Master Thesis

MSc Energy for Smart Cities

Collective Self-Consumption in the European Union

Report

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Review

In November 2016, the European Union Commission announced its Winter Package: Clean Energy for All Europeans, a set of eight proposals that aims to transition the continent to a clean energy economy while actively engaging citizens in the process. One component of the package is that Member States must allow their citizens to participate in collective self-consumption of renewable electricity, in which electricity consumers are able to collectively produce and consume their own renewable energy without facing discriminatory conditions or procedures that may preclude their participation in such a scheme. This was set into law in 2018 when the Renewable Energy Directive of 2009 was recast, and Member States must include in their updated National Energy and Climate Plans for 2021-2030 how they will enable the formation of collective self-consumption in their country.

This paper aims to analyze how five different EU Member States are enabling collective self-consumption, discuss the advantages and disadvantages of each approach, and make a recommendation for which approach works best and should be followed by other countries. The countries were selected based on which ones have already implemented a regulatory framework that supports a form of collective self-consumption. Spain, Greece, Slovenia, France, and Germany were chosen. The analysis first takes a look at the current energy and electricity situation in each country and then provides an overview of the National Energy and Climate Plans for 2021-2030. This sets the stage to compare each country’s legislation regarding collective self-consumption, such as the proximity requirements, size restrictions, Collective formation, administrative components, technical requirements, and the economics of self-consumed and surplus electricity.

Finally, the paper discusses the limitations and barriers of each country’s approach and, based on the entire analysis and literature review performed, recommends best practices for Member States to consider when drafting and updating their collective self-consumption legislation.
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<td>CEC</td>
<td>Citizen energy community</td>
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<td>CSC</td>
<td>Collective self-consumption</td>
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<td>DSO</td>
<td>Distribution system operator</td>
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<tr>
<td>ES</td>
<td>Electricity supplier</td>
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<td>EU</td>
<td>European Union</td>
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<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>GHG</td>
<td>Greenhouse gas emissions</td>
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<td>NECP</td>
<td>National Energy and Climate Plan</td>
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<td>PV</td>
<td>Photovoltaic</td>
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<tr>
<td>REC</td>
<td>Renewable energy community</td>
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<td>REDII</td>
<td>Renewable Energy Directive 2018</td>
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<tr>
<td>SME</td>
<td>Small or medium enterprise</td>
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<tr>
<td>toe</td>
<td>tons of oil equivalent</td>
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2. Preface

Before you lies the thesis titled “Collective Self-Consumption in the European Union”, written to fulfil the graduation requirements of InnoEnergy’s MSc in Energy for Smart Cities at the Universitat Politècnica de Catalunya. I was engaged in researching and writing this thesis from February to October 2020.

The thesis originated at the request of the company in which I performed my internship, FlexiDAO, by the CEO Simone Accornero. FlexiDAO is a software company that uses blockchain technology to trace the origin of renewable energy. The current use case for the software is for corporate consumers to prove to their stakeholders that they are buying renewable energy produced in the moment of consumption, thereby directly supporting local, renewable energy. FlexiDAO is interested in collective self-consumption (CSC) because it is a new use case that their technology may be able to help enable, providing new business opportunities to the company.

Although I ended my internship, I continued with the thesis topic suggested by FlexiDAO because I had a personal interest in the topic, as I believe that collective self-consumption will positively impact many issues that I am passionate about. CSC is a great tool to increase energy literacy. Most people I know who are not electrical or energy engineers have very little idea about what electricity is, how it is generated, or how it arrives into our houses or offices to power the technology-filled world in which we live. In fact, one of the reasons I chose to study electrical engineering is because I wanted to better understand the physical phenomena that has drastically changed human life in the past two centuries. I believe that better understanding electricity will empower consumers to reduce their electricity consumption, saving money and helping the planet, and make better choices when choosing an electricity supplier and voting on energy and climate policy. And as EU countries create legislation allowing CSC schemes, an average citizen can actively take part in the energy transition and even economically benefit it while playing an important role in combating climate change. Further, CSC schemes, depending on the rules stipulated by the legislation, can help fight energy poverty and make local, renewable energy attainable for all, regardless of economic status. I approached the thesis with these values in mind, which is why I chose to put the consumer first when ranking the countries against each other and determining the best practices.

I hope you enjoy your reading.

Mackenzie Banker
3. Introduction

As the planet warms and extreme weather events become the norm, citizens, businesses and governments across the globe are increasingly taking action to combat climate change. One of the most important changes happening globally is a transition to a decentralized, digitized, and decarbonized energy system. This “energy transition” unlocks new opportunities for a number of stakeholders, veterans in the energy sector and newcomers alike, and the European Union is seizing upon these opportunities and spearheading this transition.

3.1. Energy and Climate in the European Union

At a government level, the European Union has historically been a “first-mover” in the transition to renewable energy and setting ambitious greenhouse gas (GHG) emissions reduction targets and remains so today. In 1991, Germany was the first nation to subsidize renewable energy production through its feed-in-tariff policy. Next, in 1997, the EU set its first renewable energy target to achieve 12% renewables in the energy mix by 2010. Four years later, renewables targets were set for each Member State. In 2009, the Commission passed the Renewable Energy Directive, which set a target of 20% renewables by 2020 as well as binding renewable targets for each Member State. Member States were required to draft National Renewable Energy Action Plans that indicate how they will achieve these targets, and their progress towards achieving their targets were tracked every two years through national progress reports [1].

3.1.1. Clean Energy for All Europeans Winter Package

During the past decade, the EU has become even more ambitious and cemented itself as the global leader in the combat against climate change. In 2016, the Commission introduced its Winter Package of eight proposals, called Clean Energy for All Europeans (CE4AE), to help the continent transition to a clean energy economy and reform the electricity market, while simultaneously empowering and encouraging consumers to take an active role in the market. It set a goal of 27% of renewables in the energy mix by 2030 and called for recasts and revisions of existing legislation about climate change and energy markets, including the Renewable Energy Directive of 2009 and Electricity Market Directive of 2012, along with proposals for new measures [2]. The Renewable Energy Directive of 2009 was recast in 2018. This revised version ensures that renewable energy replaces fossil fuels within Europe and increases the 2030 target to 32% of renewables [3]. Further, the package requires Member States to draft new National Energy and Climate Plans for the coming decade, as mandated by the Regulation on the Governance of the Energy Union and Climate Action,
that outlines, among other things, how each MS will reach their individual renewables targets for the period of 2021 to 2030 [4].

### 3.1.1.1. Recast Renewable Energy Directive

As called for in the CE4AE Package, the Renewable Energy Directive of 2009 was recast in 2018, and will be referred to as the REDII throughout this report. The REDII includes articles about Renewables self-consumers and Renewable energy communities [3].

Article 21 of the directive dictates that Member States must allow consumers to become “Renewables self consumers” which allows them to generate renewable energy for their own consumption, store the energy using energy storage devices, and sell their excess energy through a variety of trading schemes, all without paying taxes or fees (except under certain circumstances) or facing discriminatory treatment [3].

Article 22 of REDII states that final consumers, particularly households, have the right to participate in a renewable energy community (REC), which is entitled to generate renewable energy that it is able to produce, store, sell and consume. The REC is able to share the produced energy amongst the members. Its primary purpose is not to make financial profits, but instead to provide environmental, economic, or social benefits to its members or the surrounding community [3].

Both articles also stipulate the Member States must provide an enabling framework to promote such activities and include the main elements of such framework in the National Energy and Climate Plans [3].

### 3.1.2. The European Green Deal

Then, in its most ambitious proposal to date, the EU Commission under Ursula von der Leyen introduce the European Green Deal in December 2019. The Green Deal is a growth strategy for Europe for the next 30 years that will help the continent prosper while fighting climate change and preserving its ecosystems and natural resources. It intends to transform the economy to be resource-efficient and competitive, with three key tenets that put sustainability and citizen well-being at the center: no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use, and no person or place is left behind.

In addition to this growth strategy, it provides a roadmap with actions on how to achieve this transformation that include boosting resource efficiency by switching to a circular economy, restoring biodiversity, and cutting pollution. In March 2020, the Commission proposed the European Climate Law that makes the commitments of the European Green Deal, namely carbon neutrality by 2050, legally binding. It is currently open for feedback from the Member States [5].
3.2. Objectives of the project

The objectives of this thesis are as follows:

1. To compare the collective self-consumption approach of five European countries in a standardized manner;

2. To rank the five countries’ approaches across various categories in terms of which approach makes CSC more accessible and flexible and gives consumers the most right and benefits.

3. To discuss country specific limitations and barriers that may impact the uptake of CSC.

4. To provide best practice recommendations for the various CSC categories analyzed from a “consumer first” perspective that Member States can take into consideration when designing their CSC legislation and approaches.

3.3. Scope of the project

The scope of this project is limited to legislation regarding collective self-consumption in five EU countries: Spain, Greece, Slovenia, France, and Germany. While some countries’ CSC schemes allow for any type of renewable energy source to produce the electricity shared among the Collective, this thesis only considers CSC schemes that use PV installations to produce electricity.

3.4. Methodology

To reach the objectives of this thesis, a qualitative analysis was performed. The following steps were taken:

1. Review and understand EU level legislation about CSC and RECs. This was done by studying the Clean Energy for All Europeans Winter Package, the Recast Renewable Energy Directive of 2018, and the European Green Deal.

2. Determine the current state of CSC legislation in the EU by reading summaries and analyses from various sources including PVP4Grid, Compile, and Bridge.
3. Select five countries who have already implemented a regulatory framework that supports at least one form of CSC based on the literature review done in the previous step.

4. Benchmark each country in terms of their current electricity market and National Energy and Climate Plans.

5. Select appropriate categories about CSC to analyze across each country.

6. Review the legislation and approach for each country to determine the CSC rules and approach for each category.

7. Based on the key values portrayed in the EU legislation that put the consumer at the heart of the energy transition, rank the countries against each other for each CSC category.

8. Draw any trends and correlations about the approaches the countries took based on the benchmarking performed.

9. Discuss barriers and limitations for each country’s approach based on other countries’ approaches and a literature review of criticisms and policy recommendations.

10. Compile all learnings into a set of best practices recommended for Member States to consider when drafting or updating their CSC legislation.

### 3.5. Limitations

This work is meant to provoke discussion and not to be an up to date source of truth for the five countries’ CSC legislation. Regulatory frameworks are constantly changing, and as the analysis was performed over the course of nine months, legislation may have changed within that timeframe. Further, legal documents about energy code can be difficult to decipher even when in the reader’s native language. The legislation and often times corresponding literature and criticisms are in the country’s native language, so the analysis was done based off Google translations, which brings into question the accuracy of both the translation and the author’s interpretation.

Collective self-consumption is a new topic so for some countries it was difficult to find much literature about how it is being applied there, and there were very few documents that looked at each of the five countries selected in a holistic and comparable way. It is also a very broad topic with many facets and nuances, so the analysis was restricted to the lens of the
consumer-centric approach to manage the scope, although a more complete ranking and best practice recommendations would consider many other components.
4. Collective Self-Consumption

4.1.1. Definition

The REDII defines a “Renewables self-consumer” as “a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do no constitute its primary commercial or professional activity” [3].

It further defines a “jointly acting renewables self-consumer” as “a group of at least two jointly acting consumers in accordance with [the definition of a renewables self-consumer above] who are located in the same building or multi-apartment block” [3].

Based on the REDII, joint renewables self-consumption is one of the activities in which a REC may partake, but the activity is not limited to only RECs, but instead a way of which the jointly acting renewables self-consumers may organize, as shown in the figure below from Compile In fact, Article 21 of the directive states that all final consumers have a right to participate in joint renewables self-consumption (from here on out referred to as collective self-consumption, or CSC) and that the installations may be owned or managed by third party ownership and leasing arrangements, suggesting that no preference is given to RECs for CSC. Therefore, jointly acting renewables self-consumers can organize in other ways to form a CSC scheme [6].
Due to this relation between CSC and RECs, the two are often studied together and legislation of one impacts the other. This is best seen with the concept of local and the proximity requirements that countries implement for CSC. The REDII only states that CSC must be allowed for multi-unit buildings and multi-apartment blocks. Yet, as discussed in the subsequent chapters, many countries’ legislation allow CSC in spatial contexts that extend beyond a building or a block. This may be because the REDII states that the shareholders/members of a REC should be “located in the proximity of the renewables installations” that they control. This definition is much vaguer and more open to the interpretation of each Member State. Therefore, one can assume that some Member States have or will apply their definition of “in the proximity” to both RECs and CSC so that the proximity requirements of a CSC scheme do not conflict with those of a REC [7].

It should be clarified that the concept of a citizen energy community (CEC) exists at the EU level, introduced in the recast Electricity Market Directive. It is similar to the concept of a renewable energy community, in that it is an organizational structure that permits citizens, SMEs, and local authorities to participate in the energy sector, but are not limited to renewable energy or proximity requirements of “local” as are RECs. A REC can be considered a sub-category of a CEC [7].

The term “local energy community” was abandoned at the EU level and replaced by the two concepts of RECs and CECs, but some Member States may refer to local energy
4.1.2. Benefits

Self-consumption has many benefits. It allows a consumer to reduce its electricity bills, helps reduce grid congestion, and contributes to more installed renewable energy capacity. Even more benefits are gained when self-consumption is allowed to be collective. Depending on the scheme, CSC can allow more electricity to be self-consumed than for a single self-consumer scheme, maximizing the value of the electricity for the consumers and reducing grid congestion and losses. It also reduces the overall cost of the installation, as buying PV panels in bulk can lower the per unit cost, and only one meter and inverter are required for the installation, whereas if five consumers were purchasing their own installations to self-consume individually, they would each need to purchase a meter and inverter. Further, the cost of the installation can be divided among the Collective participants however they agree, so that those with less money to invest can purchase a lower percentage, and consumers with lower socio-economic status can still benefit from self-consumption. Finally, over 40% of Europeans live in apartment blocks, and without CSC legislation, are unable to participate in self-consumption. With CSC, consumers who live in multi-tenant buildings, or who live in a building with a roof not suitable for PV, can still reap the benefits of self-consumption and become an active part of the energy transition [8].

4.1.3. Overview of CSC in the EU

Until passage of the REDII, there was little support at the EU level to assist consumers becoming involved with their own renewable energy production, and only some local and national legislation provided support, which varied greatly by city, region, and country. The REDII closes that gap, and Member States have until June 30th, 2021 to transpose it into national law [8].

Self-consumption (both individual and collective) and energy communities have the potential to make a huge impact on the European electricity sector. A 2016 study by CE Delft predicts that by 2050, half of EU citizens (including local communities, schools, and hospitals) could be self-consumers, meeting 45% of their electricity demand [8]. This translates to 1550TWh of potential electricity from wind and solar produced by public entities, small and medium enterprise (SMEs), households, and Collectives, over 600TWh of which is from solar [9].

