Global Perspectives on Rooftop Solar Energy

A Deep Dive on How Leading Economies Advance Rooftop Solar Energy Adoption

Bhawna Tyagi, Debanjan Bagui, Arohi Patil, Kumaresh Ramesh, Aryadipta Jena, and Megha Chaudhary

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About CEEW

The Council on Energy, Environment and Water (CEEW) is one of Asia's leading not-for-profit policy research institutions and among the world's top climate think tanks. The Council uses **data, integrated analysis, and strategic outreach to explain — and change — the use, reuse, and misuse of resources.** The Council addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high-quality research, develops partnerships with public and private institutions, and engages with the wider public. CEEW is a strategic/ knowledge partner to 11 ministries for India's G20 presidency.

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The Council has a footprint in over 20 Indian states, working extensively with 15 state governments and grassroots NGOs. Some of these engagements include supporting power sector reforms in Uttar Pradesh, Rajasthan, and Haryana; energy policy in Rajasthan, Jharkhand, and Uttarakhand; driving low-carbon transitions in Bihar, Maharashtra, and Tamil Nadu; promoting sustainable livelihoods in Odisha, Bihar, and Uttar Pradesh; advancing industrial sustainability in Tamil Nadu, Uttar Pradesh, and Gujarat; evaluating community-based natural farming in Andhra Pradesh; and supporting groundwater management, e-auto adoption and examining crop residue burning in Punjab.

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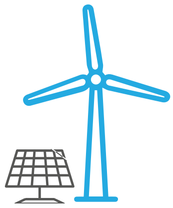
Rooftop solar penetration in the residential sector is expected to reach 100 million installations by 2030 and 240 million by 2050.

Image: iStock

Executive summary

Across the world, increasing populations, expanding manufacturing capacities, and rising living standards have led to a higher demand for electricity. According to International Energy Agency (IEA) projections, global electricity demand is expected to increase by 75 per cent by 2050 (IEA 2022). Simultaneously, geopolitical disruptions, such as the Russia–Ukraine conflict and the economic rebound following the COVID-19 pandemic, have heightened the need for nations to transition from fossil fuels to renewable energy (RE) sources. In 2023, the global RE installed capacity increased by 50 per cent compared to the previous two years (IEA 2024). Solar photovoltaic (PV) technologies, particularly distributed solar, are well positioned to play a critical role in this global energy transition. Leading economies such as China, the United States (US), Japan, and Australia use distributed solar or rooftop solar (RTS) as an instrument to enhance energy security and facilitate the energy transition, aiming to achieve their net-zero goals. Distributed solar also offers an opportunity to improve electricity access in developing countries, where approximately 760 million people still lack electricity, especially in sub-Saharan Africa (IEA 2023). Rooftop solar systems can be integrated into buildings, avoiding land conflicts and providing a decentralised and sustainable solution. This allows consumers to generate low-cost energy on-site while increasing overall system efficiency by reducing transmission and distribution losses.



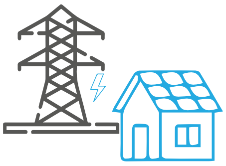
Global electricity demand is expected to increase by 75% by 2050

This report primarily focuses on the distributed solar segment, especially RTS, across consumer categories. We selected the top ten countries leading in distributed solar PV deployment (as of 2022) for our study: China, Germany, the US, Japan, Australia, Italy, Brazil, India, and Viet Nam. However, Turkey was excluded due to the unavailability of information in the public domain. The report provides a comparative analysis of RTS development across nine top-performing countries. Insights from these countries can inform strategies in other countries aiming to scale up RTS deployment and facilitate the transition towards a cleaner and more resilient energy future. However, the definition and size limit of distributed PV systems vary across countries. In this report, considering the prevailing regulations in the countries selected for our study, PV systems with a capacity of under 6 MW are considered as distributed PV.

A. Key drivers accelerating deployment across countries

Several factors have accelerated the adoption of RTS in leading economies. Policy and regulatory support have been instrumental in driving market growth, while diverse financial mechanisms and innovative business models have played a significant role in this transition. Meanwhile, technological advancements have reduced the cost of solar modules, making rooftop installations more economically viable. The following are some of the key drivers:

- **Feed-in tariffs (FiT)** and feed-in premiums (FiP) programmes have significantly contributed to the rapid expansion of RTS by improving the economic viability of systems during the early stages of the industry. Countries such as the US, Italy, China, and Japan have successfully implemented these schemes through a phased approach, gradually reducing the FiT rate while ensuring market demand remains high in the distributed PV segment. In contrast, Viet Nam's FiT scheme failed; the lack of a long-term policy framework, inadequate energy infrastructure, and limited grid capacity led to the eventual discontinuation of the FiT scheme despite its initial momentum.



Feed-in tariffs utilised as key instrument across countries to accelerate RTS deployment

- **Diverse financial mechanisms**, such as capital subsidies for the residential segment and financing options, including low-interest loans, have enhanced consumer access to RTS. For instance, India provides capital subsidies for residential consumers of up to 3 kW. China and Japan have adopted similar approaches, whereas the US, Brazil, and Germany offer low-interest loans to consumers.

- **Dedicated programmes** have been adopted launched by countries to tap target the lower-income consumer segment, such as the *Whole County PV Programme* and the *Solar Energy for Poverty Alleviation Programme* (SEPAP) in China, the *Social Renewable Energy Development Programme* (PERS) in Brazil, and the *PM Surya Ghar: Muft Bijli Yojana* in India.

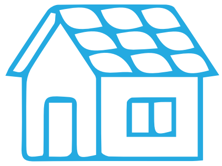
- **Tax credit programmes** have also emerged as a critical instrument in developing the RTS segment across countries. For instance, federal tax credits in the US, such as the Ecobonus Decree, and the Super Bonus Scheme in Italy, have significantly contributed to creating markets in these respective countries. Unlike other countries, Viet Nam provided tax exemptions to solar developers rather than consumers which significantly boosted the growth of the sector.

- **Business models** such as third-party ownership and power purchase agreements (PPAs) have also expanded consumer access to RTS systems. The introduction of innovative concepts such as balcony solar, tenant electricity models, and energy cooperatives in Germany; small-scale technology certificate (STC) schemes in Australia; and net metering schemes in Brazil, which offer energy credits instead of monetary compensation, have been crucial for driving RTS adoption across countries.

- **Streamlining the application procedure** has boosted RTS adoption in many countries. For instance, the US has implemented initiatives such as the *SolSmart* programme and *SolarAPP+*, and India has developed a dedicated solar rooftop portal with a consumer-centric approach by providing ease to access information through a single national portal. Additionally, programmes such as solar accreditation, including the *Solar Panel Validation Initiative* in Australia, and the vendor rating programme in India, have supported the creation of a robust RTS ecosystem.

Leading economies are also investing in grid infrastructure and distributed renewable energy (DRE) integration to increase the share of RTS in the electricity mix, achieve their net-zero emission goals, and build a more sustainable future.

B. Key recommendations for scaling up rooftop solar deployment



The global push for RE has prompted numerous countries to develop robust RTS programmes crucial for their energy transition and net-zero commitments. Insights from these leading economies offer valuable insights and strategies for other countries to accelerate their RTS deployment.

- **Create demand through consumer engagement and innovative business models.** To accelerate the adoption of RTS, governments and RE agencies must undertake targeted consumer awareness campaigns to disperse information in an easy-to-understand way and deliver clear calls to action, as seen in the successful Solarise campaigns in the US and Delhi. Creating comprehensive national online platforms, such as India's *PM Surya Ghar: Muft Bijli Yojana*, can also help streamline communication on incentives, policies, and application processes. Finally, innovative business models, such as community solar programmes, landlord-to-tenant electricity supply, and plug-in balcony solar PV systems in Germany, can help overcome challenges related to high upfront costs and limited roof space, thereby making solar energy more accessible to a wider range of consumer categories.

- **Leverage policy levers to unlock rooftop solar potential.** Governments must accelerate RTS adoption by introducing targeted incentive mechanisms, such as FiT and capital subsidies, with a straightforward phase-down approach, as seen in Japan, Germany, and Australia. Affordable and inclusive financing options, such as Brazil's low-interest credit and China's zero-cost financing, are essential for making solar systems economically viable. Adopting inclusive solar programmes, such as the US's *Solar for All* and China's rural poverty alleviation initiatives, can ensure equitable access to solar energy across different income classes and regions. Additionally, mandates requiring new government, residential, and commercial buildings to install RTS systems, as implemented in Germany and Viet Nam, can significantly drive adoption.

- **Incentivise rooftop solar adoption through regulatory interventions.** To promote RTS adoption, regulatory authorities should develop metering arrangements such as net metering, net billing, and virtual net metering to compensate consumers for excess energy generation. These transitions should be evidence-based and involve public consultations, as seen in the recent shift towards self-consumption and battery storage in California (US). India introduced net metering in 2012, and various states have since adopted and amended regulations to implement newer systems. A conducive regulatory environment is also essential to support innovative models such as virtual net metering in rural areas in India and simplified rules for balcony solar in Germany to overcome barriers related to limited roof space and ownership issues.

Governments must accelerate RTS adoption by introducing targeted incentive mechanisms, such as FiT and capital subsidies

- **Create an enabling ecosystem to ensure ease of implementation**. To expedite RTS adoption, local governments and utilities should automate and streamline the permit application process, as seen with SolarAPP+ in the US, which significantly reduced permit processing time. Implementation agencies can leverage existing government programmes, such as Brazil's *Minha Casa Minha Vida* social housing programme, to integrate solar solutions and lower consumer acquisition costs. Local capacity building is crucial, as exemplified by the *SolSmart* programme in the US, which provides technical training to local governments. Governments should also institute vendor rating programmes to help consumers make informed decisions and ensure quality installations, as seen in India's *PM Surya Ghar: Muft Bijli Yojana* scheme. Performance monitoring systems, similar to Australia's *Solar Panel Validation Initiative*, can also enhance system reliability and maintain consumer trust in solar technology.
- **Plan for sustainable rooftop solar expansion**. National electricity authorities must regularly assess and plan for transmission and distribution needs, working closely with distribution companies (discoms) and other stakeholders to avoid issues related to curtailment, as experienced in Viet Nam. Countries such as China have addressed grid uncertainties by enhancing transmission capacity and developing energy storage. Maintaining granular and periodic data through national registries, such as Germany's Master Register (MaStR) and Australia's Distributed Energy Resource Register, is crucial for informed policymaking, infrastructure planning, and identifying beneficiaries. Reliable data helps drive better decisions and supports the overall growth of RTS infrastructure.

By adopting these effective strategies, countries can accelerate their transition to RE, harnessing RTS as a critical component of their sustainable energy future. Drawing from the insights and best practices from leading economies provides a valuable roadmap for overcoming common challenges and unlocking the full potential of RTS globally.

1. Introduction

Image: iStock

Global electricity demand is rising rapidly due to population growth, regional manufacturing expansion, and higher living standards. According to an IEA forecast, global electricity demand could increase by 75 per cent by 2050 (IEA 2022). In addition, the post-COVID-19 economic recovery and the Russia–Ukraine conflict have significantly disrupted global energy supplies, causing a spike in electricity prices worldwide. This has consequently accelerated a shift towards renewable energy (RE) to ensure energy security in many countries. In 2023, globally approximately 507 GW of renewable capacity was added – a 50 per cent increase over the past two years. The total RE capacity is expected to reach 7,300 GW by 2028 (IEA 2022; 2024). Solar PV, a key contributor, accounted for 4.5 per cent of global electricity in 2022 and is projected to reach 13 per cent by 2028 due to its reliability and versatility as an instrument to reducing carbon emissions and achieving net-zero goals (IEA 2024).

1.1 Evolution of solar PV: From rooftop dominance to utility-scale growth and recent challenges

In the early 2000s, solar PV gained momentum with supportive programmes such as feed-in tariffs (FiT) in Japan and Germany – the two countries initially dominated by rooftop installations. Between 2000 and 2005, rooftop solar (RTS) PV accounted for over 90 per cent of the global installed capacity driven by the residential segment. Later, from 2006 onwards, a worldwide decline in module prices and favourable incentive programmes in several countries boosted the deployment of utility-scale projects, which surpassed RTS in 2013 and dominated until 2016, accounting for approximately 78 per cent of total installed solar capacity.

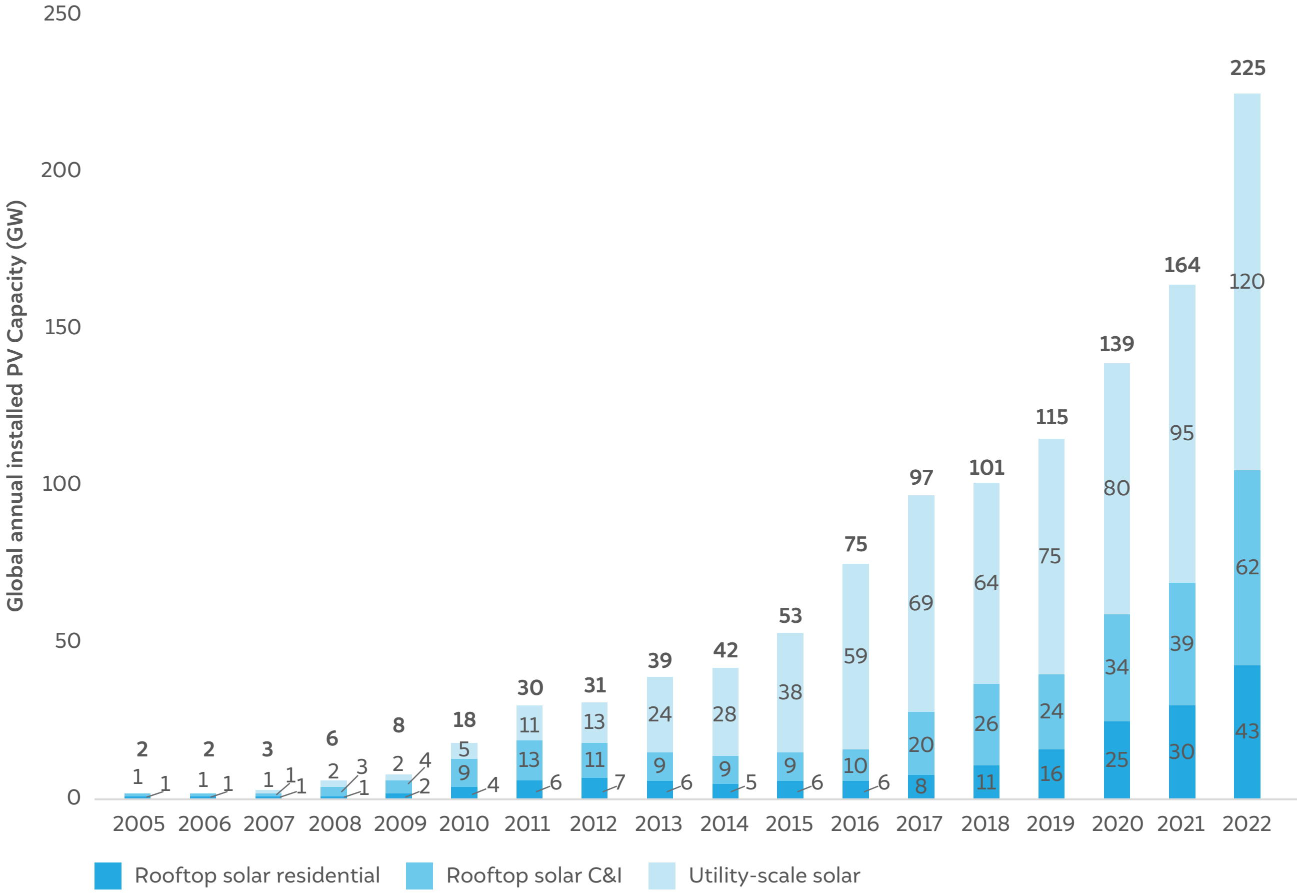
However, between 2021 and 2022, the share of utility-scale installations dropped to 58 per cent and 53 per cent, respectively, due to supply chain issues and the increased cost of PV system components, installation, and logistics in the post-pandemic period (ISA 2023). This resulted in delays or cancellations of large-scale projects globally. Meanwhile, rising retail electricity prices have driven residential as well as commercial and industrial (C&I) consumers to adopt RTS to lower their bills.

1.2 Global growth of rooftop solar: Policies, market trends, and future projections

Recognising its potential to address current and future energy needs, countries worldwide have been implementing enabling policies and regulations to scale up the adoption of RTS systems, such as capital subsidies, tax credits, and innovative business models. Moreover, in the past decade, solar module costs have decreased by over 80 per cent, supported by government incentives, making RTS economically feasible worldwide.

As of 2023, the total RTS installed capacity globally is approximately 636 GW (IEA-PVPS 2024; ISA 2023). The RTS market witnessed a significant surge of 67 per cent in 2023, with installations reaching approximately 175 GW, compared to 105 GW in 2022. The C&I sectors dominate the deployments. In 2022, about 62 GW of capacity was installed in the C&I sectors, compared to 43 GW in the residential sector (ISA 2022; 2023) (Figure 1). Annual RTS capacity installations are expected to grow to 183 GW by 2024 and 268 GW by 2027 (SolarPower Europe 2024). Additionally, according to the IEA's Net Zero Emissions by 2050 Scenario, the RTS penetration in the residential sector is expected to reach 100 million installations by 2030 and 240 million by 2050 (IEA 2021).

Figure 1 From 19 GW to 105 GW, 15% increase in annual rooftop solar installation during the last decade



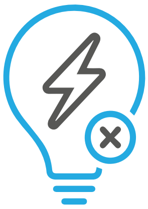
Source: Authors' compilation based on data from ISA 2022; 2023

In terms of deployment, China maintains its dominance in the global RTS segment, with a cumulative installed capacity of approximately 225 GW in 2023 (Rashida 2024), followed by Germany and the US. The residential sector in the US has grown about seven times in the past decade. In Brazil, the residential sector leads RTS deployment with a 48 per cent market share as of March 2024. Australia leads globally in per capita RTS deployment with 0.83 kW per capita. Like the US, India has prioritised more inclusive development centred around the needs of the people by shifting the focus towards distributed solar energy with the introduction of *PM Surya Ghar: Muft Bijli Yojana*, targeting residential households.

1.3 Role of rooftop solar in facilitating a people-centric energy transition

Accelerating the adoption of RTS systems holds immense promise for contributing to a more sustainable and resilient future for global energy. Developed nations such as China, the US, Japan, and Australia prioritise achieving energy security while pursuing sustainability and cleaner energy goals. However, approximately 760 million people worldwide, predominantly in regions like sub-Saharan Africa, still lack access to electricity (IEA 2023). This persistent energy deficit in sub-Saharan Africa is partly due to massive underinvestment in electricity infrastructure.

Consequently, there may be more feasible solutions for African regions than the traditional grid model. For instance, a simple standalone RTS system can effectively meet most energy demands by leveraging Africa's abundant solar resources. Unlike utility-scale systems, RTS has the advantage of being integrated into buildings, thus avoiding land conflicts. Moreover, it offers a decentralised and sustainable solution, empowering consumers to generate their energy on-site at a low levelised cost of electricity (LCOE). This eventually reduces grid costs and minimises transmission and distribution losses, making it a highly efficient and feasible energy solution.



~760 million people worldwide, predominantly in regions like sub-Saharan Africa, still lack access to electricity

1.4 Pioneering the rooftop solar revolution: Lessons from leading economies

Around the world, while some countries are just beginning to realise the potential of RTS, others have already embraced this energy transition. Economies such as China, Japan, and Australia have become leaders in unlocking the potential of RTS through innovative policies, regulations, market mechanisms, and advanced technological solutions. This report delves into the success stories of these leading economies and critically analyses their RTS development to draw valuable insights from their experiences. The report offers relevant recommendations to help other nations transition towards a cleaner and more resilient energy future by understanding these countries' key drivers and challenges.

2. Methodology and approach for country selection

Image: iStock

In this report, we employed a two-step approach for country selection. In the first step, we shortlisted countries with at least a 1 per cent market share of the global total installed solar capacity of 1.1 TW (as of 2022) (IEA-PVPS 2023). From 195 countries, we shortlisted 16 with a cumulative installed capacity of more than 10 GW. In the second step, we ranked these countries based on their cumulative installed capacity in the distributed PV segment (as of 2022). We selected the top ten countries for the comparative analysis. However, we included only the top nine countries in the study due to a need for more relevant information regarding the tenth country, Turkey. The selected countries are highlighted in Figure 2.

Figure 2 **Top nine countries leading in distributed solar PV deployment selected for the analysis**

Source: Authors' compilation based on data from IEA-PVPS 2023

After selecting the countries, we employed a two-pronged approach to delve deeply into each country's solar journey, as outlined below:

- **Literature review**: We conducted an exhaustive review of the relevant literature to understand the RTS market in the selected countries. This review focused on identifying and analysing the key drivers that have accelerated the deployment of RTS systems in these economies. Additionally, we examined the challenges faced during the deployment process and explored alternative strategies that have been adopted to overcome these obstacles. Our literature review included academic papers, industry reports, policy documents, and case studies, which provided a robust foundation for understanding the RTS landscape in each country.
- **Stakeholder engagement**: We engaged with a diverse range of stakeholders to validate and enrich the information obtained from the literature review. We contacted research scholars, professors, regulatory authorities, industry experts, and other relevant stakeholders from the selected countries. This consultation process was also aimed at providing insights into the evolving policy perspectives and market scenarios that might not be fully captured in the existing literature. The feedback and perspectives from these engagements were invaluable in ensuring our analysis was grounded in the RTS markets' current realities and future trends.

After completing both stages, the collected data and information were meticulously organised to facilitate seamless comparison and analysis across different countries. This enabled us to draw meaningful insights and identify best practices and common challenges as well as areas for improvement. We converted all the financial metrics into US dollars (USD) where needed to ensure a consistent comparison. For the conversion, we used the exchange rate[1] of 31 March 2024.

1 1 INR=0.0120 USD, 1 EUR=1.0792 USD, 1 JPY=0.0066 USD, 1 AUD=0.6532 USD, 1 VND=0.000040 USD, 1 CNY=0.1385 USD

3. Country-level analysis: A deep dive into how these economies transformed the rooftop solar sector

Image: iStock

This section provides detailed country-specific analyses of the shortlisted countries. Each country's profile includes an overview of its RTS market, key drivers, challenges, alternative strategies, and policy perspectives. Additionally, we offer key recommendations from other leading countries to support the growth and development of RTS markets in these economies.

3.1 China: Pioneering the rooftop solar revolution

China possesses a technical solar potential of 2,070 GW (Wang, Luo, and Kang 2017). The cumulative solar installations in China had reached 609 GW by the end of 2023 (Rashida 2024). The country is expected to achieve 1 TW solar PV capacity by 2026, with the distributed solar segment expected to account for nearly 50 per cent of the total installation.

National targets

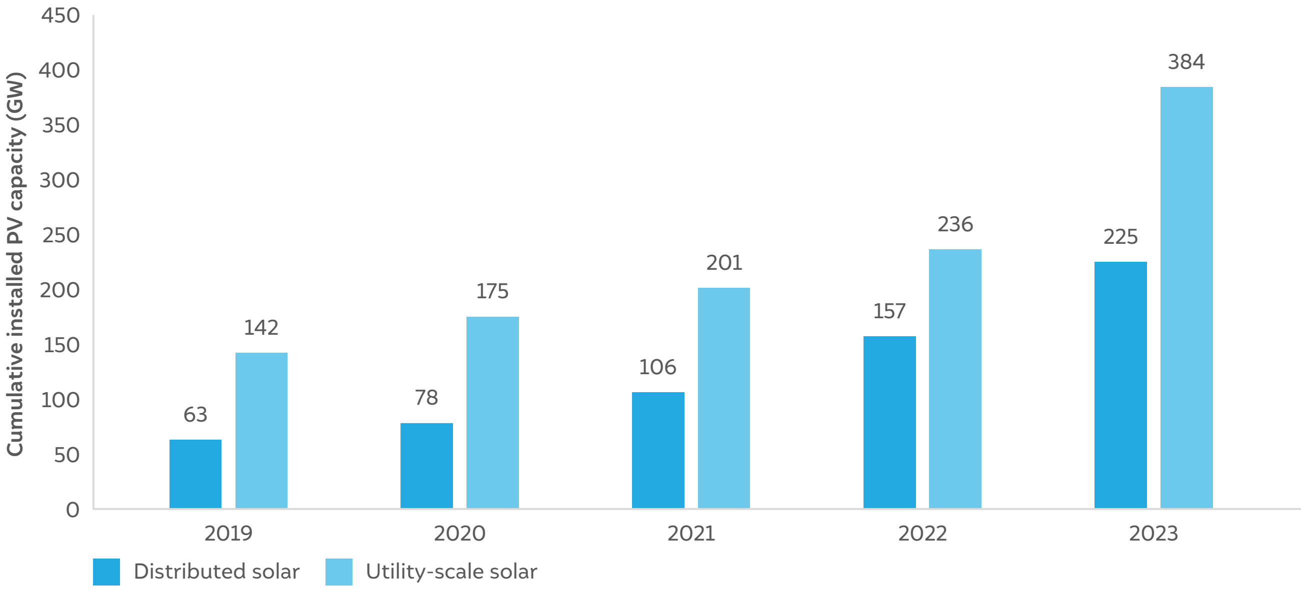
- China aims to achieve 1,200 GW solar and wind capacity by 2030.
- It also aims to achieve net-zero emissions by 2060.

Current deployments

- Approximately 37% of the total solar PV installation is contributed by distributed solar (225 GW).
- Residential sector deployment has increased from 20 GW in 2020 to 105 GW in 2023.

