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Review

Review of Community Solar in the United States of America

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Abstract: Community solar is a concept where a large number of entities (consumers, businesses, charitable foundations, investors, etc.) can participate with or without having 100% ownership of the solar hardware. The objective of this paper is to provide an in-depth review of community solar. Although we have kept the global picture in mind, the United States has been our focus. The authors have provided details of the overall role of photovoltaics and battery-based power networks in global electrical power generation. Based on published reviews and research papers, the authors have analyzed the operation of community solar, ownership models and business models used in community solar projects. Based on the published results, the authors found that community solar might grow exponentially. However, due to ultra-small scale power level, this concept has not played a significant role as compared to residential, commercial, industrial and utility-scale use of solar photovoltaics. For the growth of community solar, the authors have proposed a new concept where new constructions can provide large-scale use of community solar projects. The proposed concept is off-grid and can be implemented without the introduction of any new public policy. In conclusion, the proposed concept can play a major role in providing green electrical power for new loads that also include the charging of electrical vehicles.

Keywords: community solar; photovoltaics; energy storage; batteries; standalone power system; local power

1. Introduction

The number one issue that is facing humanity is climate change. Because of this issue, greenhouse gas (GHG) emissions are rising. In 2023, global emissions from fossil fuels reached a high [1]. According to the United Nations [2], global GHG emissions are predicted to rise by 9%. Based on current data, climate action falls vastly short of the 45% targeted drop in emissions required to curb global warming [2]. Therefore, there is an urgency to reduce GHG emissions levels.

Electrical power generation is transforming toward green and clean generation methods. Currently, a potential solution to overcome the climate change issues is to replace the fossil fuel-based large-scale energy production system with small, medium and large-scale green technologies that can be implemented in various parts of the world. An emerging concept called community solar is gaining attention so that more solar energy can be used to overcome the climate change crisis [3]. The increased use of free fuels-based solar photovoltaics will make the energy sector shift toward a more decentralized scheme [4].

This paper focuses primarily on the emerging concept that is based on the use of solar photovoltaic systems, and it is called community solar. The definition of community solar by the U.S. Department of Energy is as follows “any solar project or purchasing program, within a geographic area, in which the benefits of a solar project flow to multiple customers such as individuals, businesses, non-profits, and other groups” [5].

Numerous relevant research papers have delved into this emerging topic from various points of view. One paper on community solar provides a review of this concept and its technical and economic motivations, trading schemes, price negotiation algorithms, and benefits for the grid [6]. Another paper describes the development and evolution of community renewable energy business models and how the English community renewable business models have developed over time [7]. Based on an unlabeled survey-based choice experiment that took place in Guangdong Province, China, the authors of reference [8] examined the determinants of the potential users' willingness to participate in the community-shared solar programs. The impacts of the configuration of the energy communities and their economic and technical performance were discussed in reference [9]. The status and development of the community energy sector in Italy is characterized by having a smaller number of community energy developments [10]. The authors of reference [11] discuss the drives of the development of community energy in Denmark, Germany, Belgium and the UK by using Elinor Ostrom's Social-Ecological System framework. In the Netherlands, the study was conducted to explore the factors that stimulate or hamper the appearance and development of local renewable energy organizations [12]. In order to determine the factors of the financial investment size, the authors conducted a large-scale survey of the members (located in Flanders in the northern part of Belgium) in the community renewable energy [13]. The aim of the authors of reference [14] was to identify the studied factors of the emerging concept of energy communities.

Most of the published literature reviews have not investigated the possibility of establishing the community solar as an off-grid or stand-alone system. Due to that limitation, the purpose of this paper is to provide a comprehensive review of the current state of community solar in the United States and around the world. We have also covered the future prospects of the community solar as a vehicle for the growth of green electrical power.

The rest of the paper is structured as follows: why solar photovoltaics is described in Section 2. In Section 3, the storage of solar generated electrical power is covered. In Section 4, we have covered the charging of electric Vehicles. Section 5 presents multiple definitions and different terminologies for the community solar. In Section 6, we have described how community solar works. Section 7 illustrates the models of the community solar projects. Section 8 covers the future prospects for the emerging concept. The discussions are covered in Section 9. Finally, Section 10 presents the conclusions.

2. Why Solar Photovoltaics?

According to the U.S. Department of the Interior, in one hour and a half, the amount of sunlight that is directed toward the surface of the earth is enough to produce energy for the entire world that lasts for a full year [15]. Solar technologies have the ability to convert sunlight into electrical energy by using either mirror that concentrates solar radiation and is called concentrating solar-thermal power (CSP), or by using photovoltaic (PV) panels, or by using concentrating photovoltaics (CPV).

Historically, solar energy technologies were financially expensive to deploy, however according to International Energy Agency (IEA), solar photovoltaics is now the cheapest energy in history [16]. The free fuel solar energy is the most widely available energy resource on the planet. Figure 1 shows the abundance of solar energy that surpasses the rest of the resources either renewable or non-renewable [17]. Figure 1 shows all renewables and non-renewable energy in Terawatt-years. The period that is given for renewables and consumption is 30-year and it will be referred to TWyr over 30 years as TWyr30. In addition, the area of the circles in the same figure represents the energy reserve from both renewable and non-renewable resources over the next 30 years; and the image of the earth represents the total demand over the same period, and it can be compared with the other area of circles [17].

By the middle of this century, solar energy will eventually dominate the global electricity market without adding any new climate policies or creating any new policies that support renewable energy technologies. This is because the cost of generating electricity from solar energy is declining far below the cost of generating electricity from any other alternative methods [18]. Figure 2 shows the share of global power production by using different techniques for generating electricity whether it is renewable or non-renewable technology [18]. PV module prices have fallen in the $0.1/Watt range [19]. Figure 3 shows the dominance of solar PV panels over the span of ten years from 2020 to 2030 [18]. The author of the article titled "Solar Energy Revolution: A Massive Opportunity" talked about solar energy through his 6 D's paradigm and how the implementation of that paradigm could lead to the potential elimination of energy poverty as well as global poverty. The 6 D's are digitized, deceptive, disruptive, dematerialized, demonetized, and democratized [20]. In terms of numbers, the installed capacity of solar PV panels globally has crossed the 1 Terawatt (TW) threshold of solar power in the year 2022; and it is expected to reach above the 2 TW of operating capacities by year 2025 [21].

