UNIVERSITY OF PIRAEUS
Department of International & European Studies
MSc in Energy: Strategy, Law and Economics

A dissertation submitted in partial fulfillment of the requirements of Piraeus University, Master Science Program in Strategy, Law & Economics

Department: International & European Studies

Title: Energy Communities: The case of Greece

Triantafyllopoulou Krystallia (MEN23046)

Supervisor: Galanos Georgios

Piraeus, 2025

Submission Date: 03/11/2025

Affirmation

The intellectual work fulfilled and submitted based on the delivered master thesis is exclusive property of mine personally. Appropriate credit has been given in this diploma thesis regarding any information and material included in it that has been derived from other sources. I am also fully aware that any misrepresentation in connection with this declaration may at any time result in immediate revocation of the degree title.

Triantafyllopoulou Krystallia

Abstract

The global energy landscape has endured reflective transformations the recent years, considering urgent concerns which have arisen. Climate change, which is intricately linked to fossil fueling overdependence or even energy security crisis, are among the challenges which drive the profound evolution in the energy industry. Dynamically, the European Union has been engaged in this transition through motivated legislation and ambitious strategies such as the European Green Deal. Collective efforts aim to facilitate decarbonization and simultaneously shape undisrupted and correlated energy systems. The evolution of Energy Communities has been considered a structural new era innovation which combines social cohesion and sustainability.

Focusing on Greece, which has been historically dependent to external energy suppliers and for years have placed lignite production as a principal energy strategy, the forthcoming European shift on energy related issues, bears complicated integration challenges. Although facing internal financial and social uncertainty, Greece demonstrates valuable endeavors to associate with European energy guidelines. After 2018, with the establishment of Energy Community legislation and proving support of energy democracy, Greece oversees both internal and external pressure to properly adjust to a carbon-neutral environment while facing energy poverty due to the financial vulnerable Greek economy and the complex geographical characteristics.

Keywords: Energy Communities (ECs), Renewable Energy Directive II, Prosumer Participation, Collective Self-Consumption (CSC), Greek Legal Framework, Decarbonization, Energy Transition

Acknowledgements

Educational journeys often resemble navigation through uncertain seas; therefore, I wish to express my gratitude to those who helped me adjust the sails through my personal educational experience.

Therefore, I sincerely thank my professors for their pivotal contribution to my academic path, specifically Professor George Galanos for his valuable insights on my dissertation. Finally, I am deeply indebted to the close people in my life for the support and inspiration they have consistently offered me.

Table of Contents

Energy Communities: The case of Greece

List of Figures

List of Tables

Chapter 1: Introduction

Transitioning to sustainable energy sources has been converted into a critical matter in our era. Global leadership and geopolitics demonstrate the instability of global coordination as it comes to climate policy issues. President Trump, on January 20th, 2025, declared that "*I, Donald J. Trump, President of the United States of America, provide notification of withdrawal from the Paris Agreement*"[1]. Thus, USA's significant involvement to climate change commitments has been paused. This withdrawal challenges global collaboration on climate related governance. On the contrary, the European landscape on energy governance encounters internal disputes in reaching climate neutrality and greener future. For instance, Emissions Trade System (EU ETS)[2] has been considered controversial as it has been applied to industrial sector or European maritime industry and vacillates between greener practices and commercial competitiveness. Whereas European orientation on renewables has been clearly proven, via various projects such as the formation and support of Energy Communities.

Global leadership inconsistencies appear contradictory to public environmental concerns which only become greater. Public awareness of environmental crisis has unveiled multiple movements towards greener habits which keep the momentum alive, even if national policies seem to be inefficient. Public participation in energy transition is of core importance, consequently Energy Communities could have not been developed if it were not citizen's devotion and dedication to sustainability. More specifically, via the 2025 European Climate Survey[3] we may obtain data regarding the environmental concerns among European Citizens. There is convincing evidence that climate change alarms EU citizens, since 81% confirm that by 2025 Europe has to reach the target of becoming climate neutral. Complementing the abovementioned, nine out of ten citizens demand more EU action in strengthening renewable energy generation. Focusing on Greece, public opinion interconnects energy security and limited trust to national environmental policies as a reasonable ground to engage in sustainable initiatives.

Greece's structural energy vulnerability presents an attractive case for scrutiny. Energy Communities have been established as a response to several European legislation and environmental guidelines. They present a key instrument to combat energy poverty and to ensure social cohesion. By reviewing Energy Communities' status in Greece, with focus on Solarity Urban

[1]Executive Order 14162—Putting America First in International Environmental Agreements | the American Presidency Project, 2025 https://www.presidency.ucsb.edu/documents/executive-order-14162-putting-america-first-international-environmental-agreements
[2]Emissions Trade System https://climate.ec.europa.eu/eu-action/carbon-markets/eu-emissions-trading-system-eu-ets_en
[3]Citizen support for climate action https://climate.ec.europa.eu/citizens-stakeholders/citizen-support-climate-action_en?utm_source

Energy Community it is possible to outline the constrains which hider further development on such transition. Also, this dissertation illustrates how via citizens' engagement, environmental awareness is reinforced alongside the European vision on climate neutrality.

1.1 Aim of the dissertation

Within the context of this dissertation, the development of Energy Communities in Greece is explored in relation to the European Unions' energy transition targets. More particularly, the integration extent of core EU models (such as collective energy generation/consumption) to the Greek institutional energy framework is assessed in order to evaluate the effectiveness of these measures in suppressing national and European energy issues as exemplified by energy security, energy poverty or overdependence on fossil fuels. Through the analysis of Energy Communities, both theoretically and practically and with detailed case study on Solarity Urban Energy Community, this dissertation aspires to underscore the contribution of modern energy trends to energy democracy and social cohesion. In essence, by delineating the benefits and the limitations of Energy Communities is Greece, the objective is to shed light on whether Greece has adequately adapted on European key guidelines related to energy transition.

1.2 Methodology

The methodology is based on a qualitative approach and review of existing literature on the topic. European and Greek legislation texts and related documentation on Energy Communities have been reviewed in the context of this dissertation. To support the legislative foundation of Energy Communities both in a national and European spectrum, core legislative texts such as RED II or Internal Electricity Directive or national Greek framework on Energy Communities have been employed. Additionally, Solarity Urban Energy Community has been centered in order to estimate the structure and efficiency of an operational Greek Energy Community. Data on Solarity has been assembled from the authorized registrations of Athens Chamber of Small and Medium Industries, retrieving the founding statue and from the official website of the cooperative. Ultimately, with the assessment of legislative and secondary data, and the systematic demonstration of Solarity UEC functions, as a case in point, the dissertation aims to assess Greece's orientation towards the EU energy agenda.

1.3 Structure of the study

The dissertation is divided into 8 Chapters, each one being valuable to the purpose of this analysis.

Chapter 1, being introductory, indicates the objective, methodology, structure, and the contribution of this examination.

Chapter 2 refers to the historical energy background of Greece during the 20th century, while mentioning the distinct national energy demand and consumption patterns.

Chapter 3 presents the foundations of Energy Communities' creation whereas converging on prosumers and the pivotal social dimensions of energy on citizens.

Chapter 4 examines the range and consistency of Greek and European energy legislation.

Chapter 5 is dedicated to Energy Communities in Greece, in terms of their role, structure, regional dispersion and technical application.

Chapter 6 recapitulates the above Chapters' spectrum with the reflective case study of Solarity Urban Energy Community in terms of formation, activity, performance, and environmental range.

Chapter 7 synthetizes the core findings of this assessment in terms of presenting and evaluating the Energy Communities in the Greek national background.

Chapter 8 stands for the references and bibliography section which contributed this analysis.

1.4 Contribution of the study

This study reinforces the research on Energy Communities within the context of the urgent energy transition European countries and specifically Greece, are required to fully adapt. By examining core European legislation on Energy Communities, the sufficiency and efficiency of the respective Greek energy legislation is assessed. The presentation of Solarity Urban Energy Community approaches practically the operational strengths and limitations of the Greek Energy Communities. Thereby, the valuable contribution of Energy Communities in energy democracy and social inclusion is depicted. Lastly, the obstacles Greece is required to overcome, in order to align with EU energy targets are delineated.

Chapter 2: Before the Creation of the Energy Community's Concept

Decades before green energy and sustainability targets evolved, Greece and various European nations covered their extensive energy needs with traditional fuels such as lignite, coal, and derivatives. The previously mentioned overreliance on fossils significantly hinders clean energy, and currently, the transition to cleaner energy sources is considered one of the most complex aims of the European Union. Regarding Greek practices from the past, mining operations were a key activity in energy production. Nevertheless, it caused an over-dependence on an energy source that is currently not considered sustainable and renewable. Environmental concerns raised awareness of expanding global research on RES, and most EU nations have embraced this shift towards a greener future. Greek energy policies and legislative mentality still require further adaptation of sustainability measures. Improving energy security and sustainability has since become urgent, necessitating infrastructure development, regulatory alignment, and regional cooperation; factors that would later reinforce the Energy Community model.

2.1 Critical Aspects of Greece's Energy Transition; From Lignite to Renewables in Europe

Balancing and altering energy production and relevant consumption dynamics has been a challenging issue for most European countries, including Greece, and undoubtedly, it has been proven to be an extensive and well-promising field of research. Historically, energy production has relied on hydrocarbons and fossil fuels. During the Industrial Revolution, coal and lignite resources were crucial in energy production across European regions. Extensive mining operations met the high energy demands of major European countries such as Germany and the UK. They significantly boosted their economic output, making mines, symbols of wealth and industrial power (Lelek & Kulczycka, 2021). The internal energy mix of EU countries has depended solely for many years on mining operations and lignite excavations. Advances in technology, equipment, and energy materials have since marked considerable progress in this sector.

Lignite and coal mining operations necessitate flushing oxidized minerals, which have been pointed out to increase the risk of contamination. Heavy minerals are released from the ground into nearby water bodies. Traditional coal mining in European countries (Germany, Greece, Poland, Spain, and the UK) has utilized, among others, geological processing methods, this technique as well, to ameliorate and boost their fossil fuel production (Gombert et al., 2019***)***. With various initiatives in recent years, the European Soil Data Centre

(ESDAC)[4] has attempted to identify both the sites and the pollutants that pose immediate contamination threats to public health. It is worth noting that there were no considerations for climate impact during the First and Second Industrial Revolutions (1760-1840 and 1870-1914, correspondingly). The primary focus was on investing in mass production techniques and establishing the foundations of urbanization.

Greece's economy was distinctly underdeveloped compared to massive European industrialized production countries in the 18th and 19th centuries. Central energy production sources in the Greek territory were biomass from agricultural activities such as wood and some hydroelectric plants for limited use. The focus of this project will be on Greece, a country that possesses significant lignite reserves. Greece has historically adjusted foreign energy importation requirements by exercising its sovereign rights to exploit these resources. Conversely, despite this self-sufficiency, Greece remains a nation that, due to its comparatively modest size, is particularly vulnerable to external dynamics that can disrupt its economic, social, and developmental equilibrium (Nikas et al., 2020).

The earliest indications of lignite resource wealth were detected in the 1920s in the Ptolemaida region of Northern Greece. By the 1950s, mining operations had been instituted and developed in Aliveri, Euboea and Megalopolis, Peloponnese regions which were acknowledged for their geological resource intensity. These undertakings were segments of an extensive endeavor to utilize Greece's energy perspective, which aligned with European equivalent developments. The Public Power Corporation (PPC)[5] has performed a predominant function in Greece's energy sector since its formation in 1950. PPC, created by Greek Legislative Decree No. 4483/1950[6], issued by the government on August 8, 1950, was authorized as a public interest organization accountable for supervising lignite extraction and electricity production throughout the country. Over its 74-year history, PPC has overseen Greece's energy production evolution, transitioning from lignite to renewable energy sources (RES).

Under governmental auspices, the exploitation of the sites, along with many others, served as the primary energy source in Greece until the late 1970s. The Public Power Corporation (PPC) classified itself as a revolutionary entity within the Greek territory by incorporating solar, hydroelectric, wind, and geothermal power into the nation's energy production. In both global and European circumstances, the shift away from traditional energy production practices was accelerated by vast ecological concerns. Newly introduced environmental concerns were formally presented and acknowledged in the

[4]European Soil Data Centre (ESDAC) https://esdac.jrc.ec.europa.eu/content/progress-management-contaminated-sites-europe-0

[5]Public Power Corporation https://www.ppcgroup.com/el/omilos-dei/sxetika-me-emas/istoriki-diadromi/

[6]Greek Legislative Decree No. 4483/1950
https://www.kodiko.gr/nomothesia/document/580255/nomos-4483-1965

Stockholm Declaration of 1972[7] and embraced in the Rio Declaration of 1992[8]. Both declarations represented distinguished moments for the development of environmental diplomacy across nations, and United Nations Conferences spread world widely a more sustainable consensus on resource management for future generations and humanity. The establishment of the Intergovernmental Panel on Climate Change (IPCC)[9], in 1988, dynamically demonstrated that environmental concerns require coordinated reflection and well-orchestrated action plans.

In conclusion, as Zou et al. (2016) suitably detected, "world energy development is entering a new historical period when clean and low-carbon energy is inevitably required." The European Union acknowledged this context in the early 1990s by enacting the Electricity[10] and Gas Directives[11] (from 2004, no longer in force), ratifying the Kyoto Protocol[12] in 1997, and adopting the Lisbon Treaty[13] in 2007. These initiatives and successive adjustments were deliberately associated with global Sustainable Development Goals (SDGs)[14], highlighting the EU's pledge to enhance a sustainable, low-carbon energy future. As a member state of the European Union since 1981, Greece has constantly supported the Union's environmental directives by making strategic adjustments in its energy production policies. Despite enduring significant economic and political instability, principally throughout phases of severe monetary crisis, Greece has attempted to embrace the transition to renewable energy sources (RES) despite various obstacles.

2.2 Factors Influencing Greece's Energy Demand and Consumption Patterns

Environmental targets and climate change mitigation have caused energy consumption and production patterns to fluctuate. From a broader developmental perspective, the GDP growth of European countries, encompassing Greece, demonstrates a close correlation between energy production and energy consumption. Bartoletto and Rubio (2008) similarly documented that early industrialization in Mediterranean countries marked a shift from the consumption of firewood, which met basic human needs in the late 1800s, to the rise of fossil fuels and electricity (including nuclear energy) throughout the 1900s to the present day. In Western economies, such as France and Germany, leaders in production industries, similar production and consumption patterns have traditionally been recorded to meet their energy demands.

[7]Stockholm Declaration of 1972 https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=6471
[8]Rio Declaration of 1992 https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf
[9]Intergovernmental Panel on Climate Change https://www.ipcc.ch/
[10]Electricity Directive 96/92/EC https://eur-lex.europa.eu/eli/dir/1996/92/oj
[11]Gas Directive 98/30/EC https://eur-lex.europa.eu/eli/dir/1998/30/oj
[12]Kyoto Protocol, 1997 https://unfccc.int/kyoto_protocol
[13]Lisbon Treaty, 2007 https://www.europarl.europa.eu/factsheets/en/sheet/5/the-treaty-of-lisbon
[14]Sustainable Development Goals https://sdgs.un.org/goals

World War I and II significantly impacted population and GDP development in Greece during the 20th century. However, the Greek Civil War (1946-1949) introduced profound ideological conflicts that delayed Greek economic progress. As Bartoletto and Rubio (2008) noted, *"changes in the economic structure, demographic growth, technological change in general"* profoundly influence the energy consumption preferences of most nations. Demographic evolution and urbanization, in particular, have been observed to correlate positively with increased energy demands. While advancements in science and technology have accelerated energy efficiency measures, they have also introduced additional requirements that drive energy consumption. Greek energy consumption patterns, until the early 2000s, were moderately influenced by these dynamics.

Greece's energy reserves substantially influence the country's energy demand dynamics. Greece has substantial fossil fuel reserves and remarkably black coal deposits in Macedonia and the Peloponnese. Over the past 75 years, these reserves have been widely exploited by the Public Power Corporation (PPC), contributing to the development of a largely fossil fuel-dependent country. From a contemporary perspective, as illustrated by Papanicolaou et al. (2004), industrial minerals and rocks are widespread across Greek territory, alongside various valuable geological resources. Although the calorific value of Greece's lignite is relatively low, its abundance has made it a key energy resource.

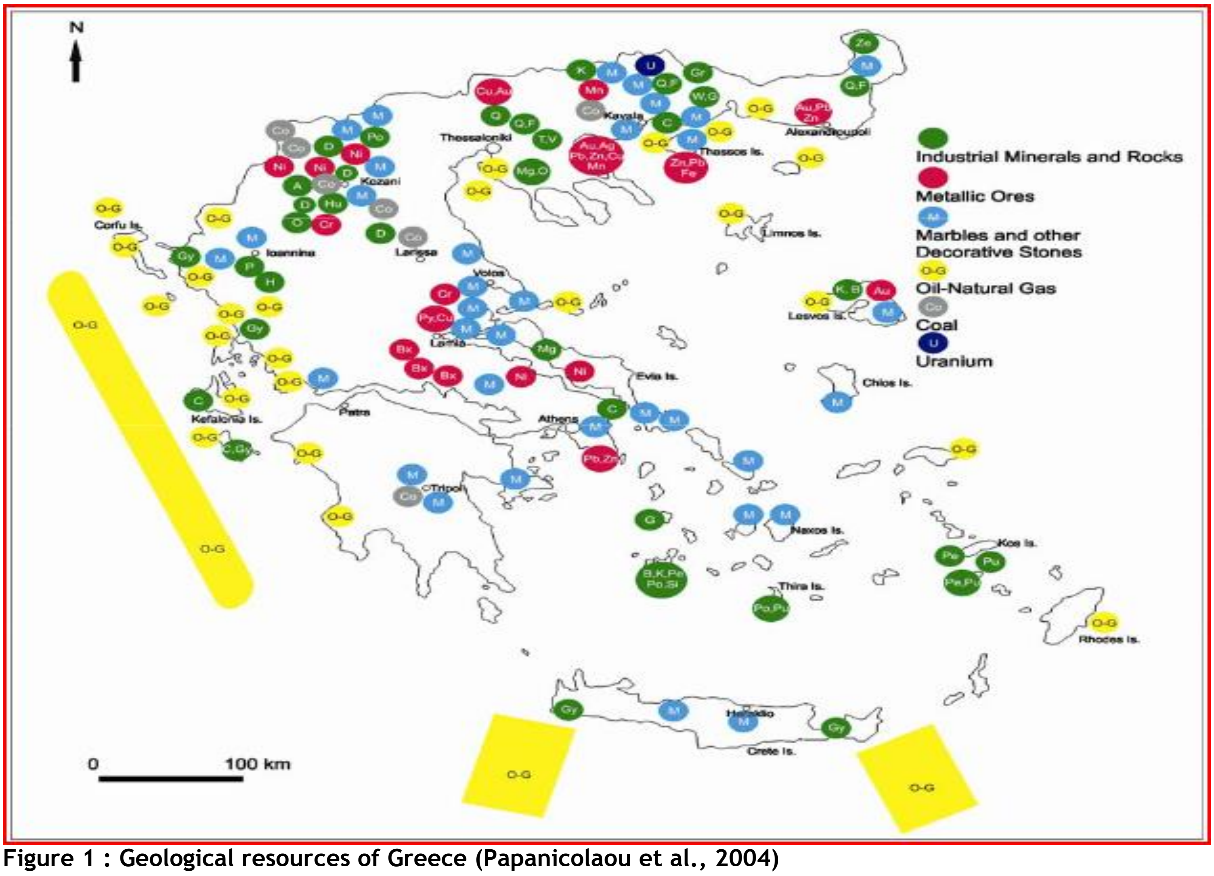

Figure 1 : Geological resources of Greece (Papanicolaou et al., 2004)

However, Greece lacks broad natural gas and oil reserves *(O-G indications in Figure 1)*, restricting its ability to meet domestic energy needs through local resources. Existing reserves are either at the exploration stage or in early exploitation phases. Subsequently, Greece relies heavily on energy imports from Türkiye, Azerbaijan, and Bulgaria, particularly in natural gas. The country's participation in major pipeline projects and the development of LNG storage facilities are decisive mechanisms of its energy strategy, facilitating the obtaining of a more stable and distinct energy supply.

Greek energy demand is severely shaped by the Mediterranean climate dynamics. Even though it shares commonalities with the general European climate, Greece's distinctive geographical features—extending from vast coastal zones to mountainous regions (Asimakopoulos et al., 2012)—establish additional complexity to its energy consumption patterns. The interface between this diverse topography and cyclical climatic variations results in significant fluctuations in energy demand, with consumption peaks occurring during the summer and the colder winter months, depending on the specific region. These climatic and geographical dynamics highlight the requirement for a highly adjustable energy management strategy that effectively responds to the varying energy requirements across different regions and seasons.

2.3 Energy Security and Policy Evolution in Greece

In recent decades, European awareness of energy security has evolved significantly. The multifaceted nature of energy security was first redefined during the 1973 Oil Crisis, emphasizing the tactical importance of resource control for national security. As Arman et al. (2020) describe, this period shifted towards *"ensuring the continuity of the flow of resources, a must for the economy…as a state's military security."* Reflecting that current energy tendencies prioritize the social element, Jones et al. (2017) underline that energy security imbalances currently encompass *"qualitative dimensions, such as social acceptability, availability, and affordability of energy supplies."* Despite undergoing periods of energy shortages, Greece has become a fundamental participant in Eastern Mediterranean energy security. Greece has actively embraced greener energy policies and alternative energy projects to balance imports and secure regional stability.

Geopolitics highly impacts energy flows. Countries also reflect on public perception when developing and implementing energy schemes. Several EU countries have implemented austerity measures (Papada & Kaliampakos, 2016), resulting in energy insecurity contributing to energy poverty. This issue concerns low and middle-income households, limiting their ability to meet fundamental everyday energy needs. Greece has encountered substantial socioeconomic challenges for several years. According to Papada & Kaliampakos (2016), using the official expenditure-based approach, energy poverty in Greece affects up to 58% of vulnerable households. Greek society recognizes the need to transition from the conventional reliance on fossil fuels to a more sustainable future, based on renewable energy for domestic energy generation and consumption (Jones et al., 2017).

Energy autarky and effective energy management both represent societal challenges linked to sustainability, as they affect public well-being, climate stability, and resource availability for forthcoming generations. Most of the literature on energy autarky underlines community ownership and awareness, with a particular focus on developing energy autonomy at the community level, notably within the agricultural sector. Conversely, most researchers commonly determine that achieving complete energy autonomy is likely unrealistic. Likewise, Müller et al. (2011) emphasize that *" energy autarky should be understood as a vision to move towards, rather than a call for regional isolation,"* a model that aligns closely with both European and Greek regional energy policies.

Greek energy policies foster mutual benefits with neighboring countries. Nonetheless, diplomatic efforts, independently, appear insufficient to address the weaknesses in energy infrastructure and the deficiency of investment incentives (Deniozos, 2019). Greek authorities' obligation aligns the legal and regulatory energy framework with the country's specific needs and current trends, to safeguard Greek interests effectively. As thoroughly examined by Gkonis et al. (2020), launching a robust energy framework is a complicated, multidirectional task for government authorities. The EU's energy agenda, directives, measures, and proposed technologies must be incorporated into the interests of multiple stakeholders in the national public and private sectors. Appropriate frameworks should oversee domestic constraints and the multidimensional risks of efficiently managing energy systems.

Chapter 3: Prosumer Concept & Energy Communities

The shift from traditional utility grids to smart energy grids has transformed the conventional consumer role, encouraging citizens for a more active participation in energy transactions. This evolution gives rise to the concept of the "prosumer," wherein the typical energy consumer, once solely subject to provider pricing, based on usage, now also takes on the role of an energy producer. The Prosumer Community Group (PCG) (Espe, Potdar and Chang, 2018) represents users who generate and share energy within the smart grid. Espe, Potdar, and Chang's, 2018, literature review highlights that smart grids are built on intelligent energy and exchange principles, supported by a more resourceful management system and a robust legislative framework focused on sustainability and efficiency. Their study also presents several key propositions to explore the "prosumer further" concept.

Various consumer community groups exist, primarily distinguished by their shared goals and interrelated relationships. Nonetheless, it is critical to note the distinction between PCGs and traditional energy consumers. Prosumers consume energy and generate, share, store, and manage energy production to boost household energy use effectively. Advanced grid technologies and new data generation methods have been integrated into households' daily supply and demand cycles, aligning with the shared energy grid's capacity fluctuations. Under these principles, Espe, Potdar, and Chang's 2018, conclude that prosumers provoke evolutionary advancements into the grid by demonstrating economic, operational, and environmental gains.

The evolution of smart grids reinforces sustainability within the complex energy network, positioning prosumers as essential contributors who boost flexibility and create mutual benefits through their active engagement and devotion. Energy system planning and proper prosumer management empower the energy sharing process, *"positive reciprocal relationship between prosumers and energy providers motivates prosumers to reduce energy consumption leading to an efficient smart grid."*[15] Enriched efficiency in energy management establishes a positive ecological footprint within the energy network, enabling prosumers to energetically contribute to energy activities that were formerly inaccessible to them.