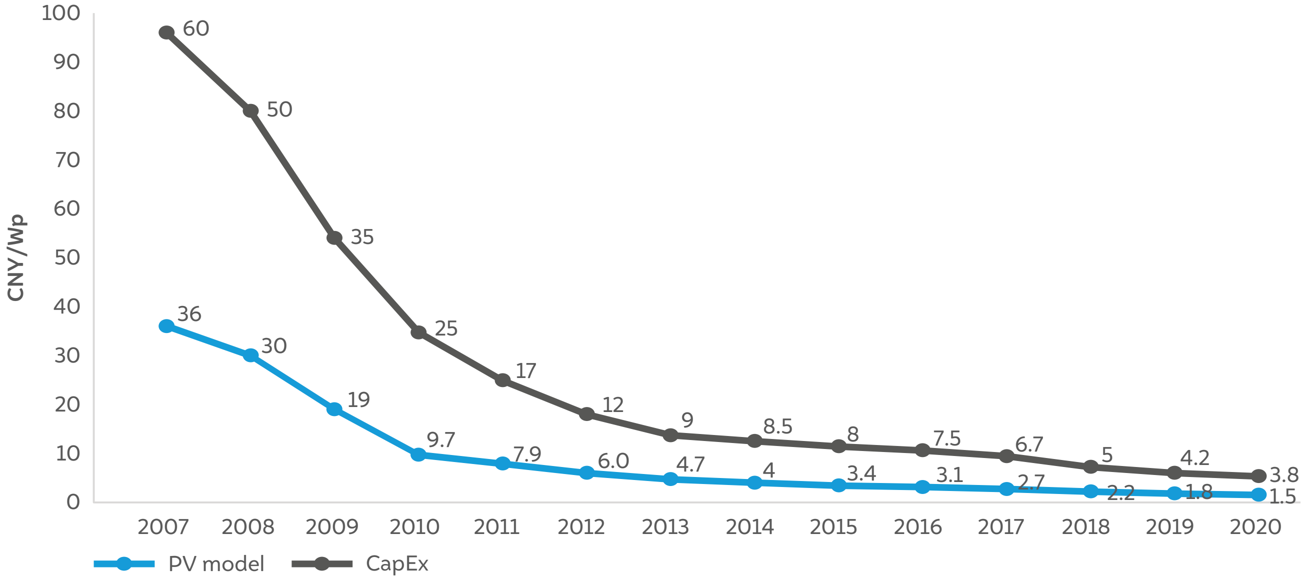
Source: Authors' compilation based on data from Rashida 2024 and REGlobal 2023

Figure 3 **Distributed solar contributed 37% of total installed solar capacity in China**



Source: Authors' compilation based on data from IEA-PVPS 2019, REGlobal 2023, and Rashida 2024

Figure 4 Significant reduction in solar PV module and CapEx costs in China



Source: Authors' adaptation from WRI 2020

Ambitious *Golden Sun Programme* for domestic solar market creation (2009–2011)

China has been a leader in deploying utility-scale projects and continues to lead, with a total installed capacity of 384 GW in 2023 (see Figure 3). Initially, the focus was on large-scale solar; however, with the rollout of the *Golden Sun Programme* over the last decade, the distributed PV segment has also grown significantly. The programme aimed to improve electricity access, particularly in rural areas, through distributed solar systems with limited or no grid connectivity. Additionally, it aimed to create solar PV projects exceeding 300 kW in grid-connected areas (Ministry of Finance and Ministry of Science and Technology, National Energy Administration 2009). This initiative aimed to demonstrate PV technologies, boost domestic solar demand, and industrialise PV technologies nationwide (Ministry of Finance and Ministry of Science and Technology, National Energy Administration 2009).

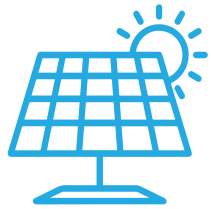
The policy supported both distributed (less than 6 MW) and utility-scale projects, offering a 70 per cent capital subsidy for rural projects lacking power supply and a 50 per cent subsidy for grid-connected projects exceeding 300 KW, with a cap of CNY 100 million (USD 13.85 billion) per project (Wang, Luo, and Kang 2017). Each region (both counties and autonomous) was tasked with developing 20 MW of solar capacity, with each project having a capacity of 300 kW and above and a lifespan of 20 years. System integrators and critical equipment suppliers were selected through bidding. The programme primarily focused on self-consumption by industrial consumers, with a provision to sell excess power to the national grid at a benchmark price for local desulfurised coal-fired units. The government provided over CNY 10 billion (USD 1.38 billion) in subsidies (Ying 2011).

The *Golden Sun Programme* significantly boosted solar adoption, achieving 5,930 MW of installed solar capacity by 2012, with 95 per cent in the distributed segment. Consequently, this increased the share of distributed solar systems in the total market share from 32 per cent in 2011 to 36.4 per cent in 2012 (Wang, Luo, and Kang 2017). However, the programme encountered challenges due to design issues, a lack of clarity in the implementation plan, and regional governments' non-adherence to policy provisions. Detailed challenges are explained in Annexure 1.

Rural poverty alleviation through *Solar Energy for Poverty Alleviation Programme* (SEPAP) (2014–2020)

Following the *Golden Sun Programme*, China launched the *Solar Energy for Poverty Alleviation Programme* (SEPAP), aimed at benefiting 2 million people across 35,000 rural villages by installing 10 GW of distributed solar capacity (Zhang 2020). The projects were divided into three categories: village-level arrays (for projects with a capacity of no more than 300 kW), village-level joint construction arrays (for projects with a capacity of no more than 6,000 kW), and rooftop installations targeted towards poor villagers (typically with a capacity of 3 kW).

The National Energy Administration (NEA) and the State Council's Leading Group Office of Poverty Alleviation and Development (LGOPAD) coordinated the programme at the central and provincial levels. The programme offered various enabling provisions, such as 100 per cent subsidies for low-income families and zero or low-cost financing options, with the opportunity to repay the loan by selling surplus electricity to the grid (Jin 2023). The policy, which was estimated to provide each beneficiary with an annual income of CNY 3,000–3,500 (approximately USD 415–485), benefited 4.18 million impoverished households by adding roughly 26 GW of solar power capacity by 2020, exceeding the initial target of 10 GW (Jin 2023). More details on the business models are discussed in Annexure 2.



***Whole County PV programme* in China benefits 140 million people in 676 counties and has significantly increased distributed PV capacity**

Whole County PV Programme drives the growth of distributed solar capacity addition

China launched the *Whole County PV Programme* in 2021 to accelerate distributed solar deployment. The programme aimed to reduce capital investment in transmission infrastructure and enhance grid stability by locating renewable units near load centres. Under the programme, the government set a target to build RTS systems on at least 50 per cent of government buildings, 40 per cent of public buildings (including schools and hospitals), 30 per cent of commercial buildings, and 20 per cent of rural homes (Jiang 2023).

The programme addresses implementation challenges from the earlier *Golden Sun Programme*. A single bidder is selected as the investment company for each county to provide economies of scale and reduce the soft costs related to customer acquisition and contracting (Jiang 2023). More details on the implementation models are elaborated in Annexure 3. Under the programme, the investment company builds the project under the Renewable Energy Service Commission (RESCO) model by generating revenue from power sold to building owners and the grid. The programme benefits 140 million people in 676 counties and has significantly increased distributed capacity in China, with 87.4 GW added in 2022, 50 per cent of which is in rural areas. Additionally, over the years, the falling costs of PV modules and capital expenditure (CapEx) have significantly boosted RTS adoption in China (see Figure 4).

Future outlook for RTS sector in China: Distributed solar integration and grid modernisation

China is investing CNY 500 billion (approximately USD 70 billion) in infrastructure upgrades to support distributed solar grid integration and is installing battery and pumped hydro storage facilities for grid balancing. In December 2023, Chongqing municipality installed a 1 GW pumped storage plant, which serves as a 'superpower bank' for the southwest power grid (The State Council 2023). The country is also extending green certificates to distributed solar generators.

3.2 Germany: Putting renewable energy first

Germany has an RTS technical potential of 409 GW (Hartz 2023), nearly twice the total solar PV 2030 target set by the federal government. The current installed capacity is 53 GW as of March 2024 (The Federal Network Agency 2024c).

National targets

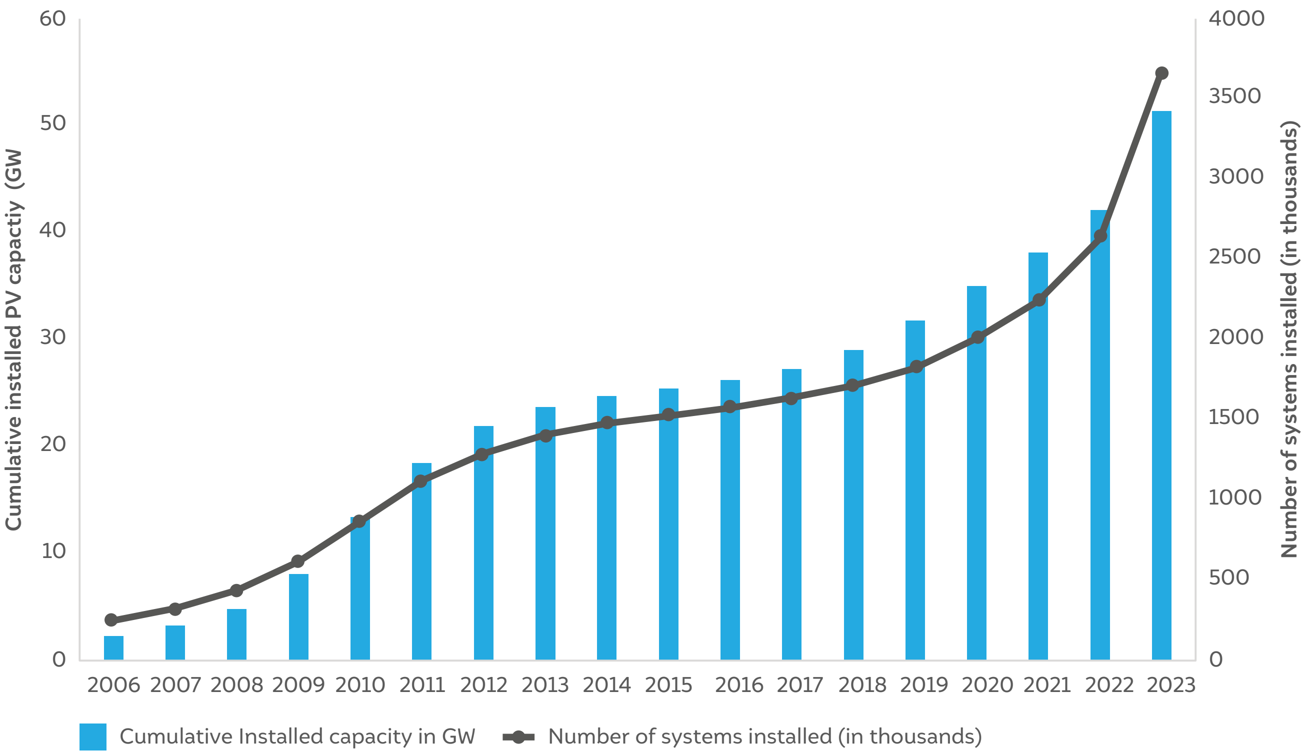
- Germany aims to increase the share of renewables in the gross electricity consumption to 80% by 2030.
- It targets to deploy 215 GW of PV capacity by 2030, with the addition of 11 GW of RTS capacity every year from 2026 to 2030.

Current deployments

- The total installed solar capacity in Germany reached 82.2 GW in 2023, with ~51 GW of RTS installed capacity.
- In 2023, solar capacity increased by 14.7 GW, with residential and commercial segments accounting for 7 GW and 2.5 GW, respectively.
- Approximately 260,000 balcony solar PV systems were added in 2023 and account for 220 MW.

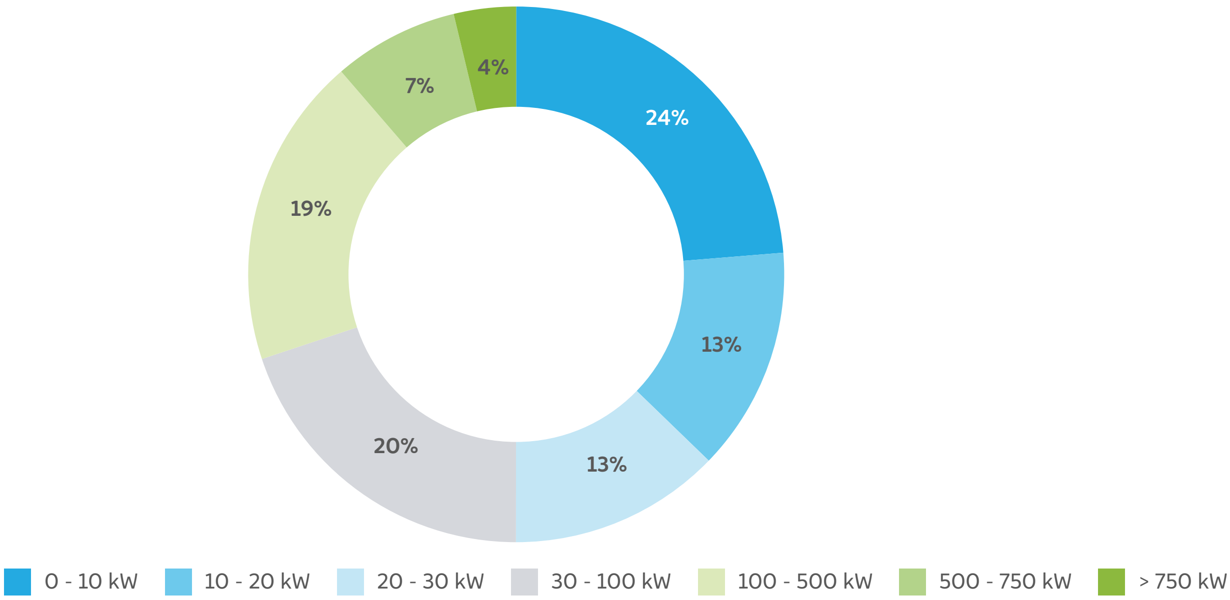
Source: Authors' compilation based on data from The Federal Government 2022, BMWK 2023b, BMWK 2023c, and The Federal Network Agency 2024a

Figure 5 **Germany has achieved a record level of RTS installed capacity in 2023**



Sources: Authors' compilation based on data from MaStR

Figure 6 RTS systems ranging from 0–30 kW form half of the total 2022 capacity



Sources: Authors' compilation based on data from Fraunhofer ISE

Overview of Germany's rooftop solar journey

The consistent increase in Germany's RTS deployment, particularly in the 0–30 kW category, has been driven by government programmes and legislation such as the *1,000 Roofs and 100,000 Roofs* programmes, the *Renewable Energy Sources* (EEG) *Act*, and *Solar Package I* (Figure 5, 6). Feed-in tariffs have been crucial for adoption and have been complemented by a decrease in installation costs from EUR 14,000/kWp (USD 15,000/kWp) in 1990 to EUR 1,400/kWp (USD 1,500/kWp) in 2023 (Fraunhofer ISE 2024). This has been further supported by citizen- and community-led initiatives such as energy cooperatives investing in RE technologies. The key institutions and ministries involved in energy are outlined in Annexure 4.

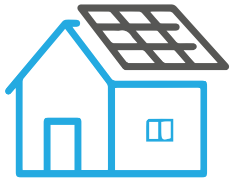
Launch of rooftop solar programmes

- The *1,000 Roofs* programme was introduced in 1990, targeting residential roofs with technical inspections and performance monitoring provisions. By 1995, approximately 2,100 systems were installed with a total capacity of 5.3 MW (Becker et al. 1997). Performance evaluation under the programme highlighted challenges such as inverter failures, module power below the nameplate rating, and partial shading (IEA-PVPS 2002a).

- In continuation, the *100,000 Roofs* programme was introduced in 1999 with a target capacity of 300 MW and achieved 261 MW installed capacity from 55,000 installations, offering low-interest loans and financing up to EUR 500,000 (USD 539,600). Loan sizes were restricted by system capacity: EUR 6,750/kW (USD 7,285/kW) for up to 5 kW and EUR 3,375/kW (USD 3,642/kW) for systems larger than 5 kW. The programme ended in 2003 with a shift to FiT-led RTS deployments (IEA 2012).

Feed-in tariffs played a crucial role in accelerating rooftop solar deployment

The EEG was introduced in 2000 to accelerate the deployment of new technologies, including solar PV, through fixed FiTs for specified periods, purchase guarantees, and priority grid access (BMWK 2015). For instance, the EEG 2000 set the FiT at 50 ct/kW for 20 years. Subsequent reforms to the act (2004, 2009, 2012, 2014, 2017, and 2023) also played a pivotal role in Germany's energy transition – for example, the 2014 amendment aligned RE deployment more closely with market developments (BMWK 2019).



The *Renewable Energy Sources* (EEG) *Act* and its amendments are instrumental in Germany's RTS journey

Under the EEG, different remuneration models are developed depending on the plant size and type (Wirth 2024). For instance, the fixed tariff model for systems less than 100 kW and the market premium[2] model for systems up to 750 kWp were introduced in 2012 (Frondel, Kaeding, and Sommer 2022). The tendering model was introduced in the 2017 amendment for utility solar projects and larger RTS installations (greater than 750 kWp) (BMWK 2017b, IEA-PSPV 2017). In the 2023 revisions to the EEG Act, RE was recognised as critical for energy security and offered a higher FiT for RTS up to EUR 0.134/kWh (USD 0.145/kWh) and for partial feed-in[3] up to EUR 0.086/kWh (USD 0.0928/kWh) (BMWK 2022).

In addition, the EEG imposes a levy – a state-imposed component of the electricity price – to fund RE deployment in Germany. The rapid development of RE, including solar PV, led to an increase in the EEG levy paid by consumers. As a result of the 2014 EEG amendments, the levy did not increase for the first time in years (BMWK 2015). Furthermore, the EEG levy was reduced from 3.72 ct/kWh to 0 ct/kWh in 2022 and abolished in 2023 (BMWK 2023d).

Energy cooperatives allow citizens to invest in solar projects

Since the early 2000s, energy cooperatives led by citizens, communities, or local governments have actively contributed to developing solar PV projects facilitated by FiTs under the EEG Act. Nearly 950 cooperatives have been established since 2006, with 80 per cent focusing on solar PV (DGRV 2023). The cooperatives law was amended to facilitate democratic participation of the members, with equal voting rights irrespective of financial contribution (Nordic Energy Research 2023). However, energy cooperatives face challenges such as a need for more information, community conflicts, inadequate financing, reducing FiTs, and land acquisition issues, which have slowed their growth post-2013. Consequently, the amendment to the EEG Act in 2023 exempted energy cooperatives from tender requirements for installations less than 6 MW (BMWK 2023d) to address their sluggish growth.

Extending rooftop solar to more consumers: Landlord-to-tenant model and balcony solar PV

Germany introduced innovative models to offer opportunities for consumers living in rented properties. One such model is the landlord-to-tenant model, which provides tenants with access to low-cost solar PV electricity supplied by the system in their buildings or nearby buildings. The tenants are also exempt from grid electricity charges under this model. Tenants were offered funding and bonuses for electricity supplied through the 2017 amendment to the EEG Act (BMWK 2017a). Later, the bonus was available even if electricity was provided to a third-party energy supplier. In 2021, the electricity bonus was set at 3.79 ct/kWh for systems up to 10 kW, 3.52 ct/kWh for systems up to 40 kW, and 2.37 ct/kWh for systems up to 100 kW (BMWK 2021).

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2 The market premium is calculated ex post on a monthly basis, representing the difference between the feed-in-tariff and the technology-specific average market value of electricity in the previous month.

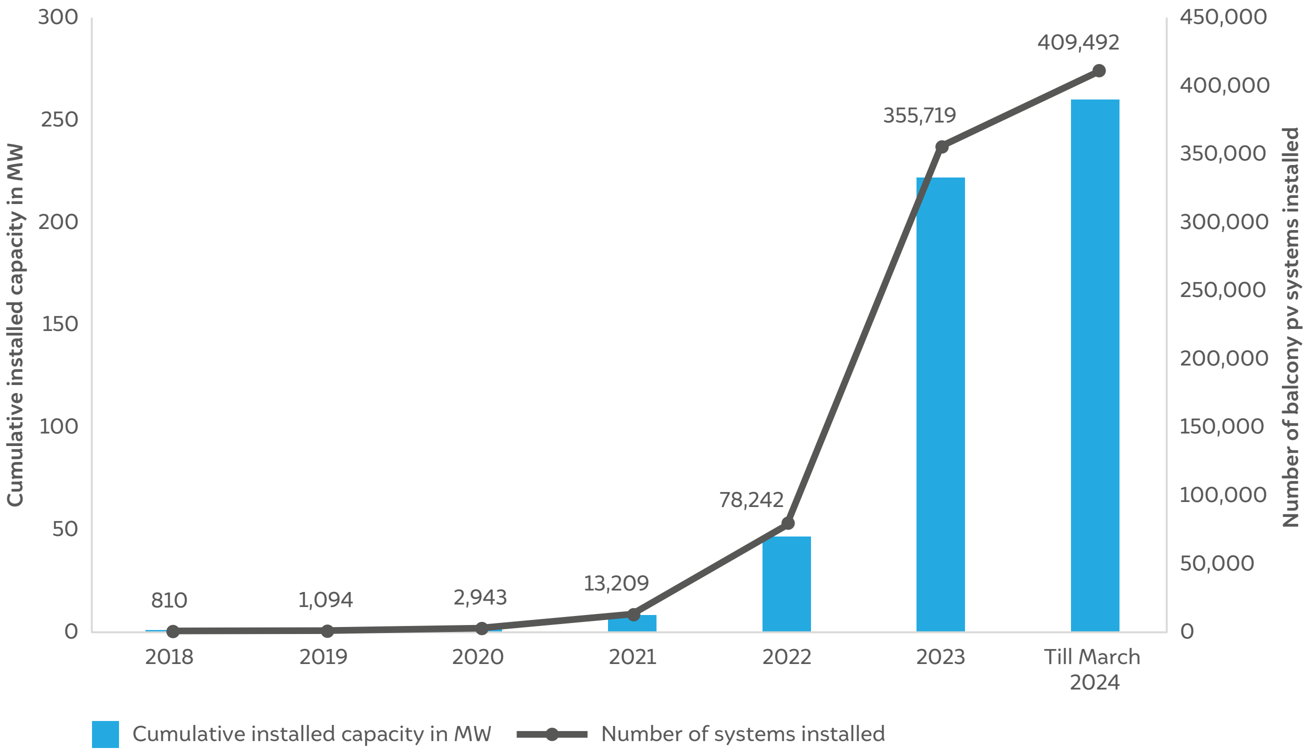
3 Systems without self-consumption are termed 'full feed-in', while those with self-consumption are called 'partial feed-in'. Full feed-in systems receive higher remuneration compared to partial feed-in systems.

Another innovation driving distributed solar includes balcony solar PV systems (plug-in solar PV devices). These systems power a few household appliances with a maximum output of 600 W, supporting the reduction of grid electricity usage. Furthermore, the simplified registration process through MaStR, the core market data register, has boosted deployment since 2022 (BMWK 2023c, leading to increased installations, as seen in Figure 7. State capital subsidies ranging from EUR 50 to EUR 1,450 (USD 54–1,564) per system have also supported deployment (Hommel de Mendonça 2023).

Solar mandates and tax concessions are enabling RTS deployment

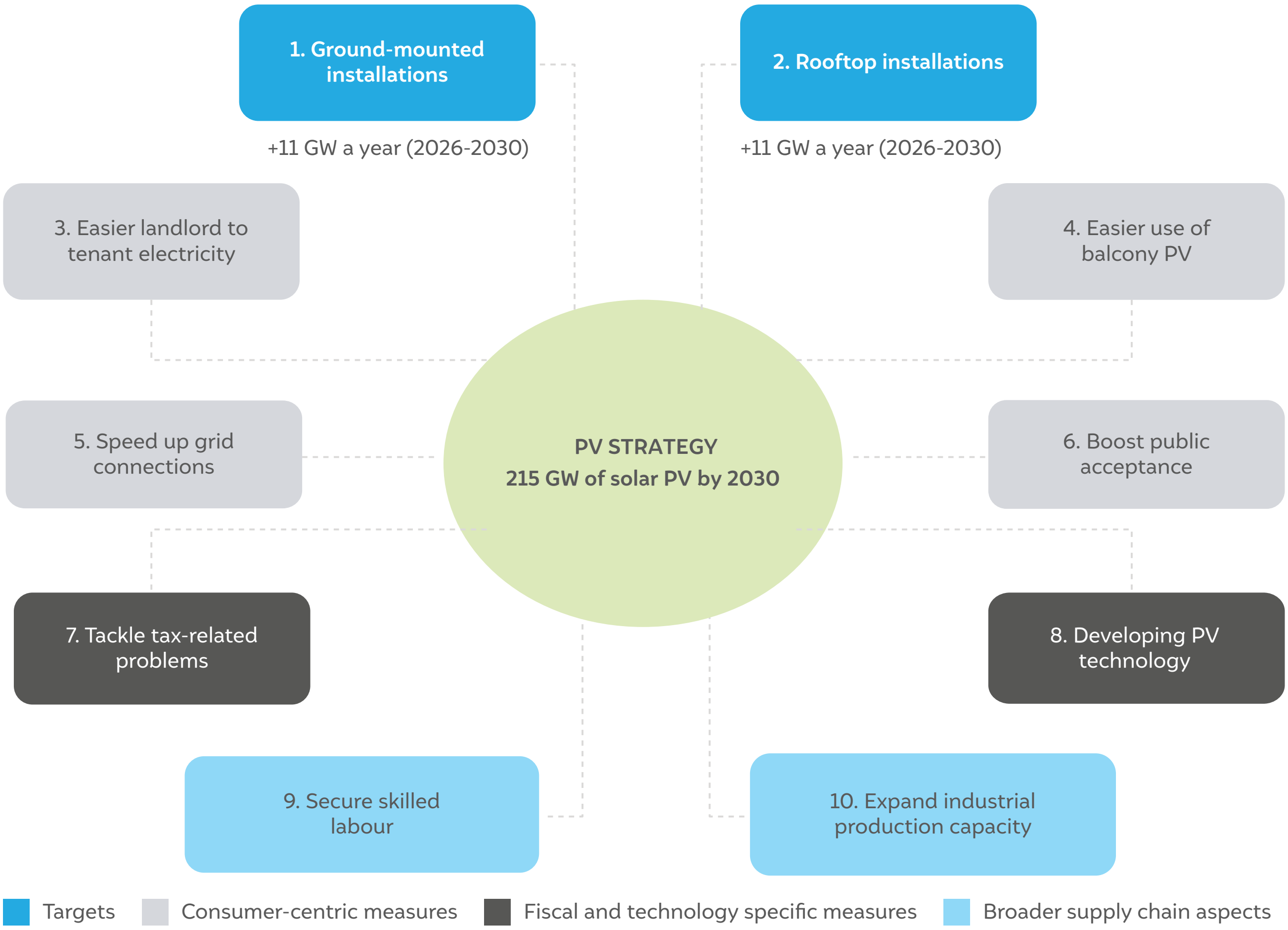
Factors such as falling solar module costs, tax concessions (exemption of VAT, income tax on electricity sale), and public trust have supported RTS adoption (SolarPower Europe 2023). Additionally, some states and city-states have adopted solar mandates. For instance, Baden-Württemberg introduced a phased solar mandate in 2022 for all new non-residential buildings and extended it to all roofs undergoing renovation in 2023 (Hockenos 2022). Public surveys by the German Solar Association showed strong support for simplified installation processes, a key enabler boosting adoption (BSW 2023).