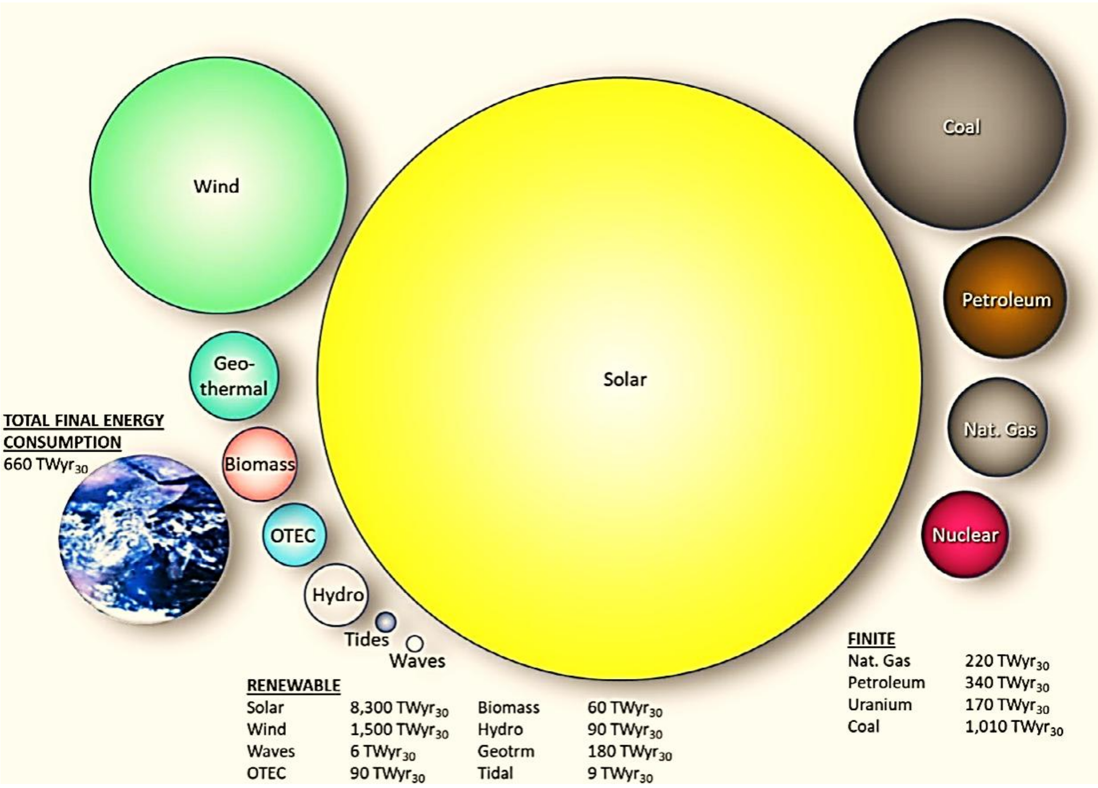

Figure 1. Renewable and non-renewable energy sources [17].

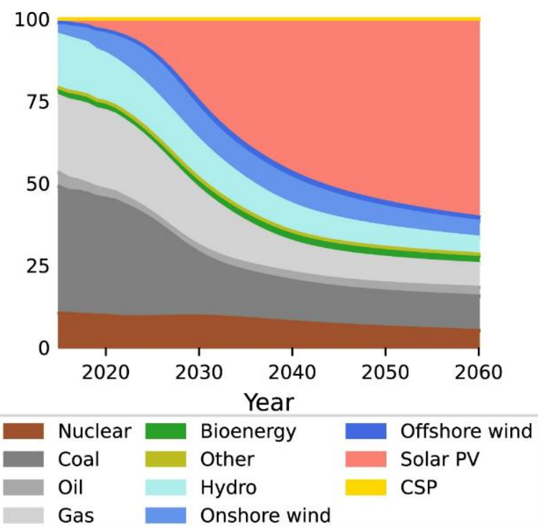

Figure 2. Global share of electricity production by various techniques [18].

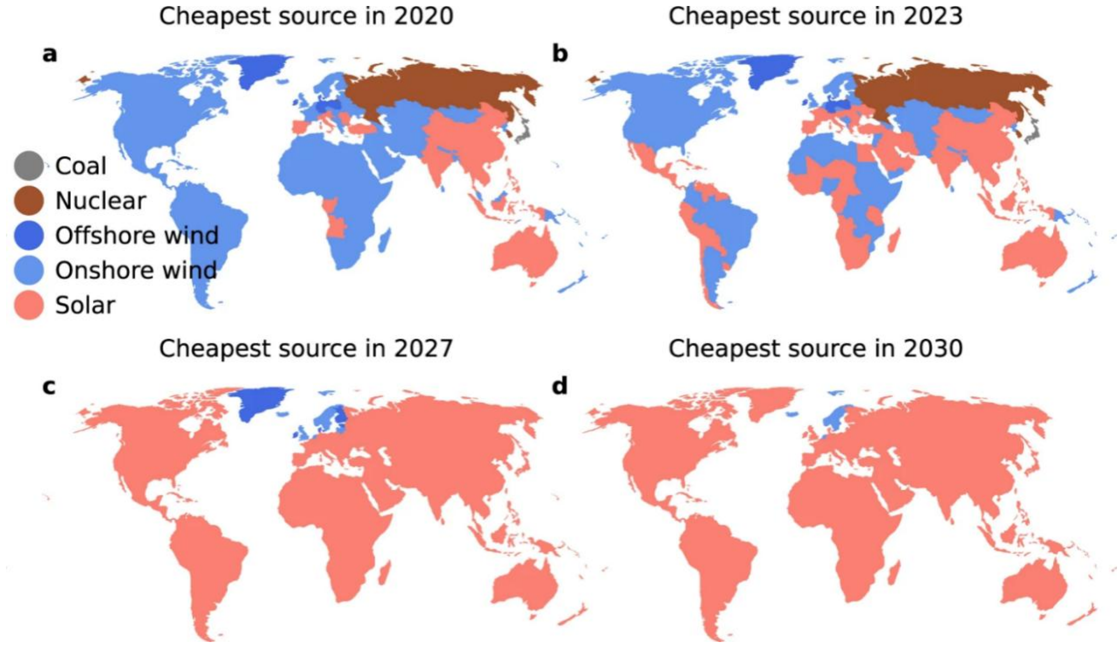

Figure 3. Worldwide use of the solar PV panels over a period of time [18].

In recent years, solar and wind energies have dominated the growth of renewable energy sources [22]. There is no direct competition between solar and wind. However, one of us predicted in 2014 [23] that due to inherent advantages (no moving parts, semiconductor device with high reliability and pathway to cost reduction), photovoltaics will dominate wind turbines. This is indeed the case. As shown in reference [24], although solar commercialization started almost 10 years later than wind turbines, we have more installed PV now than wind turbines. At the end of 2023, we installed PV [25] and wind turbines [26] at 1,598 GW and 983 GW respectively. Figure 4 shows the projected new power generation and storage growth in the US in 2024 [27]. Bloomberg projects that in 2024, we may have 500 GW new installation of PV [28]. In the coming years, we expect the addition of one TW of PV in 2–3 years. The data presented in this paragraph demonstrates the expected dominance of photovoltaics for electrical power generation.

3. Solar Power Storage

The general definition of energy storage is the method of storing energy at a certain time and then using it for a time in need such as to provide a balance between energy production and energy consumption [29]. Fundamentally, electrical energy can be stored in the form of mechanical energy, chemical energy, electrochemical energy, magnetic energy, and cryogenic energy. Mechanical energy can be stored by using flywheels, pumped hydro, gravity, compressed air and liquid piston. For storing chemical energy, hydrogen can be used. Batteries and supercapacitors are used to store electrochemical energy. Superconductors are used to store magnetic energy. Liquid air is used to store cryogenic energy. From a practical point of view, hydro, batteries and hydrogen are the three main sources of storing electrical energy.

Pumped hydro storage has been used extensively in the past and accounts for over 90% of bulk storage capacity worldwide [30]. The pumped storage hydroelectricity has a problem, which is the geographical location of the facility in a country that has access to clean water at different altitudes. Due to the constraint of clean water, this form of energy storage is only located in 10 countries [31]. In recent years, there has been a small growth in pumped hydro storage. As shown in Figure 4, we do not expect any growth of pumped hydro storage in the United States in 2024.