The prosumer concept is intricately linked to developing Energy Communities, granting consumers greater autonomy in managing specific energy flows within the grid. Energy Communities, primarily oriented toward sustainable energy production, share a common goal-driven purpose with the prosumer model. Built upon this prosumer framework, these organized communities have, by 2025, gained official recognition and protection through legislative instruments at local, national, and global range. Citizens are encouraged to invest in advanced technologies to reduce dependence on monopolistic energy providers, securing their right to participate actively in the energy

[15]Espe, E., Potdar, V. and Chang, E. (2018) 'Prosumer Communities and Relationships in Smart Grids: A Literature Review, Evolution and Future Directions' https://doi.org/10.3390/en11102528

market. Community members enhance their bargaining power through these collective entities and assert fundamental rights within the energy network, establishing a balanced presence among traditional energy players.

The extensive terminology surrounding new-era energy network participants reflects the broad application of local communities. The following self-made table provides terminology to display the diversity of concepts and roles within contemporary energy networks, highlighting the plentiful ways local communities and individuals are progressively involved in energy production, management, and consumption. The terminology table provided in this thesis will be a key reference, presenting clarity on terms principal to understanding Energy Communities' growth, functioning, and influence.

Term	Definition	Source
I. Renewable Energy Community (REC)	"A cooperative effort involving individuals, businesses, or public organizations that work together to generate, manage, and distribute energy produced from renewable sources such as wind, solar, or biomass."	European Union's Renewable Energy Directive (RED II) 2018.
II. Citizen Energy Community (CEC)	"Citizens primarily drive a community to produce, consume, and manage energy, often from renewable sources."	European Parliament, Directive (EU) 2019/944 on standard rules for the internal electricity market.
III. Collective Self-Consumption (CSC)	"A system where multiple participants share energy produced from a common renewable installation for local use."	Bauwens, T., et al. (2016). Explaining the diversity of motivations behind community renewable energy.
IV. Peer-to-Peer (P2P) Energy Trading	"A decentralized energy exchange system where individuals or entities directly trade energy with each other."	Morstyn, T., et al. (2018). Using peer-to-peer energy-trading platforms for residential demand response.

V. Sustainable Energy Community (SEC)	"A group that works towards adopting sustainable energy practices and reducing carbon emissions in energy use."	Dóci, G., et al. (2015). Community energy: A review of the research literature on the socio-technical transition and motivation behind it.
VI. Clean Energy Communities	"Communities focused on generating and utilizing clean, renewable energy to reduce environmental impact."	Seyfang, G., & Smith, A. (2007). Grassroots innovations for sustainable development: Community energy initiatives in the UK.
VII. Low Carbon Communities (LCC)	"Communities that aim to reduce carbon emissions through renewable energy, energy efficiency, and sustainability."	Middlemiss, L. (2018). Sustainable consumption at home: Community energy and social action.
VIII. Energy Resilience Community	"A community that enhances resilience to energy disruptions by relying on local, renewable energy sources."	Walker, G., & Devine-Wright, P. (2008). Community renewable energy: What should it mean?
IX. Prosumer Group	"A group of individuals or organizations that produce and consume energy, often from renewable sources."	Gui, E. M., et al. (2017). Prosumers, innovation, and the disruptive role of renewable energy in Australia.
X. Energy Storage Community (ESC)	"A group that collectively invests in energy storage technologies to effectively manage energy supply and demand."	Hall, S., & Roelich, K. (2016). Business model innovation in electricity supply markets: The role of local energy.

Table 1 Energy Community Categories

3.1 Collective Self-Consumption (CSC)

The evolution of energy policies, driven by the need for sustainability and climate change mitigation, has shaped various energy consumption trends across Europe. Collective Self-Consumption (CSC) has been widely adopted and implemented at the individual level, with consumers increasingly embracing the concept of the "prosumer" as examined above. On the other hand, there is the synchronized growth of Energy Communities (EC), with analogous aims such as Collective Self Consumption, which embody clean energy generation and effective energy management. As it will be analyzed later on, in Chapter 4, European Union with Clean Energy Package (introduced 2016, last updated in 2019)[16] along with RED I (2009/28/EC)[17] & RED II (2018/2001/EU)[18] with the newest update on 16.07.2024, promotes these innovative energy proposals with the contribution of all Member States. The above-mentioned provisions as per the EU's instructions, are to be incorporated into all members' national legislation dynamically, by directing to engage in "*the empowerment of European citizens in the energy market*" (Frieden et al., 2020)

Collective Self Consumption (CSC) framework is widely presented on RED II (Art 21)[19], with the division of the term into two subcategories of "Renewables Self-Consumer" & "Jointly Acting Renewables Self-Consumers". This provision seeks to safeguard the rights of consumers who become renewable energy self-consumers, enabling them to generate, store, use, and trade renewable energy fairly and equitably. As clarified by Frieden et al., 2020, Collective Self Consumption activities shall arise equally under the scope of an Energy Community. Still, legislation distinguishes the terminology, underlining this version's *"less organizational format and market aspect"* application. Abiding by the RED II provisions, the transition from individual-self-consumption to joint-acting consumption shall arise when *"self-generated renewable electricity is produced in installations with a total installed electrical capacity of more than 30 kW"* and players *"located in the same building, including multi-apartment blocks"*.

Collective Self-Consumers (CSCs) are urged to contribute any energy surplus to the central grid, receiving fair, market-based compensation under *"non-discriminatory and proportionate…fees"* [20].The EU asks Member States to disregard excessive obstacles to renewable energy production by implementing structures that energetically empower consumers. These frameworks aim to grant mutual benefits by ensuring cleaner, more accessible energy, even for vulnerable households. Moreover, noticeably acknowledged in RED II (Art. 21 [6]), as authorized by Regulation (EU) 2018/1999 (Governance of the Energy Union and Climate Action Regulation)[21], a segment of Clean Energy for All EU, Member States shall provide reviews and reports of their projects of implementation.

Local energy generation from RES improves effectiveness by *"reducing power losses and deferring future investments in transmission and distribution infrastructure"* (Gallego-Castillo, Heleno, and Victoria, 2021) and refers mainly to electricity generation. From a social perspective, the EU's ongoing

[16]Clean Energy Package https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en
[17]RED I https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en
[18]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
[19]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
[20]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
[21]Governance of the Energy Union & Climate Action Regulation https://eur-lex.europa.eu/eli/dir/2018/2001/2024-07-16

attempts focus on ensuring the inclusion of all household consumers as emerging actors in the energy sector, with a visible reduction in electricity bills as a motive. Conversely, competing with dominant market players in renewable energy generation, such as photovoltaic (PV) production, remains challenging without sufficient funding and knowledge-sharing for self-consumers. Similarly, as expressed by Dehler et al., 2017, PV energy storage for self-consumption, is based on battery technology as a more affordable option, which is opposed to the clean energy concept proposed.

Technological and financial constraints hinder the extensive adoption of the Collective Self-Consumption (CSC) model, as energy generation autonomy requires a substantial investment that most households cannot afford, given the risks related to this emerging concept. Furthermore, the operational maturity of established players in the energy sector creates significant competition, making it challenging for new actors to participate in and contribute to the grid's energy supply. As a result, Collective Self Consumption schemes require revision and improvement to enable self-consumers to increase. For this model to succeed, it is fundamental that each Member State, vigorously reinforces prosumers, through a comprehensive policy framework, financial incentives, and technical assistance.

Despite the above-mentioned barriers, many European countries have effectively integrated Collective Self Consumption into their central grids and have begun to benefit from its encouraging outcomes. It is imperative to underline that each country has achieved a specific level of Collective Self Consumption incorporation based on its exclusive potential and regulatory setting. The following insights are drawn from the comparative analysis by Frieden et al. (2021), entitled *"Are We on the Right Track? Collective Self-Consumption and Energy Communities in the European Union."* Various aspects shape this enactment procedure, exhibiting distinct legislative methods and operational versions. Further below, in line with the introductory efforts to accommodate Collective Self Consumption lie key features of the process in Austria, Croatia, Greece, Portugal, Slovenia, and Spain as European Union Member States equally engaged in green energy transition.

Collective Self Consumption initial implementation frameworks across European countries are diverse. Each country's internal attempts at integration prove contrasting levels of efficiency. Austria and Spain lead the way with expanded structures. Austria announced Collective Self Consumption in 2017, appointing essential roles to Distribution System Operators (DSOs) and developing its structure in 2021 via the Renewables Expansion Law (EAG)[22]. Regardless of the development, various challenges delayed the process, such as constrained use of the public grid and inadequate real-time data admission. Equally, Spain's framework, recognized under Royal Decree 244/2019[23], permits electricity sharing from neighboring renewable

[22]Renewables Expansion Law https://commission.europa.eu/projects/entry-force-law-climate-change-and-energy-transition_en
[23]Spanish Royal Decree 244/2019 https://climate-laws.org/document/royal-decree-244-2019-regulating-the-administrative-technical-and-economic-conditions-of-the-self-consumption-of-electric-energy_8775

sources and incorporates public grid use under outlined specifications. Conversely, Spain faced severe geographic limitations and governmental complexities which in the initial stages limited wider involvement. Both countries finally presented functioning models after addressing the aforementioned emerged limitations

What is more, Greece and Slovenia introduced backgrounds that concentrate on collective and community-driven attempts but also encountered substantial obstacles for progression. Greece's 2018 Energy Community law[24] reinforced cooperative models, indicating a sizable listing of Energy Communities. Nonetheless, concerns like abuse of motivation, fragmented regulations, and virtual net metering limitations impeded further advancement. Slovenia's 2019 regulation[25] allowed Collective Self Consumption in multi-apartment buildings and *"RES communities"* without involving a legal entity, except for spatial constraints and indeterminate roles for Distribution System Operators scalability. Both countries emphasized the potential for community-driven Collective Self Consumption initiatives but primarily concentrated on operational and regulatory disputes. Croatia and Portugal in 2021 displayed delayed operational progress. Portugal introduced Collective Self Consumption in 2019 but paused various active projects due to transparency concerns, governmental gaps, and inadequate financial cooperation. Both countries enforced robust governmental support to promote their Collective Self Consumption frameworks and foster citizen-led energy programs.

To conclude, the integration of Collective Self-Consumption (CSC) across Europe revealed meaningful progress despite numerous constraints. Austria and Spain lead with advanced frameworks but face limitations in grid access and geographic restrictions. Greece and Slovenia emphasized community-driven initiatives yet encountered regulatory and operational barriers. Croatia and Portugal remained in the preliminary stages in comparison to other Member States, hindered by transparency, financial, and administrative issues. Only after they applied tailored policies and simplified methods, they succeeded in overcoming the initial barriers.

As we have observed, Energy Communities development was a coordinated action that confirmed the high value of the energy sector and the gains of significant transformation breakthroughs. As Gjorgievski, Cundeva, and Georghiou mentioned in 2021, sociopolitical interactions among consumers, energy service operators, grid operators, and government officials signify a mixture of conflicting interests. However, often the accomplishments are concealed in the orientation of mutual goals. The Clean Energy Package, with its apparent reference to Renewable Energy

[24]Law No. 4513/2018 https://clean-energy-islands.ec.europa.eu/countries/greece/legal/community-energy-policies/energy-communities-energy-cooperatives-energy

[25]Preliminary assessment of the satisfactory fulfilment of milestones and targets related to the second payment request submitted by Slovenia
https://commission.europa.eu/document/download/35548e22-8052-4702-ac2e-eccee904cec1_en?filename=C_2023_8211_1_annexe_EN.pdf&prefLang=sl

Communities (REC) on RED II and Citizen Energy Communities (CEC) on EMD II, proposes two similar kinds of Energy Communities.

Below is an insight into both Renewable Energy Communities and Citizen Energy Community proceeding with a brief comparison among them.

3.1.1 Citizen Energy Communities (CECs) & Renewable Energy Communities (RECs)

Under European Union law, both types of Energy Communities (ECs), Citizen Energy Communities (CECs), and Renewable Energy Communities (RECs) - are officially recognized as legal entities. These entities are identified by principles of accessible and voluntary involvement, guaranteeing that individuals and organizations can join without restrictive barriers. Membership admissibility extends beyond individual residents, incorporates small and medium-sized enterprises (SMEs) and community bodies like local authorities and municipalities. This all-encompassing context fosters broad participation while inspiring diverse local participants to collaborate in sustainable energy initiatives. The service-oriented model increases the sense of shared purpose, encouraging members to dynamically contribute and gain from locally operated resources.

The EU's framework for Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) enhances flexibility, particularly for Citizen Energy Communities, regarding geographical scope and cross-border collaboration. While Citizen Energy Communities face no geographic restrictions, allowing them to operate across various regions with enhanced resilience of energy projects, Renewable Energy Communities are generally limited to a more localized focus. Citizen Energy Communities pool resources and expertise from diverse areas, encouraging broad alliances and knowledge sharing.

The prohibition of large and medium-sized enterprises (LMEs) from successful supervision in both Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) is a planned approach by the EU to foster a fair-minded and wide-ranging energy market. Under this scope, EU ensures that community energy models spotlight local interests, sustainability, and reasonable access over solely profit-driven goals. This limitation allows individuals, small businesses, and local authorities to preserve decision-making power, safeguarding that the fundamental emphasis is placed on community resilience, environmental responsibility, and affordability. For Renewable Energy Communities, which aim to promote renewable energy at a community level, this measure is remarkable, as it permits local actors to drive the adoption of renewables without being surpassed by larger organizations.

Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) contrast with their scope and energy focus, yet both aim to support the EU's renewable energy growth objectives. Citizen Energy Communities are predominantly restricted to electricity but are not limited in utilizing only renewable energy sources. This flexibility permits them to combine diversity in electricity generation while fostering broader participation in the energy market incorporating also renewable sources. In contrast, Renewable Energy Communities are entirely focused on renewable energy, combining both electricity and heat, and are devoted to developing renewable energy projects at the national level. Renewable Energy Communities (RECs) follow a balanced cost structure for grid fees, charges, levies, and taxes, focusing market-driven approaches. This approach enables Renewable Energy Communities to participate in the energy market sustainably, ensuring they are not subject to undue financial pressure and are able to fulfill their role effectively, in advancing community-based renewable energy initiatives.

As per "*The Role of Local Citizen Energy Communities in the Road to Carbon-Neutral Power Systems: Outcomes from a Case Study in Portugal*," Algarvio, 2021, asserts that the presence of locals in sustainable carbon-neutral societies is an indispensable component of success. European governments incentivize Citizen Energy Communities (CECs) by offering discounts and subsidies for those engaging in self-consumption, making CECs an attractive opportunity for consumers interested in plummeting energy costs and contributing to the energy market. These motivations inspire membership to reduce reliance on the central grid. Nonetheless, CECs face operational challenges due to the fundamental changeability of renewable energy sources. Renewable energy imbalances may vary significantly in the short term and influence long-term uncertainties in capacity factors Their limitations on variables such as geographic sites and resource surroundings, theoretically and practically impact the reliability of energy production.

The International Energy Agency[26] supports that authorities should tolerate energy aggregation in generation and capacity, while reducing incentives and subsidies that disturb natural price variations. In addition, as they underline, such interventions can interfere with the free market and reduce social welfare by limiting competition. In contrast, free price adjustment seems to be more efficient for the market and society. On the contrary, as Pereira et al., 2021 present in their study, system digitalization and innovative grid management are key for citizens to join and comprehend all aspects of energy production. The electronic platforms utilized by Energy Communities are web-based, enabling community operators to examine the historical data of end-users and perform diverse services to ensure efficient community supervision.

[26]International Energy Agency (2025) *IEA* https://www.iea.org/.

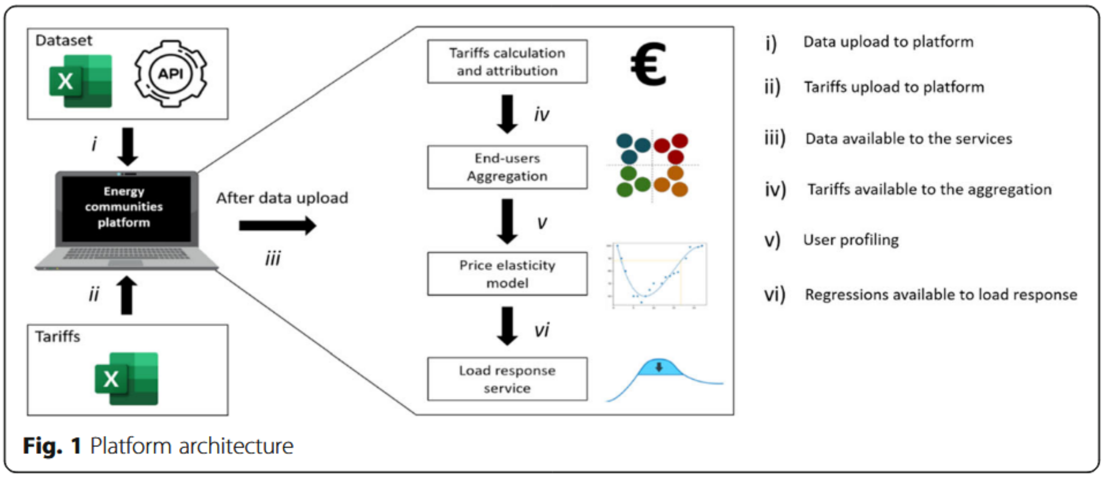

Figure 2 Proposed Energy Communities platform (Pereira et al., 2021)

As a case in point, Figure 2 provides a detailed overview of the design of a web-based platform offered to reinforce the management of Energy Communities. The platform enables community operators to upload datasets and tariff information, which develops availability for a range of systematic services. Once data is uploaded, the platform simplifies numerous key purposes: it computes and allocates optimal tariffs, aggregates end-users based on their energy profiles, models price elasticity to comprehend how users might respond to price changes and offers load response alternatives to adjust demand. This multidimensional approach allows community operators to analyze user data successfully, by optimizing energy usage patterns while reducing management costs, and ensuring the productivity of the Energy Community. Each section of the platform operates in coordination with historical data and tariff intelligence. Thus, dynamic energy management fits the needs of community members. The presented platform model demonstrates how technology and expertise have been expanded in the energy sector, even on a community level, and makes energy market involvement more accessible than expected.

3.1.2 Social Barriers in Green Energy Transition

The invaluable worth of citizen contribution in this transitory effort is not to be overlooked. The EU and national government authorities estimate that local communities' united participation will boost and facilitate energy transition. Although all kinds of Energy Communities may have different structural characteristics, locals constitute them, willing to participate in these greener initiatives. Nevertheless, evident societal issues also affect their formation and activities scope. As depicted by Sassman (2021), a membership societal gap has been observed, which challenges local energy initiatives.

Economic and racial inequality is also expressed in Energy Communities composition, and various Justice and Social movements have argued that equality in RES initiatives will only enable efficiency in cleaner energy adoption. Yet, since lower-income households are excluded from these initiatives, their vulnerability to energy poverty is indirectly maximized. Due to their limited investment budget, enjoying the upcoming benefits of more affordable energy generation is portrayed as illusional.

New Green Deal[27] proposed by the EU embodies all citizen participation. Since renewable energy on a community level is primarily generated by wind and sun within-house building installations, there is no reason other than an economic-racial background which excludes vulnerable households. The notion of decarbonizing is active, and citizens have grasped the immediate need to minimize our dependence on fossils, predominantly at an electricity generation spectrum. It has been considered a weak spot of energy and environmental laws that often omit community empowerment initiatives. Education in decarbonization will elevate community potential since participation is a tool for inclusion in decision-making.

Sassman (2021) also mentions that societal impediments only hinder partially communities' participation in greener energy transition. Opposition movements have emerged from citizens' objection to this transition. Undoubtedly, the well-known “Not in My Back Yard” movement (NIMBY[28]) was initiated in the US, regarding major environmental projects that local community authorities tried to implement in neighborhoods without receiving full support from locals. Nevertheless, dealing with global warming and urgent energy transition, surely requires cooperation and dispute resolution. Certain sacrifices should be made in order to achieve such large-scale targets. To be clarified, the issues of EU local communities are not identical to those of the US, yet there are similarities in their marginalization pattern. Discussing racial representation, even the origins of the NIMBY movement apply mainly to wealthy communities which choose to ignore global problems and do not wish to alter their habits while participating in cleaner energy efforts. It is frequently refrained from being used in literature due to its racial-related background.

The ‘Green vs. Green’ community opposition has vastly expanded in EU communities. Specific green energy initiatives could potentially harm the wildlife balances of village communities, so locals preferentially deny being a part of this transition. Surely, damaging the natural environment and wildlife would be better avoided, yet village and city communities should participate in this transition. In combination with political discussion, public participation makes it possible to eliminate opposing interests. Societal values must be stressed during this transition era, and equality matters in green energy. These normative issues prove that energy transition does not focus only on technological application but stems from a positive citizen attitude on a core level.

3.2 Citizen Participation in Energy Transition

[27] EU Green Deal https://www.consilium.europa.eu/en/policies/european-green-deal/
[28] Not in My Back Yard Movement https://dictionary.cambridge.org/dictionary/english/nimby

As depicted above, energy transition is not simply a technological and industrial evolution. Managing this transition and emphasizing social justice perspectives, is an active prerequisite for successfully implementing a new way of meeting human energy needs. As Dunphy and Lennon, 2022, present in their study regarding citizen participation in energy transition, they propose that the energy system should first be examined as a social system. Their methodology demonstrates that energy transition is a multidimensional sociotechnical structure in which the social element is often neglected.

Energy democratization was deemed to resolve social justice issues. Under the context of this dissertation, local communities are dynamic systems, and precise societal transformations will enable them to align with carbon-neutrality at a local level. As demonstrated at the beginning of this chapter, the "prosumer" concept has emerged in the need for citizen involvement in energy-related activities via multiple roles. Under this principle, the EU has endorsed the New Green Deal, with Energy Packages to be citizen-oriented to accelerate this roadmap.

To validate those societal aspects of energy transition, which require precise handling, the H2020 project (Green Energy Transition Actions)[29] is an initiative of the Lappeenranta-Lahti University of Technology (LUT)[30] in Finland, with various collaborate countries across Europe such as the Netherlands, Italy, Germany, Portugal, Finland & Spain. The European Union supported this initiative according to official budgeting statistics of the project, contributing a net contribution of 2.277.829,29 €. The initiative's target was to document the barriers that hinder energy citizenship evolution, from May 2021 to October 2023, to set a firm foundation for further research. The project was structured upon two essential pillars: "Community Transition Pathways" (CTP) and "Energy Citizen Contracts" (ECCs). Boeri et al., 2024, upon their scientific research on "*Decarbonization Roadmaps and Community Transition Pathways: empowering Energy Citizenship in the EU,*" have illustrated the primitive aspects of the H2020 project.

The Community Transition Pathways concept relates to numerous geopolitical backgrounds and is funded by the notion that there is no single path to achieving clean energy. The decision-making engagement shall encompass the adoption of RES and support of local Energy Communities proposals for energy modernization. The interconnection of various groups as variables in this energy project brought valuable results in entangling energy transition routes. Community Transition Pathways are demonstrated to be politically manipulated as all transition pathways represent societal values as normative instruments. Their role was to offer direction (present and future-oriented) in a collaboration formula of geographical and behavioral contexts (Boeri et al., 2024). Due to this fact, they consist of three sections: *"Setting the Boundaries," "Defining the Vision,"* and *"Envisioning the Needed Actions."* These steps enable corridors for dialogue, recognizing the diversity of the groups yet approaching the concerns with open-minded measures.

[29]H2020 project https://cordis.europa.eu/project/id/101022317
[30]LUT University (2024) https://www.lut.fi/en.

The successful implementation of Community Transition Pathways has led to a collaborative status between stakeholders and locals. The Energy Transition Contracts guide the transactional relationship among all participating parties. They are displayed by Boeri et al., 2024, as city agreements to seal political commitments to locals and value their truthful involvement in common agreed goals. Overall, driving this dynamic transformation in energy involves engagement in diverse governance paths and combines multidimensional perspectives, which have often led to a conflict of interests. The guidelines given to citizens must always balance ambition, sustainability, and community potential. The H2020 was deemed a successful trans-European scale project structured across citizens and was not as technological as most initiatives.

Chapter 4: European and Greek Legislation on Energy Communities

Official legislation and relevant national frameworks on Energy Communities enable these dynamic systems to evolve. The EU energy market has undergone various alterations over the last four decades. They have shaped newly introduced operational and functional transitions. It is obvious that for Energy Communities to flourish, social acceptance dimensions need to be fortified. Active citizen involvement bears exclusive benefits and equal responsibilities. In 2019, the EU dynamically enforced RED II and ED to unite European efforts in energy transition, mitigate climate change effects, and support zero net GHG emissions by 2050. Although energy markets shall vary in size, maturity, and overall capacity characteristics, they shall all abide by the legislative framework of the EU, and national governments shall make sure to incorporate the proposed legislation into their national[31].

All proposed directives are accompanied by relevant deadlines for implementation into member states' national legislation. Regarding environmental and energy laws, Member States shall balance their internal obstacles and incorporate the proposed directives to avoid any infringement fines by the EU authorities. For instance, Greece is known for major bureaucratic issues which cause institutional delays. Nevertheless, as will be demonstrated, Greece has overcome relevant ineffectiveness in internal procedures and has adopted and even developed the proposed guidelines of the EU regarding clean energy and Energy Communities. It shall be highlighted that various EU Member States have exhibited remarkable progress in adopting RED II and IEMD, respecting that European Law imposes a higher hierarchy ranking in comparison to national law.