Figure 7 An increase in balcony solar PV installations is observed post-2021–2022



Source: Authors' compilation based on data from MaStR

Figure 8 Rooftop solar is a key pillar of Germany's photovoltaic strategy



Source: Authors' compilation based on data from BMWK 2023d

Germany's rooftop solar strategy modifications are key to meeting 2030 PV targets

Germany's PV strategy, announced in May 2023, aims to accelerate the deployment of rooftop installations, with a target of 11 GW of RTS capacity per year starting in 2026, as seen in Figure 8 (BMWK 2023).

The *Solar Package I*, approved by the German Federal Parliament and Federal Council in April 2024, consolidates measures from the PV strategy to accelerate deployment, including balcony solar installations and systems on single-family and multi-family homes and commercial buildings (Enkhardt 2024). It aims to enhance energy sharing through community building supply and tenant electricity models. Grid connection processes for systems up to 30 kW and balcony solar PV registration have been simplified. Additionally, the package increases the FiT by 1.5 ct/kWh for commercial RTS installations over 40 kW (BMWK 2024). The Electricity Storage Strategy emphasises the need for flexibility in the energy system with an increasing share of renewables by 2030 (BMWK 2023a). It outlines small-scale storage facilities, including registered home energy storage units, for storing electricity from RTS systems. The *Electricity Network Development Plan 2023–2037/2045*, notified in March 2024, focuses on building 4,800 km of power lines and reinforcing 2,500 km of existing lines (The Federal Network Agency 2024b).

3.3 United States: Role of rooftop solar in building a clean energy economy

Rooftop solar's technical potential is estimated at 1 TW, spread over 8 billion sq. m. of rooftops (Gagnon et al. 2016; SETO 2024b). Residential and other small rooftops represent 65 per cent of this potential. According to the decarbonisation scenario, RTS installed capacity is expected to reach 200 GW by 2050 (DoE 2021).

National targets

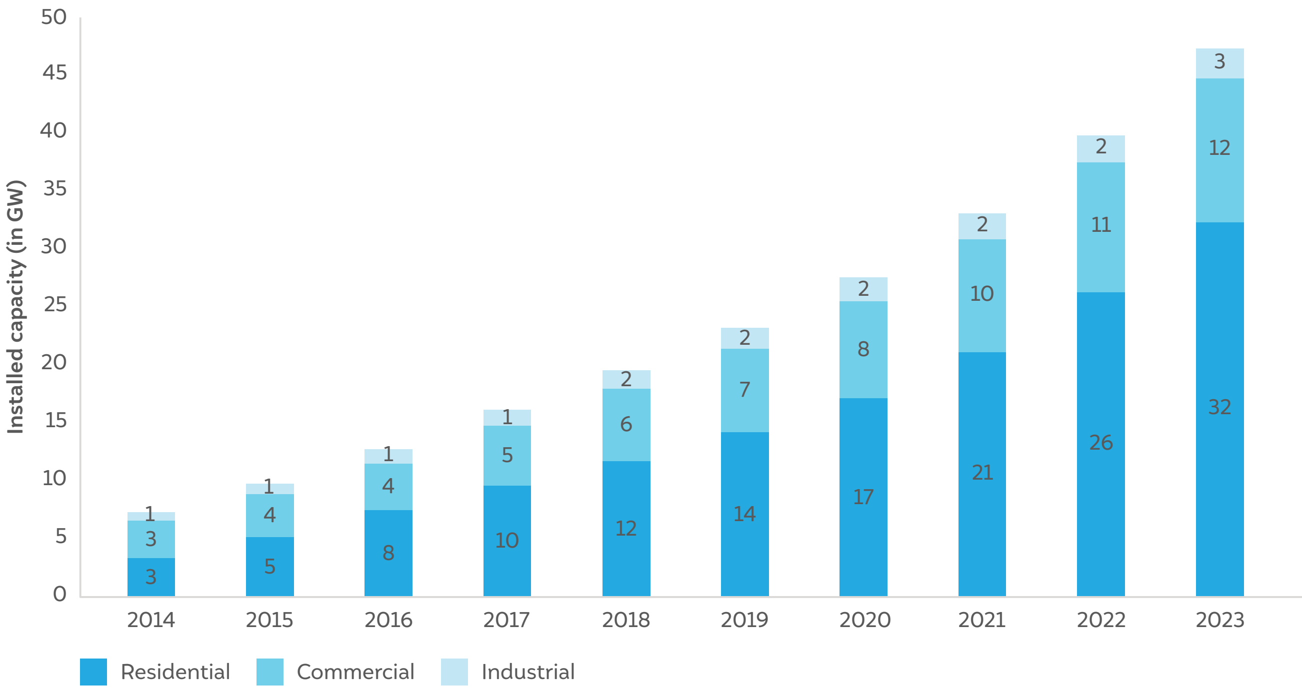
- The US aims to reach 80% RE generation by 2030.
- It also targets the installation of 30 GW of solar capacity each year from 2022 to 2025 and 60 GW each year from 2025 and 2030.
- It aims to ensure that 100% of US consumers can choose residential solar or community solar without experiencing an increase their electricity costs by 2025.
- It targets to reduce the levelised cost of electricity to less than USD 0.1/kWh for residential solar PV and USD 0.08/kWh for commercial solar PV.

Current deployments

- RTS generation has increased from 7.3 GW in 2014 to 47 GW in 2023 – the residential segment and C&I segment contributed 32 GW and 15 GW, respectively.
- For RTS deployment, California (16 GW) leads in total installed capacity, followed by New York, Texas, Massachusetts, and Arizona (2.5–3 GW each).
- As of December 2023, community solar4 capacity was 7.3 GW, with Florida, New York, Minnesota, and Massachusetts accounting for three-quarters of this capacity.

Sources: Authors' compilation based on data from The White House as cited in Mai 2023, DoE 2022, SETO 2021, and EIA 2024

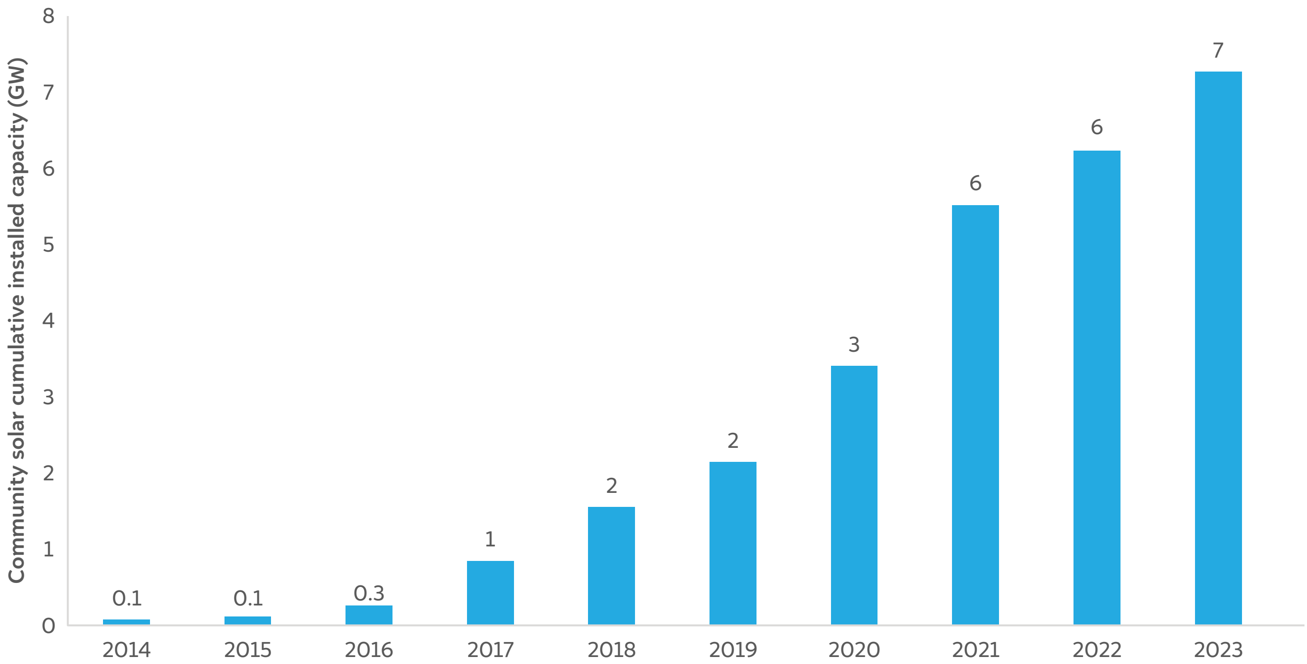
Figure 9 RTS has witnessed an increasing trend during the last decade



Source: Authors' compilation based on data from EIA 2024

4 Community solar is defined as any solar project or purchasing programme through which consumers can subscribe to or own a portion of the electricity generated by solar panels, typically at an off-site, and will receive an electricity bill credit based on their subscription or share of the project.

Figure 10 Community solar installations are driven by state-level programmes



Source: Authors' compilation based on data from NREL 2023

Unpacking the US rooftop solar story

Over the past decade, the US has seen a 25 per cent compound annual growth rate (CAGR) in RTS capacity, driven by falling module prices, high electricity tariffs, and supportive federal and state policies (see Figure 9). Key instruments include federal tax credits, metering and billing regimes, and streamlined solar permitting and interconnection measures. State programmes, such as community solar (Figure 10), have also contributed significantly. Both federal and state governments offer technical assistance to local governments and detailed information to consumers. The key institutions are listed in Annexure 5.

Federal tax credit for solar PV with well-defined trajectory played a pivotal role in RTS adoption

Federal tax credits for solar PV (solar tax credit) have been crucial for boosting RTS deployment in the US. These credits reduce the upfront cost of RTS systems (Borenstein and Davis 2016; SETO 2024a). Consumers receive a dollar-for-dollar reduction in income tax, with any excess credit carried forward to future years. The solar tax credits were introduced in 2006 as part of the *Energy Policy Act* of 2005 and were initially set at 30 per cent for residential and commercial installations. The credits have been extended multiple times. For instance, in 2008, they were extended for eight years until 2016 (Congressional Research Service 2021). Solar tax credits were scheduled to decrease to 26 per cent in 2020 and 22 per cent in 2021.

Continued push for rooftop solar through the extension of solar tax credits under the *Inflation Reduction Act*

The *Inflation Reduction Act* (IRA 2022) extended the solar tax credits, maintaining the 30 per cent rate for installations from 2022 to 2032, with a phase-down to 26 per cent in 2033 and 22 per cent in 2034 (SETO 2023b). The IRA also extends benefits to commercial entities, non-profits, and local and a tribal government, offering two types of tax credits: the investment tax credit (ITC) and the production tax credit (PTC)[5]. The ITC is preferable for high installation costs, while the PTC benefits projects in high solar radiation areas. Installations between 2022 and 2033 qualify for a 30 per cent ITC or a 1.5 ct/kWh PTC, with a gradual phase-down after 2033. An overview of the solar tax credits is provided in Figure 11, and more details on the relevant acts are in Annexure 6. Additionally, the IRA offers a 10 per cent bonus ITC for solar facilities in low-income communities, tribal lands, or energy communities[6] (The White House 2023).

The Inflation Reduction Act **(IRA 2022) has extended the clean energy tax credits till 2034**

State-level metering regulations incentivise RTS adoption through compensation for excess generation

State-level metering regulations are a crucial driver for RTS adoption in the US, providing compensation for excess generation through consumer credits. As of November 2023, 34 states and four territories (District of Columbia [DC], Guam, Puerto Rico, and the US Virgin Islands) have mandatory net metering rules, with two states transitioning to other distributed generation compensation rules. Additionally, 11 states have other distributed generation (DG) compensation rules, such as net billing, while other states do not have mandatory state-wide net metering rules[7] (NC Clean Energy Technology Center 2023b).

Figure 11 The federal clean energy tax credits received an impetus under the IRA of 2022

Segment	Instrument type	2006-07	2008-14	2015	2016	2017-19	2020	2021	2022	2023-32	2033	2034	2035
Residential	Clean energy credit (Tax code 25D)	30%	30%	30%	30%	30%	26%	22%	30%	30%	26%	22%	0%
C&I	ITC (Tax code 48, 48E)	30%	30%	30%	30%	30%	26%	22%	30%	30%	26%	22%	0%
	PTC in ¢/kWh (Tax code 45, 45Y)	-	-	-	-	-	-	-	1.5 cents[1]	1.5 cents	0%[2]	0%	0%

Source: Authors' compilation based on data from IRS 2024a, IRS 2024b, SETO 2023a, The White House 2023, and SEIA 2023

Note: 1- Amount is adjusted for inflation; 2 - Phase down of PTC is linked to the applicable year i.e. year in which the annual GHG emissions from electricity production in the US are equal to or less than 25 per cent of the emissions from 2022.

5 The ITC is a tax credit that reduces the federal income tax liability by a percentage of the cost of a solar system installed during the tax year. On the other hand, PTC provides a per kilowatt-hour tax credit for electricity generated by solar systems during the first ten years of operation.

6 Energy communities are areas with a closed coal mine or coal-fired power plant or those that have been economically reliant on the extraction and processing of coal, oil, or natural gas, and now face higher-than-average unemployment.

7 In net metering, excess electricity is exported to the grid, and the customer receives kWh credits valued at the retail rate. These kWh credits can be applied within the billing cycle or in future billing cycles. In net billing, the excess electricity exported to the grid by the consumer is credited at a predetermined sell rate credit at the moment the energy is injected into the grid. Consumers cannot carry forward the kWh credits for future use.

The case of California stands out among states that are creating an enabling ecosystem for RTS adoption through state-level metering regulations. California leads in small-scale RTS capacity, driven by federal tax credits, state programmes such as the *California Solar Initiative* (CSI), and net energy metering (NEM). NEM and net billing tariff (NBT) arrangements provide credit for excess electricity generated by distributed systems. The California Public Utilities Commission (CPUC) introduced the first NEM tariff (NEM 1.0) in 1996, followed by NEM 2.0 in 2016, which added a one-time interconnection fee and time of use (TOU) rates. In April 2023, California transitioned to a new NBT, introducing 'electrification' tariff rates[8] and credit calculations based on the CPUC avoided cost calculator. This new rate, often lower than the retail rate, can exceed retail rates during late summer evenings, reflecting its grid value. The billing cycle changed from annual under NEM 1.0 and NEM 2.0 to monthly under NBT (CPUC 2023). More details on the transition between the three regimes are provided in Annexure 7. A NEM 2.0 lookback study informed the transition, assessing the cost-effectiveness of customer-sited RE resources (Verdant Associates, LLC 2021). While NEM 2.0 was cost-effective for RTS adopters, its benefits were not extended to all electricity consumers. The NBT aims to promote grid reliability, incentivise solar and battery storage, and manage electricity costs for all California consumers. Moreover, the transition process in California's metering regime underscored the importance of data analysis, public consultations, and providing prior notice to consumers regarding changes in the metering regime.

Innovative interventions such as the SolarAPP+ can streamline the local permitting process for RTS

SETO has introduced strategic programmes to accelerate RTS deployment

To achieve its 2025 targets, the Solar Energy Technologies Office (SETO) has funded several programmes and initiatives, including *SolSmart, SolarAPP+*, and peer network programmes. These initiatives focus on reducing soft costs, providing technical expertise to local governments, and improving consumer engagement.

- ***SolSmart* programme**: Launched in 2016 and extended until 2027, the *SolSmart* programme offers no-cost technical assistance to local governments, targeting the reduction of solar soft costs related to permitting, financing, and installation. It awards platinum, gold, silver, and bronze designations to local governments based on specific criteria and performance (see Annexure 8). As of 2024, 524 communities across 43 states have received a *SolSmart* designation, with the programme also highlighting success stories (SolSmart n.d).
- ***SolarAPP+***: Developed by the National Renewable Energy Laboratory (NREL) in collaboration with the solar industry and local authorities, *SolarAPP+* is an online platform that standardises and automates the solar permitting process (SETO 2024c). It aims to streamline permit processing, reduce project timelines, and improve efficiency. *SolarAPP+* facilitates instant permits for code-compliant residential solar and battery storage systems, cutting the permitting process by an average of 13 business days and reducing inspection failures by approximately 29 per cent compared to traditional methods (SETO 2023a).

8 This tariff is characterised by lower off-peak prices and higher on-peak prices compared to other TOU rates.

Innovative models such as community solar have expanded access to solar

Community solar has seen consistent growth, particularly during the 2016–2021 phase, with some slowdown during the pandemic. Enabling legislation has been adopted in 22 states, DC, and Puerto Rico (NC Clean Energy Technology Centre 2023). Community solar projects are developed through state-required programmes or pilot projects and are supported by regulations such as virtual net metering. Notable programmes include *SolarTogether* in Florida, the *Solar Massachusetts Renewable Target* in Massachusetts, and *IL Shines* in Illinois (Xu, Chan, and Sumner 2023). Additionally, 17 states and the DC focus on low-income communities, offering specific capacity or financial incentives for (low to moderate) LMI[9] consumers (Xu, Chan, and Sumner 2023).

The *National Community Solar Partnership* (NCSP), led by SETO with NREL and Lawrence Berkeley National Laboratory (LBNL), was launched in 2019 (DoE 2024a). It aims to power 5 million households with community solar by 2025 and achieve USD 1 billion in energy savings. Key components include technical assistance, stakeholder networks, and peer-learning collaboratives to foster collaboration, disseminate best practices, and improve customer acquisition methods. One such measure is the Clean Energy Connector, developed by the Department of Energy (DOE) and the Department of Health and Human Services in partnership with NREL. This digital tool, launched in 2024 in the DC, Illinois, and New Mexico, makes community solar subscriptions more accessible to *Low-Income Home Energy Assistance Programme* (LIHEAP) recipient households, reducing consumer acquisition costs for community solar programmes (DoE and NREL 2024; DoE 2024b).

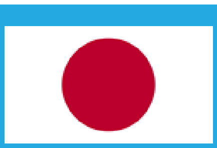
Unlocking synergies with existing government schemes can help community solar programmes reduce consumer acquisition costs

Going forward, the RTS sector in the US will focus on the adoption of equity and incentivising self-consumption

Rooftop solar adopters typically have higher annual incomes than the average population. In 2022, the median income of solar adopters was USD 117,000 per year – 70 per cent higher than the median income of all US households (Forrester et al. 2023). However, solar adoption is gradually shifting towards less affluent households due to falling solar PV prices, attractive financing options, and LMI-focused programmes. Moving forward, federal, and state-level programmes increasingly emphasise equity in RTS adoption. For instance, the Environmental Protection Agency's (EPA) *Solar for All* programme, introduced in June 2023, offers USD 7 billion to close the equity gap in solar access (EPA 2024). In April 2024, the EPA announced 60 selected applicants who proposed customised programmes across all 50 states and territories, with 90 per cent including funding for residential RTS. As states transition to new metering regimes, the focus on self-consumption of generated electricity has increased. States such as Hawaii and California are witnessing high adoption of energy storage due to net metering reforms and resilience concerns. Storage adoption rates have risen for all types of consumers. The IRA 2022 also included battery storage technology as an eligible expenditure for residential solar tax credits.

9 Low-to-moderate (LMI) households are defined as households with income levels lower than 80 per cent of the area median income (AMI), which is the midpoint of a specific area's income distribution.

3.4 Japan: A consistent performer in rooftop solar deployment



Japan has consistently led in distributed solar deployment, with a 39 per cent contribution to the total installed renewable capacity as of April 2024. It achieved 1 GW of RTS deployment within the residential sector in 2022, following the success of its FiT scheme (METI n.d.; REI n.d.).

National targets

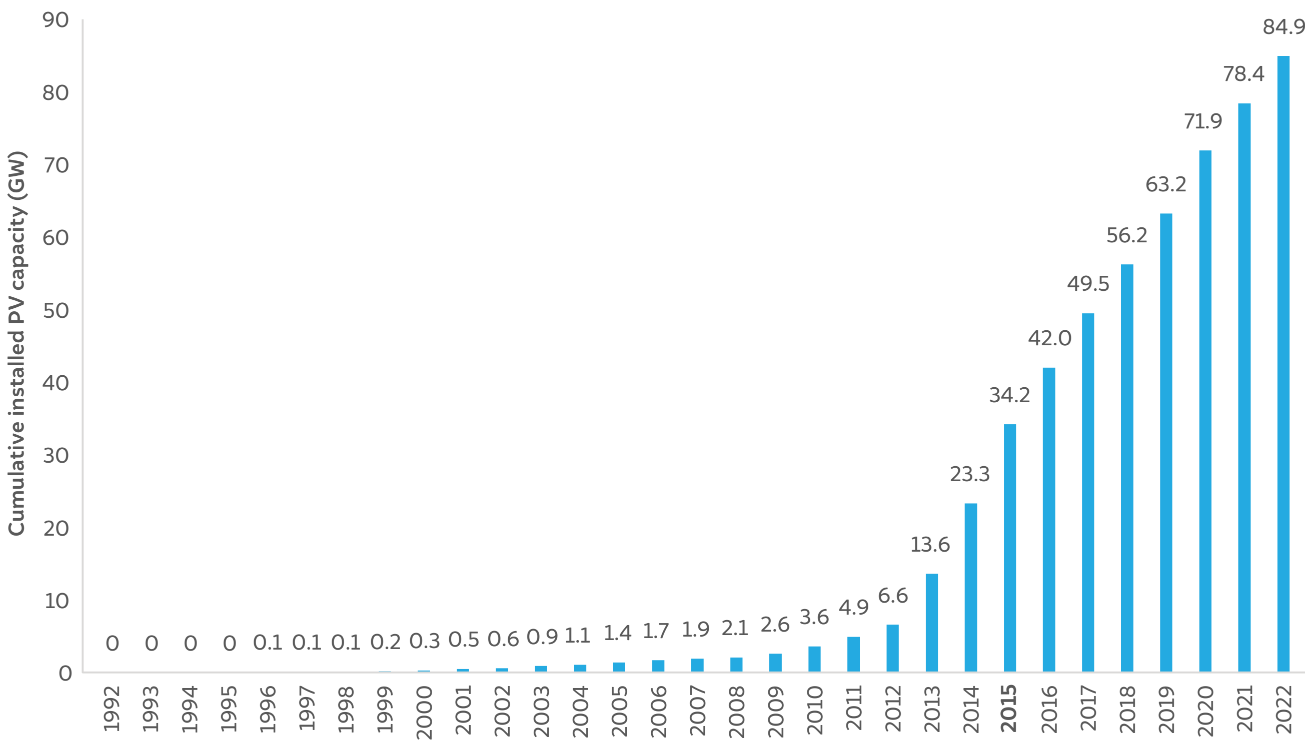
- Japan targets to install 147 GW cumulative PV capacity to meet carbon reduction up to 50% by 2030.
- The country aims to achieve between 36 to 38% share of RE in the energy generation mix by 2030.

Current deployments

- A total capacity of 84.9 GW has been deployed by 2022, with 1 GW in the residential sector.
- The share of renewables in primary energy supply increased to 11% in 2022 from 4.5% in 2000.

Source: Authors' compilation based on data from METI 2021, and REI n.d.

