected in significantly lower values of α2, α3, α4 and α5, compared to the pre-liberalization α1 value.

An additional significant insight gleaned from the analysis is that, in harmony with EU directives, the Spanish regulatory framework, by incorporating the concept of EEE, places value and compensation in the CHP sector according to the efficiency in generating electricity. This approach, however, overlooks the fundamental origin of this technology, which is designed to fulfil the thermal requirements of heat-intensive processes with superior efficiency compared to conventional systems like boilers.

The analysis of the evolution of CHP in Spain concerning the regulatory scenario undertaken in this paper could be helpful for other countries wishing to develop and promote the CHP sector together with the RES sector. It also highlights the need for regulatory stability to promote investor confidence and the importance of designing robust and

adequate support schemes and effective updating mechanisms to ensure the predictability of the economic accounts of renewable assets in the long run.

Author Contributions: Conceptualization, A.A. and J.D.l.H.; methodology, A.A., J.D.l.H. and H.M.; validation, A.A., J.D.l.H., H.M., S.C. and J.R.; formal analysis, A.A. and J.D.l.H.; investigation, A.A.; data curation, A.A. and J.D.l.H.; writing—original draft preparation, A.A.; writing—review and editing, A.A., J.D.l.H., H.M., S.C. and J.R.; visualization, A.A.; supervision, J.D.l.H. and H.M.; project administration, J.D.l.H. and H.M.; funding acquisition, A.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Agència de Gestió d'Ajuts Universitaris i de Recerca (AGAUR) and Consorci de Serveis Universitaris de Catalunya (CSUC), with the collaboration of Fundació Catalana per a la Recerca i la Innovació (FCRI), grant number 2021 DI 00010.

Data Availability Statement: Not applicable (All the data considered during the preparation of the paper is published in the paper).

Conflicts of Interest: Author Angela Adamo was employed by the company SEAT S. A. Autovia A2 km 585, 08760 Martorell (Barcelona), Spain. Author Joan Rubio was employed by the company SEAT S. A. Autovia A2 km 585, 08760 Martorell (Barcelona), Spain. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy. Energy Union Package. European Commission. Communication from the Commission 25.2.2015, COM (2015)80 Final. Available online: http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF (accessed on 7 November 2023).
2. Europe 2020: A Strategy for Smart, Sustainable and Inclusive Growth. European Commission. Communication from the Commission. 3 February 2010, COM (2010) 2020 Final. Available online: https://op.europa.eu/en/publication-detail/-/publication/6a915e39-0aab-491c-8881-147ec91fe88a/language-hr (accessed on 7 November 2023).
3. IEA. Energy Efficiency Market Report 2014. Market Trends and Medium-Term Prospect. Paris 2014. Available online: https://www.iea.org/reports/energy-efficiency-market-report-2014 (accessed on 7 November 2023).
4. A Clean Planet for All. A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy. European Commission. Communication from the Commission. 28 November 2018. COM(2018) 773 Final. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773 (accessed on 7 November 2023).
5. Directive 2012/27[5]/EU of 25 October 2012. Official Journal of the European Union, L 315, 14 November 2012. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32012L0027 (accessed on 7 November 2023).
6. Directive 2018/2002/EU of 11 December 2018. Official Journal of the European Union, L 328, 21 December 2018. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0210.01.ENG (accessed on 7 November 2023).
7. Directive 2004/8/EC of 11 February 2004. Official Journal of the European Union, L 52, 21 February 2004. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32004L0008 (accessed on 7 November 2023).
8. Lips, J.; Lens, H. Dynamic Modelling and Simulation of the Steam Cycle Utility System of a Waste Incineration Cogeneration Plant. *IFAC-PapersOnLine* **2022**, *20*, 139–144. [CrossRef]
9. Yusta, J.M.; De Oliveira-De Jesus, P.M.; Khodr, H.M. Optimal energy exchange of an industrial cogeneration in a day-ahead electricity market. *Electr. Power Syst. Res.* **2008**, *78*, 1764–1772. [CrossRef]
10. Jiménez-Espadafor Aguilar, F.; García, M.T.; Trujillo, E.C.; Becerra Villanueva, J.A.; Florencio Ojeda, F.J. Prediction of performance, energy savings and increase in profitability of two gas turbine steam generator cogeneration plant, based on experimental data. *Energy* **2011**, *36*, 742–754. [CrossRef]
11. Shankar, R.; Rivera, W. Modeling of a thermodynamic cycle integrating a dual and a triple-pressure cogeneration cycle. *Appl. Therm. Eng.* **2022**, *201*, 117705. [CrossRef]
12. Zhang, H.; Liu, X.; Hao, R.; Liu, C.; Liu, Y.; Duan, C.; Qin, J. Thermodynamic performance study on gas-steam cogeneration systems with different configurations based on condensed waste heat utilization. *Energy* **2022**, *250*, 123836. [CrossRef]
13. Abdel-Dayem, A.M.; Hawsawi, Y.M. Feasibility study using TRANSYS modelling of integrating solar heated feed water to a cogeneration steam power plant. *Case Stud. Therm. Eng.* **2022**, *39*, 102396. [CrossRef]
14. Ustaoglu, A.; Torlaklı, H.; Ergün, A.; Erdoğmuş, E.; Emin Akay, M. Advanced exergy analysis of an integrated solid waste fueled cogeneration system based on organic Rankine Cycle for different working fluids. *Energy Convers. Manag.* **2022**, *270*, 116294. [CrossRef]
15. Ali, R.H.; Abdel Samee, A.A.; Attalla, M.; Maghrabie, H.M. Energy-exergy approach of a cogeneration system in pulp and paper industry with a chemical recovery of black liquor and soda. *Case Stud. Therm. Eng.* **2023**, *42*, 102712. [CrossRef]

