

Review Article

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The renewable energy cooperatives as a solution to the global energy problem

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Highlights

- The renewable energy
- Global energy problems
- Renewable energy cooperative

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ABSTRACT

Despite the fact that the global population is currently undergoing a period of decelerated growth, projections indicate that the rate of increase will persist in the future. As the global population continues to grow, it is anticipated that the demand for resources and services will also increase at a faster rate than the population itself. The growth and diversification of consumer demand have led to the prominence of mass production, which will continue to be a dominant feature of the global manufacturing landscape in the future. As is the case with all forms of production, the use of industry and machinery will be a necessity in factory production. This type of fuel, which has supplanted the mass-scale use of fossil fuels and causes environmental damage in excess of its use, must be promptly removed from the agenda of humanity. The initial response to this challenge will likely be the adoption of renewable energy sources, which derive their fundamental source from the sun. This transition will inevitably create a demand with implications for both human and economic aspects. The global energy crisis has underscored the necessity for alternative energy sources. One potential solution is the establishment of renewable energy cooperatives, which could serve as a global outlet for energy. However, it should be noted that the utilization, administration, and distribution of renewable energy would represent a shared value for humanity. From this perspective, this study aims to examine the full range of renewable energy cooperatives, which propose not only the use of renewable energy but also its administration and distribution as a means of addressing the global energy crisis. To achieve this objective, the literature review method was applied in the study, and within this method, the research question and keywords were determined. Domestic and foreign literature was reviewed regarding the terms "renewable energy" and "cooperativism," and the subject was summarized under subheadings to ensure that domestic and foreign sources were reviewed in accordance with the study's objective. It has been concluded that the development of renewable energy cooperatives indicates that the future world can be safe and clean.

Keywords: Cooperative, energy, renewable energy, renewable energy cooperative

1. INTRODUCTION

Global warming is defined as a long-term increase in the average temperature of the planet. The rate of this warming has accelerated significantly over the past century, largely due to the excessive use of fossil fuels. The human population has increased significantly, particularly following the Industrial Revolution, due to the decline in mortality rates. Consequently, the use of fossil fuels has risen in parallel with mass consumption. The mass consumption of fossil fuels, including coal, oil, and natural gas, to meet the increasing energy demand has resulted in the accumulation of greenhouse gases in the atmosphere. This has initiated a continuous and increasing warming of the planet [29, 46, 60]. The planet has experienced global warming because of the greenhouse effect, which has also given rise to macro-scale climate changes and the advent of a novel standard of living, accompanied by an inherent threat. The extent to which this inevitable course of events will have a profound impact on the future of our planet depends on the decisions that humanity makes today. It is unlikely that we will make mistakes that will have irreversible consequences. One of the most favorable scenarios is that the increase in CO₂ will cease after 2050 and the global average temperature will rise by 1-1.5 °C. Conversely, the most adverse scenario is one in which CO₂ emissions are unabated, resulting in a projected temperature increase of 4.5-5 °C [19, 21, 51].

A recent report published by the United Nations indicates that the world population is projected to reach 8.6 billion in 2030, 9.8 billion in 2050, and 11.2 billion in 2100. Approximately 83 million individuals are added to the global population on an annual basis. Even in the event that fertility rates remain in decline, the world population is projected to continue its growth [52]. The growth of the global population will inevitably lead to an escalation in energy requirements on a daily basis. In particular, the Industrial Revolution has led to a rise in both mass production and mass consumption, which has in turn resulted in a corresponding increase in energy demand and environmental pollution. It is evident that the utilisation of conventional fuels, or more specifically, fossil fuels, is neither a rational nor a sustainable option for the global population and the future of humanity. Given that fossil fuels cannot be renewed, their depletion will inevitably lead to adverse effects on environmental pollution and human life. In such a situation, additional health-care costs will increase, and the occurrence of global epidemics such as SARS-CoV-2 will become inevitable [41]. It will no longer be sufficient for humanity to merely identify alternative energy sources; it must also be able to locate and utilize them, thereby integrating renewable energy into everyday life. The utilisation of energy sources that undergo renewal at a faster rate than they are

consumed will constitute a global revolution. This will be designated as clean, alternative or renewable energy and will be integrated into the fabric of life.

The principal renewable energy sources are solar, wind, biomass, wave and hydro, and geothermal energy. The sun is the primary source of all of these energy sources. The advent of renewable energy represents a transformative shift in the global energy landscape, with the potential to revolutionize the entire supply chain, from the generation of electricity from solar and wind sources to the direct powering of homes and industry. It will result in a cleaner environment by reducing greenhouse gas emissions and dependence on limited resources. The use of renewable energy sources, including solar, wind, geothermal, and hydro, is expected to become more prevalent in the coming years. This is due to the fact that these sources do not emit greenhouse gases during electricity production, and they offer greater reliability than traditional energy sources. As indicated in the International Energy Agency (IEA) Renewable Energy 2023 report, the anticipated expansion of renewable electricity capacity is projected to reach 507 gigawatts (GW) by 2023, with solar photovoltaics expected to account for approximately three-quarters of the global additions [16]. In the Net Zero Emissions by 2050 scenario, it is anticipated that renewable sources will provide for the near-total decarbonization of electricity generation. Concurrently, the utilization of renewable transportation fuels and renewable heat is contributing to a notable reduction in emissions within the domains of transportation, buildings, and industry. It is encouraging to note that the global capacity for renewable energy is expected to increase more rapidly in the next five years than it has since the first commercial renewable energy power plant was constructed over a century ago. Another promising development is the expectation that approximately 3,700 GW of new renewable capacity will come online in the 2023-2028 period, driven by supportive policies in more than 130 countries [10, 55].

