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Our Solar Future Roadmap to Mobilize USD 1 Trillion by 2030

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HIGHLIGHTS

- Scaling solar energy can help deliver clean, affordable, and reliable energy access worldwide.
- Average annual investment in solar solutions needs to double from 2021 through 2030 if the world is to achieve the Paris climate goals and the UN Sustainable Development Goals (SDGs). Targeted action is needed to ensure that developing countries and emerging markets receive an equitable share of investment.
- Across all market segments, major barriers to scaling up solar include a lack of enabling policies and regulations, a lack of bankable project pipelines, and risk-management challenges.
- Governments can take action immediately, in partnership with commercial banks and development finance institutions, to address these barriers and to replicate and scale effective solutions.
- Broader international collaboration is also needed to scale up available resources, manage risk at scale, speed up transactions and standardize good practices, support innovative business models, and develop systems to monitor commitments, track progress, and measure impacts of solar investment.

EXECUTIVE SUMMARY

In the decisive years between now and 2030, solar energy will be essential to our ability to reach global development and climate goals. This roadmap provides guidance for rapidly and equitably scaling solar investment and deployment across the globe.

Background

The Intergovernmental Panel on Climate Change (IPCC) points to solar energy as the mitigation option with the highest potential contribution to net greenhouse gas emission reduction. Falling costs for solar energy and battery energy storage have made solar cost-competitive with fossil fuels and other renewable energy solutions. Tapping into abundant solar resources in developing and emerging economies will improve energy access and security and can help achieve the UN Sustainable Development Goals (SDGs) (i.e., SDG-7 on affordable and clean energy and SDG-13 on curbing climate change).

The International Energy Agency (IEA) and BloombergNEF (BNEF) project that, to meet net zero emission goals, solar needs to become the largest single global energy source by 2050. To achieve this growth, the International Renewable Energy Agency (IRENA) and BNEF estimate that average annual solar investment through 2030 needs to more than double.

Scaling up solar investment and deployment faces three primary barriers: the lack of conducive energy sector planning, enabling policies, and regulations; an inadequate pipeline of bankable projects with creditworthy off-takers; and risk-management challenges. These barriers affect countries to different degrees depending on their investment readiness and market conditions.

This roadmap provides guidance that can accelerate and scale up solar deployment and reduce regional investment gaps by equitably mobilizing US$1 trillion of investment in solar energy solutions by 2030. It has been prepared by World Resources Institute (WRI) and the International Solar Alliance (ISA), in partnership with Bloomberg Philanthropies and in collaboration with CONCITO, the Investment Fund for Developing Countries, and the World Climate Foundation.

This roadmap builds on reports by IEA, IRENA, IPCC, and other clean energy and climate institutions, as well as consultations with more than 100 solar development and finance experts around the globe. It identifies and prioritizes ways to overcome barriers to scaling solar investment, particularly in developing countries and emerging economies. It focuses on solutions with the greatest potential to

- catalyze private investment;
- improve energy access and energy security; and
- provide other socioeconomic benefits.

These solutions include actions that countries can pursue in four solar market segments: off-grid and decentralized solar, utility-scale and grid-connected solar, energy storage and grid flexibility infrastructure, and advanced solar and storage technologies. To address barriers that cannot be solved at the country level, this roadmap offers recommendations for new collaborative actions to be taken by international institutions, governments, and private sector actors.

Findings

Governments—often in collaboration with national development banks, commercial banks, and development finance institutions—can take solar investment to scale by setting deployment targets and helping to improve investment readiness, manage risk, and strengthen bankable project pipelines. They can create conditions that make investing in solar more attractive and profitable, particularly in developing and emerging economies.

Barriers that cannot be overcome at the country level require new types of collaboration among international institutions to enhance solar investment and deployment goals; coordinating and scaling risk-mitigation efforts; promoting good practices in sector regulation; standardizing systems for tracking progress, performance, and impact; demonstrating credible solar project pipelines; developing innovative rating tools for funds designed for emerging markets; and supporting the global scale-up of vendor finance.

INTRODUCTION

Decarbonizing the power sector and energy use is vital to achieving the Paris climate goals and the UN Sustainable Development Goals (SDGs). Clean energy transition scenarios by the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), and Intergovernmental Panel on Climate Change (IPCC) (IEA 2021a; IRENA 2022b; IPCC 2022) suggest that this will require a dramatic increase in renewable—and particularly solar—energy deployment over the next few decades, especially in developing countries and emerging economies.

The IPCC points to solar energy as the mitigation option with the highest potential contribution to net greenhouse gas (GHG) emission reduction (IPCC 2022). Life-cycle greenhouse emissions (in grams of carbon dioxide equivalent per kilowatt-hour, or gCO_2e/kWh) of solar to 2050—which include embodied energy from the manufacture of solar photovoltaic (PV) panels—are estimated to be only about 6 percent of the emissions from coal and 8 percent of emissions from gas, even with carbon capture and storage systems in place for these fossil fuel sources (Evans 2017; Pehl et al. 2017). Where it displaces power and electricity generation from coal, natural gas, diesel, and oil-fired plants, solar also reduces harmful air pollutants such as nitrogen oxides, sulfur dioxide, particulate matter, and mercury (NREL 2008; IRENA 2016a).

Decentralized solar energy is uniquely suited to provide affordable energy access to hundreds of millions of people. Off-grid and mini-grid solar PV technologies offer the potential to bring new electricity access to 425 million to 581 million people by 2030 (UN 2021a). Steep cost declines for crystalline solar PV modules—which fell by 88–91 percent between 2009 and 2021 (IRENA 2022c)—as well as utility-scale solar energy technologies (see Box 1) have made solar cost-competitive with fossil fuels and other renewable energy options.

According to the IPCC, solar energy has the "largest technical potential of all energy sources" (IPCC 2012). Many developing countries have high untapped solar energy potential (World Bank 2020). Adding solar generation capacity to the power grid, along with other renewables, can help countries lower their reliance on fossil fuel imports and reduce associated price volatility. Combining grid-supplied with decentralized solar technologies can also help build the resilience and reliability of power supply for households and businesses where grid supply is limited or unreliable; for example, by replacing diesel-powered backup generators or diesel use in agriculture and rural areas (IPCC 2022; Babajide and Brito 2021).

The last decade has seen significant progress in solar investment and deployment. Global annual investment in solar more than doubled between 2010 and 2021, and global installed capacity of solar PV increased 21-fold during the same period, from 40 to 843 gigawatts (GW) (Figure 1) (IRENA 2022a; BNEF 2022). Solar energy's share in the global electricity mix has risen from a negligible 0.2 percent in 2010 to about 3.7 percent (Statista 2022). In 2021, global investment in renewable energy exceeded US$417 billion, with roughly half—an estimated $205 billion—focused on solar development (BNEF 2022).

IRENA and BNEF both estimate that average annual investment in solar PV between 2021 and 2030 needs to more than double (BNEF 2021a; IRENA 2022b) to achieve the needed level of growth. Toward that objective, the International Solar Alliance was launched by India and France in 2015 to ramp up investment in and deployment of solar energy, with an aim to mobilize $1 trillion of investment in solar energy solutions by 2030.

Box 1 | Costs for utility-scale solar energy are plummeting

The International Energy Agency calculates that "in a significant majority of countries worldwide, utility-scale solar photovoltaic (PV) is the least costly option for adding new electricity capacity." The levelized cost of electricity (LCOE) from utility-scale solar PV fell 85 percent between 2010 and 2020, from US$381 per megawatt-hour (MWh) to $57/MWh, and prices of lithium-ion battery packs declined approximately 85 percent from 2010 to 2018. New solar technologies, such as Perovskite solar modules, offer further price reductions and conversion efficiency gains. Although global supply chain disruptions caused by the COVID-19 pandemic, the sourcing of polysilicon raw materials, and geopolitical conflicts have caused the costs of solar PV to increase 10–20 percent since 2020, the global weighted average LCOE from utility-scale solar PV continued to fall by 13 percent year-on-year to $48/MWh, bringing the total decrease in LCOE since 2020 to nearly 88 percent. Projections by the International Renewable Energy Agency show continued cost declines over the long term.

Sources: IRENA 2019, 2020, 2022c; BNEF 2019; IEA 2022a, 2022b.