Currently, the EU Member States are in various stages of implementing the REDII and allowing CSC. A June 2019 analysis by Compile reviewed the regulatory approaches to CSC of the Member States and found that Austria, Spain, the Wallonia region in Belgium, Germany, France, Greece, and Slovenia have established frameworks for CSC. At the time, Portugal and Luxembourg were planning proposals for CSC that had not yet entered into
law, and Denmark, Sweden, Estonia, Finland, and the UK allowed for CSC in some form through exceptions but did not have a regulatory framework in place supporting it [7].

Five of the countries with established frameworks were chosen for the analysis that is the subject of this thesis. Spain was chosen as the author lives in studies in Spain so has a particular interest in the legislation of that country. Greece was selected because it is the only country to have fully implemented Article 22 of the REDII, supporting the formation of Renewable Energy Communities [7]. Slovenia was chosen because it is the only post-Soviet country with a regulatory framework for CSC. Austria and Germany both only allow CSC at the building level. This is a very strict CSC scheme so only one country with such restrictions was desired to be included in the analysis, and Germany was selected because of its historic support for rooftop PV via feed-in-tariffs. This left Wallonia and France, and France was selected because CSC is not supported at the national level in Belgium, which could create potential complexity for the analysis of Wallonia [7].
5. Country Specific Analyses

The energy and electrical system, National Energy and Climate Plan, and approach to collective self-consumption for Spain, Greece, Slovenia, France, and Germany are described in this chapter.

5.1. Spain

5.1.1. Country Overview

Spain is a southern European and Mediterranean country located between Portugal and France and bordering Andorra. It has a population of approximately 47 million people (2019) and a land area of 500,000 square kilometers [11], giving a population density of 94 people per square kilometer. Spain’s Gross Domestic Product (GDP) in 2019 was $1,39 trillion [12], or €1,24 trillion\(^1\), making it the fourth largest economy in the European Union (excluding the United Kingdom), and giving a GDP per capita of $29,600 per person [13], or €26,400\(^1\) per person, the twelfth highest in the EU.

5.1.1.1. Energy and Electrical System

In 2018, Spain’s Total Primary Energy Supply was 125,02 Mtoe. Of this, approximately 15% originated from renewable sources. Spain also has a high foreign dependency on energy, with 73% being imported [14]. The primary energy consumption per capita, or the total primary energy supply divided by the population, was 2,66 toe per person. The country’s energy intensity, calculated by dividing the Total Primary Energy Supply by the Gross Domestic Product, was 0,1007toe/$1000. The amount of electricity generated in 2018 was 269,59TWh, giving an electricity consumption of 5,5 MWh per person. Of the electricity generated, 38%, or 102,5TWh, was generated from renewable sources, and 3%, or 7,877TWh, was generated from solar photovoltaics specifically. The country’s largest source of renewable electricity is generated from wind (19% of all electricity generated, or 50,896TWh). All energy statistics are from the International Energy Agency unless otherwise stated [15].

\(^1\) The World Bank provides GDP and GDP per capita data in USD. The amount was converted into Euros using the average exchange rate throughout 2019, $0,8931/€ [67].
The Spanish electricity market has an average amount of competitiveness compared to the other EU countries, ranking 12th in competitiveness out of 28 [16]. The electrical grid has a very low level of interconnectivity to other countries, with only 5% of generation capacity interconnected, the lowest in the EU [14]. Smart meters had been rolled out to 93.1% of electricity metering points in the country as of 2018 [17].

The average household price of electricity in 2019 was 0.2394€/kWh, the fifth most expensive in the EU, though the price had fallen by 3.4% compared to the year before. When adjusted for Purchasing Power Parity, the electricity price of Spain ranks as the third most expensive, falling only behind Romania and Germany. 45% of the electricity price is for taxes and levies, which is the fourth highest share of the EU countries [18].

5.1.1.2. National Energy and Climate Plan 2021-2030

Spain wants to position itself as a leader in the energy transition throughout the next decade. The country has a large land area with great renewable energy potential, due to large amounts of sunlight and onshore and offshore wind energy potential. Spain views the energy transition as a great opportunity to boost the economy, create jobs, and increase the quality of life for its citizens, including by making them active participants of the energy market [14].

The key objectives of the plan are to provide certainty to investors so they will be more willing to make the necessary investments to decarbonize and decentralize the energy system; take advantage of the opportunities provided to develop the economy and create new jobs; protect the common good, which includes combatting climate change, preserving ecosystems, and maintaining good air quality; and protect the most vulnerable groups, such as those living in energy poverty, and others who are employed in sectors that will be adversely impacted by the NECP [14].

The long-term goals of the plan are to achieve carbon neutrality and 100% renewable electricity generation by 2050. The plan further outlines Spain’s energy and climate targets for 2030, which are as follows:

- Reduce greenhouse gas emissions by 23% compared to 1990 levels;
- Achieve a 39.5% improvement in energy efficiency compared to 2007 levels;
- Source 42% of end energy use from renewables;
• Generate 74% of electricity from renewables [14].

Spain’s NECP largely focuses on the energy sector as 75% of emissions originate in the energy system. The methods of decarbonization chosen are based on the principals of technology neutrality and cost efficiency, to minimize costs of the transition. Decarbonization will be achieved through increasing renewable energy capacity, phasing out coal, and switching to cleaner modes of transit. Energy efficiency is central to achieving the other targets and is of huge importance in the plan, which will partially be achieved through renovation of the public building stock. Greater energy security will be achieved by reducing fossil fuel imports, diversifying energy sources, and increasing resilience and flexibility of the energy system. For the internal energy market, the plan focuses on increasing interconnectivity of the electrical system, with plans for new interconnections with France and Portugal, and making the market more competitive and transparent. Finally, regarding research, innovation and competitiveness, the government and public institutions will focus on technological development along with private companies [14].

An estimated 241 trillion euros will be invested to achieve the objects of the plan, with 80% of it being invested by private companies and 20% from public funds, a portion of which will be funded by the EU. Implementing the plan will result in the creation of between 253,000 and 348,000 new jobs, resulting in a 1.7% increase in employment by 2030, and it will increase GDP by 1.8%. And the improvement of air quality from reduced burning of fossil fuels will prevent 2,400 premature deaths [14].

Spain has already implemented many policies and measures throughout the past decade and a half aimed at decarbonization and combatting climate change. The Spanish Strategy on Climate Change and Clean Energy was approved by the Council of Ministers in 2007. The Renewable Energy Plan was approved in 2009 and set the renewable energy targets for 2020. The National Energy Efficiency Action Plan implements the country’s energy efficiency policy (first for 2014-2020 and then updated for 2017-2020), and the National Energy Efficiency Fund helps finance the initiatives. The 2015-2020 Electricity Transmission Network Development Plan governs the electricity transmission infrastructure and includes environmental and economic efficiency criteria along with security and reliability requirements for the electrical grid. The MCI department in the government is responsible for research, innovation, and competitiveness activities, and uses the Spanish Strategy for Science, Technology and Innovation 2013-2020 as its framework for action. The above policies, plans, and strategies are merely a brief overview of action Spain has taken to date regarding energy and climate [14].

Spain’s NECP sees self-consumers and renewable energy communities as mechanisms to help achieve some of the 2030 targets, including the 23% reduction in GHG emissions and 39.5% improvement in energy efficiency. Development of own consumption is a key
measure in the plan to promote renewable energy, which includes collective self-consumption. Specific objectives for self-consumption targets will be specified in the future, but it is seen as a key way to fight energy poverty, and Spain intends to experiment with schemes in which self-consumers can donate surpluses to vulnerable households. It will develop a national strategy for self-consumption, create soft-financing mechanisms to support it, and promote it at the local level by simplifying the process and creating a manual for it. The plan also see the creation of local energy communities, which it defines as encompassing both RECs and citizen energy communities, as a measure to promote renewable energy, but the country has yet to create them in law [14].

5.1.2. Collective Self-Consumption in Spain

5.1.2.1. Background

Spain has a tumultuous history regarding support for solar photovoltaic systems. In 2004, the government passed the Royal Decree 436/2004, which incentivized installation of renewable energy capacity by offering a fixed tariff to generators [19]. The world’s first commercial concentrated solar power plant, PS10 Solar Power Tower, opened in Andalusia in 2007, and the second one, PS20, opened nearby a couple years later in 2009 [20]. Investments in renewables greatly increased in the country due to the generous subsidies to the point that by 2008, half of all new PV capacity in the year was installed in Spain, and 24% of installed solar photovoltaic capacity globally was located in Spain, second only to Germany [21]. But with the growing global financial crisis of 2008, the government decided to start scaling back the subsidies and capped future subsidies for solar PV projects at 500 MW per year, which had resounding impacts to investments in PV globally [22]. In 2010 to further alleviate deficits in the Spanish electricity market, the government further cut the subsidies for PV through Real Decreto Ley 14/2010, which put annual limits on the number of hours a PV plant was eligible to receive the feed-in-tariffs. These changes made Spain a very unappealing market for investing in renewable energy, and the country went from a world-leader in renewable energy to having very little new installed capacity over the next decade [23].

Then, in 2012, the government implemented a 7% tax on all electricity production, renewable or not, further deterring investments [24]. Meanwhile, between 2006 and 2012, the electricity price for end consumers in Spain increased by 60%, placing Spain as the country with the third highest electricity costs in Europe, trailing only behind Ireland and Cyprus [25]. While the high cost of electricity might entice residents to invest in rooftop PV to offset costs, enactment of the so-called “sun tax” in 2015 by the conservative government slashed hopes
of increasing rooftop solar PV [26]. This law required homeowners and small business with solar panel installations of 10 kW or more to pay a 7% tax to be connected to the electrical grid. Experts estimate this would cause the average household with solar panels to pay an additional 70€ per month in taxes to remain connected to the grid [27]. This completely hindered growth of solar PV in Spain, so much that as of 2018 only 1000 households were estimated to have solar PV [28].

The “sun tax” was finally overturned by the new Socialist government under Prime Minister Pedro Sanchez, when Royal Decree 15/2018 was passed in October 2018 [29].

Royal Decree 15/2018 aims to dismantle the regulatory barriers that existed in Spain that discouraged self-consumption due to the complexities of implementing it, or because it was economically unviable. It establishes three principles to govern self-consumption in Spain:

1. The right to self-consume electricity without charges.
2. The right to shared self-consumption by one or more consumers to take advantage of economies of scale.
3. The principle of administrative and technical simplification, especially for small power installations [29].

It defines self-consumption as consumption by one or more consumers of electrical energy from production facilities close to and associated with the consumer(s) [29].

Solar PV further received a boost when Royal Decree 244/2019 was passed in April 2019, providing protections for self-consumption and allowing for collective self-consumption and Renewable Energy Communities [30]. These new laws helped boost growth of solar PV in Spain so much so that Spain returned once again as the market leader in solar PV in Europe in 2019, with 4.7 GW of capacity installed, 459 MW of which were for self-consumption [31].

5.1.2.2. CSC Concepts

The Spanish regulations define three different “modalities” for collective self-consumption:

1. Collective self-consumption without surpluses;
2. Collective self-consumption with surpluses receiving simplified compensation; and
3. Collective self-consumption with surpluses not receiving simplified compensation (i.e. sold on the open electricity market) [30].

**Proximity Requirements**

For CSC without surpluses, the PV installation must be directly linked to the consumers through the internal network, and a device must be installed that prevents any surpluses from flowing back into the grid. A typical use case for this modality is a homeowner’s association in a residential building that collectively buys the installation and shares the consumed electricity between the owners living in the residential building [30].

For CSC with surpluses, under both modalities, the PV installation can be linked to the self-consumers if at least one of the following conditions is met:

1. There is a direct link between the installation and the consumers through the internal network;

2. The consumers are connected to the same low voltage grid fed from the same transformation station as the installation;

3. The consumers and installation are connected to low voltage and within a 500 m orthogonal distance from each other; or

4. Is located in the same cadastral reference as the consumer according to the first 14 digits of the 20-digit number [30]. (In Spain, a cadastral reference is an official and obligatory identifier for real estate that is 20 alphanumeric numbers long. For densely populated areas the first 14 digits identify the block and building, whereas for rural areas these digits identify the parcel of land [32].) This condition may be necessary for self-consumers that own a vast parcel of land in a rural area [30].

**Size Restrictions**

For all three modalities, the installation must have a power of less than 100 kW, or else it must be formally registered as an electricity production facility and receive all the corresponding licenses and permits [30].

**5.1.2.3. Participants and Stakeholders**

*Collective Membership:* Any consumer of electricity who meets the proximity requirements for the modality selected may be part of the “Collective” [30].

*Installation Owner & Responsible:* For all modalities, the installation owner and the consumers may be distinct entities, but the self-consumers must be the collective “titulares”,
or responsible party, for the installation. In all cases, the installation company of the PV panels may assist with the administrative procedures required to register and connect it. As long as the installation is less than 100 kW, the owners do not have to register themselves as an electricity supplier [30].

Consumers: Only members of the Collective can self-consume the electricity produced by the installation. All consumers in the Collective must sign an agreement indicating the allocation of consumption between the members, which must be communicated to the DSO, either directly or through the Electricity Supplier [30].

Distribution System Operator: The local DSO handles the connection process and is responsible for providing the metering data of the installation and the consumers to the applicable Electricity Suppliers and ensuring the production is allocated to each consumer in accordance with the distribution agreement [30].

Electricity Supplier: The Electricity Supplier is responsible for performing the net billing to remunerate the consumers for their portion of energy produced, and for providing the consumers with any additional electricity they need that is not covered by their portion of the production [30].

5.1.2.4. Administrative Components

Collective Formation: The members of the Collective do not need to form a legal organization/entity; the contract sent to the DSO outlining the allocation between the consumers suffices to recognize participation in the CSC scheme [33].

Installation Connection Process: Each Autonomous Community is responsible for defining the process for self-consumption installations, but in general, the Collective must obtain a work permit from the local government to set up the PV panels and then request a connection permit from the local DSO. The DSO then has 1 month to respond to the request with a proposal, which the Collective then has 3 months to accept the conditions. The DSO then has 15 days to provide the costs and technical specifications of the connection point. On average this study costs about 260€ for installations between 15kW and 100kW [33]. Connection permits are not required for installations without surpluses, or for installations with surpluses but under 15kW [30].

Collective Self-Consumption Distribution Process: Each consumer is able to select an Electricity Supplier on the open market to supply them with electricity and manage their production allocation. The collective contract sent to the DSO outlines the distribution coefficient of the production assigned to each consumer. The coefficients are not dynamic – they must remain constant throughout a billing cycle, but can be updated through an
addendum to the agreement. The Collective can allocate the production however it desires, as long as the coefficients are constant for each consumer [30].

5.1.2.5. Technical Requirements

For each modality, the installation and participating consumers must have all the required metering devices for accurate billing. This means there must be a bi-directional meter at the border point of the grid and a meter at each consumption point. For modalities with surpluses, a meter to measure the production of the installation may be required as well [33]. Storage is allowed for all devices as long as it meets the regulations required for such devices and has the appropriate metering equipment required for accurate billing [33].