16. Asgari, A.; Yari, M.; Mahmoudi, S.M.S. Exergy and exergoeconomic analyses and multi-objective optimization of a novel cogeneration system for hydrogen and cooling production. *Int. J. Hydrogen Energy* **2022**, *47*, 26114–26134. [CrossRef]
17. Cavalcanti, E.J.C.; Carvalho, M.; da Silva, D.R.S. Energy, exergy and exergoenvironmental analyses of a sugarcane bagasse power cogeneration system. *Energy Convers. Manag.* **2020**, *222*, 113232. [CrossRef]
18. Singh, O.K. Exergy analysis of a grid-connected bagasse-based cogeneration plant of sugar factory and exhaust heat utilization for running a cold storage. *Renew. Energy* **2019**, *143*, 149–163. [CrossRef]
19. Souza, R.J.; dos Santos, C.A.C.; Ochoa, A.A.V.; Marques, A.S.; Neto, J.L.M.; Michima, P.S.A. Proposal and 3E (energy, exergy, and exergoeconomic) assessment of a cogeneration system using an organic Rankine cycle and an Absorption Refrigeration System in the Northeast Brazil: Thermodynamic investigation of a facility case study. *Energy Convers. Manag.* **2020**, *217*, 113002. [CrossRef]
20. Zhang, S.; Wang, X.; Li, Y.; Wang, W.; Li, W. Study on a novel district heating system combining clean coal-fired cogeneration with gas peak shaving. *Energy Convers. Manag.* **2020**, *203*, 112076. [CrossRef]
21. Badami, M.; Gerboni, R.; Portoraro, A. Determination and assessment of indices for the energy performance of district heating with cogeneration plants. *Energy* **2017**, *127*, 697–703. [CrossRef]
22. Gładysz, P.; Ziebik, A. Complex analysis of the optimal coefficient of the share of cogeneration in district heating systems. *Energy* **2013**, *62*, 12–22. [CrossRef]
23. Iacobescu, F.; Badescu, V. Metamorphoses of cogeneration-based district heating in Romania: A case study. *Energy Policy* **2011**, *39*, 269–280. [CrossRef]
24. Franco, A.; Versace, M. Multi-objective optimization for the maximization of the operating share of cogeneration system in District Heating Network. *Energy Convers. Manag.* **2017**, *139*, 33–44. [CrossRef]
25. Delmastro, C.; Mutani, G.; Schranz, L. Advantages of Coupling a Woody Biomass Cogeneration Plant with a District Heating Network for a Sustainable Built Environment: A Case Study in Luserna San Giovanni (Torino, Italy). *Energy Procedia* **2015**, *78*, 794–799. [CrossRef]
26. Amiri, S.; Weinberger, G. Increased cogeneration of renewable electricity through energy cooperation in a Swedish district heating system—A case study. *Renew. Energy* **2018**, *116*, 866–877. [CrossRef]
27. Kotowicz, J.; Uchman, W. Analysis of the integrated energy system in residential scale: Photovoltaics, micro-cogeneration and electrical energy storage. *Energy* **2021**, *227*, 120469. [CrossRef]
28. Moya, J.A. Impact of support schemes and barriers in Europe on the evolution of cogeneration. *Energy Policy* **2013**, *60*, 345–355. [CrossRef]