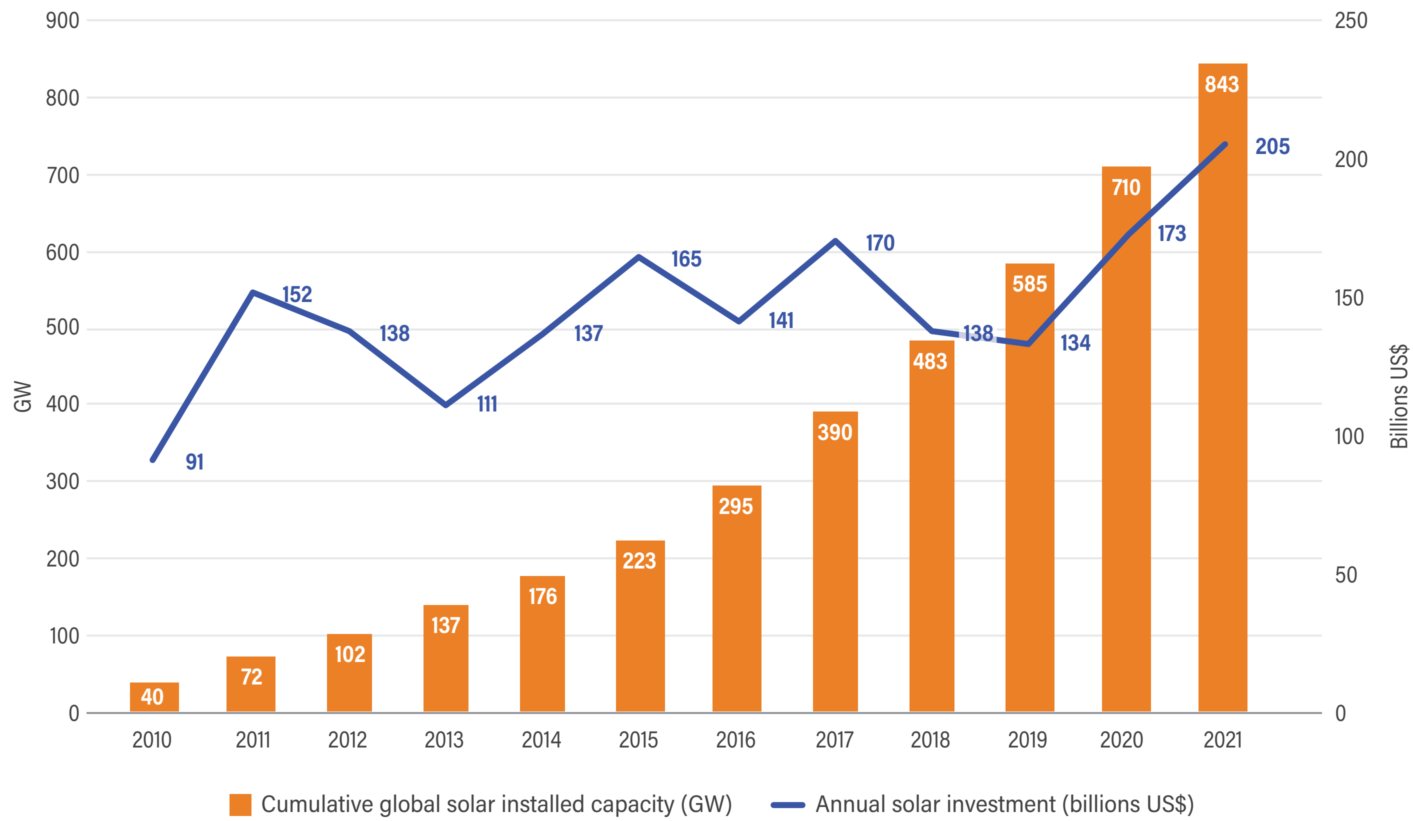
Roadmap to Mobilize USD 1 Trillion by 2030

This roadmap identifies priority actions to scale solar investment to meet the $1 trillion goal and ensure that investment reaches countries and communities whose energy needs are unmet today. It includes guidance to help governments, financial institutions, and the broader international community address the barriers to scaling solar and equitably achieving global development and climate goals.

The roadmap supplements existing resources and initiatives, including the International Finance Corporation (IFC)/World Bank Group Scaling Solar program, the *Ease of Doing Solar* reports published by Ernest & Young (EY), and ISA's Country Partnership Framework. Its goal is to **aggregate the knowledge from these and other sources and identify priority actions that will have the greatest impact on scaling solar investment**. The roadmap makes two principal contributions:

- *Proposed solution pathways* consisting of priority actions that countries can take in the near term—alone or with support from financial institutions—to rapidly scale up solar investment and make it less risky and more profitable in developing and emerging economies. To illustrate how these measures work, and how they could be replicated, the roadmap offers
  - solution cases: examples of successful implementation of specific solutions; and
  - country examples: analyses of individual countries' experience implementing various elements of the solution pathway.

Figure 1 | **Cumulative global solar installed capacity (GW) and annual solar investment (billion US$) from 2010 to 2021**



Sources: IRENA 2022b; BNEF 2022a.

- *Recommendations for new types of collaboration* among international institutions to address barriers to scaling solar that cannot be solved at the country level.

Methodology

The findings and recommendations in the roadmap build on two sources:

- *Published reports* by development finance institutions (DFIs), other international institutions, and companies respected in the clean energy field. The roadmap team aggregated information on investment gaps and trends, barriers, and solutions for solar and other renewable energy sources from recent reports by the IEA, IRENA, BNEF, IPCC, World Bank, EY, IFC, the Climate Policy Initiative (CPI), DNV, the Global Off-Grid Lighting Association (GOGLA), and Wood Mackenzie, among others.

- *Consultations* with more than 100 solar development and finance experts who participated in eight targeted consultations between August 2021 and May 2022. These consultations were virtual, interactive meetings organized and led by WRI. Each consultation focused on solar investment in a specific geographic region (Africa, Asia-Pacific, Latin America and Caribbean), market segment (off-grid solar, utility-scale solar, advanced solar technologies), or sectoral group (private sector). Each consultation included 15–30 participants, consisting of decision-makers and high-level practitioners in various sectors (government, international development finance, private investors or developers, and research and other nongovernmental organizations). The participants were selected based on recommendations from ISA, WRI, and the project's Advisory Group, as well as through research to identify prominent individuals in the field. The consultations addressed the following topics: What are the key barriers to solar investment in different regions and country contexts?

What private or public sector interventions are needed to address the barriers? What mechanisms have been the most successful at mitigating risk, improving investment readiness, and building project pipelines? Where are new, collaborative approaches needed?

The roadmap team analyzed the main gaps in solar investment in various market segments and geographic regions as well as priority solutions for closing them. It selected these solutions based on demonstrated success and scale-up potential, particularly in developing countries and emerging economies; likelihood of catalyzing private investment; and ability to improve energy access and energy security and deliver other socioeconomic benefits.

Trends, Gaps, and Opportunities

This roadmap identifies opportunities for overcoming barriers to scaling solar in the following four market segments:

Off-grid and decentralized solar applications are important for affordably reaching 785 million people who still need energy access and another 2.6 billion who need reliable grids (IRENA 2022e), as well as for helping to decarbonize the grid in many locations. These solar applications include

- solar lighting devices, solar home systems (SHS), and household applications that are typically below 50 kilowatts peak to boost clean energy access;
- mini-grid and household or commercial rooftop solar PV installations and stand-alone solar parks for areas with low or unreliable grid coverage, or where policies such as net metering incentivize connections under the grid; and
- larger decentralized solar installations that are off the centralized electrical grid system for dedicated uses for rural health services and clinics, schools, and agriculture (e.g., irrigation, cold storage, food processing).

Off-grid renewables represent only about 1 percent of the overall finance currently deployed for projects to expand energy access in developing countries (CPI and IRENA 2020). According to the *Off-Grid Solar Market Trends Report* (GOGLA and World Bank 2020), expected business-as-usual investments in off-grid solar ($1.7 billion to $2.2 billion from 2020 to 2024) are far below the levels needed to achieve universal energy access; reaching this goal will require $6.6 billion to $11 billion in additional solar finance between 2020 and 2030, including up to $7.7 billion in investment for off-grid solar companies, and up to $3.4 billion of public funding to bridge the affordability gap.

Utility-scale and grid-connected solar includes

- power generation grid-connected projects that are owned by government, state-owned enterprises (SOEs), or utilities and are at least 1 megawatt (MW) in size, with the private sector as equipment suppliers and solar engineering, procurement, and construction contractors;
- privately owned independent power producers (IPPs) selling power under long-term contracts from solar projects procured by the government, SOE, or utility—either through auctions or self-developed by an IPP and awarded on a sole source basis; and
- privately developed and owned projects with commercial, industrial, or small and medium enterprise (SME) off-takers and contracts directly negotiated between suppliers and large consumers.

With the addition of sufficient storage to address intermittent generation issues, utility-scale solar projects offer a viable pathway to accelerate the shift away from fossil fuels, reduce energy cost, and improve reliability of electricity supply. Construction of large solar PV plants often takes less than a year (IFC 2015), compared with an average of about four years for thermal plants (IEA 2019), offering the opportunity to quickly scale clean energy to meet growing demand.

In 2020, utility-scale PV accounted for 58 percent of new on-grid solar capacity built, and BNEF estimates that this share will grow at an annual rate of 16 percent over the next 30 years (BNEF 2021b). IRENA estimates that utility-scale solar will need to account for the majority of the 450 GW of annual solar PV capacity that needs to be added by 2030 to achieve net zero emission goals, with roughly half of this capacity growth concentrating in Asia—chiefly in China and India (IRENA 2022d). To achieve this, utility-scale solar will need to reach 4 TW, or 75 percent of total solar installed capacity by 2030, and at least 16.5 TW (84 percent of the total) by 2050 (BNEF 2021a; Olson and Bakken 2022).

Investment in **energy storage and grid flexibility infrastructure—**including battery energy storage system (BESS) and power transmission and distribution (T&D) infrastructure—is essential to connect solar energy supply to demand for energy, integrate solar energy resources into regional electricity infrastructure, and facilitate load management. Expanding storage capacity also can defer or avoid the need for additional T&D infrastructure or extend the life of existing T&D equipment by serving a portion of peak demand (ESA 2013). Investments in interregional and transcontinental high-voltage transmission systems can increase the reliability and resilience of grid-supplied electricity.