5.1.2.6. Self-Consumed Electricity

The self-consumed electricity is not taxed in any way. For the modality without surpluses, 100% of the electricity produced by the installation is consumed between the members of the Collective based on each consumer’s actual demand, while for the modalities with surpluses, no minimum self-consumption rate is specified in the regulation. The production is divided in accordance to the distribution outlined in the agreement with the DSO, and if a consumer’s portion of the production exceeds the demand, the excess electricity is injected into the grid as surpluses [33].

5.1.2.7. Surplus Electricity

By definition, there are no surpluses for the first CSC modality. For the second modality, the surplus electricity is remunerated through a simplified net billing process, done on an hourly basis. If during an hour period, a consumer consumes 10kWh of electricity and is allocated 5kWh of self-produced electricity from the PV installation, the monthly bill will include taxes and fees for the 10kWh of electricity consumed, but only charge the consumer for 5kWh of electricity at the tariff for the given time slot. If the produced electricity exceeds the consumed electricity for the hour, the net electricity will be set to 0; the value of the produced electricity can never be greater than the value of the consumed electricity, and the Electricity Supplier will never pay money to the consumer for it. For the third modality, the surpluses are not remunerated through net billing with the Electricity Supplier, and instead, if opting for this modality, the Collective must sell the surplus electricity on the electricity market or contract it with a third party [33].

5.1.2.8. Example Projects

The first CSC instance in Spain in an urban environment is a neighborhood scheme in
Valencia that began in 2019. Javier Cervera installed 24 PV panels on the roof of his house and shares the energy with 6 neighboring households [34]. This is an example of the second CSC modality, in which the installation has surpluses receiving simplified compensation.

5.2. Greece

5.2.1. Country Overview

Greece is an eastern European and Mediterranean country made up of thousands of islands and a mainland that is connected to the European continent. It borders Albania, North Macedonia, Bulgaria, and Turkey. It has a population of approximately 11 million people (2019) [10] and a land area of 129,000 square kilometers [11], giving a population density of 85 people per square kilometer. Greece’s GDP in 2019 was $210 billion [12], or €188 billion, making it the 16th largest economy in the EU and giving a GDP per capita of $19,600 per person [13], or €17,464 per person, the 19th highest in the EU.

5.2.1.1. Energy and Electrical System

In 2018, Greece’s Total Primary Energy Supply was 22,57 Mtoe. Of this, approximately 13% originated from renewable sources. The primary energy consumption per capita, or the total primary energy supply divided by the population, was 2,05 toe per person. The country’s energy intensity, calculated by dividing the Total Primary Energy Supply by the Gross Domestic Product, was 0,1203 toe/€1000. The amount of electricity generated in 2018 was 48,74TWh and the amount consumed was 54,3TWh, giving an electricity consumption of 4,94 MWh per person. Of the electricity generated, 35%, or 17,2TWh, was generated from renewable sources, and 8%, or 3,961TWh, was generated from solar photovoltaics specifically. The country’s largest source of renewable electricity is generated from wind (15% of all electricity generated, or 7,278TWh). All energy statistics are from the International Energy Agency unless otherwise stated [15].

The Greek electricity market is less competitive compared to the EU average, ranking 18th in competitiveness out of the EU 28 [16]. The electrical grid is not well interconnected, with only 10% of generation capacity interconnected [35]. Smart meters had been rolled out to only

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2 The World Bank provides GDP and GDP per capita data in USD. The amount was converted into Euros using the average exchange rate throughout 2019, $0,8931/€ [67].
3% of electricity metering points in the country as of the end of 2017 [17].

Electricity in Greece is less expensive than the EU average; the average household price of electricity in 2019 was 0.1551€/kWh, the 19th most expensive in the EU. 31% of the electricity price is for taxes and levies, which is below the EU average at the 22nd highest share of the EU countries [18].

5.2.1.2. National Energy and Climate Plan 2021-2030

Greece also wants to position itself as a Member State that has adopted ambitious climate and energy goals and views its NECP as a roadmap for the next decade that will lead to a wide range of development and economic activities that will have great benefits to society [35].

Greece will use its NECP as the key tool to develop its energy and climate policy through 2030 and it will help the country determine its energy and climate priorities. The plan’s main objective is to design, plan and implement socially and environmentally efficient and cost-effective policy measures that will help attain the medium- and long-term national energy and climate objectives, help the economy grow, reduce energy costs, and protect consumers [35].

The 2030 targets laid out in the plan are:

- Reduce GHG emissions by at least 40% compared to 1990 levels;
- Increase the share of renewables in the gross final energy consumption to at least 35%;
- Reach a 60% share of renewables in gross final electricity consumption;
- Achieve an improvement in energy efficiency by 38% [35].

Greece’s NECP largely focuses strengthening the security of its own domestic energy supply and that of the surrounding region, ensuring smooth and reliable coverage and access to affordable and secure energy for end consumers. Greece is restructuring its energy sector, so another focus is making the energy market more competitive and transparent. It will also focus on integrating renewables into the electricity mix competitively, while ensuring those employed in industries that will be negatively impacted by this transition are not left behind. The plan also focuses on the impacts of urban development and how better planning can bring the urban environment into better harmony with the natural environment and the climate, using a term called “bioclimatic”. Finally, it focuses on increasing the energy
efficiency of the building, mobility, and transport sectors, as well as increasing research and innovation. All of this is done with the UN’s sustainable development goals in mind [35].

In the plan, Greece states that both net metering and energy communities will contribute to the implementation of more renewable energy sources and energy savings investments, and to the active participation of citizens in the energy transition. It aims to achieve a minimum number of projects in both of these schemes so it can better shape and assess the required implementation framework, and so that innovative net metering schemes can arise. It sets a target of having over 600 MW of power needs covered through self-consumption and net metering schemes by 2030, to reach over 1 GW of installed capacity [35].

5.2.2. Collective Self-Consumption in Greece

5.2.2.1. Background

A 2009 law in Greece first allowed PV panels to be installed on roofs and for the owner to receive remuneration for the energy injected into the grid, but self-consumption was not permitted. This feed in tariff price was set by the Ministerial, and it was reduced in 2013 and the program finally expired at the end of 2019 [36]. A new law that went into effect in 2017 allowed for net metering and virtual net metering for farmers and municipalities, essentially allowing self-consumption and collective self-consumption in the country. And then in 2018, Greece became the leader in Europe in terms of implementing the Clean Energy for All Europeans Winter Package by passing legislation legally recognizing the right of citizens to form Renewable Energy Communities and giving them the legal rights and protections to perform numerous activities as this entity. This expanded the possibility for collective self-consumption to members of the RECs [7].

Law N4513/2018 defines Renewable Energy Communities in Greece. They are urban cooperatives that operate exclusively in the energy sector, with objectives of innovation and social and economic solidarity. Their purpose is to reduce energy poverty and promote energy sustainability, efficiency, production, storage, self-consumption, -distribution, and -supply, and self-sufficiency and security in the islands. They have the right to produce, distribute, and supply energy from installations of any type of renewable energy [7].

5.2.2.2. CSC Concepts

The CSC concept that is the focus of this report for Greece is that of virtual net metering. Net metering is also allowed in the country for cases where the PV installation is connected to the internal network of the building consuming the energy produced, but as the regulations for this concept are essentially the same for that of virtual net metering, it will not be analyzed separately [36]. While virtual net metering is allowed for various types of renewable energy
technologies, the scope of this report is limited to the case of PV [37]. For simplification purposes, the CSC concept analyzed is also only for the interconnected network of Greece and excludes the rules and regulations for CSC on the non-interconnected Greek islands [36]

**Proximity Requirements**

The PV installation and consumers must be located in the same region in which the Renewable Energy Community headquarters is located. If the installation is connected to the low voltage grid, the consumers must also be connected to low voltage. If it is connected to medium voltage, the consumers may be connected to medium voltage or low voltage [37].

**Size Restrictions**

The PV installation may have a power capacity up to 20kW, or it may have a power capacity equal to the sum of the agreed power of the total consumption to be offset, if this value is greater than 20kW. The absolute maximum power of the installation can be 1MW [37].

### 5.2.2.3. Participants and Stakeholders

**Collective Membership:** To participate in virtual net metering, the electricity consumer must be a not for profit legal entity, such as a school, local municipality, university, or farmer’s association, or a member of a Renewable Energy Community [38]. Members of a REC may include:

- Natural persons with full legal capacity,
- Legal persons,
- Legal entities under public or private law, and
- Local governments in the region of the REC headquarters.

At least 50% of the members of the REC, plus one person, must be associated with the location of the headquarters [39].

**Installation Owner & Responsible:** The Collective/Renewable Energy Community must own and manage the PV installation. An Electricity Supplier is chosen by the members to “represent” the installation [37].

**Consumers:** The Collective/REC members are able to consume the electricity generated by the installation, as well as vulnerable consumers or those living below the poverty line within the Region [37].
**Distribution System Operator:** Hellenic Electricity Distribution Network Operator, or HEDNO, is the DSO and handles the connection process of the installation and also provides the metering data to the Energy Supplier to perform the virtual net metering between the production and consumption points [37].

**Electricity Supplier:** The REC chooses an Electricity Supplier to represent the installation, and all consumers must contract with this same Supplier. The Electricity Supplier is responsible for splitting the production of the installation between the consumers in accordance with the percentages provided by the REC and ensuring that the bill of each consumer accurately reflects the total consumption minus the “self-consumed" electricity [37].

5.2.2.4. **Administrative Components**

**Collective Formation:** To participate in virtual net metering, the participants must be part of a not for profit legal entity [38] or must form a legally recognized Renewable Energy Community in accordance with Law N4513/2018 [7].

**Installation Connection Process:** The REC must submit a connection request to the local HEDNO office to connect the PV installation to the grid. HEDNO will respond with an offer including the costs (in the range of 350€-600€ depending on the size of the installation [40]), and the REC has three months to agree and respond with an application for a Connection Agreement and the required supporting documentation. Once both parties are in agreement about the price and process, they sign the Connection Agreement [37].

**Collective Self-Consumption Distribution Process:** The REC also must select an Electricity Supplier to represent the installation and handle the virtual metering for the collective self-consumers. The Supplier is responsible for ensuring that all requirements are met for the virtual energy netting scheme, and the two parties sign a Virtual Energy Offset Agreement which includes the consumers participating in the scheme and the percentage of the production to be offset for each consumer [37].

5.2.2.5. **Technical Requirements**

The PV installation must be equipped with a meter to measure the amount produced and injected into the grid. Each consumer must be equipped with a meter to measure the total consumption so the net consumption can be calculated by deducted the portion assigned to the consumer [36].

5.2.2.6. **Self-Consumed Electricity**

All of the energy produced by the installation is virtually “consumed" by the consumers
participating in the scheme in accordance with the distribution percentages as stated in the Virtual Energy Offset agreement. The Collective/REC can inform the Electricity Supplier of any changes to the allocation, which will go into effect for the next billing cycle if notice is given at least 7 days in advance [37].

The “self-consumed” electricity is not taxed in any way and is instead deducted from the metered count of electricity consumed from the grid by each consumer. If a consumer consumes 3000kWh in a month, and the PV installation produced 1200kWh for the consumer’s portion, the consumer will be charged for 1800kWh of electricity for the month. For cases in which a PV installation is connected to medium voltage and a consumer is connected to low voltage, a reduction rate of 95.85% is used to account for distribution losses, so 1000kWh injected by the installation at medium voltage is equivalent to 958kWh at low voltage. Consumers are subject to a maximum charge of 0.25€ per month by the Electricity Supply for management costs of performing the virtual net metering [37].

5.2.2.7. Surplus Electricity

All of the energy produced by the installation is injected to the grid, but 100% of it is allocated virtually. If after 3 years a self-consumer has a negative balance on the electricity bill because the production allocated to him/her exceeded the consumption, the balance will be reset to 0. Therefore, the self-consumers will never receive any money for surpluses, only reductions in their energy bills [37].

5.2.2.8. Example Projects

In 2017, after the new law on virtual metering was passed, but preceding the law on RECs, a 10kW PV system was installed on the rooftop of a school in a town called Thessaloniki. The electricity produced by the installation is injected into the grid and “self-consumed” by a hostel that houses women and children who are victims of violence [41].

Hyperion Solar Community is another example of virtual net metering in Greece. It is a 180 kW solar installation in Athens owned by a Collective with 57 members that is currently under construction [42].

5.3. Slovenia

5.3.1. Country Overview

Slovenia is a small central European country that borders Italy, Austria, Hungary, and Croatia. It has a population of approximately 2 million people (2019) [10] and a land area of 20,100 square kilometers [11], giving a population density of 104 people per square
kilometer. Slovenia’s GDP in 2019 was $53.7 billion [12], or €48 billion\(^3\), making it the 23\(^{rd}\) largest economy in the EU and giving a GDP per capita of $25.700 per person [13], or €22.900\(^3\) per person, the 15\(^{th}\) highest in the EU.

5.3.1.1. Energy and Electrical System

In 2018, Slovenia’s Total Primary Energy Supply was 6.94 Mtoe. Of this, approximately 17% originated from renewable sources. The primary energy consumption per capita, or the total primary energy supply divided by the population, was 3.3 toe per person. The country’s energy intensity, calculated by dividing the Total Primary Energy Supply by the Gross Domestic Product, was 0.1447 toe/€1000. The amount of electricity generated in 2018 was 16.10TWh and the amount consumed was 14.95TWh, giving an electricity consumption of 7.12 MWh per person. Of the electricity generated, 33%, or 5.247TWh, was generated from renewable sources, and 2%, or 0.303TWh, was generated from solar photovoltaics specifically. The country’s largest source of renewable electricity is generated from hydro (29% of all electricity generated, or 4.682TWh). All energy statistics are from the International Energy Agency unless otherwise stated [15].

The Slovenian electricity market is more competitive compared to the EU average, ranking 10\(^{th}\) in competitiveness out of the EU-28 [16]. The electrical grid is extremely well interconnected, with 84% of generation capacity interconnected [35]. Smart meters had been rolled out to 58% of electricity metering points in the country as of the end of 2017 [17].

Electricity prices in Slovenia are slightly less than the EU average; the average household price of electricity in 2019 was 0.1666€/kWh, the 16\(^{th}\) most expensive in the EU. 31% of the electricity price is for taxes and levies, about the EU average at the 14\(^{th}\) highest share of the EU countries [18].

5.3.1.2. National Energy and Climate Plan 2021-2030

Slovenia is a much smaller country than the others analyzed, and while it recognizes the need to decarbonize, it will face some challenges achieving ambitious climate and energy targets. Its economy was severely impacted after the financial crisis of 2008, and combined with its aging population, there is already pressure on the financial sustainability of social protection and pension systems [43].

\(^3\) The World Bank provides GDP and GDP per capita data in USD. The amount was converted into Euros using the average exchange rate throughout 2019, $0.8931/€ [67].
Slovenia’s central objective is to ensure quality of life for all, a core tenant of its NECP. It views the NECP as a guideline to transition to a low-carbon circular economy and sustainable management of natural resources. The country will also develop a long-term climate strategy for 2020-2050 along with an Energy Concept of Slovenia, which will be a long-term development document for the energy sector. It’s main objective of the plan is to ensure a reliable, secure, sustainable and competitive supply of energy that ensures the transition to a carbon neutral society, stimulates the economy and leads to job growth, increases environmental responsibility, and provides acceptable energy services to the population [43].