While the technical characteristics, use, and consumption of renewable energy are of great importance, the management of this energy is equally significant. The management of energy systems is typically achieved through the coordinated efforts of public distribution, transmission, and production systems. Furthermore, the organizational structure of energy management serves to maintain equilibrium between energy supply and demand. In particular, fluctuations in energy supply result in corresponding fluctuations in consumption. It will be feasible to guarantee planning, organization, and coordination in energy management [24]. In conclusion, the global structure of energy requires the implementation of a global management approach. The current

and potential energy crises have prompted the need for a more robust and participatory approach to energy management, one that is founded on democratic principles and collaborative partnerships. There is no consensus on the definition of a renewable energy cooperative. A variety of organizational forms and financing models exist, yet a number of common elements can be identified, namely a set of core principles and values. Cooperatives are not only a pertinent business model for financial citizen participation within the energy sector; for example, in Germany, they constitute the most relevant organisational form regarding active participation in local energy policy [47]. The corruption-ridden economy that the public sector can create, and the transformation of the private sector into a system based on impoverishment and inequality, has become inevitable in many countries. However, considering cooperatives, which propose mutual aid, solidarity, and cooperation, as a third way could be a very wise approach. In particular, the issue of meeting essential needs like energy with renewable energy, a sustainable energy source instead of finite fossil fuels, should not be confined to the private and public sectors. In this context, the use of renewable energy through cooperatives would be a fair, equitable, and sustainable approach.

The use of renewables is also closely related to the Net Zero Emissions by 2050 Scenario (NZE Scenario). The IPCC AR6 Report emphasised that achieving net zero CO₂ by 2050 in the energy sector relies on the deployment of a broad portfolio of low-emission technologies and emission reduction options, but also relies on high levels of global cooperation and solidarity. Advanced economies lead the way, reaching net zero emissions overall by 2045 in the NZE Scenario, followed by China by 2050 and other emerging market and developing economies after 2050. The comprehensive NZE Scenario update presented here reflects real-world progress and ongoing assessment of feasibility across sectors and technologies since our 2021 report *Net Zero by 2050: A Roadmap for the Global Energy Sector*, but it is also important to note that this is not the only way to achieve net zero emissions by 2050 [20].

Another important issue related to energy is the storability of this energy. The general advantages of energy storage are summarized as increasing the operational efficiency, durability and flexibility of the systems used to produce energy and reducing the mismatch between energy supply and demand periods. In addition, there are some disadvantages of energy storage. These are; energy storage technologies cause a large investment cost to be integrated into the electricity grid and electrical energy must first change its form in order to be stored (converting from

alternating current to direct current, from electrical energy to chemical energy, etc.). This situation causes a loss of efficiency in energy storage [26]. A key benefit of being able to store this energy is that it helps to prevent renewable resources from going to waste.

There are times when the amount of electricity being generated by renewables can exceed the amount that is needed at the time. When this happens, some renewable generators may need to curtail their outputs in order to help the system remain ‘balanced’ – i.e. when electricity supply meets demand – meaning that an opportunity to generate clean electricity has essentially gone to waste.

Energy storage allows these renewable energy resources to continue to generate electricity even if it is not needed at that particular time, as it can be stored until a later time when it is needed. These are some of the different technologies used to store electrical energy that’s produced from renewable sources: pumped hydroelectricity energy storage, electrochemical battery energy storage, lithium-ion battery storage, flow battery storage, and his flowing reduction-oxidation operation – known as ‘redox flow’ – allows the batteries to store large amounts of energy for long durations and be cycled many times without degradation. However, they do have a relatively large project footprint [38].

A renewable energy cooperative (RE co-op; REC) is defined as a decentralized, non-governmental initiative of local communities and citizens, whose objective is to promote the production and consumption of renewable energy [28]. As with other cooperatives, RE co-ops adhere to the fundamental principles set forth by the International Cooperative Alliance (ICA). These principles include voluntary and open membership, democratic member control, economic participation by members, autonomy and independence, education and training, cooperation among cooperatives, and concern for the community [2, 14, 57]. At present, renewable energy cooperatives are most prevalent in the United States, Canada, the United Kingdom, and northern European countries such as Germany, Denmark, and the Netherlands. The rationale behind the establishment of renewable energy cooperatives encompasses a multifaceted array of considerations, including environmental, economic, and social issues. Their initial objective is to facilitate a transition in the energy system towards a cleaner and more sustainable line of renewable energy sources, thereby mitigating the adverse effects of climate change. Additionally, they facilitate the dissemination of renewable energy technologies by functioning as an alternative to the prevailing system of state-

or corporate-owned, highly centralized energy generation. Such a system is democratic in nature, with energy generation controlled by numerous local movements rather than a small number of companies. For instance, in Spain, five companies hold this power. The establishment of RE co-ops confers greater autonomy and control to citizens, reducing their reliance on external energy sources and enhancing their capacity to influence and engage with their energy supply. Civic participation in energy sourcing allows communities to collectively develop a more sustainable society, reducing their reliance on large energy companies. The decentralization of energy sources allows for the implementation of pricing structures that are more equitable, which in turn helps to alleviate energy poverty and to empower local communities. By acting as both producers and consumers, citizens have the opportunity to profit by selling the energy generated and/or purchasing energy at a lower cost. Such cooperatives are capable of adaptation.

The most important benefit of renewable energy cooperatives is undoubtedly meeting the increasing energy demand in the most harmonious way with nature. This situation will contribute positively to the formation of a livable world as well as energy saving. Creating local government support, education, environment and financing conditions for the development of renewable energy cooperatives will further increase this benefit. Various academic studies have been conducted on the use of solar energy among renewable energy sources and the economic benefits it will provide. According to some findings obtained from these, while the share of solar energy in renewable energy sources was 0.16% in 2000, it started to increase rapidly since 2010 and reached approximately 23% in 2019, and it is predicted that this will increase 22 times more with the scenario developed by more than 50 experts and analysts from [12]. In the study of [25], the importance of complementarity between capital and energy in production technology is emphasized in the study of Diaz, Marrero, Puch and Rodriguez (2019) in order to analyze the relationship between energy and economy. Various empirical studies investigating the relationship between economic growth and energy use have found results supporting all four hypotheses.