Global investment in battery energy storage has climbed sharply and is projected to reach $18 billion in 2022—doubled from 2021 and six times what it was in 2017 (IEA 2022a). However, to achieve net zero emissions by 2050, BNEF estimates that an average of 245 GWh of battery storage needs to be added each year globally between now and 2030—more than 10 times the record-setting 24 GWh added in 2021 (BNEF 2021c). IPCC scenarios to limit warming to below 1.5°C estimate that global annual investment in storage needs to average $221 billion per year between 2023 and 2032 (IPCC 2022).

Although public actors almost exclusively financed T&D investments before 2019, participation by private actors has grown in recent years, particularly in developed countries (CPI 2021). Driven by the increasing share of variable renewable energy sources, chiefly solar and wind, annual investment in grid infrastructure and flexibility is expected to rise from between $250 billion and $300 billion (the prepandemic level) to between $400 billion and $500 billion by 2030 (DNV 2021). The IPCC estimates that global average investment in T&D needs to reach $549 billion per year from 2023 to 2032 to limit warming to below 1.5°C (IPCC 2022).

Investing in the development of **advanced solar and storage technologies** is important for scaling solar deployment in difficult-to-serve industries and locations and for addressing intermittency issues related to solar. Examples include

- floating solar, which uses marine or open freshwater environments for solar generation and reduces impacts on land cover, while co-location with hydropower reservoirs can reduce evaporation and enable the complementary use of existing transmission infrastructure;
- agri-voltaics, which combine solar PV panels with crops to enable multiple productive uses of available land;
- concentrating solar-thermal power;
- hybrid systems to complement wind energy, solar in conjunction with storage from electric vehicles (EVs), and EV charging stations;
- solar power as an input for new clean energy sources, notably green hydrogen production; and
- new solar materials (e.g., bifacial modules, higher-efficiency heterojunction technology, Perovskite), advances in tracker technology and solar software, and new battery chemistries that offer potential for future improvements in the cost and efficiency of global solar deployment.

While the scale of deployment for many of these advanced solar and storage technologies is small compared to other mainstream solar applications today, the momentum of growth is strong and potential is high. For example, in 2020 floating solar represented less than 0.5 percent of total global solar PV installation (IFC 2020) and 1 percent of annual solar demand, but demand is expected to grow by an average of 22 percent annually by 2024 (Wood Mackenzie 2019). The market size of floating solar is also expected to grow more than eightfold by 2027, reaching $3.2 billion (Research and Markets 2022a).

Regional investment gaps and opportunities for scaling

Between 2016 and 2020, all emerging markets and developing economies, excluding China, accounted for only 20 percent of global investment in solar energy. The IEA estimates that this share needs to reach 36 percent by 2030 to limit the increase in global average temperatures to well below 2°C (IEA 2021b). Energy demand in these economies continues to grow, driven by rising populations, standards of living, and temperatures. Tapping abundant solar resources—particularly in sub-Saharan Africa, Southeast Asia, and the Latin America and Caribbean region—can help meet this demand while limiting climate impacts.

- Africa: About 44 percent of Africa's population lacks access to electricity. In 2020, 77 percent of the global population without access was in sub-Saharan Africa (SSA) (IEA 2022b)—but this region attracts less than 5 percent of global energy investment (IEA 2022c). Although Africa has 60 percent of the world's solar resources (IEA 2022c), the continent accounted for only 1.7 percent of global electricity generation from solar PV in 2020 (IRENA 2022b). The IEA estimates that achieving full modern energy access and system resilience in Africa by 2030 would require $65 billion of additional annual investment in the region (IEA 2022c). Current policies and plans in SSA are projected to bring this region to about 49 GW of solar capacity by 2030 and 85 GW by 2050. However, to meet the Paris goals, IRENA's Transforming Energy Scenario estimates that solar capacity in SSA would need to grow 60 percent more than this projected amount by 2030, reaching 79 GW—and six times as much by 2050, reaching 548 GW (IRENA 2020).

- Asia: While most countries in the region have high average electricity access rates, large variations exist in energy access and reliability in many countries, and access gaps persist in Cambodia and Myanmar. Most economies in the region have more than doubled in size since 2000, resulting in surging energy demand. Southeast Asia invested about $12 billion per year in all renewable energy from 2016 to 2020. The IEA estimates that while $9.4 billion of investment in solar and wind is needed from 2026 to 2030 to achieve current national clean energy goals, nearly three times as much, $27.3 billion, is needed to limit the temperature to well below 2°C (IEA 2022d; IEA 2022e). Current policies and plans aim for 1,445 GW of solar capacity by 2030 and 3,236 GW by 2050. However, IRENA's Transforming Energy Scenario estimates that to meet the Paris goals 43 percent more capacity (for a total of 2,064 GW) would be needed by 2030 and 50 percent more (a total of 4,837 GW) would be needed by 2050 (IRENA 2020).
- Latin America and the Caribbean: In 2020, 68 percent of the region's electricity generation came from renewable sources—but the majority of this (53 percent of total electricity generation) was from hydropower (IRENA 2022a), whose reliability is lessened by climate change. For example, Brazil's 2016 drought resulted in blackouts and forced the country to rely on thermoelectric plants. Despite the region's abundant sunlight, solar's share in power generation is only 17 percent of the renewable energy contribution (IRENA 2019). While the overall region has an average 98 percent energy access rate, there are still pockets of low access: 17 million Latin Americans lack access to electricity (IEA 2021c). Although current policies and plans in Latin America and the Caribbean are projected to bring this region to about 76 GW of solar capacity by 2030 and 177 GW by 2050, IRENA's Transforming Energy Scenario estimates that to meet the Paris goals solar capacity in the region needs to grow 42 percent more than this projected amount by 2030, reaching 108 GW—and almost 60 percent more by 2050, reaching 281 GW (IRENA 2020).

Barriers to Scaling Solar Investment

Research and consultations for this roadmap highlighted three overarching barriers to scaling up solar investment. While these barriers are intertwined and share elements, the categories below provide a useful framework for the solutions presented in the roadmap.

LACK OF ENERGY SECTOR PLANNING, ENABLING POLICIES, AND REGULATIONS CONDUCIVE TO SOLAR INVESTMENT, DEPLOYMENT, AND OPERATION AT SCALE

Scaling up solar requires policy and regulatory structures that foster investment in renewable energy. Barriers to investment include a lack of clear energy planning or procurement policies (e.g., duration of feed-in tariffs, structure of power auctions), a lack of coordination among government ministries that can result in project delays, and inconsistent tariff policies that can discourage private developers and investors. Entrenched regulatory and institutional structures in the power sector can also limit new market entrants for solar.

LACK OF BANKABLE PROJECTS

A pipeline of bankable projects—projects with risk-return profiles that meet investors' criteria and can thus secure financing—is necessary to build momentum for scaling up solar investment and deployment. Underwriting solar project development is difficult because banks and investors are often unfamiliar with solar technology and uncertain about the regulatory environment. Creditworthy utility off-takers are scarce in many countries as well. Small market size, and a lack of start-up capital and financial instruments tailored for local consumers, can pose additional challenges, especially for small island nations and other small countries. Another constraint is the lack of programs and resources designed to address these challenges—including solar market and project feasibility studies, sectoral training, and project preparation facilities. Limited private sector experience with solar in many developing countries creates a need for development finance to take on early-stage risk and encourage private investors and developers.

RISK-MANAGEMENT CHALLENGES

Cost-benefit and risk analyses can discourage solar investment. Solar investors and developers face a range of risks:

- *Liquidity risk*, or the potential inability to meet short-term debt obligations.
- *Currency convertibility risk*, or the risk that local currency cashflows cannot be converted into hard currencies.
- *Foreign exchange (FX) risks*, or the risk that fluctuations in exchange rates will negatively impact the profitability and feasibility of an investment in the eyes of a foreign investor.
- *Regulatory risks* associated with changes in local energy laws or regulations.
- *Political risk* related to policy instability or changes and potential expropriation.

- *Off-taker credit risk* in markets where utilities and other counterparties do not have strong financial performance or a track record of fulfilling specific contractual obligations.
- *Financial risks*, including market conditions and other factors that adversely affect profitability.
- *Supply chain risks* related to potential shortages or delays in obtaining solar equipment and materials.
- *Lack of financial products*: many financial institutions prefer to invest in traded and liquid financial instruments (bonds or stocks or other traded financial instruments) that are not yet available for local or smaller solar industries. In addition, lending assessments are often based on asset-backed lending structures that discourage investment in high-risk sectors.

These real and perceived risks can raise the cost of capital for solar projects, particularly in developing countries, where the average interest cost of external borrowing is three times that in developed countries (Spiegel and Schwank 2022).

A variety of financial tools have been developed to mitigate such risks, including first loss, credit, and partial risk guarantees, and blended finance. First loss guarantees, which essentially take the first loss on a loan, help build credibility and confidence among creditors. Partial credit guarantees, often from international financial institutions, reduce risks on bonds and loans by promising to pay the principal and/or interest up to a predetermined amount. And partial risk guarantees protect private lenders or investors from losses in case a government (or government-owned entity) fails to fulfill its commitments related to a private project. Blended finance uses public funds—including development finance and philanthropic funds—to mobilize private capital by accepting early-stage risk that the private sector is unwilling to absorb (OECD 2022).