The 2030 targets in the plan are:

- Reduce GHG for non-trading scheme sectors by at least 20% compared to 2005;
- Achieve a 27% share of renewables in end energy use;
- Achieve a 43% share of renewables in the electricity sector (33.5% in 2020);
- Increase installed solar PV capacity from 400MW in 2020 to 1650MW in 2030;
- Improve energy efficiency by at least 35% compared to 2007 [43].

Slovenia’s NECP focuses on striking a balance between sustainability, security of the energy supply, and competitiveness of the energy supply. It realizes that the country will need to become resilient and be able to adapt to a changing climate, and that it should take advantages of opportunities that arise from this. Energy efficiency is the first key measure of the plan as it will reduce costs for consumers, create jobs and economic growth, positively impact human health, make Slovenian industries more competitive, and reduce foreign dependency on fossil fuels. It also recognizes the need to improve the electricity distribution network of the country so it can handle greater intensity, be resistant to disruptions, and exploit the flexibility of resources and loads. Transport contributes to a high percentage of GHG, so the plan focuses on upgrading the rail system and developing integrated public transit options. Finally, the country will need to increase renewables in the energy system and will facilitate this through legal incentives and reducing bureaucracy [43].

The NECP references “local energy communities”, which it considers one instrument to help promote electricity generation from renewables. Slovenia will establish a scheme by 2022 to promote their development that includes technical and human resource support. Another instrument is “incentives for faster development of the RES community”, which Slovenia will do by first analyzing and removing legislative barriers, creating a one-stop shop for REC creation in 2021, providing financial benefits such as green bonds, also in 2021, and promoting and raising awareness in 2022 [43].
5.3.2. Collective Self-Consumption in Slovenia

5.3.2.1. Background

At the end of 2015, Slovenia introduced a new decree on self-supply and net-metering that went into force in January 2016, allowing households and small businesses to self-consume electricity from their own renewable energy production installations. A net metering scheme was used so that any surpluses injected into the grid were deducted from the total consumption [44]. In 2018, the legislation on net-metering was updated to allow self-consumption for multi-apartment buildings and renewable communities, in addition to individuals, which went into effect in 2019 [45].

5.3.2.2. CSC Concepts

The March 2019 Regulation on self-sufficiency in electricity from renewable sources defines two possibilities of collective self-consumption in Slovenia:

1. Multi-apartment buildings, which can include fully residential buildings, mixed use buildings, commercial buildings, or any other building with two or more measuring points connected to a common low-voltage internal network; and

2. Renewable Energy Source (RES) Communities made up of customers who consume electricity through two or more metering points [46].

While the production may originate from any type of renewable energy source, the scope of this report is limited to solar PV installations.

Proximity Requirements

For the first CSC concept, the installation and consumers must be connected to the same internal low-voltage network of a building. For the RES Community concept, the consumers and installation must be connected to the same low-voltage network that originates from the same transformation station. More than one RES Community may participate in CSC within the network from the same transformation station. If the network structure changes after the formation the RES Community and CSC scheme, the consumers still have the right to participate in the REC even if this condition is no longer met [46].

Size Restrictions

For both concepts, the maximum power of the PV installation(s) producing energy for the self-consumption scheme may not exceed 0.8 times the sum of the connected power consumption of the measuring points for each consumer [46].
5.3.2.3. Participants and Stakeholders

Collective Membership: An individual/household, a small business, or another individual who consumes electricity who meets the proximity requirements may join the “Collective” or RES Community [46].

Installation Owner & Responsible: For both cases, either the building collective / RES Community participants may own and manage the installation, or a third party may own it. A participant may be an individual/household, a small business, or another individual who consumes electricity [46].

Consumers: Only members of the building collective or the RES Community may benefit from self-consumption of the PV installation [46].

Distribution System Operator: The local DSO handles the registration of the Collective and the connection process and is responsible for providing the metering data of the installation and the consumers in accordance with the distribution coefficients of each consumer, along with the billing data, to the applicable Electricity Suppliers through a single portal [46].

Electricity Supplier: Each self-consumer may choose their own Electricity Supplier on the open market, who is responsible for providing the consumers with any excess electricity demanded that is not covered by self-consumption and bills the consumer based on the data provided by the DSO. [46] The Community selects an Electricity Supplier to represent the installation, who is responsible for balancing the production and can buy any surpluses at an agreed upon rate. [47]

5.3.2.4. Administrative Components

Collective Formation: The members do not need to form a legal entity. The CSC agreement with the DSO serves as the contract that forms the Renewable Energy Source Community. The contract should include how the members relate to each other as well as the distribution of the production. All members must sign it, and if the installation is owned by a third party, it must sign the contract as well. The DSO then registers the group as a RES Community performing CSC [46].

Installation Connection Process: The Collective/RES Community must submit a CSC contract to both the DSO (as detailed above) and the chosen Electricity Supplier that represents the installation. The DSO then registers the Community and handles the connection process [46].

Collective Self-Consumption Distribution Process: The distribution of the produced electricity should be divided between the CSC participants based on their respective consumption
profiles [47]. The distribution is dictated to the DSO in the CSC agreement [46].

5.3.2.5. Technical Requirements

The PV installation must be equipped with a meter to measure the amount produced and injected into the grid. Each consumer must be equipped with a meter to measure the total consumption so the net consumption can be calculated by deducted the portion assigned to the consumer [46]. An energy storage device is allowed to be connected to the installation or the network in which the CSC scheme is connected, but the Community must agree in advance on the distribution of shares between the members [47].

5.3.2.6. Self-Consumed Electricity

The “self-consumed” electricity is not taxed in any way and is instead deducted from the metered count of electricity consumed from the grid by each consumer via virtual net metering, as is the case in Greece. If during a billing period a self-consumer has a negative balance on the electricity bill because the production allocated to him/her exceeded the consumption from the grid, the balance will be reset to 0. Therefore, the self-consumers will never receive any money for surpluses, only reductions in their energy bills [46].

5.3.2.7. Surplus Electricity

For the first CSC concept, electricity will be injected into the grid only if production exceeds consumption, whereas for the second concept all of the electricity is injected into the grid and consumed “virtually” by the self-consumers. For both CSC concepts, if there is excess electricity not consumed by the CSC participants, the installation owner cannot sell it on the open electricity market, but can sell it to the representative Electricity Supplier at the agreed upon price [47].

5.3.2.8. Example Projects

The community of Luče in Slovenia installed 102kW of solar PV across nine buildings, along with a 150kW battery system for the installation and five smaller house batteries. The electricity is shared among the community and is enough to power the entire village [48].

5.4. France

5.4.1. Country Overview

France is a large Western European country that borders Spain, Andorra, Belgium, Luxembourg, Germany, Switzerland, and Italy. It has a population of approximately 67 million
people (2019) [10] and a land area of 548,000 square kilometers [11], giving a population density of 122 people per square kilometer. France’s GDP in 2019 was $2,72 trillion [12], or €2,43 trillion [4], making it the second largest economy in the EU and giving a GDP per capita of $40,5004 per person [13], or €36.100 per person, the 10th highest in the EU.

5.4.1.1. Energy and Electrical System

In 2018, France’s Total Primary Energy Supply was 246 Mtoe. Of this, approximately 11% originated from renewable sources. The primary energy consumption per capita, or the total primary energy supply divided by the population, was 3,67 toe per person. The country’s energy intensity, calculated by dividing the Total Primary Energy Supply by the Gross Domestic Product, was 0,1013toe/€1000. The amount of electricity generated in 2018 was 570TWh and the amount consumed was 480TWh, giving an electricity consumption of 7,17 MWh per person. Of the electricity generated, 21%, or 119,4TWh, was generated from renewable sources, and 2%, or 0,303TWh, was generated from solar photovoltaics specifically. The country’s largest source of renewable electricity is generated from hydro (11% of all electricity generated, or 62,1TWh). All energy statistics are from the International Energy Agency unless otherwise stated [15].

The French electricity market is less competitive compared to the EU average, ranking 22nd in competitiveness out of the EU-28 [16]. The electrical grid is not well interconnected, with only 11% of generation capacity interconnected [49]. Smart meters had been rolled out to 22% of electricity metering points in the country as of the end of 2017 [17].

Electricity prices in France are close to the EU average; the average household price of electricity in 2019 was 0,1913€/kWh, the 12th most expensive in the EU. 35% of the electricity price is for taxes and levies, which is above the EU average at the 10th highest share of the EU countries [18].

5.4.1.2. National Energy and Climate Plan 2021-2030

France’s National Energy and Climate Plan was drafted based off its existing Multiannual Energy Plan, which establishes the priorities in the energy sector for the next decade, and the National Low-Carbon Strategy, its roadmap for mitigating climate change that includes

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[4] The World Bank provides GDP and GDP per capita data in USD. The amount was converted into Euros using the average exchange rate throughout 2019, $0,8931/€ [67].
guidelines for all sectors to transition to a low-carbon economy. Both of these documents were drafted so France was prepared to meet the EU targets for energy and climate, and its NECP is a combination of the two [49].

France’s 2030 targets include:

- Reducing both primary and final energy consumption by 32.5% compared to 2012;
- Achieve a 33% share of renewable energy in gross final energy consumption;
- Achieve a 40% share of renewables in the electricity mix;
- Reduce GHG emissions by 37% compared to 2005 levels [49].

The plan focuses on decarbonizing by using carbon budgets to reduce GHG emissions and developing renewable energies. It recognizes the importance of energy efficiency and plans to achieve it through joint actions by citizens, businesses, regions, and the national government, with a core tenant to reduce energy consumption. Security of supply is key for the benefit of all consumers but is a major challenge. France is planning many electrical interconnections with other countries in Europe to transition its internal energy market into an interconnected, decentralized, European energy market [49].

France’s NECP includes self-consumption and energy communities as measures for the internal energy market, specifically electricity infrastructure. It sets a target of having 200,000 PV sites for self-consumption in 2023, 50 of which are collective. It also recognizes that establishing a legal and regulatory framework for renewable energy communities and citizen energy communities is necessary to help develop self-consumption further [49].

5.4.2. Collective Self-Consumption in France

5.4.2.1. Background

Ordinance 2016-1019 of July 27, 2016, added a Chapter V on self-consumption to Title 1 Book III of the French Energy Code [50]. It set a feed-in-tariff for surplus electricity generated from self-consumption PV installations under 100 kW. It also stated that DSOs must facilitate self-consumption operations in the country. This made self-consumption much more accessible and economically viable, causing a large increase in PV installations. Collective self-consumption was also allowed if the participants were part of a legal entity and if the installation and consumers were connected to the same low-voltage grid [51]. Then the 2019 French Energy and Climate Law established the concept of Renewable Energy Communities in the context of collective self-consumption [47]. In March 2020 the laws were further updated on CSC, increasing the threshold for tendering to installations of 300 kW or higher,
and eliminating the experimental period of CSC [51].

5.4.2.2. CSC Concepts

While CSC is allowed in France for any renewable energy source in the electricity and heat sectors, the focus of this thesis is on PV installations. Self-consumption is allowed within a single building, but French law views this as individual self-consumption and therefore will not be analyzed in this report. The CSC concept that is the focus of this section is that of “extensive” CSC, or CSC that occurs between more than one site [52].

Proximity Requirements

The PV installation and consumers must be connected to low-voltage and within a 1km radius of each other. They do not have to be connected to a grid originating from the same transformation station [52].

Size Restrictions

The maximum size of the installation is 3MW, though installations above 300 kW must go through a tendering process [52] [53].

5.4.2.3. Participants and Stakeholders

Collective Membership: Any end consumer of electricity is able to join a CSC scheme as long as the proximity requirements are met, and the consumer becomes a member of the required legal organization, a Personne Morale Organisatrice (PMO) or a Renewable Energy Community [54].

Installation Owner & Responsible: The installation can be owned by the Collective, or a separate entity may own and manage it. The owner is considered to be an Electricity Supplier, but does not need to go through the standard process to register as such [52].

Consumers: Only members of the PMO or the REC may benefit from self-consumption of the PV installation [52].

Distribution System Operator: Enedis is the DSO for most of France. The CSC participants sign an agreement with it for self-consumption, and it manages the distribution of the electricity generated by the installation among the participants in 30-minute time intervals. Enedis also handles the connection process of the installation to the grid [52].

Electricity Supplier: Each self-consumer may choose their own Electricity Supplier on the open market, who is responsible for providing the consumers with any excess electricity demanded that is not covered by self-consumption and bills the consumer based on the data
provided by the DSO. The Electricity Supplier is responsible for balancing the demand and also collects the taxes and fees from the consumers for their self-consumed electricity [52].

### 5.4.2.4. Administrative Components

**Collective Formation:** The CSC participants must form a legal entity called a *Personne Morale Organisatrice* (PMO), or a Renewable Energy Community, to be able to perform CSC [55]. The installation owner and consumers are part of the entity and have a contract between each other for the sale or gifting of the electricity from the installation. The PMO or REC also has the contract with the DSO for the CSC scheme, called a *Convention d’autoconsommation* [52].

**Installation Connection Process:** The PMO/installation owner makes a connection request to the DSO, who then verifies the feasibility of the project. Once both parties are in agreement, the DSO connects the installation to the grid. The installation owner must pay the grid connection fee, which typically costs 10% of the total project cost [52].

**Collective Self-Consumption Distribution Process:** The DSO is responsible for allocating the produced electricity among the consumers in accordance with the distribution outlined in the *Convention d’autoconsommation* [52]. The distribution may be variable (such as based on each consumer’s respective consumption), or however agreed upon by the PMO or REC members [55].

### 5.4.2.5. Technical Requirements

The PV installation must be equipped with a meter to measure the amount produced and injected into the grid. Each consumer must be equipped with a meter to measure the self-consumed energy and the energy purchased from the supplier [52]. An energy storage device is allowed to be connected to the installation. When it is charging, it is considered a consumer, and when discharging it is considered a producer [53].

### 5.4.2.6. Self-Consumed Electricity

A minimum of 50% of the electricity produced by the installation must be consumed by the CSC participants in order for the scheme to be considered CSC [51]. In 30-minute intervals, the DSO measures the production of the PV installation and allocates the production in accordance with the distribution provided in the *Convention d’autoconsommation* [52]. French law views the self-consumption of electricity from the installation as a sale of energy from the installation owner (producer) and the consumers, so the self-consuming energy is subject to VAT, the internal tax on the final consumption of electricity (CRPE), the levy financing renewables (TCFE) and the tax for use of the public distribution network (TURPE).
The consumer pays these taxes and fees to their respective Electricity Supplier, along with the bill for the non-self-consumed electricity from the grid [55].

5.4.2.7. Surplus Electricity

The installation owner (whether the collective self-consumers or a third-party entity) is able to sell the surplus electricity from the installation that is not consumed via CSC on the electricity market or via a set contract with a buyer the owner finds. If the installation is owned by the consumers, they typically hire an aggregator to handle the sale of the surplus electricity [52].

