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Rooftop Solar PV Policy Assessment of Global Best Practices and Lessons Learned for the Kingdom of Saudi Arabia

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Abstract: The growth in global electricity demand, price volatility, and global warming is diverting the attention of power producers to look for alternative green energy sources, more specifically, solar photovoltaic (SPV). Rooftop solar PV (RSPV) is a significant contributor to the successful development and deployment of SPV in any country. Therefore, developing countries such as the Kingdom of Saudi Arabia (KSA) are seeking alternative energy sources. According to climatological studies, Saudi Arabia has an average of 3230 sun hours annually, indicating significant potential for producing solar energy. The article investigated the characteristics of policies of countries that have had massive success in developing RSPV systems like China, the US, Germany, Italy, Spain, Japan, and India). Each country has its unique policies that result in many policy structures. Therefore, it is beyond the content of this report to provide a complete overview of all policies for the selected countries. Instead, information will focus on specific aspects of solar policy in each of the seven countries. As part of the RSPV policy assessment in Saudi Arabia, this study shows the key vectors of the selected countries' success in their rooftop policies' examination, and eventually, it presents a clear policy assessment of KSA's rooftop solar PV policy.

Keywords: solar PV; rooftop PV System; policies; feed-in tariffs; subsidies and incentives

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1. Introduction

Recent studies and research show that we will run out of fossil fuel resources by the end of this century. Therefore, the world is transforming toward renewable energy to fulfill the global need for power. Moreover, worldwide electricity demand is expected to increase by 2.1% annually until 2040, so the energy sector's sustainability is urgent [1]. Renewable energy emanates from natural sources that are replenished at a higher rate than consumed. As shown in Figure 1, wind energy, solar energy, tidal energy, geothermal energy, biomass energy, and hydro energy are such sources that are constantly being replenished, plentiful, and all around us [2]. On the other hand, fossil fuels, oil, and gas are nonrenewable resources that take hundreds of millions of years to form.

The issues associated with burning coal, oil, and gas are already wreaking devastation on communities, economies, and ecosystems worldwide while introducing negative environmental impacts. Different inspiring countries use different combinations of renewable resources and efficient, targeted policies to fulfill their power needs. Moreover, optimizing the renewable energy systems for efficient utilization of resources and reducing the access to energy production due to the limitation of storage units became essential to minimize the cost and exergy destruction [3,4]. That mainly depends on the amount of renewable resources each country has. For example, wind farms are an increasingly familiar sight in Australia and the UK where they significantly contribute to the national grid. Moreover,

hydroelectric power is one of the most commercially developed in China. It operates three of the world's ten giant hydroelectric power plants, where it exploits the water resource of its rivers. Likewise, sunlight is one of Saudi Arabia's most abundant and freely available energy resources. Saudi Arabia has an average of 3230 sun hours annually, indicating significant potential for providing solar energy [5]. Even though it sounds like a perfect renewable energy source, Saudi generates 52% of its electricity from natural gas, 40% from oil, and 8% from steam [6]. Therefore, one of the main goals of Saudi Vision 2030 is to reduce its dependence on conventional power generation systems and increase the share of green and renewable sources for electricity generation.

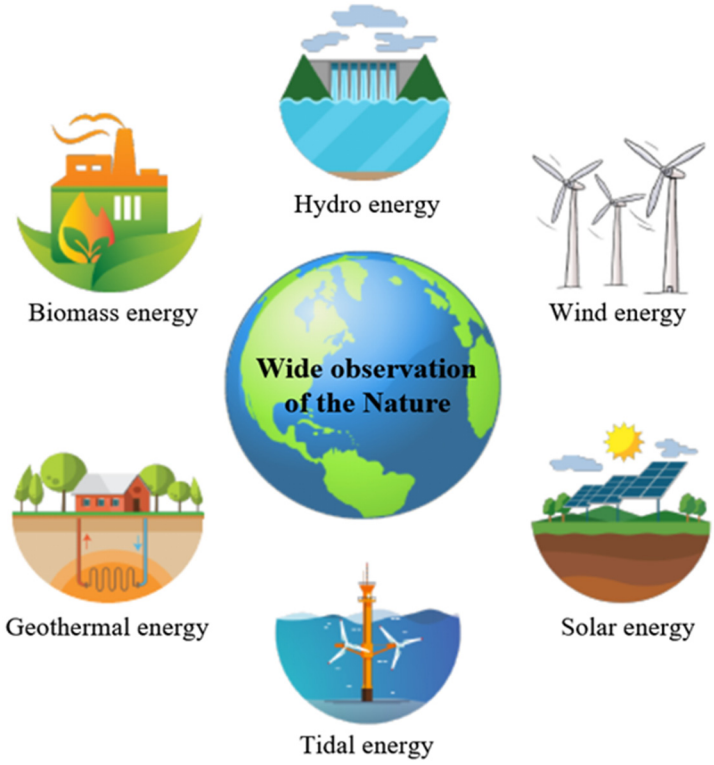


Figure 1. Renewable energy sources.

Saudi Vision 2030 is a strategic framework to minimize Saudi Arabia's dependence on oil. It points the country toward diversifying its economy, developing public service sectors, and reinforcing economic and investment activities. As oil prices have risen and solar energy prices have fallen, coupled with the environmental repercussions of global warming and carbon dioxide pollution, Saudi Arabia has strong environmental and financial motives to advance with its long-awaited solar plans. In Vision 2030, KSA has set the target to deploy 58.7 GW of renewable energy with 40 GW of solar photovoltaic, 16 GW of wind, and 2.7 GW of other renewable sources [7].

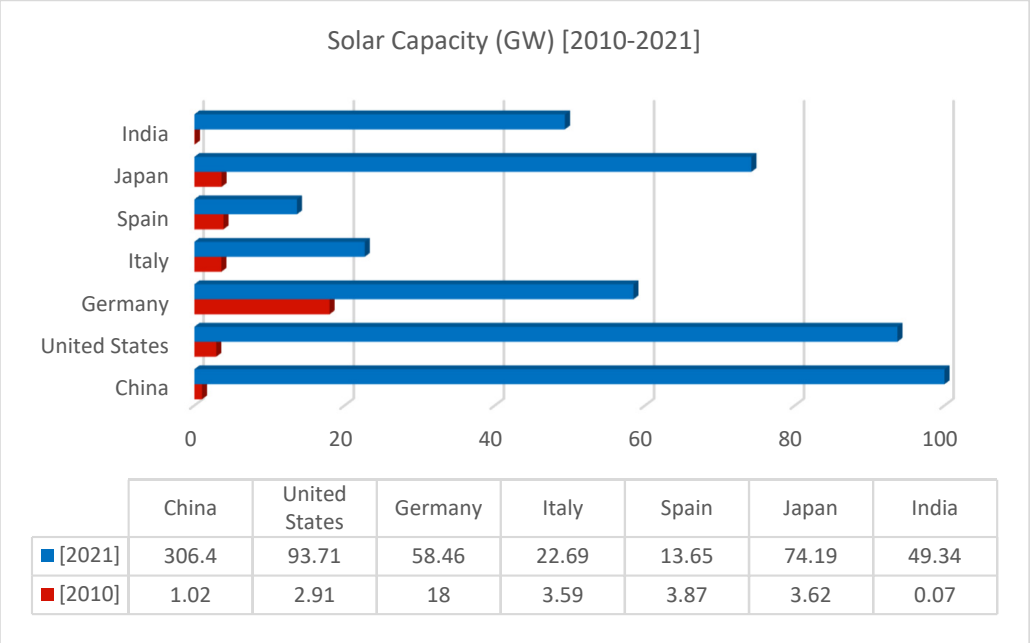
Renewable energy technologies, especially solar energy, have become significant in the world's electrical power generation. Not only that, they are the future in the move to clean energy, but solar power, for example, has obtained competitive momentum to the cost of conventional electricity generation methods. Where the sun offers much more energy than we would need to power everything on Earth, energy companies are investing heavily in solar power. Since 2021, solar energy has generated around 4% of the world's electricity [8]. In modern countries, distributed solar systems do not supply the electricity need of households in remote areas only; they are also an active alternative to serving the highly increased urban electricity demand. Some of these modern countries have become leaders in solar development, where they have set more ambitious targets toward this goal. However, some governments are dependent on generic rooftop PV assessments.