After the devastating Oil Crisis in 1973, a series of significant energy events led to the energy evolution of the new era. The table below has also been assembled to depict leading energy events and legislation that shaped today's energy markets and practices.

Year	Event/Legislation	Influence on the Energy Field
1973	Oil Embargo[32]	Uncovered global dependence on oil products and emphasized the need for immediate European energy policy reform.
1974	Creation of the International Energy Agency (IEA)[33]	Preserve energy security and coordination of relevant policies and measures.

[31]Biresselioglu, M.E. et al. (2021) 'Legal Provisions and Market Conditions for Energy Communities in Austria, Germany, Greece, Italy, Spain, and Turkey: A Comparative Assessment'
[32]Oil Embargo,1973 https://www.britannica.com/event/Arab-oil-embargo
[33]International Energy Agency (2025) *IEA* https://www.iea.org/.

1985	Single European Act[34]	Legislative Framework on European energy market unification and liberalization.
1992	UN Framework Convention on Climate Change (UNFCCC)[35]	Global conference to verify the need to mitigate climate change threats and shape relevant policies.
1997	Kyoto Protocol[36]	International agreement to reduce GHG emissions and promote RES initiatives.
2001	Renewable Energy Directive (EU, 2001/77/EC)[37]	Proposed the integration of RES in electricity generation by all EU Member States.
2009	Third Energy Package[38] (EU)	Ensured fairness in competition and consumer protection in EU energy markets. Established ACER to enable independence on national regulatory authorities.
2015	Paris Agreement[39]	Boosting Transition to Clean Energy.
2020	European Green Deal[40]	EU strategic framework on sustainability and efficient energy management.

Table 2 Important Energy Related Events (1973-2020)

Among the high points remarked above, we shall observe the manifestation of various other events that influenced energy transition throughout the decades. The First Energy Package[41] in 1996 also accelerated market unbundling and liberalization. The Second Energy Package[42] in 2003 aimed to boost market competition and provide energy efficiency before the Third Energy Package[43] in 2009. Lastly, the Clean Energy Package with RED II and IEMD aimed strategically at facilitating the evolution of Energy Communities in the European Territory.

RED II and IEMD are considered the most recently updated core legislation on Energy Communities, in a European and national context. Both legislative

[34]Single European Act, 1985 https://www.europarl.europa.eu/about-parliament/en/in-the-past/the-parliament-and-the-treaties/single-european-act
[35]UN Framework Convention on Climate Change (UNFCCC) https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change
[36]Kyoto Protocol, 1997 https://unfccc.int/kyoto_protocol
[37]Renewable Energy Directive (EU, 2001/77/EC) https://eur-lex.europa.eu/eli/dir/2001/77/oj/eng
[38]Third Energy Package https://www.europarl.europa.eu/factsheets/en/sheet/45/internal-energy-market
[39]Paris Agreement 2015 https://unfccc.int/process-and-meetings/the-paris-agreement
[40]European Green Deal https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[41]First Energy Package https://www.europarl.europa.eu/ftu/pdf/en/FTU_2.1.9.pdf
[42]Second Energy Package https://www.europarl.europa.eu/factsheets/en/sheet/45/internal-energy-market
[43]Third Energy Package https://www.europarl.europa.eu/factsheets/en/sheet/45/internal-energy-market

frameworks encompass sustainability and carbon neutrality in energy management. Below, we will examine RED II and IEMD's legislative core as essential components of the European Legislative framework for Energy Communities. Additionally, there is supportive legislation on energy and environmental laws, such as State Aid Guidelines on Environmental issues. Even the European Green Deal regarding energy issues and structural legal framework is worth mentioning.

4.1 European Framework - Key Directives and Policies

4.1.1 Renewable Energy Directive II (RED II) - Directive (EU) 2018/2001

The RED II is dedicated to renewable energy generation linked to sustainability and efficiency in using RE materials. As mentioned in the official EU text, the target of the Union was to utilize technological and industrial revolution in the renewables sector to induce further regional development and employment growth in rural areas and dense regions. The central focus is primarily on electricity production via renewable energy materials such as solar or biomass fueling. **Art. 1**[44] expresses this legislative framework to enlighten electricity production with sustainability practices in a binding operational across member states agreement supporting the 2050 target for limited GHG emissions in the EU territory. Correspondingly, in **Art. 4**[45], values transparency and non-discrimination to assert fair competition conditions in relevant energy markets. On **Art. 7-13**[46], the official legislative text encompasses collaboration terms between two or more Member States in renewable energy initiatives, with written proof that large-scale investments are managed only under transnational cooperation.

It is worth underlining that the EU values commitment to environmental initiatives, and each Member State shall officially proclaim its national development based on the proposed guidelines. More particularly, the Union's Renewable Development Platform (URDP)[47] was created so that participating Member States declare their internal data annually when deploying renewables in energy production. Respectively, in **Art 15**[48]**,** the Union provides guidelines for administrative authorizations and operational transparency in renewable energy projects to protect all parties against discrimination in the internal energy market. Furthermore, according to transparency guidelines, **Art. 18**[49] it is underlined that adequate information and training for all participating members should ensure the success of the

[44]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[45]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[46]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[47]Union Renewable Development Platform https://union-renewables-development-platform.ec.europa.eu/
[48]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[49]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

undertaking, as renewable tech requires proper handling and respective knowledge to be accurately employed.

Generally, RED II underlines diverse participation. More particularly, RECs and renewable self-consumer concepts are presented in a more straightforward and modern perspective, where all actors matter. Further clarification is required since multilevel participation has been growing over the years. The guidelines in RED II aim to diminish implementation and participation barriers in contemporary societies and be incorporated into national legislation, facilitating RES usage and a greener transition. To promote the concept of renewable self-consumers, RED II, dedicating **Art. 21**[50], declares that citizens under the auspices of RSC are still consumers. Yet, they receive respective and fair remuneration for their production activities, offering to the grid and society. National governments must respect these guidelines, eliminate any existing participatory or operational barriers, and integrate them with transparency into national legislation following climate plans and the Union's targets.

REC has been introduced in this thesis section 3.1.1, yet the legislative priorities are presented in RED II in **Art. 22**[51]. The official text thoroughly introduces membership privileges, commercial interest, and key operational functions. The legislation highlights are depicted on non-discriminative barriers and the assurance of fair treatment. Lastly, RECs are being developed under the framework of cross-border cooperation and with the relevant support of DSOs for operational facilitation. RED II described the REC concept as a legal entity interpretation, which needs to be applied in harmony with existing national legislation. As mentioned, autonomy and no barriers to shareholder participation are essential for REC.

4.1.2 Internal Electricity Market Directive (IEMD) - Directive (EU) 2019/944

The Internal Electricity Market Directive was proposed as a legislative text to structure electricity markets according to the new era's conditions. Accessible opportunities for the consumer, price equilibrium, and productivity in capital spending are the text's core targets to ensure sustainability in electricity activities and trade. The directive grants advanced specifications in existing services and develops new ones concerning decarbonization targets, as the Union's policies lean towards carbon neutrality. IEMD in 2019 focused on emissions from electricity operations. Primarily, the main target of the directive was to eliminate any existing barriers to electricity market participation and to redefine electricity market core activities with the active involvement of households. As cited in the opening of the legislation, the Union has electricity markets under close supervision since 1999, with the creation of internal and unified electricity, with the active contribution of Directive 2003/54/EC[52] & Directive 2009/72/EC[53].

[50]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[51]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001
[52]Directive 2003/54/EC https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0054
[53]Directive 2009/72/EC https://eur-lex.europa.eu/eli/dir/2009/72/oj/eng

In **Chapter 1, Art. 1**[54], regarding definitions of the legislative text, the Union declares that the future of electricity markets is envisioned as "*integrated competitive, consumer-centered, flexible, fair and transparent."* Considering the above, the transition towards a sustainable and low-carbon energy system is more approachable. **Chapter 2, Art. 3**[55] underlines the existence of "*no barriers*". Likewise, *"transparency and fair treatment in agreements and fees"* is essential in guiding parties towards all joining participants and other Member States. Under the no discrimination notion, in **Art. 6**[56], Third-Party access is clarified and even elucidated that there is also effectiveness *"to citizen Energy Communities that manage distribution networks."* **Chapter 3** is dedicated to "*Consumer Empowerment and Protection*" with **Art. 10-15**[57] mentioning contractual rights or switching related rules to ensure fair treatment in energy trading with no abuse of market power and distortions.

Citizen Energy Communities are instituted in IEMD 2019, with a systematic outline concerning membership, rights and obligations, fees, and technical market issues regarding assessing energy flows. Nondiscriminatory behavior and fair treatment are predominant in this legislative text, generating space for households to participate in this modern energy era. It must be highlighted again that Citizen Energy Communities represent various energy generation sources, unlike Renewable Energy Communities, which is established and pledged to specifically renewable energy generation sources. To be clarified, as per **Art. 16, (c), (d), (e)**[58] the function of citizen Energy Communities still resembles *"active customers"*, and fees and tariffs shall be defined after a transparent *"cost-benefit analysis"* form national authority. Impartiality is offered to the members of the community in respect to generation and sharing of the produced energy. Nevertheless, there is a functioning duty and responsibility towards the energy network, which needs to be regulated by the designated specialist to ensure relevant flow stability and hedging in pricing.

Smart metering, a groundbreaking concept presented in **Art. 19 & 20**[59], is an energy sustainability measure aiming to *"empower the final customer."* Is intertwined with utilities such *as "energy management services, developing pricing formulas, introducing smart metering systems...&...smart grids, ...with the applicable Union data protection rules."* Smart metering shall offer viable and accurate metering of the internal electricity market in connection to advanced grid establishments, which have been assessed to provide

[54]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[55]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[56]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[57]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[58]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[59]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944

operational excellence and are deployed in the "*European Standards*" to provide "*actual electricity consumption*" and "*Validated historical …data.*"

The Union's target is to ensure the use "*of the best available techniques…with the highest level of cybersecurity.*" Following **Art. 23**[60] concerning "*Data Management*", the existence of a dynamic support for security in data exchange provides numerous portals for data and information. Nevertheless, cyber-attacks threaten nations globally, and the Union shall guarantee that Europe is adequately qualified to avoid such unpleasant events. Energy Communities' reference to this legislative text proves the social value of energy. Combined with **Art. 28**[61], "*Vulnerable customers,*" & **Art. 29**[62], "*Energy poverty*"[63] , there is a specialized framework for low-income families facing energy vulnerability difficulties. The focus of the Commission on such concepts proves the augmented concern over the years that poverty has multiple dimensions.

After outlining the main principles of basic lawmaking that guided the EU into the new era of the EC, it should be recognized that these transitional efforts have been bolstered by supportive legislative initiatives, which have proven valuable in the modern energy landscape. Underneath, supportive legislative texts, and initiatives refer to addressing climate change or providing state aid for energy initiatives to EU member states.

Substantial influences have been sustained from:

I) Governance Regulation - Regulation (EU) 2018/1999 **(2018)**
II) Electricity Regulation - Regulation (EU) 2019/943 **(2019)**
III) European Green Deal **(2019)**
IV) State Aid Guidelines for Climate, Environmental Protection, and Energy (CEEAG) **(2022)**

4.1.3 Governance Regulation - Regulation (EU) 2018/1999 (2018)

Regulation 2018/1999 provides the necessary legislative base for an effective Energy Union with solid coordination and a clear strategy for Climate Action. This regulation was formulated to boost European alignment with the Paris Agreement, 2015, as a standard to overcome transnational complexity and strategic uncertainty on joint targets of 2030 and 2050. The Energy Union[64] has five separate dimensional approaches to climate action: 1) energy security, 2) unified energy market, 3) energy efficiency, 4) decarbonization goals, and 5) R&D in energy practices. This regulation invests in a fundamental formulation in the European energy system, in respect to the five core

[60]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[61]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[62]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[63]Directive (EU) 2019/944 https://eur-lex.europa.eu/legal content/EN/TXT/PDF/?uri=CELEX:32019L0944
[64]Energy Union https://energy.ec.europa.eu/strategy/energy-union_en

dimensions of the Energy Union. Affordable and sustainable energy for consumers is considered a long-term ambition for Member States, which requires innovation and evolution in new energy trends.

Among the recommendations suggested by Governance Regulation - 2018/1999, there is a focus on diminishing anthropogenic GHG emissions and alternatives to achieve the zero or negative emission objective by 2025. **Chapter 2**[65] of the Regulation is dedicated to consistent national energy policies, with all Member States being required to provide a specific layout of the long-term energy strategies, without omissions regarding renewables, as demonstrated in **Art. 5**[66]. As part of the submitted national plans according to **Art.6**[67], energy efficiency and sustainability proposals need to be developed taking into consideration the energy efficiency attribute of the Energy Unions' creation. Public consideration (**Art. 10**[68]) in energy-related legislation is a shared practice, as consumers are dynamically engaged in energy-related activities, and vulnerable ones are affected by energy poverty; thus, their outlook is reviewed in national energy policy development.

As per **Art. 11,** *"Multilevel climate and energy dialogue"*[69], energy plans and national policy configurations are multifaceted management endeavors in which local authorities, societal associations, numerous shareholders, and public contributions energetically engage in an open negotiation agenda. **Chapter 3**[70] is dedicated to long-term strategy formation for the next thirty years and submission to European Commission following their relevant guidelines. The target is to accept that Climate Action and energy transition represent dedication pathways and only with joint devotion targets will they be achieved. European Commission has dedicated various legislative articles to reporting and monitoring each Member State's progress, which shall provide valuable data on future policies and existing gaps in frameworks and regulations. Certainly, Energy Communities are included in various provisions, particularly in **Art. 20** & **Annex I**[71]**,** as they represent a multifaceted role in modern energy landscapes, so it is imperative to consider them reasonably.

4.1.4 Electricity Regulation - Regulation (EU) 2019/943 (2019)

The Clean Energy for All EU Citizens regulatory package presented by Regulation (EU) 2019/943 on the Internal Market for Electricity, targets to

[65]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[66]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[67]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[68]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[69]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[70]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en
[71]Regulation (EU) 2018/1999 https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en

ensure energy market's proper functioning and fair electricity trade. More particularly, in **Section 1, Art. 1**[72], of the regulation, it is underlined that "*security of supply*", "*innovation*", "*decarbonization*" and "*sustainability*" are considered four (4) fundamental pillars to target via developing processes such as "*energy storage*", *"demand and supply aggregation"* or *"electricity generated from renewable sources"*. All the abovementioned shall boost the European energy framework and support internal energy markets for cross-border trading in energy products. Transparency in electricity markets provides a harmonization mechanism for product exchange, considering that the well-functioning internal market sets the foundations for energy security through transnational trading.

Art. 4[73] advocates constant collaboration from the Commission for the countries that have initiated fossil fuel transition. This transition symbolizes economic and societal alterations in carbon-intensive communities, which require financial support and guidance from the EU, to avoid any imbalances in energy supply and the well-being of local communities. In **Art. 7,8,9,10**[74], there is the relevant proper functioning guidance for "*Day-Ahead and Intraday markets*" and "*Forward markets*" given that market distortions and unfair competition regimes in energy trading tend to compromise the domestic economy and societal welfare. In addition, **Chapter III** provides insight into capacity allocations concerning congestion management since price volatility and appropriate grid stability support proper market performance and ensure accessible energy prices for consumers. Generally, grid reliability and market stability across European countries represent one of the fundamental targets of the Energy Union.

Regulation 2019/943 focuses primarily on electricity markets, yet various provisions directly affect Energy Communities. Similar to Directive 2019/944, there is a strong orientation to access equality and discriminatory behavior elimination. Traditional market structures regularly enforce boundaries on Energy Communities due to their minor influence scale. Concerning Energy Communities' empowerment, the prosumer role is discussed, and relevant pricing mechanisms propose inclusion of prosumers in trading activities on fair trading terms. Congestion management on the central energy grid is essential to energy generation. Additionally, storage functions shall constantly comply with the supervisory authorities' directions. Lastly, fee allocation and network charges are designed to encourage self-generation and the development of Energy Community.

[72]Regulation (EU) 2019/943 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=uriserv OJ.L_.2019.158.01.0054.01.ENG
[73]Regulation (EU) 2019/943 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=uriserv OJ.L_.2019.158.01.0054.01.ENG
[74]Regulation (EU) 2019/943 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=uriserv OJ.L_.2019.158.01.0054.01.ENG

4.1.5 European Green Deal (2019)

As a legislative text, the European Green Deal was promoted to prepare the EU Member States for *"climate neutrality till 2025"* while *"tackling environmental related challenges and preparing for a resource-efficient economy…and…economic growth"*[75] .As stated in the introductory text of the legislation, significant issues related to *"active public participation"* or *"sustainable paths"* and even to *"security of energy supply and competitiveness"* are addressed under the text. It is vital to highlight that essential legislation has been addressed to Energy Communities, such as Directive (EU) 2018/2001 on Renewable Energy (RED II), Directive (EU) 2019/944 on the Electricity Market (EMD), and Directive (EU) 2019/944 on the Electricity Market (EMD). All they have been shaped and promoted under the EU Green Deal. They have undoubtedly supported the legal representation of Energy Communities within the concept of energy democratization. Concerning *"social transition policies on a national level"* energy poverty is mentioned in **Par. 2.2**[76] ,as a *"standard of living"* on **Par. 2.1.2**[77] .Societal participation has been elevated and perceived as an innovative approach to current energy issues.

The Green Deal also supported renewable energy projects with development funds, *"public and private funds to support transition"* on various occasions mentioned in **Par. 3**[78]. In the light of financial support schemes, the Regulation (EU) 2021/1056 introduced Just Transition Funds (JTF)[79] with vital support in energy transition in coal-dependent regions. As a heavy coal dependency case, with active lignite production sites in Western Macedonia & Megalopolis, Greece has been committed to a renewable transition on these areas. In June 2022, the EU approved a supportive investment of 1.63 billion to be provided to the Greek State for economic growth to the businesses in these regions as a broader strategic orientation towards climate neutrality objectives. Equally, with Regulation (EU) 2021/241 on Recovery and Resilience Facility (RRF),[80] approximately 40% (forty percent) of the distributed financial funds to each Member State shall be granted to green transition acceleration. With RRF support, Greece has initiated the *Greece 2.0* [81]national recovery strategy into a profound modernization of various domains, incorporating energy-related projects and relevant transition to greener practices.

---

[75]European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640
[76]European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640
[77]European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640
[78]European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640
[79]Regulation (EU) 2021/1056 Just Transition Fund https://eur-lex.europa.eu/eli/reg/2021/1056/oj
[80]Regulation 2021/241 on Recovery and Resilience Facility https://eur-lex.europa.eu/eli/reg/2021/241/oj/eng
[81]Recovery and Resilience Facility in Greece
https://www.eib.org/en/products/mandates-partnerships/rrf/greece

The Green Deal specifies overall sustainability, in alignment with current environmental plans for the following decades. As presented above, there is proven guidance and financial motive for the European nations to modernize their energy practices and actively pursue the greener energy transition. Fundamental pillars on Energy Communities and consumer nondiscrimination legislation have upgraded the energy landscape in a more innovative and data-oriented path with *"available platforms to simplify legislation and identify problematic cases"* in the direction to *"continue to ensure the Paris Agreement…and the Conference of Parties in Glasgow (2020) …as a more collective effort to devise long term strategies…"*[82].

4.1.6 Guidelines on State Aid for Climate, Environmental Protection, and Energy (2022)

State Aid guidelines keenly support the benefits and development of Energy Communities throughout the EU. They advocate the imperative need to reduce greenhouse gas emissions by forming alternative renewable energy strategies to assist in RES sustainable usage[83]. Corresponding to the guidelines, State Aid is approved to Member States for energy infrastructure development, updates on existing energy networks and Smart Grids' innovative technology to improve the decentralization of energy activities. Considering modern technological developments as fundamental for the adequate performance of Energy Communities and since there is support for energy storage application infrastructure, their self-sufficient character is utterly advanced and conserved. Lastly, as per **Art. 75**, Renewable Energy Consumption investments are assessed "*favorably… for the positive effects of participation and acceptance"*[84], so reducing the Commission's criteria for State Aid participation for funding schemes would benefit the expansion each community's scope.

In addition to the financial assistance funds of State Aid, as per **Art 109.** citizens who actively participate in energy production for the common benefit under decentralized production units also obtain additional benefits, such as tax reductions as a part of *"support schemes targeting decarbonization or energy efficiency"*[85]. Citizen participation is promoted with funding for supporting collaborative activities across various Energy Communities, with virtual platforms sharing knowledge and gathering data. Corresponding to **Art. 34,** there is the "*cross-border infrastructure collaboration …[and]… the problem of asymmetric information … linked to the uncertainty.*" Indeed, information asymmetry triggers discrimination among market participants. Meanwhile, in light of the prosumer concept, citizens have energetically

[82]European Green Deal https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640
[83]2022 guidelines on State aid for climate, environmental protection, and energy https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-environmental-protection-and-energy.html
[84]2022 guidelines on State aid for climate, environmental protection, and energy https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-environmental-protection-and-energy.html
[85]2022 guidelines on State aid for climate, environmental protection, and energy https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-environmental-protection-and-energy.html

engaged in energy-related transactions; they are entitled to viable information channels as traditional and experienced market players.

Governance Regulation 2018/1999 mentions that Energy Communities profoundly allocate energy capacity throughout the grid. Similarly, **Art. 4.8**[86] regarding *"Aid for the security of electricity supply"* on several occasions highlights that State Aid shall be essentially assigned to preserve energy supply. Energy Communities functions encompass localized production that contributes to stabilization purposes in urgent situations. State Aid funding advances the pillars of Energy supports growth under multiple environmental instances and vigorously supports clean energy transition via RES and decarbonization practices.

4.2 Greek Legal Framework Governing Energy Communities

4.2.1 Law 4513/2018 - "Energy Communities and Other Provisions"

Law 4513/2018, published on 23.01.2018 in the Greek Official Governmental Gazette, is a primary regulatory text referring to Energy Communities. In the Greek language, it is translated as "*Ενεργειακές Κοινότητες*." The law includes 32 (thirty-two) Articles, the most crucial of which will be examined below. To begin with, on **Art. 1**[87], is dedicated to the objective and the definition of Energy Communities, where they are presented as a "*civil cooperation*" with the definitive target of backing the internal energy sector in terms of "*economic solitary*" and "*technological innovation in energy*". Issues stemming from the EU energy agenda, such as the "*elimination of energy poverty*" or setting *"energy sustainability targets"* to guarantee "*energy security*" or even *"energy autonomy"* in specific local regions as a part of a unified energy efficiency strategy. The provisions are mainly dedicated to Renewable Energy, Combined Heat and Power management and the respective *"rational use"* of the energy produced as a product.

Proceeding on **Art. 2**[88]**,** which discusses membership boundaries, authorizing membership to *"individuals in a full legal capacity"*,*"legal entities of public law*" and in *"regional municipalities"*, with a limitation that *"at least the 51% of members have a straight local lien, property, or residency"*, for instance. In the prolongation of **Art.2**, **Art. 3**[89]**,** clarifying the ownership framework, highlights that there shall be a max. 20% (twenty percent) ownership in individuals, a respective max. 40% (forty percent) for municipalities and a max. 50% (fifty percent) for island municipalities of less than 3,100 (three thousand one hundred) residents in total. **Art. 4**[90] must be emphasized since it refers to the principal activities Energy Communities should engage in, at

[86]2022 guidelines on State aid for climate, environmental protection, and energy https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-environmental-protection-and-energy.html
[87]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[88]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[89]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[90]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/

least one of these—chiefly *"energy production-consumption or storage"* and respective *"energy supply management about electricity & N.G."*, and "*development of energy infrastructure for alternative sources and RES energy*". To conclude, regarding **Art. 4** spectrum, the Greek strategy has invested in energy matters education to attract potential RES investments or specific EU funds.

Furthermore, **Art. 5**[91] indicates statutory requirements for legally establishing an Energy Community within the Greek Territory, and additionally, **Art.7**[92] illustrates the legal establishment practice with a *"local court approval"* essentially needed. Regarding the distribution of profits, it is noticeable in **Art. 6**[93] that *"10% of the energy surplus"* must be stored for *"a mandatory reserve"* and it is worth citing that in case of only municipalities being members, *"the profits shall be used for local benefit projects»*. **Art. 9**[94] enlisting requirements for mergers or dissolutions on Energy Communities, mentions that in case of dissolution, the profits and the assets shall be transferred to environmental projects or be used for public benefit, since according to European Commission, all Energy Communities are being shaped not only for environmental benefit but for regional growth with contributions from the locals.

"*Collectivity*" and "*information sharing*" with the support of *"Energy Communities' federations and unions"* are stressed on **Art 10,**[95] and the Greek Strategic framework on energy proposes that the formation of unions and alliances shall benefit Energy Communities' operations. Moreover, support measures are being proposed on **Art. 11**[96] with State Aid being provided on clean energy projects and Energy Communities undertakings, being one of them. A legislation breakthrough (**Art. 12**[97]**)** is considered the implementation of virtual energy net metering as a stepping-forward policy to support the decentralization of the energy grid. Since virtual metering is a recent technology implementation, it lacks operational guidelines and suffers bureaucracy impediments. All the above Articles improve the recognized foundations of Energy Communities in Greece, in order to succeed in energy sustainability within the Greek regional territory.