Figure 12 Record capacity addition of 10.9 GW in 2015 following the FiT scheme in Japan



Source: Authors' compilation based on data from IEA-PVPS 2022 and REI n.d

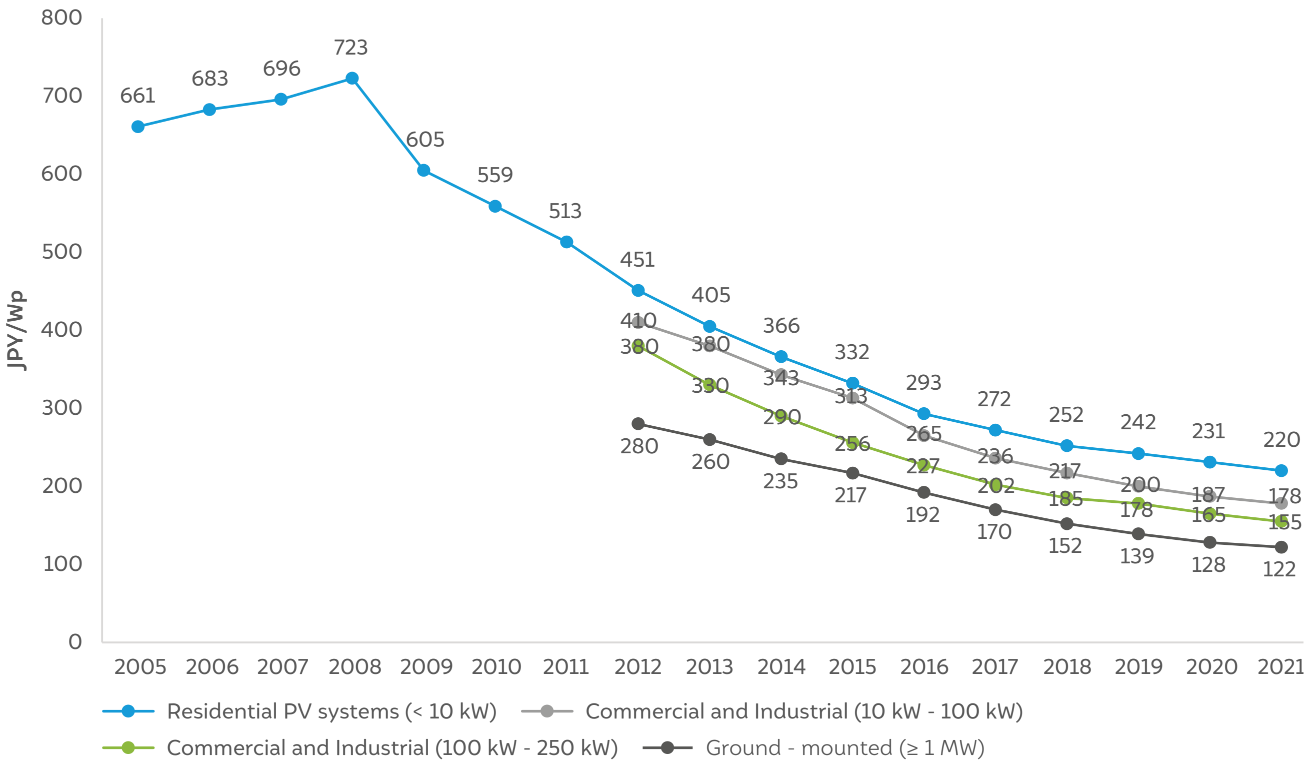
Japan has long been a pioneer in the RE sector, particularly in PV technology. From the 1990s to the early 2000s, Japan was the global leader in PV installation and manufacturing, with companies such as Sharp and Kyocera at the forefront (Hattori and Chen 2021). Furthermore, the Fukushima nuclear disaster in 2011 significantly impacted Japan's energy policies, driving a shift towards RE to address the country's power system vulnerabilities (Figure 12). Consequently, Japan introduced a comprehensive FiT scheme in July 2012 to promote RE diffusion (METI n.d.).

Three major policy and regulatory developments boosted the solar PV segment in Japan

Several vital policies and market mechanisms have shaped Japan's solar PV sector. The initiatives can be divided into four phases, as outlined below:

- **1994–2005: *Residential Solar PV Development Schemes***: Japan launched the scheme targeting residential households in 1994 under the *Sunshine Project* to ensure a reliable energy supply following the impact of the oil shock in the 1970s. The programme offered a capital subsidy equivalent to one-third of the installation cost and a maximum of JPY 340,000 /kW (USD 2,585/kW) for system sizes up to 4 kW. The programme resulted in a tenfold increase in installations. However, following the programme's discontinuation, annual installation capacity declined from 260 MW in 2005 to 180 MW in 2007, indicating that the deployment was driven by subsidies (METI n.d.).
- **2009–2012: *Buyback Programme for Photovoltaic Generation***: To revitalise its growth and respond to increasing RE commitments after the Kyoto Protocol, Japan introduced the *Buyback Programme for Photovoltaic Generation* on 1 November 2009. The programme aimed to purchase the excess power supplied by PV systems at a fixed price for ten years. The initial purchase price was set at JPY 48/kWh (USD 0.36/kWh) for households (less than 10 kW) and JPY 24/kWh (USD 0.18/kWh) for others. For private power generators, the prices were JPY 39/kWh (USD 0.3/kWh) and JPY 20/kWh (USD 0.15/kWh), respectively. The declining PV system also supported the programme's success costs over the years, as shown in Figure 13.

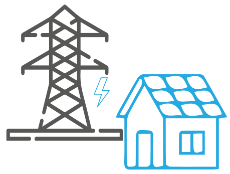
Figure 13 Residential solar PV module cost reduced to 57% during the last decade in Japan



Source: Authors' compilation based on data from IEA-PVPS 2021

- **2012–2019: Feed-in tariff scheme**: Following the Great East Japan Earthquake in Tōhoku and the subsequent Fukushima nuclear disaster in 2011, there were concerns regarding energy security. The nuclear disaster resulted in blackouts, the suspension of all nuclear plants, and a 25 per cent increase in electricity tariff (Mori 2017). This prompted the announcement of a FiT scheme in 2012 as part of the *Act on Purchase of Renewable Energy Sourced Electricity by Electric Utilities* to accelerate the deployment of RE. Under the scheme, the FiT was fixed for systems less than 10 kW for ten years and systems greater than 10 kW for 20 years. FiT of JPY 42/kWh (USD 0.32/kWh) was offered to residential households, whereas JPY 40/kWh (USD 0.3/kWh) was provided to non-residential households (METI n.d.). The purchase cost was passed on to all consumers, except large electricity consumers and those impacted by the earthquake. The favourable FiTs helped reduce PV system costs, as shown in Figure 13 (Hattori and Chen 2021; METI n.d.). During this period, increasing domestic demand and high module costs of Japanese manufacturers led to the entry of international companies from China and Taiwan to cater to the domestic market, particularly for large-scale PV. Domestic manufacturers still serve the residential segment due to the high quality and easy financing options available for Japanese systems (Hattori and Chen 2021).

  In 2015, Japan set a target to achieve 80 GW of cumulative installed PV capacity by 2030. However, the target was revised upwards to 147 GW by 2030. Japan witnessed a record addition of 10.8 GW in 2015 but showed a downward trend with declining FiTs – the rates decreased over the years to JPY 24/kWh (USD 0.158/kWh) for systems less than 10 kW and JPY 14/kWh (USD 0.099/kWh) in 2019. FiTs are funded through a surcharge on electricity paid by all consumers. A high FiT exerted upward pressure on the surcharge and increased retail power prices, impacting the financial stability of utilities as well. As a result, the FiT programme was phased out in 2019.



Feed-in tariff scheme accelerated the RTS deployment in Japan

- **Transition to feed-in premium**: Feed-in premium (FiP) aims to provide a more market-oriented approach to RE support, fostering competition and efficiency while promoting deployment of RTS installations. FiP was introduced in April 2022 with an option for solar power producers to sell their electricity directly on the wholesale market or through bilateral contracts rather than at a fixed FiT rate. The scheme aims to ensure that solar producers are more responsive to market signals and integrate better into the overall energy market. The government provides a premium on top of the market price of electricity. This premium ensures that the total revenue (market price + premium) meets a predetermined level that makes solar investments viable. The market premium stabilises the revenue for the market; that is, if market prices are high, the premium decreases, and if market prices are low, the premium increases. The specifics of eligibility criteria, premium rates, and the duration of support are determined by government regulations and can vary based on factors such as system size and technology.

  According to the Ministry of Economy, Trade and Industry (METI), this will initially impact 530,000 homes (or 2 GW of PV systems) and is expected to increase to over 1.65 million homes (or 6.7 GW of PV systems) as utilities stop purchasing excess electricity. Following the deregulation of the electricity market, homeowners have the option to sell excess power in the market. This helps to set the remuneration level linked to current electricity prices (METI 2021; SolarPower Europe 2023).

Future outlook for Japan's distributed solar sector

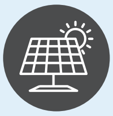
Japan is promoting its energy transition with a focus on distributed energy sources by raising its RE targets. The PV market is expected to grow from 2023, driven by residential and industrial rooftop markets, PV mandates for new buildings, and new corporate renewable PPA models. Declining module prices support deployment across all segments, making rooftop projects comparable to ground-mounted ones. Long-term cost reductions will further integrate solar power into the energy system, complementing peak daytime demand and enhancing consumer participation in energy management.

3.5 Australia: Rooftop solar as a critical driver of renewable energy generation

Australia is one of the leading countries in RTS, contributing 10 per cent to the country's total electricity consumption in 2023. Nearly two-thirds of installations are RTS, and one out of every three homes in Australia has installed an RTS PV system (Reuters 2024). Australia has an RTS potential of 179 GW (Roberts et al. 2019).

National targets

- The *2024 Draft Integrated System Plan* forecasts 36 GW of RTS by 2030 and 86 GW by 2050.
- The country-wide target is 82% RE penetration by 2030; individual state targets range between 50 and 100%.

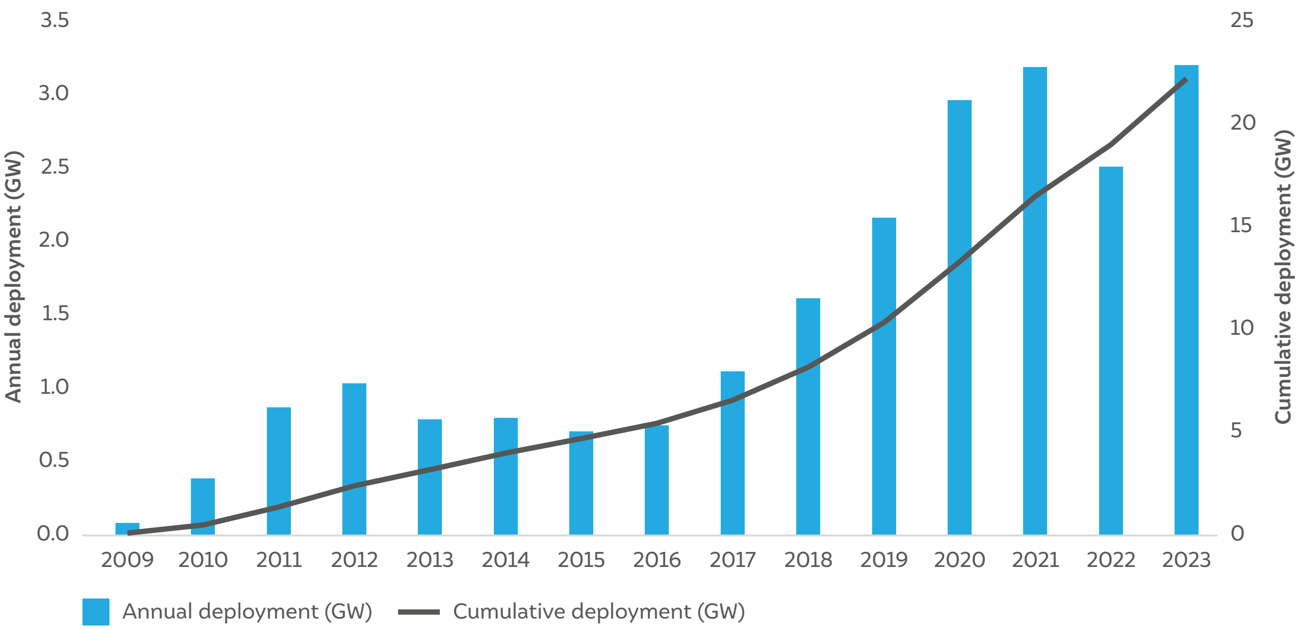


Current deployments

- RTS installed capacity is 22.2 GW, which generated 27,908 GWh in 2023.
- Between 2011 and 2023, the average size of a new system grew from 2.5 kW to 8 kW (residential) and from 7 kW to 30 kW (C&I).

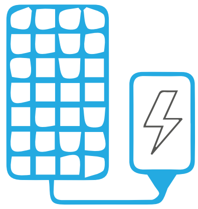
Source: Authors' compilation based on data from Australian Energy Statistics 2024

Figure 14 RTS contributes approximately 30% to the RE mix with an installed capacity of more than 22 GW



Source: Authors' compilation based on data from Australian Energy Statistics 2024

Australia is widely regarded as a leading success story in RTS. Early policy interventions were crucial, but the sector also benefited from abundant land, falling solar PV prices, increasing electrification of energy services, and high retail electricity tariffs. Attributing RTS deployment to a specific factor in any given year is challenging, as previously installed systems may influence new adoption. Nevertheless, Figure 14 outlines three phases of Australia's RTS journey: an initial boom from 2010 to 2012, a brief slowdown from 2013 to 2016, and a sustained increase from 2017 onwards (except in 2022). Critical policy interventions and market conditions during these periods help clarify the outcomes of these policies compared to their intended goals.



Interventions such as higher FiTs and the *Solar Energy Credit programme* made RTS lucrative in the initial phase

Rooftop solar boom led by policy push at state and national levels

The first surge in RTS deployments in Australia occurred in the late 2000s when state governments offered retail consumers fixed FiTs. While most states provided FiTs for excess generation, New South Wales (NSW) and the Australian Capital Territory (ACT) offered gross metering, and Tasmania offered compensation equal to the retail electricity tariff (net metering). In 2010, FiTs ranged from 40 to 60 ct/kWh, while average retail tariffs ranged between 15 and 25 ct/kWh for residential consumers and 20 and 30 ct/kWh for businesses (Chapman, Tezuka, and McLellan 2016; Economic Regulator 2010). The higher FiTs, especially under gross metering, made solar installations highly lucrative, with a lock-in period of 15 to 20 years. Consumers also benefited from the federally administered solar credit multiplier, part of the *Renewable Energy Target* (RET) programme, which offered up to five times the incentives for RTS systems compared to utility-scale projects. Consequently, installed RTS capacity grew from 117 MW to 2,415 MW between 2009 and 2012.

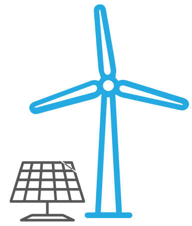
The rising electricity tariffs further drove the rapid adoption of RTS. For example, the average household electricity tariff in NSW nearly doubled from 15 ct/kWh in 2008 to 29 ct/kWh in 2013, and in Queensland, tariffs rose from 13 ct/kWh in 2008 to 25 ct/kWh in 2013. This increases outpaced income growth, making electricity more expensive in real terms (Simshauser, Gilmore, and Nelson 2022). Although rising tariffs incentivised RTS adoption, policymakers were concerned that FiTs and the solar credit multiplier contributed to higher retail electricity tariffs, creating inequity between solar adopters and non-adopters. As a result, most states phased out these lucrative FiT programmes for new entrants by 2013.

Mandating renewable energy generation through the *Renewable Energy Target* programme

Initially instituted in 2001, the mandatory RET aimed for a 2 per cent share of renewables in Australia's electricity mix, which was raised to 20 per cent by 2009. Renewable power plants received renewable energy certificates (RECs) for each megawatt-hour (MWh) of electricity generated to achieve the RET. Power plant owners sold these RECs to electricity retailers, who were mandated to procure certificates proportional to their sales. Unlike in India, where RECs cover shortfalls in actual REC procurement, these certificates were central to meeting the mandates, with their price determined by market supply and demand. In June 2009, the *Solar Energy Credit* programme was introduced within the RET scheme, offering a fivefold certificate multiplier for the first 1.5 kW of installed RTS. This meant prosumers received 5 RECs per MWh for the first 1.5 kW of generation and 1 REC per MWh for additional generation. This programme, combined with FiTs, spurred a boom in RTS deployment but led to an oversupply of RECs, reducing their market price and utility-scale RE incentives.

Targeting RTS generation with the introduction of *Small-scale Renewable Energy Scheme*

In 2011, the RET was divided into *Large-Scale Renewable Energy Targets* (LRET) for utility-scale plants and the *Small-scale Renewable Energy Scheme* (SRES) for small-scale RE, including RTS. RECs were replaced by small-scale technology certificates (STCs) for RTS systems, and the *Solar Energy Credit programme* became part of the SRES, administered by the Clean Energy Regulator (CER). Typically, the SRES covered about one-third of the RTS system's upfront cost (Residential Electrification 2023). The details of the components of SRES are explained in Annexure 10. Although the SRES will operate until 2030, the Solar Energy Credit multiplier was phased down from fivefold to threefold in June 2011 to twofold in June 2012. It was phased out entirely by December 2012. The simultaneous phase-out of state-provided FiTs and the Solar Energy Credit led to stagnation in annual RTS deployments, particularly between 2013 and 2016.



Australia's *Small-scale Renewable Energy Scheme* typically covers about one-third of the RTS system's upfront cost

Renewed focus on rooftop solar with revised policy interventions

As RTS experienced a slowdown, states revised their FiT policies. Instead of state-provided fixed FiTs, retailers began offering FiTs as part of their overall consumer packages, balancing the interests of both RTS adopters and non-adopters. Although these retailer-offered FiTs are lower, they are more sustainable in the long run. The SRES has continued supporting RTS deployment and contributed to falling PV module costs, increasing market maturity, and sustainable market-driven incentives. Starting in late 2016, the rebound was driven by aggressive marketing from PV developers highlighting the impending reduction in SRES allowances, as well as events such as the 2016 South Australia blackout and the 2017 closure of the Hazelwood Power Station, which increased wholesale electricity prices (Brazzale 2017). In 2017, RTS deployment surpassed 1.1 GW, breaking the 2012 record. Since 2019, at least 2 GW of RTS has been installed annually, with record years in 2023 (3.21 GW) and 2021 (3.19 GW). This growth has been driven by increasing individual system sizes, with average capacity rising from 7 kW to 10 kW over five years (refer to Annexure 9 for in-depth trends in average system sizes). While most systems are still 5 kW to 10 kW, the share of 10 kW to 15 kW systems has grown from 9 per cent to 39 per cent. Significant developments are summarised in Figure 15.

Figure 15 Australia has witnessed phase-wise RTS development through the evolution of the SRES and feed-in tariffs

2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Mandatory *RE Target* (2001-2010)				*Small-scale Renewable Energy Scheme* (2011-2030)												
No RTS multiplier (1x)		5x certificate multiplier		3x	2x	No RTS multiplier – STCs for 15-year generation				No RTS multiplier – STCs for generation until 2030						
No FiTs	State FiTs introduced			State FiTs reduced		Retailer –offered FiTs										

Policy interventions | RE certificate multiplier | Feed-in tariff

Source: Authors' compilation based on data from Chapman, Tezuka, and McLellan 2016, and CER

Creating an enabling environment beyond incentives through the *Solar Panel Validation Initiative*

The impressive growth of the RTS sector, reaching 3.7 million systems by 2023, has increased the risk of poor-quality installations. Poor performance from such systems reduces benefits for prosumers and diminishes the impact of the corresponding STCs on-grid penetration. The CER mandates standards and best practices for STC issuance manufacturers, importers, retailers, installers, and designers to ensure quality. Manufacturers and importers must have PV modules and inverters approved by the Clean Energy Council (CEC), with each component assigned a serial number for verification. Rooftop solar retailers must communicate their scope of work, system performance, accredited installer details, and financial benefits (including FiTs, export limits, savings, and payback periods) to prosumers, maintaining records for up to five years to reduce information asymmetry and enable informed decision-making. In addition, installers must be accredited by Solar Accreditation Australia (SAA) and ensure system components are CEC-approved, providing photographic evidence of their presence during installation. Disputes over STCs, particularly regarding their creation and value, are handled by national and state institutions such as the Australian Competition and Consumer Commission (ACCC).

The accreditation of RTS installers and the initiative for solar panel validation can act as quality checks

The *Solar Panel Validation* (SPV) *Initiative* by CER includes a mobile app for verifying system components and installations. Manufacturers or importers share product data with participating apps by paying an app fee, and installers or prosumers use the app to scan barcodes for authenticity and quality checks. This mandatory validation process benefits manufacturers and facilitates the creation of STCs by allowing retailers and installers to submit required proofs through the app, thus expediting the creation of STCs.

Shifting gears from deployment to improved access to RTS and ensuring network stability

While Australia is a leader in RTS deployment, there is significant room for growth. Households account for 69 per cent of installations, but only 25 per cent of residential RTS potential has been achieved, according to a study by the Australian PV Institute (Solar Citizens 2024). Low-income households, apartment dwellers, and renters have limited access to RTS benefits. To address this, the Australian government is investing USD 100 million to support state-level interventions to provide RTS access to 25,000 households. These interventions include rebates, subsidised loans for shared solar on building rooftops, community solar projects, and solar subscription models (DCCEEW 2024b). Electricity consumption in Australia has remained stable, but the push towards electrifying energy services such as heating, cooking, and mobility is expected to increase per capita consumption. The rise in average system size indicates that consumers anticipate higher electricity use. This trend is crucial for the RTS sector's development post-SRES, with lower FiTs making grid demand substitution the main incentive for installation.

High RTS penetration poses risks to network stability, especially in the afternoons when solar generation is high, and demand is low, notably in states such as South Australia. High evening ramping requirements have increased the market power of gas generators (Jha and Leslie 2020). To better integrate RTS into the grid, various strategies are being promoted by states and the national government. Battery deployment is incentivised in the ACT, Northern Territory, Queensland, Victoria (Solar Victoria 2024), and South Australia (Government of Australia n.d). The Australian government has allocated USD 200 million to subsidise community-level battery deployments (DCCEEW 2024a). In South Australia, all systems installed after October 2020 must be remotely disconnectable by the network operator in emergencies (GSA 2024). Business models for 'virtual power plants' are also being trialled, where aggregators pay consumers for control over their distributed energy resources (including RTS, batteries, and loads) and are compensated for balancing supply and demand on the grid (Bruce et al. 2024). These diverse interventions are crucial for maximising RTS deployments while ensuring a reliable electricity supply for all consumers in Australia.

3.6 Italy: Rooftop solar growth driven by feed-in tariffs and tax incentives

Italy has an RTS potential of 120 GW (Moser and Mazzer 2021). It is the third-largest solar market in Europe. The country added nearly 5 GW of solar capacity in 2023 (Casey 2024) and aims to produce 74 TWh of electricity from solar by 2030 (Mordor Intelligence 2024).

National targets

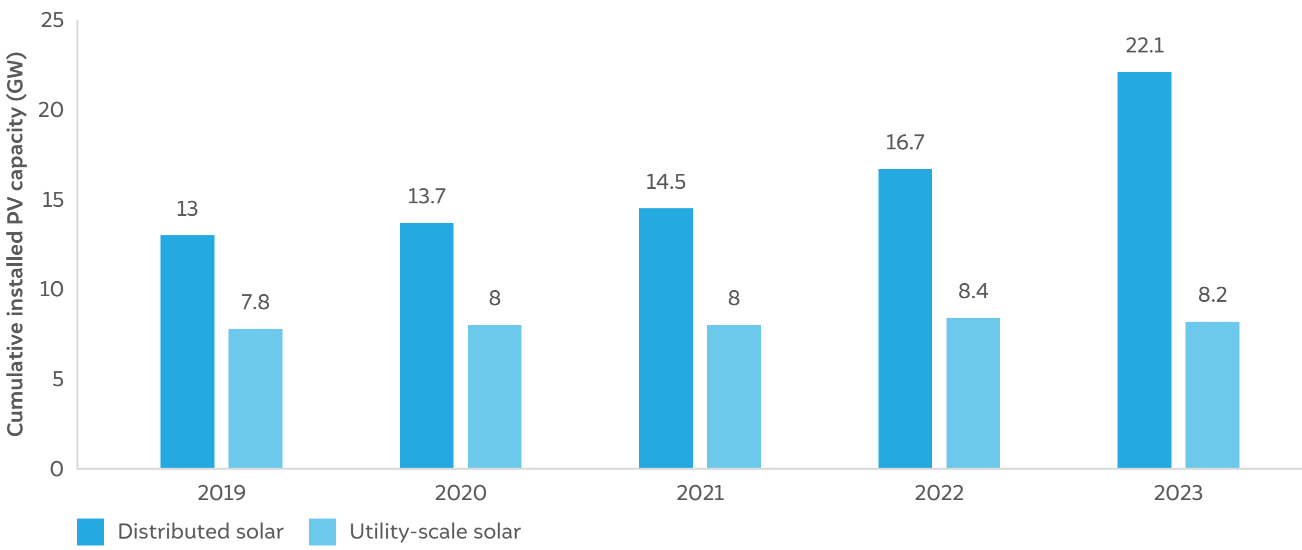
- Italy targets to reach 80 GW of total solar PV capacity by 2030, as per the National Energy and Climate Plan (NECP) it submitted to the EU.

Current deployments

- As of 2023, Italy's total cumulative solar installed capacity reached 30.3 GW.
- Distributed solar installations contribute 22 GW (~72.9%) of the total solar PV installation.