5.4.2.8. Example Projects

In the center of Bordeaux, a housing residence called “Les Souffleurs” is the first collective self-consumption project in France. Set up in 2018, a 33kW PV installation on the roof of one of the buildings generates approximately 39MWh a year. 18 residences have agreed to participate in the CSC scheme and self-consume from the installation, saving between 50€-70€ per year on their electricity bills [56].

5.5. Germany

5.5.1. Country Overview

Germany is a large central European country that borders Belgium, Luxembourg, France, Switzerland, Austria, Czechia, Poland, Denmark, and Netherlands. It has a population of approximately 67 million people (2019) [10] and a land area of 548,000 square kilometers [11], giving a population density of 122 people per square kilometer. France’s GDP in 2019 was $2.72 trillion [12], or €2.43 trillion⁵, making it the second largest economy in the EU and giving a GDP per capita of $40,500⁵ per person [13], or €36,100 per person, the 10th highest in the EU.

5.5.1.1. Energy and Electrical System

In 2018, Germany’s Total Primary Energy Supply was 302 Mtoe. Of this, approximately 16% originated from renewable sources. The primary energy consumption per capita, or the total primary energy supply divided by the population, was 3,64 toe per person. The country’s energy intensity, calculated by dividing the Total Primary Energy Supply by the Gross

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⁵ The World Bank provides GDP and GDP per capita data in USD. The amount was converted into Euros using the average exchange rate throughout 2019, $0.8931/€ [67].
Domestic Product, was 0.0878toe/€1000. The amount of electricity generated in 2018 was 618.2TWh and the amount consumed was 567.8TWh, giving an electricity consumption of 6.84 MWh per person. Of the electricity generated, 42%, or 257.1TWh, was generated from renewable sources, and 8%, or 47.5TWh, was generated from solar photovoltaics specifically. The country’s largest source of renewable electricity is generated from wind (20% of all electricity generated, or 126.0TWh). All energy statistics are from the International Energy Agency unless otherwise stated [15].

The German electricity market is more competitive compared to the EU average, ranking 9th in competitiveness out of the EU-28 [16]. Smart meters had not been rolled out to consumers as of the end of 2017 [17].

Electricity prices in Germany are very high; the average household price of electricity in 2019 was 0.2873€/kWh, the 2nd most expensive in the EU. A whopping 55% of the electricity price is for taxes and levies, which is well above the EU average, ranking at the second highest share of the EU countries [18].

5.5.1.2. National Energy and Climate Plan 2021-2030

Germany’s National Energy and Climate Plan incorporates its Climate Action Programme, passed by the government in 2019, that contains emissions measures for all sectors, as well as the Energy Efficiency Strategy 2050, which sets Germany’s energy efficiency goals and includes the country’s long-term building renovation strategy. As an industrialized nation, Germany views energy and climate policy of vital importance, and Germany’s energy policy, called the Energiewende, is focused on reliability of supply, environmental soundness, and affordability as the key goals of the energy transition [57].

Germany’s 2030 targets include:

- Reduce GHG emissions by 55% compared to 1990;
- Achieve a 30% share of renewables in gross final energy consumption;
- Reduce primary energy consumption by 30% compared to 2008;
- Achieve 65% renewables in the electricity supply [57].

The plan focuses on improving energy efficiency and increasing renewables to create a sustainable supply of energy. Its policy and actions are guided by the tenant of efficiency first. Making energy cost efficient is crucial to ensuring it is affordable in fighting energy
poverty. The energy transition will also help boost Germany’s competitiveness in the business sector and is vital to safeguarding life on this planet [57].

Germany’s NECP sees great potential for RECs to help expand renewable energies both within German and at the EU level. It has already created a regulatory framework that supports and drives the development of RECs, although it is currently limited to wind generation sources. While Germany has created a great environment for self-consumption, with estimates that 4TWh per year are generated and consumed by renewable self-consumers, it does not mention collective self-consumption in the plan [57].

5.5.2. Collective Self-Consumption in Germany

5.5.2.1. Background

While Germany has a huge amount of rooftop PV due to great subsidy schemes, its legislation for CSC is less friendly. Currently, the only viable form of CSC is within a single residential building. The Tenant Electricity Act of 2017, or Mieterstrommodell, allows a landlord to share the electricity from a rooftop PV installation with the tenants in the building at a discounted rate than provided by a traditional Electricity Supplier [58]. While the 2017 Renewable Energy Source Act allows for the creation of Citizens’ Energy Companies (or Bürgerenergiegesellschaft), they are only applicable for wind installations and not PV so will not be discussed further [47].

5.5.2.2. CSC Concepts

The only viable form of CSC currently in Germany is for the sharing of electricity from a PV panel of a residential building (at least 40% of the building space must be used for living) among the tenants who live in it [58].

Proximity Requirements

The regulation dictates that to be part of tenant sharing, the installation and consumers must be in the same building or “within close proximity” [58].

Size Restrictions

The maximum size of the installation is 100 kW to qualify for renewables subsidies [58].

5.5.2.3. Participants and Stakeholders

Collective Membership: Any consumer of electricity who holds a lease in the building may participate in the CSC scheme, but these consumers do not have any organizational relation
to each other and do not form a “Collective” [58].

*Installation Owner & Responsible:* The landlord/building owner may own the installation or may rent out the roof to an Electricity Supplier who owns the installation [58].

*Consumers:* Only the building tenants may “self-consume” the electricity from the PV installation [58].

*Distribution System Operator:* The local DSO is responsible for buying the surplus electricity from the installation in accordance with the appropriate feed-in-tariff [59].

*Electricity Supplier:* Each tenant can choose their own Electricity Supplier on the open market to cover demand not met by the installation. Either the landlord, or if the landlord leases out the roof, the Electricity Supplier is the supplier for the self-consumed electricity [58].

### 5.5.2.4. Administrative Components

*Collective Formation:* The participants in the CSC scheme do not form any sort of Collective or legal entity. The landlord or Electricity Supplier representing the installation has a contract with each tenant, separate from the tenant’s lease, who voluntarily wants to purchase the electricity, for the sale of the electricity at a set price. This contract is automatically terminated upon lease end [58].

*Installation Connection Process:* The Energy Supplier representing the installation typically handles the connection and registration processes of the installation [59].

*Collective Self-Consumption Distribution Process:* The tenants opting to participate in the CSC scheme share the electricity produced by the installation in accordance with their consumption in 15 minute time intervals [58].

### 5.5.2.5. Technical Requirements

The most common and economically viable connection of the installation and consumers is a bidirectional model at the grid connection, with the tenants and producers connected to each other. There is a meter to measure the production and a meter at each tenant’s consumption point [59].

### 5.5.2.6. Self-Consumed Electricity

The tenants purchase the electricity produced by the installation from the owner (either landlord or Electricity Supplier) at an agreed upon rate, which is no more than 90% of the
retail electricity price. The owner receives a subsidy between 3,81-2,75 ct/kWh for the electricity purchased by the tenants [58].

5.5.2.7. Surplus Electricity

The installation owner is able to inject surplus electricity produced by the installation that is not consumed by the tenants into the grid. The DSO is responsible for buying this surplus electricity at the appropriate feed-in-tariff rate in accordance with the Renewable Energy Sources Act [59].

5.5.2.8. Example Projects

The Electricity Supplier Frankfurt Energy set up tenant electricity sharing in multi-unit residences in Frankfurt, in the Riedberg district. 22 tenants have contracts to purchase the electricity generated from the PV panels installed on the roofs of the buildings [60].

5.6. Summary

Summaries of both the country statistics and the CSC approaches for the five countries are found in the following sub-sections.

5.6.1. Country Benchmarking

The following table summarizes the general statistics and energy statistics described in the above sections for Spain, Greece, Slovenia, France, and Germany.
Table 1: Population, wealth, and energy statistics for the countries analyzed [10,11,12,13,14,15,16,17,18,35,43,49,57,67].

<table>
<thead>
<tr>
<th>General Statistics</th>
<th>Spain</th>
<th>Greece</th>
<th>Slovenia</th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (2019)</td>
<td>47000000</td>
<td>11000000</td>
<td>2100000</td>
<td>67000000</td>
<td>83000000</td>
</tr>
<tr>
<td>Land Area (sq km)</td>
<td>500000</td>
<td>129000</td>
<td>20100</td>
<td>548000</td>
<td>349000</td>
</tr>
<tr>
<td>Population Density</td>
<td>94</td>
<td>85</td>
<td>104</td>
<td>122</td>
<td>238</td>
</tr>
<tr>
<td>GDP</td>
<td>€ 1,241,409,000,000</td>
<td>€ 187,551,000,000</td>
<td>€ 47,959,470,000</td>
<td>€ 2,429,232,000,000</td>
<td>€ 3,438,435,000,000</td>
</tr>
<tr>
<td>GDP Rank in EU</td>
<td>4</td>
<td>16</td>
<td>23</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>GDP per Capita</td>
<td>€ 26,374</td>
<td>€ 17,464</td>
<td>€ 22,899</td>
<td>€ 36,086</td>
<td>€ 41,253</td>
</tr>
<tr>
<td>GDP per Capita Rank in EU</td>
<td>12</td>
<td>19</td>
<td>15</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

| Primary Energy Supply (2018) | | | | | |
| Total (Mtoe)                  | 125        | 22.6       | 6.9       | 246.0     | 302.0     |
| % Renewable                  | 15%        | 13%        | 17%       | 11%       | 16%       |
| Energy Intensity (toe/€1000) | 0.1007     | 0.1203     | 0.1447    | 0.1013    | 0.0878    |
| Consumption per Capita (toe/person) | 2.66 | 2.05 | 3.30 | 3.67 | 3.64 |

| Electricity Generation (2018) | | | | | |
| Total Generation (GWh)        | 269585     | 48742      | 16095     | 570316    | 618239    |
| Total Renewable (GWh)         | 102507     | 17163      | 5247      | 119472    | 257089    |
| % Renewables                  | 38%        | 35%        | 33%       | 21%       | 42%       |
| % Solar PV                    | 3%         | 8%         | 2%        | 2%        | 8%        |
| Consumption per Capita (MWh/person) | 5.53 | 4.94 | 7.12 | 7.17 | 6.84 |

| Electricity Market            | | | | | |
| Competitiveness Rank in EU    | 12         | 18         | 10        | 22        | 9         |
| Smart Meter Rollout (2017)    | 93%        | 3%         | 58%       | 22%       | 0%        |
| Electricity Prices (€/kWh)    | € 0.24     | € 0.16     | € 0.17    | € 0.19    | € 0.29    |
| Electricity Price Rank        | 5          | 19         | 16        | 12        | 2         |
| % of Price on Taxes/Fees      | 45%        | 24%        | 31%       | 35%       | 55%       |
| Taxes/Fees Rank in EU         | 4          | 22         | 14        | 10        | 2         |
5.6.2. CSC Approaches

The below table, spread across the next 8 pages, shows the summary of the CSC approaches for the five countries analyzed.