29. Colmenar-Santos, A.; Rosales-Asensio, E.; Borge-Diez, D.; Mur-Pérez, F. Cogeneration and district heating networks: Measures to remove institutional and financial barriers that restrict their joint use in the EU-28. *Energy* **2015**, *85*, 403–414. [CrossRef]
30. Kavvadias, K.C. Energy price spread as a driving force for combined generation investments: A view on Europe. *Energy* **2016**, *115*, 1632–1639. [CrossRef]
31. Malinauskaite, J.; Jouhara, H.; Egilegor, B.; Al-Mansour, F.; Ahmad, L.; Pusnik, M. Energy efficiency in the industrial sector in the EU, Slovenia, and Spain. *Energy* **2020**, *208*, 118398. [CrossRef] [PubMed]
32. Westner, G.; Madlener, R. The benefit of regional diversification of cogeneration investments in Europe: A mean-variance portfolio analysis. *Energy Policy* **2010**, *38*, 7911–7920. [CrossRef]
33. Uran, V.; Krajcar, S. A method for the correction of the feed-in tariff price for cogeneration based on a comparison between Croatia and EU Member States. *Energy Policy* **2009**, *37*, 5427–5431. [CrossRef]
34. Rivera-Alvarez, A.; Osorio, J.D.; Montoya-Duque, L.; Fontalvo, J.; Botero, E.; Escudero-Atehortua, A. Comparative analysis of natural gas cogeneration incentives on electricity production in Latin America. *Energy Policy* **2020**, *142*, 111466. [CrossRef]
35. Ciarreta, A.; Nasirov, S.; Silva, C. The development of market power in the Spanish power generation sector: Perspectives after market liberalization. *Energy Policy* **2016**, *96*, 700–710. [CrossRef]
36. Bianco, V.; Driha, O.M.; Sevilla-Jiménez, M. Effects of renewables deployment in the Spanish electricity generation sector. *Util. Policy* **2019**, *56*, 72–81. [CrossRef]
37. Simoglou, C.K.; Biskas, P.N.; Vagropoulos, S.I.; Bakirtzis, A.G. Electricity market models and RES integration: The Greek case. *Energy Policy* **2014**, *67*, 531–542. [CrossRef]
38. Gelabert, L.; Labandeira, X.; Linares, P. An ex-post analysis of the effect of renewables and cogeneration on Spanish electricity prices. *Energy Econ.* **2011**, *33* (Suppl. S1), S59–S65. [CrossRef]
39. Martín, H.; de La Hoz, J.; Velasco, G.; Castilla, M.; García De Vicuña, J.L. Promotion of concentrating solar thermal power (CSP) in Spain: Performance analysis of the period 1998–2013. *Renew. Sustain. Energy Rev.* **2015**, *50*, 1052–1068. [CrossRef]
40. De la Hoz, J.; Martín, H.; Miret, J.; Castilla, M.; Guzman, R. Evaluating the 2014 retroactive regulatory framework applied to the grid connected PV systems in Spain. *Appl. Energy* **2016**, *170*, 329–344. [CrossRef]
41. Coronas, S.; de la Hoz, J.; Alonso, À.; Martín, H. 23 Years of Development of the Solar Power Generation Sector in Spain: A Comprehensive Review of the Period 1998–2020 from a Regulatory Perspective. *Energies* **2022**, *15*, 1593. [CrossRef]
42. Law 82/1980, of 30 December 1980. BOE No. 23. 27 January 1981. Available online: https://www.boe.es/eli/es/l/1980/12/30/82 (accessed on 7 November 2023).
43. RD 907/1982, of 27 January. BOE No. 11. 2 April 1982. Available online: https://www.boe.es/eli/es/rd/1982/04/02/907 (accessed on 7 November 2023).