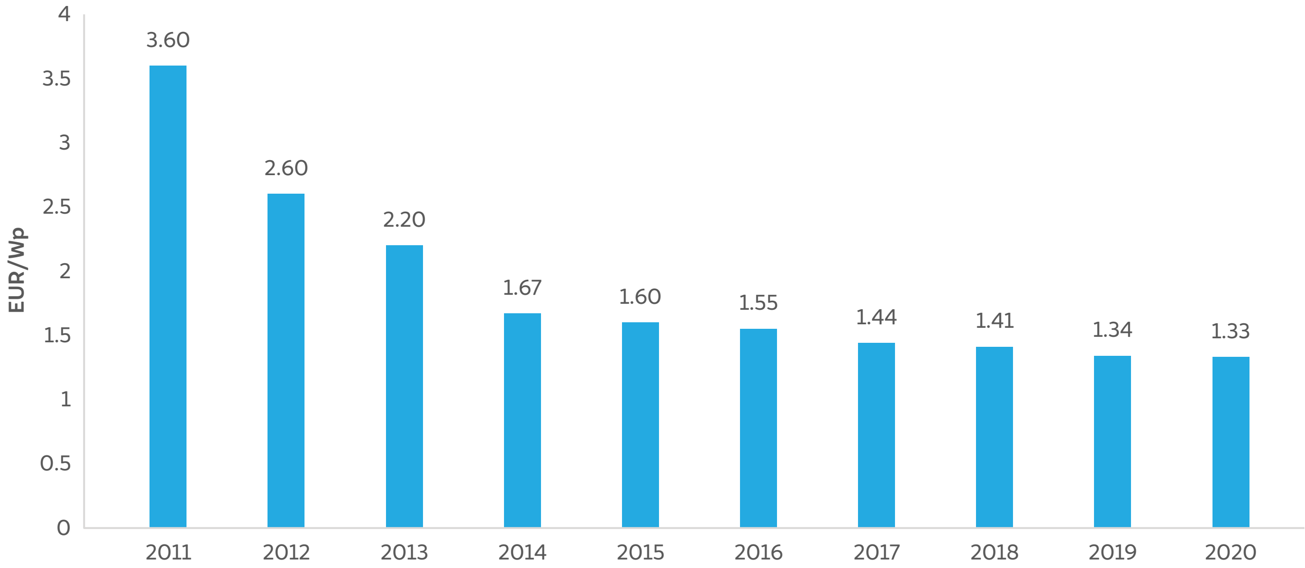
Sources: Authors' compilation based on data from Ministry of the Environment and Energy Security 2023, Statista 2024, Eniscuola 2022, and Bellini 2024

Figure 16 Distributed solar leads the deployment in Italy



Source: Authors' compilation based on data from Statista 2024, Eniscuola 2022, and Bellini 2024

Figure 17 Solar PV module cost reduced significantly over the last decade



Source: Authors' adaptation based on data from IEA-PVPS 2020

Distributed or RTS installations have played a key role in Italy's solar capacity addition over the years, as shown in Figure 16. The adoption of RE in the EU began with the directive (2001/77/EC) from the European Parliament and the EU Council, which mandated member countries to set targets for RE consumption, prompting all members to embrace RE (European Communities 2001).

Solar energy adoption in Italy accelerated in 2005 with the introduction of the *Italian Energy Bill* (2005–2007), which offered tariff incentives for solar plants with capacities between 20 kW and 50 kW (Ministry of Productive Activities 2005; Orioli 2016). The initial target was 0.5 GW, but due to a high market response, it was revised to 1.2 GW under the *Second Energy Bill* (2007–2009). The RTS target was reached ahead of schedule, leading to the launch of the *Salva Alcoa Act* in August 2010 to incentivise all solar plants commissioned before the end of 2010. Subsequent energy bills (third in 2010–2011 and fourth in 2011–2012) under the FiP tariff mode aimed for a 4 GW capacity (Ministry of Economy and Finance 2010). However, with the reduced cost of solar modules, the *Fifth Energy Bill* (2012–2013) transitioned to a FiT mode, encouraging self-consumption over energy export. High premiums during these periods increased Italy's energy expenditure by 30 per cent, leading to the closure of the *Energy Bill* programme (Orioli 2016).

Market-linked *FER-1 Scheme* accelerated solar capacity addition through FiT and FiP mechanism

The *Energy Bill* programme accelerated solar capacity in Italy through FiP and FiT, resulting in 526,000 projects generating 24,676 GWh annually, contributing 9.1 per cent of electricity production and 7.8 per cent of total consumption at the end of 2013 (Yzquierdo 2020). However, high incentives increased the government's energy burden. Consequently, a market-reflective policy framework was needed due to the falling module cost (see Figure 17) and system costs for RTS installations.

In 2019, the Italian government launched the *FER-1 Decree* to support 4.8 GW of new renewable capacity until 2021, offering incentives of EUR 1 billion per year (USD 1.08 billion per year) (Dentons 2020). Projects over 20 kW were eligible, with those up to 1 MW approved based on environmental and economic criteria, while larger projects were selected through competitive bidding. The decree prioritises public buildings, nationally important plants, EV charging facilities, and the refurbishment of older plants.

Hourly premium offered as an incentive under the *FER-1 Scheme*

Projects selected under the scheme receive a premium on the hourly zonal tariff based on the region in which the plant is installed. In any case, the premium cannot exceed the difference between the actual tariff realised for the plant and the zonal hourly market price of the technology category to which the plant belongs.

Table 1 Generous premium tariff up to 1000 kW PV power plant under *FER-1 Scheme*

Source	Power (kW)	Overall premium tariff limit (EUR/MWh)	Plant average lifecycle (years)
PV solar	20 < plant capacity ≤ 100	105 (USD 113/MWh)	20
	100 < plant capacity ≤ 1000	90(USD 97/MWh)	20
	Plant capacity > 1000	70 (USD 75/MWh)	20

Source: Authors' compilation based on data from Dentons 2020

With the incentive provisions given in Table 1, there was an additional incentive premium of EUR 12/MWh (USD 13/MWh) for solar projects installed in schools, colleges, hospitals, and other public buildings. Solar projects must be completed within 19 months to obtain these incentives.

Italy's tax exemption programme for rooftop solar adoption in the residential sector

The Italian government ended the FiT in 2013 with the expiry of the *Fifth Energy Bill* to promote self-consumption and reduce energy procurement costs, leading to stagnation in RTS adoption (Orioli 2016). The *Ecobonus Decree* in 2013 offered tax credits for residential solar systems up to 20 KW to accelerate solar adoption, with a 50 per cent tax credit for PV installations and 65 per cent for solar hot water systems, capped at EUR 96,000 (USD 1,03,603) per installation and reimbursed over ten years (Abruzzo 2013).

In 2020, the *Super Bonus* 110% policy was introduced to revive the economy post–COVID-19 (Iven De Hoon. 2017). The scheme was launched in July 2020 under Italian decree DL 34/2020. Under the scheme, consumers can receive 110 per cent tax relief for solar PV system installation as part of home improvements by claiming benefits under the energy efficiency or seismic resilience programmes. Households can install a solar system for self-consumption up to 20 kW. The maximum allowed expense for the 20 kW system cannot exceed EUR 48,000 (USD 51,800), i.e., EUR 2,400/kW (USD 2,590/kW). To receive tax relief, consumers must agree to sell the excess solar generation to the Gestore dei Servizi Energetici (GSE) and cannot benefit from other schemes for electricity generation. The policy was a massive success in Italy. By April 2022, approximately 12,200 applications had been approved by the government with an investment of EUR 21 billion (USD 22.6 billion). The scheme helps to boost the Italian GDP by creating significant job opportunities: 4,10,000 in the housing sector and 2,24,000 in the manufacturing sector. More details about the *Super Bonus* 110% policy are elaborated in Annexure 11.

Despite its success, the policy created a significant financial burden on the government (USD 119 billion) and faced corruption allegations, leading to its discontinuation on 31 March 2023. The policy was amended with a decree titled *Decreto Aiuti Quarter* (Amendment to the Subsidies Decree) to reduce the tax relief to 90 per cent after 1 January 2023, with plans to further reduce it to 70 per cent in 2024 and 65 per cent in 2025 (N26 2023). The newly amended policy details are elaborated in Annexure 12; other policy interventions to support rooftop solar installation are listed in Annexure 13.

Way forward for the Italian rooftop solar market

The increased distributed solar capacity in Italy's energy mix necessitated greater flexibility in the power system and electricity markets. The Italian regulator ARERA developed models for system flexibility, while transmission operators such as TERNA initiated projects for grid balancing, demand management, and energy storage for ancillary services. Italy is modernising its power system by adopting digital demand-driven networks (3DEN) and ISGN technologies to support the accelerated adoption of distributed RE.

3.7 Brazil: Residential solar revolution driven by PV bonus project and innovative net metering scheme

Brazil's solar potential is approximately 307 GW (NEP 2018). In 2023, solar PV witnessed significant growth, with a monthly growth rate of approximately 1 GW. Solar PV contributed approximately 17 per cent to Brazil's electricity mix in 2023 (ABSOLAR 2024).

National targets

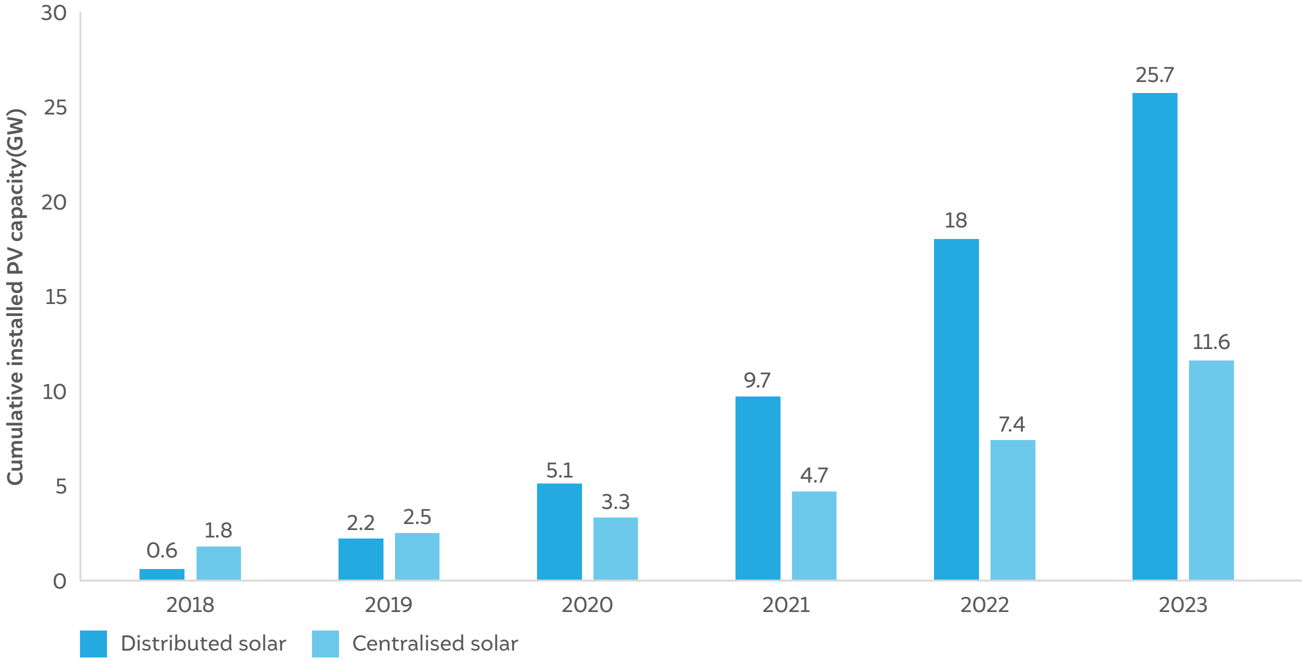
- By 2027, Brazil aims to achieve 50–60 GW of total PV capacity, including ~55% of distributed PV.
- It also aims for a 45% share of RE in the energy mix by 2030.

Current deployments

- As of 2023, the installed solar PV capacity was 37 GW, including 25 GW of distributed PV.
- Approximately 2.5 million on-grid distributed PV systems have been installed (as of March 2024).

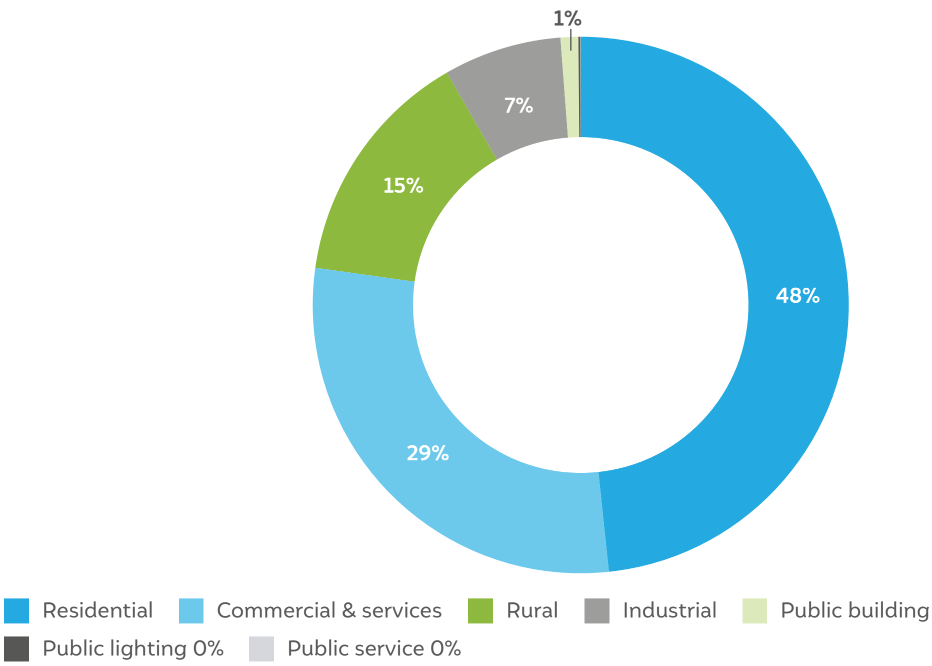
Source: Authors' compilation based on data from NEP 2018, ABSOLAR 2024, and SolarPower Europe 2024

Figure 18 Distributed solar contributes approximately 70% of total installed PV capacity in Brazil



Source: Authors' compilation based on data from ABSOLAR 2024

Figure 19 The residential segment leads the RTS deployment



Source: Authors' compilation based on data from ABSOLAR 2024

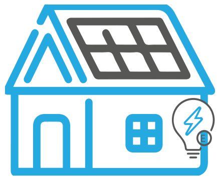
Since 2021, Brazil has been the only country in Latin America to rank among the top ten globally in annual installed solar PV capacity. The Brazilian RTS sector has seen substantial growth (see Figure 18), driven by the net metering scheme and small-scale energy efficiency programmes[10] that have increased consumer awareness.

10 As per Law nr. 9,991, 2000, public electricity distribution companies must invest 0.5 per cent of their net operating revenue in energy efficiency measures. This is mandated by the Energy Efficiency Programme, regulated by ANEEL, which aims to promote efficient electricity use, enhance energy-efficient equipment, and stimulate market transformation and new technologies.

Decentralising Brazil's power sector and evolution of the net metering scheme

Until 2011, Brazil's power system was highly centralised and heavily reliant on hydropower (approximately 82 per cent) for electricity generation (EPE 2012). Frequent droughts, such as the severe 2011–2012 drought, reduced reservoir levels and significant power shortages. Additionally, the long distances between power generators and consumers caused supply bottlenecks. Brazil introduced a net metering scheme for small-scale DRE to address these issues in April 2012 (ANEEL 2012). This scheme targeted both residential and C&I consumers, allowing them to use self-generated electricity or inject surplus energy into the grid for credits to offset future bills. A minimum charge is applied[11] if the net billing amount is lower than the minimum payable amount (see Annexure 14).

From 2012 to 2015, only 478 PV systems were installed (Kılıç 2022), mainly due to the Goods and Services Tax (ICMS) on self-generated energy, which extended payback periods, and the lack of community or shared generation provisions. In response, policymakers revised the scheme in 2015 to include a community solar concept, a shared net metering model, and ICMS tax exemptions (ANEEL 2015). Despite these revisions, the distributed segment struggled to gain momentum until the *Celesc PV Bonus Project* in 2017 revitalised interest and growth (Antoniolli et al. 2022).



Utility led rooftop solar programme has laid the foundation for Brazil's rooftop solar development and energy transition

Unlocking residential solar potential: The *Celesc PV Bonus Project* (2017)

The *Celesc PV Bonus Project* is a critical driver in Brazil's distributed solar PV development. Carried out by Celesc, a utility company in Santa Catarina, the project aimed to encourage single-family residential consumers to adopt self-consumption, increase awareness of distributed PV benefits, and promote energy efficiency. The project offered a 60 per cent discount on PV system costs through the *Celesc Energy Efficiency Programme*. Initially targeting 1,000 residential consumers, the project received over 14,000 registrations within 48 hours. Consumers benefited from annual electricity bill savings of approximately USD 2,000 under this scheme (ENGIE 2017). This scheme became a pioneer in promoting DG with a granted bonus, generating strong word-of-mouth in the small state. The active involvement of distribution utilities in promoting distributed PV garnered national attention, changing consumer perceptions and advancing Brazil's energy transition.

Understanding the key enablers for residential solar adoption

After the success of the *Celesc PV Bonus Project*, increasing retail electricity tariffs boosted the adoption in the residential sector. The retail electricity price in Brazil is relatively high in the residential segment (USD 0.162/kWh) compared to the average (USD 0.160/kWh as of 2022), mainly due to the electrical energy social tariff (TSEE), which cross-subsidises approximately 18 million low-income households through higher charges for residential and C&I consumers. Additionally, supplying electricity to remote Amazon regions costs Brazil approximately USD 2 billion annually, further impacting tariff rates. As a result, the LCOE for residential distributed PV is about 1.5 times lower than the average. Declining PV system costs, and high electricity prices have pushed residential consumers to adopt distributed PV. The residential sector now accounts for approximately 48 per cent of installed distributed PV (ABSOLAR 2024) (see Figure 19). Without government capital subsidies, consumers bear all upfront costs, with half of the installed RTS systems financed by Engineering, Procurement, and Construction (EPCs) or banks at interest rates between 14 and 20 per cent. Despite high interest rates, high electricity tariffs result in an average payback period of 3–5 years.

11 As per the law NR 1000, the minimum value charged to the consumers is based on a minimum amount of energy and the type of connection with the DISCOM.

With over 20,000 EPCs in the country, fair pricing and service availability are ensured for consumers. EPCs actively raise consumer awareness through billboards and public campaigns. In addition, their ease of accessibility provides crucial technical and regulatory support, including ideal system size, application processing, financing, etc., facilitating adoption. Besides, the online application process for DG typically takes about a month to complete, which further facilitates adoption.

Revised net metering scheme eliminates cross-subsidy, ensuring fair compensation

In Brazil, the existing net metering regime does not include the distribution system use tariff (TUSD) for energy injected into the grid by DG consumers, a cost borne by non-DG consumers. DISCOMs argue that this system does not adequately compensate for using the distribution network or allow cost transfer to other consumers. Consequently, in a 2020 regulatory review, the government reconsidered the valuation of energy injected into the grid. In 2022, Brazil revised its net metering scheme (Figure 20), ending the cross-subsidy by excluding the TUSD Fio B[12] tariff component from compensation (see annexures 14 and 15). The new policy provides legal certainty for investors and consumers, allowing benefits until 2045 (ANEEL 2022).

Brazil gradually transitioned to the new net-metering scheme in 2023 to retain new consumers confidence on perceived benefits than previously subscribed consumers

The government announced a gradual transition to the new net-metering scheme starting in 2023, ensuring that new consumers do not perceive fewer benefits than previously subscribed consumers. The transition depends on the date of the grid access request or specific project characteristics. The new tariff mechanism under revised net metering rules is elaborated in Annexure 16. In 2022, Brazil also initiated the *Social Renewable Energy Development Programme* (PERS), dedicated to low-income households, and financed by the *Energy Efficiency Programme* (PEE). PERS promotes RE investments for low-income residential subclasses, offering loans with a 2 per cent interest rate (ANEEL 2022).

Leveraging existing social schemes as a way forward to accelerate rooftop solar deployment

Distributed PV installations in Brazil have been consistent over the last few years. Although recent regulatory changes caused a temporary slowdown, declining PV costs ensure a viable payback period, encouraging adoption. The Brazilian government also relaunched the *Minha Casa Minha Vida social* housing programme, aiming to build 2 million homes for low-income households by 2026 and deploy 1 kW of solar power per household, resulting in 2 GW of installations (Secretariat of Social Communication 2024). With ongoing progress and new policies, Brazil is poised to continue leading Latin America's distributed solar PV market.

12 TUSD-FioB is the tariff for the use of the distribution system without accounting for the system losses, as well as the use of the transmission system and government or sectoral charges.

Figure 20 Brazil revised its net metering scheme to end the cross-subsidization structure

	2012	2015	2022
Capacity limit	100 kW for mini and 1 MW for micro	75 kW for mini and 5 MW for micro	75 kW for mini and 3 MW for micro (non-dispatch able source) & 5 MW (dispatchable source)
Settlement period	36 months	60 months	60 months
Business model	Local net metering, virtual net metering	Local net metering, virtual net metering, group net metering, shared community solar	Local net metering, virtual net metering, group net metering, shared community solar
Tariff compensation	Compensation for excess power generation to all tariff components	Compensation for excess power generation to all tariff components	Compensation for excess power generation is exclusively on the energy tariff

Source: Authors' compilation based on data from ANEEL 2012, 2015, and 2022

3.8 India: Rooftop solar as a key lever for achieving a people-centric energy transition

India has 637 GW of RTS potential in the residential sector (Zachariah, Tyagi, and Kuldeep 2023). As of March 2024, cumulative installed solar capacity stands at 81.9 GW, out of which 11.9 GW is grid-connected RTS. India has the fifth-largest solar power capacity globally and is the eighth-largest in terms of distributed PV installations.

National targets

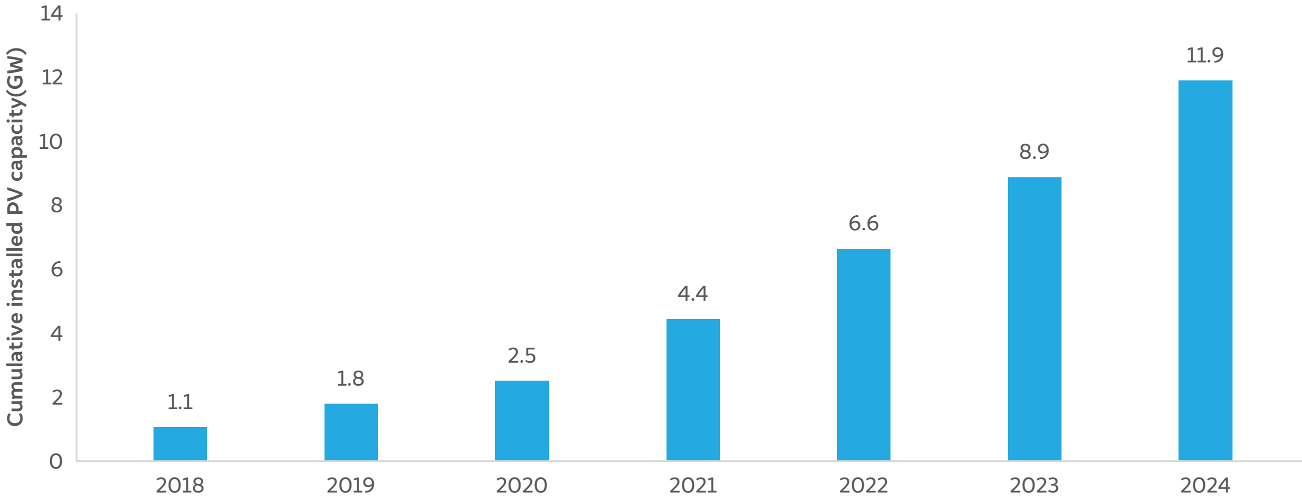
- India aims to achieve one crore RTS installations in the residential sector and install 30 GW of cumulative RTS capacity by 2026–27.
- India's Nationally Determined Contribution (NDC) includes a target to achieve 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

Current deployments

- The total grid-connected RTS capacity as of March 2024 is 11.9 GW. According to market sources, 25% of the RTS capacity is concentrated in the residential sector.
- Gujarat holds the highest deployment at 3.45 GW among of all the states and UTs, followed by Maharashtra at 2.07 GW as of March 2024.

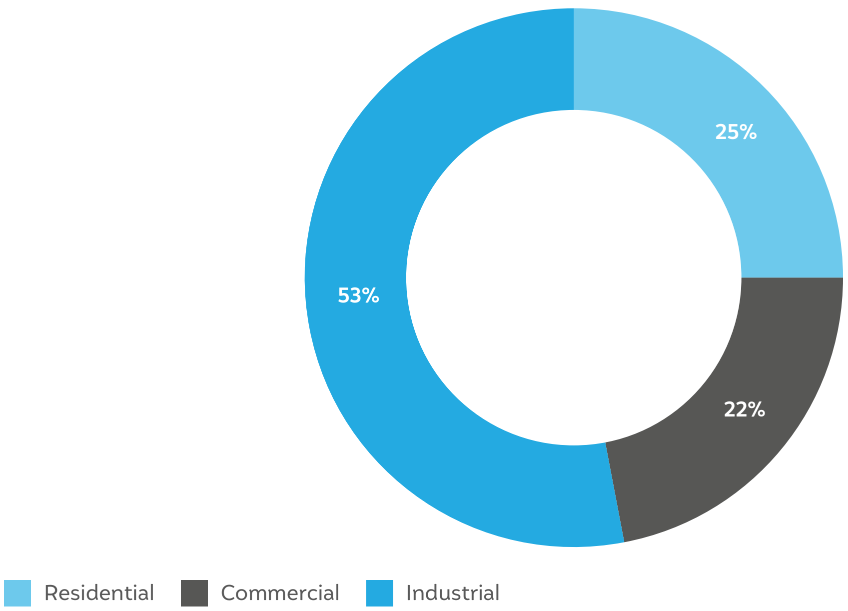
Source: Authors' compilation based on data from Bridge to India 2023, MoEFCC 2023, and MNRE 2024d

Figure 21 RTS deployment has accelerated in the last few years



Source: Authors' compilation based on data from Bridge to India 2023, MoEFCC 2023, and MNRE 2024

Figure 22 Three-fourths of the total RTS capacity falls in the C&I sector



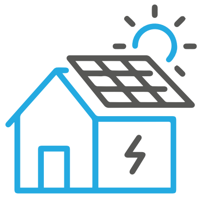
Source: Authors' compilation based on data from Bridge to India 2023, MoEFCC 2023, and MNRE 2024

India aims to achieve 500 GW of renewable energy capacity by 2030. Renewable energy deployment is largely led by utility-scale solar, with ~67.5 GW of capacity deployed by July 2024 compared to 13.4 GW in the RTS segment (Figure 21). C&I forms three-fourth of the total RTS capacity (Figure 22). RTS deployment in India is primarily driven by financial assistance provided for grid-connected systems, supported by enabling metering regulations and compensation mechanisms. Recently, to realise a people-centric energy transition, India announced an ambitious target to solarise 10 million residential households by 2026 (MNRE 2024a). The subsequent sections describe India's RTS journey thus far.