4.2.2 Law 5037/2023 On Electricity Produced From RES

Law 5037/2023 (Renaming the Regulatory Authority for Energy to the Regulatory Authority for Waste, Energy and Water, and expanding its scope to include responsibilities for water services and urban waste management, thereby strengthening water policy) was published on 28/03/2023 in the Official Greek Governmental Gazette and proposes several amendments and clarifications for Energy Communities, which were first addressed in Law

[91]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[92]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[93]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[94]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[95]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[96]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[97]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/

4513/2018. Throughout **Chapter Z** ***(Art.86-103)***[98], regarding "*Citizen Energy Communities*", the legislation seeks to enhance the current conditions for Energy Communities and environmental sustainability. To enlighten the definition of the term Energy Community on **Art. 86**[99] is worth mentioning terms such as "*legal entity*", "*voluntary and open participation*" and with the fundamental intention of "*providing environmental, financial and social benefit*", with an emphasis on energy-centric democratization. Indeed, the democratic and regional governance structure is similarly stressed in the **Arts. 87-88**[100], reviewing the Energy Communities' legal nature and membership status. Meanwhile, control and profit sharing (**Art. 89**[101]) are equally developed under a democratic rationale since "*each member… regardless of the ownership share… shall have (1) one vote only*".

Significantly, in addition to the Energy Communities' scope of activities reported under Law No. 4513/2018, in this case, **Art. 90**[102] notably mentions *"…renewable energy production… self-consumption…storage and supply … and representation in electricity markets*" for continuously involving green transition practices. Overall, as a legal entity, each Energy Community shall be governed by a *"General Assembly"* and a *"Board of Directors"* to secure operation functionality and efficiency as per **Art. 93**[103]. Energy efficacy targets are to be met under the Energy Communities' projects since the surplus shall be dedicated to supporting RES energy, local infrastructure, and the common good as proposed by the EU and verified by the Greek Government **(Art. 94)**[104]. Consumer Protection and fair market participation is analyzed on **Art. 99-100**[105].

Undoubtedly, Law 5037/2023 shares common grounds with Law No. 4513/2018, under creating clear and well-established legislation for the operation of regional Energy Communities in Greek territory, specifically for the newly formed energy landscape regarding environmental concerns. It is assessed as a reorganized text whose role is supplementary to the 2018 legislation on Energy Community structure. The expansion of their scope and activities proves energy decentralization and fairness under the auspices of the Greek government. Simultaneously, many other EU countries have delayed their respective legislation texts on the Energy Communities' conceptual framework and structural formation.

4.3 Greek Energy Community Legislation; Policy Alignment and Limitations for Future Development

As we further examined in the 2.1 section, Greece's energy legislative policy was conventionally marked as highly "conservative" since, until the EU energy market liberalization, all energy-related activities were closely monitored

[98]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[99]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[100]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[101]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[102]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[103]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[104]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/
[105]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/

and heavily controlled by governmental authorities. Nevertheless, the Greek policy also adapts to EU directions and respects proposed pathways *(Biresselioglu, M.E. et al.,2021)*. With this fact in mind, legislation 4513/2018 made Greece the first EU country to officially acknowledge Energy Communities by introducing a firm definition and a legal entity status. Along with Law 5037/2023, Greece proved she aims to ensure energy harmony and approach sustainability per EU guidelines.

4.3.1 Strengths

Fundamentally, Greece incorporated the concepts of self-generation and energy storage as the new era demands adaptability and rationality in energy handling. Additionally, another fact that proves that Greece is devoted to aligning with European legislation on energy is that Energy Communities are mentioned in the National Climate and Energy Plan, 2019[106]. The Greek legislation advocates the involvement of local citizens, small and medium enterprises, and municipalities, per EU guidelines, and interprets the newly existing concept of "prosumers" being active. Thus, these three entities enjoy access to the RES central grid, which was previously strictly denied by national regulatory authorities. Consequently, self-generation is an approachable option for citizens as Energy Communities' membership provides the required rights and resources for this sort of undertaking.

Most energy-related activities require specific techniques and expertise currently accessible to all energy-related communities and groups. Partnerships between them are desirable, as they have been supported to accelerate internal issues that may arise. As a known "coal-dependent" region, Greece has been authorized to receive financial aid, funding, and benefit from JTF aid. Under these circumstances, financial support is more accessible to Greek Citizens to develop energy-related activities and equally fulfill both community and the personal needs. Various support mechanisms in the energy field have been proven advantageous as this newly introduced sector is capital concentrated and demands high investment projects to ensure effective outcomes. Nevertheless, Greece has advanced and is a step forward in Energy Communities and RES developments, in contrast to other Member States.

The phasing out of lignite dependence has demonstrated that Greece has invested in smart tech and an innovative energy era, primarily locally and nationally, under the EU guidelines as a mutual ecological goal. Innovative energy generation proves valuable support to vulnerable customers as greener energy shall benefit traditional energy players in the central grid and care for customers on the verge of energy poverty, because acceptance in an Energy Community is translated as energy equality and compassion. Therefore, Greek legislation is not categorized as pioneering but similarly demonstrates the high value of society's sharing and solidarity. Under this conception, it is

[106]National Energy and Climate Plan (NECP) https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf

central that energy democracy rise in Greek communities under the national legislative framework, which continuously progresses.

4.3.2 Weaknesses

Conversely, it must be emphasized that despite the advanced energy agenda, Greece is requested to face multiple weaknesses that influence the whole energy sector and more explicitly hinder the evolution and resourceful operation of an Energy Community. To further explain, funding in the energy sector may be offered for national undertakings that propose energy initiatives, whereas an Energy Community has a limited regional scope. The access to available funding resources grants certain restrictions, thus less favorable citizen groups are discouraged to participate and desire to endure as old-style consumers. Subsequently, there is not enough constitutional inspiration and attractiveness due to lack of financial resources. As a result, financial pathways for Energy Communities must be simplified under less complex procedures, increasing accessibility for all members. Alternatively, the set of benefits dedicated to "prosumers" under the auspices of Energy Communities shall be more wide-ranging and cover a broader scope of citizens' everyday life requirements.

Besides the lack of funding, it has been observed that since Energy Communities projects are under development, there are potential deficiencies in current governmental frameworks or regulatory gaps. More precisely, Law 5037/2023 was proclaimed to boost the legislative background of 4513/2018 and reaffirm possible misperception arguments in the recently elaborated Energy Community's predisposition in Greek local communities. Without a doubt, the perception of Energy Communities has numerous concepts, for example, two of the most well-known concern the distinction between Renewable Energy Communities and Energy Communities, which need to be approached under a precise legislative framework, exclusively in Greek regions, which will shelter the requirements without sustaining existing gaps. Correspondingly, expertise boundaries hinder their potential expansion, particularly in Greece. It has been illustrated that the lack of energy-sharing mechanisms is exaggerated by limited guidance and funding on technological, technical, and legislative issues.

Therefore, legislative overlaps or gaps and lack of digitalization on essential procedures, are considered confusion points among participating parties. Overall, the potential delays in adapting to newly evolved legislation due to the Greek bureaucratic regime severely harms the expansion of the Energy Communities. Concurrently, such a capital-intensive sector necessitates commitment and long-term projects development. However, with insufficient national support and various organizational barriers, it is even harder to convince citizens of the benefits of holistic cooperation in the energy exchange market.

4.3.3 Policy Pathways for Strengthening Energy Communities in Greece

After assessing the strengths and weaknesses of the Greek legislative concept regarding Energy Communities, a correlation with upcoming developments shall be presented concerning the competence and appropriateness of the Greek efforts towards such energy growth trends. There are specific domains in which Greece needs to invest to ameliorate the future performance. To begin with, the digitization of existing procedures will surely benefit the evolution of Energy Communities. Specifically, licensing approval is deemed to experience delays due to bureaucratic impediments. Also, the licensing process in Greece seems to be undermined despite the original intention of Law 4513/2018 for immediate prioritization. As per Tsagari,2020, "*Only an EC in which the Local Government Organizations participate, … and more than 60 members participate are still eligible for 4 months priority in the licensing procedure*". Expanding administrative processes via technology and digitalization is a promising step for evolution as the administration between members and authorities will be immediate and precise.

Technological improvements shall also be employed to the central energy grid since the modernization of the existing system shall incorporate the gains of decentralized energy. Energy sharing or energy storage, to a greater scale, shall follow optimal guidelines from other Member States who have already invested in innovative technology. Grid expansion will improve energy exchange at multiple levels, from generation experience to trading activities. Consequently, it is a domain in which the available funding from the EU Central Bank, shall offer the opportunity for future development on the Greek potential of energy related infrastructure and projects, including Energy Communities.

Commonly, a conflict of interest in the energy sector creates impediments and disagreements for a future long-term policy on unified energy goals. Lack of clarity and ambiguity in legal acts discourage community confidence and attractive investment. Indeed, "*there is still no comprehensive research on the Greek legislation … and how the Greek regulation moved from a supportive framework… to a new focus on 'local energy*" (Tsagkari, 2020). The stability of the energy legislation and the proposed regulatory framework is crucial to generate a feeling of assurance for the affected parties. Retroactive application of legal modifications on core legislation weakens stability in citizen's investments and *"can have a big negative impact on the already submitted application. This approach can also be incompatible with the EU Energy Policy"* (Tsagkari, 2020).

On the contrary, constant revisions and introduction of updated policies create relevant uncertainty and difficulty adapting; hence, they discourage citizens' involvement. As already mentioned, Energy Communities face specific financial and operational issues. They require dedicated support measures, as mentioned also from Tsagkari, 2020, *"this will put extreme pressure on those Energy Communities that have more complicated decision-making mechanisms*". Equally vital to stability in the legislative landscape is for the Greek government to invest in social inclusion and initiatives surrounding the promotion of Energy Communities, "*this… poses significant questions regarding the opportunities for participation of local communities as well as the open-door principle according to which 'cooperatives are voluntary organizations, open to all persons…*" (Tsagkari, 2020). Educating citizens on energy issues, and introducing public consciousness on fundamental environmental aspects, will boost energy efficiency and turn aspirations for energy sustainability into a potential reality.

Chapter 5: Greek Energy Communities Today: Scale and Structure

5.1 Modern Status of Energy Communities in Greece

Law 4513/2018 created promising grounds for developing Energy Communities in Greece. Similarly, with the upcoming implementation of Law 5037/2023 in Greece, which altered various Greek practices concerning Energy Communities, there has been a promising increase in the official registration count of Energy Communities[107] .During this period, various supportive EU projects were established to facilitate the processes and address relevant technical difficulties, such as the Energy Communities Repository[108] (2022-2024), which primarily concerned CEC & RES via offering "*technical and administrative*" standards and directional commitments. It is essential to note that most of the officially published data on the evolution of Energy Communities in Greece was compiled for the year 2023 and has been verified by the EU and the Greek Government.

This graph depicts a timeline (2018–2023) showing the growth of Energy Communities in Greece in relation to the established or nominal power capacity. As observed below, there is a notable growth in 2019 -2023, from less than four hundred (four hundred) entities in 2019, to 2023. With the implementation of Law 4513/2018 we observe a rising sum of around 1600 (one thousand six hundred) active Energy Communities. There was a sharp rise in the initial years as the energy market desperately needed a shift in the energy landscape and relevant practices. Energy Communities keep flourishing as they mature into the market with more funding options and technical alternatives. From 2022, we join an equilibrium period with framework shifts stemming from Law 5037/2023, which are resulting in market saturation over the years.

---

[107]Rescoop.eu https://www.rescoop.eu/policy/transposition-tracker/enabling-frameworks-support-schemes/greece
[108]Energy Communities Repository https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-communities_en

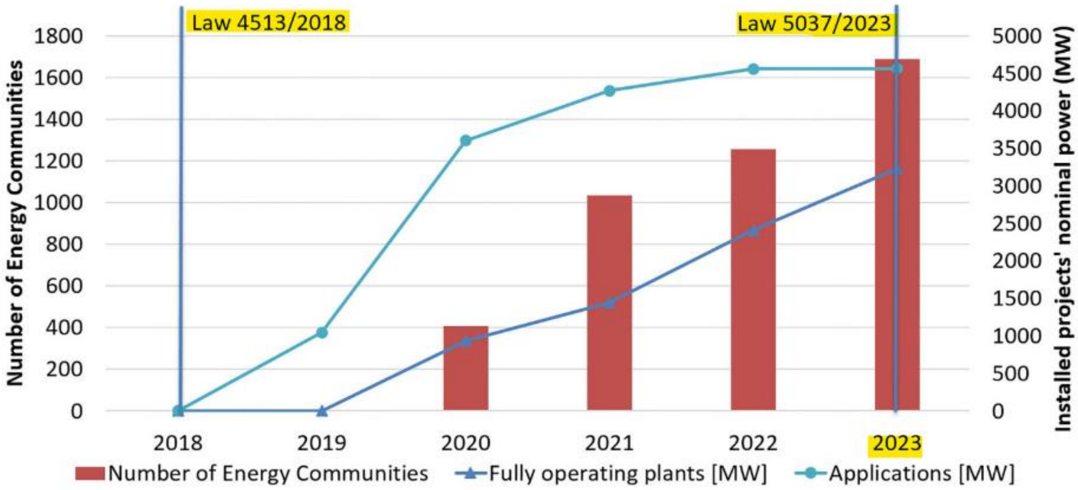

Figure 3 Number of Greek ECs and applications for new projects before and after introducing the relevant legislative frameworks (Yfantis et al., 2025)

Likewise, it is fundamental to emphasize that the leading technology embraced in Energy Communities is photovoltaic-associated installations (PV) (Yfanti et al., 2025). Additionally, as stemming from Yfanti et al., 2025, till 2023, approximately *"one thousand five hundred eighty-five (1585) photovoltaic parks, two (2) wind parks, and one (1) biogas station"* have been dynamically advanced in Greece. What is the motive for this wide supremacy of PV technology over other related tech applications? The Greek climate, with plenty of sunlight in most Greek areas, has created a cost-effective regime in PV energy. The vast use of solar panels in both private and public properties has simplified the application systems and licensing requirements over other associated technologies, such as biogas.

On the contrary, despite having enormous potential to flourish in Greece, biogas-biomass or wind plants have had limited acceptance. Both projects have elevated investment costs, and their complexity in operation hinders their vast application in rural or coastal regions. Along with stricter environmental regulations and licensing permissions, the popularity of these technologies does not seem to be flourishing in Greece currently. For instance, Finland has been a European leader in biomass energy[109] and respectively Germany has developed wind plants[110] as part of the European determination for a greener energy transition. To recap, the Greek Energy Community concept offers more realistic benefits over the employment of PV energy; however, only with the appropriate framework alignments and proper financing other Energy Community types appear to be more accessible in the future.

[109]Commission approves €2.3 billion Finnish State aid scheme to foster the transition to a net-zero economy https://ec.europa.eu/commission/presscorner/detail/en/ip_25_527
[110]Wind Energy – Germany https://www.statista.com/outlook/io/energy/renewable-energy/wind-energy/germany

5.1.1 Regional development of Energy Communities in Western Macedonia, Thessaly, Crete & realistic limitations

Specific regions in Greece are reflected as remarkable examples for Energy Communities development. Areas such as Thessaly, Western Macedonia, or Crete, each with its distinguishable characteristics, symbolize areas of strategic significance for Greece's greener energy transition.

5.1.1.1 Western Macedonia

Geographically, Western Macedonia is characterized as a mountainous area, situated in the northern part of Greece, bordering Albania, and the Republic of North Macedonia[111]. It is also divided into Grevena, Kozani, Florina, and Kastoria regional units[112]. The commercial character of the region specializes in the energy sector production, and due to its impressive countryside, attempts to attract tourists have increased in recent decades[113].

As previously stated, Western Macedonia has been a core lignite production region since the mid-20th century. With the blessings of the Greek Government and based on European Commission's guidelines, aligning with Green Deal provisions, from 2023, the whole area is facing an ongoing lignite phase-out. The transition has been scheduled to be completed by 2028. To begin with, it was July 2020 when citizens of the Kozani region, specifically the Mavrodendri area, took the initiative to commence energy production from renewable energy sources, the so-called "Smart City of Kozani"[114]. Therefore, for the purpose of this dissertation, the basic structure of the "Smart City" has been presented, from the Municipalities' Strategic Plan presentation of May 2020[115]. It is essential to note that the local University of Western Macedonia has provided practical knowledge and coordination for this initiative, as the primary objective was to mitigate energy poverty in the area, which had deteriorated due to the effects of COVID-19.

In Western Macedonia, the "Regional Energy Community of Western Macedonia Ltd"[116], is aparted from; 13 Municipalities, the local Authorities, and the local University. By around 2022, nearly one-fifth of Greece's Energy Communities have been placed in Western Macedonia, focusing mainly on solar projects and wind energy initiatives in a smaller scale (Ketikidis *et al.*, 2023). The focus has been given also to district heating technologies, with a bright example being Amindeo's biomass district heating plant[117]. The funding

---

[111]Region of Western Macedonia https://en.pdm.gov.gr/the-region/profile/
[112]Region of Western Macedonia https://en.pdm.gov.gr/the-region/profile/
[113]Region of Western Macedonia https://en.pdm.gov.gr/the-region/profile/
[114]Smart City of Kozani https://www.intelligentcitieschallenge.eu/cities/kozani
[115]Kozani-Smart City- Strategic Plan 2020
https://cityofkozani.gov.gr/documents/10182/545686/%CE%9A%CE%BF%CE%B6%CE%AC%CE%BD%CE%B7-%CE%88%CE%BE%CF%85%CF%80%CE%BD%CE%B7+%CE%A0%CF%8C%CE%BB%CE%B7+f3.pdf/29aaf021-9929-40a7-bd31-bd7b375ffdf9
[116]Energy Community Of Western Macedonia Ltd https://www.interregeurope.eu/good-practices/regional-energy-community-of-western-macedonia-energy-community-of-western-macedonia-ltd?\
[117]Municipal District Heating Company of Amindeo (D.H.C.A.) https://detepa.gr/dhca/

sources are primarily EU-related, with the European Regional Development Fund, the Just Transition Fund, and Horizon Europe being the dominant funding sources for research and development (Ketikidis *et al.*, 2023).

Relevant limitations on Western Macedonia's energy transition are discussed in the paper *"Clean energy technologies in Western Macedonia: Opportunities for jobs and growth within the coal phase-out era"* by Ketikidis *et al.*, 2023. Firstly, as a rural area, Western Macedonia suffers from a weak energy network and grid capacity. The conditions deteriorated due to limited financing resources and a lack of professionals to support the field. Likewise specific green initiatives being in smaller scale are obstructed by the conventional of financing, where SMEs and individuals cannot secure proper funding to develop their projects. It is vital to mention that Energy Communities are a new encounter for Greece, and even though there has been plenty of legislative support, the overall institutional agenda, exclusively at a local regional scale, is considered to be suffering from administrative gaps.

Figure 4 AMYDON Energy Community (2025)

5.1.1.2 Thessaly

Thessaly region, it is positioned in central Greece, bordering Western Macedonia, and, except for the significant regions of Volos, Karditsa, and Trikala, it also includes the Sporades Islands[118]. Agricultural activities mainly support the region financially[119]. Thessaly has a slightly different green energy-related profile than Western Macedonia. Renewable biofuels and support in the bioeconomy are generated from biogas, which is produced from the anaerobic digestion of livestock and farming leftovers (Argyropoulos *et al.*, 2023). Especially in Greece, the anaerobic digestion method has gained attractiveness due to the availability of raw materials and the effectiveness of the energy produced (Argyropoulos *et al.*, 2023). Under this approach, it is evident that Thessaly exploits renewable energy resources in an economically profitable manner. More specifically, the well-known and successful biomass community of Karditsa (ESEK), from 2010 onwards, operates efficiently on an agricultural basis, with vital participation from local farmers. The structure of ESEK will be examined further below as one of the innovative developments in Greek Energy Communities.

Various other Renewable Energy projects in Thessaly region currently take place. For instance, the French RE company AKUO, has invested in the local energy market by establishing 4 PV plants in partnership with local authorities and the Municipality. Sourced from the organization's official site, the plants will be completed with the installation of floating PV assets that will enable the use of water surfaces for energy production[120]. In line with the plant, Akuo declared that "*With this project, Akuo will demonstrate that Greece's objectives of reaching 60% of renewable energy in its mix by 2030 are not only feasible but also economically and socially relevant.*"[121].

Consequently, the concept of "*agrivoltaism*" considers the region's extensive agriculture and supports Renewable Energy activities with relevant integration to the local grid. An alternative, groundbreaking approach of Thessaly, is the "Apollon program. Under the auspices of the municipality, from 2024, with the installation of RE plants, there is a net contribution directly to the electricity billing of member-consumers. As stemming from the official Apollon webpage, the vulnerable consumers entitled to "category A social billing practices" will notice a considerable reduction of the scale 80-90% on their electricity bills[122].

[118]Region of Thessaly http://www.interreg-balkanmed.eu/project-partner/199/
[119]Region of Thessaly http://www.interreg-balkanmed.eu/project-partner/199/
[120]Akuo-Thessaly PV plant https://www.akuoenergy.com/en/akuo-in-the-world/all-our-projects/thessaly
[121]Akuo-Thessaly PV plant https://www.akuoenergy.com/en/akuo-in-the-world/all-our-projects/thessaly
[122]Apollon program-Thessaly https://www.ekp-peth.gr/#apollo

Figure 5 Akuo PV Project – Thessaly (2025)

Lastly, the Municipality of Crete is Greece's largest island, divided into Irakleio, Lasithi, Rethimno, and Chania. Commercial activities are related mainly to agriculture and tourism businesses. The island contributes equally to energy sustainability by developing Renewable Energy Sources. The Minoan Energy Community was established in 2019 and has two hundred thirty (230) members. The community aims to boost Renewable Energy generation through various PV and wind power projects and to allocate refunds to its members. The Minoan Energy Community has proved that Europe is engaged to various energy initiative projects, such as the "Crete Valley." The community also asserts the corporation's local character, by being active in the earthquake-stricken regions, especially in the Archalochori region, by establishing PV projects to electrify the consumption of local citizens directly[123].

It needs to be highlighted that Energy Communities were established in the view of collaboration and commonality, to support the need for fluctuating practices on energy activities, against the ongoing climate crisis. Under this scope, in the circumstance of urgency, the community has proven a self-driven sense of responsibility towards the rest of the citizens via operationally efficient projects.

[123]Minoan Energy Community https://minoanenergy.com/en/%ce%b4%cf%81%ce%ac%cf%83%ce%b5%ce%b9%cf%82-%ce%b1%ce%bb%ce%bb%ce%b7%ce%bb%ce%b5%ce%b3%ce%b3%cf%8d%ce%b7%cf%82/

Figure 6 Minoan Energy Community Project (2025)

Furthermore, the project "Crete Valley," also co-funded by the EU, is an ongoing attempt to transform the existing traditional Cretan energy production to "*decentralized*" and "*sustainable*"[124]. Under this project's practices, the *"Labs"* will consist of *"Renewable Energy Valley 'Living Lab' (REV-Lab)"* and as per the official description of the project, the undertakings are being equipped with "*data-driven, multi-carrier grid systems"*[125]. The four (4) active projects on the island are worth presenting since they combine various RES such as hydrogen, biomass, biogas, geothermal, solar, and wind. More particularly:

- **Arvi**; situated on the southern coast of Crete, with around four hundred (400) permanent inhabitants, needed a cooling and heating system due to the specific climate requirements. The project is being employed for twenty (20) residential households utilizing a geothermal-hydraulic network and energy produced from PV, to achieve around seventy percent (70%) reduction in the electricity bills.
- **Lasithi Plateau;** situated at an altitude of eight hundred meters (800), has an explicitly cold climate and is a residential area of two thousand four hundred (2400) families. The need for a space heating system was crucial, and as the main commercial activity of the citizens is associated with agriculture, livestock and relevant waste are being utilized in a biogas plant. The mountainous area favors the established wind plant. As mentioned, the plants support twenty (20) residential buildings and one hundred seventy-five (175) households with cutbacks in heating and electricity costs.
- **Arkalochori;** situated in a semi-mountainous region, holds around five thousand (5.000) residents and possesses an extensive oil-related industry. To cover their heating and cooling needs, the community hosts a biomass facility fueled with agricultural waste, and for

[124]Crete Valley https://cretevalley.eu/about/
[125]Crete Valley https://cretevalley.eu/about/

additional needs, wind, and PV decentralized plants. The final users are around fifty (50), including SMEs and households.

- **Atherinolakos;** situated on the southeastern coast of Crete, has an active hydrogen community of sixty (60) buildings and uses PV energy to fuel the future energy demand potentially. The project is a Greek African collaboration to boost the electricity and hydrogen market with promising results. The benefits are scheduled to be incorporated into hydrogen electric buses for community transportation and an effective heating system.