Sometimes, these assessments do not cover all business-related aspects and may have low accuracy [9,10]. If the development of such reviews does not cover all private and government sector aspects, it could harm the market and the electricity grid.

Gradual policy-making for solar energy assessment has the most significant impact on the renewable energy future, especially in developing countries such as KSA. In the past decade, the cost of the technology for implementing rooftop solar power has dropped dramatically. Leaving the driver for integrating solar power to householders is the main policy at national and international levels. First, a literature review was carried out about some modern countries' most effective government rooftop policies. Then, study cases were carried out to compare these countries' policies and practices regarding residential rooftop solar PV. The seven countries in the case study were selected from multiple continents: China, the United States, Germany, Italy, Spain, Japan, and India. Solar energy capacity, also called Rated Capacity or Rated Output, is the maximum amount of electricity the solar system can produce under ideal conditions. Data collected from international sources shows that the selected countries, as shown in Figures 2 and 3, have a good share of electricity production from solar compared to their solar capacity.

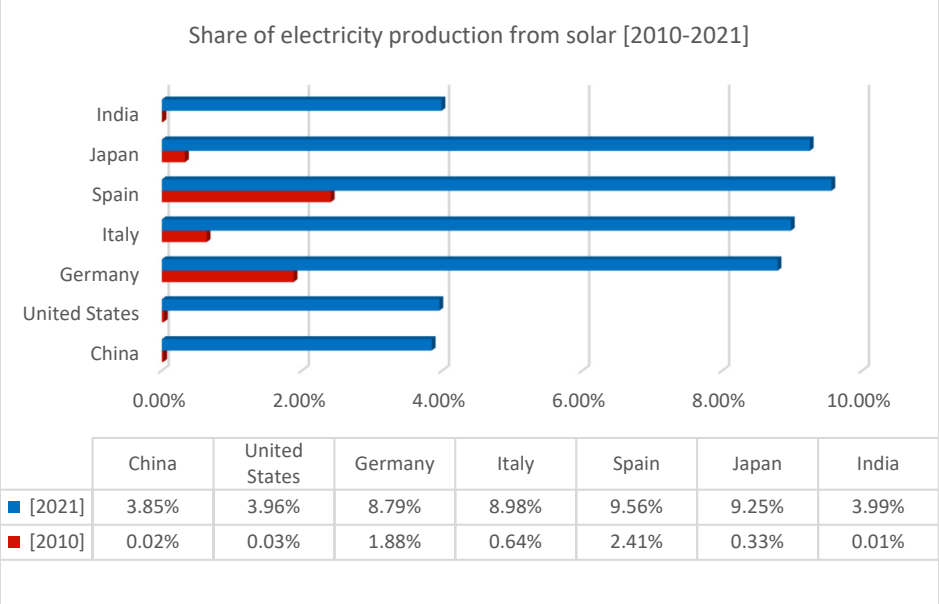
Some countries, e.g., Spain, Japan, Italy, and Germany, may perform better in terms of their electricity production from solar power than others, especially when they offer clear and encouraging policies regarding residential rooftop solar PV installations. For example, on 27 April 2021, Germany produced up to 40 GW in a region with only 1000 kWh per kWp solar potential [11]. According to the data above (Figures 2 and 3), this is more than 60% of the necessary solar capacity of 58.64 GW.

As part of the rooftop solar PV policy assessment in KSA, a detailed study will be presented for the selected countries, discussing their assessment policies for rooftop solar photovoltaic deployment, mainly the implementation in the residential sector. As for the structure of the paper, it will first present the most successful solar policies for each of the seven top countries individually and then summarize them into the ones that suit KSA the most. The goal is for solar energy to be an increasingly popular way to supplement KSA citizens' energy usage.



	China	United States	Germany	Italy	Spain	Japan	India
[2021]	306.4	93.71	58.46	22.69	13.65	74.19	49.34
[2010]	1.02	2.91	18	3.59	3.87	3.62	0.07

Figure 2. The top seven countries' Solar Capacity in (GW) for 2010–2021 [7].



	China	United States	Germany	Italy	Spain	Japan	India
[2021]	3.85%	3.96%	8.79%	8.98%	9.56%	9.25%	3.99%
[2010]	0.02%	0.03%	1.88%	0.64%	2.41%	0.33%	0.01%

Figure 3. The top seven countries' share of electricity production from solar 2010–2021 [7].

2. Solar PV Policy Assessment for the Selected Top Countries

A variety of policies help to promote the use of renewable energy sources. Policies like feed-in-tariff (FIT), low-interest loans, pricing laws, government rebates, trading systems, and others were applied to the selected countries in this study [12]. They have major objectives, such as prompting new industrial development and reducing dependency on fossil fuels [13,14]. Each country can decide which policies apply to their particular circumstances and objectives. The following section discusses the seven chosen countries and their practices regarding solar PV policies. The idea is for the Kingdom of Saudi Arabia to learn from the top countries' experiences and make the most of them to build its own helpful policy system.

2.1. The United States

Since the beginning of 2008, solar energy deployment has increased significantly in the United States and worldwide. Most of the solar power generated in the US comes from rooftops and increasingly from community solar arrays. The United States generated over 115 TWh with utility-scale solar power in 2021, meeting around 2.8% of the electricity consumption. In addition, around 49 TWh was generated from small-scale PV arrays in the same year [15]. As shown in Figure 4, the US accomplished its most significant growth with 93.713 GW of installed solar energy capacity in 2021 [16].

The United States has a variety of feed-in tariffs, which could put solar power within reach for most people in the country. It also has enough rooftop policies that fairly compensate all rooftop solar-array owners for the excess power they would sell back to the grid. Such policies encourage people who have invested or want to invest in rooftop solar panels. In addition, many states have launched Solar Roofs Initiatives programs that motivated many householders to install solar power in their homes [17].

To motivate the market transformation toward installing rooftop solar systems, the federal ITC, many states, counties, municipalities, and utilities offer many incentives for residential and commercial customers. These incentives will encourage householders to take the first step and produce renewable energy using their roofs. Generally, the set of solar incentives differs from one state to another. However, there are some common ones. Some of these incentives and their clarifications are presented next.