**Table 2**: Summary of CSC approaches for the five countries [7,30,32,33,36,37,38,39,40,46,47,51,52,53,54,55,58,59].

<table>
<thead>
<tr>
<th>Type</th>
<th>Spain</th>
<th>Greece</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Scheme</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSC Concept</td>
<td>CSC without surpluses</td>
<td>CSC with surpluses receiving simplified compensation</td>
</tr>
<tr>
<td>Proximity Requirements</td>
<td>Installation is directly linked to the consumers through an internal network</td>
<td>The installation and consumers must be: 1. Directly linked through an internal network; 2. Connected to low voltage from the same transformation center; 3. Connected to low voltage and less than 500 m away; OR 4. Within the same cadastral reference</td>
</tr>
<tr>
<td>Size Restrictions</td>
<td>100kW</td>
<td>100kW</td>
</tr>
<tr>
<td>Type</td>
<td>Slovenia</td>
<td>France</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------</td>
<td>-------------------------------------</td>
</tr>
<tr>
<td><strong>General Scheme</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSC Concept</td>
<td>Multi-apartment buildings</td>
<td>CSC in Renewable Energy Source Community (RESC)</td>
</tr>
<tr>
<td>Proximity Requirements</td>
<td>Direct connection of installation and consumers through low voltage network of the building</td>
<td>PV installation and consumers must be connected to the low voltage grid from the same transformation center</td>
</tr>
<tr>
<td>Size Restrictions</td>
<td>80% of the sum of the coupling capacities of the consumption points</td>
<td>80% of the sum of the coupling capacities of the consumption points</td>
</tr>
<tr>
<td>Type</td>
<td>Spain</td>
<td>Greece</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>CSC Concept</strong></td>
<td><strong>CSC without surpluses</strong></td>
<td><strong>CSC with surpluses receiving simplified compensation</strong></td>
</tr>
<tr>
<td></td>
<td><strong>CSC with surpluses not receiving simplified compensation</strong></td>
<td><strong>CSC via Virtual Net Metering</strong></td>
</tr>
<tr>
<td><strong>Participants &amp; Stakeholders</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collective Membership</strong></td>
<td>Any consumer of electricity who meets the proximity requirements</td>
<td>Any consumer of electricity who meets the proximity requirements</td>
</tr>
<tr>
<td></td>
<td>Any consumer of electricity who meets the proximity requirements</td>
<td>Any consumer of electricity who meets the proximity requirements</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td>Third party may own it but Collective must hold the title</td>
<td>Third party or Collective</td>
</tr>
<tr>
<td>Owner/Responsible</td>
<td>Third party may own it but Collective must hold the title</td>
<td></td>
</tr>
<tr>
<td><strong>CSC Consumers</strong></td>
<td>Collective members only</td>
<td>Collective members only</td>
</tr>
<tr>
<td></td>
<td>Collective members only</td>
<td>Collective members only</td>
</tr>
<tr>
<td><strong>Distribution System Operator</strong></td>
<td>The local DSO:</td>
<td>The local DSO:</td>
</tr>
<tr>
<td></td>
<td>1. Handles the grid connection process</td>
<td>1. Handles the grid connection process</td>
</tr>
<tr>
<td></td>
<td>2. Ensures the generated electricity is allocated to the consumers in accordance with the distribution coefficients</td>
<td>2. Ensures the generated electricity is allocated to the consumers in accordance with the distribution coefficients</td>
</tr>
<tr>
<td></td>
<td>3. Provides metering data to each consumer’s Electricity Supplier</td>
<td>3. Provides metering data to each consumer’s Electricity Supplier</td>
</tr>
<tr>
<td><strong>Electricity Supplier</strong></td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
</tr>
<tr>
<td></td>
<td>1. Accurately billing consumer only for non-self-consumed electricity</td>
<td>1. Accurately billing consumer only for non-self-consumed electricity</td>
</tr>
<tr>
<td></td>
<td>2. Providing consumer with needed electricity not covered by installation</td>
<td>2. Providing consumer with needed electricity not covered by installation</td>
</tr>
<tr>
<td></td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
</tr>
<tr>
<td></td>
<td>1. Performing net billing in accordance with simplified remuneration process for surpluses</td>
<td>1. Accurately billing consumer only for non-self-consumed electricity</td>
</tr>
<tr>
<td></td>
<td>2. Providing consumer with needed electricity not covered by installation</td>
<td>2. Providing consumer with needed electricity not covered by installation</td>
</tr>
<tr>
<td></td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
<td>Each consumer may choose ES on open market. ES is responsible for:</td>
</tr>
<tr>
<td></td>
<td>1. Allocates the production among the consumers in accordance with the percentages provided by the REC</td>
<td>1. Allocates the production among the consumers in accordance with the percentages provided by the REC</td>
</tr>
<tr>
<td></td>
<td>2. Performs the virtual net metering and bills the consumers accordingly</td>
<td>2. Performs the virtual net metering and bills the consumers accordingly</td>
</tr>
<tr>
<td>Type</td>
<td>Slovenia</td>
<td>France</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>CSC Concept</strong></td>
<td>CSC in Renewable Energy Source Community (RESC)</td>
<td>Extensive CSC in Personne Morale Organisatrice (PMO) or REC</td>
</tr>
<tr>
<td><strong>Collective Membership</strong></td>
<td>An individual/household, a small business, or another individual who consumes electricity that has an apartment/office in the building</td>
<td>Any consumer of electricity who meets the proximity requirements</td>
</tr>
<tr>
<td><strong>Installation Owner/Responsible</strong></td>
<td>Collective or third party</td>
<td>PMO/REC can own it or a third-party. Owner considered an ES</td>
</tr>
<tr>
<td><strong>CSC Consumers</strong></td>
<td>Collective members only</td>
<td>Collective members only</td>
</tr>
<tr>
<td><strong>Distribution System Operator</strong></td>
<td>The local DSO: 1. Registers the Collective 2. Handles the grid connection process 3. Allocates the production among the consumers in accordance with the percentages provided by the Collective 4. Provides metering and billing data to ES through single portal</td>
<td>The local DSO: 1. Registers the RESC 2. Handles the grid connection process 3. Allocates the production among the consumers in accordance with the percentages provided by the Collective 4. Provides metering and billing data to ES through single portal</td>
</tr>
<tr>
<td><strong>Electricity Supplier</strong></td>
<td>Collective selects ES to represent installation. ES: 1. Balances the production 2. Buys surpluses at agreed upon rate Each consumer chooses on ES on open market. ES: 1. Provides consumer with electricity not covered by CSC 2. Accurately bills the consumer in accordance with data provided by DSO</td>
<td>RESC selects ES to represent installation. ES: 1. Balances the production 2. Buys surpluses at agreed upon rate Each consumer chooses on ES on open market. ES: 1. Provides consumer with electricity not covered by CSC 2. Accurately bills the consumer in accordance with data provided by DSO</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Enedis is the DSO: 1. Handles the grid connection process 2. Ensures the generated electricity is allocated to the consumers in accordance with the distribution coefficients 3. Provides metering data to each consumer's Electricity Supplier</td>
</tr>
<tr>
<td>Type</td>
<td>Spain</td>
<td>Greece</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>CSC Concept</strong></td>
<td><strong>CSC without surpluses</strong></td>
<td><strong>CSC via Virtual Net Metering</strong></td>
</tr>
<tr>
<td></td>
<td><strong>CSC with surpluses receiving simplified compensation</strong></td>
<td>Members must either be part of a non-profit legal entity (such as a school, university, city council) or form a Renewable Energy Community.</td>
</tr>
<tr>
<td><strong>Administrative Components</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collective Formation</strong></td>
<td>No legal entity. Members sign CSC contract with DSO</td>
<td>No legal entity. Members sign CSC contract with DSO</td>
</tr>
<tr>
<td></td>
<td>No legal entity. Members sign CSC contract with DSO</td>
<td>No legal entity. Members sign CSC contract with DSO</td>
</tr>
</tbody>
</table>
| **Installation Connection Process** | Connection permit not required                                      | 1. Collective obtains work permit from locality
2. Collective submits connection request to DSO
3. DSO responds within 1 month with proposal (average cost 260€)
4. Once in agreement DSO handles the connection
Note: Connection permit not required if under 15kW |
|                     |                                                                         | 1. Collective obtains work permit from locality
2. Collective submits connection request to DSO
3. DSO responds within 1 month with proposal (average cost 260€)
4. Once in agreement DSO handles the connection
Note: Connection permit not required if under 15kW |
<p>| <strong>CSC Distribution</strong> | Constant percentages based on however Collective decides. Stated in CSC contract with DSO | Constant percentages based on however Collective decides. Stated in CSC contract with DSO | REC sets percentages in Virtual Energy Offset agreement with Electricity Supplier. Unknown if can be dynamic or must be constant. |</p>
<table>
<thead>
<tr>
<th>Type</th>
<th>Slovenia</th>
<th>France</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Administrative Components</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Collective Formation</strong></td>
<td>No legal entity. Members sign a CSC agreement with the DSO.</td>
<td>No legal entity. Members sign a CSC agreement with the DSO.</td>
<td>No legal entity or organization is formed. Each tenant has a contract with the landlord or ES to purchase the produced electricity at a set price</td>
</tr>
<tr>
<td><strong>Installation Connection Process</strong></td>
<td>1. Collective submits CSC contract to the DSO. 2. DSO registers Collective 3. DSO handles grid connection</td>
<td>1. RESC submits CSC contract to the DSO. 2. DSO registers RESC 3. DSO handles grid connection</td>
<td>Very complex process that varies by the DSO. Typically handled by the ES who owns the installation</td>
</tr>
<tr>
<td><strong>CSC Distribution</strong></td>
<td>Distributed based on consumption profiles of consumers. Unclear if constant of dynamic. Stated in CSC agreement with DSO</td>
<td>Distributed based on consumption profiles of consumers. Unclear if constant of dynamic. Stated in CSC agreement with DSO</td>
<td>Distributed based on consumption of the tenants</td>
</tr>
<tr>
<td>Type</td>
<td>Spain</td>
<td>Greece</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td><strong>CSC Concept</strong></td>
<td><strong>CSC with surpluses receiving simplified compensation</strong></td>
<td><strong>CSC with surpluses not receiving simplified compensation</strong></td>
</tr>
<tr>
<td><strong>Technical Requirements</strong></td>
<td><strong>CSC without surpluses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metering Points/Schematic</strong></td>
<td>Anti-spill device at connection point of internal network to the grid. Bi-directional meter required at border point and at consumption points (what is necessary for correct billing). Generation meter also needed in some cases</td>
<td>Bi-directional meter required at border point and at consumption points (what is necessary for correct billing). Generation meter also needed in some cases</td>
<td>Bi-directional meter required at border point and at consumption points (what is necessary for correct billing). Generation meter also needed in some cases</td>
</tr>
<tr>
<td><strong>Storage</strong></td>
<td>Allowed. Must meet regulations for such devices and have appropriate measurement instruments</td>
<td>Allowed. Must meet regulations for such devices and have appropriate measurement instruments</td>
<td>Allowed. Must meet regulations for such devices and have appropriate measurement instruments</td>
</tr>
<tr>
<td><strong>Self-Consumed Electricity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Minimum Self-Consumption Rate</strong></td>
<td>100%</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Taxes / Fees on Self-Consumed Energy</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>Surplus Electricity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metering Time Step</strong></td>
<td>N/A</td>
<td>1 hour</td>
<td>1 hour</td>
</tr>
<tr>
<td><strong>Surpluses Allowed?</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Remuneration Scheme</strong></td>
<td>N/A</td>
<td>Net billing. If surpluses exceed consumption in the 1 hour balance is set to 0</td>
<td>Installation owner sells on electricity market</td>
</tr>
<tr>
<td><strong>Buyer of Surpluses</strong></td>
<td>N/A</td>
<td>Consumer’s Electricity Supplier</td>
<td>Buyer found on electricity market</td>
</tr>
<tr>
<td>Type</td>
<td>Slovenia</td>
<td>France</td>
<td>Germany</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>CSC Concept</strong></td>
<td>Multi-apartment buildings</td>
<td>Extensive CSC in Personne Morale Organisatrice (PMO) or REC</td>
<td>Tenant Electricity Sharing</td>
</tr>
<tr>
<td>Technical Requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metering Points/Schematic</td>
<td>Meter required to measure production of the installation and at each consumption point</td>
<td>Meter required to measure production of the installation and at each consumption point</td>
<td>Meter required to measure production of the installation and at each consumption point. Installation and consumers connected via a bidirectional model</td>
</tr>
<tr>
<td>Storage</td>
<td>Allowed</td>
<td>Allowed</td>
<td>Unknown</td>
</tr>
<tr>
<td>Self-Consumed Electricity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Self-Consumption Rate</td>
<td>None</td>
<td>None</td>
<td>50%</td>
</tr>
<tr>
<td>Taxes / Fees on Self-Consumed Energy</td>
<td>None</td>
<td>None</td>
<td>VAT, TCFE, CRPE, TURPE</td>
</tr>
<tr>
<td>Metering Time Step</td>
<td>Unknown. Negative balance reset to 0 at end of billing period</td>
<td>Unknown. Negative balance reset to 0 at end of billing period</td>
<td>Tenant purchases electricity at rate that is no more than 90% of the retail price. Installation owner receives subsidy between 3,81-2,75 ct/kWh for the electricity purchased by the tenants.</td>
</tr>
<tr>
<td>Surplus Electricity</td>
<td></td>
<td>30 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>Surpluses Allowed?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Remuneration Scheme</td>
<td>Collective sells surpluses to ES representing the installation at agreed upon price</td>
<td>Collective sells surpluses to ES representing the installation at agreed upon price</td>
<td>Sold on electricity market, typically through an aggregator</td>
</tr>
<tr>
<td>Buyer of Surpluses</td>
<td>ES of installation</td>
<td>ES of installation</td>
<td>Buyer found on electricity market</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DSO buys surpluses from owner at rate dictated by the feed-in-tariff</td>
</tr>
</tbody>
</table>
6. Discussion

6.1. Country Comparisons

6.1.1. CSC Rankings

The five countries were ranked against each other for each category regarding their respective CSC legislation. The ranking was performed on the basis of:

- Alignment with the Renewable Energy Directive: which legislation best follows the rules for self-consumption laid out in the REDII?
- Consumer’s rights and benefits: which legislation places the consumer first and provides them with the most economic benefit?
- Accessibility: which legislation makes it the easiest for consumers to participate in CSC?
- Flexibility: which legislation allows for the widest range of use cases applying CSC?

These values align with the consumer centric approach that the Clean Energy for All Europeans Package, the Renewable Energy Directive, and the European Green Deal, and legislation that best incorporates these tenants will likely see more uptake of CSC by consumers. Therefore, the ranking was done with these values in mind. For countries with more than once CSC concept (Spain and Slovenia), the “best” option among them was selected for the ranking.

6.1.2. CSC Concepts

Proximity Requirements

The ranking of the proximity requirements, or interpretation of “local” from the RED II, was based on which country allows for CSC over the greatest area and the widest range of voltages (low and medium). A larger area makes participation in a specific CSC scheme more accessible to potential consumers, as does allowing multiple voltage levels to participate. Based on this lens, the countries were ranked as follows:

1. Greece allows CSC for the largest distance and for both low and medium voltage installations and consumers.
2. France allows for the second largest distance at a 1 km radius.
3. Spain allows for third largest distance at 500 m and provides the most ways to be considered in “proximity”.

4. Slovenia is based on grid topography only.

5. Germany only allows if direct connection in a single building.

Size Restrictions

Allowing installations with larger capacities increases the number of potential consumers who can participate in a CSC scheme, as there is more electricity generated by the installation to be shared. Larger installations will also be able to cover a higher percentage of the demand for the same number of consumers, and as self-consumed electricity is more valuable to the consumer than purchased electricity, will result in great economic benefits for the participants. Therefore, the country ranking was based on the legislation that allows the largest PV installations, with the following results:

1. Slovenia has no absolute maximum limit on the size of the installation and instead bases it on the demand of the participating consumers.

2. France has the highest of the absolute maximum limit at 3MW.

3. Greece has absolute max of 1MW and bases limits on demand of the participating consumers.

4. & 5. Spain and Germany tie for last with absolute max of 100 kW to qualify for the subsidies and remuneration schemes.

6.1.3. Participants and Stakeholders

The Participants and Stakeholders section of the table includes Collective Membership, Installation Owner & Responsible, Consumers, DSO, and Electricity Supplier. The ranking excludes the role and responsibilities of the DSO as it has little impact on the accessibility, flexibility, and consumers’ rights and benefits in the scheme.

Collective Membership: The ranking of who is able to join the “Collective” was based on which countries have the least restrictions to be able to join. Greece was ranked first, as it is the only country that allows members to be outside of the proximity requirements (although these members cannot participate in self-consumption of the installation). France and Spain ranked next as they allow any consumer of electricity who meets the proximity requirements to join. The results of the ranking are below:

1. Greece ranks first because only 50% + 1 members of the REC must have ties to
the region in which the REC is headquartered.

2. & 3. Spain and France tie for second because both countries allow any consumer of electricity who meets the proximity requirements to join the Collective.

4. Slovenia ranks fourth because it limits membership to “an individual/household, a small business, or another individual who consumes electricity” who meets the proximity requirements, which is more restrictive than any consumer of electricity.

5. Germany ranks last because only building tenants can participate in CSC and there is no “Collective” or other type of organization that is formed among them.

Installation Owner & Responsible:

The REDII directive states that the installation owner should be able to be the Collective or a third party [3], which allows for more accessibility, flexibility and CSC use cases. But in some cases, increased accessibility and flexibility result in reduced rights and protections for the consumers. To best align with the Clean Energy for All Europeans Package and RED II, the countries were ranked in accordance with how best the rules about the installation owner and responsible align with the directive. This put Slovenia and France in first as they allow for either the Collective or a third party to own and operate the installation.

1. & 2. Slovenia and France tie for second and third because the collective consumers or a third party may own the installation, providing flexibility for potential CSC use cases.

3. Spain allows the Collective or third party to own the installation, but includes confusing clauses about “titularidad”, or who must be the responsible party, that limits use cases.

4. Greece requires the Collective to own and manage the installation, though the Collective selects an Electricity Supplier to represent it.

5. Germany requires the owner to be registered as an Electricity Supplier, a very complex process, significantly limiting the amount and types of parties who might be interested in owning a CSC installation.

Consumers:

The ranking of the consumers able to participate in the CSC scheme was based on if any consumer outside of the Collective is able to consume electricity generated by the installation. Greece is the only country that allows consumers who are not part of the collective organization to benefit from CSC, with a specific focus on energy poverty. As one
of the main pillars of the Winter Package and the RED II is to fight energy poverty and make sure no one is left behind in the energy transition, while all the other countries only allow the Collective, or in the case of Germany, the building tenants, to self-consume the electricity. The results of the ranking are as follows:

1. Greece ranks first because it is the only country that allows consumers who are not in the Collective to participate in the CSC scheme.

2., 3., 4., & 5 Spain, Slovenia, France and Germany tie for last because they only allow the Collective or building tenants to self-consume electricity generated from the installation.