These financial tools are not used at the scale needed to significantly accelerate solar investment. An IRENA study found that the use of guarantee instruments for renewable energy projects accounts for only 4 percent of the value of total infrastructure risk mitigation issued by international financial institutions. Some organizations report that they have no experience deploying risk-mitigation instruments for renewable energy projects, and most of the guarantees used are to support larger-scale projects (IRENA 2016b). The World Bank also has long noted that partial credit guarantees, blended finance, and other risk instruments face scaling barriers, including cumbersome implementation processes and a lack of capacity and awareness among project developers (World Bank 2009).

FINDINGS: SOLUTION PATHWAYS FOR SCALING AND ACCELERATING SOLAR INVESTMENT AT THE COUNTRY LEVEL

Numerous near-term actions at the country level—which can be taken by governments alone or in collaboration with utilities, national development banks, commercial banks, and development finance institutions—have proved effective in overcoming barriers to scaling solar. Countries have historically succeeded at adopting new clean energy frameworks through a combination of target setting, policy reform, and DFI finance to crowd in private capital (Box 2). Progress has been uneven. For example, while almost three-quarters of the emerging markets surveyed for Climatescope 2020 have set clean energy targets, few have implemented strong policies conducive to clean energy deployment.

The **solution pathways** below describe priority actions needed in each of the four solar market segments to accelerate progress toward achieving country-level solar or clean energy targets. Each pathway provides a menu of available solutions that have proved effective for that market segment in various country contexts. Some similarities exist among the actions listed for different market segments; this highlights how certain actions can help address barriers in multiple market segments. Figures 2–5 provide summaries of priority actions (by actor) for each market segment and indicate how these actions address the three main barriers to scaling solar.

Solution pathway for off-grid and decentralized solar

In addition to the broad barriers discussed in the introduction, off-grid and decentralized solar solutions face specific hurdles related to their unique markets, small transaction sizes, and financing models. Solar home systems and solar device markets have grown quickly in some countries with the use of PAYGo and other consumer financing business models, but affordability is still a barrier, and many small-scale, off-grid markets rely on government subsidies (GOGLA and World Bank 2020). Financiers of small SHS, which can allow millions of households to own low-cost systems, face additional obstacles in figuring out how to process millions of transactions and managing the portfolios that arise. Uncertainty about national energy planning also can constrain growth in this sector, since unexpected grid

Box 2 | Development of new clean energy frameworks: Elements of success

Based on BNEF analysis in support of this roadmap, the following enabling conditions and actions have historically accelerated progress across most country contexts:

- Governments implement policy reforms to provide clarity to investors on their nation's vision for the power sector, notably through binding renewable energy targets and planning for grid expansion, renewables capacity, and rural electrification, with targets for solar electrification.
- Reforms include regulations and policies for renewable energy procurement and tariffication (e.g., standard power purchase agreements [PPAs] through auctions or feed-in tariffs [FiTs]) to improve market access and reduce bureaucracy.
- Governments may also offer investors fiscal incentives in the form of capital subsidies, grants or rebates, investment tax credits, tax reductions, or production tax credits.
- Such government reforms may be supported by international partners to incentivize renewable investment in the grid and off-grid sectors.
- Developers often count on the support of international development banks—which are comfortable taking higher risks and can offer investment at lower cost—to help finance the earliest projects. Such risk assumption from development banks or other international partners may take the form of guarantees or insurance, first-loss capital, or other forms of "blended" finance, all designed to attract co-finance from private investors.
- After the first projects are built, investors' perceptions of risk tend to diminish, private capital starts to "crowd in," and the need for development finance fades.

Source: BNEF 2021b. See also Regulatory Indicators for Sustainable Energy on policy and regulatory reforms needed to support and guide countries in their reform processes; https://rise.esmap.org/indicators#pillar-renewable-energy.

expansion can delay or jeopardize off-grid solar investments and create stranded assets that deter future investment.

The following **off-grid and decentralized solar solution pathway** highlights priority actions for various actors to address these barriers and mobilize solar investment in this market segment.

National government

- *Set national energy access targets and clarify rural electrification and grid extension plans, including solar deployment targets and time lines.* This enables businesses to assess the market and consumers to assess whether to purchase systems in advance of planned grid extension. Governments should use available online data platforms to inform energy planning, such as the Energy Access Explorer, an open-source energy access mapping platform available for Africa and Asia.
- *Develop clear and consistent tariff policies and solar incentives, including regulations and pricing for both suppliers and consumers, as well as net-metering or net-billing schemes* (see Solution example 1). This is especially important for SHS and rooftop solar purchased on credit to minimize the risk that policies and pricing will change during the repayment period.
- *Standardize government procurement mechanisms to facilitate scaling in purchasing.* Governments can plan for rural electrification, purchase SHS equipment from manufacturers at scale, and act as wholesalers to local solar installers and distributers. They can also manage import logistics to drive down unit costs and provide more predictable markets.
- *Create project incubators* to test new business models and offer low-cost or no-cost start-up capital and project preparation assistance for new players in this market segment.

Solution example 1 | Residential rooftop solar policies in Mexico

The Government of Mexico set a target to produce more than one-third of its electricity from clean energy by 2030, with a large portion slated to come from solar. To support this goal, the government adopted net-metering and net-billing schemes, enabling customers to install rooftop solar to meet their own energy needs and sell excess solar power to the grid, receiving credit against future consumption. As a result of these efforts and Inter-American Development Bank (IDB) financing support for solar installations, between 2018 and 2019 residential rooftop installations in Mexico grew 12 percent and rooftop solar capacity grew 22 percent.

Source: Research and Markets 2022b.

Central and national development banks

- *Regulate and lead green financing practices to mobilize capital through credit operations, collateral policies, asset purchases, green taxonomies, and green bond guidance, including for off-grid solar.*
- *Allocate a percentage of loans for solar projects (national development banks).* This can help shift incentives for banks that otherwise tend to avoid lending for these businesses or projects because they consider them exceptional or risky and assign them higher interest rates. Such allocations would encourage the use of currently underutilized World Bank and other DFI facilities that lend to governments (for on-lending to SHS businesses and suppliers), since the DFIs' subsidized interest rates and TA programs would provide attractive options for meeting the banks' mandated solar portfolios.
- *Support training of bank staff on clean energy finance and modernization of credit risk assessments to boost capacity for solar lending (in partnership with DFIs).*
- *Provide credit to financial institutions that provide low-interest-rate financing for solar projects.*

Commercial banks

- *Create a securitization capability for off-grid solar loans*. This is a financial product that can consolidate hundreds—and potentially thousands—of small loans into a single instrument that financial institutions can purchase, attracting capital from institutional investors. This allows the recycling of capital, improves liquidity, and facilitates growth of the market.
- *Work with governments to develop and deliver subsidized loan programs for solar solutions*. These loans can provide access to local finance and be particularly effective when combined with public grants and other subsidies (see Solution example 2).
- *Develop standardized, stand-alone consumer credit programs to finance solar home systems, ensure affordability, and share risk*. High volumes of low value loans can be streamlined by subsector (such as farmers and small and medium enterprises) using standardized approaches and documentation, reducing transaction costs. Once large portfolios of loans accumulate, they can be refinanced in well-structured securitizations to recycle capital and share risk. Similar standardized credit programs can support business expansion of SHS service providers.

Solution example 2 | Subsidized loans for solar water pumps in India

India's Ministry of New and Renewable Energy launched the Pradhan Mantri Kisan Urja Suraksha evem Utthan Mahabhiyan (PM KUSUM) scheme in 2019, aiming to add solar and other renewable capacity of 25,750 megawatts (MW) in the country by 2022 and allocating around $4.59 billion of central public funding to support implementing agencies. The scheme includes loans to farmers to install solar pumps and other grid-connected solar. Farmers who receive loans pay only 10 percent of the total cost up front and 30 percent more through a bank loan. The remaining costs are paid by India's central government (30 percent) and by the state government (30 percent). By the end of July 2022, India had installed decentralized ground-mounted and grid-connected solar plants with a total capacity of 59 MW and more than 130,000 standalone or individual solar water pumps. However, the massive success of this scheme has resulted in concerns about rapid groundwater depletion—an issue that will require coordinated planning and mitigation efforts before further replication and scaling.

Source: GOI 2022.

DFIs (bilateral and multilateral)

- *Create solar lending programs and concessional lines of credit with standardized risk underwriting approaches to help local banks build their solar lending portfolios.* Solar lending requires banks to understand solar technology and engage with businesses (SHS suppliers, etc.) as partners who will find customers, install and maintain equipment, and recycle it at end of life. Standardization can help structure solar lending to provide good commercial opportunities for the banks and signal that lending programs operate within acceptable risk parameters, helping to incentivize business activity and grow markets.
- *Link solar lending programs with capacity-building for local financial institution personnel and project developers so they better understand the technical risks of solar.* Understanding these risks makes banks less likely to overestimate and overprice them.
- *Partner with utilities to develop self-financing mini-grids and ensure sustainability through local capacity-building* (see Solution example 3).