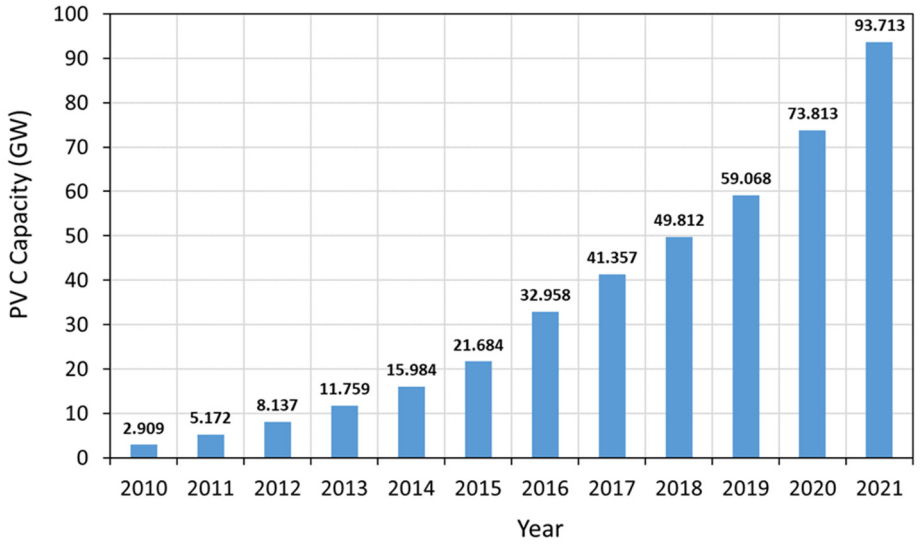


Figure 4. Cumulative Solar PV capacity growth in the US (in GW) 2010–2021.

2.1.1. Net Metering

Net metering is essential in jump-starting the PV market in the United States (US). Therefore, many US states are allowing net metering for residential and commercial customers. It enables people to generate electricity from solar power and feed the electricity they do not use back into the grid. Especially when they cannot afford storage batteries, residential customers with photovoltaic (PV) systems in their homes can reduce their electric bills by offsetting their electricity consumption with the amount of their PV systems generation [18]. Furthermore, through the net metering policy, many householders can benefit from selling the extra electricity they generate through daylight. Moreover, it can create many jobs and motivate people to invest in the country [19].

2.1.2. State Tax Credits

The investment tax credit (ITC) for residential solar systems can be claimed on federal income taxes for a portion of the cost of the solar PV system [20]. They help the investors, residential or commercial, by reducing the cost of their systems from their tax obligation. In the US, solar PV systems installed between 2020 and 2021 are eligible for a 26% solar investment tax credit (ITC) [21]. CSP systems, also known as concentrated solar thermal systems, generate solar power by using mirrors or lenses to concentrate huge amounts of sunlight into a receiver [22]. Electricity is generated when the concentrated light is converted to heat that drives a heat engine connected to an electrical power generator. Moreover, in August 2022, congress passed an extension of the investment tax credit and raised it to 30% for the installation between 2022 and 2032 [23]. Furthermore, no maximum amount for the ITC can be claimed.

2.1.3. Low-Interest Loans

Generally, solar panel technology costs have declined over the past two decades. A typical rooftop installation cost in the US can range between USD 25,000 and USD 30,000 [24]. With the governments continuing to offer many financial incentives for rooftop installations, anyone can use solar panel loans. People are qualified to finance their solar projects for little to no money out of pocket [25]. Then, they shifted what they used to pay for their electricity company to their new monthly loan payment. Local utilities or any nongovernment organization offer loans with below-market rates for solar energy projects. This service will significantly help people finance their home purchase of solar panel systems. In short, with this type of financial support, solar panel systems do not have to cost tens of thousands of dollars. Moreover, residents can save up and offer such plans for many years. Anyone can start within a few days and move quickly toward building their rooftop solar system.

Figure 5 presents different bank loan options for solar panel system installation in the US [26]. The annual payment depends on the duration of the payment, where the owner can pay more and finish his payment early, or he can pay the same low amount during the maximum duration. The loan plan also includes maintenance after ten years of installation. Different bank loan options are making solar energy accessible to even more people.

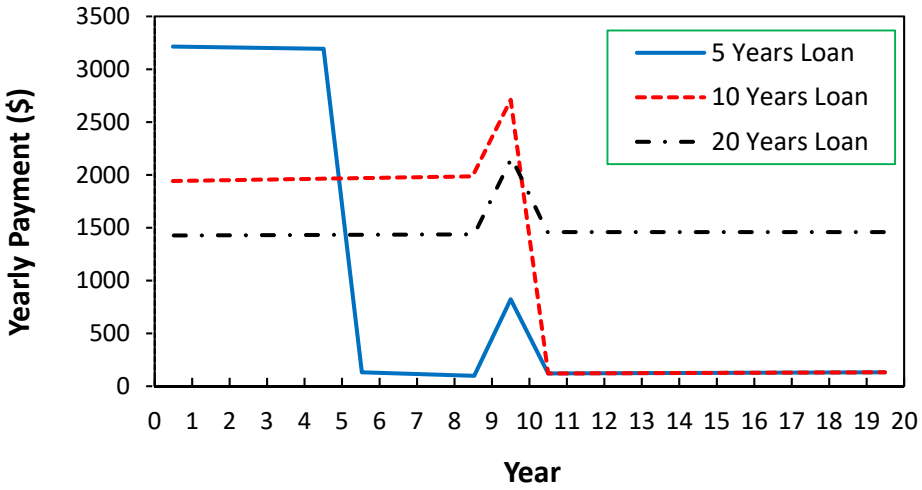


Figure 5. Different financing options for solar systems in the US.

2.2. Italy

Italy is considered one of the top countries in solar power generation capacity. Since the beginning of this century, Italy has been one of the top countries, with Germany and Spain, to have an exceptional growth of solar panel installations. As shown in Figure 6, Italy accomplished its most significant growth with 22.7 GW of installed solar energy capacity in 2021, giving it a leading position in solar generation for the time being [16,27,28].

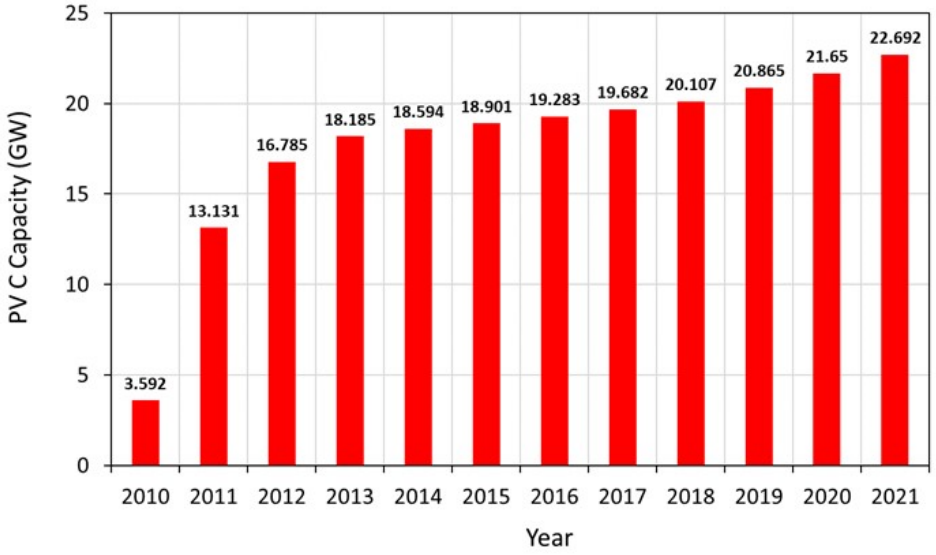


Figure 6. Cumulative Solar PV capacity growth in Italy (in GW) 2010–2021.