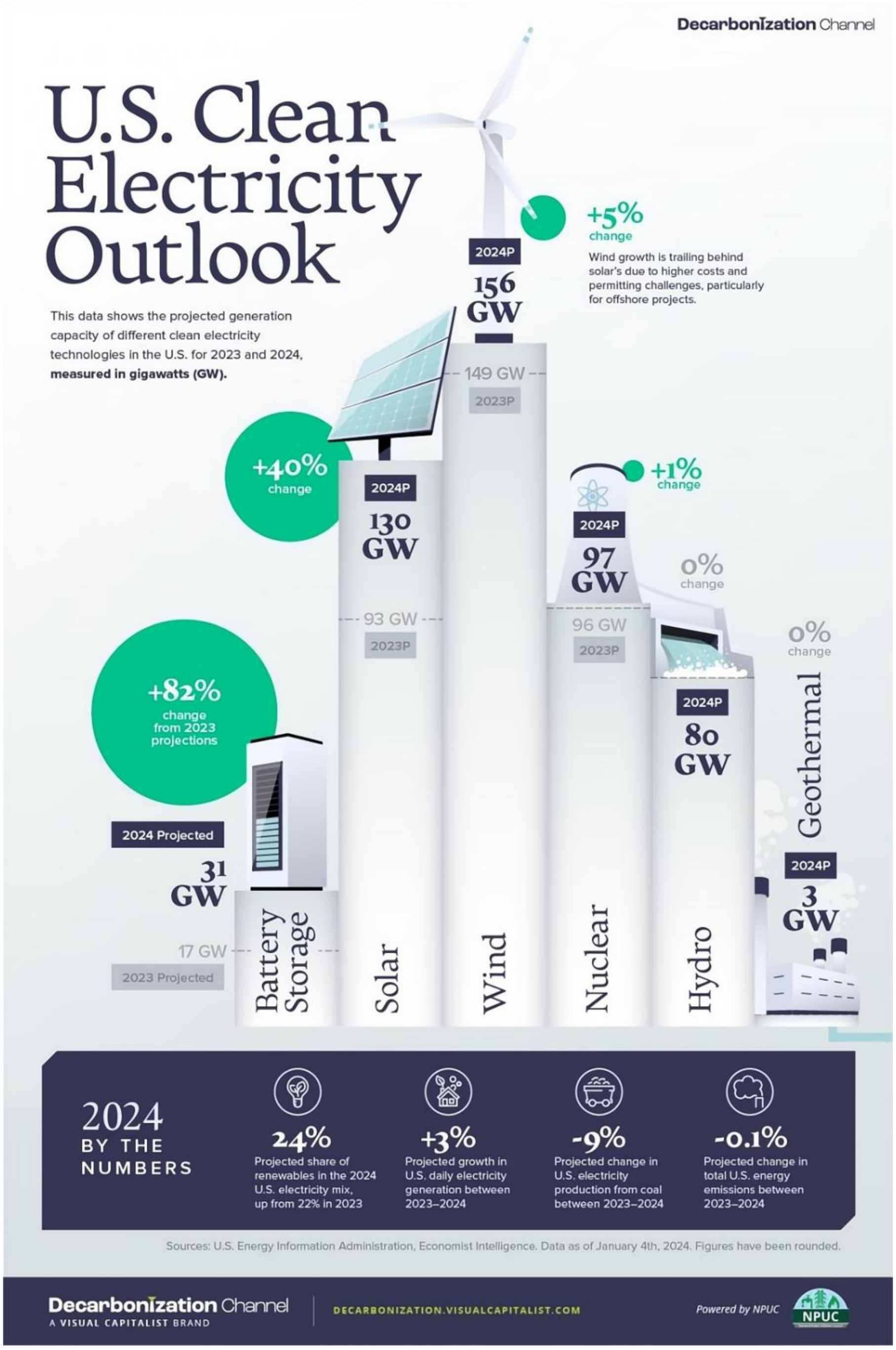

Figure 4. Projected growth of energy sources and battery storage in US in 2024 [27].

Another form of energy storage is the battery energy storage system (BESS). In recent years, BESS has become very popular due to its ability to enhance power system flexibility and enable high levels of renewable energy integration such as solar energy [32]. Another reason that makes this storage system favorable to use is the reduction in the cost of batteries. According to reference [33], the price of battery storage has fallen below $100/kilowatt hour (kWh) in the month of August in the year 2023; and that gives a big support to accelerate the transition to renewable energy technologies such as solar and wind as well as electric vehicles (EVs). As shown in reference [33], the lithium-ion battery price has been plummeting for the last two years [33]. An updated news provided by Goldman Sachs research anticipates that the battery prices will fall to $99/kWh for storage capacity by 2025, and the prices of battery packs are anticipated to drop on average by 11% per year from 2023 to 2030 [34].

Other than lithium-ion, two important battery chemistries can play an important role in the future. The performance of sodium-ion batteries is lower than lithium-ion batteries. Certain electrical vehicle manufacturers will use sodium ion batteries due to lower cost with a driving range lower than lithium-ion batteries based EVs, [35]. The other important battery chemistry is solid-state batteries. The performance of solid-state batteries is superior to lithium-ion batteries, but there are a number of challenges [36] that must be solved before one can commercialize solid-state batteries for large-scale applications. There is a large number of other battery chemistry under investigation, but it remains difficult to see a path to commercialization.

According to reference [37], the grid-scale battery storage has an operational charging capacity of 1,541 megawatts (MW) exceeding the pumped storage hydro charging capacity of 1,340 MW. Thus, in Australia, the capacity of battery storage has surpassed the charging capacity of pumped hydro storage.

According to reference [38], the state of California has the highest capacity of battery energy storage systems worldwide with more than 6,600 MW. More deployment of energy storage projects in the future will help the state to transition to 100% clean energy by the year 2045. Figure 5 shows the battery growth in the US in recent years and in the near future [39].

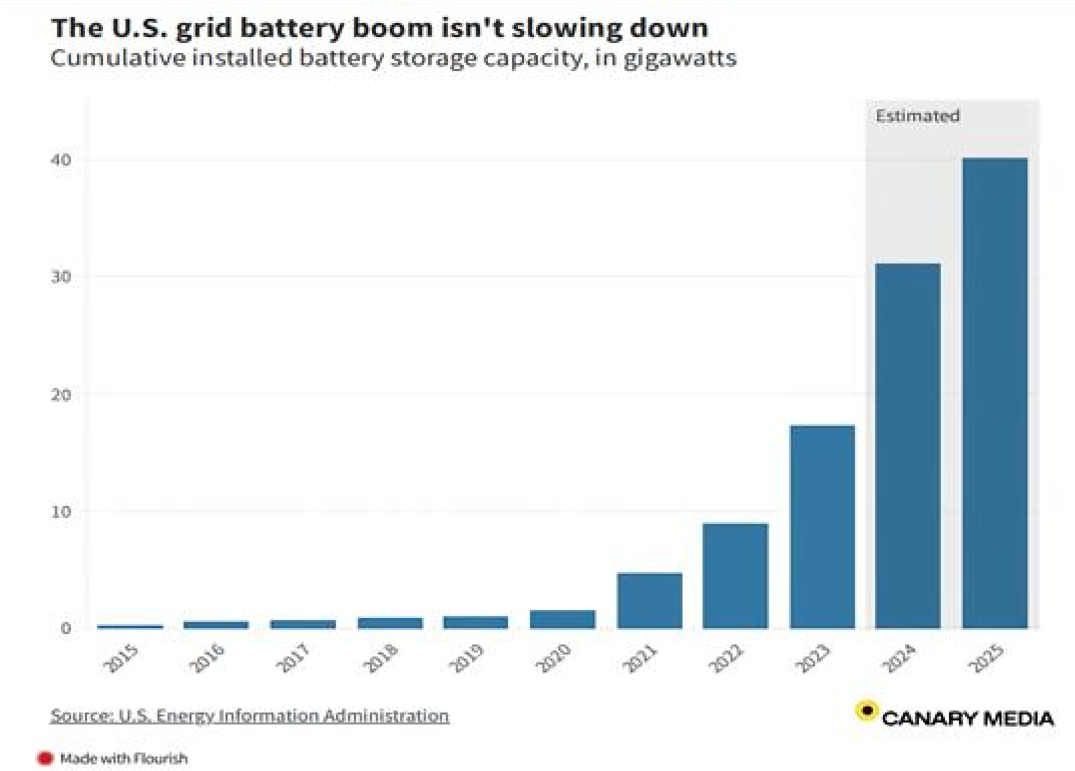

Figure 5. Growth of utility scale battery storage in United States in recent years and in near future [39].

As the lightest element, fundamentally hydrogen storage is quite attractive. However, the green hydrogen is very expensive. This is due to the fundamental problem of low energy conversion efficiency of fuel cells. The typical efficiency of fuel cells is about 60%, while lithium-ion batteries have energy storage efficiency in the range of 92–95%. Globally, billions are being invested in hydrogen. There are many negative reports about the availability of low-cost commercial green hydrogen. As an example, according to steel manufacturer ArcelorMittal green hydrogen is too expensive, although we have received billions in subsidiaries [40]. Thus, it remains to be seen if green hydrogen can ever be widely used for storing electrical power.