National Solar Mission–the initial push to tap into solar energy in 2010

After taking small, incremental steps to deploy solar energy in the early 2000s, there was a significant boom with the launch of the *National Solar Mission* (NSM) in 2010 as part of the broader *National Action Plan on Climate Change* (NAPCC). The NSM aimed to develop grid-connected and off-grid solar applications, emphasising domestic manufacturing and R&D to address energy security and climate change. The mission's initial goals were to reduce the cost of solar energy to achieve grid parity by scaling up capacity and meeting the country's energy demand through large-scale deployments. The programme aimed to establish 20 GW of grid-connected solar power by 2022, including 2 GW of RTS. The government introduced capital subsidies for RTS and allocated INR 15,050 crore (USD 1.81 billion) for viability gap funding (VGF) projects (MNRE 2015).

The mission was divided into three phases (SECI 2008): In the first phase, the government aimed to ramp up grid-connected solar, including RTS, to achieve 1 GW of installed solar capacity from 2010 to 2013. The first phase focused on low-hanging options that were more realistic to achieve and related to solar thermal, off-grid systems, and grid-connected capacity. The second phase (2013–2017) aimed to increase solar capacity to 4 GW. It also sought to establish an additional 3 GW of capacity by 2017 through mandatory renewable purchase obligations (RPOs) for utilities at preferential tariffs (Department of New and Renewable Energy 2008). The last phase (2017–2022) set a target of installing 40 GW of solar capacity by 2022. This phase aimed to ramp up installations based on the learnings from the first two phases. In 2010–2015, installed capacity expanded rapidly from 18 MW to 3,800 MW, and module prices started declining. In June 2015, the target for the last phase was revised to 100 GW by 2022, with 40 GW from RTS and 60 GW from grid-connected projects (MNRE 2015). This revision marked the beginning of RTS–focused schemes.



In June 2015, India expanded its national solar energy strategy by bringing rooftop solar into the mainstream, complementing the ongoing focus on utility-scale solar projects

Accelerating RTS deployment through a central financial assistance scheme

The Government of India approved the *Grid Connected Rooftop and Small Solar Power Plants Programme in* 2015 (MNRE 2014). The scheme aimed to deploy 4.2 GW of RTS by 2019–2020, with 50 per cent of the capacity supported by central financial assistance (CFA). The goals were to promote grid-connected RTS, reduce fossil fuel use, and stimulate investment in the solar sector. The scheme covered systems from 1 kWp to 50 kWp for self-consumption and grid supply. The programme also focused on capacity building, awareness campaigns, and IT-enabled monitoring and evaluation for effective rollout. Under the scheme, state nodal agencies received targets based on state demand and interest, with 10 per cent of the CFA allocated to the state as an advance. The Solar Energy Corporation of India (SECI) formulated implementation plans with various government bodies. Distribution licensees or discoms and channel partners were eligible for direct programme implementation. CFA was provided based on the benchmark costs decided by the Ministry of New and Renewable Energy (MNRE) – 30 per cent of the benchmark cost or the actual project cost, whichever is lower (70 per cent for special category states). The CFA was disbursed to channel partners by the MNRE unless otherwise decided by State Nodal Agencies (SNAs). Projects totalling approximately 2 GW capacity were sanctioned under the programme, of which 1.9 GW of RTS capacity has been installed (MNRE 2020).

Bringing discoms to the forefront of RTS deployment

Despite the provision of financial assistance, deployment was limited in Phase 1. In 2019, Phase 2 of the *Grid Connected Rooftop Solar* (RTS) *Programme* was launched to involve discoms and streamline the process, making it more uniform and accessible for consumers. The second phase aimed to deploy an additional 38 GW – 4 GW in the residential sector and 34 GW in the commercial, industrial, and institutional sectors (MNRE 2019). In this phase, the local offices of discoms were made responsible for implementing the RTS programme to address the challenges consumers faced in engaging with multiple stakeholders. The CFA (Table 2) was restructured because lower consumption slabs pay lower tariffs; therefore, higher capital subsidies were needed to make RTS a viable option.

In this phase, discoms empanelled agencies for the supply, installation, testing, and commissioning of RTS systems, ensuring quality control through a bidding process. Beneficiaries paid vendors the amount net of CFA, with implementing agencies responsible for CFA disbursal to vendors. When the scheme was amended during the second phase, a simplified procedure was introduced through the updated the national RTS portal in 2022 to facilitate project approval, reporting, and tracking. Further, the scheme mandated that to avail of CFA, only indigenously manufactured PV panels could be used. This was meant to boost domestic manufacturing. Approximately 2.65 GW of RTS capacity has been installed through the subsidy component under the second phase of the programme (as of November 2023) (MNRE 2023a).

Table 2 Capital subsidy offered to incentivise adoption in the residential sector under Phase 2

Type of installation	Up to 3 kW	3 kW to 10 kW
Households	40%	20%
Group housing societies/ resident welfare associations (RWAs)	20%	

Source: Authors' compilation based on data from MNRE 2019

Enabling policies and regulations accelerating the deployment

India introduced the net metering policy in 2012 to accelerate RTS deployment, allowing owners to substitute grid electricity for solar and receive compensation for excess energy fed into the grid. However, discoms prefer gross metering to net metering as the compensation tariffs are less than the retail supply tariff rates in the former, hence lesser overall payments need to be made (CEEW 2019). Presently, states have implemented varying net metering regimes with differing compensation tariffs for excess energy. To further accelerate deployment and resolve challenges related to limited or no roof ownership, high upfront costs, and fragmented demand, virtual net metering (VNM) and group net metering (GNM) regimes were introduced. VNM was offered for residential and institutional consumers, while GNM was offered to commercial and industrial consumers (Mercom India 2022). The *green energy open access rules* were notified in 2022 to allow consumers to purchase green energy. They also cater to the needs of small consumers by reducing the limit for open-access transactions from 1 MW to 100 kW for green energy. Moreover, C&I consumers were also permitted to purchase green power voluntarily. The objective was to ease the approval process for accessing green energy and reduce costs (Ministry of Power 2023).

Impetus on the rooftop solar at the central-level is well supported by the state-driven policies and programmes to further promote its adoption

In addition to national measures, states have also announced specific RTS targets, financial and non-financial incentives, and innovative models to accelerate deployment. For example, Uttarakhand announced a solar villages scheme focusing on rural areas, whereas Delhi's solar policy announced innovative models such as peer-to-peer trading. For detailed information on measures and briefs, refer to Annexure 17.

Rooftop solar programmes were complemented by distributed solar schemes

To promote distributed renewable energy (DRE) in livelihood applications, the MNRE issued a framework to develop ecosystems in rural and remote areas (MNRE 2022). This includes off-grid programmes in Ladakh, supported by MNRE, to build nearly 350 off-grid solar power plants up to 5 kWp (MNRE 2023b). *The off-grid and distributed solar PV applications programme* provided capital subsidies for solar streetlights and study lamps. In November, 2023, the government announced *Pradhan Mantri Janjati Adivasi Nyaya Maha Abhiyan*, focusing on particularly vulnerable tribal groups (PVTGs) and targeting the provision of electricity to 1 lakh households. In addition, the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana* (PM KUSUM) scheme was launched in 2019 to target the solarisation of agricultural demand. The scheme aimed to promote standalone solar pumps, grid-connected solar power plants up to 2 MW, and the solarisation of existing agricultural pumps (MNRE 2023b).

Future strategy: Towards an inclusive people-centric energy transition

Going forward, India plans to leverage the RTS potential in residential homes through the rollout of *PM Surya Ghar: Muft Bijli Yojana* in 2024 (MNRE 2024a). Phase 2 of the initiative will be implemented through a national portal, incentivising discoms and local bodies to adopt RTS. Further, model solar villages will be set up in each district. The scheme has allocated INR 75,021 crore (USD 9 billion) for CFA (details in Table 3) for systems ranging from 1 kW to 3 kW (PIB 2024).

Table 3 Continuation of capital subsidies for residential consumers under the PM Surya Ghar scheme

Type of installation	Capacity up to 2 kW	Additional capacity of up to 1 kW
Households	INR 30,000/kW (USD 360/kW) INR 33,000/kW for special category states (USD 396/kW)	INR 18000/kW (USD 216/kW) INR 19,800 /kW for special category states (USD 237/kW)
Group housing societies/RWAs	INR 18000/kW (USD 216 /kW) INR 19,800/kW for special category states (USD 237 /kW)	

Source: Authors' compilation based on data from MNRE 2024c

The applications are processed online through a national portal, simplifying handling requests and CFA disbursals. As of July 2024, there were 1.28 crore registrations and 14.9 lakh applications under the scheme (MNRE 2024c). It also lists empanelled vendors and integrates with the Jan Samarth portal for loan applications. It features a knowledge centre with training modules, case studies, and more. In addition, the scheme mandated the use of domestically manufactured modules and cells and introduced a new vendor rating programme to ensure consumers make informed decisions.

3.9 Viet Nam: Rooftop solar boom led by an attractive feed-in tariff scheme

Viet Nam's estimated total solar power potential is ~963 GW, including ~48 GW from RTS (Government of Viet Nam 2023). Viet Nam dominates the Southeast Asian solar market, with a 61 per cent (SolarPower Europe 2024) share of total installed PV capacity as of 2022. According to projections, the solar energy market will grow to ~20 GW by 2027 (Mordor Intelligence 2023).

National targets

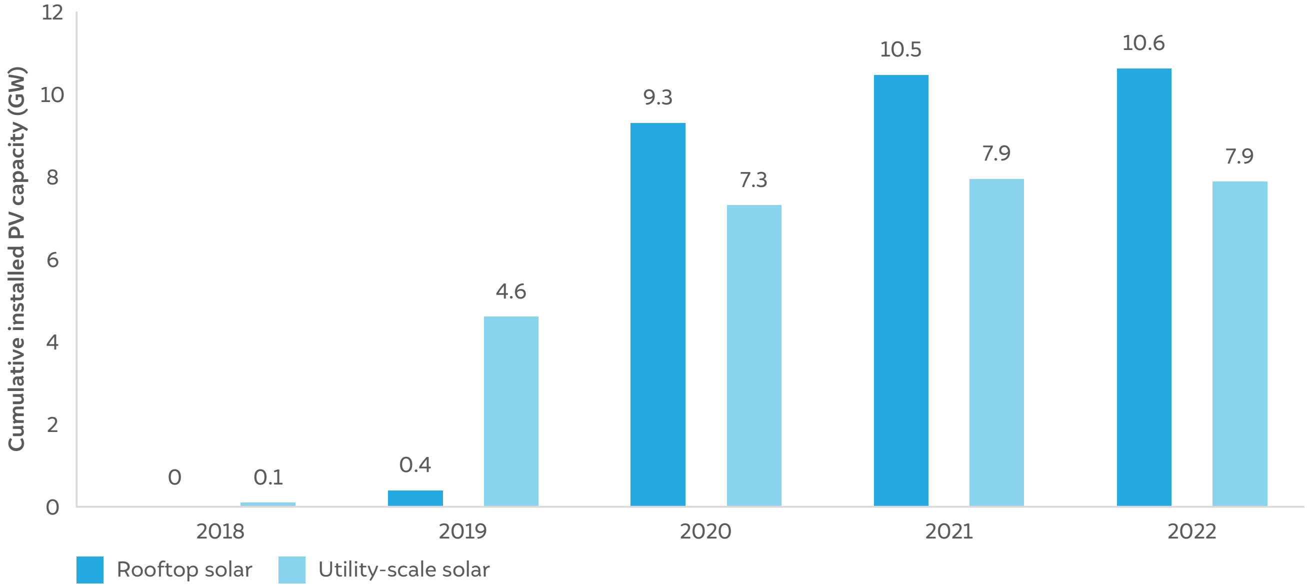
- The total solar capacity of Viet Nam is expected to increase to ~170 GW by 2050, including 2.6 GW of new RTS capacity by 2030.
- In total, 50% of office and residential buildings' demand to be met by RTS by 2030 to promote self-sufficiency.

Current deployments

- Viet Nam's total installed PV capacity stands at 18.5 GW, including 10.6 GW of RTS as of 2022.
- In total, 0.1 million RTS have been installed till now.

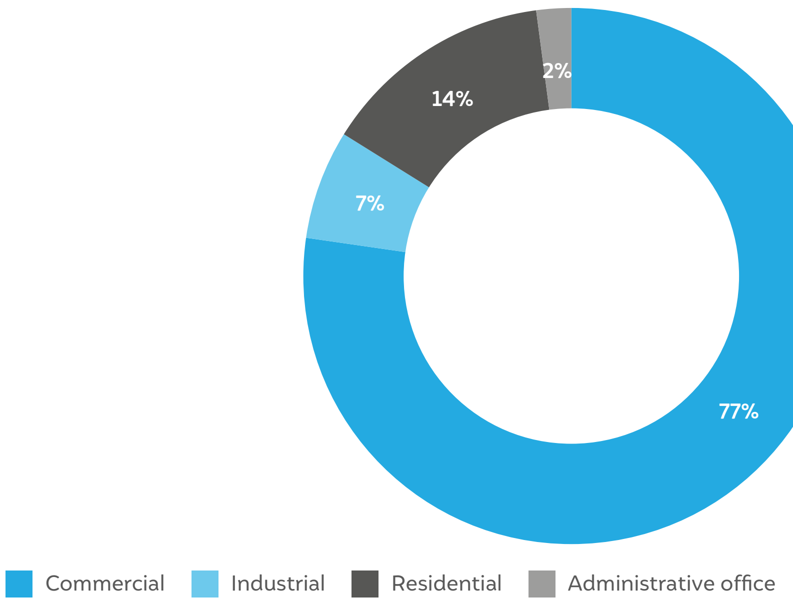
Source: Authors' compilation based on data from Government of Viet Nam 2023, and IEA-PVPS 2023

Figure 23 Viet Nam witnessed a boom in RTS adoption in 2019–2022



Source: Authors' compilation based on data from VEPG 2020

Figure 24 C&I consumers dominate RTS deployment in Viet Nam



Source: Authors' compilation based on data from VEPG 2020

Viet Nam's RTS sector has experienced significant highs and lows. Despite not being an early investor, Viet Nam now ranks ninth globally in distributed PV installed capacity (IEA-PVPS 2023). The country began promoting solar energy in 2016 with favourable FiT schemes, creating substantial market demand. Declining module prices and high retail electricity rates further contributed to the sector's success. By 2020, Viet Nam ranked third globally in annual solar PV deployment (ISA 2023). However, the initial momentum was hindered by the lack of a policy framework, prospective planning, an underdeveloped energy infrastructure, and limited grid capacity. These problems had an impact on the FiT schemes, which eventually affected the growth of the sector. This section analyses Viet Nam's key policy interventions to provide a deeper understanding of the Vietnamese RTS market.

Addressing energy shortages through the *Renewable Energy Development Strategy* (REDS)

In the early 2000s, when countries such as the US, Australia, Japan, and China were investing in renewable energy, Viet Nam relied heavily on fossil fuels and hydropower, which comprised ~93 per cent of its electricity generation until 2016 (EVN 2017); Solar energy contributed nil to Viet Nam's energy mix during this period. In late 2015, Viet Nam announced its first *Renewable Energy Development Strategy* (REDS) which set targets for up to 2030 and with a vision for 2050 (Government of Viet Nam 2015). The strategy aimed to expand renewable energy use to reduce fossil fuel dependence, enhance energy security, mitigate climate change, protect the environment, and promote sustainable development. In response to a power shortage in northern Viet Nam in 2016– 2017 due to rising energy demand, policymakers turned to solar energy for its convenience and accessibility. As part of REDS, Viet Nam introduced its first solar energy programme in 2017 (Government of Viet Nam 2017), implementing a FiT scheme and net metering similar to Italy and Japan.

~7 GW of RTS systems installed in December 2020 alone and ~9 GW throughout 2020 in Viet Nam

The rapid expansion of RTS resulted in challenges for Viet Nam's solar energy sector

Initially, despite offering a FiT rate ~10.5 per cent higher than average electricity retail prices (Qureshi et al. 2023), Viet Nam installed just over 100 MW of RTS capacity due to the high levelised cost of electricity (LCOE) for solar PV (Hang Le et al. 2022). The high LCOE was attributed to the industry's heavy dependence on foreign investments for technology, engineering, and project development (Hang Le et al. 2022). Starting in 2016, China-based companies expanded manufacturing in Southeast Asia, leveraging lower costs and stable policies to expand their market. A few Vietnamese companies gradually entered the manufacturing sector, lowering PV system costs. Meanwhile, between 2005 and 2019, Viet Nam revised its electricity tariffs 13 times, with the average retail tariff (ART) rising from ~USD 0.047/kWh to ~USD 0.08/kWh due to fossil fuel price fluctuations and reliance on fossil fuels (UNICEF 2022).

Consequent to the decline in global module prices, the increase in Viet Nam's manufacturing capacity, and a generous FiT rate, the LCOE reduced for consumers; LCOE for solar in Viet Nam was USD 0.046/kWh in 2021, the lowest in the Association of Southeast Asian Nations (ASEAN) region (IRENA 2022). The increased retail electricity tariff and declining PV system costs encouraged RTS adoption even after reducing the FiT rate in 2020 (Government of Viet Nam 2020). By 2022, Viet Nam accounted for 6.4 per cent of global PV module production (IEA-PVPS 2023).

Solar developers were exempted from corporate income tax for the first 4 years, with a 50 per cent reduction on total tax for the next 9 years, and a 10 per cent reduction until the 15th year (UNICEF 2022). Anticipation of expiring FiT incentives spurred a boom in installations, with ~7 GW of RTS systems installed in December 2020 alone and ~9 GW throughout 2020 (VEPG 2020) (Figure 23). Viet Nam does not enforce local content requirements for FiTs, and imported equipment is exempt from tariffs, lowering technology costs and attracting foreign investment. For commercial and industrial consumers, the FiT and weighted average tariff difference was 20–30 per cent (Qureshi et al. 2023), making generating solar power much more cost-effective than relying on grid electricity at higher tariffs. Consequently, C&I segment led the deployment in that phase (see Figure 24). However, due to inadequate roof infrastructure and low consumer awareness, the residential segment only contributed 14 per cent during the later phase.

Figure 25 Evolution of the feed-in-tariff scheme in Viet Nam (2017–2020)

	Phase I (2017–2019)	Phase II (2019–2020)
Eligibility	RTS systems with solar cell efficiency >16% or module efficiency >15%, commissioned before 30 June 2019.	RTS systems with solar cell efficiency >16% or module efficiency >15%, commissioned from 1 July 2019 to 31 December 2020.
Fit rate	USD 0.0935 /kWh	USD 0.0838 /kWh
Surplus energy compensation	Consumers fulfilling the above criteria can sell surplus electricity to state-owned Viet Nam Electricity (EVN) and its subsidiaries for 20 years. The settlement was yearly. The applicable exchange rate between VND and USD was published by the State Bank of Viet Nam on the last day of the year to calculate the payment of power invoices for the following year.	

Source: Authors' compilation based on data from Government of Viet Nam 2017, 2020

Viet Nam became a victim of its success

Viet Nam initially aimed to address power shortages in the northern region by promoting RTS deployment there. The government planned to gradually reduce the FiT rate after raising awareness. However, they did not anticipate the overwhelming nationwide response. As a result, deployment was uneven. In 2019, 94 per cent of new installations were concentrated in the central and southern regions, which had higher solar irradiation, while only 6 per cent was installed in the north (VEPG 2020).

This sudden surge strained the national power grid, as no new power plants were built to manage and provide a stable base load. The concentration of solar PV in specific regions led to significant grid concerns, including solar power curtailment, load distribution, and instability. To address these issues, Viet Nam scrapped the FiT scheme in 2020 and shifted focus to a self-consumption model, encouraging on-site consumption without selling surplus electricity back to the grid. The evolution of Viet Nam's net metering scheme is displayed in Figure 25.

Future outlook for the Vietnamese RTS market

Despite abundant solar resources and initial momentum, Viet Nam's RTS installations declined after discontinuing the FiT scheme and introducing policy changes that created market uncertainties. Administrative bottlenecks, such as an extensive permitting process, documentation requirements, and delays by local service providers, further slowed approvals, feasibility studies, and PPA agreements with Viet Nam Electricity (EVN) or third parties. The lack of clear guidelines deterred potential investors from committing to large-scale projects. With the recent *Power Development Plan* (PDP-VIII), Viet Nam aims to unlock its full solar potential to drive sustainable economic growth and enhance energy security. According to PDP-VIII, Viet Nam will invest USD 135 billion in developing power sources and transmission grid infrastructure. The country is also working on its renewable energy policy law, which might be introduced in 2025. The upcoming policy is expected to empower:

- the State Bank of Viet Nam to instruct commercial banks to reduce lending rates or provide a preferential lending package for owners of RTS power projects;
- the Ministry of Finance to allocate budget funds to support the installation of self-consumption RTS power systems and give options for tax and charge exemption and reduction.

The plan also includes varying the FiT scheme rates by region and time of the day, with a capped system for residential consumers based on subscribed load demand. However, the FiT rate will not be as generous as before. Additionally, plans are underway to establish a carbon trading market in Viet Nam by 2025. Also, the government is set to mandate all organisations to control their carbon emissions by 2027 to achieve net-zero emissions by 2050. Installing RTS on a self-consumption basis is expected to be crucial in achieving this goal.

The government's targets to mandate organisations to control their carbon emissions by 2027 to achieve net-zero emissions by 2050

4. Comparative analysis across countries

Image: iStock

This section provides a comprehensive comparative analysis across the nine countries selected for this study. The table highlights key metrics, including solar potential, national targets, key policy and regulatory interventions, and innovative business models (Table 4). Furthermore, it provides a brief overview of how leading economies have explored diverse strategies to develop their RTS market. This will help us develop our recommendation for other countries to facilitate some of these programmes to redefine their energy sector.

Table 4 Comparative analysis across countries

Parameters	China	Germany	United States	Japan	
Solar potential	2070 GW of technical total solar potential.	409 GW of technical RTS potential.	1000 GW of technical RTS potential.		
National target (including solarisation target for government buildings)	1,200 GW solar and wind capacity by 2030. Solarise 50% of government, 40% of public, and 30% of commercial buildings.	215 GW of solar capacity by 2030, with the addition of 11 GW of RTS capacity per year from 2026 to 2030.	30 GW of solar capacity per year between 2022–2025 and 60 GW per year between 2025–2030.	147 GW of total solar capacity by 2030.	
Installed capacity	225 GW of distributed PV capacity as of 2023.	82.2 GW of total solar capacity with 51 GW of RTS installed capacity as of 2023.	47 GW of RTS capacity as of 2023.	84.9 GW of total solar capacity as of 2022.	
Distributed PV size limit	Up to 6 MW.	Up to 1 MW.	Up to 1 MW.		
Key policy and regulatory instruments	*Golden Sun Programme, Solar Energy Poverty Alleviation Programme, and Whole County PV programme.*	FiT and federal tax credits are for residential consumers and businesses; *Renewable Energy Sources Act* or EEG and its Amendments; *Solar Package I.*	*Renewable Energy Sources Act or EEG Amendment; Solar Package I;* Federal tax credits for residential consumers and businesses, and metering regulations at the state level.	Residential solar PV development schemes; buyback programme for PV; FiT; feed-in premium.	
Feed-in tariff or Feed-in-premium rate **(USD/kWh)**	.	USD 0.145 /kWh for full feed-in and USD 0.093 /kWh for partial feed-in.	-	2012: USD 0.30-0.32/ kWh 2019: USD 0.099-0.158 /kWh based on PV system size. Discontinued post-2019.	

	Australia	Italy	Brazil	India	Viet Nam
	179 GW of RTS potential.	120 GW of RTS potential.	307 GW of total solar potential.	637 GW of RTS potential in the residential sector.	963 GW of total solar potential.
	36 GW of RTS by 2030 and 86 GW by 2050.	80 GW total solar capacity by 2030.	50–60 GW of total PV capacity, including ~55 % of distributed PV by 2027.	30 GW of RTS capacity by 2026–2027.	170 GW of total solar capacity by 2050, including 2.6 GW of new RTS capacity by 2030. 50% of office and residential buildings to be self-sufficient by 2030.
	22.2 GW of RTS capacity as of 2023.	22 GW distributed PV capacity as of 2023.	25 GW distributed PV capacity as of 2023.	11.9 GW of total grid-connected RTS capacity as of March 2024.	10.6 GW of RTS capacity as of 2022.
	Up to 100 kW (based on RTS eligibility under the *Small-scale renewable energy* scheme).	Up to 1 MW.	Up to 3 MW (non-dispatchable) and 5 MW (dispatchable).	Systems from 1 kWp to 50 kWp were included for self-consumption and grid supply.	Up to 1 MW.
	FiT (state-level and retailer-offered), Small-scale Renewable Energy Scheme.	FiT and feed-in premium schemes and Super Bonus tax credit mechanism for residential consumers.	Net metering with an energy credit settlement period of up to five years.	Rooftop Solar Programme Phase-II, *PM Surya Ghar: Muft Bijli Yojana.*	Generous FiT to create market demand.
	2010: 40 to 60 ct/kWh for residential consumers.	USD 0.075–0.113 /kWh based on PV system size. Discontinued post 2021.		-	2017–2019: USD 0.0935 /kWh 2019–2020: USD 0.0838 /kWh Discontinued post-2020.