Furthermore, as a national goal, Italy set a target of 50 GW to reach by the year 2030 [29]. The government's different support plans for solar PV projects helped achieve 1.6% made of solar energy out of the total 18.2% of renewable energy sources in 2015 [30]. While promoting solar power actively, Italy's incentive policies had a significant role in Italy's accomplishment in solar energy generation. It has implemented various policy actions to encourage investment in solar electricity generation.

2.2.1. Italian Green Certificates

The Italian energy service provider is responsible for implementing renewable electricity incentive programs [31]. It qualifies, issues, and trades green certificates in Italy. In general, this mechanism was implemented by the Italian government to encourage electricity generation from renewable sources. The legislation forces all participants to provide a specific percentage of renewable electricity into the grid [32]. For the electricity generators to comply with their obligation, they can either generate and supply that percentage of renewable electricity into the grid or purchase green certificates from renewable power producers. Green certificates are tradable with the Italian energy service provider and grants to eligible renewable-energy power plants [33]. By demanding that a specific amount of electricity be generated from renewable sources, the quota system was developed to promote the demand for renewable power, where one green certificate is issued for each unit of solar electricity produced. Typically, each unit is measured in megawatt hours (MWh). The certificates are also subject to multipliers ranging from 0.8 to 1.8 [34]. However, this program can be replaced with feed-in tariffs and incentive mechanisms.

2.2.2. Feed-In Tariffs (Conto Energia)

The Italian government first presented feed-in tariffs (FIT) for PVs connected to the grid in 2005, called the Conto Energia scheme [35]. The program was designed to replace the power green certificate. The payments for photovoltaic projects were intended to be made over 20 years per the schemes to incentivize smaller scale and larger scale generators to invest in installing PV plants and systems. This scheme still describes the current version of Italy's solar PV policy. Moreover, by ministerial decree, the method was modified many times with differing terms and conditions and tariffs for the producers between 2005 and 2013 [36]. The current version of Conto Energia presented an average incentive cut of 43% for ground-mounted installations and 39% for rooftop systems [37], encouraging smaller and larger producers to invest in installing photovoltaic plants and systems.

2.3. Spain

Spain is considered one of the first countries to deploy large-scale solar photovoltaic systems. It is also the world's leader in concentrated solar power (CSP) production [38]. Spain's market has strong fundamentals that have made it one of the most attractive markets in the world for renewable energy power purchase agreements (PPAs) [39]. With around 3000 h of sunshine annually, Spain is one of the top European countries in photovoltaic power potential due to these high annual hours of sunshine [28]. As shown in Figure 7, Spain has accomplished its most significant growth with 13.648 GW of installed solar energy capacity in 2021 [16].

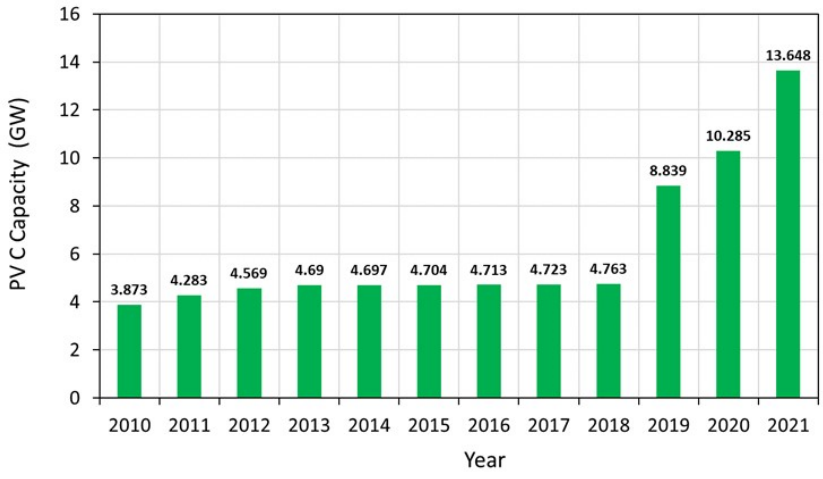


Figure 7. Cumulative Solar PV capacity growth in Spain (in GW) 2010–2021.

Spain seeks to double its share of renewable energy, in general, to 74% of power generation by 2030. The country is leading in developing solar power systems, offering great prices for grid-connected solar power to encourage the power industry [40]. In Spain, support for renewable energy technologies has a variety of policies that motivate solar electricity generation through solar rooftop system installation [41]. Renewable electricity tariffs, grid access, and market premium options exemplify how Spain created good solar policies.

2.3.1. The Technical Building Code (TBC)

In March 2006, the Spanish government implemented a regulatory instrument of national jurisdiction delivered by the Royal Decree 314/2006 [42]. It is referred to as the technical building code (TBC). The regulatory instrument was designed to regulate the essential quality requirements of new buildings and their respective installations concerning thermal and photovoltaic solar energy [43]. It includes an obligation from the new constructions to cover 30–70% of their domestic hot water consumption using solar energy. The code also applies to any modifications made to existing constructions to guarantee and promote the use of renewable energy sources. The Spanish Technical Building Code stands as a model for all energy policymakers all over Europe.

2.3.2. Feed-In Tariffs

Tariffs that are paid by renewable electricity in Spain are defined in Royal Decrees. According to the Real Decreto 436/2004, a representation of FITs for electricity generated from PV systems in Spain is shown in Table 1 [44].

Table 1. FITs for generated electricity from PV systems in Spain.

Type of PV Systems Installation	FIT (€/kWh)
First 25 years, Rated power ≤100 kWp	575% of RAT
First 25 years, Rated power >100 kWp	460% of RAT
Following years, Rated power ≤100 kWp	300% of RAT
Following years, Rated power over 100 kWp	240% of RAT

The new regulatory framework, established in the Royal Decree 1578/2008, also implies some changes. The main difference is reducing the Fits' value to 30% with better values for PV installation in roofs and facades [44]. In addition, an important step has been taken to adjust electricity rates to reflect the all-in cost of electricity in terms of generation, transmission, and distribution. As a result of selling, many rooftop solar PV installers continue to benefit by paying rates that are less than all-in electricity costs.

2.4. India

Solar power in India is a fast-developing industry. In October 2022, India's solar energy capacity exceeded 60 GW, which makes the country's solar power generation rank fourth globally [45]. In the middle of the last decade, solar products have significantly helped to meet rural needs in India. The government provided solar lanterns, solar home lighting systems, and solar street lighting installations as part of a national program [46]. By 2021, India was able to accomplish significant growth with 49.34 GW of installed solar energy capacity, as shown in Figure 8 [16].

As seen in Table 2, whether residential or commercial, the second most significant portion of the installed capacity was rooftop solar [46].

The following points discuss how India reached this fast-track development in terms of rooftop solar power deployment.