4. Important Role of Photovoltaics and Batteries in Charging of Electric Vehicles (EVs)

High penetration of photovoltaics for global electricity generation will provide green electrical power for charging EVs. Currently, houses have level 2 chargers at home, photovoltaics on roofs and battery storage in garages can use green electrical power for EV charging. In rural areas and near highways we have proposed a new concept based on PV and batteries [41]. A solar farm is built very close to the highways (approximately within one or two km from the highway) and batteries are used for storing electrical power. Without using any transformers and long-haul transmission, an end-to-end DC network is proposed to charge the batteries. Overall, the charger cost is reduced by about 30% and as compared to the current AC grid, more than 25% of energy can be saved [41].

5. Definition and Terminology Related to Community Solar

The authors conducted the search for community solar within different bibliographic databases for scientific and engineering such as ScienceDirect, the Institute of Electrical and Electronics Engineers (IEEE), and many others to find different terminologies with the same concept in more than two different parts of the world.

There are two terms and in general cover the same concept. One of the terms originated from some countries in the European Union (EU) and that term is named energy communities (ECs). The other term originated and used in the North American continent, more specifically Canada and the United States, and that term is called community solar (CS).

According to the EU: “Energy communities organize collective and citizen-driven energy actions that help to pave the way for a clean energy transition while moving citizens to the fore” [42]. Bauwens et al. systematically reviewed 183 different definitions of community in relation to energy systems [43]. An Energy Community is defined as a form of a community-driven institution taking social control of shared energetic resources through decentralization [44]. The framing of EC was framed within the concept of sharing economies. Individual consumers, producers, and prosumers are located in an enclosed topology, which can create such space to develop independent initiatives, to actively contribute towards a more sustainable paradigm [44]. However, all the different definitions of energy community emphasize two main characteristics, which are collective action and renewable energy technologies [45].

The term “community solar” is often used to describe solar photovoltaic systems that supply electricity to multiple customers within a geographical area. Since community solar is an emerging concept, every organization or entity can give a definition that suits their needs. In 2006, the first community solar project was established in Ellensburg, WA [46]. In the following paragraphs, there are a couple of definitions for community solar from various organizations and entities, which will give the reader a sense of how every organization or entity defines the emerging concept.

The following definition is from the U.S. Department of Energy: “Community Solar is any solar project or purchasing program, within a geographic area, in which the benefits of a solar project flow to multiple customers such as individuals, businesses, nonprofits, and other groups. In most cases, customers are benefiting from energy generated by solar panels at an off-site array” [5].

The following definition is from the National Renewable Energy Laboratory (NREL): “Community relates to solar, also known as shared solar or solar gardens, is a distributed solar energy deployment model that allows customers to buy or lease part of a larger, off-site shared solar photovoltaic (PV) system” [47].

The following definition is from the National Community Solar Partnership (NCSP), and it is a U.S. Department of Energy initiative led by the Solar Energy Technologies Office: “Community solar is a form of solar energy generation that allows community members of all types to access meaningful benefits of renewable energy, including reduced energy costs, low- to moderate-income household access, increased resilience, community ownership, and equitable workforce development and entrepreneurship” [48].

The following definition is from the Solar Energy Industries Association (SEIA): “Community solar allows residents, small businesses, organizations, municipalities, and others to receive credit on their electricity bills for the power produced from their portion of a solar array, offsetting their electricity costs” [49].

The following definition is from the Solar Reviews website: “Community solar is when multiple parties share in the power and/or financial benefits of a solar electric system” and it is worth mentioning that community solar offers a chance to gain the benefits of solar without having to install solar panels on the roof of your home [50].

The definition from reference [51] is as follows: “Shared solar can manifest in a variety of forms, but is generally an arrangement where a group of individuals (often referred to as ‘subscribers’) lease or purchase solar panels or shares (kilowatts of capacity) in a neighborhood solar power installation”.

6. How Community Solar Works?

The solar PV system in the United States has been growing drastically for the last two decades. From the period of early 2000 to 2014, solar PV installations increased from 4 MW to 6,201 MW [52]. Furthermore, the magnificent growth of solar PV installation continues. In the first half of the year 2023, the United States has reached a record capacity of solar energy for nearly 32 GW [53]. Most experts in the field of solar energy speculate that solar energy growth will continue to rise at a phenomenal rate during the coming few years [53]. The rooftop solar panels installed on houses make up the majority portion of the overall solar energy growth after the utility solar PV [52]. In the year 2000, the residential rooftop solar panels were almost nothing but by the end of the year 2014, the annual installed capacity was around 1,200 MW [52]. According to reference [53], the annual growth of installed rooftop solar panels in residential has reached approximately 7,000 MW in the first half of the year 2023.

Accompanying the incredible growth of the annual capacity installed for solar PV panels, there has been an incredible drop in the cost of the installation of residential solar PV systems [54,55]. Driven by low cost, CS will be an attractive option for groups of individuals or utilities that are interested in investing in solar panels for generating electricity. In the US, community solar is estimated to grow exponentially in the next couple of years [53].

When utilities, developers, and customers decide to establish a community solar project, they will be faced with the job of designing the paradigm of a community solar program. The first step in designing a new community solar program is to identify its objectives. Some of those objectives might include meeting renewable energy or environmental mandates, increasing customer access to clean energy, or creating economic value for subscribers or the utility [56].

Once the objectives are identified, some key decisions need to be made. One of those key decisions is defining the ownership model and the other is defining the subscription model [56]. In addition, other decisions may include availability of incentives, the processing of bill credits to determine the length of the program, and where the solar system should be sited [56].

The responsibility of each party is shown in Figure 6. Regardless of who is the owner of the system, the level of success of a community solar project is dependent on the level of subscription [56]. The two key business models regarding community solar are discussed in Sections 6.1 and 6.2.

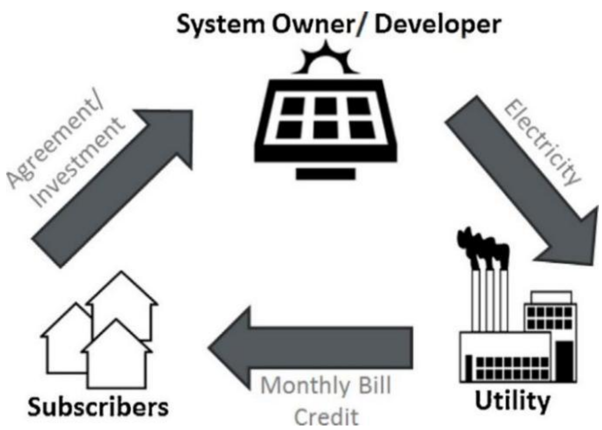

Figure 6. Community Solar Operating Model [56].

6.1. Ownership Model

There are many owner/operator models that exist for community solar programs. The community solar programs can be sponsored by the utility, a third-party developer, or a special entity. Reference [56] presents multiple models, the associated roles and responsibilities, and the relative advantages and disadvantages of each model. Based on the ownership model of the community solar, costs and benefits associated with the project will flow to different stakeholders. The financing options and tax implications for the impacted parties should be fully understood before selecting the model.

6.2. Subscription Model

The next step for the program sponsor is to develop the subscription structure for community solar, which is a critical decision. Just like the ownership model, there are a variety of methods to structure the process of subscription for the program participants in the community solar project. Panels can be bought or leased, or subscribers may be offered an option to invest in the system or buy energy or capacity. Reference [56] presents the details of these customer participation structures with the pros and cons associated with each one. In order to ensure the highest levels of subscription, the subscription structure for the community solar project should be based on customer preferences. Once the participation method is determined, the conditions of the subscription should be defined including but not limited to the length of the subscription term, the transferability of the subscription, and the capacity of the subscription.

7. Models of Community Solar Projects

The primary objectives of establishing community solar projects are to: (a) increase the overall level of solar energy deployment, and (b) broaden access to the benefits of adopting solar energy [57]. In this section, we will provide an overview of the various business models for the community solar project. In addition, we have discussed a number of the challenges that could arise when developing the community solar project. We have also presented case studies of different regions of the US that have structured and developed a successful community solar project.