Parameters	China	Germany	United States	Japan
Tax benefit		Tax concessions and exemptions related to income tax on electricity sales for RTS.	Tax credit up to 30% of the total cost of solar systems for the residential segment.	-
Financing mechanism	Up to 100% subsidy under the *Solar Energy for Poverty Alleviation Programme* (SEPAP) and zero or low-cost financing.	Germany's *10,000 Roofs* programme included financing with a low interest rate and a ten-year repayment period.	Tax credit of upfront cost reduction, financing options, LMI-focused programmes, and *Solar for All* programme.	Capital subsidy for residential PV of <4 kW, one-third of the installation costs, and a maximum of USD 2,585 /kW.
Awareness campaigns		BMWK's national campaign on '80 million Together for Energy Change'.	Solarise campaigns by local organisations, developers, and counties.	
Innovative Business models	Up to 100% subsidy under the Solar Energy for Poverty Alleviation Programme (SEPAP). Whole county PV programme with lease rooftop model.	Landlord-to-tenant electricity supply model, balcony solar PV model, and energy cooperatives.	Community solar model.	
Ease of adoption		Simplification of the registration process for installations such as balcony solar PV and systems up to 30 kW under *Solar Package I*.	*SolsSmart* and *SolarAPP+* to streamline and fast track the application procedure.	
Installation standards & performance monitoring		Performance monitoring under the *1000 Roofs* programme, installation data monitored under core market data register.	-	

	Australia	Italy	Brazil	India	Viet Nam
	-	Up to 110% tax credit under the Super Bonus scheme for residential consumers.		Taxation benefits for power generation. Moreover, tax benefits can be availed through accelerated depreciation on the system components.	Income tax exemptions for solar developers for the first 4 years, a 50% reduction for the next 9 years, followed by 10% until the 15th year of operation.
	Subsidised loans for shared solar on building rooftops.		Low-cost financing (2%) for low-income groups. In general, the interest rate ranges between 14–20%.	Capital subsidy ~70% of the total cost for up to 3 kW residential system.	
	-		Utility-driven solar RTS pilot programme *(Celesc PV Bonus Programme)*, as well as utilising billboards and public places.	1% of the financial outlay of the rooftop scheme is assigned to awareness. It includes electronic, print, and social media. Additionally, states have specific programmes, such as the Solarise campaign in Delhi.	
	Small-scale Technology Certificates (STC) scheme and community solar and virtual power plants.		Net-metering scheme with an energy credit settlement period of up to five years instead of monetary compensation.	Net metering and gross and virtual net-metering regimes. Low-cost financing through nationalised banks.	
	Installers accredited by Solar Accreditation Australia.			A dedicated RTS application portal provides a one-stop solution for consumers.	
	Solar Accreditation Australia (SAA), *Solar Panel Validation* (SPV) programme, and CER-mandated standards. and best practices.			A vendor rating programme helps consumers differentiate high-performing vendors.	

Rooftop solar systems can be integrated into buildings, avoiding land conflicts and providing a decentralised and sustainable solution.

Image: iStock

5. Key recommendations for scaling up rooftop solar deployment: Learnings from leading economies

The global push for renewable energy has led several countries to develop robust RTS programmes as a fundamental strategy to advance their energy transition ambitions and net-zero commitments. The experiences and insights from these leading RTS adopters provide valuable lessons and strategies for other countries to enhance their RTS deployment and make it central to their energy transition. These recommendations have been presented under five key pillars – demand creation, policy measures, regulatory interventions, enabling ecosystem, and infrastructure and data requirements.

Consumer awareness campaigns, coupled with innovative business models, can streamline and accelerate rooftop solar adoption

5.1 Create demand through consumer engagement and innovative business models

- **Implement consumer awareness campaigns**: The relevant renewable energy departments and agencies at the state and national levels must introduce targeted consumer awareness campaigns. The information needs to be simplified and tailored to consumers' current level of awareness of RTS. The key message should be delivered to consumers with a clear call to action – for example, the Solarise campaigns in the US and the *Whole County Programme* in China. In Delhi, the pilot Solarise campaigns had a conversion rate of 18.8 per cent (with 117 leads and 22 proposals) and achieved results comparable to those of Solarise Connecticut campaigns held in various towns (with conversion rates ranging from 4 to 24 per cent). Introducing such campaigns will educate and motivate consumers and accelerate the adoption of RTS.

- **Develop online platforms for consumer engagement**: Countries should develop a comprehensive national online platform to communicate incentives, policy and regulatory updates, and other relevant information to consumers. For example, India's national portal under the *PM Surya Ghar: Muft Bijli Yojana* scheme serves as a one-stop solution for consumers to access information on applications, disbursal of financial assistance, financing options, and training modules. Such a national platform can streamline communication between government agencies and end consumers.

- **Design innovative business models**: National and state governments, renewable energy agencies, and discoms should roll out innovative business models to unlock RTS potential across consumer categories. For example, dedicated community solar programmes have been successful in several US states. The tenant electricity model (landlord-to-tenant electricity supply) in Germany has allowed apartment building tenants to access low-cost solar electricity – it is currently being extended to commercial buildings. In addition, Germany was able to tap into the less than 1 kW category through balcony solar PV systems, which work as plug-in devices with a maximum output of 600 W. Innovative business models such as community solar, energy cooperatives, landlord-to-tenant electricity supply, and balcony solar PV can help address the challenges of high upfront costs and limited ownership or availability of roof areas.

5.2 Leverage policy levers to unlock RTS potential

- **Launch targeted incentive mechanisms**: National and state government departments should offer financial incentives to reduce the high upfront costs associated with adopting RTS systems and make them economically viable for consumers. The targeted financial incentives should be introduced with a clear phase-down trajectory. For example, Japan, Germany, and Australia offered lucrative FiTs with a clearly defined trajectory. However, unlike other countries, Viet Nam faced infrastructure-related challenges as lucrative FiTs to boost deployment led to a sudden surge in PV adoption, ultimately leading to the scheme's abrupt closure. In addition to FiTs, countries have offered various economic incentives to scale up the adoption of RTS. Australia boosted RTS adoption through the *Solar Energy Credit programme* after scaling down FiTs. The US uses the federal tax credit to incentivise deployment. India has a capital subsidy scheme for residential consumers looking to implement systems of up to 3 kW system size, covering nearly 70 per cent of the project cost, to make them attractive to consumers in this category who otherwise pay low electricity tariffs. Therefore, a mix of economic instruments with clear targets and a phase-wise trajectory can be introduced to incentivise RTS adoption, particularly when the RTS market is in its nascent stage.

- **Ease access to affordable and inclusive financing options**: Government departments and financial institutions should also develop inclusive and affordable financing options to make RTS systems economically viable. For example, under the PERS programme, Brazil offers a line of credit with a 2 per cent interest rate for low-income households. China's SEPAP programme offers low or zero-cost financing options. Germany's *100,000 Roofs* programme included financing with a low interest rate and a ten-year repayment period. India offers solar loans through various banks and financial institutions at low interest rates to multiple consumer categories. The high upfront costs and the nature of the technology necessitate the introduction of affordable financing options.

- **Devise inclusive solar programmes**: Countries should focus on developing inclusive and people-centric energy transition programmes, ensuring equitable access to RTS by different communities across income classes and regions. For example, the US focuses on equitable access through its initiatives, such as LMI-focused programmes and the *Solar for All* funding programme. China introduced the *Solar Energy for Poverty Alleviation Programme* through DRE in rural areas. Australia provided rebates to low and marginalised communities. India is also focusing on promoting RTS in rural areas with a component dedicated to developing solar villages in every district in the country.

- **Build mandates for RTS adoption**: Another successful measure deployed by countries is the mandatory installation of RTS in specific buildings. Governments can mandate RTS installations on new government, residential, and commercial buildings to scale up RTS adoption. For example, Baden-Wurttenberg (Germany) has adopted phase-wise mandates for all new non-residential buildings and renovations, boosting RTS adoption significantly. Under PDP-VIII, Viet Nam aims to have half of its office buildings and homes powered by RTS systems by 2030.

5.3 Incentivise rooftop solar adoption through regulatory interventions

- **Develop metering arrangements**: State and national regulatory authorities should develop metering regimes such as net metering and net billing to compensate for excess generation from RTS systems. Further, transitions in metering regimes must be informed by evidence-based analyses and follow a participatory approach involving public consultations. For instance, California (US) transitioned to a new metering regime in 2023 to promote self-consumption and battery storage. India introduced the net metering regime in 2012, and multiple states have developed their own mandates for net metering and gross metering for RTS. Several Indian states have also amended their existing regulations and introduced newer regimes such as net billing, virtual net metering, and group net metering.

- **Enable regulations to facilitate the rollout of innovative models**: A conducive regulatory ecosystem is needed to facilitate the implementation of innovative models. National- and state-level electricity regulatory authorities must periodically introduce, amend, and adopt enabling regulations. For example, virtual net metering can be instrumental in promoting deployment in rural and remote areas. In the US, several states have adopted enabling regulations for community solar. In the case of Germany, simplifying regulatory requirements for balcony solar PV systems led to increased installation. With the help of such enabling regulations, these innovative models can help unlock potential by overcoming barriers such as roof ownership, limited space, etc.

5.4 Create an enabling ecosystem to ensure ease of implementation

- **Automate local-level permitting**: Implementation authorities, such as local governments and discoms, must standardise and streamline the permitting process to fast-track RTS adoption. For example, *SolarAPP+* in the US has significantly reduced the time required to process permits at the local level, which can serve as a model for other countries. Adopting novel methods to streamline permitting processes can prevent delays in installing and commissioning RTS systems.

Implementation authorities, such as local governments and discoms, must standardise and streamline the permitting process to fast-track RTS adoption

- **Leverage existing programmes for RTS adoption**: State and national programme implementation agencies should leverage existing government schemes to extend benefits under RTS or community solar programmes. For example, *Clean Energy Connector* in the US is a digital tool that makes community solar subscriptions more accessible to recipient households under the *Low-Income Home Energy Assistance Programme*. The Brazilian government relaunched the *Minha Casa Minha Vida* (My House, My Life) social housing programme, which aims to build 2 million new housing for low-income and homeless people by 2026 and deploy 1 kW of power per household, resulting in 2 GW of solar installation. Such measures can help identify existing beneficiary networks and reduce consumer acquisition costs.

- **Build capacity at the local level**: Implementation agencies must develop specific programmes to enhance technical capacity at the local government and discom levels. For instance, the *SolSmart* programme in the US provides local governments with technical know-how and recognises their performance through a well-defined ranking system. Such measures are vital in reducing the soft costs involved in RTS implementation.

- **Institute a vendor rating programme**: Relevant government ministries or agencies should introduce a dedicated vendor rating programme to enable consumers to make informed decisions. For example, India's vendor rating guidelines under the *PM Surya Ghar: Muft Bijli Yojana* scheme include the evaluation process for vendor rating. It helps consumers to differentiate and identify high-performing vendors. In Australia, only an installer accredited with Solar Accreditation Australia can design and install RTS. Such measures ensure that good-quality components are installed while ensuring the safety and performance of the systems. It is important to ensure the quality of installations, as improper or faulty installation can lead to lower system performance and adversely impact consumers' perception of the technology.

- **Monitor system performance**: National and state government departments must include provisions for technical inspection and system performance monitoring in their schemes or programmes. For example, the CER in Australia sets standards and good practices for manufacturers, importers, retailers, and installers. Manufacturers and importers are required to have components approved by the Clean Energy Council. The *Solar Panel Validation Initiative* is a recent framework by CER, whereby the system components as well as the installation, can be verified using an app. Germany's *1000 Roofs Programme* focused on performance monitoring and helps identify reasons for the poor performance of systems. India has an in-built annual maintenance contract for up to 3 kW systems for five years. Such measures help reduce the risk of poor-quality modules and installation processes impacting system performance in the long run and consumer confidence in the technology.

5.5 Plan for sustainable RTS expansion

- **Assess grid connectivity and distribution planning**: Relevant electricity authorities at the national level need to periodically assess transmission and distribution needs and conduct medium- to long-run transmission and distribution planning in consultation with discoms, transmission companies, and state nodal agencies. Viet Nam's case highlights the need for better planning to address issues such as curtailment. On the other hand, China is investing in augmenting its power transmission capacity and developing energy storage facilities to reduce grid uncertainty due to higher RE capacity.
- **Enhance the availability of granular and periodic data**: National government agencies should develop and maintain an RTS data registry. The MaStR data registry in Germany, the EIA's official energy statistics in the US, and the generation data from AEMO's Distributed Energy Resource register in Australia are inspiring examples of such datasets. The availability of comprehensive, periodic, and reliable data plays a critical role in decisions related to policy-making, identification of beneficiaries, infrastructure upgrades, and so on.

On the basis of the country-level deep-dive, it is evident that there is no one-size-fits-all approach for the acceleration of RTS adoption. The implementation agencies across countries can tailor the above five pillars based on their national and sub-national context. A combination of the relevant interventions on demand creation, policy measures, regulatory interventions, enabling ecosystem, and infrastructure and data requirements can be adopted for driving RTS adoption.

Availability of comprehensive, periodic, and reliable data plays a critical role in making informed decisions by policymakers

Acronyms

ACCC	Australian Competition and Consumer Commission
ACT	Australian Capital Territory
AEMO	Australian Energy Market Operator
AMI	area median income
ARERA	The Italian Regulatory Authority for Energy Network for Environment
ART	average retail tariff
ASEAN	Association of Southeast Asian Nation
C&I	commercial and industrial
CAGR	compound annual growth rate
CapEx	capital expenditure
CEC	Clean Energy Council
ct	cent
CER	Clean Energy Regulator
CFA	Central Financial Assistance
CNY	Chinese Yuan
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
DC	District of Columbia
DG	distributed generation
DISCOM	distribution company
DOE	Department of Energy
DRE	Distributed Renewable Energy
EEG	Energy Source Act
EPA	Environmental Protection Agency
EPC	Engineering, Procurement and Construction
EU	European Union
EUR	Euro
EVN	Viet Nam Electricity
FiP	feed-in premium
FiT	feed-in tariff
GDP	gross domestic product
GNM	group net metering

GSE	Gestore Dei Servizi Energetici
GW	gigawatt
GWh	gigawatt hour
ICMS	goods and service tax
IEA	International Energy Agency
INR	Indian Rupee
IRA	Inflation Reduction Act
ITC	investment tax credit
JPY	Japanese Yen
kW	kilowatt
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LCOE	Levelised cost of electricity
LGOPAD	Chinese State Council Leading Group Office for Poverty Alleviation and Development
LIHEAP	Low Income Home Energy Assistance Programme
LMI	low-to-moderate income
LRET	Large-scale Renewable Energy Target
METI	Ministry of Economy, Trade and Industry
MNRE	Ministry of New and Renewable Energy
NAPCC	National Action Plan on Climate Change
NBT	net billing tariff
NCSP	The National Community Solar Partnership
NDC	Nationally Determined Contribution
NEA	National Energy Administration
NECP	National Energy and Climate Plan
NEM	net energy metering
NREL	National Renewable Energy Laboratory
NSM	National Solar Mission
NSW	New South Wales
PDP	Power Development Plan
PEE	Energy Efficiency Programme
PERS	The Social Renewable Energy Development Programme
PPA	power purchase agreement
PTC	production tax credit

PV	photovoltaic
R&D	research and development
RE	renewable energy
REC	renewable energy certificate
REDS	Renewable Energy Development Strategy
RESCO	Renewable Energy Service Commission
RET	Renewable Energy Target
RPO	renewable purchase obligation
RTS	rooftop solar
SAA	Solar Accreditation Australia
SECI	Solar Energy Corporation of India
SEPAP	Solar Energy for Poverty Alleviation Programme
SETO	Solar Energy Technologies Office
SNA	state nodal agencies
SPV	solar panel validation
SRES	Small-Scale Renewable Energy Scheme
STC	small scale technology certificates
TOU	time of use
TSEE	electrical energy social tariff
TUSD	distribution system use tariff
TW	terawatt
US	United States
USD	US dollar
UT	union territory
VAT	value added tax
VGF	viability gap funding
VND	Vietnamese Dong
VNM	virtual net metering

References

Abruzzo. 2013. "Ecobonus Decree: Founds to Go Green." Abruzzo Rural Property. https://www.abruzzoruralproperty.com/blog-en/entry/ecobonus-decree-founds-to-go-green.

ABSOLAR. 2024. "Solar Photovoltaic Energy in Brazil." Brazilian Association of Photovoltaic Solar Energy. https://www.absolar.org.br/en/market/infographic/.

ANEEL. 2012. "Agência Nacional De Energia Elétrica – Aneel." Agência Nacional De Energia Elétrica. https://www2.aneel.gov.br/cedoc/atren2012482.pdf.

—. 2015. "Agência Nacional De Energia Elétrica – Aneel Resolução Normativa Nº 687, DE 24 De Novembro De 2015." https://www2.aneel.gov.br/cedoc/ren2015687.pdf.

—. 2020. https://www2.aneel.gov.br/cedoc/aren20231060_2_1.pdf

—. 2022. "Law Nº 14.300, of January 6, 2022." Presidência da República, Secretaria-Geral, Subchefia para Assuntos Jurídicos. https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2022/lei/L14300.htm#:~:text=LEI%20N%C2%BA%2014.300%2C%20DE%206%20DE%20JANEIRO%20DE%202022&text=Institui%20o%20marco%20legal%20da,1996%3B%20e%20d%C3%A1%20outras%20provid%C3%AAncias.

Antoniolli, Andrigo Filippo, Helena Flávia Naspolini, João Frederico de Abreu, and Ricardo Ruther. 2022. "The Role and Benefits of Residential Rooftop Photovoltaic Prosumers in Brazil." Renewable Energy 187 (March): 204–222. https://doi.org/10.1016/j.renene.2022.01.072.

Australian Energy Statistics. 2024. "Australian Energy Statistics." Government of Australia. https://www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2022-23-and-2023.

Becker, H, K Kiefer, V Hoffmann, U Rindelhar, and G Heilscher. 1997. "5 Years of Operational Experience in the German 1000-Roof-Programme: Results of Monitoring and Inspection." Helmholtz-Zentrum Dresden-Rossendorf. https://www.hzdr.de/publications/Publ-1596.

Bellini, Emiliano. 2024. "Italy's Annual New Solar Additions Hit 5.23 GW in 2023." *PV Magazine*. https://www.pv-magazine.com/2024/02/20/italy-added-5-23-gw-of-new-solar-in-2023/.

BMWK. 2015. "Fifteenth anniversary of EEG: Ongoing success story." *Energiewende Direkt* 2 (2015). https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2015/02/Meldung/15-years-of--eeg.html.

—. 2017a. "Landlord-to-Tenant Electricity Supply: The Energy Transition in Your Own Home." Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Artikel/Energy/landlord-to-tenant-electricity-supply.html.

—. 2017b. "The Next Phase of the Energy Transition: The 2017 Renewable Energy Sources Act." Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Artikel/Energy/res-2017.html#:~:text=The%202017%20Renewable%20Energy%20Sources%20Act%20brings%20in%20a%20change,is%20now%20determined%20by%20auctions.

—. 2019. "Second Progress Report on the Energy Transition – The Energy of the Future (Reporting Year 2017)." Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Publikationen/Energie/second-progress-report-energy-transition.pdf?__blob=publicationFile&v=1.

—. 2021. "What Exactly Is Landlord-to-Tenant Electricity?" *Energiewende Direkt* 1 (2021). https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2021/01/Meldung/direkt-account.html#:~:text=When%20the%20photovoltaic%20system%20does,%2Dto%2Dtenant%20electricity.

—. 2022. “First Rules of New 2023 Res Act Enter into Force: ‘Renewable Energy First’ and Higher Remuneration for Solar Power.” Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2022/07/20220729-first-rules-of-new-2023-res-act-enter-into-force-renewable-energy-first-and-higher-remuneration-for-solar-power.html.

—. 2023a. “Electricity Storage Strategy.” Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/electricity-storage-strategy.pdf?__blob=publicationFile&v=4#:~:text=In%20Germany%2C%20there%20are%20currently,straight%20into%20the%20German%20grid.

—. 2023b. “Federal Minister Habeck: ‘We Need to Speed up the Expansion of Solar Energy’.” Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2023/05/20230505-federal-minister-habeck-we-need-to-speed-up-the-expansion-of-solar-energy.html.

—. 2023c. “Renewable Energy Sources in Figures.” Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/EN/Publikationen/Energie/renewable-energy-sources-in-figures-2022.pdf?__blob=publicationFile&v=7.

—. 2023d. “Stepping up the PV Roll-out.” *Energiewende Direkt* 5 (2023). https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2023/05/Meldung/direkt-answers.html.

—. 2024. “The Solar Package I at a Glance (English translation).” Federal Ministry for Economic Affairs and Climate Action of Germany. https://www.bmwk.de/Redaktion/DE/Downloads/S-T/solarpaket-im-ueberblick.html.

Borenstein, Severin, and Lucas W Davis. 2016. “The Distributional Effects of US Clean Energy.” Tax Policy and the Economy 30 (1): 191–234. https://www.journals.uchicago.edu/doi/epdf/10.1086/685597.

Brazzale, Ric. 2017. “Australia Rooftop Solar Market Recovers Late in 2016, But Falls Short Of Target.” Renew Economy. https://reneweconomy.com.au/australia-rooftop-solar-market-recovers-late-in-2016-but-falls-short-of-target-42347/.

Bridge to India. 2023. “India Solar Rooftop Map.” https://bridgetoindia.com/report/india-solar-rooftop-map-december-2023/.

Bruce, Anna, Baran Yildiz, Dani Alexander, and Mike Roberts. 2024. “As Australia’s Net Zero Transition Threatens to Stall, Rooftop Solar Could Help Provide the Power We Need.” University of New South Wales. https://www.unsw.edu.au/newsroom/news/2024/01/as-australia_s-net-zero-transition-threatens-to-stall--rooftop-s.

BSW. 2023. “70% of Population Support Coalition Plans to Remove Solar Barriers.”https://www.solarwirtschaft.de/en/press/downloads/.

Casey, J.P. 2024. “Italy Adds 5.23GW of Solar Capacity in 2023, Pushes Total Installed Capacity Above 30GW.” PV Tech. https://www.pv-tech.org/italy-adds-5-23gw-of-solar-capacity-in-2023-pushes-total-installed-capacity-above-30gw/.

Zachariah, Sachin, Bhawna Tyagi, and Neeraj Kuldeep. 2023. “Mapping India’s Residential Rooftop Solar Potential.” CEEW. https://www.ceew.in/sites/default/files/residential-rooftop-solar-market-potential-in-indian-households_0.pdf.

CEEW. 2019 “Difference between gross metering and net metering” https://www.ceew.in/cef/quick-reads/explains/difference-between-gross-metering-and-net-metering#:~:text=Figure%201%3A%20Gross%20metering,a%20fixed%20period%20of%20time

Chapman, Andrew J, Tetsuo Tezuka, and Benjamin McLellan. 2016. “Residential Solar PV Policy: An Analysis of Impacts, Successes and Failures in the Australian case.” Renewable Energy 86 (February): 1265–1279. https://doi.org/10.1016/j.renene.2015.09.061.

Clean Energy Regulator. 2023. “Residential Electrification.” Australian Government Clean Energy Regulator. https://www.aph.gov.au/DocumentStore.ashx?id=56a2f91c-37b7-4247-b78d-fa47c5d73124&subId=748949.

Congressional Research Service. 2021. “The Energy Credit or Energy Investment Tax Credit (ITC).” https://crsreports.congress.gov/product/pdf/IF/IF10479.

CPUC. 2023. “Net Energy Metering and Net Billing.” California Public Utilities Commission. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/customer-generation/net-energy-metering-and-net-billing.

DCCEEW. 2024a. “Community Batteries for Household Solar Programme.” Australian Government Department of Climate Change, Energy, the Environment and Water. https://www.dcceew.gov.au/energy/renewable/community-batteries.

DCCEEW. 2024b. “Community Solar Banks.” Australian Government Department of Climate Change, Energy, the Environment and Water. https://www.dcceew.gov.au/energy/renewable/community-solar-banks.

Dentons. 2020. “The 2019–2020 Incentives Regime for Renewable Energy.” https://www.dentons.com/en/pdf-pages/-/media/fcaeaba3d7424b2da0b0110ec08f6b06.ashx.

—. 2022. Italy: “‘DL Energia’ A Guide to the New Simplification Rules for Renewables (Updated to the New Conversion Law).” https://www.dentons.com/en/insights/guides-reports-and-whitepapers/2022/may/4/italy-decree-energia-a-guide-to-the-new-simplification-rules-for-renewables.

Department of New and Renewable Energy, Haryana. 2024. “Introduction JNNSM.” Government of Haryana. https://hareda.gov.in/intoduction-jnnsm/.

DoE. 2021. “Solar Futures Study.” US Department of Energy Solar Energy Technologies Office https://www.energy.gov/sites/default/files/2021-09/Solar Futures Study.pdf.

—. 2022. “The United States’ Clean Energy Goals.” Office of Energy Efficiency and Renewable Energy. https://www.renewable-ei.org/pdfdownload/activities/01_Key_AlejandroMoreno.pdf.

—. 2023. “Community Solar Market Trends.” https://www.energy.gov/communitysolar/community-solar-market-trends.

—. 2024a. “About the National Community Solar Partnership.” https://www.energy.gov/communitysolar/about-national-community-solar-partnership.

—. 2024b. “Clean Energy Connector.” https://www.energy.gov/communitysolar/clean-energy-connector.

DoE and NREL. 2024. “Clean Energy Connector.” US Department of Energy. https://connector.nrel.gov/.

DGRV. 2023. “Energy Cooperatives in Germany - State of the Sector 2023 Report.” https://www.dgrv.de/wp-content/uploads/2023/07/DGRV_Survey_EnergyCooperatives_2023.pdf.