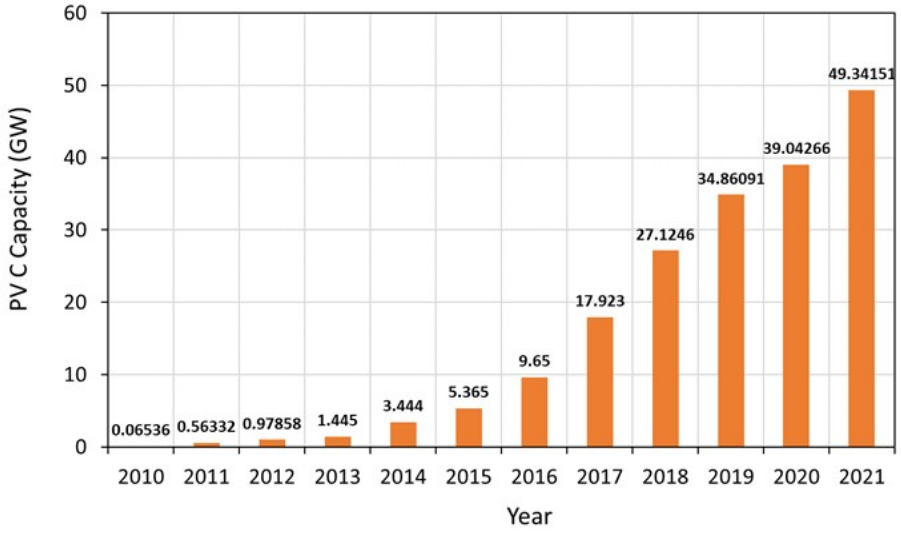


Figure 8. Cumulative Solar PV capacity growth in India (in GW) 2010–2021.

Table 2. PV installed capacity by application in India (MW).

Application	January 2022
Ground mounted solar power	42,430.57 GW
Rooftop Solar power	6405.55 GW
Off-grid solar power	1467.44 GW
Total	50,303.56 GW

2.4.1. Reducing the Import Duty on Solar Panels

The Indian government has allocated hundreds of millions of dollars to the National Solar Mission and a clean-energy fund. This budget encouraged all private solar companies to reduce the import duty on solar panels by a significant amount. It also resulted in reducing the cost of rooftop solar panel installation.

2.4.2. Low Solar Tariffs

A solar tariff is the cost at which we purchase electricity from the owner of a solar power system. The price is agreed upon for a fixed period per the agreement clause. In addition, the agreement clause isolates the purchaser from any tariff hike in the short term. As a result, India's solar power tariffs have reached a historic low record. India has accomplished two new record low solar power tariffs in less than five months.

There are some key factors behind these records in India:

- The assurance of power purchase for the developers. That is the signed agreement between the seller of the solar power and the buying entity.
- More access to low-cost financing. That is a cheaper interest rate for international developers.
- A better chance for customers to install bifacial modules and single-axis trackers.
- Expect a fall in module prices due to an expected surge in production.

2.5. Germany

Historically, Germany was among the first countries to deploy large-scale solar power. Along with Japan, Germany was the first to reach greater than 1 GW of cumulative installed PV capacity. In 2014, around 1.5 million PV power systems were installed in Germany, ranging from small rooftop solar systems to large grid-scale solar stations [47]. Now, it has one of the world's most significant shares of total solar capacities. As shown in Figure 9, Germany accomplished significant growth with 58.46 GW of installed solar energy capacity,

making it one of the top modern countries in the share of electricity production from solar in the world [16].

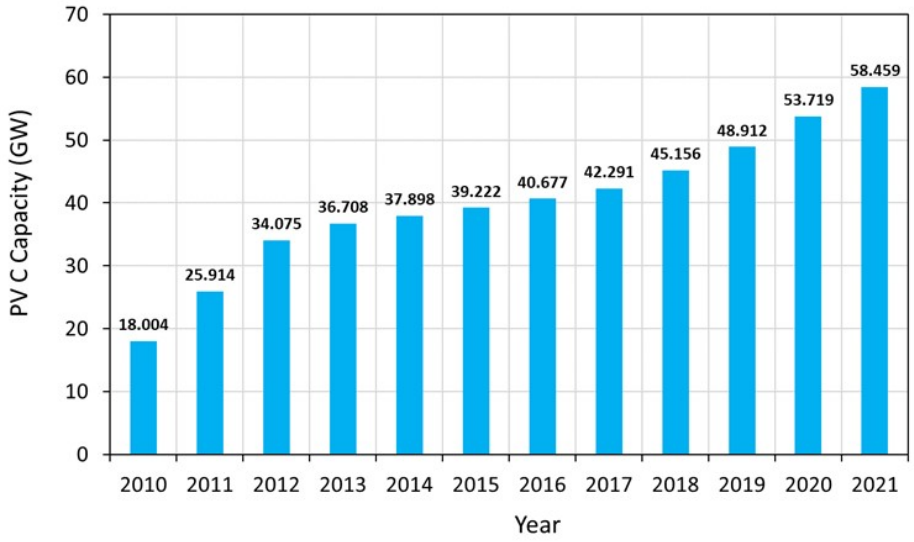


Figure 9. Cumulative Solar PV capacity growth in Germany (in GW) 2010–2021.

Most of this outstanding success in solar power in Germany had to do with innovative support from the government. It has been mainly accomplished by the country's feed-in tariffs for renewable energy. A feed-in tariff is a policy tool encouraging investment in renewable energy sources. It means, in our case, promising small-scale solar energy producers with a price above the market for the amount of electricity they provide to the grid.

Feed-In Electricity Tariffs

FIT was introduced in Germany to promote the use of solar photovoltaics. Feed-in tariffs in Germany range from 12.88 €/kWh to 17.3 €/kWh for small rooftop systems [48]. With this policy, Germany aims to meet the goal of 55% to 60% electricity consumption from renewable energy in 2035. The policy also targets the development of renewable technologies and achieving the security of energy supply.

2.6. China

China has had significant economic growth rates for the past few decades, which has had enormous implications for energy consumption [49]. As a result, China had environmental impact issues associated with energy consumption, such as carbon emissions. It is ranked the world's second-largest producer of carbon emissions [50,51]. However, with the rapid rise of fuel prices, solar energy production is accelerating in China, which brings excellent environmental and economic benefits. China is considered the largest market in the world for photovoltaic energy. The industry of China's photovoltaics started by making panels for satellites. Then, it transitioned to manufacturing domestic panels in the late nineties [52]. Hundreds of factories have produced millions of photovoltaic systems over the last five years [53].

The central government of China has developed solar energy policies that operate throughout the nation. With significant government incentives introduced in 2011, China's solar power market grew dramatically. Eventually, surpassing Germany, it became the world's leading producer of photovoltaic energy in 2015 [54,55]. Moreover, China was the first country to have over 100 GW of total installed photovoltaic capacity in 2017 [56]. As seen in Figure 10, only in 2021, China's installed solar energy capacity growth reached more than 306 GW, which is over 30% of the world's total installed photovoltaic capacity (940 GW) [16,57].