There are a number of methods to structure a community solar project business model. Each one of those project business models is structured to obtain specific goals, but all those models have three key components in common, which are the system, the developer, and the subscribers. The three business models that can structure the community solar project are discussed in Sections 7.1 to 7.3.

7.1. Utility-Sponsored Model

By purchasing the output power of a community solar project, a utility could own or operate a project that is open to voluntary ratepayer participation. Under this utility-sponsored model, utility companies can help make solar power more accessible to a range of participating customers.

Under the utility-sponsored model, the utility or some identified third party will own the community solar project. The participating customers can lease the solar panels from the utility. In exchange, the participating customers receive a credit on their electric bills equivalent to the amount of electricity that is produced by their share of the solar panels in the community.

The participating customer does not have an ownership stake in the community solar project. Rather, the participating customer buys the rights to the benefits of the energy produced by the community solar project. The utility, which could own or operate the community solar project, sells the energy or the rights to the energy from specific community solar installations with or without the Renewable Energy Certificates (RECs) at a rate that is generally locked in for a period of years.

It is worth mentioning here that community solar projects under utility-sponsored model programs differ from traditional utility green power programs. In the green power programs, the program sells Renewable Energy Certificates (RECs) from different renewable energy resources and in general do not act as a hedge against rising electricity costs.

The ability of utility-sponsored model projects to utilize the tax incentives depends on each utility's characteristics. Electric cooperatives, municipal utilities, and public utility districts are exempt from federal income taxes. These entities cannot benefit from federal tax incentives, such as the Investment Tax Credit (ITC) and depreciation. On the other hand, the utility-sponsored model projects can make use of the Clean Renewable Energy Bonds (CREBs) and that is not available to a profit investor-owned project or private electric utilities.

There are some legal issues that the utility-sponsored model projects could encounter, and these issues are discussed in Sections 7.1.1 to 7.1.3.

7.1.1. Securities Compliance

At the designing stage for the customer's participation in the community solar project, the utilities have to carefully comply with the state and federal securities regulations. Thus, one has to consider what benefit or benefits could be offered to a customer in exchange for a financial contribution to the project. For instance, the customer could be offered ownership stakes in the community solar project itself or the rights to certain benefits from the energy that is produced such as credit on their electricity bills, renewable energy certificates (RECs), or access to a special electricity rate.

7.1.2. Allocation of Incentives

Besides the federal tax incentives that the utilities could not claim by building renewable projects, a utility-sponsored community solar project could be eligible for various state incentive programs that can provide cash benefits or savings on the project. This means the utilities have to consider if those incentives will be passed on to the customer participants and how the tax implications of the incentives are handled. For instance, in Washington State, participants in a utility-sponsored program are eligible for production incentives. While the state Department of Revenue has ruled that the incentive is not taxable, the Internal Revenue Service (IRS) has not ruled definitively on whether subsidies for solar PV in community solar installations are taxable income [58].

7.1.3. Renewable Energy Certificates (RECs)

For a utility-sponsored community solar project, customers wish to claim the environmental benefits of using solar energy. There are two ways for customers to claim the environmental benefits. First, customers have to receive a renewable energy certificate. Second, the utility retires the renewable energy certificate on behalf of the customers. If the utility decides to keep the renewable energy certificate, then the utility will be the only one who can make a claim to the environmental benefits related to the solar PV system. If the utility wants the customers to claim the renewable energy certificate, they should know how the renewable energy certificate would be allocated by the utility. Figure 7 [59] presents the community solar project that is structured by a utility-sponsored model as well as some existing projects in Tables 1 and 2 with some important information regarding each project.

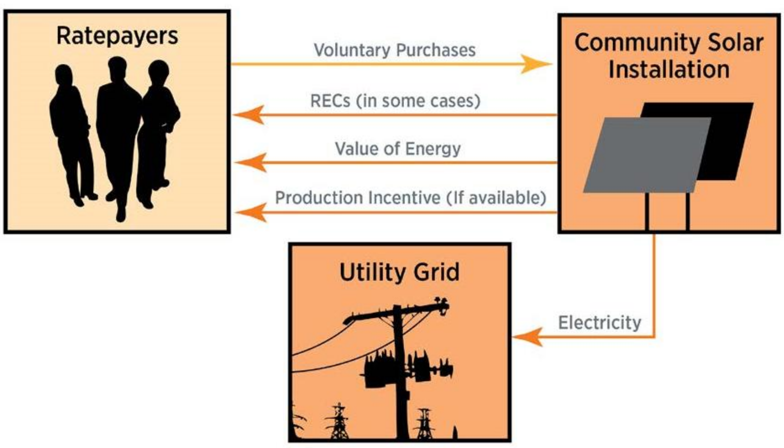

Figure 7. Utility-Sponsored business model project [59].

Table 1. The Ellensburg solar community project [60].

City of Ellensburg's Utility:	The Ellensburg Renewable Energy Park (The nation's first Community Solar Project)
Project Launched in	2006
Location	Ellensburg, WA
System Owner	City of Ellensburg Utility
Beneficiary	City of Ellensburg Utility customers who did participate in the project
Installed Capacity	165 kW
Participant Agreement	A compensation based (local ratepayers to provide financial support in exchange for compensation for each kilowatt-hour of electricity produced by the project - in the form of a credit on their utility bill, for a period of 20+ years)
Electricity	Participated customers will be powered by solar energy
Number of Participants	Information not found
RECs	Members own the rights
Capital Financing	Local customers' utility
Tax Credits	Not qualify for Production Incentive and Federal Tax Credit because it is a public utility

Table 2. The Sacramento Municipal Utility District [59].

Sacramento Municipal Utility District (SMUD)	Solar Shares Program
Project Started	2008
Location	Sacramento, CA (leased site in Wilton)
System Owner	enXco becomes EDF Renewables [61]
Beneficiary	SMUD purchasing 100% of the output under a 20-year Power purchase agreement (PPA)
Installed Capacity	1 MW
Participant Agreement	Fixed monthly fee
Electricity	kWh generated by a customer's share is netted against the customer's consumption at home
Number of Participants	600
RECs	SMUD [60]
Capital Financing	Third party, enXco (EDF Renewable) [59,60]
Tax Credits	30% federal business investment tax credit taken by enXco; depreciation taken by enXco

7.2. Special Purpose Entity (SPE) Model

Some individuals come together to establish a business enterprise to develop a community solar project. When a group of individuals chooses to develop a community solar project as a special purpose entity, they should assume the significant complexity of establishing and running a business enterprise. The group of individuals must know how to navigate the legal and financial obstacles of setting up a business, raising capital and complying with securities regulations. Furthermore, the group of individuals must negotiate contracts among the participants/owners, the site host, and the utility; set up legal and financial processes for sharing benefits; and manage business operations.

Because of the complexity of forming a business enterprise, it is not surprising that many special-purpose entities, that are pursuing a community solar project, are organized by other existing business entities that have legal and financial capabilities. Solar installation companies such as My Generation Energy in Massachusetts have successfully created limited liability companies (LLCs) to purchase solar installations funded by groups of investors. Even though this expands the market for solar, the benefits are limited to a small group of tax-motivated investors. In an alternative model, the Clean Energy Collective in Colorado has created a business structure under which participation is offered to an unlimited number of utility customers. References [62,63] have a list of companies dealing with special-purpose entities.

The federal tax benefits offer significant value for solar projects, but it can be challenging for community solar projects to use it effectively. In order to make use of the tax credits or losses from depreciation, it requires significant taxable income. In addition, passive investors, who do not take an active role in the company or its management in a community solar project, can only apply for the Investment Tax Credit (ITC) to passive income tax liability. In a community solar project, most investors will probably be passive investors and some of them will have passive income. Because of this, most individuals cannot fully use the federal tax benefits.

It is worth mentioning here that there has been a lot of interest in the possibility of structuring a community solar enterprise as a cooperative (co-op). In fact, co-ops are not exempt from the complex securities issues and project organizers have often decided to do business as LLCs. Several rural electric co-ops have started community solar programs, but these programs are peripheral as their main function is the distribution of electricity to rural customers. Figure 8 presents the community solar that is structured by a special purpose entity model as well as some existing projects in Table 3 with some important information regarding the project.