2. WHY RENEWABLE ENERGY COOPERATIVES?

Two different approaches can be developed to answer this question. The fact that the topic of this study is renewable energy cooperatives shows that this topic consists of two main headings: renewable energy and cooperatives. Both titles are actually very important for humanity. The idea of cooperatives will be very effective in the energy that can sustain human existence and survival, and in the management of this energy. First, when considering the renewable energy aspect of the

issue, it should be examined what renewable energy is and why it is necessary [9]. That is, human needs increase with the population and the need for energy increases. It is an expected development that the demand for energy will increase day by day and the question is from which source this energy will be obtained. In general, the increase in the demand for energy has not only increased due to the population, but also due to the widespread use of machinery in the production process created by the industrial revolution. With the increase in energy demand, the widespread use of fossil fuels has become necessary along with the increasing energy demand. The use of oil, coal and their derivatives, known as fossil fuels, has become widespread on a global scale, causing the resources of these fuels to diminish. In short, these fuels are never renewable and their quality decreases, as they are used [8, 30]. This situation is in itself a threat to humanity and has necessitated the creation of a new and inexhaustible energy source. In addition to the non-renewable nature of fossil fuels, another important issue on a global scale is the increasing pollution and global warming caused by the use of these fuels, which threatens humanity more than their depletion. In other words, fossil fuels put the use of alternative energy sources on the agenda, as they are an investment that is both depleting and sustainable.

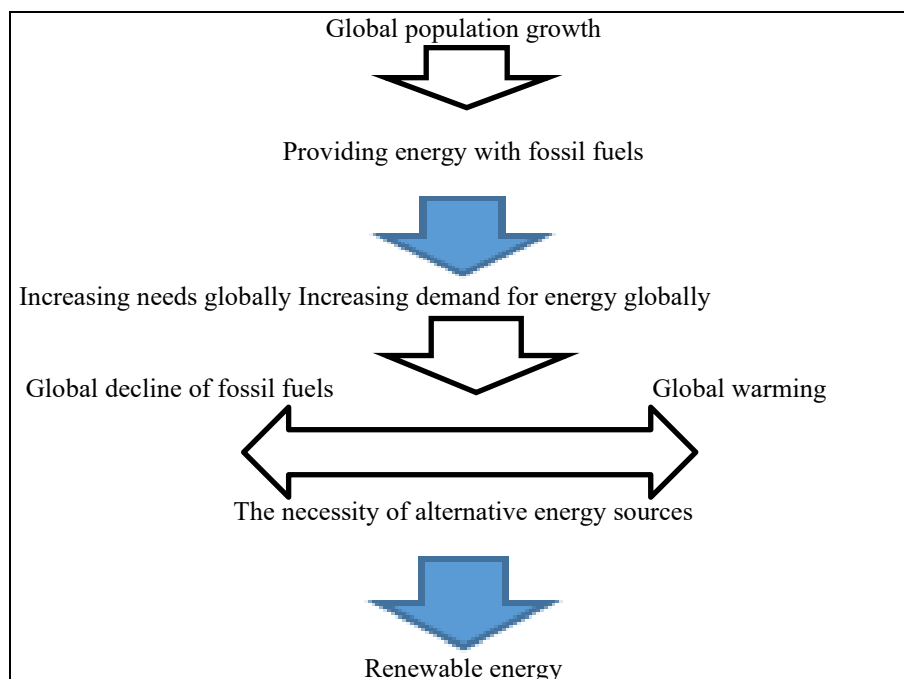


Figure 1. The importance and process of renewable energy

There is a very close relationship between global warming and the use of renewable energy sources. The theoretical basis of this relationship;

1. Renewable energy sources (solar, wind, hydroelectric, biomass, geothermal) have much lower greenhouse gas emissions than fossil fuels. These sources do not release carbon dioxide (CO₂) and other greenhouse gases while producing energy, or they release very low amounts. This makes a significant contribution to slowing down global warming.
2. Renewable energy can be used instead of fossil fuels, thus reducing fossil fuel consumption. The burning of fossil fuels is a significant factor that accelerates global warming. Switching to renewable energy eliminates this dependency and reduces greenhouse gas emissions.
3. Renewable energy systems generally operate with high efficiency and less energy is lost during energy production. This reduces overall energy consumption and therefore greenhouse gas emissions.
4. Renewable energy sources, unlike fossil fuels, do not run out. This helps to meet long-term energy needs and minimize environmental impacts. Sustainable energy production can permanently reduce the effects of global warming.
5. Renewable energy projects can provide local environmental improvements. For example, wind and solar projects can improve air quality and protect local ecosystems.
6. Renewable energy technologies are rapidly evolving. More efficient and cost-effective solutions are enabling the wider adoption of renewable energy, making it an effective tool in the fight against global warming.
7. Renewable energy plays a critical role in mitigating the effects of global warming by reducing greenhouse gas emissions and eliminating fossil fuel dependency. This transition provides both environmental and economic benefits. The vital importance of energy is an integral part of economic and social life, and this is a subject that can be addressed with a multifaceted approach, with cooperative organizations playing a supporting role.

3. RENEWABLE ENERGY DIMENSION

The issue of renewable energy is primarily related to global population growth. This situation is revealed by the population growth projections calculated by various organizations. It is predicted

that in the future there will be an increase in the world's population and a parallel increase in needs. In fact, the latest projections by the United Nations suggest that the world population could grow to about 8.5 billion in 2030, 9.7 billion in 2050, and 10.4 billion in 2100 [58]. Figure 2.