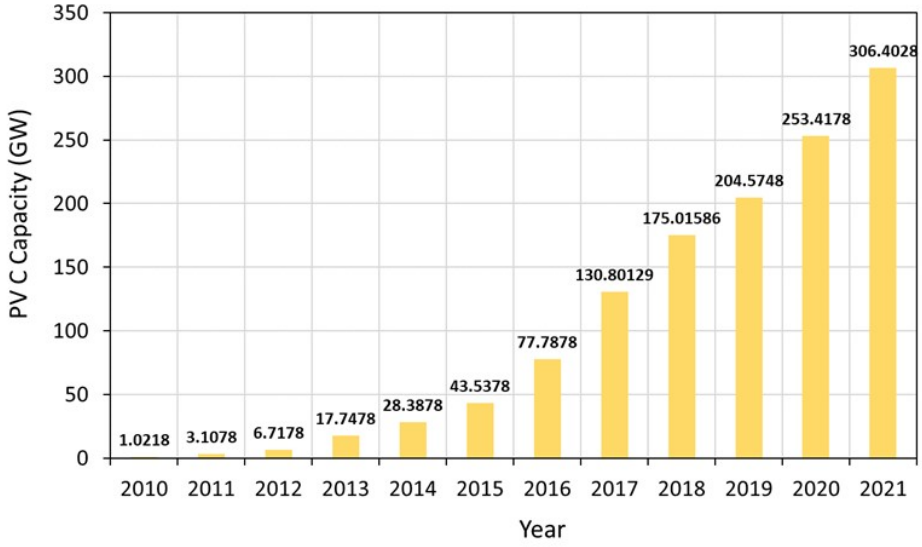


Figure 10. Cumulative Solar PV capacity growth in China (in GW) 2010–2021.

China has this high potential due to the special consideration of solar power, where they effectively reduced the cost of PV power generation and other factors.

Renewable Energy Law (REL)

The National People's Congress initiated the Renewable Energy Law (REL) in 2005 [58]. The law represented a new phase of China's renewable energy development program. Since its introduction, several supporting standards and regulations have been added and executed to the REL program. In addition, the National Development and Reform Committee issued guidelines for using public funds for renewable energy development. These guidelines have three main priorities.

- First is the support for renewable electricity generation (including solar energy).
- The second is supporting research on energy sources and the ability to replace oil.
- Third is the support for using renewable energy (including solar energy) in buildings' heating and cooling systems.

The National Development and Reform Committee decided that public funds could be used in two forms. First, funds could be issued to recipients as a grant where they use the funds for renewable energy research and development. Second, it could finance loan interest (including solar system installation). Moreover, solar power projects can obtain public funds to pay a portion of their loan interest [59]. These funds would help the installer of rooftop solar systems in the regions of China where there is a lack of infrastructure to transfer energy toward the primary power grid due to low electricity demand.

2.7. Japan

Since the late 1990s, solar power has been expanding rapidly in Japan. Japan is now a major manufacturer and exporter of photovoltaic (PV) systems. It is also a large installer of rooftop solar PV systems connected to the grid [60]. The country shifted its policies toward renewable energy in 2011 after the Fukushima Daiichi nuclear disaster, and solar power became an important national priority [61,62]. Japan's cumulative solar capacity reached 50 GW by the end of 2017, which made it the world's second-largest solar PV installer after China [63]. Moreover, Japan's growth of installed solar energy capacity kept increasing, and in 2021, it reached 74.191 GW, as seen in Figure 11 [16].

With that capacity, solar energy was estimated to supply nearly 5% of the nation's annual electricity demand in 2016 [64]. Figure 12 shows how the participation of solar energy in providing national electricity demand kept enhancing year after year until it reached 7.6% by the end of 2019 [28,65–73].

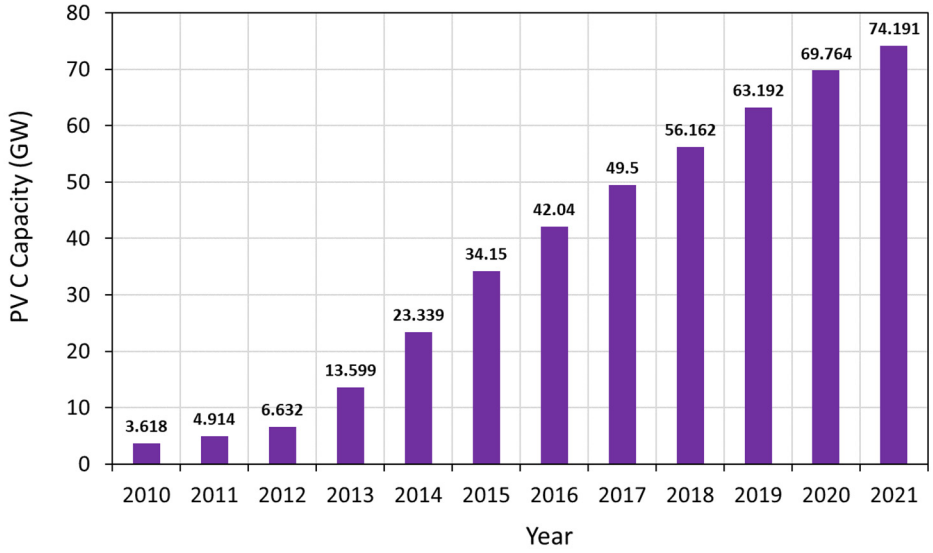


Figure 11. Cumulative Solar PV capacity growth in Japan (in GW) 2010–2021.

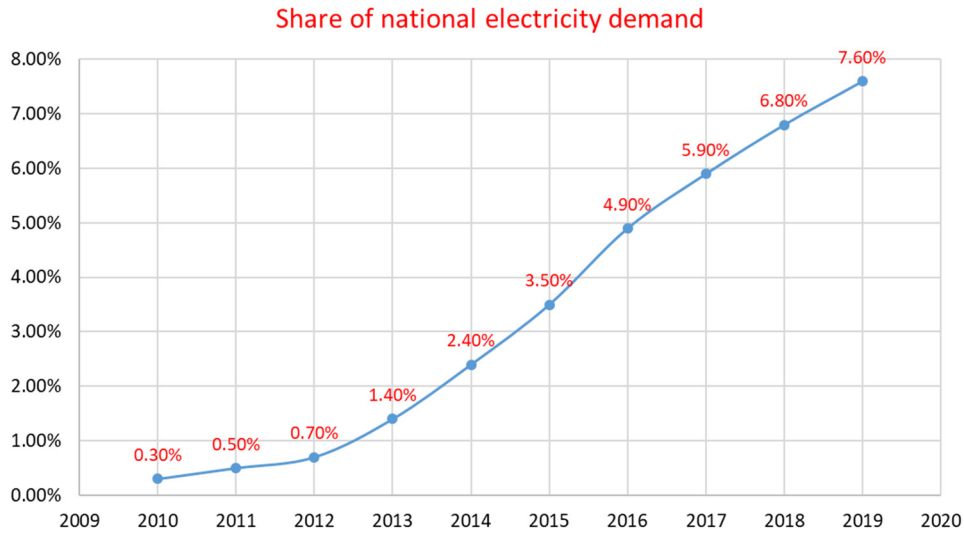


Figure 12. Japan's solar energy shares in providing national electricity demand 2010–2019.

As part of its effort to support renewable energy usage, Japan has issued a new policy that forces the transformation toward solar energy.

Mandatory Rooftop Solar Panels

Introduced policies for the purchasing period and installation prices have helped promote solar photovoltaic installation capacities. Feed-in electricity tariffs are one of the most attractive policies. However, the Tokyo Metropolitan Government is moving toward a new policy to fulfill the huge energy demand required to power up the metropolis of over 14 million people. Starting in April 2025, Tokyo plans to make installing rooftop solar panels on new homes and buildings mandatory [74]. Therefore, the metropolis pushes its citizens and corporations to shift to renewable energy. The metropolitan assembly approved the plan, which is considered a part of the capital's efforts to lower carbon dioxide emissions by 2030 [75]. Thousands of new homes are being built in the capital per year, and this move gives restrictions to them in harvesting solar energy.