Figure 7 Crete Valley Projects (2025)

To conclude, despite the state-of-the-art technology applications and the observable accomplishments of various Energy Community models, specific limitations have been identified for the current projects. The Western Macedonia, Thessaly, and Crete regions, with their significant agricultural potential and environmental wealth, are considered sensitive areas in terms of ecology-related interventions. Indeed, they have suffered economically from COVID-19 and the subsequent phases of lignite substitution. As a result, despite the success of Energy Communities in these regions, the social aspect and the realistic challenges in effective coordination demonstrate that the prospective evolution of these initiatives seems more complex than initially expected. Under these circumstances, citizen engagement and investment attractiveness are affected. Undoubtedly, the models to be employed should support local citizens and stimulate a diversified, low-carbon energy mix with a clean energy policy. The vision to elaborate sustainable and resilient infrastructure requires a holistic strategic approach with a transparent assessment of regional gaps.

5.2 Technical Implementation Models

5.2.1 Peer-to-Peer Models

Peer-to-Peer (P2P) energy sharing is closely related to the concept of prosumers. The individuals exchanging energy under these circumstances are consumers who have progressed to actual energy producers. The energy flows strengthen the local network, which is comprised of various prosumers within the scope of an Energy Community. According to Margosi and Koukoufikis (2024), in their article published in the European Journal of Spatial Development, *"Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece"* the concept of P2P Models is not precisely defined in Greek Legislative texts. Yet, they flourish under self-consumption and virtual net metering. More precisely, locals shall be encompassed in "*generation, distribution and consumption of renewable energy through decentralized …projects*"[126].

P2P models signify justice and equality in energy sharing. As stated also in the article, around "*48% of the sampled population spends over 10% of their household income on energy"*[127] .In line with *"distributive justice"*[128] under a shared grid, this model provides affordable energy in households, in contradiction to various established practices connected to high billing prices. Furthermore, local authorities are also engaged, making decision making processes more direct. As a result, procedural transparency gaps are addressed since "*stakeholders have a say in energy decision-making and policy development"*[129]. Lastly, it must be highlighted that Greek legislation already recognized the urgency of social groups defined as "vulnerable," with relevant benefits and discounts in household energy bills. P2P mechanisms shall expand with further investment in social inclusion initiatives.

As reported in the research article aforementioned, the Greek Law 4513/2018 supported active Energy Communities by incorporating *"collective self-consumption, distribution, and supply"*[130] which shaped a prosperous environment for energy sustainability. Yet despite the various updates which were introduced with Law 5037/2023, the geographical attributes of Energy Communities were eliminated as "*the requirement that more than half (50% +1) of an Energy Community's members have a connection to the geographical area where the project is officially registered"*[131]. This feature modifies the character of Energy Communities and affects P2P models that rely on proximity. Nevertheless, it needs to be mentioned frequently that locals are

[126] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralised Transition: The Case of Energy Communities in Greece'.
[127] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.
[128] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.
[129] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.
[130] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.
[131] Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.

not adequately informed of the respective benefits, as around *"45% reported no knowledge of ECs"*[132]. To conclude, after informing citizens on the spectrum of local energy production, *"over half the respondents (54%) showed concrete interest in EC involvement"*[133] which proves that local citizens are willing to engage in a greener energy future.

The lack of grid accessibility in Greece depletes P2P models by establishing infrastructural gaps. In combination with limited institutional support, the evolution of localized energy production is a multifaceted process. The newly introduced energy-related methods create uncertainty among locals, and with a notable lack of legislative and financial guidance, marginalized groups encounter difficulties with participation. Alternatively, although it is reflected as an evolutionary approach in energy democracy and green practices, barriers must first be addressed to achieve effectiveness in relevant operations.

5.2.2 Building-Level Self-Consumption

The building-level self-consumption model features improved photovoltaic (PV) and battery storage systems in inhabited areas, reducing reliance on the central electricity grid. Multi-tenant buildings in densely populated residential areas are typically monitored. In the research by Reimuth et al. (2021), the base model employs a combination of photovoltaic (PV) and battery storage systems per building. The authors grouped data from three thousand one hundred sixty-three (3,163) buildings in Bad Tölz, Germany, by examining their consumption outlines and system capacity to offer insights on energy flow scenarios and installation configurations.

The research demonstrated that battery storage technology has a significant impact on self-consumption patterns. More particularly, *"the charging and discharging of residential storage increases the self-consumption from 28.9% to a mean value of 46.8% depending on the battery-coupling rate"* (Reimuth et al.,2021). Under these circumstances, self-sufficiency in energy consumption is enhanced, demonstrating that energy storage is reflected as an asset in energy technology, which, combined with PV expertise, balances the out-of-range energy production and consumption patterns. Nevertheless, it is highlighted that energy storage applications in tenant buildings boost self-consumption rather than contributing supplementary energy to the central grid.

Modifying practices related to PV and battery storage shall enhance the self-consumption energy model. As per the study from Reimuth et al. (2021), in household buildings with low PV technology participation, the respective *"no significant change in residential …loads"* proves the necessity for funding in local energy infrastructure to foster energy production evolution. Otherwise, where PV participation is measured at around (eighty percent) 80% in energy

[132]Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.
[133]Margosi, M. and Koukoufikis, G. (2024) 'Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece'.

production, the involvement of battery storage systems is considered obligatory in managing the excess in solar energy production. Generally, this study provides valuable insight into the technological and policy scopes of self-consumption systems, proving that specific limitations impede energy independence. Thus, the function is founded on residential density and specific strategic approaches based on community needs.

5.3 Virtual Net Metering

Virtual Net Metering (VNM) integrates the concepts of energy sharing and energy democratization, as collective participation in renewable energy (RE) is empowered. Net Metering was deemed an alternative to feed-in tariffs (FiTs) to minimize state subsidization. FiTs are based on fixed rates for the total amount of electricity generated. Yet, NEM (Net Energy Metering) as per Christoforidis et al. (2016) clarifies, *"NEM offers an …option for positive investment…from small-scale PV generation …in the residential sector"*[134]. More specifically, as a substitute for FiTs, consumers who install PV systems under the NEM framework can balance their expenditures and actively reduce their electricity bills. The proximity factor poses a limitation as the model is utilized within the residential multi-apartment context. Also, as the authors simplify, there is *"a lack of a universal policy harmonizing … legislations of the E.U. member countries,"*[135] with core policies that cause discrepancies in fundamental issues such as *"installation capacity limits, settlement period... [and] the price of the compensated energy"*[136].

The study's primary focus is on the Greek VNM model, as supported by Law 4203/2013[137], which pertains to the internal PV market structure. The Greek VNM framework applies a mixed netting practice: *"the prosumer is charged for the total amount of energy consumed... for the 'services of general interest' charge"*[138] and in the case of excess of supplementary generation, there is no financial motive but is compensated as Renewable Energy Credits (RECs). This specific system is dedicated to self-consumption dynamics, as the study's outcomes declare. More specifically, *"the higher the self-consumption rate, the lower the energy exported to the grid is,"*[139] and, respectively, prosumers may consider the grid as a virtual battery, "*an asset*

[134]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies.
[135]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies.
[136]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies.
[137]Law 4203/2013 https://www.hellenicparliament.gr/Nomothetiko-Ergo/Psifisthenta-Nomoschedia?law_id=fd683678-97a0-4d4e-9b6f-7e2658321207
[138]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies.
[139]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies

that all consumers pay for"[140], theoretically reject equity and network sustainability.

The core foundation of the system, as portrayed by Lee et al. (2021), is the sharing of energy among several users by a central solar-related energy system. The energy consumption shall be specific to the user. Yet, this concept overcomes the constraints of solar power as *"renters and homeowners living in shared buildings cannot go solar as they do not own the shared spaces"*[141], so collective initiatives are essential. It is worth noting that every system inevitably suffers from limitations once it is introduced. In this case, VNM had no control over the overall energy usage. In their research, Lee et al. (2021) propose an *"Auto Share"* virtual framework that provides each user with the illusion of owning a solar and battery installation. This systemic computer illusion *"provides a virtual solar and battery abstraction to users,"*[142] which delivers the freedom of management and decision-making regarding energy handling.

The personal handling in energy profiling of each user, provides the sense of responsibility and has deemed to improve joint effectiveness on the model as "*AutoShare can reduce solar array size by 14.6% and battery capacity by 75% compared to a dedicated system"*[143], with outcomes to lead to an energy saving path in a community level. Complementarily, Alahmed and Tong (2024) leveraged the virtualization era to introduce the "*Dynamic Net Energy Metering (D-NEM)*" [144]framework. As net metering tariffs are fixed, in contrast, the D-NEM model defines the rates dynamically, taking into consideration mass community production. Within this scope, collectivity, and collaboration, being fundamental characteristics of an Energy Community, are promoted, reflecting there is no advantage in opposing to community practices since they guarantee stability in energy exchange.

In combination, both systems upgrade the operational flexibility of net energy metering. "Autoshare" satisfies asynchronous demand by utilizing shared resources, while "D-NEM" promotes the concept of collaboration in pricing and energy harmonization. The primary benefit lies in energy market autonomy, eliminating the need for external energy support. Both models encourage time-of-use pricing related to battery storage usage. The algorithms implemented in "AutoShare" satisfy the electricity-related rates and weather forecasting effects. "D-NEM" becomes accustomed to fluctuations in production and triggers battery storage services when necessary. VNM is founded on user-related proliferation, with each model

[140]Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E., 2016. A model for the assessment of different net-metering policies
[141]Lee, S., Shenoy, P., Ramamritham, K. and Irwin, D. (2021). AutoShare: Virtual Community Solar and Storage for Energy Sharing. Energy Informatics, 4(10).
[142]Lee, S., Shenoy, P., Ramamritham, K. and Irwin, D. (2021). AutoShare: Virtual Community Solar and Storage for Energy Sharing. Energy Informatics, 4(10).
[143]Lee, S., Shenoy, P., Ramamritham, K. and Irwin, D. (2021). AutoShare: Virtual Community Solar and Storage for Energy Sharing. Energy Informatics, 4(10).
[144]Alahmed, A.S. and Tong, L. (2024). Dynamic Net Metering for Energy Communities

being fair and supporting instruction-oriented optimization, especially in multi-apartment buildings.

5.4 Virtual Net Billing

Autonomy and democratization in energy exchange practices led to the introduction of Net Billing as a fundamental tool. To clarify, as mentioned above, Net Metering flourishes based on kilowatt-hour offsets; however, Net Billing practices rely on accurate methods to value electricity flows. More particularly, in line with Gjorgievski et al. (2021) proclamation, *"the virtual net-billing (VNB) method... enables the members of an Energy Community to fairly share energy in real-time, based on their… contribution."*. To emphasize the importance of VNB, the EU's legislative framework for Clean Energy for All EU citizens, which the Greek government supports, includes relevant directives on Net Billing promotion and Consumer Self Consumption models.

To begin with, Virtual Net Billing is considered more advantageous than Virtual Net Metering. Virtual Net Billing considers real-time consumption patterns, and as it comes to generation, the flows are allocated fairly and proportionally. Regarding equitable share allocation, Gjorgievski et al. (2021) declare that *"each member is guaranteed to keep their… self-consumption... and gets a part of the shared electricity... based on their contribution,"*. Virtual Net Billing proposed model from Gjorgievski et al. (2021) is justified on a game-theoretic background. Thus, it is viewed as more effective holistically. The model adopted basic financial principles and incorporated them into a cooperative game to achieve outcome stability. The authors clarify that *"the cooperative game is balanced, which means that the economic surplus of the community can be distributed so that coalition stability is achieved."* In addition, to encourage their model on a vast application level, they examined around six hundred (600) hypothetical Energy Communities demonstrating also that participated members had no motivation to abandon the project due to the beneficial outcomes.

Greek Energy Communities have implemented Net Billing, which has been officially reinforced through the national legislative framework.More specifically, the regulatory foundation was established through Ministerial Decision "ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190/2020"[145], which enabled the modern Energy Communities to allocate their exchange flows virtually based on predefined rates. In line with the abovementioned legislation, the context of Virtual Net Billing is advocated respectively by Law 5037/2023[146], which promotes Renewable Energy Communities' operation and creates incentives

[145]Ministerial Decision ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190/2020, Government Gazette B' 1045/2020. https://helapco.gr/ypourgikes-apofaseis/arithm-ypen-dapeek-30971-1190-fek-1045v-26-3-2020-prosthiki-neon-katigorion-stathmon-paragogis-ilektrikis-energeias-apo-a-p-e-kai-s-i-th-y-a-kai-kathorismos-ton-t-a-epanaprosdiorismos-ton-katigorion-s/

[146]Law 5037/2023 https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/

for Net Billing alternatives. Real-time sharing and equitable allocation in energy flows have been addressed in Greek legislative texts, constructing thriving prospects for Virtual Net Billing application.

To sum up, upon observing the Virtual Net Billing application, it is essential to note that it addresses the limitations of traditional metering methods by incorporating fairness and practical criteria into its application. As Gjorgievski et al. (2021) underline, citizens' participation is a core element in every Energy Community group and requires being treated with equitable respect in their transactions, and *"Without fairness, the members …are left unsatisfied... potentially leading to its gradual disintegration."* Greece, in line with advancements in energy democracy and robust citizen participation, shall monitor the upgrades of billing and metering methods on a European level, primarily, and correspondingly, integrate the essential alterations in the legislative text governing Energy Communities promptly.

5.5 Net Billing vs. Net Metering

Energy generation in Energy Communities across the EU primarily utilizes photovoltaic systems, and the proliferation of the community is mainly dependent on the billing mechanism implemented. Within the research scope of Fuster-Palop et al. (2023) and Jasiński et al. (2024), we aim to comprehend the various representations of Net Metering (NM) and Net Billing (NB), which are the most widely applicable billing models. Both articles discuss the economic status and efficiency of the models in terms of grid stability and market feasibility. To clarify, both models process stronger and weaker points, and the following analysis presents various points to conclude on the most valuable concept in billing.

In the Net Metering system, the credit context of the energy flows produced with the possibility of subsequent consumption promotes a simple and efficient economic model. Simultaneously, at Net Billing, excess energy is offered in the wholesale energy market at usually lower selling rates. As stated by Fuster-Palop et al. (2023), "*since surplus remuneration in NB represents approximately one-third of the regular price in the electricity tariff, the sizing optimization tends to minimize the surpluses*". Under the above circumstances, the overall performance of the economic model is downgraded unless high-tech modeling is used to match production with consumption patterns. Regarding payback time issues, Jasiński et al. (2024) affirm that in the case of *"developing energy independence in the Energy Community formula results in a significant reduction in the cost of purchasing electricity… can lead to a reduction in the payback time…"*.

Furthermore, it is anticipated that Net Billing increases risk exposure in the energy market by linking surplus flows to the wholesale electricity market. This technique exposes producers to market risk, which is frequently viewed as unnecessary and undesirable. To justify the above, Jasiński et al. rationalize that, *"the prosumer billed under that mechanism is exposed to the risk of negative prices in the wholesale market…will result in a loss on the prosumer's portfolio."* Subsequently, Net Metering is demonstrated to be more beneficial to the participant. To prevent negative pricing, Spanish regulatory authorities, as noted by Fuster-Palop et al. (2023), impose a constraint in large-scale Energy Communities; *"the sum of the economic surplus remuneration cannot be higher than the economic value of the energy consumed from the grid"* in the context of a billing period.

On the contrary, Net Billing might be more approachable to the user, yet it entails precision in energy flows generated and consumed. In their study, Fuster-Palop et al. (2023) aimed to demonstrate the sensitivity of energy flows and introduced the "Load Profile Factor" to monitor the alignment of energy patterns. Thus, they conclude that *"poor alignment between demand and irradiance hours reduces profitability significantly."* The above-mentioned matching necessity is not a prerequisite in Net Metering, as there is the possibility of energy storage for later use in the central grid. It is considered favorable that energy storage techniques are not needed, and even real-time consumption is diminished.

From a feasibility point of view, for individual prosumers such as households, Net Metering is typically employed because the operation is more straightforward and does not require forecasting of energy flows, making it more suitable for short-term generation. On the contrary, for grid operators, Net Billing, which is based on scaling, is more suitable. Fuster-Palop et al. note that Net Billing is theoretically more appropriate in the long run since it *"helps to minimize surpluses to guarantee high self-sufficiency rates and low payback"* and correspondingly as it comes to EU guidelines it shall be highlighted, that Net Billing affiliates with European energy market dynamics, in pricing, grid stability, and generation surpluses. To conclude, for small-scale users, Net Metering is preferred for protecting user profiles, whereas on a larger scale, Net Billing is considered more valuable for handling energy billing.

5.6 Energy Storage

Energy Communities utilize storage technology to accumulate and manage excess energy flows. These surpluses contribute to boosting local Renewable Energy consumption and decentralizing from grid dependence. Bartolini et al. (2020) highlight that *"storage systems allow shifting of the energy use from the production time to the consumption time, thus increasing the self-consumption rate"*. This energy allocation system creates benefits for Renewable Energy installations and addresses the issues of autonomy that often lead to financial imbalances for end-users. Likewise, as per Farfan et al. (2024) there is a positive operational productivity when PV installations are accompanied with energy storage units: *"The combination of PV generation with storage units was found … reduce electricity imports… while increasing energy self-reliance"*. As a result, grid stabilization is a valuable asset in energy storage generation. For instance, especially battery technology is regarded advantageous as stated from Bartolini et al., since they *"mitigate the variability of renewable generation and reduce peak demand"* resulting in enrichment in grid capacity conditions.

Users tend to invest in energy storage applications as a strategic option, aiming to improve service quality and reliability of the exchanged energy flows to avoid shortage events. Economic benefits and profitability attract new members to the community and preserve satisfaction among users. Regarding the issue of commercial profit, Bartolini et al. claim that *“collective storage can achieve economies of scale …and increase efficiency through coordinated control*.” Inclusion strategies in Energy Communities create bonding ties among users, with vulnerable members being equally reinforced rather than excluded. Except for the beneficial outcomes regarding autonomy, storage units improve flexibility for the users. Bartolini et al. affirm that *“storage systems, if appropriately managed, can offer backup services and hedge against electricity price volatility*”. The augmented risk exposure for prosumers in the competitive energy market is minimized, as the energy stored in storage units balances the potential energy deficit. Equally, Farfan et al., stated that via energy storage technologies applications, equipped Energy Communities *“showed greater operational flexibility and reduced vulnerability to time-of-use pricing fluctuations”*.

In conclusion, in view of energy storage units, it is demonstrated that PV technologies represent profit on a large scale. The profile of Energy Communities is boosted economically and operationally. Cost-related efficiency and stability mitigate risk in energy trading, supporting self-consumption and sustainability. Similarly, Farfan et al. underline that *“storage unlocks the full potential of shared…systems.”* As self-sufficiency is achieved, storage technologies may expand investment budgets; yet, the profit of autonomy is desirable, particularly in energy transactions.

Chapter 6: Solarity Urban Energy Community

6.1 Introduction to Urban Energy Communities

When Energy Communities operate in urban areas, they shall be characterized under the term “Urban Energy Communities.” The term defines primarily energy exchange and relevant governance in energy activities occurring in the cities, with relevant benefits and limitations. As per Bukovszki et al. (2020), the Urban Energy Communities are not just *“social innovations”;* they are equally supporting *“decarbonization of energy systems through … democratization”.* Commonly, in the last decade, the concept of energy sharing and collectivity in the energy production contradicts central market governance and exclusivity practices, which were a foremost hindrance for citizen contribution and involvement in the past. Urban areas have particularly embraced the need for transition, as major energy flows are being consumed locally. More particularly, Todeschi et al. (2021), highlight that *“70% of citizens live in urban areas and consume around 75% …energy supply.”*, it is a matter of urgency that city areas transit more rapidly to sustainable operational practices.

Energy Communities facilitate the path of a decentralized energy handling landscape. Energy shortages, especially in densely populated areas, initiate emergency energy security solutions. In lieu of the above, Todeschi et al. (2021), emphasize that Urban Energy Communities *“may help to address the challenges of urban sustainability … through local energy production,”*. Specifically, Urban Energy Communities frequently encounter technical issues that hinder their effectiveness. Urban districts, in most cases, utilize PV installations along with storage facilities in residential buildings. In their study, Todeschi et al. (2021), focused on Turin, Italy, and concluded that *“different values of self-sufficiency and self-consumption can be reached depending on the shape and dimension of each building,”*. Under this scope, each urban community has specific needs and tailor-made models regarding energy consumption and production patterns shall be applied. Furthermore, they highlight that dedicated planning is of foremost importance in order *“to satisfy the … requirements to become an Energy Community in an urban environment with good levels of self-sufficiency.”*

On the contrary, Bukovszki et al. (2020), stated that the difficulty of developing an Energy Community lies within the comprehension of the framework and the role of the prosumer. Exclusively, they developed an “Urban Energy Building Model” within the effort of *“reducing risks, engaging, motivating and guiding actors.”* It is regular that modeling and planning on Urban Energy Communities fall out of realistic expectations. Bukovszki et al. (2020) concluded that forecasting, is particularly challenging since *“the influence of urban surroundings on their energy performance has not been properly incorporated,”*. As a result, technical enhancement only covers the wide scope of Urban Energy Communities. Enrichment shall incorporate social characteristics in lien with a real-time evolving society. Precisely, Basu et al. (2019) focused their research on this specific domain since Urban Energy

Communities are fast-developing systems, characterized as *"multi-layered, hierarchical, and socially embedded"*. This concept contradicts static and straightforward environments, and as per Basu et al. (2019) they seem to *"embrace, trace and map the complexity"* as cities possess social characteristics that define them.

Urban Energy Communities signify leadership as the control of energy flows is passed to the prosumer. The prosumer influences energy governance, and as per Bukovszki et al. highlight, they are considered to *"give control to the ones who benefit from the outcomes,"* In line with the above, Todeschi et al. underline that in the Italian case, the gains of an Urban Energy Community converge essentially on energy autarchy and community bonding. As Urban Energy Communities are explicitly considered complex, the challenging environment stems primarily since they *are "deeply embedded within national and international infrastructures, processes and institutions,"* (Basu et al,2019). As a result, the handling and the modeling of a dynamic system requires regulatory and technical management. Nevertheless, Urban Energy Communities present technical opportunities, as Todeschi et al. illustrate, provided that proper spatial and storage models are applied. Also, following the above, they represent a holistic urban movement and *"not just a technology, but a way of reorganizing energy as a social relationship."* (Basu et al,2019).

6.2 Emerging Innovations and Challenges for Energy Communities in Urban Surroundings

As already acknowledged, Urban Energy Communities are the core foundation for the energy transition phase that we are experiencing. The definitive target of renewable energy production and sustainability shall be achieved through technological developments and energy cluster management. On the contrary, the decentralized energy governance raises substantial challenges in the regulatory framework and the inclusion of all citizens on the project. Indeed, advanced modeling in the smart energy grids displays multiple benefits. As per Reddy et al., 2022, within the context of their stud, they affirm that *"microgrids are presently evolving as intelligent local grids… demand-side management…energy efficiency enhancement,"*. More specifically, smart settings of modern modeling applied to energy grids, care for more than production and supply management. They employ optimization techniques to improve self-sufficiency. Smart Microgrid Systems also aim for load management, which is ideal for densely populated urban areas.

However, as clarified by Reddy et al., 2022, RES have certain limitations since *"their self-electricity generation is based on renewable energy sources, which are uncertain due to their environmental dependency"*. This circumstance, perceived as susceptibility to energy generation, could be counterbalanced only with storage installations and proper forecasting equipment. Under this prism, Urban Energy Communities have displayed elevated investment costs both stemming from the equipment needs and the digital support that they require. It is reasonable that the effective operation of an Urban Energy Community requires digitalization of the microgrid for the necessary practical basis. Data collection and reorganized control are considered as core functions and with remote monitoring they are being facilitated. Regarding the digitalized management system, as per Reddy et al., 2022, *"to establish such useful ISMs, a well-established communication mechanism has to be adopted"* to hinder any instability events that shall jeopardize systems resilience. Nevertheless, digitalization on urban installations seems to raise cybersecurity risks which create uncertainty in operations. The challenge on the one hand is to properly digitalize the grid infrastructure. On the other hand, achieving systemic protection of cyberthreats is a major challenge to overcome.

A key innovative step in connection to Urban Energy Communities is the governance concept which prioritizes energy democratization. As specified by Lowitzsch et al., 2020, *"these systems are supposed to be open, voluntary and autonomous associations with the right to generate, consume, store and sell renewable energy"*, turning passive consumers to actively engaged prosumer members. This distinctive characteristic reinforces resilience enrichment. Nonetheless, regulatory gaps and procedural delays generate unforeseen bottlenecks. Various member states in the EU have adopted energy transitions techniques at multiple levels, resulting in unforeseen gaps in implementation developments. It is mentioned also from Lowitzsch et al., 2020 that *"the transposition of the EU Directives is still pending in many Member States,"*. The transitional gaps hinder investment opportunities and associated actors consider engagement in energy generation risky and unattractive. Thus, system gaps seem to keep vulnerable members unprotected from risks. The lack of inclusive design threatens to exclude low-income households from the benefits of Energy Communities (Lowitzsch et al., 2020). Defined policies need to encompass all community members and not only the higher income households, which in fact are not depleted from the energy poverty effect in the first place.

Urban Energy Communities pose several benefits despite the tremendous implementation challenges. The prosperous model application depends primarily on social dynamics for citizen encouragement. Human element is the key to invest as it comes to Urban Energy Communities, and considering the well-known self-determination theory, Bӧgel et al.,2021support that *"Enabling the people to self-determine, control, and secure their energy provision … is likely to increase their acceptance"*. Awakening individuals for the environmental benefits and the personal improvement value of Urban Energy Communities increases involvement despite structural differences or social complexity.