- *Explore co-financing and syndicate financing schemes*, acting as a lead financier, and inviting local banks to participate under a pari-passu (or "equal footing") arrangement that gives multiple lenders equal claim to the assets used to secure a loan.
- *Align project preparation facilities to match specific types of off-grid projects*. Tailoring project approaches to specific market and lending needs can reduce perceived risk and lower processing costs. For example, SHS project preparation facilities require a high level of standardization to assist businesses in managing a high volume of low-value credits, while businesses investing in mini-grid facilities need to manage large up-front costs, paid back over time by connected users.
- *Scale up blended finance solutions and take the first-loss position in a blended capital structure*. This will accelerate the development of deal and transaction pipelines to help private sector actors scale portfolios and drive down prices and costs.
- *Working with local financial institutions (commercial banks, national development banks), create local-currency financing facilities that can provide financing in smaller amounts*. Local consumers and businesses often need to borrow in foreign currency for solar projects. Credit issued in local currency makes borrowing easier and reduces losses from fluctuating exchange rates.
- *Build green finance capacity among regional and national development banks and other local financial institutions*. Many banks lack internal technical expertise for solar lending and need more capacity to shift concessional funding toward "green finance" and "climate finance" (see Solution example 4).

Figure 2 summarizes the priority actions outlined in this solution pathway and highlights how each group of actors can help address the key barriers to scaling investment in off-grid and decentralized solar.

Solution example 3 | **Tonga's off-grid solar cooperatives**

Many of Tonga's remote islands require off-grid solar facilities to access energy. The country initiated its first major off-grid solar investment in 2019 with a 1.25 MWp mini-grid solar facility to deliver electricity to more than 700 residents on the island of Niuatoputapu. The facility, with nine individual solar plants, was funded by Asian Development Bank's (ADB) Outer Island Renewable Energy Project (OIREP) and sells electricity to the country's sole utility company, Tonga Power Limited (TPL). TPL then resells the solar power to local residents through prepaid metering with a subsidized tariff, with the ADB OIREP team providing technical assistance. Solar electricity costs are further lowered because the facilities are operated and maintained by local residents who have received vocational training and technical capacity-building from OIREP and TPL.

Source: ADB 2022a.

Solution example 4 | **Greening the Banks Initiative in the Philippines**

The Greening the Banks (GTB) initiative was launched in 2019 by Allotrope Partners to help financial institutions, developers, regulators, and other market stakeholders in Southeast Asia actively participate in green finance. In the Philippines, GTB hosted a dialogue series with the Philippines' Central Bank during 2020–22 that engaged more than 1,400 participants to build capacity among local banks and foster collaboration with other entities. The GTB initiative also shares data, tools, and best practices to enhance risk analysis and increase knowledge of innovative green products and technologies, including solar technologies.

Source: Allotrope Partners 2022.

Country example 1. Bangladesh's solar home systems program to develop off-grid solar

Since 2003, Bangladesh has electrified more than 4 million rural households by stimulating investment in SHS. The government funded a public-private partnership (Infrastructure Development Company Limited, or IDCOL) mandated to design and support the rollout of SHS by offering consumer incentives, including generous subsidies and collateral-free loans, and by standardizing procurement mechanisms. IDCOL procures services from a network of partners ranging from local SHS manufacturers and businesses to microcredit financiers who finance the delivery of affordable SHS to households. This model is being studied by other countries, including Uganda, Sudan, Ghana, Ethiopia, and Guinea (Willcox and Cooper 2018).

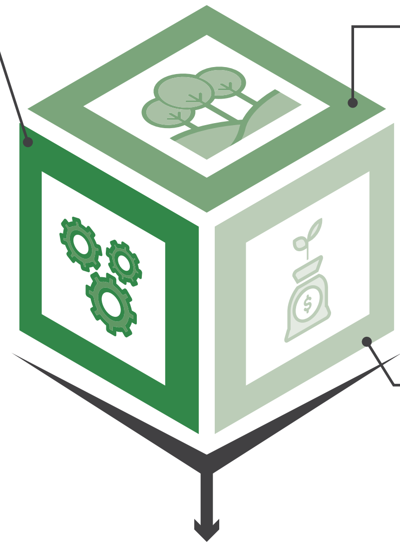
Bangladesh's experience illustrates perils as well as successes. Planners failed to anticipate future grid expansion (Hellqvist and Heubaum 2022). The grid pushed into areas targeted by off-grid solar suppliers, threatening to strand off-grid assets. In addition, insufficient regulatory oversight over SHS quality has driven a drop in system performance and consumer confidence.

Figure 2 | **Solution pathway addresses barriers to scaling solar: Off-grid and decentralized solar**

National governments, central banks, and national development banks

Enabling policies, regulations, and public financing

- Government/utilities – Set clear access and rural electrification targets, and grid expansion plans
- Government – Develop tariff policies, pricing rules, solar incentives; remove import restrictions
- Government – Standardize procurement and contracting mechanisms
- Central banks – Regulate and lead green financing practices for off-grid solar
- NDBs – Reinforce solar policy with solar lending practices: allocate portion of loans for off-grid solar and provide solar investment incentives to off-grid businesses



Accelerate and scale solar investment to 2030

Development finance institutions and commercial banks

Risk management

- DFIs – Standardize risk underwriting and concessional credit lines to support solar lending by local banks
- DFIs - Create local currency facilities; scale up blended finance for off-grid businesses
- Commercial banks – Standardize consumer and business credit for off-grid solar; work with government to provide subsidized loans for solar
- Commercial banks and NDBs – Aggregate and securitize small transactions (working with DFIs); support local currency finance for businesses

Project pipeline development

- DFIs – Align project preparation facilities with solar targets by type of off-grid or mini-grid project
- Government and DFIs – Create incubators to promote innovative projects and lending
- DFIs and NDBs – Build solar and clean energy finance capacity in local bank staff and workforce
- NDBs – Support project pipeline development; liaise with commercial banks and DFIs

Notes: DFI = development finance institution; NDB = national development bank.
Source: Authors.

Available subsidies have also shrunk (Cabraal et al. 2021), raising costs, eroding demand, and destabilizing the market for off-grid solar. Still, by 2020 the program helped provide electricity to 20 million people and push the share of Bangladesh's population with access to energy to 97 percent (Cabraal et al. 2021). (For more details on Bangladesh's experience, see Appendix A.)

Solution pathway for utility-scale and grid-connected solar

One major constraint to scaling up utility-scale and grid-connected solar is a lack of clarity surrounding government procurement plans for electricity supply. Another is uncertainty about plans for public investment in grid infrastructure and technologies to enhance integration of renewable energy into the grid. Such investment is needed to enable the grid to connect to and absorb power generated by solar and other renewable energy facilities.

Another challenge is a lack of financial solvency of state-owned utility companies or enterprises (SOEs).

In many regions, generating power and maintaining grid infrastructure are state-owned activities, and electricity prices to consumers may be highly politicized. When governments cap electricity prices for grid-supplied power, SOEs (e.g., distribution companies) may be forced to sell power below cost and operate at a loss. Accumulated losses over time can result in utilities or other SOEs becoming financially insolvent (World Bank 2018a). Investment in generation and transmission thus lags behind growth in demand, a vicious cycle that results in interruptions and limited access to power due to constraints in power supply or outdated grid infrastructure. Over time, accumulated losses can undermine the ability of the utility or SOE to access capital needed to modernize and integrate new sources of generation, such as solar. Accelerating investment in solar is further complicated because institutions and vested industry interests, with a long history of grid-based fossil fuel or hydropower generation, are often reluctant to adopt new technologies or models for electrification.

The **utility-scale and grid-connected solar solution pathway** highlights priority actions for various actors to address these barriers and mobilize solar investment in this market segment.

National governments

- *Set transparent short- and long-term targets for solar capacity and power system buildout*. This provides needed clarity and reduces risk for potential investors and financiers by guaranteeing a market for their power.
- *Strengthen utilities' financial position by eliminating subsidies gradually and ensuring that the costs of production and system upgrades are covered*. This can help the utility to become profitable and raise its credit ratings, making it a more attractive commercial partner for other power producers.
- *Streamline permitting and tendering processes to attract additional private sector investment in solar.* This includes simplifying permitting through better alignment among regulators, utilities, and government ministries (see Solution example 5); clarifying commercial structures for solar investment; and creating transparent and competitive auctions or tender processes with predictability at the design, bidding, and operating phases.
- *Work with other electricity generators to create standardized power purchase agreements (PPAs)* and a stable framework for purchasing power from a range of solar power producers, such as utility-scale solar projects, industrial users, and households with excess capacity.
- *With DFI support, provide capacity-building for national, regional, and local utilities*, focusing on integrating utility-scale solar PV into national grids, leveraging BESS to manage solar variability, and integrating solar with other renewables.
- *Establish investment protections and policies*: open the generation market to private investment to attract additional capital and incentivize foreign direct investment in utility-scale solar projects. Decrease counterparty risk by issuing sovereign guarantees for solar projects through nodal agencies.
- *Develop "renewable energy (RE) zones" for solar:* RE zones are areas with land features that are appropriate for cost-effective renewable energy development, available RE resources, and developer interest.

Central banks and NDBs

- *Reform policies and coordinate initiatives and actions to reward green financial activities* such as lending and investments in clean energy and penalize those that pollute. This may include green macroprudential policies, monetary policies, and public co-funding (Monasterolo et al. 2022; D'Orazio 2021).

Solution example 5 | Promoting transparent and competitive permitting in South Africa

The government of South Africa initiated the Renewable Independent Power Producer Programme to increase private sector investment in solar PV and other grid-connected renewable sources to achieve its national target of adding 17.8 GW of renewable energy by 2030. The program is a competitive tender process that selects IPPs based on multistage bidding covering the contractual and implementation phases. It has attracted project developers, sponsors, and equity shareholders domestically and abroad, as well as banks, insurers, development finance institutions, and international utilities. Two and a half years after its launch, it had awarded 64 private sector projects for a total of $14 billion investment committed.