3. Rooftop Solar PV Policies in Saudi Arabia

The Kingdom of Saudi Arabia is one of the largest oil consumption countries. Therefore, the residents' electrical energy consumption is very high, and the demand is still increasing. However, over 50% of Saudi Arabia's electricity comes from oil burning [76]. That is why solar power in Saudi Arabia has become more important as oil prices have increased. In addition, the Kingdom is considered a strategic geographical location as it is located on the sunbelt. That means it is exposed to the sun's direct irradiation with an average of 2200 kWh/m^2 annually [77]. This radiation exposure is considered one of the world's highest values, almost twice the average in most European countries. However, as we can see from Figures 13 and 14, The Kingdom's share of electricity production from solar is less than 1% and is considerably low compared to its photovoltaic power potential [16,78].

KA.CARE, the Saudi agency for developing the renewable energy sector, stated that the country could install 54 GW of solar energy by 2032. Out of this so far, 16 GW have been completed or nearly completed. Earlier, it was projected that by 2020 24 GW of solar power plants would be commissioned, but this target was never reached [79].

The Kingdom of Saudi Arabia (KSA) has enough potential solar capacity to meet its total power consumption needs without using fossil fuels [80]. Moreover, given that the cost of solar technologies has recently decreased dramatically, the Saudi government should raise its ambitions. That being said, the influential factor that is the critical driver for getting solar systems into householders' roofs is policy assessment and correct policy-making at the residential level. They are the key to incentivizing private and public sector solar projects. Energy policy-making is the strategy through which governments decide how to address energy development issues [81]. That also includes energy production, distribution, and consumption. Therefore, advanced and correct policy-making significantly affects Saudi solar energy's future.

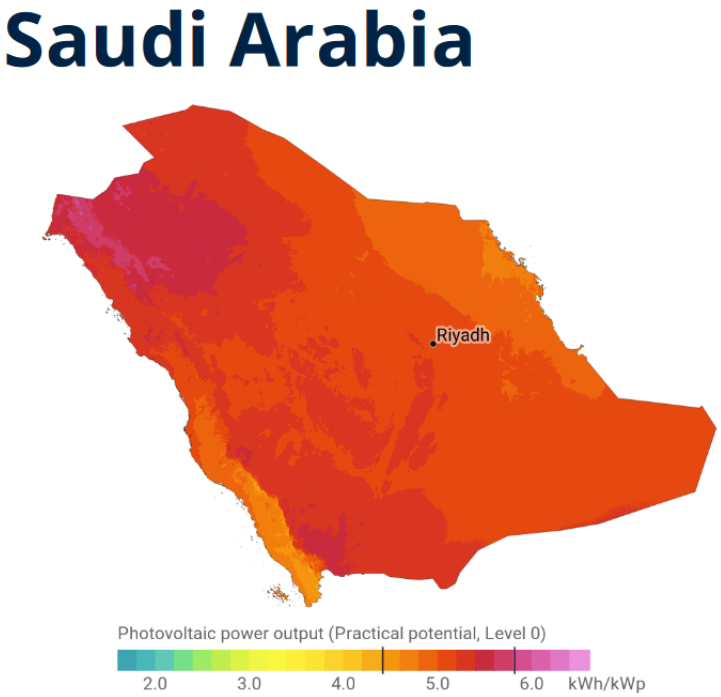


Figure 13. Photovoltaic power potential in KSA (4.5–5.9 kWh/kWp).

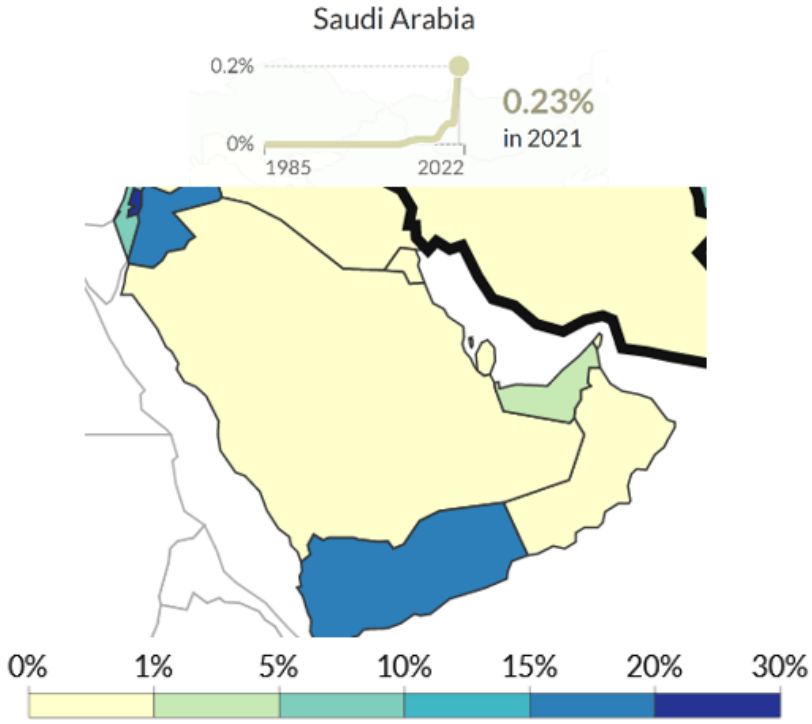


Figure 14. Share of electricity production from solar in KSA is less than 1%.

4. Suggestions and Recommendations to KSA Rooftop Solar PV Policies

Based on the case studies we conducted in this paper, we have collected what we consider to be the most effective and practical government policies to enable rooftop solar system installation in Saudi Arabia. This study found that those countries mainly rely upon common policies, such as net metering, instruments like feed-in tariffs (FIT), green certificates, investment tax credits (ITC), market premiums, low-interest bank loans, and national renewable energy targets [82,83]. Table 3 shows the summary of solar energy policies for those countries. They were all used to develop solar energy in the selected top countries worldwide. As seen in Figure 15, they resulted in a significant share of solar electricity production by 2021 [16].

Table 3. Summary of solar energy policies for the seven top countries.

Country	Net Metering	Residential Feed-In Tariffs (FIT)	Renewable Energy Certificates (RECs)	Investment Tax Credits (ITC)	Low-Interest Bank Loans	National Renewable Energy Targets
China	YES	YES	YES	NO	NO	YES
United States	YES	YES	YES	YES	YES	YES
Germany	YES	YES	YES	NO	YES	YES
Italy	YES	YES	YES	YES	YES	YES
Spain	YES	YES	YES	NO	YES	YES
Japan	NO	NO	YES	YES	NO	YES
India	YES	NO	YES	YES	YES	YES

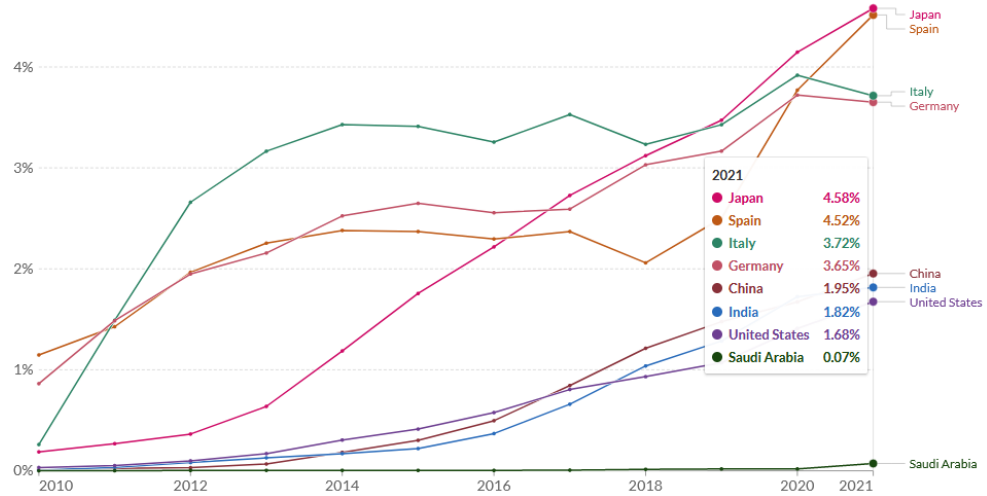


Figure 15. Share of electricity production from solar.