6.3 Case Study: Solariry Urban Energy Community

6.3.1 Introduction to the Case Study

For this dissertation, the Solarity Urban Energy Community will be examined as a real-world example of an operative Energy Community located in the urban area of Attika region. Like all Energy Communities, Solarity represents citizens' cooperation to take action and be active in energy production and consumption. The establishment of the Urban Energy Community was validated under the Greek Energy Law 4513/2018[147].Under the European context, the functions of the community abide by the directions of RED II[148] legislation. This specific community is functional and has procced from being a conceptual notion to an operational success in energy related activities. The members involved have proven their dedication by turning potential plans into real-time projects with noticeable benefits. The range and the concept of this urban community signify a common shared goal towards energy democratization.

To present Soraliry urban community, data have been obtained from two principal sources. Firstly, the official Athens Chamber of Small and Medium Industries[149] ,where the community is registered as all legal economic entities are required to, under Greek Legislation. In this portal structure, legal aspects and functional utilities are accessible. Secondly, the official online website[150] where the current activities and objectives of the community are being continuously updated. Under this scope, these two sources grant an integrated approach on the everyday operation of Solarity Energy Group, illustrating its contribution to sustainability as it comes to urban energy.

6.3.2 Background of the Solarity Energy Community

In the name of clean energy and heading towards sustainability, in 2023 in the municipality of Nea Ionia, Attica Region based on "*the notion for the creation of an urban Energy Community … [Solarity Energy Community] … was established in order to develop a photovoltaic park under the scheme of virtual net metering, aiming to enhance democratic participation in the energy sector and tackle energy poverty*"[151]. Taking into consideration the willingness of both citizens and local authorities to procced with the realization of the initiative, in April 2024, in context of a social purpose civil cooperative stemming from Greek national energy framework (Law 4513/2018), the founding board of the community was finalized. In alignment with **Art. 4**[152] of the founding statue, the solid purpose of the community as a nonprofit legal entity, (translated essentially for this thesis) is to "*promote sustainable development …energy transition … energy production …consumption … [and] storage, …while ensuring access…inclusion…and environmental protection*". Under this scope, all members could enjoy benefits from collective activities and social inclusion.

As stemming from Law 4513/2018 on Energy Communities[153], Solariry Energy Community operates under General Commercial Registry no. 171775602000,

[147]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/
[148]RED II https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC
[149]Solariry Business Portal https://publicity.businessportal.gr/company/171775602000
[150]Solarity Renewable Energy https://solarity.coop/
[151]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[152]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[153]Law 4513/2018 https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/

with an inclusive membership policy. As mentioned in **Art. 7**[154] of its founding statute, considering membership particularities, all actors are permitted to participate as long they abide by the requirements of national law, particularly being natural people or legal entities under public or private law governance and do not participate in another Energy Community (second degree cooperative). The membership formation is citizen adapted, with approximately ninety-two (92) members, with each one maintaining at least one (1) cooperative share, as the statute instructs. The sum of shares provided is around one hundred (100) with active members opting for expanded contribution and benefits from the community's projects, yet with all shareholders being entitled to vote equality. For the sake of good order, based on G.E.M.I. official registrations[155] it shall be pointed out that both women and men participate equally, asserting social inclusion values.

To encourage energy democracy, **Art. 6**[156] of the statute provides 1 (one) vote to each member and for the purpose of reinforcing future renewable energy investments, the potential profits are dedicated *to "reinvestment …for the community's social purposes"* based on **Art 5.5**[157] of the funding statute. The organizational structure of the community refers to RE generation and handling as a social justice activity to support sustainability via citizen active participation and equality. The member structure provides a comprehensive approach to enhance pluralism. **Art 6.2**[158] additionally states that "*members are obliged to participate in the activities of the community and to contribute to achieving its objectives*", proving that the targeted achievements are based on collaboration and active participation.

6.3.3 Legal and Organizational Formation

The structure of Solarity Energy Community is based on a democratic governmental vision. **Art.13**[159] of the statute refers to governing body particulars of the community. As mentioned, there is impartiality in the selection practices, (each member, one (1) vote), and *"The General Assembly is the supreme decision-making body"* of this community, involving all members. As per **Art. 15**[160], the General Assembly elects the Board of Directors, which consists of five (5) members. Additionally, relating to the Board's responsibility spectrum, as per **Art. 17**[161], the selected members are delegated to officially represent the community, and supervise, align, and execute both running projects and Assembly's decisions. To highlight, regarding the issue of legal representation, **Art. 18**[162], declares that *"the president is the main representative"* and *"the Treasurer co-approves financial resources handling"*. Nonetheless, supervision adheres to the

[154]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[155] Solarity Official Registration (G.E.M.I) https://publicity.businessportal.gr/company/171775602000
[156]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[157]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[158]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[159]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[160]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[161]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[162]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000

General Assembly's obligations as there is no supplementary supervision body revealed on the statute.

Regarding the membership rights, all members have access to the decision-making procedures for the various projects of the community. It is noticeably indicated in the statute, in **Art. 6,15,16,17** [163], that every member possesses voting rights equal to the General Assembly's and collectively they elect the Board of Directors, in a structure which promotes energy fairness. The official website[164] actively encourages open participation for the members and equality of opportunity. In fact, it is stated that in local energy handling, effective results shall be accomplished only *"with active citizen participation instead of exclusions."* Respectively, the community proves the abovementioned declaration, with active engagements tools for the members, via a private member forum, a Viber Group, and a Slack Channel as communication networks. This specific participatory framework is deemed to be successful since it invests in social cohesion and collectivity.

The participation conception upgrades the cooperative's goals for a more comprehensive and greener energy system at a community level first. Solarity has demonstrated flexible governance and despite mentioning in **Art. 2**[165] that it is based on Attica, it reserves in the future the right for branch expansion. The regulatory framework is developed internally, with purposely dedicated internal operational techniques, authorized by the General Assembly, a fact which reveals flexibility and tailor-made tactics to the community's demands (**Art. 22**[166]).

6.3.4 Scope of Activities

The Solariry Energy Community has a multidimensional scope of activities related to energy. The range of the projects are mentioned on the legal statute and the official website along with specific initiatives and projects which justify the mission and the targets of this community. The community, via its wide range of activities, supports energy consensus and citizens' unity for greener and sustainable communities. The value of sharing and treating with rationality the produced energy volume actively raises sustainability awareness in everyday practices.

6.3.5 Permitted Projects

As per **Art. 2** of the statute, Solariry Energy Community engages in specific energy-related activities. More particularly, the community opts to invest in *"production, storage, and self-consumption of electricity from renewable energy sources"* and worths to be mentioned that the majority of Greek Energy Communities are active in this scope of activities. Furthermore, Solarity Urban Energy Community is dedicated to evolving supplementary services such as *"smart metering," "environmental education," "R&D and*

[163]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[164]Solarity Renewable Energy https://solarity.coop/
[165]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000
[166]Solarity founding proceedings, 2023 https://publicity.businessportal.gr/company/171775602000

innovation initiatives” in the light of approaching energy handling more holistically. The range of activities is also aligned with the official website, as a member-driven energy initiative aiming for social benefit reinforcement. Taking into consideration the complexity of energy activities and the recent citizen involvement, the community provides additionally “*advisory [educational] services*,” as a valuable guiding tool during the current energy transition era.

Members, in spite of the major PV park investment, are also participating in supportive projects which are of increased operational complexity and are expected to be beneficial for the participants. To clarify, the community has energetically been engaged in R&D applications (Horizon EU program[167]) and examined further the Ubitech group proposal as we will analyze further below. PV Park requires supplementary operation activities, which is the reason members opted to assure the security of infrastructure by gathering insurance and security proposals from a variety of security (mostly local) businesses and insurance related organizations. As already presented, Virtual Net Metering concept promotes clean energy production. Solariry Energy Community, as a pilot initiative, attempted to engage in developing a Virtual Net Metering model, where the production of energy from renewable sources will be balanced with each member’s energy consumptions remotely.

6.4 The Development of a Photovoltaic Park

Solarity Energy Community is actively engaged in energy production via solar energy. More specifically, the success of the community as to comes to realistic energy production, stems from the shared PV park facility, located in the region of Klimenti, Corinthia. The facility, from the preliminary stages of its development, was coordinated to offer electrical power by taking advantage of the Virtual Net Metering model. The collective ownership context allows members to engage in advanced technological and operational procedures, as the new energy era requires. The citizen-led energy production in the PV park verifies the common shared values of such endeavors. Democratic energy distribution and environmental sustainability are ensured through its daily operation. Klimenti, PV park is the proof that citizens’ commitments to sustainability could empower and boost clean energy initiatives.

6.4.1 Land Boundary Determination

The PV Park, as mentioned earlier, is located in Klimenti region in Korinthia municipality. The land area to be used for the development of the park needed to be accurately demarcated. Thus, on their 23/07/2024 meeting[168], the community entrusted the procedure to civil engineer Skourti Konstantina, taking proactive action to prevent future legal impediments and delays. The

[167]Horizon EU program,2021-2027 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
[168]Meeting Minutes of the Board of Directors 2024-07-23 – Solarity Renewable Energy Community, Regional Unit https://publicity.businessportal.gr/company/171775602000

Greek legislation from Ministry of Agriculture, which is based on the 1965 land distribution, frequently creates unexpected issue regarding land limitations in rural areas, such as Klimenti. Therefore, the community proceeded with fencing and land limitation actions which facilitated the commencement of the construction.

6.4.2 Certification and Construction Supervision

It was vital that the construction oversight and the verification of the PV park operations were conducted by dedicated organizations on these subjects. At the Board Meeting held on 11/10/2024[169], the aforementioned issues were addressed and assessed.

The members entrusted the certification assignment to TÜV Austria[170], to act as a certifying authority for the PV park. All members have concluded that a certifying authority appointment would be deemed imperative, in order to ensure the credibility of the site. Furthermore, only the certifying authority could verify the park's compatibility potential with HEDNO's specific connection prerequisites to the grid. The cost of 1,922€ including two inspections on separate occasions to the park was accepted from the community. TÜV Austria would also validate that the operational standards abide by both national and European legislation on PV facilities. Under this scope, the completion of the certification was authorized on 04/02/2025, with proposed future renewal on 18/12/2028, after certain scheduled maintenances as per the operational guidelines.

Regarding technical oversight, which is a high priority issue, as it comes to the construction of the facility since it is related to operation success, the matter was holistically addressed in the meeting of 13/11/2024[171]. The assignment was entrusted to SolarWay[172], a renewable energy project organization, located in Kalamata, Messinia. It is worth noting that the community strived to support local businesses in Peloponnese, while taking care of the necessary requirements for the PV park. The role of SolarWay was multisided and complex during the PV development. The technical implementation of the site and the grid connection are core activities requiring accurate planning. SolarWay indeed, progressed with success in the installation of the PV equipment and simultaneously managed communication with HEDNO[173] to obtain connection to the grid endorsement, along with coordinating the Net Metering contractual terms agreement.

[169] Meeting Minutes of the Board of Directors 2024-10-11 – Solarity Renewable Energy Community, Regional Unit https://publicity.businessportal.gr/company/171775602000
[170] TÜV Austria https://tuvaustriahellas.gr/
[171] Meeting Minutes of the Board of Directors 2024-11-13 – Solarity Renewable Energy Community, Regional Unit https://publicity.businessportal.gr/company/171775602000
[172] SolarWay https://solarway.gr/en/
[173] Hellenic Electricity Distribution Network Operator (HEDNO) https://deddie.gr/en/

SolarWay's vital role in the development of the site was addressed during multiple Board Meetings in terms of services assessment and scheduled progress of the site. Abiding by the regulatory parameters of HEDNO[174] was the initial target of the community.

6.4.3 PPC & Solarity in a Virtual Net Metering Contract

Solarity Members have acknowledged from the beginning of the project that in order to benefit from the energy produced at the PV site, they would have to procced with a contractual agreement with an electricity supplier. The mechanism of Virtual Net Metering as previously analyzed, would grant direct offsets on the electricity bills of the cooperative's members, considering the already generated energy amount at Klimenti. This agreement would be vital since the members are located in the Attica region and are not physically connected to the installation. It is imperative to highlight that in the Greek Power Market they are multiple energy suppliers, such as PPC[175] as a leader, and alternatively Elpedison[176], Volton[177], Protergia[178] or Zenith[179].

On 13/10/2024 Board Meeting[180] the members explicitly debated the matter of signing a contractual agreement with an energy supplier and the possibility of choosing one or more energy supplier for the Virtual Net Metering project. It needs to state that various members supported PPC is not the most dominant option since there are multiple energy suppliers, and the concluding decision shall be reached only after careful assessment. On the grounds that private energy providers offered more competitive economic gains, yet the potential collaboration with them posed legal complexities difficult to encounter in comparison to PPC. The cooperative had a complicated dilemma to tackle. Regarding the beforementioned private supplier collaboration matter, during the Board Meeting it was recorded that *"concerns were raised regarding legal clarity and the complexity of implementation with third-party suppliers."*

Under this scope, the General Assembly authorized PPC as the initial energy supplier to procced with the Virtual Net Metering model. More particularly, PPC was selected due to *"operational simplicity, legal clarity, and … compatibility with members' existing electricity accounts."* The contractual agreement with PPC aimed exactly at what the cooperative hoped to achieve as a community benefit, "*receive energy offset on their own electricity consumption based on their share of participation."* Additionally, to facilitate calculation process with transparency, accuracy and to guarantee objectivity among the benefits, the cooperative adopted that *"the share ratio for each*

[174]Hellenic Electricity Distribution Network Operator (HEDNO) https://deddie.gr/en/
[175]PPC https://www.ppcgroup.com/en/ppc/
[176]Elpedison https://www.elpedison.gr/el/
[177]Volton https://volton.gr/
[178]Protergia https://www.protergia.gr/
[179]Zenith https://zenith.gr/el/
[180]Meeting Minutes of the Board of Directors 2024-10-13 – Solarity Renewable Energy Community, Regional Unit https://publicity.businessportal.gr/company/171775602000

member will be calculated with a precision of two decimal places to be accepted by PPC's system".

6.5 Performance of Klimenti PV Park

Klimenti PV park became fully operational in the beginning of 2025. The system has a peak power capacity of 399.7 kWp, referring to its size[181]. To be clarified, kWp refers to the maximum peak capacity that a solar system is able to produce as an output under the standard test conditions[182].The kWp valuation states peak performance as a commercial measurement scale, commonly utilized in facilities similar in size to Klimenti PV park.

6.5.1 Theoretical vs. Actual Output

In solar panel energy, theoretical production contradicts the actual produced output. The theoretical approach is based on ideal expectations regarding solar production. As per Cococcioni et al., 2011, *"solar radiation is the most important parameter in the performance prediction of renewable energy systems"* as a prediction model. Nevertheless, this approach is considered simplified and does not take into account any inconstant atmospheric specifications, since environmental viables tend to be unpredictable. Thus, the actual output frequently deviates from theory since it is affected by real-life circumstances. For example, produced output often diverges from theory due to real-world variables. The authors point out that even *"rapid changes in solar radiation or temperature... sensibly change [actual] produced power"*[183]. As a result, weather conditions such as cloud movement or weather volatility, even with elevated temperatures, cannot be apprehended on prediction model calculations.

The performance ratio (PR) is an important metric in PV system quantification. It is related to the effectiveness which arises when a PV unit converts solar energy into electricity. As per Asoh et al., 2022, "*The PR is the ratio between the final yield and the reference yield,"* which has been created to depict the gap between actual and theoretical output stemming from irradiation. To be clarified, a potential performance ratio of 100% would signify a total conversion which does not practically correspond to reality since there are unescapable losses. Regularly, a core issue arises from inverter inefficiency, even in the case of high-quality units. In addition to the above, dust and soiling on units signify *"energy losses in the field,"*[184], which

---

[181]Solarity- System Performance https://monitoringpublic.solaredge.com/solaredge-web/p/kiosk?guid=a1a98d22-cfce-45cc-8ce1-898ec93d6da5

[182]Sharma, V. and Chandel, S.S. (2013) 'Performance analysis of a 190 kWp grid interactive solar photovoltaic power plant in India', Energy, 55, pp. 476–485. Available at: https://doi.org/10.1016/j.energy.2013.03.075.

[183]Cococcioni, M., D'Andrea, E. and Lazzerini, B. (2011) '24-hour-ahead forecasting of energy production in solar PV systems', in 2011 11th International Conference on Intelligent Systems Design and Applications. Available at: https://doi.org/10.1109/ISDA.2011.6121835

[184]Asoh, D.A. and Awangum, N.N. (2022) 'Low-Cost Automated PV Panel Dust Cleaning System for Rural Communities', Smart Grid and Renewable Energy, 13(08), pp. 173–199. Available at: https://doi.org/10.4236/sgre.2022.138011.

is really common in dry surroundings that necessitate consistent cleaning to be resourceful.

Furthermore, actual production is mutually related to and influenced by thermal losses and unit degradation. Asoh et al., 2022, stated that *"temperature has an influence on the module efficiency,"*, acting as a factor which reduces efficiency when units operate in high volumes. Moreover, it is evident that "*module aging may lead to a progressive decrease in performance,"*[185]. Taking into consideration the above, there are several factors which manipulate the divergency of the production model in an actual operation period contrasted with a theoretical background.

On Klimenti PV park the performance load depends heavily on sunlight activity during peak hours and theoretically it could produce within a range of 1,918.56 to 2,238.32 kWh per day. As a utilized method, to calculate the potential production of 1,918.56 to 2,238.32 per day, the methodology from "*Design and Performance Analysis of Solar PV System 2,56 kWp (2019)"*[186] has been employed. The simple equation *"Daily Energy Output (kWh) = System Size (kWp) * Average Peak Sun Hours/day"* fits to our system as it is a relatively small-medium sized PV park.

*Daily Energy Output (kWh) = System Size (kWp) * Average Peak Sun Hours/day*

- System Size (kWp) → 399.7[187] (1)
- Average Peak Sun Hours/Day → as per NTUA research [188]
    - ✓ On a fixed tilt ~ 4.8 hours (2)
        - ✓ 1-axis tracking ~5.4 hours (3)
        - ✓ 2-axis tracking ~5.6 hours (4)

Accordingly, taking into consideration the above:

(1) System Size: As per Solarirty's official performance published, we shall obtain the below monthly outputs for the first half of 2025 (January-June)[189]

[185]Asoh, D.A. and Awangum, N.N. (2022) 'Low-Cost Automated PV Panel Dust Cleaning System for Rural Communities', Smart Grid and Renewable Energy, 13(08), pp. 173–199. Available at: https://doi.org/10.4236/sgre.2022.138011.

[186] M. H. Radhi, E. J. Mahdi and A. K. Mftwol, "Design and Performance Analysis of Solar PV System Size 2.56 kWp," 2019 4th Scientific International Conference Najaf (SICN), Al-Najef, Iraq, 2019, pp. 70-73, doi: 10.1109/SICN47020.2019.9019373.
[187]Solarity- System Performance https://monitoringpublic.solaredge.com/solaredge-web/p/kiosk?guid=a1a98d22-cfce-45cc-8ce1-898ec93d6da5
[188]Solar Peak Hours – Greece https://www.researchgate.net/publication/319864978_Investigation_on_the_stochastic_nature_of_the_solar_radiation_process#pf3
[189]Solarity- System Performance https://monitoringpublic.solaredge.com/solaredge-web/p/kiosk?guid=a1a98d22-cfce-45cc-8ce1-898ec93d6da5

Inverter	AC Energy (kWh)	kWh/kWp
Inverter 1	88,695.37	772.61
Inverter 2	88,155.92	777.39
Inverter 3	87,893.25	775.07
Inverter 4	44,700.02	769.36
Total	309,444.56	3,094.4

Table 3 Solarity PV Park - Unit Performance (2025)

The six-month production presents an output of 773.6kWh/kWp as a result,

System Size (kWp) = Energy (kWh) / Specific Yield (kWh/kWp) ⇒
System Size (kWp) = 309,444.56 / 773.6 ⇒ System Size (kWp) = **399.7 kWp**

To conclude, the system size is approximately 399.7 kWp.

(2) Daily Energy Output (kWh) = System Size (kWp) * Average Peak Sun Hours/day ⇒ Daily Energy Output = 399.7 * 4.8 = **1,918.56 kWh**
(3) Daily Energy Output (kWh) = System Size (kWp) * Average Peak Sun Hours/day ⇒ Daily Energy Output = 399.7 * 5.4 = **2,158.38 kWh**
(4) Daily Energy Output (kWh) = System Size (kWp) * Average Peak Sun Hours/day ⇒ Daily Energy Output = 399,7 * 5.6 = **2,238.32 kWh**

To conclude, the park shall potentially offer an output of 1,918.56-2,238.32 kWh from a theoretical point of view, with a close estimate of 1,920 -2,240 kWh/day and on an average 2,105 kWh/day.

The production table below stems both from personal calculations in the context of this thesis and from data officially published for the Solarity Energy Community on their online website. Columns Actual Production (MWh)/Predicted (MWh)/Difference (MWh) refer to data presented by the cooperative[190], and the column Difference has been created for the analysis of the produced output.

[190]Solarity- System Performance https://monitoringpublic.solaredge.com/solaredge-web/p/kiosk?guid=a1a98d22-cfce-45cc-8ce1-898ec93d6da5

Month	Actual Production (MWh)	Predicted (MWh)	Difference (MWh)	Difference [191](%)
January	36.74	34.45	+2.29	+6.65%
February	24.13	38.47	-14.34	-37.27%
March	54.48	54.58	-0.10	-0.18%
April	54.09	60.58	-6.49	-10.72%
May	64.47	64.14	+0.33	+0.51%
June	75.51	63.28	+12.23	+19.33%
Total	309.42	315.50	-6.08	-1.93%

Table 4 Solarity PV Park - Unit Performance per Month (1st half 2025)

Resulting from the above figures, it is worth noting that from January to June, the Klimenti PV park produced a total of 309.42 MWh, which is 1.93 MWh less than the predicted energy (315.50 MWh), in line with the Solar Edge platform, which is presented on the official Solarity website as an energy prediction model. Generally, there is an alliance pattern in the forecasted values; however, notable deviations in production require attention. Firstly, in February, there was an intense underperformance of minus 37.27% MWh. This deviation probably stems from unfavorable weather conditions during this month. In addition, in line with NASA's POWER[192] weather data for this specific period and region in Greece, February typically exhibits lower "Global Horizontal Irradiance" (GHI), indicating extensive cloud coverage and increased rainfall. Atmospheric instability creates imbalances in production, as evidenced by the underperformance in April, at a rate of minus 10.72%. Since spring months are considered unstable due to both rainy days and storms, NASA's POWER also confirms this instability[193] electronic website.

[191]Personal Calculations

Percent Difference Calculation

(2.29 / 34.45) * 100 = 6.65%
(-14.34 / 38.47) * 100 = -37.28%
(-0.1 / 54.58) * 100 = -0.18%
(-6.49 / 60.58) * 100 = -10.71%
(0.33 / 64.14) * 100 = 0.51%
(12.23 / 63.28) * 100 = 19.33%
(-6.08 / 315.5) * 100 = -1.93%

[192]NASA's POWER https://power.larc.nasa.gov/
[193]NASA's POWER https://power.larc.nasa.gov/

Despite being characterized as unstable in the first months of operation, the plant displayed a fast recovery within the following high irradiance months. The combined production of May and June showed an overproduction of 12.56%. The impressive result was achieved in June, considering the favorable weather conditions for solar production, which are typical in summer months. A surplus of 19.33% was produced, contrary to the initial prediction rate. Additionally, through NASA's POWER platform, we obtain data that confirms the GHI in the region was among the highest in Europe in June.

Weather volatility highly influences solar production, and strong performances require favorable weather conditions. In March (-0.18%) and May (+0.51 %), we can highlight an obvious alignment between production rates and the respective predictions for the SolarEbge model. As a result, when the seasonal weather expectations demonstrate stability, both the prediction model and the units present the predicted offsets without discrepancies. Annual targets appear to be achieved in a predictable pattern, with early-year losses offset by overperformance during the traditional high irradiance months.

6.6 Environmental Impact

It is worth highlighting that Solarity's environmental contribution has been notable. Drawn from the official website[194], these data depict the meaningful contribution of Klimenti PV Solar Park to green energy and decarbonization to stand against climate change.

I. CO_2 Emissions Evaded: 125,000 kg
II. Corresponding Car Travel Replaced by Solar Energy: 903,000 km.
III. Energy Source: 100% Renewable

Arising from plant's total production for the first half of 2025, 309.42 MWh of energy, are equivalent to 125 kg of CO_2 emissions avoidance. Greece's CO_2 emissions for year 2024 were approximately 256 g CO_2 eq/kWh and till August of 2025 the emissions figures approach 120 g CO_2 eq/kW[195] In line with Greenhouse Gas Equivalencies Calculator[196], the 125 kgs of CO_2 emissions is equivalent to carbon sequestered by 2.1 tree seedlings grown for 10 years or even GHG emissions avoided by 10.6 trash bags of waste recycled instead of landfilled. To sum up, by producing solar energy, the site has already boosted the global effort to reduce carbon footprints within just six (6) operational months.