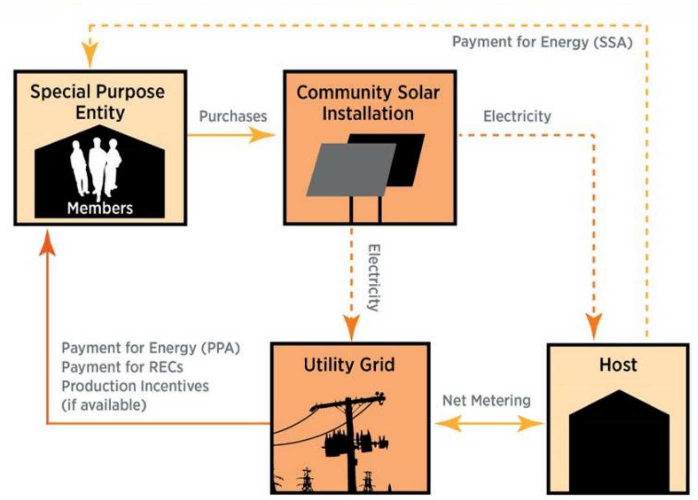

Figure 8. Special purpose entity business model project [59].

7.3. Nonprofit Model

In this case, the charitable nonprofit corporation administers a community solar project on behalf of donors or members. Nonprofit entities can engage in community solar projects in the following three ways: (i) solicit donations for the project, (ii) organize and administer a project that shares benefits with participating members, and (iii) partner with a third-party for-profit entity, which can own and install the system and take advantage of the tax benefits.

Table 3. The University Park community solar [59].

University Park Community Solar, LLC	
Project Launched in	2010
Location	On the roof of the Church of the Brethren in University Park, Maryland.
System Owner	University Park Community Solar, LLC.
Beneficiary:	The Church of the Brethren.
Installed Capacity:	22 kW
Participant Agreement:	LLC passes net revenues and tax credits to members.
Electricity:	LLC sells the solar power output to the church below retail rate.
Number of Participants:	35 LLC Members
RECs:	LLC is working to auction RECs independently.
Capital Financing:	Project was financed by member investments.
Tax Credits:	$39,000 ITC taken as the 1603 Treasury Grant in lieu of a tax credit.
Grants:	$10,000 from the state of Maryland.

Many nonprofit organizations such as schools and churches are collaborating with local citizens to develop community solar projects. Under the nonprofit model, supporters of nonprofit organizations can help fund the solar PV system through tax-deductible donations or direct investment in the project. In the investment option, the nonprofit organization is required to comply with the state and federal securities regulations. The nonprofit organization is not eligible for the federal commercial Investment Tax Credit (ITC), but it might be eligible for grants or other sources of foundation funding that would not be eligible for a business enterprise. An example of the nonprofit model is the "Solar for Sakai" project (Bainbridge Island, Washington state). In this project, a community nonprofit raised donations for a solar installation, and in return, donated the installation to a local school.

Nonprofit organizations usually are not eligible for tax incentives since they are non-taxpaying entities. However, individuals who donate to a nonprofit entity to develop a project can receive a tax benefit in the form of a tax deduction. The Internal Revenue Service allows taxpayers who itemize deductions to deduct verifiable charitable contributions made to qualified organizations. It is worth mentioning here that a tax deduction is much less in value than a tax credit. For instance, a $100 tax credit reduces taxes owed by $100 while a $100 tax deduction reduces taxes owed by $25 for a taxpayer in the 25% federal bracket.

Donors can deduct their contributions to a community solar project if the project sponsor obtains tax-exempt status as a charitable organization under the Internal Revenue Code (26 U.S.C. § 501(c)(3)). Section 501(c)(3) organizations must be organized and operated exclusively for exempt purposes such as charitable, religious, educational, or scientific purposes. Section 501(c)(3) organizations may not be operated for the benefit of private interests and are restricted in how much time they can devote to lobbying activities. The Application for Recognition of Exemption under Section 501(c) (3) is IRS Form 1023. Figure 9 presents the community solar that is structured by the nonprofit model as well as some existing projects in Tables 4 and 5 with some important information regarding each project.

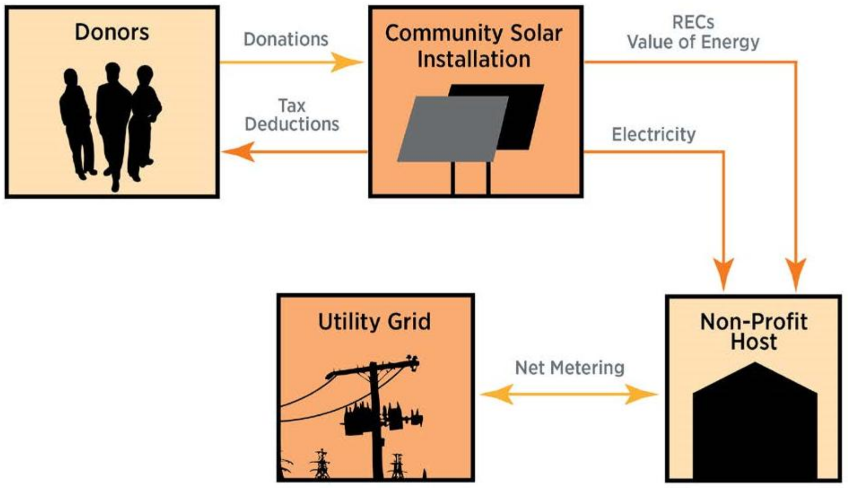

Figure 9. Nonprofit business model project [59].

Table 4. The Winthrop community solar project [59].

Winthrop Community Solar Project, Washington	
Project Launch in	2010
Location	Town of Winthrop, Washington
System Owner	Participating members of Okanogan County Electric Cooperative (OCEC)
System Administrator	Partnership for a Sustainable Methow
Installed Capacity	22.8 kW ground mounted array
Participant Agreement	Investment ranged from $500 to $15,000 and then ownership will then transfer to the project host
Electricity	Net metering benefits accrue to host, production incentive benefits accrue to owners
Number of Participants	49 investors
RECs	Remain with participating OCEC members
Capital Financing	Financed by investors
Tax Credits	None

Table 5. The Sonoji Sakai intermediate [59].

Sakai Intermediate School, Washington	
Project launch in	2009 [64]
Location	Bainbridge Island, Washington
System Owner	Sakai Intermediate School.
Beneficiary	The school.
Installed Capacity	5.1 kW.

Participant Agreement	Donors
Electricity	Net metering
Number of Participants	Donors
RECs	Accrue to the school.
Capital Financing	Through donations and grants, Grants: $25,000 from utility (Puget Sound Energy), Donations: $30,000 through Community Energy Solutions.
Tax Credits	None

8. Future Prospects

It is well established by now that solar photovoltaic energy systems with storage provide electricity with minimum CO2 emissions at affordable cost. The most important point is that the projects related to community solar are rising, but are very small in comparison with residential, commercial, and utility solar PV installations [53]. For any emerging concept or technology to be accepted and utilized by the public at large, the public policies agreement must be well established, and the technological availability and affordability must be proven.

Despite the technological availability and affordability for the solar PV panels and the potential advantages for the community solar model, there are still few countries implementing this concept with even fewer numbers of projects. The main reason is the lack of existence for the public policies agreement for deployment of community solar project. For instance, Germany has less than 1800 community solar projects comparing to over 2 million individual PV systems installed [65]. In the United States, for example, there are 1600 community solar projects by the end of 2020 [66]; and that is less than 4% of the total installed PV capacity [67].

In the United States, there was some form of community solar policy in 16 states plus the District of Columbia, which has enabled those states to construct community solar projects [68]. By the end of year 2021, the number of states that have policies that is supportive of community solar projects has increased to 22 states plus Washington, D.C. Today, community solar projects are in 39 states and the District of Columbia [47]. Figure 10 shows the states with enabling community solar policy.