The following subsections will provide an overview of the four primary types of solar rooftop photovoltaic policies that will be useful for expanding and developing residential and commercial rooftop solar systems in KSA. Moreover, they will help the Kingdom to overcome the environmental and economic challenges associated with the power industry.

4.1. Feed-In Tariff (FIT)

A feed-in tariff is an incentive strategy for renewable electricity that generally satisfies two main objectives. First, it ensures that electricity produced by renewable energy systems will be purchased and have access to the electrical grid (the "feed-in" part of the FiT). Second, it provides a long-term price guarantee for the electricity produced by the renewable project (the "tariff" element of the FiT), typically for 15–30 years or even for the whole duration of the project. This long-term price is because the tariff, or rate, paid for renewable electricity is generally set higher than the prevailing wholesale electric power price. Therefore, FiT incentives eliminate the two highest investment risks. Those are the purchase risk and the price risk. Consequently, the FiT mechanism can produce an attractive investment option for electricity generators that would encourage developing and installing renewable power generation capacity.

Country-specific FiT incentive plans differ where there are many ways to cover their expenses. For example, some nations use a surcharge on consumer electricity bills to allocate FiT costs to specific electricity ratepayers. Other countries commit national government budget resources to guarantee FiT payments to power system operators.

Saudi Arabia can start by guaranteeing FiT compensation from the national government budget as a strong motivation for rooftop solar installation. They can also include some design conditions. For example, they set the minimum and maximum solar electricity capacity that the FiT can support. Also, with time, they can apply a periodic reduction of the FiT based on defined criteria. Furthermore, FiT incentives must be reviewed regularly to make rate modifications considering technological advancements, electric power, and the capital markets.

4.2. Government Solar Energy Incentives

Aside from the issues of climate change and fluctuating utility costs and the fact that people need to live sustainably, solar energy is proven to be financially rewarding. Saudi government can use that to incentivize the installation of rooftop solar power in the residential sector. There are many programs the Saudi government can bring in, such as rebates, tax credits, enabling net energy metering, and utility subsidies for solar PV system installation. The following are some examples of government incentives.

The Solar Investment Tax Credit (ITC): This is a government incentive offering a considerable portion of the tax credit percentage. When people or companies file their taxes, the government provides a cashback on the annual taxes, usually computed as a percentage of the overall cost. Moreover, when the utility company offers subsidies to installers of rooftop solar PV systems, they can be excluded from income taxes. Therefore, the utility rebate for installing rooftop solar systems is subtracted from the system costs before calculating the tax credit.

Enable the Net Energy Metering (NEM): It allows residential and commercial customers with rooftop solar systems to generate electricity to sell the unutilized electricity they are not using back to the utility company. Therefore, the utility company can credit rooftop solar PV users for all excess solar energy sent to the utility system. This system guarantees that no electricity is wasted and that ordinary householders that generate extra solar power can sell it and compensate for their investment. As a result, this clean, reliable, and renewable energy takes the pressure off the grid and protects the environment. Not to mention it saves the householders tons of money and raises the value of their house. People can stop paying their monthly bills for good, save money in the long term, and use these government incentives to install residential and commercial solar panels.

4.3. Finance Rooftop Solar Energy System

As more Saudis start looking into and exploring installing rooftop solar panels and converting their homes to use solar power, the majority will be thinking about the cost. In the US, modern residential solar installation costs range from USD 15,000 to USD 35,000, depending on the characteristics of the building, the roof size and shape, where the house is located, and how much power the system should produce. So, for the government to deploy the idea of transforming to solar power, the government, through national banks, may offer some loans or lease the solar system to residents who do not have enough money to buy a new system upfront. Banks, credit unions, or solar installers can offer multiple loan options, including zero-down financing. The following are some solar financing options that these facilities can offer:

Personal loans: The good thing about personal loans is that they offer fixed interest rates and monthly payments; therefore, a person will always know how much he pays. Householders should be able to get a long-term loan in order to pay off the cost of their solar system installation over many years. However, there is also the option of short-term loans. Short-term loans shall allow the use of government credits immediately instead of waiting until the borrower files his taxes. In fact, the borrower can combine this short-term loan with a long-term loan to cover the overall cost of installation.

Residential mortgage loan: It is any loan primarily for personal, family, or household use. It is tied by a mortgage, deed of trust, or another comparable security interest on a house or any property on which the owner plans to construct a house. The Saudi government should allow loans that can be secured on any property, allowing everyone to pay their loan back throughout the loan period. Moreover, if anyone intends to sell their house, the loan will be transferred to the new buyer. Residential mortgage loans work like personal loans, with monthly payments, but they allow people to borrow against their homes.

4.4. Mandate Rooftop Solar Systems on New Homes

Nowadays, most people know the benefits of solar power. They know how cheap, clean, and limitless it is. However, despite its obvious benefits, most of Saudi Arabia's rooftops still do not have any solar panels, even when homeowners can afford to equip their houses with solar rooftop systems.

To promote rooftop solar power in Saudi Arabia in both commercial and public buildings and new residential buildings, the Saudi government may need to pass a new regulation that states that all new public and residential buildings in Saudi Arabia must install solar power panels. In addition, all new buildings must include energy-saving

measures, such as solar PV, and be relatively self-sufficient. Furthermore, the government should attend to new buildings' energy performance ratings by introducing clear regulations. Therefore, it should be against the law to rent or sell a property without passing these ratings. So, all new buildings must pass these ratings. As a result, Saudi Arabia would reduce greenhouse gas emissions by an enormous amount by 2030 and establish sustainable living by building new homes.

5. Conclusions and Policy Implications

This study paper shows that top countries that utilize solar energy for power generation have policies specific to solar energy. Furthermore, the findings of this paper spotlight the critical factors for the success of China, the United States, Germany, Italy, Spain, Japan, and India regarding solar energy utilization, including rooftop solar power. It was found that clear solar energy policies for rooftops were a significant reason for the solar power generation increase. Eventually, these policies usually include feed-in tariffs, formation incentives, reducing import duties, and others. Saudi Arabia's involvement with solar power generation is still relatively new. Therefore, adding the experiences it gets from rooftop solar energy policies of the top countries would greatly assist the Saudi goals in this regard. Energy policy assessments intensely focus on the effects of negative externalities that nonrenewable energy sources can cause on the environment, human health, and countries' economic development and growth.

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