The CO_2 emissions saved, symbolize the national dedication to reinforce EU climate neutrality goals for 2025[197]. Solarity's aim was to displace fossil fuel-

[194]Solarity- System Performance https://monitoringpublic.solaredge.com/solaredge-web/p/kiosk?guid=a1a98d22-cfce-45cc-8ce1-898ec93d6da5
[195]Nowtricity emission calculation https://www.nowtricity.com/country/greece/
[196]Greenhouse Gas Equivalencies Calculator https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
[197]EU Climate Neutrality 2025 https://climate.ec.europa.eu/eu-action/european-climate-law_en

based electricity from the grid and to replace it with solar produced one. International Energy Agency[198] urges that RES shall be utilized at least 90% of total energy generation by year 2030, in order to conform with Paris Agreement[199] principles. Taking into consideration, the combined EU coordination towards greener practices, Solarity does not denote exclusively a PV park for energy generation, but an initiative to emphasize carbon free energy systems.

6.7 Solarity: A valuable Energy Community model

Solariry is a competently accomplished model with a structured and transparent underpinning. The members initiated this effort to achieve economic savings in the final electricity bills. Simultaneously, the environmental benefits by targeting CO_2 emissions offset could not be ignored. The community serves as a respected operational Energy Community model for other Greek initiatives which has proved that willingness and devotion, could overcome the various bureaucracy and legislation obstacles been present in Greece in relation to green energy initiatives. Additionally, Klimenti PV Solar Park demonstrates that collective action for common benefit stands against energy crisis.

On a community scale, increasing self-sufficiency and collective ownership strengthens public engagement which is vital for a successful energy transition. The participatory model of Solarity raises RE awareness via education and sustainable practices among members. The active support of energy diversification in the energy mix supports grid stability on a national level. The decentralized production technics of a PV solar park shall mitigate energy price volatility if adopted on a wider scale. Every Energy Community and among them Solarity, in the long term they have been developed to boost energy security and national plans for energy efficiency. The noticeable contribution of offsetting 125 kg CO_2 emissions in the first six months of operation, proves that local air quality and ecological footprint could be improved firstly in a regional and afterwards in a national level.

[198]IEA https://www.iea.org/energy-system/renewables
[199]Paris Agreement 2015 https://unfccc.int/process-and-meetings/the-paris-agreement

Chapter 7: Conclusions

7.1 General Conclusions

The Greek energy market has been distinguished by the country's long term dependance on inherited national lignite sources. In combination with energy importations as a longstanding practice, the energy sector's internal landscape has been compromised in terms of vulnerability and energy security imbalances. Furthermore, dependance on fossils signifies unsustainable energy production which presently is a core issue on a global environmental scale. As an alternative approach, Energy Communities have arisen to cease external energy dependance and boost state renewable energy production via sustainable techniques. It needs to be highlighted that Energy Communities symbolize a social movement towards green conscience cultivation which could likewise modify the out-of-date foundations of the Greek energy sector.

In Greece, the Energy Community development signify an overwhelming turn towards energy democracy and enchased social cohesion. To be clarified, this support all over Europe has been underlined by European Union with the relevant supportive legislation and Directives applicable to all EU member states. Energy Communities have been majorly influenced by Renewable Energy Directive (RED II) and Internal Electricity Market Directive (IEMD) as supportive frameworks. Greece is known to be suffering from bureaucratic delays and such multifaceted energy frameworks, as it is reasonable, face adaptation complications. Lack of proper funding support and authorization in applications process primarily pose as boundaries to the potential flourishing of the beneficial Energy Communities.

Solarity Urban Energy Community, retaining unclouded vision and enthusiastic commitment to sustainability, demonstrated that it is feasible to defeat national frameworks' insufficiencies. In Solariry, the productive citizen-led endeavor of the Klimenti photovoltaic site, sustained tangible energy related benefits via collective cooperation. Such models being decentralized, offer grid balance and mitigate energy price volatility. The renewable energy generated raises environmental consciousness and confirm that Greece associates strongly with European Unions' attempts towards climate neutrality. Energy Communities developments despite being newly introduced, they have managed to combine social inclusion and energy governance dynamically, in an era when energy democracy is being doubted regularly.

7.2 Recommendation for further examination

It would be stimulating that future research is centered on the generated output of different Energy Community Models. Urban applications in comparison to rural ones, worth to be examined towards their characteristics and effectiveness within the Greek context. Additionally, stressing on the practicability of Energy Communities expansion, it is notable that actual household gains are assessed in contrast to application and improvement expenditures. Nowadays, the human element is viewed as a component of equivalent interest on such topics. Societal involvement and potential conflicts across the Greek regions are valuable factors taken in account. To conclude, the magnitudes of Greek energy poverty and the liberation that Energy Communities could offer on vulnerable households worth to be evaluated in the future.

Chapter 8: Bibliography - References

- Arman, M.N. *et al*. (2020) 'The Shift in the Energy Policy of Greece after the 2008 Financial Crisis in the Context of Energy Security'. (Accessed: 14 Sep. 2024).
- Asimakopoulos, D.A. *et al*. (2012) 'Modelling the energy demand projection of the building sector in Greece in the 21st century', *Energy and Buildings*, 49, pp. 488–498. Available at: https://doi.org/10.1016/j.enbuild.2012.02.043. (Accessed: 14 Sep. 2024).
- Bartoletto, S. and Rubio, M. d. M. (2008) 'Energy Transition and CO_2 Emissions in Southern Europe: Italy and Spain (1861-2000), *Global Environment*, 1(2), pp. 46-81. Available at: https://doi.org/10.3197/ge.2008.010203. (Accessed: 22 Sep. 2024).
- 'Green Energy Transition Actions' (2021). Available at: https://doi.org/10.3030/101022317 (Accessed: 14 Sep. 2024).
- Alahmed, A.S. and Tong, L. (2024) 'Dynamic Net Metering for Energy Communities', *IEEE Transactions on Energy Markets Policy and Regulation*, pp. 1–12. Available at: https://doi.org/10.1109/tempr.2024.3354162 (Accessed: 14 Sep. 2024).
- Algarvio, H. (2021) 'The Role of Local Citizen Energy Communities in the Road to Carbon-Neutral Power Systems: Outcomes from a Case Study in Portugal', Smart Cities, 4(2), pp. 840-863. Available at: https://doi.org/10.3390/smartcities4020043 (Accessed: 28 Sep. 2024).
- Argyropoulos, C., Petrakis, T., Roditi, L.-A. and Kavga, A. (2023) Opportunities and Potential for Energy Utilization from Agricultural and Livestock Residues in the Region of Thessaly', Sustainability, 15(5), p. 4429. Available at: https://doi.org/10.3390/su15054429 (Accessed: 29 Sep. 2024).
- Bartolini, A., Carducci, F., Muñoz, C.B. and Comodi, G. (2020) 'Energy Storage and Multi Energy Systems in Local Energy Communities with High Renewable Energy Penetration', Renewable Energy, 159, pp. 595-609. Available at: https://doi.org/10.1016/j.renene.2020.05.131 (Accessed: 28 Sep. 2024).
- Bauwens, T. (2016) 'Explaining the Diversity of Motivations behind Community Renewable Energy', *Energy Policy*, 93, pp. 278–290. Available at: https://doi.org/10.1016/j.enpol.2016.03.017. (Accessed: 29 Sep. 2024).

- Bauwens, T., Gotchev, B. and Holstenkamp, L. (2016) Explaining the diversity of motivations behind community renewable energy', *Energy Policy*, 93, pp. 278-290. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421516300178 (Accessed: 17 Sep. 2024).
- Biresselioglu, M.E. *et al.* (2021) 'Legal Provisions and Market Conditions for Energy Communities in Austria, Germany, Greece, Italy, Spain, and Turkey: A Comparative Assessment', *Sustainability*, 13(20), p. 11212. Available at: https://doi.org/10.3390/su132011212. (Accessed: 28 Nov. 2024).
- Biresselioglu, M.E., Limoncuoglu, S.A., Demir, M.H., Reichl, J., Burgstaller, K., Sciullo, A. and Ferrero, E. (2021) 'Legal Provisions and Market Conditions for Energy Communities in Austria, Germany, Greece, Italy, Spain, and Turkey: a Comparative Assessment', *Sustainability*, 13(20), p. 11212. Available at: https://doi.org/10.3390/su132011212. (Accessed: 28 Nov. 2024).
- Biresselioglu, M.E., Limoncuoglu, S.A., Demir, M.H., Reichl, J., Burgstaller, K., Sciullo, A. and Ferrero, E. (2021) 'Legal Provisions and Market Conditions for Energy Communities in Austria, Germany, Greece, Italy, Spain, and Turkey: a Comparative Assessment', *Sustainability*, 13(20), p. 11212. Available at: https://doi.org/10.3390/su132011212 (Accessed: 28 Nov. 2024).
- Boeri, A., Murielle, O., Longo, D. and Turillazzi, B. (2024) 'Decarbonization Roadmaps and Community Transition Pathways: Empowering Energy Citizenship in the EU', *IOP Conference Series Earth and Environmental Science*, 1402(1), pp. 012010-012010. Available at: https://doi.org/10.1088/1755-1315/1402/1/012010 (Accessed: 28 Nov. 2024).
- Commission approves €2.3 billion Finnish State aid scheme to foster the transition to a net-zero economy (2025) European Commission - European Commission. Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_25_527 (Accessed: 28 Nov. 2024).
- Communication from the commission to the european parliament, the european council, the council, the european economic and social committee and the committee of the regions *REPowerEU Plan* (2022). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52022DC0230 (Accessed: 14 Nov. 2024).
- Crete Valley (2024) Crete Valley. Available at: https://cretevalley.eu/about/ (Accessed: 15 June 2025).
- Dean Holland Clift, Hasan, K.N. and Rosengarten, G. (2024) 'Peer-to-peer Energy Trading for Demand Response of Residential Smart Electric Storage Water Heaters', *Applied Energy*, 353, pp. 122182-122182. Available at:

https://doi.org/10.1016/j.apenergy.2023.122182. (Accessed: 14 Nov. 2024).

❖ Dehler, J., Dogan Keles, Telsnig, T., Fleischer, B., Baumann, M., Fraboulet, D., Aurélie Faure-Schuyer and Fichtner, W. (2017) 'Self-Consumption of Electricity from Renewable Sources', Elsevier eBooks, pp. 225–236. Available at: https://doi.org/10.1016/b978-0-12-809806-6.00027-4 (Accessed: 14 Nov. 2024).

❖ Deniozos, N. (2019) 'Energy security in Balkans and the energy economy of Greece'. (Accessed: 14 Nov. 2024).

❖ Dinah, S. (2008) Stockholm Declaration (1972) and Rio Declaration (1992)', in Dinah, S., *Max Planck Encyclopedia of Public International Law*. Oxford University Press. Available at: https://doi.org/10.1093/law:epil/9780199231690/e1608. (Accessed: 5 Nov. 2024).

❖ Directive - 2009/72 - EN - EUR-Lex (2020) Europa.eu. Available at: https://eur-lex.europa.eu/eli/dir/2009/72/oj/eng (Accessed: 5 Nov. 2024).

❖ Directive - 2018/2001 - EN - EUR-Lex (2018) Europa.eu. Available at: https://eur-lex.europa.eu/eli/dir/2018/2001/oj/eng (Accessed: 5 Nov. 2024).

❖ Directive - 96/92 - EN - EUR-Lex-Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning Common Rules for the Internal Market in Electricity (not date) eur-lex.europa.eu. Available at: https://eur-lex.europa.eu/eli/dir/1996/92/oj (Accessed: 5 Nov. 2024).

❖ *Directive - 98/30 - EN - EUR-Lex-Directive 98/30/EC of the European Parliament and of the Council of 22 June 1998 concerning Common Rules for the Internal Market in Natural Gas* (2024) *Europa.eu*. Available at: https://eur-lex.europa.eu/eli/dir/1998/30/oj (Accessed: 31 August 2024).

❖ Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources (Text with EEA relevance.) (2018). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC (Accessed: 5 Nov. 2024).

❖ Directives directive (eu) 2018/2001 of the european parliament and of the council of 11 december 2018 on the promotion of the use of energy from renewable sources (recast) (text with eea relevance) (no date). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001 (Accessed: 5 Nov. 2024).

- Dóci, G., Vasileiadou, E. and Petersen, A.C. (2015) Community energy: A review of the research literature on the socio-technical transition and motivation behind it', *Renewable and Sustainable Energy Reviews*, 31, pp. 218-229. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1364032114007094 (Accessed: 5 Nov. 2024).
- Dóci, G., Vasileiadou, E. and Petersen, A.C. (2015) 'Exploring the Transition Potential of Renewable Energy Communities', *Futures*, 66, pp. 85–95. Available at: https://doi.org/10.1016/j.futures.2015.01.002. (Accessed: 13 Nov. 2024).
- Dunphy, N.P. and Lennon, B. (2022) 'Whose Transition? a Review of Citizen Participation in the Energy System', Routledge Handbook of Energy Transitions, pp. 430-444. Available at: https://doi.org/10.4324/9781003183020-30. (Accessed: 5 Nov. 2024).
- Energy Communities, Energy cooperatives, Energy Clusters | Clean Energy for EU Islands (no date) clean-energy-islands.ec.europa.eu. Available at: https://clean-energy-islands.ec.europa.eu/countries/greece/legal/community-energy-policies/energy-communities-energy-cooperatives-energy. (Accessed: 5 Dec. 2024).
- Energy Union (2023) Energy. Available at: https://energy.ec.europa.eu/strategy/energy-union_en (Accessed: 11 January 2025).
- *Entry into Force of Law on Climate Change and Energy Transition - European Commission* (no date) *commission.europa.eu*. Available at: https://commission.europa.eu/projects/entry-force-law-climate-change-and-energy-transition_en (Accessed: 10 March 2024).
- *ESDAC - European Commission*, *esdac.jrc.ec.europa.eu*. Available at: https://esdac.jrc.ec.europa.eu/ (Accessed: 5 Dec. 2024).
- Espe, E., Potdar, V. and Chang, E. (2018) Prosumer Communities and Relationships in Smart Grids: a Literature Review, Evolution and Future Directions', Energies, 11(10), p. 2528. Available at: https://doi.org/10.3390/en11102528 (Accessed: 5 Dec. 2024).
- *EUR-Lex - 32018L2001 - EN - EUR-Lex*, *eur-lex.europa.eu*. Available at: http://data.europa.eu/eli/dir/2018/2001/oj. (Accessed: 5 Dec. 2024).
- EUR-Lex - 32018R1999 - EN - EUR-Lex (no date) eur-lex.europa.eu. Available at: http://data.europa.eu/eli/reg/2018/1999/oj (Accessed: 18 December 2023).
- EUR-Lex - 4628467 - EN - EUR-Lex (not date) eur-lex.europa.eu. Available at: https://eur-lex.europa.eu/EN/legal-content/summary/2022-guidelines-on-state-aid-for-climate-

environmental-protection-and-energy.html (Accessed: 16 December 2023).

- EUR-Lex - 52019DC0640 - EN - EUR-Lex (no date) eur-lex.europa.eu. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0640 (Accessed: 15 January 2024).
- European Commission (2023) Renewable Energy Directive, energy.ec.europa.eu. Available at: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en
- European Commission, Clean energy for all Europeans package, energy.ec.europa.eu. Available at: https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en (Accessed: 5 Dec. 2024).
- European Parliament (2009) Internal Energy Market | Fact Sheets on the European Union | European Parliament, Europa.eu. Available at: https://www.europarl.europa.eu/factsheets/en/sheet/45/internal-energy-market (Accessed: 5 Dec. 2024).
- European Parliament (2019) *The Treaty of Lisbon | Fact Sheets on the European Union | European Parliament*, *Europa.eu*. Available at: https://www.europarl.europa.eu/factsheets/en/sheet/5/the-treaty-of-lisbon (Accessed: 5 Dec. 2024).
- European Parliament (2025) Directive - 2003/54 - EN - EUR-Lex, Europa.eu. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32003L0054 (Accessed: 15 March 2025).
- European Parliament and Council of the European Union (2018) *Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (recast)*. Official Journal of the European Union. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001 (Accessed: 15 March 2025).
- European Parliament and Council of the European Union (2019) *Directive (EU) 2019/944 on common rules for the internal market for electricity and amending Directive 2012/27/EU*. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944 (Accessed: 15 March 2025).
- European Parliament and Of the Council (2024) Directive (Eu) 2018/2001 Of the European Parliament and Of the Council Of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources. (2018) Europa.eu. Available at: https://eur-lex.europa.eu/eli/dir/2018/2001/2024-07-16 (Accessed: 15 March 2025).

❖ European Union (2025) Energy Communities Repository - Homepage, Energy Communities Repository. Available at: https://wayback.archive-it.org/12090/20240807065631/https://energy-communities-repository.ec.europa.eu/select-language?destination=/node/23 (Accessed: 15 June 2025).

❖ Farrell, N., Darby, S.J. and McCulloch, M.D. (2018) Using peer-to-peer energy-trading platforms for residential demand response', *Applied Energy*, 228, pp. 189-196. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0306261918308624

❖ *First Energy Package* (no date). Available at: https://www.europarl.europa.eu/ftu/pdf/en/FTU_2.1.9.pdf (Accessed: 23 November 2024).

❖ Frieden, D., Roberts, J., and Gubina, A.F. (2019) Overview of emerging regulatory frameworks on collective self-consumption and Energy Communities in Europe'. Available at: https://doi.org/10.1109/eem.2019.8916222 (Accessed: 15 March 2025).

❖ Frieden, D., Tuerk, A., Antunes, A.R., Athanasios, V., Chronis, A.-G., d'Herbemont, S., Kirac, M., Marouço, R., Neumann, C., Pastor Catalayud, E., Primo, N. and Gubina, A.F. (2021) 'Are We on the Right Track? Collective Self-Consumption and Energy Communities in the European Union', Sustainability, 13(22), p. 12494. Available at: https://doi.org/10.3390/su132212494 (Accessed: 8 March 2025).

❖ Gallego-Castillo, C., Heleno, M., and Victoria, M. (2021) 'Self-consumption for Energy Communities in Spain: A regional analysis under the new legal framework', Energy Policy, 150, p. 112144. Available at: https://doi.org/10.1016/j.enpol.2021.112144 (Accessed: 8 March 2025).

❖ Gjorgievski, V.Z., Cundeva, S. and Georghiou, G.E. (2021) 'Social arrangements, technical designs and impacts of Energy Communities: A review', Renewable Energy, 169, pp. 1138–1156. Available at: https://doi.org/10.1016/j.renene.2021.01.078 (Accessed: 8 March 2025).

❖ Gjorgievski, V.Z., Cundeva, S., Markovska, N. and Georghiou, G.E. (2022) Virtual net-billing: a Fair Energy Sharing Method for Collective self-consumption', Energy, 254, p. 124246. Available at: https://doi.org/10.1016/j.energy.2022.124246. (Accessed: 2 March 2025).

❖ Gkonis, N. *et al*. (2020) multi-perspective design of energy efficiency policies under the framework of national energy and climate action plans', *Energy Policy*, 140, p. 111401. Available at: https://doi.org/10.1016/j.enpol.2020.111401. (Accessed: 2 March 2025).

❖ Gombert, P. *et al.* (2019) 'An Overview of Priority Pollutants in Selected Coal Mine Discharges in Europe', *Mine Water and the Environment*, 38(1), pp. 16-23. Available at: https://doi.org/10.1007/s10230-018-0547-8. (Accessed: 2 March 2025).

❖ Governance of the Energy Union and Climate Action (no date) climate.ec.europa.eu. Available at: https://climate.ec.europa.eu/eu-action/climate-strategies-targets/governance-energy-union-and-climate-action_en (Accessed: 16 November 2023).

❖ Greece - REScoop (2023) Rescoop.eu Available at: https://www.rescoop.eu/policy/transposition-tracker/enabling-frameworks-support-schemes/greece. (Accessed: 15 November 2023).

❖ Greece's Draft Updated National Energy and Climate Plan Highlights of the Commission's Assessment (no date). Available at: https://commission.europa.eu/system/files/2023-12/Factsheet_Commissions_assessment_NECP_Greece_2023.pdf (Accessed: 16 November 2023).

❖ Gui, E.M., Diesendorf, M. and MacGill, I. (2017) 'Prosumers, innovation, and the disruptive role of renewable energy in Australia', *Energy Policy*, 108, pp. 360-370. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421517305158 (Accessed: 16 November 2023).

❖ Hall, S. and Roelich, K. (2016) Business model innovation in electricity supply markets: The role of local energy', *Energy Policy*, 92, pp. 286-296. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421516302507 (Accessed: 17 November 2023).

❖ Hall, S. and Roelich, K. (2016) 'Business Model Innovation in Electricity Supply markets: the Role of Complex Value in the United Kingdom', *Energy Policy*, 92, pp. 286–298. Available at: https://doi.org/10.1016/j.enpol.2016.02.019. (Accessed: 28 November 2023).

❖ Hellenic Republic Ministry of the Environment and Energy (no date). Available at: https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf (Accessed: 28 November 2023).

❖ Herenčić, L., Melnjak, M., Capuder, T., Andročec, I. and Rajšl, I. (2021) 'Techno-economic and Environmental Assessment of Energy Vectors in Decarbonization of Energy Islands', Energy Conversion and Management, 236, p. 114064. Available at: https://doi.org/10.1016/j.enconman.2021.114064 (Accessed: 8 March 2025).

❖ IPCC (2024) *IPCC — Intergovernmental Panel on Climate Change*, *Ipcc.ch*. IPCC. Available at: https://www.ipcc.ch/ (Accessed: 8 March 2025).

❖ Jasiński, J., Kozakiewicz, M. and Sołtysik, M. (2024) 'Analysis of the Economic Soundness and Viability of Migrating from Net Billing to Net Metering Using Energy Cooperatives', Energies, 17(6), p. 1330. Available at: https://doi.org/10.3390/en17061330. (Accessed: 8 March 2025).

❖ Jones, C.R., Kaklamanou, D. and Lazuras, L. (2017) 'Public perceptions of energy security in Greece and Türkiye: Exploring the relevance of pro-environmental and pro-cultural orientations', *Energy Research & Social Science*, 28, pp. 17-28. Available at: https://doi.org/10.1016/j.erss.2017.04.002. (Accessed: 8 March 2025).

❖ Karolina Świeca (2023) 'Legal Status of the Prosumer of Renewable Energy Sources in Selected Aspects of National Law and Secondary Law of the European Union on the Example of the Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources', Teka Komisji Politologii i Stosunków Międzynarodowych, 17(1), pp. 91-101. Available at: https://doi.org/10.17951/teka.2022.17.1.91-101 (Accessed: 8 March 2025).

❖ Ketikidis, C., Triantafillidis, A., Stogiannis, P., Amarantos, P., Kontodimos, I. and Grammelis, P. (2023) Clean Energy Technologies in Western Macedonia: Opportunities for Jobs and Growth within the Coal Phase-Out Era', Engineering Proceedings, 56(1), p. 243. Available at: https://doi.org/10.3390/ASEC2023-15404. (Accessed: 8 March 2025).

❖ Kozani | Intelligent Cities Challenge (2025) Intelligentcitieschallenge.eu. Available at: https://www.intelligentcitieschallenge.eu/cities/kozani (Accessed: 15 June 2025).

❖ Law 4203/2013 (2025) Ψηφισθέντα Νομοσχέδια, Hellenicparliament.gr. Available at: https://www.hellenicparliament.gr/Nomothetiko-Ergo/Psifisthenta-Nomoschedia?law_id=fd683678-97a0-4d4e-9b6f-7e2658321207 (Accessed: 15 June 2025).

❖ Law 5037/2023 (2025) Fao.org. Available at: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/ (Accessed: 15 March 2025).

❖ Law 5037/2023 (2025) Fao.org. Available at: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC217254/ (Accessed: 15 March 2025).

❖ Lelek, L. and Kulczycka, J. (2021) 'Life cycle assessment of opencast lignite mining', *International Journal of Coal Science & Technology*, 8(6), pp. 1272-1287. Available at: https://doi.org/10.1007/s40789-021-00467-9. (Accessed: 15 March 2025).