44. Congreso de los Diputados. Plan de Ahorro y Eficiencia Energética 1991–2000. 13 September 1991. Available online: https://www.congreso.es/public_oficiales/L4/CONG/BOCG/A/A_055-06.PDF (accessed on 7 November 2023).
45. Law 40/1994, of 30 December. BOE No. 313. 31 December 1994. Available online: https://www.boe.es/eli/es/l/1994/12/30/40 (accessed on 7 November 2023).
46. RD 2366/1994, of 9 December. BOE No. 313. 31 December 1994. Available online: https://www.boe.es/eli/es/rd/1994/12/09/2366 (accessed on 7 November 2023).
47. RD 2818/1998, of 27 January. BOE No. 312. 30 December 1998. Available online: https://www.boe.es/eli/es/rd/1998/12/23/2818 (accessed on 7 November 2023).
48. RD 436/2004, of 12 March. BOE No. 75. 27 March 2004. Available online: https://www.boe.es/eli/es/rd/2004/03/12/436 (accessed on 7 November 2023).
49. RD 661/2007, of 25 May. BOE No. 126. 26 May 2007. Available online: https://www.boe.es/eli/es/rd/2007/05/25/661 (accessed on 7 November 2023).
50. RD 413/2014, of 6 June. BOE No. 140. 10 June 2014. Available online: https://www.boe.es/eli/es/rd/2014/06/06/413 (accessed on 7 November 2023).
51. Ministerio de la Economía. Secretaría de Estado de Energía, Desarrollo Industrial y de la Pequeña y Mediana Empresa. Estrategia de Ahorro y Eficiencia Energética en España 2004–2012. 28 November 2003. Available online: https://www.idae.es/publicaciones/estrategia-de-ahorro-y-eficiencia-energetica-en-espana-2004-2012-e4 (accessed on 7 November 2023).
52. Ministerio de Industria, Turismo y Comercio; Instituto Para la Diversificación y Ahorro de la Energía, IDAE. Plan de Acción 2005–2007. 6 July 2005. Available online: https://www.idae.es/publicaciones/plan-de-accion-2005-2007-estrategia-de-ahorro-y-eficiencia-energetica-en-espana-2004 (accessed on 7 November 2023).
53. Ministerio de Industria, Turismo y Comercio; Instituto Para la Diversificación y Ahorro de la Energía, IDAE. Plan de Acción 2008–2012. July 2007. Available online: https://www.idae.es/publicaciones/plan-de-accion-2008-2012-estrategia-de-ahorro-y-eficiencia-energetica-en-espana-2004 (accessed on 7 November 2023).
54. Official Journal of the European Union, L 114. 27 April 2006. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0032 (accessed on 7 November 2023).
55. Ministerio de Industria, Turismo y Comercio; Instituto Para la Diversificación y Ahorro de la Energía, IDAE. Plan de Acción 2011–2020. 21 September 2018. Available online: https://www.idae.es/publicaciones/plan-de-ahorro-y-eficiencia-energetica-2011-2020-2o-plan-de-accion-nacional-de (accessed on 7 November 2023).
56. European Commission, Directorate-General for Energy, Clean Energy for All Europeans, Publications Office. 2019. Available online: https://data.europa.eu/doi/10.2833/9937 (accessed on 7 November 2023).
57. Ministerio Para la Transición Ecológica y el Reto Demográfico. Integrated National Energy and Climate Plan 2021–2030. 20 January 2020. Available online: https://www.miteco.gob.es/content/dam/miteco/images/es/pnieccompleto_tcm30-508410.pdf (accessed on 7 November 2023).
58. Law 54/1997, of 27 November. BOE No. 285. 28 November 1997. Available online: https://www.boe.es/eli/es/l/1997/11/27/54 (accessed on 7 November 2023).
59. CNMC. Energía. Estadísticas. Available online: https://www.cnmc.es/estadisticas (accessed on 7 November 2023).
60. RDL 7/2006, of 23 June. BOE No. 150. 24 June 2006. Available online: https://www.boe.es/eli/es/rdl/2006/06/23/7 (accessed on 7 November 2023).
61. RD 616/2007, of 11 May. BOE No. 114. 12 May 2007. Available online: https://www.boe.es/eli/es/rd/2007/05/11/616 (accessed on 7 November 2023).
62. RDL 6/2009, of 30 April. BOE No. 111. 7 May 2009. Available online: https://www.boe.es/eli/es/rdl/2009/04/30/6 (accessed on 7 November 2023).
63. RDL 1/2012, of 27 January. BOE No. 24. 28 January 2012. Available online: https://www.boe.es/eli/es/rdl/2012/01/27/1 (accessed on 7 November 2023).
64. RDL 2/2013, of 1 February. BOE No. 29. 2 February 2013. Available online: https://www.boe.es/eli/es/rdl/2013/02/01/2 (accessed on 7 November 2023).
65. RDL 9/2013, of 12 July. BOE No. 167. 13 July 2013. Available online: https://www.boe.es/eli/es/rdl/2013/07/12/9 (accessed on 7 November 2023).
66. Law 24/2013, of 26 December. BOE No. 310. 27 December 2013. Available online: https://www.boe.es/eli/es/l/2013/12/26/24 (accessed on 7 November 2023).
67. RDL 15/2018, of 5 October 2018. BOE No. 242. 6 October 2018. Available online: https://www.boe.es/eli/es/rdl/2018/10/05/15 (accessed on 7 November 2023).
68. RDL 17/2019, of 22 November 2019. BOE No. 282. 23 November 2019. Available online: https://www.boe.es/diario_boe/txt.php?id=BOE-A-2019-16862 (accessed on 7 November 2023).

69. Ministerio de Industria, Turismo y Comercio; Instituto Para la Diversificación y Ahorro de la Energía, IDAE. Plantas de Cogeneración de Pequeña y Mediana Potencia. October 1998. Available online: https://www.idae.es/publicaciones/plantas-de-cogeneracion-de-pequena-y-mediana-potencia (accessed on 14 January 2024).
70. Ministerio de Industria, Turismo y Comercio; Instituto Para la Diversificación y Ahorro de la Energía, IDAE. November 1999. Available online: https://www.idae.es/publicaciones/instalacion-de-cogeneracion-en-una-industria-de-impregnacion-de-papel-casco-decor (accessed on 14 January 2024).