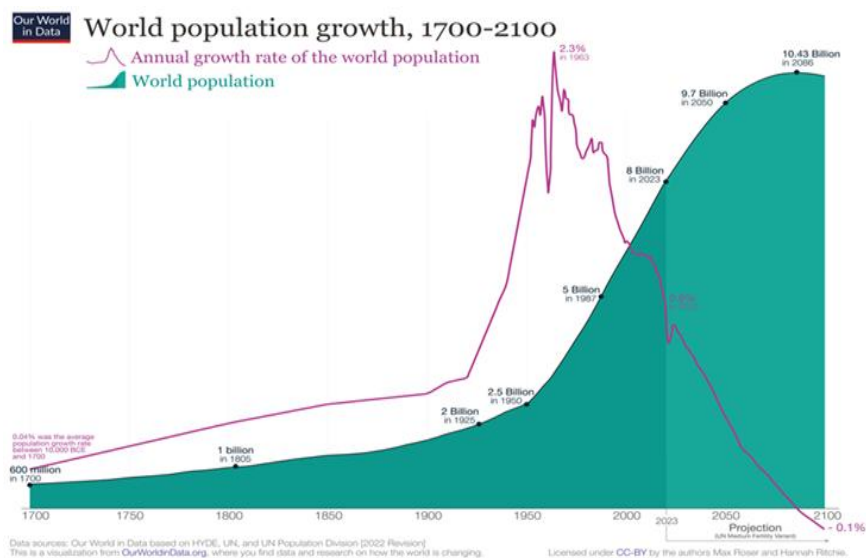


Figure 2. Worl population growth (1700-2100); (Wikipedia, 2025)

Another relevant dimension of renewable energy is the demand that will increase with the growth of the world's population. Increasing demand can be explained by the increase in agricultural and industrial products, especially food, the need for raw materials, and the increase in manufacturing production that will be used in the production of all these products and that will require the use of energy. As the world's population grows, access to food for that population must increase at the same rate. To better understand how this might be achieved by 2050, researchers at the USDA Economic Research Service (ERS) conducted a study consisting of a series of scenarios [53]. One of these scenarios is that the world population in 2050 will be approximately 9.7 billion and that approximately 14,060 trillion calories will need to be produced to feed this population. This scenario is based on 2011 and concludes that the increase in production will naturally increase the increase in calories by about 47%. Similarly, a second scenario is that the population will be 10.8 billion and that this will require approximately 15.4 trillion calories, and again based on 2011, the increase will be approximately 61%. In short, the conclusion is that in all scenarios, more calories will be needed as the population grows, resulting in more energy demand [53]. (Figure 3).

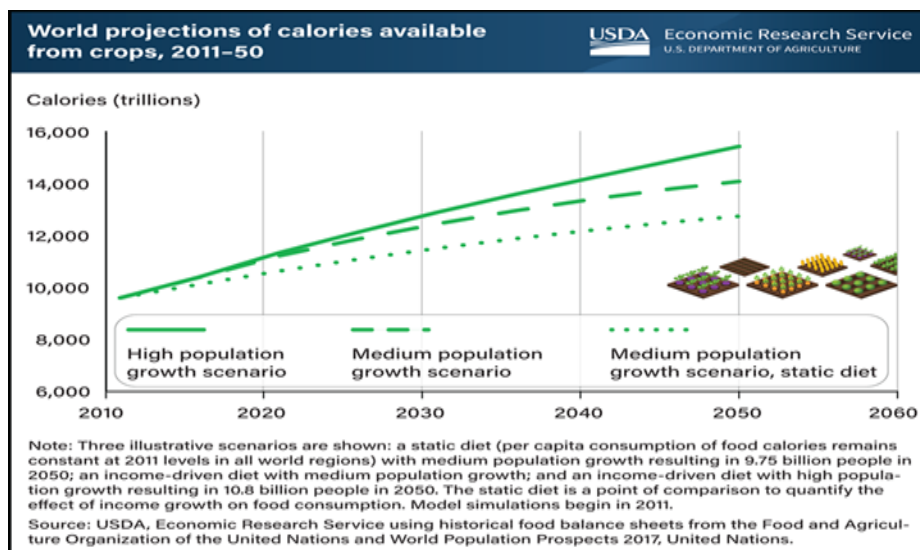


Figure 3. World projection of calories available from crops (2011-2050), (USDA, 2025)

It is a fact that the world's needs will increase exponentially and the amount of energy it will use will increase in parallel with population growth, which will increase for a certain period and then stagnate. It is a fact that the use of energy in production began with the Industrial Revolution, and the main reason for this is explained by the increase in mass production with the Industrial Revolution. The Energy Information Administration's International Energy Outlook 2021 report predicts that global energy consumption and carbon dioxide emissions will increase by about 50% by 2050 due to population and economic growth [16]. According to the EIA, most oil and natural gas production will be used to support the growing energy consumption of developing Asian economies. It is also known that the economies of developing countries are more willing to use fossil fuels. While fossil fuels will account for about 80% of the world's primary energy consumption in 2020, the EIA projects that this share will drop to 70% by 2050. In short, according to the EIA, fossil fuels will continue to be the world's largest source of energy in 2050 [16]. (Figure 4).