Figure 10 also shows the twenty-two states that have policies that are in favor of the deployment for community solar projects along with seven states that introduced legislation which would enable or incentivize community solar projects. Figure 11 [69] shows that in the year 2021, the majority of solar PV installed capacity contribution came from the state of Florida and the state of Texas. By looking at Figure 10, it will be noticed that the two states (Florida and Texas) do not have any policy that support the deployment of community solar projects and yet these two states have vast amount of installed capacity. It appears that the government officials and the high decision making employees in the electric companies of the two states do not have to create a policy that will allow a good emerging concept to be deployed.

Despite the vast spared of the community solar projects around the United States, some electric companies think this emerging concept has number of issues. These utilities claim that community solar projects will reduce the revenues of the company since they are in the business for profit and a similar issue is about the distributed energy generation [70].

The electric utilities have also mentioned that there is difficulty for the current electricity grid to accommodate non-dispatchable resources such as community solar, because it is often deployed on the distribution grid not as a central power source. According to utility, the quantity and the timing of the electricity produced is not reliable and cannot be controlled by the grid operators [71].

Advocates for community solar are convinced that this concept is more economically efficient than the residential rooftop solar PV, because of the accessibility and affordability of the solar panels and the various models of the concept. Furthermore, they claim that by aggregating consumers on big project that will achieve economies of scale as well as attract utility providers because it can be located close to substations and distribution feeders in which it will reduce the interconnection issues mentioned previously [72].

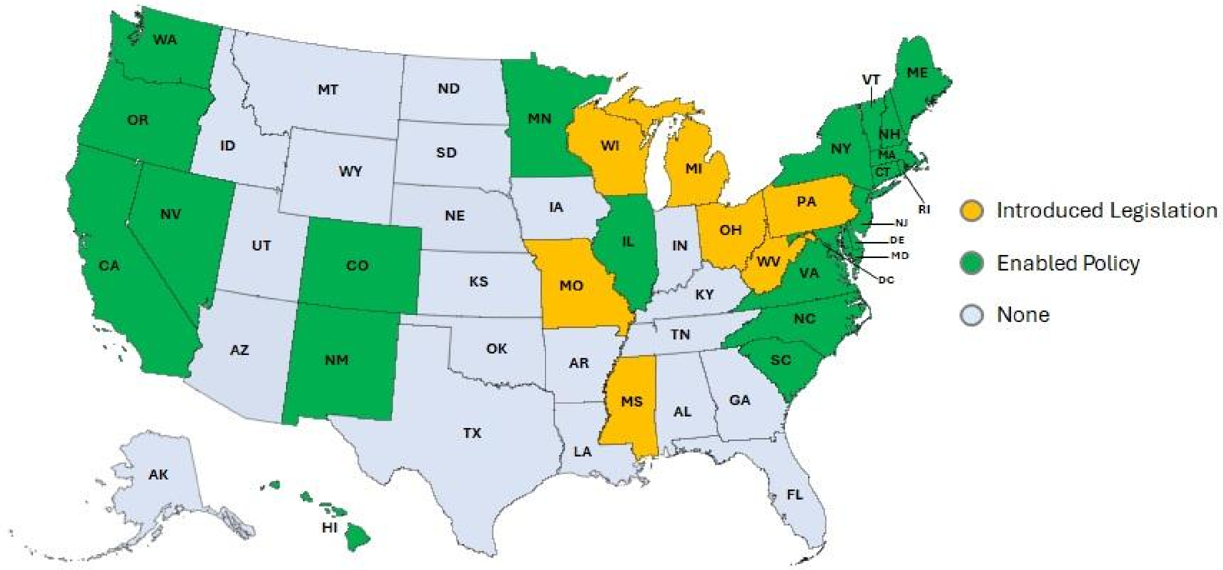

Figure 10. Active states with community solar policy (Adapted from NREL 2022) [69].

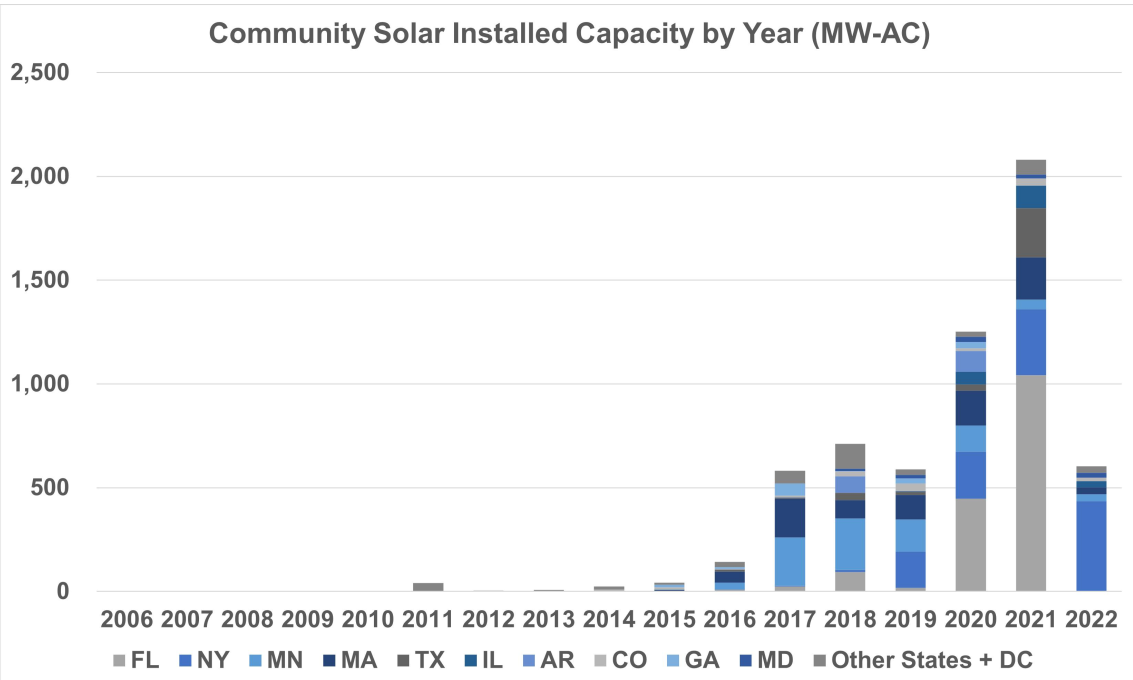

Figure 11. Annual community solar installed capacity (Adapted from NREL, 2022) [69].

9. Discussion

Most of the existing community solar projects in the states are built on a large scale and they are owned by the utility companies as mentioned in the utility-sponsored business model. The approach that the utility companies have used in these projects is either the subscription approach or the purchase approach. The prospective customer can choose between the two approaches depending on their need. A utility company that is using a subscription approach, for instance, is Duke Energy South Carolina; and the name of their program is Shared Solar [73]. Another example for a company that is using both approaches (subscription and purchase) is Dominion Energy South Carolina; and the name of their program is community solar [74].

Since the majority of these projects are owned by the utility providers that means these projects are directly connected to the grid and they are not stand-alone or micro grid projects. These projects were built on a vast piece of land outside the city, which will make it a solar farm. By taking that approach, there will be a need for building a step up power transformer station and transmission network lines; and that does not agree with what it was mentioned at the end of the previous section.

For the large-scale growth of community solar, we have proposed a new concept. In our approach, for the new construction of a sub-division, the community solar project is a group of houses in a close vicinity with solar panels on their rooftops. In addition, there can be a nearby solar farm connected to the sub-division. The solar panels will be acting as the main source of energy generation and the battery energy storage system is used for storing the excess energy. The number of houses could be a large number and if the group of houses decided, their community may have a bi-directional flow of electrical power. Without connecting to the grid, community solar can flourish. In the free world, there is no limitation in building such a system as long as the design is flexible because additional PV panels and battery systems must be added to account for the degradation of PV systems and batteries with time. Without getting utility involved, the emerging concept can provide high growth of community solar.