Source: REIPPP 2022.

- *Provide expertise and market feedback* to decision-makers to advance solar as part of the clean energy policy framework.
- *Establish a pathway and rules for the issuance of green bonds by local actions* (e.g., see Colombia [SBN and IFC 2018]).

Commercial banks

- *Provide training to staff in assessing risks and underwriting large, complex projects*. More experienced teams can better price risk, which enables lower interest rates, makes loans more attractive to borrowers, and encourages market expansion.
- *Partner with DFIs* in loans for solar projects.

DFIs

- *Provide technical assistance to support countries in reforming policies and institutions (e.g., the utility sector)*. This can include the creation of "fit-for-solar" regulatory frameworks, such as simplified solar permitting procedures, standardized PPAs, and tax incentives for clean energy.
- *Support development of regional markets for solar power (e.g., power pools)* to create economies of scale, manage load, and reduce the need for local storage to advance the uptake and use of large-scale solar.
- *Provide blended financing to leverage private finance and investment in large-scale solar facilities* and related transmission system and battery storage investments (see Solution example 6).

Figure 3 summarizes the priority actions outlined in this solution pathway and highlights how each group of actors can help address the key barriers to scaling investment in utility-scale and grid-connected solar.

Country example 2. Tonga's experience scaling up utility-scale solar

Tonga's experience illustrates how government actions and DFI support can attract significant private sector investment in large-scale solar projects and build project pipelines even in small and island states. In 2008, Tonga's government became the first in the Pacific Islands to establish a feed-in tariff (FiT) to attract private investment (REEEP 2022). In parallel, Tonga's Energy Roadmap (2010–20) set a goal of supplying 70 percent of the country's grid power from renewable energy by 2030 and laid out clear power system procurement plans, defining the roles of the government, the utility, and the private sector (UN 2022). This clarity and Tonga's long-term commitment to solar, which accounts for more than 80 percent of its current renewable energy capacity (IRENA 2022a), attracted private sector funding for large-scale projects. These include a 6 MW solar farm (the second-largest in the Pacific region) built by Suner-

Solution example 6 | **Leveraging private finance to deploy Mozambique's first utility-scale solar plant**

In 2017, a financing package of $55 million—from the International Finance Corporation, Climate Investment Funds, and a syndicated loan, along with a $7 million Viability Gap Funding grant from the Private Infrastructure Development Group—enabled Mozambique to construct its first utility-scale solar photovoltaic power plant. Support from development finance institutions helped mitigate the risks related to Mozambique's deteriorating credit rating and strict restrictions on using U.S. dollars, arising from its debt crisis, and enabled the project to attract private sector investment. The 40 megawatt solar plant, located in a Special Economic Zone in Mozambique, went online in 2018 and delivers 79 gigawatts of electricity per year to rural areas. The project was jointly developed by Scatec Solar, a Norwegian independent power producer; Norfund; and Mozambique's utility company, Electricidade de Moçambique (EdM), with a 25-year power purchase agreement to sell the generated electricity to EdM.

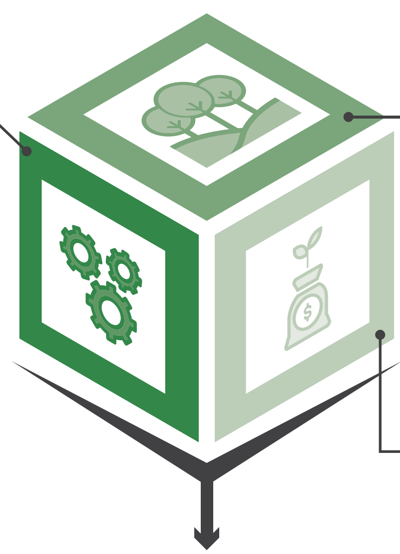
Sources: IFC 2017; Norfund 2020.

Figure 3 | **Solution pathway addresses barriers to scaling solar: Utility-scale and grid-connected solar**

National governments, central banks, and national development banks

Enabling policies, regulations, and public financing

- Government – Set transparent short- and long-term targets for solar
- Government – Strengthen financial performance of utilities and raise credit ratings
- Government – Streamline permitting, tendering, standardized PPAs, and pricing
- Government – Establish RE zones for solar power generation and storage, and regional power pools
- Central banks – Regulate and lead green financing practices, including green bonds
- NDBs – Champion and reinforce solar policy with solar lending practices; co-finance solar projects
- DFIs – Support governments in creating "fit-for-solar" regulatory frameworks and development of regional power pools



Accelerate and scale solar investment to 2030

Development finance institutions and commercial banks

Risk management

- DFIs – Standardize transaction process for utility-scale deals
- DFIs – Create local currency facilities; establish and scale up flexible blended finance facilities
- Government – Policies for investment protection; work with DFIs to build utility-scale solar capacity
- Commercial banks and NDBs – Partner with DFIs in lending; train staff in assessing and underwriting projects

Project pipeline development

- DFIs and NDBs – Build capacity across bank staff on solar and clean energy finance

Notes: DFI = development finance institution; NDB = national development bank; PPA = power purchase agreement; RE = renewable energy.

Source: Authors.

gise, a private company with an IFC equity investment, that will sell electricity to the utility for 25 years. The World Bank and ADB provided pivotal financing and technical assistance to develop a highly competitive tender process and standardized PPAs (ADB 2019). As a result of these combined efforts, 13 percent of Tonga's grid power is now supplied by renewable energy (IRENA 2022a). (For more details on Tonga's experience, see Appendix B.)

Country example 3. Argentina's auction scheme to scale up utility-scale solar

Argentina has set an ambitious goal of 20 percent electricity generation from renewable energy by 2025 (GoA 2015). Policy reforms enacted in 2015–16, including the RenovAr renewable auction scheme, have enabled the country to increase its installed solar capacity more than 100-fold—from 8 MW to nearly 1.1 GW—between 2018 and 2022 (IRENA 2022a; Kind 2022). The competitive auctions under RenovAr offer 20-year PPAs to sell electricity to Argentina's national utility company, along with guarantee mechanisms provided by the government-established Fund for the Development of Renewable Energy (FODER) to mitigate off-taker risk as well as financial and political risk. Argentina received a massive response to the auctions (Saurabh 2017); the bids offered on installed capacity were more than six times the requested amount in Round 1 (Braud 2018) and eight times the requested amount in Round 2—a reflection of the country's effective regulatory framework and robust guarantee mechanisms (Kind 2022). From 2015 to 2022 the renewable energy share in Argentina's total electricity generation increased from less than 2 percent to 16 percent (Kind 2022). However, momentum for additional solar deployment has stalled somewhat since 2018 as the result of a decrease in long-term renewable investment. (For more details on Argentina's experience, see Appendix C.)

Solution pathway for energy storage and grid flexibility infrastructure

Expanding and improving electricity grid T&D and storage systems to adequately serve existing and unserved customers—and build flexibility for integrating future increases in solar generation—is critical for scaling solar. The use of well-established BESS technologies is expanding worldwide, but a 10-fold increase in the pace of battery storage additions is needed (BNEF 2021c) to connect solar energy supply to demand and manage loads. Challenges to rapidly scaling investment in electricity T&D and battery storage include limited public funds available to apply to large-scale new initiatives, a history of government ownership and operation structures that need to be adapted for new investment from the private sector, and a need for capacity-building in management of new technologies and systems.

The following **solution pathway for energy storage and grid flexibility infrastructure** highlights priority actions for various actors to address these barriers and mobilize solar investment in this market segment.

Governments

- *Set yearly and long-term electricity grid expansion plans with clear transmission, distribution, and battery storage objectives* to provide clarity for potential investors. Allocate budget for grid investment (public funding).
- *Develop "renewable energy (RE) zones" for solar and storage resources.*
- *Adopt policies to manage the grid integration of variable solar PV.*
- *Increase regional power pool cooperation* to enable economies of scale in grid management, energy storage, and energy trading. Governments can raise funding through sovereign Green Bonds to invest in solar projects at scale across geographies and over long time frames.

DFIs

- *Support training programs to build government and utility capacity in energy planning.* Training should include topics related to solar integration into grids and T&D, including
  - collecting and analyzing data to identify supply shortages;
  - optimizing management of variable electricity production and grid integration;
  - systems modeling to plan for BESS and other energy storage solutions; and
  - systems modeling to show the value of RE and storage and calculate the amount of storage required.
- *Develop blended finance solutions for grid enhancements* in collaboration with national financial institutions. Guarantees, concessional finance, and equity positions will help attract first-time private investment into the sector. As scale and track records grow, the need for blended finance will abate.
- *Support regional efforts to create and strengthen regional power pools* that enable countries to manage differences in solar power generation and optimize reliable supply; efforts can be modeled on successful initiatives to share excess hydroelectric generation (e.g., Southern African Power Pool).

- *Directly support countries in upgrading T&D infrastructure and power management systems* to enable future solar energy integration (see Solution example 7).

Figure 4 summarizes the priority actions outlined in this solution pathway and highlights how each group of actors can help address the key barriers to scaling investment in energy storage and grid flexibility infrastructure.