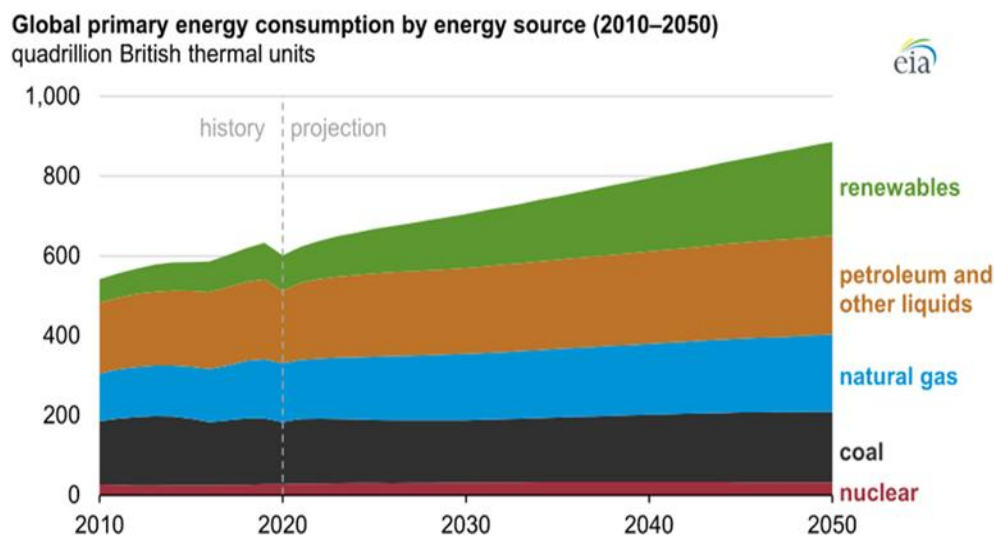


Figure 4. Global primary energy consumption by energy source (2010-2050); (EIA, 2025)

The most important path to renewable energy on a global scale is the expectation that the population will increase, the needs will increase, and of course, the demand for energy will increase. However, another important fact brings global renewable energy to the forefront and that is the pollution that has been and will be experienced. Environmental pollution is actually global warming, which is the main determinant of the most important environmental disasters of the last century, and this warming is directly related to the energy used and to be used [34]. In short, the use of fossil fuels worldwide will increase the emission of harmful gases that will be released directly into the atmosphere, and the natural global warming will trigger natural events. In fact, the Covid 19 pandemic, supernatural events and disasters seriously threaten humanity. This situation alone causes the issue of renewable energy to be at the top of the agenda.

Various data are used in the world regarding the energy consumption of countries. One of the most important of these is the data of the countries with the highest energy consumption per capita. According to 2024 data, the top five countries consuming the most energy per capita in the world are Qatar (817 GJ/cap), Singapore (577 GJ/cap), United Arab Emirates (539 GJ/cap) and Kuwait (366 GJ/cap). However, according to 2023 data, China, USA, India and Russia are at the top of the list for fossil fuels. According to another data, the countries consuming the most energy in total in 2022 are China (159 billion kWh), USA (95.9 billion kWh), India (36.4 billion kWh) and Russia (28.9 billion kWh). [59].

There is a widespread belief that both population growth and increased demand for food will naturally increase energy consumption on a global scale. However, whether the source of this energy is environmentally friendly or not is one of the most important reasons. With population, consumption, energy demand and the use of fossil fuels, the increasing threat to the environment and ultimately global warming will be inevitable. Different scenarios have shown that global warming can be a serious threat and to what extent it can be reached by energy use or, in short, by using the wrong energy access. The limit of warming is 1.5°C above pre-industrial levels, greenhouse gas emissions are decreasing rapidly over the years, approximately halving by 2030 and decreasing to zero immediately after the average current intensity [21]. According to official records, more than 8,000 climate-related disasters occurred in the world between 1990 and 2014, with floods, hurricanes, and epidemics being the most common. Of course, the source of these disasters is largely global warming and the deep causes behind it. In a study conducted in a sample and scenario consisting of 228 countries and regions, it was determined in a sampling and simulation study covering the years 1990-20100 that global warming could reach frightening proportions [18]. It was found that even small developments in the transition from fossil fuels to renewable energy sources could reduce these catastrophes. (Figure 5).

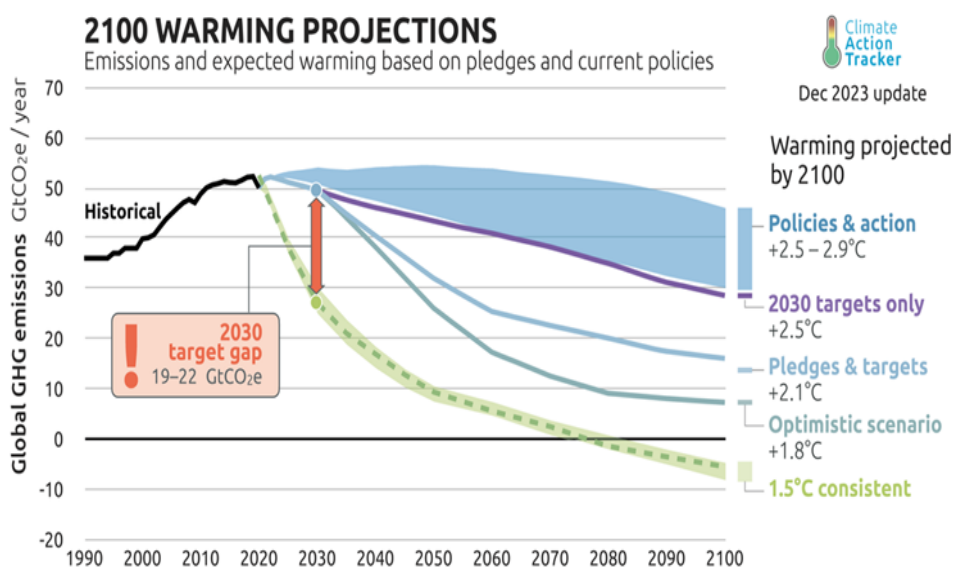


Figure 5. 2100 warming projection, (IPCC, 2025)

The connection between global warming and renewable energy is obvious in every way. In particular, migration scenarios clearly demonstrate this. Although migrations occur for many different reasons, the factors that cause migration can generally be grouped as socio-economic, political or environmental [32,39]. Income and unemployment are important factors in the context

of economic structure. Political reasons include threats to security and freedom that can lead to conflict. Today, environmental problems are increasingly linked to displacement and migration. World Bank studies show that by 2050, 216 million people in sub-Saharan Africa, South Asia and Latin America will be forced to migrate because of the effects of climate change [17]. (Figure 6)