Economic Regulator. 2010. “Comparison of 2010 Australian Standing Offer Energy Prices.” Office of the Tasmanian Economic Regulator, Government of Australia. https://www.economicregulator.tas.gov.au/Documents/Standing%20Offer%20Prices%20September%202010%20%2810%203847%29.pdf.

EIA. 2024. “Estimated Net Summer Solar Photovoltaic Capacity From Utility and Small Scale Facilities (Megawatts).” *Electric Power Monthly*. https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_6_01_a.

ENGIE. 2017. “Efficient Bonus – Photovoltaic Line Promotes Residential Microgeneration With a 60% Discount.” https://www.engie.com.br/en/imprensa/press-releases/efficient-bonus-photovoltaic-line-promotes-residential-microgeneration-with-a-60-discount

Eniscuola. 2022. “Solar Energy in Italy: Where Do We Stand?” https://eniscuola.eni.com/en-IT/articles/2022/energy/solar-energy-ita.html.

Enkhardt, Sandra. 2024. “Germany Launches New Measures to Support Solar.” *PV Magazine*. https://www.pv-magazine.com/2024/04/26/germany-launches-new-measures-to-support-solar/.

EPA. 2024a. “Biden-Harris Administration Announces $7 Billion Solar for All Grants to Deliver Residential Solar, Saving Low-Income Americans $350 Million Annually and Advancing Environmental Justice Across America [Press Release].” US Environmental Protection Agency. https://www.epa.gov/newsreleases/biden-harris-administration-announces-7-billion-solar-all-grants-deliver-residential.

—. 2024b. “Solar for All.” US Environmental Protection Agency. https://www.epa.gov/greenhouse-gas-reduction-fund/solar-all.

EPE. 2012. *Brazil Energy Balance*. Empresa de Pesquisa Energética. https://www.epe.gov.br/sites-en/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-131/topico-103/Relatório%20Final%202012.pdf.

European Communities. 2001. *Directive 2001/77/EC of the European Parliament and of yhe Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. European Communities. Accessed May 2024*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32001L0077&from=en.

EVN. 2017. “Annual Report 2017.” Viet Nam Electricity. https://en.evn.com.vn/userfile/User/huongbtt/files/2018/2/AnnualReport2017.pdf.

Forrester, Sydney, Galen L Barbose, Eric O’Shaughnessy, Naïm R Darghouth, and Cristina Crespo Montañés. 2023. “Residential Solar-Adopter Income and Demographic Trends: 2023 Update.” Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/residential-solar-adopter-income-2.

Fraunhofer ISE. 2024. “Photovoltaics Report.” https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf

Frondel, Manuel, Matthias Kaeding, and Stephan Sommer . 2022. “Market Premia for Renewables in Germany: The Effect on Electricity Prices.” Energy Economics 109 (May): 105874. https://www.sciencedirect.com/science/article/abs/pii/S0140988322000573#:~:text=Germany’s%20market%20premium%20for%20RES,and%20to%2065%25%20by%202030.

Gagnon, Pieter, Robert Margolis, Jennifer Melius, Caleb Phillips, and Ryan Elmore. 2016. “Rooftop Solar Photovoltaic Technical Potential in the United States.” National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy16osti/65298.pdf.

Government of South Australia. n.d. “The Home Battery Scheme.” https://www.energymining.sa.gov.au/consumers/solar-and-batteries/hbs-closed.

Government of Viet Nam. 2015. “Viet Nam’s Renewable Energy Development Strategy up to 2030 With an Outlook to 2050.” https://policy.asiapacificenergy.org/sites/default/files/Decision%20No.%202068-QD-TTG%20on%20Development%20Strategy%20of%20Renewable%20Energy%20of%20Viet Nam%20by%202030%20with%20a%20vision%20to%202050_EN.pdf.

—. 2017. “Support Mechanisms for the Development of Solar Power Projects in Viet Nam.” https://policy.asiapacificenergy.org/sites/default/files/Decision%20No.11-2017-QD-TTg%20of%20the%20Prime%20Minister%20on%20the%20mechanism%20for%20encouragement%20of%20the%20development%20of%20solar%20p-ower%20projects%20in%20Viet Nam%20(2017)%20EN.pdf.

—. 2020. “On Mechanisms to Promote the Development of Solar Power Projects in Viet Nam.” https://policy.asiapacificenergy.org/sites/default/files/Decision_13_2020_on_Solar-FiT-2_EN.pdf.

—. 2023. “National Power Development Plan for the 2021–2030 period.” Office of the Prime Minister, Government of Viet Nam. https://vepg.vn/wp-content/uploads/2023/05/PM-Decision-500-approving-PDP-VIII_150523.pdf.GSA. n.d. “Regulatory Changes for Smarter Homes.” Government of South Australia https://www.energymining.sa.gov.au/industry/hydrogen-and-renewable-energy/solar-batteries-and-smarter-homes/regulatory-changes-for-smarter-homes.

Hang Le, Thi Thuy, Eleonora Riva Sanseverino, Dinh-Quang Nguyen, and Maria Luisa Di Silvestre. 2022. “Critical Assessment of Feed-In Tariffs and Solar Photovoltaic Development in Viet Nam.” *Energies* 15 (2): 556. https://doi.org/10.3390/en15020556.

Hartz, Katharina. 2023. “Solar Power From the Roof.” *Agora Energiewende*. https://www.agora-energiewende.de/publikationen/solarstrom-vom-dach.

Hattori, Takashi, and Yi-chun Chen. 2021. “Impact of Chinese Renewable Technology Exports on Japan’s Energy Transition.” *In China’s Carbon-Energy Policy and Asia’s Energy Transition*, edited by Akihisa Mori, 210–230. Routledge. doi.org/10.4324/9781003190905-13.

Hockenos, Paul. 2022. “Will Solar Mandates Prompt a Boom in Europe’s Rooftop Solar?” *Energy Transition - The Global Energiewende*. https://energytransition.org/2022/12/will-solar-mandates-prompt-a-boom-in-europes-rooftop-solar/.

Hommel de Mendonça, Sarah. 2023. “The Demand for Plug-in Solar Equipment in Germany Remains High.” *InterSolar Europe*. https://www.intersolar.de/news/balcony-power-plants-in-germany.

IEA-PVPS. 2002a. “Reliability Study of Grid Connected PV Systems.” International Energy Agency. https://iea-pvps.org/wp-content/uploads/2020/01/rep7_08.pdf.

—. 2017. “National Survey Report of Photovoltaic Applications in Germany.” International Energy Agency. https://iea-pvps.org/wp-content/uploads/2020/01/National_Survey_Report_of_PV_Power_Applications_in_Germany_-_2017.pdf.

—. 2019. “National Survey Report of PV Power Applications in China.” https://iea-pvps.org/wp-content/uploads/2020/09/NSR_China_2019.pdf.

—. 2020. “National Survey Report of PV Power Applications in Italy in 2020.” International Energy Agency. https://iea-pvps.org/wp-content/uploads/2021/11/NSR_Italy_2020.pdf.

—. 2021. National Survey Report of PV Power Applications in Japan. International Energy Agency. https://iea-pvps.org/wp-content/uploads/2021/09/NSR_Japan_2020.pdf.

—. 2022. “National Survey Report of PV Power Applications in Japan.” International Energy Agency. https://iea-pvps.org/wp-content/uploads/2022/11/NSR_Japan_2021.pdf

—. 2023. *Trends in PV Applications*. International Energy Agency. https://iea-pvps.org/trends_reports/trends-2023/.

—. 2024. “Snapshot of Global PV Markets.” International Energy Agency. https://iea-pvps.org/snapshot-reports/snapshot-2024/.

IEA. 2012. “100,000 Roofs Solar Power Programme.” International Energy Agency. https://www.iea.org/policies/3476-100-000-roofs-solar-power-programme.

—. 2021. *Net Zero by 2050*. International Energy Agency. https://www.iea.org/reports/net-zero-by-2050.

—. 2022. *World Energy Outlook*. International Energy Agency. https://www.iea.org/reports/world-energy-outlook-2022/outlook-for-electricity.

—. 2023. *SDG7: Data and Projections*. International Energy Agency. https://www.iea.org/reports/sdg7-data-and-projections.

—. 2024. *Renewables 2023*. International Energy Agency. https://www.iea.org/reports/renewables-2023.

Iven De Hoon. 2017. “What is the Superbonus in Italy?” nomoretax.eu. Accessed May 2024. https://nomoretax.eu/what-is-the-superbonus-in-italy/.

IRENA. 2022. “Renewable Power Generation Costs.” International Renewable Energy Agency. https://www.irena.org/Publications/2023/Aug/Renewable-Power-Generation-Costs-in-2022.

IRS. 2024a. "Residential Clean Energy Credit." US Internal Revenue Service. https://www.irs.gov/credits-deductions/residential-clean-energy-credit.

—. 2024b. "Updates to Frequently Asked Questions about Energy Efficient Home Improvements." *IRS Factsheet*, US Internal Revenue Service. https://www.irs.gov/pub/taxpros/fs-2024-15.pdf.

ISA. 2022. "World Solar Market Report." International Solar Alliance. https://isolaralliance.org/uploads/docs/d998384d914dbf6499abe666ddb47f.pdf.

—. 2023. "World Solar Market Report." International Solar Alliance. https://isolaralliance.org/uploads/docs/a85d84a7a402f9209262f855b273da.pdf.

Jha, Akshaya and Gordon Leslie. 2020. Dynamic costs and market power: Rooftop solar penetration in Western Australia. SSRN. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=L3bhG-sAAAAJ&citation_for_view=L3bhG-sAAAAJ:R3hNpaxXUhUC.

Jiang, Wen. 2023. "Cost-Benefit Analysis of China's Whole County PV Program: A Case Study of Julu County, Hebei Province." *Journal of World Economy* 2(4): 23–48. doi.org/10.56397/JWE.2023.12.03.

Jin, Zhe. 2023. "Governance Challenges and Solutions of the Solar Energy for Poverty Alleviation Program in China: The Case of Jinzhai County." *Journal of Asian Energy Studies* 7: 20–38. doi.org/10.24112/jaes.070002.

Kılıç, Uğur. 2022. "A Review of Solar Photovoltaic Incentives and Policy: Selected Countries and Turkey." *Ain Shams Engineering Journal* 13(5): 101669. https://doi.org/10.1016/j.asej.2021.101669.

Mai, HJ. 2023. "Energy Experts Share how the US can Reach Biden's Renewable Energy Goals." NPR. https://www.npr.org/2023/02/02/1148370220/biden-renewable-energy-goals.

Mercom India. 2022. "MNRE Proposes Group and Virtual Net Metering for Rooftop Solar in Remote Areas." https://www.mercomindia.com/mnre-group-virtual-net-metering-rooftop-rural-areas.

METI. n.d. "Policy Index". Ministry of Economy, Trade and Industry. https://www.meti.go.jp/english/policy/index.html#ep.

—. 2021. "Outline of Strategic Energy Plan." Agency for Natural Resources and Energy, Ministry of Economy, Trade and Industry. https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf.

Ministry of Economy and Finance. 2010. "Conversion into Law, with Amendments, of the Legislative Decree of 8 July 2010, N. 105, Containing Measures on Urgent Issues Regarding Energy. Extension of Deadline for the Exercise of Legislative Delegation in the Matter Of Reorganization of the Incentive System." https://www.gazzettaufficiale.it/eli/gu/2010/08/18/192/sg/pdf.

Ministry of the Environment and Energy Security. 2023. "National Plan Integrated for Energy and Climate." Italian Ministry of the Environment and Energy Security. https://commission.europa.eu/system/files/2023-07/ITALY%20-%20DRAFT%20UPDATED%20NECP%202021%202030%20%281%29.pdf/.

Ministry of Finance and Ministry of Science and Technology, National Energy Administration. 2009. "Notice on the Implementation of the Golden Sun Programme." https://www.gov.cn/zwgk/2009-07/21/content_1370811.htm.

Ministry of Power. 2023. "Shri R. K. Singh Exhorts Industry Leaders to Set Targets for Going Green; Asks Them to Bring to Government's Notice Such Cases Where the Green Energy Open Access Rules Are Not Being Followed." https://pib.gov.in/PressReleasePage.aspx?PRID=1923863

Ministry of Productive Activities. 2005. "Criteria for Encouraging the Production of Electricity Through Photovoltaic Conversion of Solar Energy." https://www.gazzettaufficiale.it/eli/id/2005/08/05/05A07837/sg.

MNRE. 2014. "Grid Connected Rooftop and Small Solar Power Plants Programme." Ministry of New and Renewable Energy. https://smartnet.niua.org/sites/default/files/resources/Scheme-Grid-Connected-Rooftop-%26-small-solar-power-plants.pdf.

—. 2015. “Revision of Cumulative Targets under National Solar Mission from 20,000 MW by 2021–22 to 1,00,000 MW.” https://pib.gov.in/newsite/PrintRelease.aspx?relid=122567.

—. 2019 “Admissibility of CFA for residential sector rooftop solar projects installed under Rooftop Solar Programme Phase-II” https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/01/2023012761.pdf

—. 2020. “Annual Report 2019–2020.” Ministry of New and Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/202308311810944609.pdf.

—. 2022. “Framework for Promotion of Decentralised Renewable Energy livelihood applications.” Ministry of New and Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2022/12/2022122711.pdf.

—. 2023a. “Roof Top Solar Capacity Installations Growing at Compound Annual Growth Rate of Around 46%: Union Power and New & Renewable Energy Minister.” Ministry of New and Renewable Energy. https://pib.gov.in/PressReleasePage.aspx?PRID=1989806.

—. 2023b. “Annual Report 2022–2023.” Ministry of New and Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/2023080211.pdf.

— . 2024a. “Operational Guidelines for Implementation of PM Surya Ghar: Muft Bijli Yojana for the Component ‘CFA to Residential Consumer.’” Ministry of New and Renewable Energy. https://pmsg-production-public.s3.ap-south-1.amazonaws.com/notifications/PMSG_Guidelines_for_Residential_CFA_Capex_Mode.pdf

—. 2024b. “Approved Models and Manufacturers of Solar Photovoltaic Modules.” Ministry of New and Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2024/05/202405201613154184.pdf.

—. 2024c. “Draft Guidelines on Implementation of PM Surya Ghar: Muft Bijli Yojana in Residential Sector.” Ministry of New and Renewable Energy. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2024/04/202404162127034309.pdf.

—. 2024d. “PM Surya Ghar: Muft Bijli Yojana - Redefining Solar Power and Energy Access.” https://pib.gov.in/PressNoteDetails.aspx?NoteId=152016&ModuleId=3#:~:text=1.28%20crore%20registrations%20and%2014.84%20lakh%20applications%20fuel%20India’s%20solar%20energy%20expansion&text=The%20PM%20Surya%20Ghar%3A%20Muft,Modi%20on%20February%2015%2C%202024

MoEFCC. 2023. “India Achieves Two Targets of Nationally Determined Contribution Well Ahead of the Time.” Ministry of Environment, Forest, and Climate Change. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1987752.

Mordor Intelligence. 2023. “Viet Nam Solar Energy Market Size and Share Analysis.” https://www.mordorintelligence.com/industry-reports/Viet Nam-solar-energy-market.

—. 2024. “Solar Energy in Italy Market Size & Share Analysis - Growth Trends & Forecasts (2024–2029).” https://www.mordorintelligence.com/industry-reports/italy-solar-energy-market.

Mori, Akihisa. 2017. “Temporal Dynamics of Infrasystem Transition: The Case of Electricity System Transition in Japan.” *Technological Forecasting and Social Change* 145 (August): 186–194. https://doi.org/10.1016/j.techfore.2017.05.003.

Moser, David, and Massimo Mazzer . 2021. “How Solar Energy Could Power Italy Without Using More Land.” *Nature*. https://www.nature.com/articles/d43978-021-00048-z .

N26. 2023. “Italy’s Superbonus Tax Credit: Key Changes in 2023.” https://n26.com/en-it/blog/superbonus-italy.

NC Clean Energy Technology Center. 2023a. “Community Solar Policy.” https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/11/CommunitySolarRules_Nov2023.pdf.

—. 2023b. “DSIRE Insight - Net Metering.” https://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2023/11/DSIRE_Net_Metering_Nov2023.pdf.

NEP. 2018. National Energy Plan 2050. https://antigo.mme.gov.br/documents/20182/1045954/02+Discurso+NATIONAL+ENERGY+PLAN+2050++dia+5+dez1530+a+16+hs+REVISADO++MINISTRO.pdf/e2fa7c7f-0595-2abd-f9a1-d4fad9df51ce.

Nordic Energy Research. 2023. "Country studies - Germany." https://pub.norden.org/nordicenergyresearch2023-03/germany.html#:~:text=Historically%2C%20there%20is%20a%20long,in%20rural%20areas%20in%20Germany.

NREL. 2023. "Sharing the Sun Community Solar Project Data." National Renewable Energy Laboratory. https://data.nrel.gov/submissions/233.

Orioli, Aldo. 2016. "The Recent Change in the Italian Policies for Photovoltaics: Effects on the Energy Demand Coverage of Grid-Connected PV Systems Installed in Urban Contexts." *Energies* 9(11): 944. https://doi.org/10.3390/en9110944.

Qureshi, Shahab, Tuyen Nguyen-Duc, Linh Dan Nguyen, and Long Phan-Van. 2023. "Rooftop Solar Policies Feasibility Assessment Model: Viet Nam Case Study." *Energy Policy* 177 (June): 113577. doi.org/10.1016/j.enpol.2023.113577.

Rashida. 2024. "China's Solar Capacity Surpasses 600 GW." Saur Energy International. https://www.saurenergy.asia/chinas-solar-capacity-surpasses-600-gw/.

REGlobal. 2023. "Outlook for solar power growth in China and Japan." https://reglobal.org/solar-power-growth-and-outlook-for-china-and-japan/.

REI. n.d. "Trends in Cumulative Installed Solar PV Capacity in the World and in Selected Countries." Renewable Energy Institute. https://www.renewable-ei.org/en/statistics/re/.

Reuters, 2024. Australia's push to put more solar panels on rental homes. https://energy.economictimes.indiatimes.com/news/renewable/australias-push-to-put-more-solar-panels-on-rental-homes/107743696

Roberts, M, K Nagrath, C Briggs, J Copper, A Bruce, and J Mckibben. 2019. "How Much Rooftop Solar Can be Installed in Australia?" Clean Energy Finance Corporation. https://www.cefc.com.au/document?file=/media/rcalz41c/isf-rooftop-solar-potential-report-final_.pdf.

Secretariat of Social Communication. 2024. "New Minha Casa, Minha Vida begins Hiring Housing for Low-Income Families ." https://www.gov.br/secom/pt-br/assuntos/noticias/2024/02/novo-minha-casa-minha-vida-inicia-contratacoes-de-moradias-para-familias-de-baixa-renda.

SEIA. 2023. "Solar Investment Tax Credit (ITC)." Solar Energy Industries Association. https://www.seia.org/initiatives/solar-investment-tax-credit-itc.

SECI. 2008. "Jawaharlal Nehru National Solar Mission." Solar Energy Corporation of India, Government of India. https://www.seci.co.in/upload/static/files/mission_document_JNNSM(1).pdf

SETO. 2021a. "Multi-year Program Plan." Solar Energy Technologies Office. https://www.energy.gov/sites/default/files/2021-05/Solar%20Energy%20Technologies%20Office%202021%20Multi-Year%20Program%20Plan_1.pdf.

—. 2021b. "Solar Energy Technologies Office Multi-Year Program Plan." *US Department of Energy*. https://www.energy.gov/sites/default/files/2021-05/Solar%20Energy%20Technologies%20Office%202021%20Multi-Year%20Program%20Plan_1.pdf.

SETO. 2023a. "160 Communities Now Automating Solar Permitting with SolarAPP+." Solar Energy Technologies Office. https://www.energy.gov/eere/solar/articles/160-communities-now-automating-solar-permitting-solarapp.

—. 2023b. "Federal Solar Tax Credits for Businesses." Solar Energy Technologies Office. https://www.energy.gov/eere/solar/federal-solar-tax-credits-businesses.

—. 2024a. "Homeowner's Guide to the Federal Tax Credit for Solar Photovoltaics." Solar Energy Technologies Office. https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics.

—. 2024b. “Solar Rooftop Potential.” Solar Energy Technologies Office. https://www.energy.gov/eere/solar/solar-rooftop-potential.

—. 2024c. “Streamlining Solar Permitting with SolarAPP+.” Solar Energy Technologies Office. https://www.energy.gov/eere/solar/streamlining-solar-permitting-solarapp

Simshauser, Paul, Joel Gilmore, and Tim Nelson. 2022. “The Sunshine State: Cause and Effects of Mass Rooftop Solar PV Take-up Rates in Queensland.” Working Paper Series 2022-05, Centre for Applied Energy Economics & Policy Research, Griffith University. https://www.griffith.edu.au/__data/assets/pdf_file/0033/1799250/No.2022-05-Queensland-Solar-Cause-and-effects-of-mass-rooftop-solar-PV-take-up-rates.pdf.

Solar Citizens. 2024. “Rooftop Solar Potential of Australian Housing Stock by Tenure.” https://apvi.org.au/wp-content/uploads/2024/04/Solar-potential-of-Australian-housing-stock-published-16-4-24.pdf.

Solar Victoria. 2024. “Solar Battery Loans.” https://www.solar.vic.gov.au/solar-battery-loan.

SolarPower Europe. 2023. “EU Market Outlook for Solar Power 2023–2027.” https://www.solarpowereurope.org/insights/outlooks/eu-market-outlook-for-solar-power-2023-2027.

—. 2024. *Global Market Outlook Solar Power Report* 2023–2027. SolarPower Europe’s. https://www.solarpowereurope.org/insights/outlooks/global-market-outlook-for-solar-power-2023-2027/detail.

SolSmart. n.d. “Introducing SolSmart.” https://solsmart.org/why-solsmart.

Statista. 2024. “Capacity of Cumulative Grid-Connected Distributed Solar Photovoltaic Power Installations in Italy from 2019 to 2022.” https://www.statista.com/statistics/945946/cumulative-grid-connected-distributed-installed-pv-power-in-italy/.

Tauil Chequer and Mayer Brown. 2022. “Brazil Energy Journal.” *Brazil Energy Journal* 4 (June). https://www.mayerbrown.com/-/media/files/perspectives-events/publications/2022/06/brazil-energy-journal--june--power-distributed-generation.pdf.

The Federal Government. 2022. “EEG 2023 - We’re Tripling the Speed of the Expansion of Renewable Energies.” *The Federal Government - Bundesregierung*. https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/amendment-of-the-renewables-act-2060448.

The Federal Network Agency. 2024a. “Growth in Renewable Energy in 2023.” https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2024/20240105_EEGZubau.html#:~:text=Growth%20in%20solar%20capacity%20in,in%202023%2C%20with%203.5%20GW%20.

—. 2024b. “Bundesnetzagentur confirms Electricity Network Development Plan 2023–2037/2045 for climate-neutral transmission network.” https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/EN/2024/20240301_NEP.html.

—. 2024c. “Market Data Register MaStR.” https://www.marktstammdatenregister.de/MaStR/.

The State Council. 2023. “China beefs up renewable energy to boost green development.” The People’s Republic of China. https://english.www.gov.cn/news/202312/26/content_WS658abe16c6d0868f4e8e2892.html.

The White House. 2023. “Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act’s Investments in Clean Energy and Climate Action.” https://whitehouse.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf.

Toxiri, Riccardo. 2014. “The Italian Net Metering Scheme.” Gestore dei Servizi Energetici. https://www.irena.org/-/media/Files/IRENA/Agency/Events/2014/Nov/7/3-Electricity_Storage_Nov2014_Toxiri.pdf?la=en&hash=9439F4680846C68E76F76F1880B1887900B5577B.

UNICEF. 2022. “Rooftop Solar Power: A Potential Solution in Clean Energy for Climate-smart Schools in Viet Nam.” https://www.corecommitments.unicef.org/kp/Viet Nam---rooftop-solar-power.

VEPG. 2020. "Viet Nam Energy Partnership Group: Factsheet on Rooftop Solar Development." Viet Nam Energy Partnership Group. https://vepg.vn/wp-content/uploads/2021/02/VEPG_RTS_Factfile_Dec_2020_EN_fin.pdf.

Verdant Associates, LLC. 2021. "Net Energy Metering 2.0 - Lookback Study." https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/nem-2_lookback_study.pdf.

Wang, Yonghua, Guoliang Luo, and Huang Kang. 2017. "Successes and Failures of China's Golden-Sun Program." Proceedings of the 2017 6th International Conference on Energy, Environment and Sustainable Development (ICEESD 2017). Atlantis Press. doi.org/10.2991/iceesd-17.2017.109.

Wirth, Harry. 2024. "Recent Facts about Photovoltaic in Germany." Fraunhofer ISE. https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/recent-facts-about-photovoltaics-in-germany.pdf.

WRI. 2020. "Distributed Energy in China: Review and Perspective 2020–2025." World Resources Institute. https://wri.org.cn/sites/default/files/2021-11/distributed-energy-in-china-review-and-perspective.pdf.

Xu, Kaifeng, Gabriel Chan, and Jenny Sumner. 2023. "Sharing the Sun: Community Solar." National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy24osti/87235.pdf.

Ying, Yuan. 2011. "Burned by the Sun." Dialogue Earth. https://dialogue.earth/en/energy/4232-burned-by-the-sun/.

Yzquierdo, Javier Heredia, and Antonio Sánchez-Bayón. 2020. "The European Transition to a Green Energy Production Model: Italian Feed-in Tariffs Scheme & Trentino Alto Adige Mini Wind Farms Case Study." *Small Business International Review* 4 (2): 39–52. https://www.econstor.eu/bitstream/10419/224312/1/10.26784-sbir.v4i2.246.pdf.

Zhang, Huiming. 2020. "Solar Photovoltaic Interventions have Reduced Rural Poverty in China." Nature Communications 11, 1969 (2020). https://doi.org/10.1038/s41467-020-15826-4.

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