In place of alternating current (AC), the use of direct current (DC) power networks originally conceived by Thomas Edison could further reduce capital, equipment cost, and overall cost as compared to the corresponding AC power network. One of the authors co-authored a paper in 2014 [75] that keeps the legacy of Thomas Edison in mind; as well as co-founded a new IEEE conference on DC power in 2015 [76]. The community solar will utilize DC power and that will be the highest energy efficiency of the power system. The reason behind this concept is that the distance between the source and the load is at a minimum as shown in Figure 12 [75]; and the number of power conversion steps such as DC to AC, DC to DC, or AC to AC is at a minimum as well. Furthermore, Figure 13 [77] represents the schematic of a local DC power network, and that representation could be the applicable concept to a community solar or several buildings in the same area whether they are a corporation or industrial buildings.

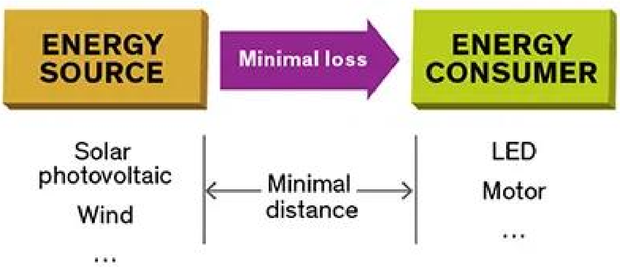

Figure 12. Local power network based on DC power system [75].

The main advantage for the author's visualization of the community solar project is the co-location. In addition to the rooftop solar, additional solar panels can be located in the vicinity to meet the power needs of the entire network. The concept is the same as co-location of solar and agriculture which is called agrivoltaics. The definition of agrivoltaics by the U.S. Department of Energy is as following "the use of the agriculture land, which contains its production such as crop or livestock, underneath solar panels or adjacent to solar panels" [78]. Based on reference [79], the concept of agivoltaic originated in 1980. Agrivoltaic is called many names and that depends on the application and region such as co-location, dual- use, agri-PV, agri-solar, solar sharing, and pollinator-friendly solar [80].

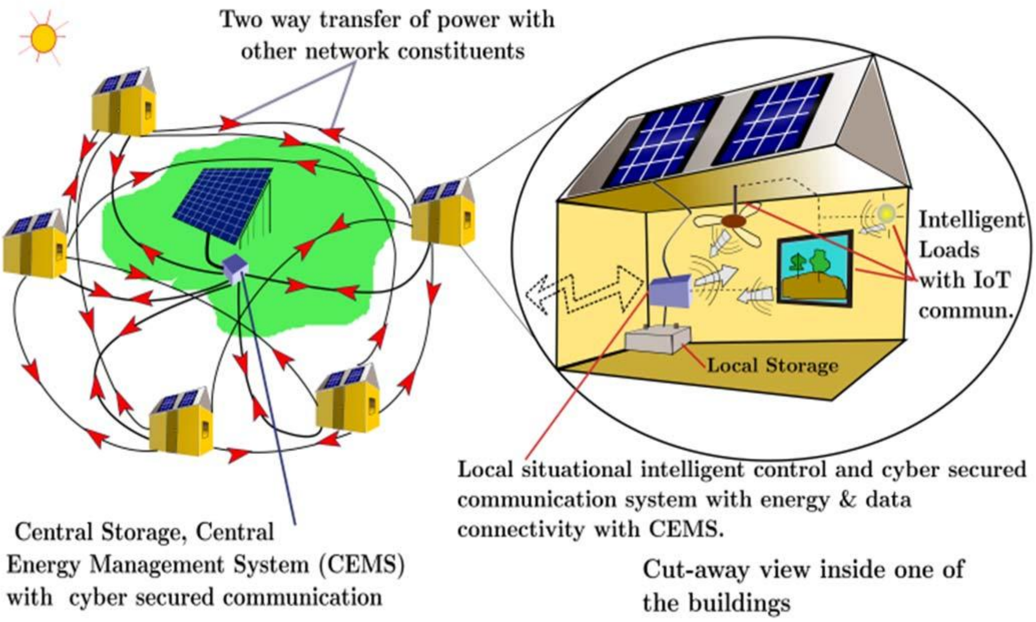

Figure 13. Local DC power network based on PV and batteries systems [77].

According to solar futures study, solar energy could supply as much as 40% of the electricity to the entire country by 2035; and it could rise to be 45% by 2050 [81]. This level of deployment for solar PV energy system will require millions of acres of land area and the U.S. has plenty of land area. Since the solar farms are built on a large scale, which requires a large land, they will not be distributed equally across the landscape; and that is because it will require a step up power transformer station and transmission lines network and those are needed to be located close to the solar farms or built from the ground up.

The solution could be combining solar and agriculture on the same land, which is agrivoltaics. Agrivoltaics is still a nascent concept as well as a new business model; and it is a research initiative by the Department of Energy (DOE) with $15 million of funding on how it could work for farmers, the solar industry, and communities [82]. The community solar is similar in concept to agrivoltaics with the exception of using the rooftop instead of using the land for the two purposes; that will provide a great advantage for community solar, which is a great saving in capital for constructing transformer stations and transmission networks and more importantly is the preservation of land for other purposes.

The current and popular model of community solar projects namely utility-sponsored model has limited scope and value, and it will continue to grow but at a slow pace because the model is connected to the grid. On the other hand, our proposed model has enormous potential if the community is off grid and that is because of the advancement in battery and photovoltaic technology as well as the internet of things (IoT) [77]. An example of solar remote grid is PG&E, California's largest utility; and the solar off grid system replaces 0.7 miles of overhead distribution line and that system can cost-effectively meet the customer needs [83]. It is worth mentioning here that PG&E has five renewable remote gird and they have been operational since 2021 [83].

Another example for off grid solar PV and battery storage project is located in many developing countries including a remote village in the Islamic Republic of Pakistan [84]. The small village of Burriro in Jacobabad district in Sindh province, Pakistan contains eight houses and three stores, along with a small medical center, school, mosque, and community center. The project is led by researchers from the Air University in Pakistan and the purpose of the project is to come up with a cost-effective approach to determine the cost of powering remote net zero energy (NZE) villages with off grid solar PV system. According to the researchers, the Sindh province is characterized by its dry and hot climate [85] and challenging socio-economic conditions, presents unique obstacles to achieving NZE villages. The standalone solar PV system generates about 30,078 kWh/year with surplus electricity generation of 4,072 kWh/year; and that will enable the remote village to be self-sufficient and independent from the grid. The payback period for the standalone renewable system is 7.2 years [84].

10. Conclusions

Conversion of abundant solar energy by photovoltaics has proven to be the lowest cost of electricity generation. Owing to its continuing decreasing price for the battery energy storage system (BESS), the solar PV panels will be more desirable to utilize by individuals or group of individuals living in residential or commercial buildings. In the United States, there are twenty-two states plus District of Columbia have policies that support the emerging concept of community solar; and that allows those community solar projects to constructed on those states. Because of the affordability and availability of the solar PV panels and the battery storage, the community solar projects are being built in states, which do not have policies that are in favor of the construction of those type of projects; and yet those states (Florida and Texas) have the majority amount of installed capacity for the community solar projects. In addition, the emerging concept of community solar with off grid power networks has great potential to utilize the solar PV technology along with the battery system technology to generate electricity locally. With the proven successful standalone projects in many countries, the concept of community solar can be established in a big scale. In addition, the concept of the direct current replacing the alternating current is to be employed. Furthermore, the community solar projects have great potential to decarbonize the electricity field as well as reducing the effect of climate change worldwide. In this comprehensive review paper, the authors have shed the light on the opportunities of having the community solar project models as standalone systems rather than the current existing model. To the best of the author's knowledge, it is the first study to discuss this approach. The proposed model is feasible due to the advancements and affordability of the PV technology as well as the BESS technology.

Author Contributions

Conceptualization, R.S. and E.A.; methodology, R.S. and E.A.; validation, R.S. and E.A.; resources, R.S. and E.A.; writing—original draft preparation, R.S. and E.A.; writing—review and editing, R.S. and E.A.; supervision, R.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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