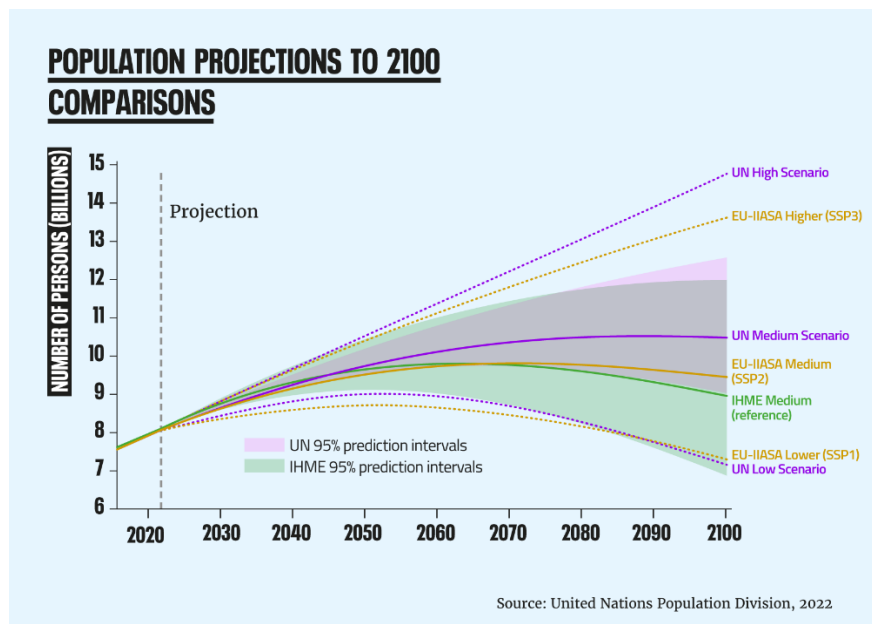


Figure 6. World population by 2100; (Populationmatters, 2025)

All these developments have indeed led to the emergence of ideas that renewable energy sources have advantages. However, a more rational and useful approach would be to consider the advantages and disadvantages of renewable energy sources together. There are various advantages and disadvantages in the use of renewable energy [1,7]. Even the fact that their disadvantages are at a tolerable level can be considered an advantage in itself. Among these advantages, the most important feature that can be used in a renewable energy cooperative for these resources is that the sun, which forms the basis of the renewable energy source, is common and there is enough abundance in its use that it does not disrupt the partnership. The advantages and disadvantages of renewable energy are summarized in the following table. (Table 1)

Table 1. Advantages and disadvantages of renewable energy

Advantages	Desavantages
Renewable energy doesn't run out.	Renewable energy has high initial costs.
Renewables require less maintenance.	Renewables are intermittent.
Renewable energy saves money.	Renewable energy has limited storage capabilities.
Renewable energy has many environmental benefits.	Renewables have geographic limitations.

Renewable energy reduces dependence on foreign energy sources.

Renewable energy leads to cleaner water and air.

Renewable energy creates jobs.

Renewable energy can reduce waste.

Renewable energy isn't always 100% carbon-free.

4. COOPERATIVE DIMENSION

The International Co-operative Alliance (ICA) defines a cooperative as "an autonomous association of persons voluntarily formed to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise. This definition emphasizes that cooperatives are member-driven organizations that focus on the needs of their members and promote participation, equality, and community involvement. Cooperatives are member-owned and democratically controlled organizations that operate for the benefit of their members [50]. They are formed by groups of people who come together voluntarily to meet common economic, social, or cultural needs and aspirations. The primary objective of a cooperative is to pool resources and share risks and benefits among its members, rather than to maximize profits for shareholders. Cooperatives can exist in a variety of sectors, including agriculture, finance, retail, and housing, and are guided by principles such as voluntary and open membership, democratic member control, and concern for the community [24].

Cooperatives are owned by the members who use their services or work for them. Each member usually has an equal share and voice in the cooperative. Decisions in a cooperative are made democratically, often on a one member, one vote basis, regardless of the amount of capital a member has invested. Members contribute equally to the capital of the cooperative. Any surplus or profit is often distributed among members, reinvested in the cooperative, or used to provide services at a lower cost [3]. Cooperatives are independent organizations controlled by their members. Even when they enter into agreements with other organizations, they maintain their autonomy. Cooperatives provide education and training to their members and employees so that they can effectively contribute to the development of the cooperative. Cooperatives often work together through local, national and international structures to strengthen the cooperative movement. Cooperatives work for the sustainable development of their communities through policies approved by their members.

In the development process of renewable energy cooperatives, especially in the industrial revolution, mass production and the increase of energy demand have been an important factor. In short, energy cooperatives lie at the root of renewable energy cooperatives in the world. Especially

after the "Great Depression" in 1929, the evaluation of energy cooperatives as a development tool in the United States showed the success of the cooperative model. At that time, President Roosevelt sent a message to rural areas that did not even have electricity [22]. Democracy and dysfunction: Rural electric cooperatives and the surprising persistence of the separation of ownership and control. *Ala. L. Rev.*, 70, 361.49]. Electricity was provided through energy cooperatives, which were created as part of the New Deal document. Thus, energy cooperatives played a leading role in the renewable energy cooperatives that were created and developed in the following years [62, 4]. Steps such as the development of cooperatives, the establishment of energy market organizations, and energy cooperatives have formed the basis of today's renewable energy cooperatives. In many countries of the world, cooperatives are involved in the production of clean energy thanks to the support mechanisms implemented to promote the production of energy from renewable sources. These support mechanisms have directly formed a resource within renewable energy cooperatives. In particular, changes in energy policies due to the oil crisis of the 1970s, environmental problems that began to threaten human existence, and rising energy prices brought environmentally conscious citizens together to create renewable energy. It enabled them to become energy cooperatives. With the contribution of successful incentive mechanisms such as feed-in tariff, renewable energy cooperatives have become popular in developed countries of the world such as Canada, USA and Australia, especially in Germany, England and Denmark [36].