6.1.4. Administrative Components

Collective Formation:

This ranking was based on which countries have progressed the most towards implementing the RED II. Therefore, countries in which permit a true REC to form ranked highest, those that create a legal entity in that direction ranked next, and those that do not give any legal standing to the Collective last. The results are as follows:

1. Greece ranks first because it is the only country who has transposed the RED II into law and allows the formation of RECs who have all the corresponding rights and protections.

2. & 3. Slovenia and France tie for second because the members of the Collective are viewed as a legal entity, and while not truly RECs as defined in the RED II are a step in that direction.

4. Spain ranks fourth because the Collective is not a legal entity and it is only formed via the contract with the DSO.

5. Germany ranks last because no Collective is formed at all.

Installation Connection Process:

The installation connection process was ranked based on the countries that had the easiest, shortest, and least expensive process, because these attributes will make the formation of a CSC more accessible to potential consumers. This ranking is less exact, as the author does not have personal experience going through the process, and literature only describes some of the steps and does not do a full-blown comparison of the process for each country. Additionally, the process varies by DSO in some countries, so it is not consistent among a single country. Estimated costs found in literature are also just estimates and can vary
greatly depending on the specifics of the PV installation setup. Further, cost estimates and durations were not able to be found for all countries. Therefore, this ranking is deeply flawed and is only a best guess based on literature that provides country specific criticisms, estimated costs, and predicted timelines of the process. The results are as follows:

1. & 2. Greece and Slovenia tie for first because the process seems the most straightforward and efficient, and minimal criticism of the processes were able to be found.

3. & 4. France and Spain rank in the middle because the process can be quite complex and lengthy. In Spain there can be months long delays, and in France the process often needs to be spearheaded by local authorities who can better navigate the bureaucracy.

5. Germany has the worst process because the installation owner must register as an Electricity Supplier and then work with the DSO to obtain the permits and connection request for the installation. This process varies greatly based on the DSO and usually cannot be done digitally.

**Collective Self-Consumption Distribution Process:**

The CSC distribution process was ranked based on flexibility. The more flexible the options to distribute the electricity produced by the installation, the more consumers may want to participate in a CSC scheme. Therefore, the countries that allow for the widest range of distribution keys were ranked highest, and those with the least flexibility ranked lowest. Note that this perspective can clash with the most efficient usage of the produced electricity, which is to distribute the production based on the consumption, thereby maximizing the amount of electricity that is self-consumed. But keeping in line with the consumer-centric focus of the CE4AE Package, the ranking was approached in terms of which provides the most flexibility for the participants.

1. France places first because the PMO/REC is able to dictate how the electricity should be distributed, at the distribution is able to be dynamic based on the consumption of the participants.

2. & 3. Spain and Greece tie for second because the Collective is able to dictate how it wants the electricity to be distributed, but in Spain the percentages cannot be dynamic and must stay the same throughout a billing cycle, and in Greece it is unclear if it can be dynamic.

4. & 5. Slovenia and Germany tie for last because they require the distribution to be based on the consumption, giving the least flexibility to the participants.
6.1.5. Technical Requirements

The technical requirements section looks at which setups are the simplest and least expensive to implement, particularly from a metering perspective. If the legislation requires lots of meter to be put in place, this significantly increases the cost of the installation and can prohibit consumers from participating in a CSC scheme because it is too expensive and can increase the Return on Investment timelines. Therefore, the countries that require the minimum number of meters necessary for correct billing ranked the highest, and those with more complex metering requirements ranked the lowest.

1., 2., & 3. Greece, Slovenia and France all tie for first because meters are only required to measure the production of the installation and to measure the consumption of each consumer.

4. Spain ranks next because the legislation is less clear. It requires meters required for proper billing, which, according to the rules, may include a meter to measure the production, a meter to measure the power consumed by the inverter, and a meter to measure the consumption and discharge of a battery, if the installation has one.

5. Germany comes in last because the installation and consumers must be connected in a certain way, and the metering must be done every 15 minutes, which requires special, more expensive meters. In some cases, the building may need to be re-wired to meet the specifications required by the legislation to participate in CSC.

6.1.6. Self-Consumed Electricity

The approach for self-consumed electricity was based on which countries give it the highest value and charge the least amount of taxes and fees on it, as this provides the consumers with the greatest benefit. Therefore, the countries that allow CSC participants to consume the energy without any charges, taxes or fees ranked highest and those in which the self-consumed electricity is the most expensive ranked the lowest.

1. and 2. Spain and Slovenia tie for first because the self-consumed electricity is not subject to any taxes or fees.

3. Greece comes in third because the consumers are only subject to a very nominal fee of max 0,25€/month to the ES for managing the CSC.

4. France ranks fourth because consumers must pay the VAT, TCFE, CRPE, and TURPE on the self-consumed electricity.

5. Germany ranks last because the consumers only receive a slight discount on the
self-consumed energy (they pay up to 90% of what they would pay for electricity from a normal supplier).

6.1.7. Surplus Electricity

The approach for surplus electricity again took the approach of value. The CSC participants receive a greater benefit if they are able to receive economic remuneration for the surpluses of the PV installation. Therefore, countries in which the highest value is given to surpluses ranked the highest, but only if the self-consumers are able to own the installation and receive this benefit. In the case of Greece, 100% of the energy is considered to be self-consumed because it allows for a 3-year time period for the consumption to compensate for any excess production. The other approaches would consider there to be surpluses, so because Greece is maximizing the energy that is considered to be self-consumed it ranks first.

1. Greece ranks first because although surpluses are not allowed, net metering is performed in a way that only if a consumer’s allocation of the electricity produced by the installation exceeds the consumer’s demand over a three-year time period will the consumer not receive any compensation for the generation.

2. Slovenia ranks second because like Greece it performs net metering but over a 1-month time period. The Collective/RESC can also sell surpluses to the Electricity Supplier at an agreed upon rate.

3. Spain ranks third because the consumer’s surpluses (remember the distribution key is not dynamic) are used to offset the consumption from the grid through net billing performed on an hourly basis.

4. France ranks fourth because surpluses must be sold on the electricity market and have no guaranteed value.

5. Germany ranks last because the installation owner can sell the surpluses to the DSO at the feed-in-tariff rate, but the consumers are not the owner.

6.1.8. Overall Results

Based on the rankings described in the above sections, an overall “winner” can be declared that in general provides the most accessible, flexible, and consumer-centric approach to CSC. If a first-place rank in a category receives 5 points, second place 4 points, third place 3 points, etc., the “best” approach from this lens would be the country with the highest score, and the “worst” would be that with the lowest score. This scoring approach was applied using different weights for the categories, and the results are described below.
This scoring system was applied giving each category the same weight and then giving both the self-consumed electricity and surplus electricity categories double the weight as the others and then five times the weight as the others. These two categories were given more weight because the best way to motivate consumers is economically, so it is crucial that countries make CSC profitable for participants if they want it to be implemented at any scale. The results of these three weighting approaches are shown in Tables 3 and 4 below.

**Table 3:** Rankings of the three weighting mechanisms used to compare the overall CSC approaches of each analyzed country.

<table>
<thead>
<tr>
<th></th>
<th>Equal</th>
<th>Electricity Categories x 2</th>
<th>Electricity Categories x 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Greece</td>
<td>Greece</td>
<td>Greece</td>
</tr>
<tr>
<td>2</td>
<td>France</td>
<td>Slovenia</td>
<td>Slovenia</td>
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<tr>
<td>3</td>
<td>Slovenia</td>
<td>France</td>
<td>Spain</td>
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<td>4</td>
<td>Spain</td>
<td>Spain</td>
<td>France</td>
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<tr>
<td>5</td>
<td>Germany</td>
<td>Germany</td>
<td>Germany</td>
</tr>
</tbody>
</table>

**Table 4:** Actual point values of each country for the three weighting mechanisms to compare the overall CSC approaches of each analyzed country.

<table>
<thead>
<tr>
<th></th>
<th>Equal</th>
<th>Electricity Categories x 2</th>
<th>Electricity Categories x 5</th>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>38</td>
<td>46</td>
<td>70</td>
<td>1st</td>
</tr>
<tr>
<td>Greece</td>
<td>48</td>
<td>56</td>
<td>80</td>
<td>2nd</td>
</tr>
<tr>
<td>Slovenia</td>
<td>43</td>
<td>52</td>
<td>79</td>
<td>3rd</td>
</tr>
<tr>
<td>France</td>
<td>44</td>
<td>48</td>
<td>60</td>
<td>4th</td>
</tr>
<tr>
<td>Germany</td>
<td>17</td>
<td>19</td>
<td>25</td>
<td>5th</td>
</tr>
</tbody>
</table>

Regardless of the scoring, Greece consistently ranked in first and Germany in last. This can be expected, as the criteria was based on the consumer-centric values touted in the CE4AE Package, RED II, and Green New Deal. Greece has already transposed the RED II into national law, impacting its CSC approach, whereas Germany has not, and indeed its Tenant Electricity Sharing Act can only loosely be considered a form of CSC. It is important to keep in mind that while Germany appears to do very poorly across the board, the ranking is against the four other countries who have implemented regulatory frameworks to support collective self-consumption. The majority of Member States have yet to do so, and Germany is ahead of the curve, although still needs to fully implement Articles 21 and 22 of the REDII.
France’s ranking changed the most based on the weighting approach used. Using equal weights across categories, it ranked second overall, but as more weight was given to the economics of the electricity self-consumed and surpluses generated, it fell to third and fourth place. Slovenia moved from third to second, and for the weighting approach that gave five times the weight to the electricity categories, it was only one point behind Greece. Spain also benefited from giving more weight to the electricity categories, moving from fourth to third.

As stated above, the profitability of a CSC scheme and the financial benefits to the consumers are the most important components that will entice consumers to participate. Therefore, it is recommended to consider the third weighting approach when ranking the “best” approaches from each of the countries.

6.1.9. Benchmarking

Statistics about each country’s population density, wealth, and energy system were included in the analysis to determine if any correlations and trends could be made in the CSC approaches based on these data points. Based on the analysis few clear trends could be made that were generally consistent among the five countries.

A prediction could be made that the least densely populated countries would have the broadest proximity requirements. The cases of Greece, the least densely populated country of the group but that with the broadest proximity requirement, and that of Germany, the most densely populated and the most restrictive in terms of proximity requirements, do align with this hypothesis, but this trend is not clear for Spain, Slovenia, and France.

Another prediction could be made that the poorest countries in terms of GDP and GDP per capita would include legislation about CSC aimed to reduce energy poverty. One way of approaching this is allowing Collectives participating in CSC to donate surpluses to vulnerable consumers. Greece, the poorest country, does allow this, but the second poorest country, Slovenia, does not. Another prediction about the poorest countries could be that they would have the most generous remuneration schemes for both self-consumed electricity and surplus electricity. This does seem to align with the approaches of each country, as Greece, Slovenia and Spain have the most generous remuneration schemes, while the two wealthiest countries, France and Germany, are the least generous to the self-consumers.

The price of electricity could be another driving factor in the CSC approach. A hypothesis can be made that countries with the highest electricity prices would have the most generous remuneration schemes for electricity self-consumed and surpluses. Again, the approaches for the five countries do not consistently align with the hypothesis, as Germany has the highest electricity prices and the least generous remuneration scheme for the consumers, and Spain has the second highest prices and while the best remuneration scheme for self-
consumed electricity, not the best for surpluses.

Finally, a prediction could be made that countries with the biggest gap between their current share of renewables in the electricity mix and their 2030 targets would have the most accessible, flexible, and consumer-centric approaches to encourage the most uptake of CSC, as this will help the country achieve its renewables targets. Spain has the biggest gap, needing to increase its share of renewables in the electricity mix by 37%, but its CSC approach consistently ranks in the middle compared to the other five countries. Greece has the next biggest gap at 25% and does have an approach that would help encourage uptake. But Germany has the third biggest gap at 23% and has the most restrictive approach.

Overall, few concrete trends and correlations can be drawn from the benchmarking done on the five countries and how each country’s specific situation impacts their CSC approach, though a plethora of predictions and analyses could be made, and only a handful were selected here. A more robust analysis could be performed by analyzing the approaches of all of the EU 28 countries (once each country has implemented CSC legislation) that also considers the uptake of CSC in the countries.

6.2. Limitations and Barriers

This section discusses some of the limitations in the analyzed countries’ approach to CSC, along with barriers that may prevent its uptake among potential consumers. It is not comprehensive and aims to focus on the key limitations and barriers, rather than regurgitating what the highest ranked country does or the best practices as discussed in the subsequent section.

6.2.1. Spain

While Spain’s new rules about collective self-consumption are laudable and lightyears ahead of where they were just a few years ago, they have a number of limitations that will prevent the country from reaping in the benefits of CSC to their fullest extent and will preclude a large number of potential self-consumers from participating.

To begin, although the new legislation has greatly simplified the process, forming a CSC scheme is still requires the participants to go through very complex administrative procedures that are not uniform across the nation. As each Autonomous Community manages the registration process for CSC, it varies by community, and further the municipality is responsible for components as well, such as the work permit to install the PV installation, which can take 6-8 months to obtain alone. The connection permit process with the DSO can also be lengthy, and with the new legislation the DSOs have been inundated
with requests, causing bottlenecks and long delays [61].

Further, the CSC participants are not a legal entity and do not have the rights and protections of a Renewable Energy Community, as outlined in the recast Renewable Energy Directive at the EU level. Formation of the Collective can face barriers at the building level, as to install the PV installation on the roof a majority of the homeowners in the building, in accordance with the Horizontal Property Law of the 1960s, must agree to it, even if they are not in the Collective [61].

The rules also don’t maximize the efficiency of the scheme. The distribution of the electricity produced by the installation amongst the consumers must be static and cannot be dynamic based on each consumer’s respective demand. This prevents the percentage of electricity that is self-consumed from being as high as possible, which, as described in the introduction, is the most efficient use of the installation to minimum grid use and losses. And based on Spain’s remuneration process of surplus electricity from CSC, the consumer only recovers about 50% of the value of the electricity if it had been self-consumed, as net billing is used to offset the consumption [62].

Finally, the laws make it difficult for the most beneficial, from a social standpoint, types of energy communities to form. In order to participate in CSC, the consumers must be part of the Collective and always partake in self-consumption. This means that if the installation has surpluses, the Collective is unable to gift them to neighbors or vulnerable consumers. Further, due to the rules about ownership and “titularidad” of the installation and the rules about metering and connection permits for inverters of the PV installation, a scheme in which the municipality or other third party owns the installation and, for a fee, allows consumers to share the electricity generated, is not allowed to benefit from simplified compensation, and the municipality would instead have to sell the surpluses on the electricity market [62].