Country example 4. Zambia's experience attracting investment in solar generation and T&D

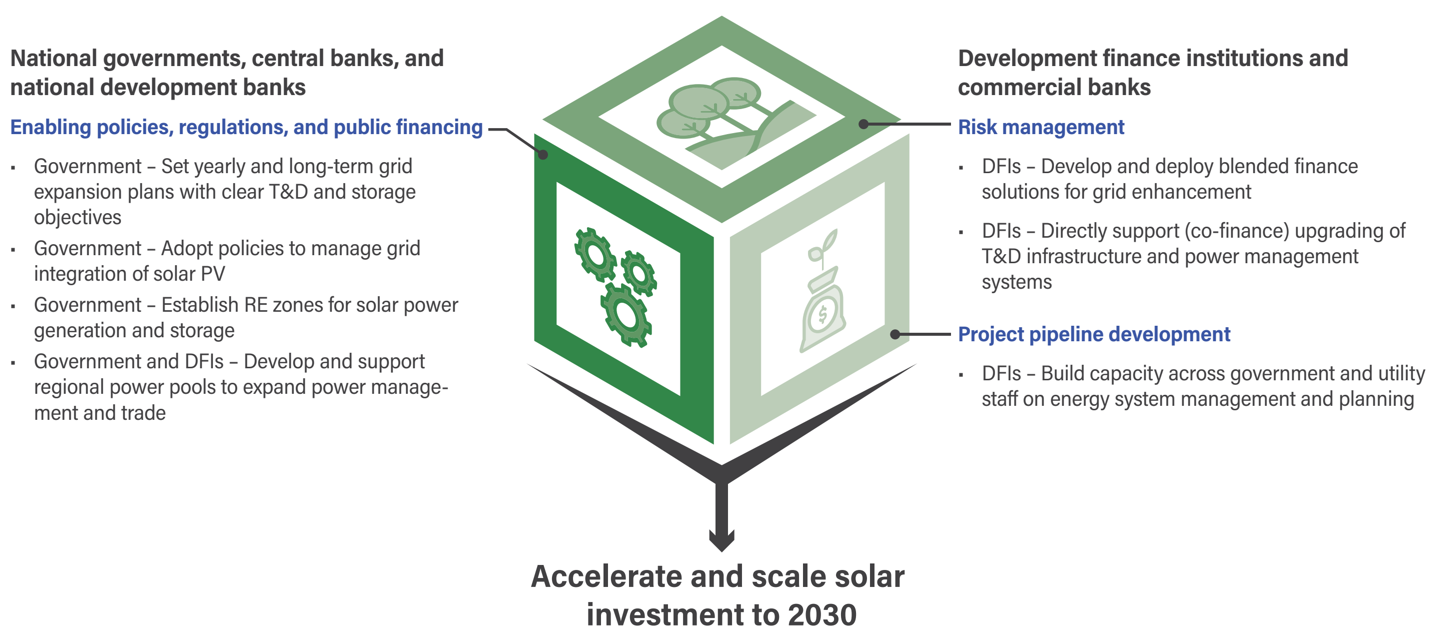
Striving for universal energy access, Zambia has sought private participation in every segment of the electricity market, including solar generation, T&D infrastructure, and power trading with other countries in the region. Adding solar capacity may be critical because extended droughts have begun to reduce the output of Zambia's hydro projects, which account for more than 80 percent of the country's electricity supply. This has led to power shortages and social and economic disruptions. In 2015, with support from the U.S. Agency for International Development (USAID), Zambia implemented a renewable

Solution example 7 | Desert to Power Initiative

The Desert to Power Initiative, launched by the African Development Bank (AfDB) in 2018, aims to install 10 GW of solar power capacity with energy storage across 11 countries in North Africa. The program empowers North African countries to expand grid-connected solar power generation capacity by supporting independent power producers in the solar sector and hybridizing existing thermal power plants, upgrading existing transmission and distribution (T&D) infrastructure and power management systems, and constructing new T&D networks. Among the 85 identified priority projects, more than 25 percent are focused on T&D. The program is expected to deliver technical conditions for a regional solar market with cross-border transmission of clean energy for up to 3 gigawatts.

Source: AfDB 2022.

Figure 4 | **Solution pathway addresses barriers to scaling solar: Energy storage and grid flexibility infrastructure**



Notes: DFI = development finance institution; NDB = national development bank; PV = photovoltaic; RE = renewable energy; T&D = transmission and distribution.

Source: Authors.

energy feed-in tariff (REFiT) (UN 2021b). In 2017, following the success of the competitive auction under the IFC and World Bank Group (WBG) Scaling Solar program, the Government of Zambia revised its national REFiT strategy to utilize the Global Energy Transfer Feed-in Tariff (GET FiT) solar tender process, designed initially for East African countries to produce and support IPP projects with German government support. In 2018, the GET FiT Zambia program accelerated efforts to diversify the country's power mix and make market conditions more attractive to investors. GET FiT Zambia Solar launched a tender for 100 MW of solar projects, and in 2019 it awarded 120 MW of solar PV across six projects in 2019, the largest single solar PV tender implemented in sub-Saharan Africa (outside of South Africa) to date (UN 2021b). As of 2022 these GET FiT–supported projects have not yet been commissioned, largely due to the financial instability of Zambia's utility, the Zambia Electricity Supply Corporation (ZESCO) (US DoC 2022). (For more details on Zambia's experience, see Appendix D.)

Solution pathway for advanced solar and storage technologies

Unique challenges constrain the scale-up of investment in advanced solar technologies (such as floating solar, agri-voltaics, and green hydrogen) and emerging energy storage technologies (such as advanced chemistry batteries including flow batteries, compressed air, and solar thermal energy storage). The challenges include uncertainty about cost and performance of emerging technologies; complex or inconsistent permitting and regulation; the lack of expertise in new technologies among government and other local market actors; and financial and other risks accompanying new technology development and deployment.

The **advanced solar and storage technologies solution pathway** highlights priority actions for various actors to address these barriers and mobilize solar investment in this market segment.

Governments

- *Create and invest in ambitious research and development (R&D) programs and business incubators,* including pilot demonstration programs, with private sector partners, targeting advanced solar technologies.
- *Invest in national market development programs*, including pilot and demonstration projects, best suited to address local needs and opportunities for advanced technologies (see Solution example 8).
- *Streamline permitting processes for advanced solar projects* to reduce delays, complete demonstrations, and help build project pipelines.
- *Consider packages of specific financial incentives* to position the country as a first mover in advanced solar technologies.
- *Develop standards or certification programs* to drive the development of markets for new solar technologies or derived products (see Solution example 9).

DFIs

- *Provide capacity-building and technical assistance* to governments to plan, develop, and implement early investment and demonstration programs and to manage new supply-demand dynamics for advanced solar technologies.
- *Increase country-level financing for business incubators and pilot projects* to develop and adapt advanced technologies to country needs and speed the path to larger-scale deployment (partnering with government and/or NDBs).
- *Provide blended finance support such as insurance and partial risk guarantees* to lower new-technology project risks and provide equity capital and grants for early-stage investment. Concessional debt capital is particularly helpful to support advanced technology projects that otherwise struggle to access bank loans despite positive performance records.

Solution example 8 | **Investment in floating solar in Thailand to address scarcity and cost of land**

In October 2021, the Government of Thailand began operating the "world's largest floating hydro-solar farm," the Sirindhorn Dam farm in the northeastern province of Ubon Ratchathani. With more than 144,000 solar cells and covering 720,000 square meters of water surface, the farm converts sunlight to electricity during the day and generates hydropower at night. It has a capacity of 45 megawatts (MW). These types of integrated projects are key to meeting Thailand's target of generating 30 percent of its energy from renewables by 2037 and helps solve one of the country's main constraints to solar power development: the scarcity and cost of land. The farm is managed by the Electricity Generating Authority of Thailand, and most of the generated electricity goes to the provincial electricity authority, which distributes power to nearby homes and businesses. The $35 million project, which took nearly two years to build—in part due to pandemic-related delays—is the first of 15 such farms Thailand plans to build by 2037, with a planned total power generation capacity of 2,725 MW.

Sources: SEI 2021; Sangwongwanich 2022.