Cooperatives have long been involved in the production, distribution, sale and service of energy. Cooperative models in this area include energy consumer cooperatives, energy producer cooperatives, energy producer and consumer cooperatives, and energy service cooperatives. Most evaluations of cooperatives focus on the user or end consumer. Renewable energy cooperatives appear as part of the broader energy community. There is a growing interest in this community from academia, the public sector and civil society. The impacts associated with renewable energy cooperatives were assessed by dividing them into four categories. The impacts of renewable energy cooperatives are evaluated primarily in economic terms for members. The cooperative business model allows individuals to reduce costs, risks and responsibilities. By sharing, they are able to make capital-intensive renewable energy investments that they could not make on their own. When renewable energy projects become operational, members benefit from the economic return of the electricity and/or heat produced [2]. Renewable energy cooperatives (RECs) are member-owned organizations that focus on the production, distribution, and use of renewable energy, often in local communities. These cooperatives aim to provide sustainable energy

solutions, promote community ownership, and encourage local participation in energy systems. They often operate in sectors such as solar, wind, biomass, and hydropower. The cooperative model allows for the decentralization of energy production and is seen as an effective way to achieve energy democracy by empowering citizens to participate in and benefit from the energy transition [44].

4.1. The History and Growth of Renewable Energy Cooperatives

The concept of energy cooperatives can be traced back to the early 20th century when rural communities, particularly in the U.S. and Europe, established cooperatives to bring electricity to underserved areas. The modern version of this movement, focusing on renewable energy, began in the 1980s in response to growing concerns over fossil fuel dependency and environmental sustainability. Germany has played a significant role in advancing renewable energy cooperatives. The country's Energiewende (energy transition) policies, introduced in the 1990s, encouraged citizens to form cooperatives to produce renewable energy [11]. Energy transition and behavioural change in rural areas—the role of energy cooperatives as of 2020, and Germany had over 1,000 energy cooperatives, producing around 20% of the country's renewable energy. Electricity production from renewable energy sources in Germany increased by 7.1 percent in the third quarter of the year compared to the same period last year, reaching 57 billion kWh [42]. Denmark is another pioneer in this field, with a history of community-owned wind farms. The country's "Wind Guilds" emerged in the 1980s, and by the early 2000s, about 150,000 households were part-owners of wind turbines [23]. In Canada, energy cooperatives have flourished, with provinces like Ontario leading the way. The province's Green Energy Act (2009) was pivotal in fostering community-based renewable energy projects. Local cooperatives have been essential in achieving Ontario's goal of phasing out coal power and increasing the share of renewables [35]. Key Features and objectives of this Act;

1. **Local Ownership and Control:** Members of renewable energy cooperatives usually own a stake in the cooperative and have a say in its operations through democratic decision-making processes. This promotes local involvement and transparency.
2. **Environmental Sustainability:** The primary objective of these cooperatives is to promote the use of renewable energy sources like solar, wind, biomass, and hydropower, thereby reducing reliance on fossil fuels and contributing to the fight against climate change.

3. **Economic Benefits:** Renewable energy cooperatives provide economic benefits to local communities by creating jobs, reinvesting profits locally, and reducing energy costs through collective ownership. Members share in the financial returns, and these cooperatives often prioritize local suppliers.
4. **Social Cohesion and Community Development:** These cooperatives foster social cohesion by involving local communities in energy production, promoting energy independence, and enabling more equitable access to energy. This creates a sense of ownership and empowerment among community members.

Renewable energy cooperatives have emerged as a promising global outlet for community-driven energy solutions. These cooperatives are designed to provide an alternative, decentralized approach to energy production, which empowers communities and reduces reliance on traditional fossil fuels. Globally, these cooperatives foster local control over energy resources and promote sustainability. Some examples and developments regarding these are as follows:

1. **Europe as a Pioneer:** In Europe, especially in countries like Germany and Denmark, renewable energy cooperatives have become key players in the transition towards sustainable energy. In Germany, the *Energiewende* (energy transition) strategy is driven by community-led cooperatives that own and manage wind turbines, solar panels, and biogas plants. Over half of Germany's renewable energy capacity is owned by private citizens and cooperatives, emphasizing the shift towards decentralized energy systems [43].
2. **Canada's Renewable Cooperatives:** In Canada, renewable energy cooperatives have also gained traction, with a focus on community-based solar and wind projects. Ontario's Green Energy Act of 2009 enabled the growth of such cooperatives by promoting local ownership and participation in renewable energy projects [6]. These initiatives have helped build local expertise in renewable energy and created sustainable income streams for communities.
3. **Developing Nations and Renewable Cooperatives:** Renewable energy cooperatives are also expanding in developing nations, where access to energy remains limited. In countries like Kenya, cooperative models are used to provide off-grid solar solutions in rural areas, improving

energy access while reducing carbon emissions [31]. These initiatives play a crucial role in addressing both energy poverty and climate change.

4. **Policy Support and Challenges:** Globally, policy support has been vital for the growth of renewable energy cooperatives. Feed-in tariffs, subsidies, and government incentives have supported their development. However, challenges such as regulatory barriers, financing, and technical capacity remain significant [37]. Despite these challenges, renewable energy cooperatives are increasingly seen as a viable pathway to achieving global renewable energy targets.