- Lowitzsch, J., Hoicka, C.E. and van Tulder, F.J. (2020) 'Renewable Energy Communities under the 2019 European Clean Energy Package – Governance Model for the Energy Clusters of the future?', *Renewable and Sustainable Energy Reviews*, 122, p. 109489. Available at: https://doi.org/10.1016/j.rser.2019.109489. (Accessed: 15 March 2025).
- Lowitzsch, J., Hoicka, C.E. and van Tulder, F.J. (2020) 'Renewable Energy Communities under the 2019 European Clean Energy Package – Governance Model for the Energy Clusters of the future?', Renewable and Sustainable Energy Reviews, 122, p. 109489. Available at: https://doi.org/10.1016/j.rser.2019.109489 (Accessed: 19 March 2025).
- Margosi and Koukoufikis (2024) Fostering Energy Justice through Decentralized Transition: The Case of Energy Communities in Greece. (Accessed: 13 March 2025).
- Middlemiss, L. (2018) Sustainable consumption at home: Community energy and social action', *Energy Policy*, 36(11), pp. 4296-4307. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421508002806
- Moura, R., and Brito, M.C. (2019) 'Prosumer aggregation policies, country experience and business models', *Energy Policy*, 132, pp. 820-830. Available at: https://doi.org/10.1016/j.enpol.2019.06.053. (Accessed: 3 March 2025).
- Müller, M.O. *et al*. (2011) 'Energy autarky: A conceptual framework for sustainable regional development', *Energy Policy*, 39(10), pp. 5800–5810. Available at: https://doi.org/10.1016/j.enpol.2011.04.019. (Accessed: 1 March 2025).
- Municipal District Heating Company of Amindeo (D.H.C.A.) – ΔΕΤΕΠΑ (2018) Detepa.gr. Available at: https://detepa.gr/dhca/ (Accessed: 15 June 2025).
- Nikas, A. *et al*. (2020) 'Sustainable and socially just transition to a post-lignite era in Greece: a multi-level perspective', *Energy Sources, Part B: Economics, Planning, and Policy*, 15(10–12), pp. 513-544. Available at: https://doi.org/10.1080/15567249.2020.1769773. (Accessed: 12 Jul 2025).
- On Common Rules for the Internal Market for Electricity and Amending Directive 2012/27/EU (recast) (Text with EEA relevance) (2019). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944 (Accessed: 12 Jul 2025).
- Palacios-Ferrer, J.A., Rey-Martínez, F.J., Repenning-Bzdigian, C.A. and Rey-Hernández, J.M. (2024) 'Unveiling Key Factors Shaping Energy Storage Strategies for Sustainable Energy Communities', Buildings,

14(5), p. 1466. Available at: https://doi.org/10.3390/buildings14051466. (Accessed: 17 Jul 2025).

- Papada, L. and Kaliampakos, D. (2016) 'Measuring energy poverty in Greece', *Energy Policy*, 94, pp. 157-165. Available at: https://doi.org/10.1016/j.enpol.2016.04.004. (Accessed: 4 Jul 2025).
- Papanicolaou, C. *et al.* (2004) 'Coals of Greece: a review of properties, uses and future perspectives', *International Journal of Coal Geology*, 58(3), pp. 147-169. Available at: https://doi.org/10.1016/j.coal.2003.10.006. (Accessed: 2 Jul 2025).
- Pereira, H., Gomes, L., Faria, P., Vale, Z., and Coelho, C. (2021) Web-based platform for the management of citizen Energy Communities and their members', Energy Informatics, 4(S2). Available at: https://doi.org/10.1186/s42162-021-00155-7 (Accessed: 19 Feb 2025).
- Positive preliminary assessment of the satisfactory fulfilment of milestones and targets related to the second payment request submitted by Slovenia on 15 September 2023, transmitted to the Economic and Financial Committee by the European Commission Executive summary (27AD). (Accessed: 19 Feb 2025).
- PPC GROUP GR (no date) *Istoriki Anadromi*, *https://www.ppcgroup.com/el/omilos-dei/sxetika-me-emas/istoriki-diadromi/* (Accessed: 12 Jul 2024).
- Profile - Region of Western Macedonia (2023) Region of Western Macedonia. Available at: https://en.pdm.gov.gr/the-region/profile/. (Accessed: 12 Jul 2024).
- Recovery and Resilience Facility in Greece (2025) Eib.org. Available at: https://www.eib.org/en/products/mandates-partnerships/rrf/greece (Accessed: 15 March 2025).
- Region of Thessaly (2021) Interreg-balkanmed.eu. Available at: http://www.interreg-balkanmed.eu/project-partner/199/ (Accessed: 15 June 2025).
- Regional Energy Community of Western Macedonia – Energy Community of Western Macedonia Ltd (2025) Interregeurope.eu. Available at: https://www.interregeurope.eu/good-practices/regional-energy-community-of-western-macedonia-energy-community-of-western-macedonia-ltd? (Accessed: 15 June 2025).
- Regulation - 2019/943 - EN - EUR-Lex (2019) Europa.eu. Available at: https://eur-lex.europa.eu/eli/reg/2019/943/oj/eng (Accessed: 15 March 2025).
- Regulation - 2021/1056 - EN - EUR-Lex (no date) eur-lex.europa.eu. Available at: https://eur-lex.europa.eu/eli/reg/2021/1056/oj (Accessed: 19 April 2024).

❖ Regulation - 2021/241 - EN - Rrf - EUR-Lex (2021) Europa.eu. Available at: https://eur-lex.europa.eu/eli/reg/2021/241/oj/eng (Accessed: 15 March 2025).

❖ Reimuth, A., Locherer, V., Danner, M. and Mauser, W. (2020) How Does the Rate of Photovoltaic Installations and Coupled Batteries Affect Regional Energy Balancing and Self-Consumption of Residential Buildings?' Energies, 13(11), p. 2738. Available at: https://doi.org/10.3390/en13112738. (Accessed: 12 Jul 2024).

❖ Royal Decree 244/2019 Regulating the administrative, Technical and Economic Conditions of the self-consumption of Electric Energy - Climate Change Laws of the World climate-laws.org. Available at: https://climate-laws.org/document/royal-decree-244-2019-regulating-the-administrative-technical-and-economic-conditions-of-the-self-consumption-of-electric-energy_8775. (Accessed: 12 Jul 2024).

❖ Sassman, W.G. (2021) *Community Empowerment in Decarbonization: NEPA's Role*, *UW Law Digital Commons*. Available at: https://digitalcommons.law.uw.edu/wlr/vol96/iss4/8/ (Accessed: 13 March 2025).

❖ Seyfang, G. and Smith, A. (2007) Grassroots innovations for sustainable development: Community energy initiatives in the UK', *Energy Policy*, 35(2), pp. 585-598. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0301421506003832 (Accessed: 13 March 2025).

❖ Seyfang, G., Hielscher, S., Hargreaves, T., Martiskainen, M. and Smith, A. (2014) A Grassroots Sustainable Energy niche? Reflections on Community Energy in the UK', *Environmental Innovation and Societal Transitions*, 13, pp. 21-44. Available at: https://doi.org/10.1016/j.eist.2014.04.004. (Accessed: 13 March 2025).

❖ Sloot, D., Jans, L. and Steg, L. (2018) 'Can Community Energy Initiatives Motivate Sustainable Energy behaviours? the Role of Initiative Involvement and Personal pro-environmental Motivation', *Journal of Environmental Psychology*, 57, pp. 99–106. Available at: https://doi.org/10.1016/j.jenvp.2018.06.007. (Accessed: 13 March 2025).

❖ Sofia, Y., Katsaprakakis, D., Sakkas, N., Condaxakis, C., Karapidakis, E., Syntichakis, S. and Stavrakakis, G.M. (2025) 'The Role of Energy Communities in the Achievement of a Region's Energy Goals: The Case of a Southeast Mediterranean Region', Energies, 18(6), p. 1327. Available at: https://doi.org/10.3390/en18061327. (Accessed: 13 March 2025).

❖ Sokołowski, M.M. (2020) 'Renewable and citizen Energy Communities in the European Union: how (not) to regulate community energy in national laws and policies', Journal of Energy & Natural Resources

Law, 38(3), pp. 289-304. Available at: https://doi.org/10.1080/02646811.2020.1759247 (Accessed: 13 March 2025).

- Sougkakis, V., Lymperopoulos, K., Nikolopoulos, N., Margaritis, N., Giourka, P. and Angelakoglou, K. (2020) 'An Investigation on the Feasibility of Near-Zero and Positive Energy Communities in the Greek Context', Smart Cities, 3(2), pp. 362-384. Available at: https://doi.org/10.3390/smartcities3020019. (Accessed: 12 Jul 2024).

- Tsagari and Marula (2021) How Greece undermined the idea of renewable Energy Communities: An overview of the relevant legislation.' Available at: https://heinonline.org/HOL/LandingPage?handle=hein.journals/leadjo17&div=10&id=&page= (Accessed: 25 Jul 2024).

- Tsemekidi Tzeiranaki, S. *et al.* (2019) Analysis of the EU Residential Energy Consumption: Trends and Determinants', *Energies*, 12(6), p. 1065. Available at: https://doi.org/10.3390/en12061065. (Accessed: 15 Jul 2025).

- UNFCCC (2019) *What Is the Kyoto Protocol, UNFCCC*. Available at: https://unfccc.int/kyoto_protocol (Accessed: 12 Jul 2024).

- Union Renewable Development Platform (2025) Europa.eu. Available at: https://union-renewables-development-platform.ec.europa.eu/ (Accessed: 15 March 2025).

- United Nations (1992) *Rio Declaration on Environment and Development*. Available at: https://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_CONF.151_26_Vol.I_Declaration.pdf (Accessed: 13 March 2025).

- United Nations (2024) *The 17 Sustainable Development Goals*, *United Nations*. Available at: https://sdgs.un.org/goals (Accessed: 22 Jul 2024).

- Walker, G. and Devine-Wright, P. (2008) 'Community Renewable energy: What Should It mean?', *Energy Policy*, 36(2), pp. 497-500. Available at: https://doi.org/10.1016/j.enpol.2007.10.019. (Accessed: 15 June 2025).

- Wind Energy - Germany | Statista Market Forecast (2025) Statista. Available at: https://www.statista.com/outlook/io/energy/renewable-energy/wind-energy/germany. (Accessed: 15 June 2025).

- Yu, B., Fang, D., Xiao, K. and Pan, Y. (2023) Drivers of renewable energy penetration and its role in power sector's deep decarbonization towards carbon peak', Renewable and Sustainable Energy Reviews, 178, p. 113247. Available at: https://doi.org/10.1016/j.rser.2023.113247 (Accessed: 29 Jul 2024).

❖ Zelger, B. (2022) ‘The European Green Deal and the Commission’s New Guidelines on Climate, Environmental Protection and Energy Aid 2022 (CEEAG) – a Critical Analysis’, Österreichische Zeitschrift für Kartellrecht, 15(3), pp. 87-87. Available at: https://doi.org/10.33196/oezk202203008701 (Accessed: 28 Jul 2024).

❖ Zou, C. *et al*. (2016) ‘Energy revolution: From a fossil energy era to a new energy era’, *Natural Gas Industry B*, 3(1), pp. 1–11. Available at: https://doi.org/10.1016/j.ngib.2016.02.001. (Accessed: 12 Jul 2025).

❖ Δήμος Κοζάνης (2020) ‘Στρατηγικό Σχέδιο “Κοζάνη - Έξυπνη Πόλη”’. Available at: https://cityofkozani.gov.gr/documents/10182/545686/%CE%9A%CE%BF%CE%B6%CE%AC%CE%BD%CE%B7-%CE%88%CE%BE%CF%85%CF%80%CE%BD%CE%B7+%CE%A0%CF%8C%CE%BB%CE%B7+f3.pdf/29aaf021-9929-40a7-bd31-bd7b375ffdf9 (Accessed: 13 Jul 2025).

❖ Δράσεις Αλληλεγγύης - MinoanEnergy (2021) MinoanEnergy. Available at: https://minoanenergy.com/en/%ce%b4%cf%81%ce%ac%cf%83%ce%b5%ce%b9%cf%82-%ce%b1%ce%bb%ce%bb%ce%b7%ce%bb%ce%b5%ce%b3%ce%b3%cf%8d%ce%b7%cf%82 (Accessed: 15 June 2025).

❖ Ελληνική Κυβέρνηση and Υφυπουργός Περιβάλλοντος και Ενέργειας (2020) ‘ https://ypen.gov.gr/wp-content/uploads/2020/11/FEK_B_2062.pdf Προσθη□κη Νε□ων Κατηγοριω□ν Σταθμω□ν Παραγωγη□ς Ηλεκτρικη□ς Ενε□ργειας Απο□ Α.Π.Ε. Και Σ.Η.Θ.Υ.Α. Και Καθορισμο□ς Των Τ.Α., Επαναπροσδιορισμο□ς Των Κατηγοριω□ν Σταθμω□ν 11, 29 Και 30’. Available at: https://ypen.gov.gr/wp-content/uploads/2020/11/FEK_B_2062.pdf. (Accessed: 9 Mar 2025).

❖ Ενεργειακές Κοινότητες. Available at: https://ypen.gov.gr/energeia/ape/eidika-themata/energeiakes-koinotites/ (Accessed: 5 March 2024).

❖ Ενεργειακή Κοινότητα Πολιτών Περιφέρειας Θεσσαλίας (2024) Ekp-peth.gr. Available at: https://www.ekp-peth.gr/#apollo (Accessed: 15 June 2025).

❖ Νόμος 4483/1965 (Κωδικοποιημένος) - ΦΕΚ Α 118/24.06.1965 (2025) Kodiko.gr. Available at: https://www.kodiko.gr/nomothesia/document/580255/nomos-4483-1965 (Accessed: 13 March 2025).

❖ Νόμος 4513/2018 (Κωδικοποιημένος) - ΦΕΚ Α 9/23.01.2018 - Ενεργειακές Κοινότητες Νόμος 4513 ν.4513 (2018) Kodiko.gr. Available at: https://www.kodiko.gr/nomothesia/document/341480/nomos-4513-2018 (Accessed: 15 March 2025).

❖ Νόμος 5037/2023 (Κωδικοποιημένος) - ΦΕΚ Α 78/29.03.2023 (no date) www.kodiko.gr. Available at:

https://www.kodiko.gr/nomothesia/document/872080/nomos-5037-2023 (Accessed: 6 June 2024).

- Στέλιος Ψωμάς (2020) Αριθμ. ΥΠΕΝ/ΔΑΠΕΕΚ/30971/1190, ΦΕΚ 1045Β/26.3.2020. Προσθήκη Νέων Κατηγοριών Σταθμών Παραγωγής Ηλεκτρικής Ενέργειας Από Α.Π.Ε. Και Σ.Η.Θ.Υ.Α. Και Καθορισμός Των Τ.Α., Επαναπροσδιορισμός Των Κατηγοριών Σταθμών 11, 29 Και 30 Και Τροποποίηση Των Τ.Α. - HELAPCO - Σύνδεσμος Εταιριών Φωτοβολταϊκών, HELAPCO - Σύνδεσμος Εταιριών Φωτοβολταϊκών. Available at: https://helapco.gr/ypourgikes-apofaseis/arithm-ypen-dapeek-30971-1190-fek-1045v-26-3-2020-prosthiki-neon-katigorion-stathmon-paragogis-ilektrikis-energeias-apo-a-p-e-kai-s-i-th-y-a-kai-kathorismos-ton-t-a-epanaprosdiorismos-ton-katigorion-s/ (Accessed: 15 June 2025).
- Cambridge Dictionary (2019) *NIMBY | Meaning in the Cambridge English Dictionary*, *Cambridge.org*. Available at: https://dictionary.cambridge.org/dictionary/english/nimby. (Accessed : 15 March 2025).
- Citizen Support for Climate Action (2025) Climate Action. Available at: https://climate.ec.europa.eu/citizens-stakeholders/citizen-support-climate-action_en?utm_source (Accessed: 6 September 2025).
- Directive - 2001/77 - EN - EUR-Lex (2025) Europa.eu. Available at: https://eur-lex.europa.eu/eli/dir/2001/77/oj/eng. (Accessed: 6 September 2025).
- Encyclopedia Britannica (2018) 'Arab Oil Embargo | International Relations [1973]', Encyclopædia Britannica. Available at: https://www.britannica.com/event/Arab-oil-embargo. (Accessed: 15 June 2025).
- European Commission (2019) The European Green Deal, European Commission. European Commission. Available at:https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en. (Accessed: 15 June 2025).
- European Commission (2025) EU Emissions Trading System (EU ETS), Climate Action. Available at: https://climate.ec.europa.eu/eu-action/carbon-markets/eu-emissions-trading-system-eu-ets_en. (Accessed: 15 June 2025).
- European Parliament (1986) Single European Act, Single European Act. Available at: https://www.europarl.europa.eu/about-parliament/en/in-the-past/the-parliament-and-the-treaties/single-european-act. (Accessed: 15 June 2025).
- Executive Order 14162—Putting America First in International Environmental Agreements | the American Presidency Project (2025) Ucsb.edu. Available at: https://www.presidency.ucsb.edu/documents/executive-order-14162-putting-america-first-international-environmental-agreements. (Accessed: 5 March 2024)

- International Energy Agency (2025) *IEA - the Global Energy Authority*, *Iea.org*. Available at: https://www.iea.org/. (Accessed: 15 June 2025).
- Lelek, L. and Kulczycka, J. (2021) 'Life Cycle Assessment of Opencast Lignite Mining', *International Journal of Coal Science & Technology*, 8(6), pp. 1272–1287. Available at: https://doi.org/10.1007/s40789-021-00467-9. (Accessed: 15 June 2025).
- LUT University (2024) www.lut.fi. Available at: https://www.lut.fi/en. (Accessed: 15 June 2025).
- Progress in the Management of Contaminated Sites in Europe - ESDAC - European Commission (2018) Europa.eu. Available at: https://esdac.jrc.ec.europa.eu/content/progress-management-contaminated-sites-europe-0 (Accessed: 6 September 2025).
- UNFCCC (2022) What Is the United Nations Framework Convention on Climate Change? United Nations Climate Change. United Nations Climate Change. Available at: https://unfccc.int/process-and-meetings/what-is-the-united-nations-framework-convention-on-climate-change. (Accessed: 15 June 2025).
- Akuo. (2025). *Thessaly | Akuo*. [online] Available at: https://www.akuoenergy.com/en/akuo-in-the-world/all-our-projects/thessaly. (Accessed: 15 June 2025).
- Asoh, D.A. and Awangum, N.N. (2022). Low-Cost Automated PV Panel Dust Cleaning System for Rural Communities. *Smart Grid and Renewable Energy*, 13(08), pp.173-199. https://doi.org/10.4236/sgre.2022.138011 (Accessed: 15 June 2025).
- Christoforidis, G.C., Panapakidis, I.P., Papadopoulos, T.A., Papagiannis, G.K., Koumparou, I., Hadjipanayi, M. and Georghiou, G.E. (2016). A Model for the Assessment of Different Net-Metering Policies. *Energies*, [online] 9(4), p.262. https://doi.org/10.3390/en9040262 (Accessed: 15 June 2025).
- Cococcioni, M., D'Andrea, E. and Lazzerini, B. (2011). 24-hour-ahead forecasting of energy production in solar PV systems. https://doi.org/10.1109/isda.2011.6121835. (Accessed: 5 March 2024).
- Elpedison. (2022). *Elpedison*. [online] Available at: https://www.elpedison.gr/el/ (Accessed: 5 March 2024).
- EPA (2019). Greenhouse Gas Equivalencies Calculator. [online] US EPA. Available at: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator. (Accessed: 13 March 2025).
- European Commission (n.d.). *European Climate Law*. [online] climate.ec.europa.eu. Available at: https://climate.ec.europa.eu/eu-action/european-climate-law_en. (Accessed: 13 March 2025).

- European Commission (2021). *Horizon Europe*. [online] European Commission. Available at: https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en. (Accessed: 13 March 2025).
- HEDNO. (n.d.). *Hellenic Electricity Distribution Network Operator (HEDNO)*. [online] Available at: https://deddie.gr/en/. (Accessed: 13 March 2025).
- IEA (2025). *Renewable - Energy System*. [online] International Energy Agency. Available at: https://www.iea.org/energy-system/renewables. (Accessed: 13 March 2025).
- Koudouris, G., Dimitriadis, P., Iliopoulou, T., Mamassis, N. and Koutsoyiannis, D. (2017). Investigation on the stochastic nature of the solar radiation process. *Energy Procedia*, 125, pp.398–404 https://doi.org/10.1016/j.egypro.2017.08.076. (Accessed: 13 March 2025).
- Lee, S., Shenoy, P., Ramamritham, K. and Irwin, D. (2021). AutoShare: Virtual Community Solar and Storage for Energy Sharing. Energy Informatics, 4(1). https://doi.org/10.1186/s42162-021-00144-w. (Accessed: 13 March 2025).
- Margosi, M. and Giorgos Koukoufikis (2024). Fostering Energy Justice through Decentralised Transition: The Case of Energy Communities in Greece. *European Journal of Spatial Development*, [online] 21(1), pp.33-60. Available at: https://journals.polito.it/index.php/EJSD/article/view/420 (Accessed: 26 Nov. 2024).
- MinoanEnergy. (2021). Δράσεις Αλληλεγγύης - *MinoanEnergy*. [online] Available at:https://minoanenergy.com/en/%ce%b4%cf%81%ce%ac%cf%83%ce%b5%ce%b9%cf%82-%ce%b1%ce%bb%ce%bb%ce%b7%ce%bb%ce%b5%ce%b3%ce%b3%cf%8d%ce%b7%cf%82/ (Accessed: 27 Sep. 2025).
- NASA (2012). NASA POWER | Prediction of Worldwide Energy Resources. [online] Nasa.gov. Available at: https://power.larc.nasa.gov/. (Accessed: 27 Sep. 2025)
- Nowtricity.com. (2024). *CO2 Emissions per kWh in Greece - Nowtricity*. [online] Available at: https://www.nowtricity.com/country/greece/. (Accessed: 27 Sep. 2025)
- Protergia.gr. (2024). Protergia | Πάροχος Ηλεκτρικής Ενέργειας & Φυσικού Αερίου. [online] Available at: https://www.protergia.gr/. (Accessed: 27 Sep. 2025)
- Radhi, M.H., Mahdi, E.J. and Mftwol, A.K. (2019). Design and Performance Analysis of Solar PV System Size 2.56 kWp. [online]

https://doi.org/10.1109/sicn47020.2019.9019373. (Accessed: 27 Sep. 2025)

- Sharma, V. and Chandel, S.S. (2013). Performance Analysis of a 190 kWp Grid Interactive Solar Photovoltaic Power Plant in India. Energy, 55, pp.476–485. https://doi.org/10.1016/j.energy.2013.03.075. (Accessed: 27 Sep. 2025)
- Solarity K.A.E. Π.Ε. (2018). https://publicity.businessportal.gr/company/171775602000. (Accessed: 27 Sep. 2025)
- Solarity.coop. (2023). Solarity Κοινότητα Ανανεώσιμης Ενέργειας - Ενεργειακή κοινότητα. [online] Available at: https://solarity.coop/ (Accessed: 27 May 2026).
- Solarway. (2022). *Solarway*. [online] Available at: https://solarway.gr/en/ (Accessed: 27 Sep. 2025).
- TÜV AUSTRIA HELLAS. (2024). *TÜV AUSTRIA HELLAS*. [online] Available at: https://tuvaustriahellas.gr/ (Accessed: 27 Sep. 2025).
- UNFCCC (2025). *The Paris Agreement*. [online] United Nations Climate Change. Available at: https://unfccc.int/process-and-meetings/the-paris-agreement. (Accessed: 27 Sep. 2025).
- Volton.gr (2025). https://volton.gr/. (Accessed: 27 Sep. 2025)
- Zenith.gr. (2025). *Πάροχος Ηλεκτρικού Ρεύματος & Φυσικού Αερίου*. [online] Available at: https://zenith.gr/el/ (Accessed: 27 Sep. 2025).
- **Figure 1**: Geological resources of Greece
  Papanicolaou, C., Kotis, T., A Foscolos and Goodarzi, F. (2004). Coals of Greece: a Review of properties, Uses and Future Perspectives. *International Journal of Coal Geology*, 58(3), pp.147–169. https://doi.org/10.1016/j.coal.2003.10.006 (Accessed: 25 Sep. 2024).
- **Figure 2**: Proposed Energy Communities platform
  Pereira, H., Gomes, L., Faria, P., Vale, Z. and Coelho, C. (2021) Web-based platform for the management of citizen Energy Communities and their members', Energy Informatics, 4(S2). Available at: https://doi.org/10.1186/s42162-021-00155-7 (Accessed: 17 March. 2024).
- **Figure 3**: Number of Greek ECs and applications for new projects before and after introducing the relevant legislative frameworks
  Sofia, Y., Katsaprakakis, D., Sakkas, N., Condaxakis, C., Karapidakis, E., Syntichakis, S. and Stavrakakis, G.M. (2025). The Role of Energy Communities in the Achievement of a Region's Energy Goals: The Case of a Southeast Mediterranean Region. *Energies*, 18(6), p.1327. https://doi.org/10.3390/en18061327 (Accessed: 23 March. 2024)
- **Figure 4**: ENGAIA S.A. (2025) AMYDON Energy Community. Available at: https://www.engaia.gr/en/project/amydon-energy-community-9mw/. (Accessed: 22 August 2025).
- **Figure 5**: Akuo - Thessaly PV project

Akuo. (2025). Thessaly | Akuo. [online] Available at: https://www.akuoenergy.com/en/akuo-in-the-world/all-our-projects/thessaly. (Accessed: 15 June 2025).

- **Figure 6**: Minoan Energy Community Project
Minoan Energy. (2021a). *Δράσεις Αλληλεγγύης – Minoan Energy*. [online] Available at: https://minoanenergy.com/en/%ce%b4%cf%81%ce%ac%cf%83%ce%b5%ce%b9%cf%82-%ce%b1%ce%bb%ce%bb%ce%b7%ce%bb%ce%b5%ce%b3%ce%b3%cf%8d%ce%b7%cf%82/ (Accessed: 17 June 2025).
- **Figure 7**: Crete Valley Projects
Crete Valley (2024) Crete Valley. Available at: https://cretevalley.eu/about/ (Accessed: 22 June 2025).