And finally, the outdated “auxiliary services” rules add a significant cost to the installation that lengthen the ROI of the installation, along with administrative complexities, to many CSC schemes. If any of the below conditions are not met, the installation owner must obtain a separate connection permit for the auxiliary services and pay for a separate meter to measure the energy the inverter consumes for the installation to benefit from the simplified remuneration scheme for surpluses:

1. The installation must be under 100 kW.
2. The installation must be connected to the internal network of the consumers (i.e. within the same building with direct transmission lines).
3. The consumers and the installation owner/responsible must be the same entity.
4. The total energy consumed by the auxiliary services annually is less than 1% of the net energy generated by the installation [30].

Therefore, only the CSC concept in which the residents of a building co-own an installation under 100kW are able to consider the auxiliary services negligible and avoid the headache of obtaining a separate connection permit for it and the financial cost of the extra meter. To put the cost in perspective, the appropriate meter would cost between 1200€-1600€. For a 20kW installation, the inverters would consume about 4,4kWh per year, which would cost 0,45€. The connection permit and meter are required only to bill the production owner for the 0,45€ [63].

6.2.2. Slovenia

Slovenia’s CSC legislation is an important step towards the transposition of the Clean Energy Package, but it still lacks many important aspects of it. The Renewable Energy Sources Communities that the new legislation allows do not need to be a legal entity and lack the rights and protections of a true Renewable Energy Community as outlined in the Renewable Energy Directive. Regarding collective self-consumption, Slovenia’s laws are simple and robust but do have a couple of limitations. First, it is unclear if the production key to allocate the electricity generated is able to be dynamic to fully maximize the amount of energy that is self-consumed, though it should be based on the consumption profiles. Additionally, the ability to participate in the scheme is based on grid topography, so there may be cases in which neighbors are not able to share electricity from the same installation because they are not connected to the same transformation station.

6.2.3. France

The French legislation on CSC has many great features but still faces some limitations and barriers. First, the administrative procedures are still quite complex, so typically a local authority must spearhead formation of the Collective and implementation of the CSC scheme. Further, CSC schemes in France struggle to be profitable because the self-consumed electricity is still considered a sale of energy and subject to a number of taxes and fees, which one could argue should not apply. Self-consumers must pay the CSPE levy that finances renewables projects, although CSC is a renewables project, and they pay the full TURPE or fee for use of the public network, even though the electricity is produced and consumed locally, minimizing grid usage. The surpluses do not benefit from a feed-in-tariff or a simplified remuneration scheme. Instead, the installation owner must sell the surplus electricity in the market, a very complicated process that in most cases requires the assistance of an aggregator. Finally, the regulations only allow CSC schemes for installations and consumers connected to low voltage, precluding many industrial SMEs from participating [64].
6.2.4. Germany

The German legislation allowing CSC is the least robust and most restrictive of the countries analyzed, and it faces a number of limitations and barriers. Indeed, it only allows a very limited form of CSC, in which a building owner or third-party owner sells the electricity produced by an installation on (or in close proximity) of the building in which the consumers reside.

To begin, the proximity requirements only allow for CSC within the same building in which the installation can be directly connected to the internal network, or within “close proximity”. The close proximity statement is extremely unclear and has led to a number of court cases for tenant electricity sharing schemes whose legality was questioned [7].

In addition to a lack of clarity, the legislation requires the responsible party of the installation to be registered as an electricity supplier. Therefore, it is very complicated for a landlord or condo association to manage the installation, and usually they lease the roof to an electricity supplier who then sells the electricity to the tenants. While the landlord or condo association does reap some benefits from the extra income from the lease, they are not becoming active participants in the energy transition through this scheme. The same goes for the tenants purchasing the electricity; they are able to choose a (very) local renewable energy option but are passive participants because they do not own or manage the installation and will likely be less engaged with their energy consumption.

The "self-consumers", in this case the tenants, do pay less for the electricity they self-consume (max 90% of the retail value, based on the contract they have for the tenant electricity), but because German law does not consider this scheme to be self-consumption, they still must pay the renewable energy (EEG) surcharge on the electricity.

Finally, tenant electricity can require extreme metering and reporting obligations that may further deter a building from deciding to partake in CSC. The registration process also is not standardized for the country and varies between each local DSO, and the process is often complex and not able to be done digitally [65].

6.2.5. Greece

Overall, Greece’s legislation is quite exemplary and serves as a great example to other Member States. Greece has paved the way in transposing Articles 21 and 22 of the RED II into law, and provides preferential treatment to RECs [66]. This has led to a large uptake of RECs and CSC schemes in the country [36]. In its NECP, Greece even sets a target of having over 600 MW of power needs covered through self-consumption and net metering schemes by 2030, to reach over 1 GW of installed capacity [35]. One criticism of the Greek
approach is that it does not allow the self-consumers to choose their own Electricity Supplier; they must contract with the one representing the installation that is chosen by the REC. Allowing consumers to choose any ES on the open market would give them more choice and rights. It should also allow third parties to own and operate the installations so that additional CSC use cases can arise, rather than requiring the Collective/REC to own it.

6.3. Best Practices

Based on the country comparisons, limitations and barriers, literature review, and personal opinions, the following best practices about CSC approaches are recommended for Member States that will provide consumers with the most rights and benefits and make CSC accessible and flexible to ensure the most uptake.

6.3.1. CSC Concepts

Proximity Requirements

The RED II states that CSC participants and RECs can share electricity locally but leaves it to Member States to define what “local” means. The best practice recommendation for this definition is to follow Greece’s approach, and allow CSC within a region/state/province of the country, and if the installation is connected to low voltage, allow consumers to participate from low voltage, but if the installation is connected to medium voltage, allow both low and medium voltage consumers to participate.

This recommendation may be very difficult for some countries to implement, depending on its DSO setup. In Greece, HEDNO is the DSO for the country, so taking a regional approach is less complicated than if there is more than one DSO operating in the region. Another drawback of this approach is that the electricity may need to “travel” longer distances, resulting in more grid usage and losses than for a more restrictive interpretation of local. Member States need to consider their particular situation and determine how they can allow CSC over the largest distance while ensuring the benefits to the grid of CSC are not diminished.

Size Restrictions

More consumers are able to benefit from a CSC installation with a higher power capacity. Therefore, it is recommended to not place an absolute maximum on the installation size, and instead limit the size based on the consumption of the consumers participating in the scheme. Slovenia limits the size to 80% of the consumers’ coupling capacities, while Greece limits it to 100% of the agreed total power to be offset (though does have an absolute max of 1MW). The best practice recommendation is to limit power output of the installation to 100%
of the sum of the peak demand of each consumer, so theoretically the installation could cover the total demand at a point in time. Member States should be aware that according to the RED II, they are able to charge taxes and fees on self-consumed electricity for installations with a capacity over 30kW [3]. If they do implement legislation that charges the consumers in this case, they need to make the Collective aware of this before they decide on the size of the installation to install.

6.3.2. Participants and Stakeholders

**Collective Membership:** A best practice is to be the least restrictive in terms of who can become a member of a CSC Collective. In the case of Greece, membership in a REC is not restrained by location, as only 50% + 1 members must be located in the region in which the REC is headquartered [39]. Spain and France allow any consumer of electricity to join. An argument could be made that allowing large companies to join can take power away from individuals and SMEs in the Collective, but large companies likely have the capital to invest in PV installations, and governments can ensure based on the legal entity structure of the Collective that all members have the same rights and protections and a democratic say in decision-making.

**Installation Owner & Responsible:** In accordance with the REDII, either the Collective of a third party should be able to own and/or operate the PV installation [3], allowing for many use cases and business models to emerge. If the Collective owns the installation, it should not have to obtain the registration and licenses of a traditional Electricity Supplier.

**Consumers:** Member States should allow members of the Collective to consume the electricity generated from the installation, as well as vulnerable consumers and consumers living below the poverty line, as Greece allows. The Collective should also be able to donate surplus electricity, potentially for a tax credit, to other consumers within the proximity requirements that they choose, such as a school, cultural center, low-income housing, etc. This approach provides greater flexibility for use cases, maximizes the efficiency of the installation, empowers the Collective to help others and fight energy poverty, and allows for more consumers to benefit from local, renewable energy and reductions in electricity bills.

**Electricity Supplier:** Consumers should be able to choose their Electricity Supplier on the open market and not be restricted to a single option because of their decision to participate in a CSC scheme.

6.3.3. Administrative Components

**Collective Formation:** The best practice recommendation is to allow potential CSC participants to form a Renewable Energy Community that has the rights, privileges, and
protections outlined in the RED II, or some other legal organization that gives them rights and protections. Decisions of the REC or Collective should be made democratically, so that individuals/entities have the same decision-making power as ones who invested more money. The administrative process to form the REC or Collective should be straightforward and timely. Member States should allow it to be created through an online platform and with minimal fees. Member States also need to provide education to consumers, so they are aware about the possibility of forming a REC or Collective and participating in CSC. There should also be some mechanism in place to assist a consumer or group of consumers with finding additional members to participate in the scheme. This approach will best empower an average household to garner neighbors together, form a REC or Collective, and take an active part in the energy transition, while helping Member States meet their renewables targets.

Installation Connection Process: Overall, it seems that the current process to install a PV installation and connect it to the grid is tedious at best in many of the countries. Member States need to revamp the process for CSC schemes so that Collectives can quickly and easily obtain permits. It should also be simple enough that a Collective member without an energy background can complete it. The recommendation is to have an online platform, preferably the same one in which the REC uses to form itself, with a nation-wide, standardized process agnostic of the DSO handling the connection process. To prevent huge bottlenecks from forming from an overload of requests, as is occurring in Spain, the platform could contain an automated vetting process of the project requests. Exemptions from obtaining connection permits should also be allowed, such as how Spain does not require a connection permit for installations below 15kW.

Collective Self-Consumption Distribution: The recommended best practice for distributing the produced electricity among the CSC participants is to take France’s approach in which the Collective can decide to distribute the electricity however it chooses, and it can by dynamic if desired. There should even be a mechanism in place in which, if the Collective chooses, the electricity can be distributed based on a combination of set percentages (based on investment in the installation, for example) and demand of the consumers. For example, if a participant owns 50% of the installation, but is only consuming 25% of the production while another participant is consuming 75%, the first consumer can “sell” that electricity to the second consumer based on a remuneration scheme agreed to by the Collective. A software platform can help track the amounts “sold” and can also facilitate the financial transaction between the parties. This will maximize the self-consumption rate while still offering flexibility for each consumer to be fairly compensated for the initial investment made in the installation.

6.3.4. Technical Requirements

As a best practice, Member States should make the connection and metering requirements
as simple as possible while still allowing for accurate billing of the consumers. Meters are expensive and the minimum number required should be sufficient. Spain’s legislation is quite confusing and in certain cases, such as for the inverter, additional meters are required than just to measure the installation’s production. A single meter at the border point of the grid, and meters at the consumption points, are sufficient to distribute the produced electricity among the CSC participants, bill them correctly, and determine the surplus electricity generated.

6.3.5. Self-Consumed Electricity

Self-consumed electricity should not be subject to any taxes or fees, and certainly should not be subject to taxes and fees designed to support renewables, as is the case in France and Germany. Although the RED II does state that self-consumed electricity can be subject to “non-discriminatory and proportionate charges and fees” for installations over 30kW [3], a best practice is to allow self-consumers to consume the energy produced by the installation entirely free of charge, as is the case with Spain and Slovenia.

6.3.6. Surplus Electricity

The RED II states that self-consumers have the right to be compensated for the surplus electricity they feed into the grid in a way “which reflects the market value of that electricity and which may take into account its long-term value to the grid, the environment, and society.” Therefore, the best practice recommendation is to provide a remuneration scheme for the surpluses that pays the self-consumers more than the market value of electricity, such as through a feed-in-tariff, such as how Germany compensates the surpluses generated. The next best option is net metering, which can be used to completely offset the same amount of electricity purchased from the grid, and then net billing, which still requires the consumer to pay the taxes and fees on the surplus electricity. The electricity should not have to be sold on the electricity market as this often requires the help of an aggregator to do so and leaves the purchase price open to much volatility.

6.3.7. Additional Best Practices

In addition to the best practices listed above specific to the categories analyzed for each country, there are other best practices that Member States should consider when drafting their legislation.

As CSC and RECs are new concepts, countries should share knowledge and personal experiences with each other, so that learnings from first movers can be taken into consideration as Member States later to the game begin designing their respective approaches. Countries should also include a set timeframe to revisit the legislation and
adjust it based on feedback and findings, such as France has provisioned to do in 2023 [54]. Another way of incorporating feedback and learnings is to take an approach similar to that of Portugal and Wallonia in Belgium, two countries/regions that previously had little to no experience with CSC and RECs, is to gradually transpose the directives and create a legal space to test out and experiment with the concepts and the best way of implementing them based on each country’s specific situation [47].

Another best practice is to ensure the legislation is clear and straightforward. In Germany the vagueness of “close proximity” has resulted in lawsuits, and in many cases potential participants of Tenant Electricity Sharing have to hire legal experts to clarify if they qualify due to uncertainties about the ownership structure of the building and spatial requirements in the legislation [65]. Spain’s legislation is also less straightforward and includes rules about auxiliary services and “titularidad” that are based on very outdated energy laws [63]. Countries should determine where old laws are causing CSC legislation to be unnecessarily complex and update them or make exceptions.

Finally, consumers in all parts of a country should be able to equally benefit from CSC, despite climatic conditions. For example, in the south of France, there is more uptake of rooftop PV for CSC than in the north because it has better sun conditions. Therefore, the ROI of PV panels is shorter than in the north and makes more economic sense [53]. France, and other countries with similar climatic differences, should use grants, subsidies, or some other economic scheme to make PV more viable in less sunny regions so that consumers are not excluded from actively participating in the energy transition solely based on the climatic conditions in which they live.
Conclusions

The European Union has created legislation that requires Member States to permit and develop a regulatory framework that supports the collective self-consumption of renewable electricity among two or more consumers. Collective self-consumption has the potential to help countries reach their renewable energy targets, more efficiently utilize electricity generated from solar PV, and to allow citizens to actively participate in the energy transition as well as economically benefit from it.

A number of Member States have already implemented legislation that allows collective self-consumption, or a form of it, and five of those countries were selected to analyze further. First, their population, wealth, and energy statistics were analyzed, along with their National Energy and Climate Plans, to benchmark the situation in each country. Then their legislation permitting collective self-consumption was analyzed, specifically focused on solar PV, to compare the countries across common categories that include proximity requirements, size restrictions, roles and responsibilities of stakeholders, the organization of the Collective members and other administrative procedures, the technical requirements of the installation, how self-consumed electricity is handled, and the remuneration scheme for surplus electricity. The countries were ranked against each other for the categories analyzed, with the approach that most closely followed the REDII, put the consumer first, and provided the most flexibility and accessibility ranking highest. Then trends and correlations were drawn about the approaches based on the benchmarking performed of each country. Finally, best practices for CSC were recommend for Member States to consider when updating and drafting their legislation.

As more Member States create legislation about CSC, it will be crucial to analyze and critique the approaches and try to draw conclusions about which types of approaches best work for which types of countries. Further, Member States should learn from their experiences with collective self-consumption, knowledge share with other countries, and update their legislation accordingly, so that Europe can become the continent leading the way in community renewable energy.
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Bibliography

Bibliographic references