4.2. The Use of Cooperative Model in Energy Production.

The cooperative model in energy production has gained traction globally, offering a decentralized, community-focused approach to energy generation, particularly in renewable energy sectors like solar, wind, and biomass. This model allows communities to collectively own and manage energy resources, ensuring profits are reinvested locally, increasing energy access, and promoting sustainability. Energy cooperatives, especially renewable energy cooperatives, are very effective in energy management and planning. Some of them are as follows:

1. **Community Ownership and Control:** Energy cooperatives are owned by local members who have direct control over decision-making processes, ensuring that the community's energy needs and goals are prioritized. This local control fosters a sense of ownership, which can drive greater commitment to sustainable practices.
2. **Economic Empowerment:** Profits generated from energy production are often reinvested into the local economy, benefiting members and supporting other community services. This can help reduce energy poverty and provide stable jobs, particularly in rural areas where energy access is limited. The International Cooperative Alliance (ICA) highlights that cooperatives generate economic benefits for members, often reinvesting profits in social projects that further benefit the community.
3. **Promotion of Renewable Energy:** Many energy cooperatives focus on renewable energy sources like solar, wind, and biomass, contributing to global efforts to combat climate change. Cooperative members often have a vested interest in environmental sustainability, which aligns

with the growing demand for cleaner, more reliable energy sources. A 2024 report from IRENA noted that cooperative-led renewable energy projects can help countries meet their renewable energy targets by increasing local participation and investment in green technologies [21].

4. **Decentralized Energy Systems:** By establishing localized energy production facilities, cooperatives reduce dependence on national grids and large energy corporations, making energy systems more resilient to disruptions. This decentralized approach can also reduce energy transmission losses and lower costs for consumers.

The European Federation of Renewable Energy Cooperatives (REScoop. eu) emphasizes that energy cooperatives enable more resilient and decentralized energy networks, promoting local energy independence [45]. Case Studies;

1. **Germany's Energiewende:** Germany's energy transition has seen significant involvement from energy cooperatives. By 2014, nearly half of Germany's renewable energy capacity was owned by private individuals and energy cooperatives. The model enabled widespread community participation, accelerating the country's shift towards renewables. According to [13], the cooperative model played a crucial role in Germany's successful renewable energy initiatives, particularly in community wind and solar projects.
2. **Denmark's Wind Power Revolution:** Denmark's wind power revolution was driven largely by energy cooperatives. In the 1970s, local cooperatives began investing in wind energy, and today, around 70-80% of Denmark's wind turbines are owned by cooperatives or private individuals. A report by [33] highlights that Denmark's wind energy sector succeeded largely because of the community involvement facilitated by cooperative ownership.

5. RENEWABLE ENERGY COOPERATIVES AND SUSTAINABILITY

Renewable energy cooperatives are member-owned organizations that aim to provide affordable, clean, and sustainable energy to their members and communities. These cooperatives play a key role in promoting sustainability by encouraging local control over energy resources, reducing greenhouse gas emissions, and supporting community development [48]. Here's a deeper look into how renewable energy cooperatives contribute to sustainability;

1. **Decentralization and Local Control:** Renewable energy cooperatives empower communities to take control of their energy supply. This decentralization reduces dependence on large, non-local energy providers, and often leads to more efficient energy distribution with lower transmission losses. The focus on local renewable resources, such as solar, wind, and biomass, further ensures that the energy remains environmentally sustainable and adapted to local needs.
2. **Reduction of Greenhouse Gas Emissions:** By transitioning to renewable sources of energy like solar, wind, and hydroelectric power, energy cooperatives help reduce carbon emissions, which is critical for addressing climate change. Renewable energy projects contribute to significant reductions in the carbon footprint of communities compared to traditional fossil fuels.
3. **Community Empowerment and Economic Benefits:** Renewable energy cooperatives often provide economic benefits to their communities by keeping energy spending local. They create local jobs in installation, maintenance, and operation of renewable energy systems. This also fosters local economic resilience as members save on energy costs and reinvest the profits within the community.
4. **Environmental Stewardship:** Cooperatives promote environmental education and stewardship, encouraging members and communities to adopt sustainable practices beyond energy use. Some cooperatives reinvest in local conservation efforts, like reforestation or sustainable agriculture, further contributing to the ecological health of the region.
5. **Energy Security and Resilience:** By relying on locally sourced renewable energy, cooperatives help communities build energy security and resilience against the volatility of fossil fuel markets. This makes communities more resilient to energy price shocks and geopolitical risks. These factors combined make renewable energy cooperatives a powerful model for advancing sustainable development and transitioning toward a more equitable and green energy system.

6. CONCLUSION

Global warming is the long-term increase in the overall temperature of the planet caused by the burning of fossil fuels such as coal, oil, and natural gas, the combustion of which causes what is known as the "greenhouse effect" in the Earth's atmosphere. Although this warming trend has been

going on for a long time, it has accelerated significantly in the last hundred years due to the increase in human population. This change has disrupted the Earth's climate patterns. Renewable energy is used as an alternative to fossil fuels, which are non-renewable sources of energy. Fossil fuels are used faster than they can be replenished, making them unsustainable for long-term use. They also pollute the environment and produce harmful greenhouse gas emissions. Solar energy, wind energy, biomass, wave and hydro energy, geothermal energy are the main renewable energy sources and the main source of these resources is the sun. A Renewable Energy Cooperative (aka RE Coop; REC) is a decentralized, non-governmental initiative of local communities and citizens to promote the production and consumption of renewable energy. The purpose of establishing renewable energy cooperatives touches on environmental, economic, and social issues. First, they work to promote a shift in the energy system to a cleaner and more sustainable line of renewable energy sources, helping to reduce the impact of climate change. They also disseminate renewable energy technologies by serving as an alternative to the current system of government- or corporate-owned, highly centralized energy production. Energy cooperatives are a promising model for sustainable, community-driven energy production. By fostering local ownership, promoting renewable energy, and reinvesting profits back into the community, they can help address both energy poverty and climate change while empowering communities economically and socially. What could not be achieved by working alone, can be achieved by working together.

DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Ertugrul Guresci: He conducted the literature review and wrote the study.

Ogochukwu Esther Okafor: The study provided literature support.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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