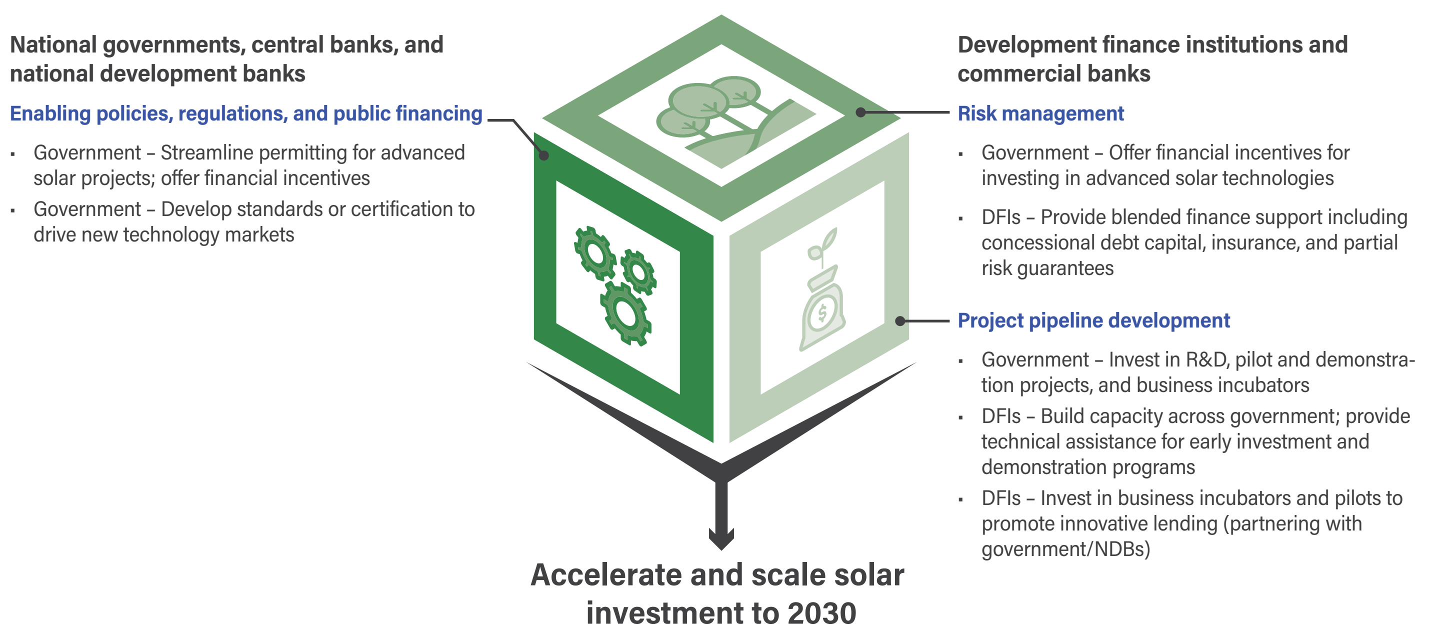
> **Solution example 9 | The European Union's CertifHy program**
>
> The CertifHy program initiated by the European Union helps guarantee that hydrogen has been produced using renewable or low-carbon energy sources, increasing transparency for consumers and lowering the market risk of investing in green hydrogen. Green hydrogen is a potential clean energy source for "hard to decarbonize" sectors of industry and transportation. Under the certification scheme, an electronic CertifHy™ document provides proof that a given quantity of hydrogen is produced with a specific quality and method of production. Extension of this type of certification program could open global trade in decarbonized industrial goods; for example, by supplying green primary iron produced from green hydrogen in developing countries with plentiful solar resources.
>
> *Sources:* CertifHy 2022; Trollip et al. 2022.

Figure 5 summarizes the priority actions outlined in this solution pathway and highlights how each group of actors can help address the key barriers to scaling investment in advanced solar and storage technologies.

Country example 5. Egypt's path to green hydrogen through solar market development

Egypt is currently building the world's largest green hydrogen project pipelines (*Energy & Utilities* 2022). Because Egypt has succeeded in implementing utility-scale solar and other large-scale renewable projects, it has the abundant renewable energy needed to produce green hydrogen (*Enterprise* 2022). The Government of Egypt has supported utility-scale solar and green hydrogen development by aligning policies to encourage investment and funding pilot and demonstration projects. Beginning in 2014, it reduced fossil fuel subsidies, liberalized the power sector to allow prices to reflect costs, and permitted bilateral direct transactions between IPPs and consumers and market competition in power generation and T&D (Breisinger et al. 2019). Combined with technical and policy support from the World Bank Group and the International Monetary Fund (IMF), these policies helped Egypt attract investment from the

Figure 5 | Solution pathway addresses barriers to scaling solar: Advanced solar and storage technologies



Notes: DFI = development finance institution; NDB = national development bank; R&D = research and development.

Source: Authors.

private sector for utility-scale solar facilities; Egypt's installed solar capacity rose from 15 MW in 2014 to 1.66 GW in 2021 (IRENA 2022a). To encourage private sector participation in its ambitious green hydrogen agenda, the Government of Egypt also adopted simplified permitting for new projects, which has helped attract billions of dollars in private investment for the multiple plants under construction (Alhosainy 2022). (For more details on Egypt's experience, see Appendix E.)

RECOMMENDATIONS FOR DELIVERING INVESTMENT AT SCALE

Realizing solar's potential will require not just country-level actions to set targets and implement policy but also coordinated and ambitious action among international institutions. The Clean Energy Ministerial, G20 Energy Ministerial meetings, Sustainable Energy for All (SEforAll), UN agencies, IRENA, ISA, and other global and multilateral organizations need to work together in new ways to accelerate the transition to solar energy to meet the Paris climate goals, Sustainable Development Goals, and net zero emission targets.

An extensive consultation process with global financial and solar development experts identified seven new collaborative efforts that could deliver the attention and resources needed to scale solar investments:

Collaborate to set and track specific and time-bound solar targets. Targets should include time-bound and geographically specific milestones to ensure rapid action. In addition, a collective effort is needed to monitor commitments, track progress, and measure the impacts of solar investment to ensure effective, equitable deployment of solar solutions.

Global entities should collaborate to

- leverage and link specific solar targets to ongoing commitment processes (e.g., nationally determined contributions, UN Energy Compacts, the Science Based Targets initiative, RE100); and
- incorporate targets and planning for grid and infrastructure enhancement and battery energy storage systems into solar targets.

Replicate and scale regional or global entities focused on risk mitigation. Specialized facilities can diversify risk across countries and across risk types and significantly speed up transaction times. Numerous entities could be replicated and/or scaled to address various types of risk.

- For political risk: Political risk insurance programs by the African Trade Insurance Agency (ATI), the World Bank Group's Multilateral Investment Guarantee Agency (MIGA), and bilateral agencies such as HERMES of Germany.
- For off-taker or liquidity risk: ATI's Regional Liquidity Support Facility, which provides short-term liquidity support by backing bank credit to approved IPPs.
- For currency risk: TCX Fund, which hedges currency risk by offering financial instruments that enable investors to provide their borrowers with financing in their own currency; and Climate Finance Lab's ACT Fund, which refinances Africa-based projects in local currency.
- For private investment risk: ISA's planned Blended Finance Facility in Africa, which aims to mitigate risk and facilitate financing for private sector–led projects by combining concessional financing with commercial funding.[1]

Activities could be coordinated through one or a combination of existing multilateral entities (e.g., the World Bank and regional development banks, the Global Environment Facility, the Climate Investment Funds' Clean Technology Fund or Strategic Climate Fund, Green Climate Fund). Risk-mitigation needs for solar investment would be assessed at a regional or country level and existing institutions best suited for replication and scaling would be identified.

Specific activities could include initiatives to

- develop and make widely available a database of risk-mitigation solutions and guidelines on their use, including innovative solutions built on cross-regional learning (e.g., South-South); and
- mobilize public capital to support implementation of the solutions, including concessional or blended finance from philanthropic organizations, bilateral donors, and global climate funds.

Coordinate international efforts to promote good practices in energy sector regulation as they affect solar investment and deployment. Information about good practices in solar sector policies and regulations is dispersed and segregated. Creating and widely promoting a global repository of data and support resources is critical to enable learning and replication across countries in different stages of solar development—and to help create consistent policy and regulatory frameworks despite political fluctuations. This effort can build on the templates developed by the IFC / World Bank Group Scaling Solar program and include the following elements:

- Developing and promoting principles for national regulatory regimes that are optimal for scaling up solar energy to guide governments and DFIs.
- Tailoring these principles to various market scales, private sector roles, and country priorities—such as utility solar through a feed-in tariff structure, large-scale procurement through auctions, mini-grid development, and solar thermal for direct heat utilization.
- Providing planning elements to clarify the role of solar in countries' energy mix, including planning for least-cost power, off-grid development, grid enhancement, spatial and temporal variability of supply and demand, and balancing solar with other generation sources.
- Coordinating with existing global vehicles (e.g., UN energy compacts and energy transition roadmaps developed by the Energy Transition Commission) to promote and incentivize the use of the principles—such as qualification for solar-targeted DFI support.

Establish an international platform to promote standardization in solar finance and support common systems for tracking progress, performance, and impact. Creating standardization among financing entities and processes will be essential to accelerating solar investment. It would include the following steps:

- Identify and engage international financial entities to participate in the development and endorsement of the standardized processes and products (e.g., PPAs).
- Develop globally or regionally applicable, standardized contract structures and negotiation processes to mitigate risk and avoid project pipeline delays.
- With leadership from IRENA, build on existing renewable energy tracking platforms (e.g., IRENA, SEforAll, REN21) to monitor and track progress of solar investment and deployment and lessons learned. Review and improve standardized indicators to measure project-level financial and energy performance, socioeconomic benefits, and other impacts from solar deployment. Coordinate international funding and resource support from DFIs and investors to gather and analyze data to measure outcomes and impacts.
  Track commitments and actions by governments, DFIs, investors, and partnerships to hold stakeholders accountable, promote consensus-building, and strengthen collaboration between the public and private sectors to accelerate solar investment and deployment globally.

Demonstrate credible solar project pipelines. Spur a concerted effort among regional development banks or other DFIs to coordinate regional platforms dedicated to accelerating solar project deal transactions. The lead entity identified for each region would define its detailed focus (e.g., size and types of projects, specific actors) based on the needs, priorities, regulatory frameworks, and country readiness levels in the region. The platforms would share information and experience to encourage replication of successful activities.

Regional platforms to grow solar project pipelines could

- pilot innovative financing platforms led by multilateral development banks, including by convening project developers with clients and financiers and providing financing programs for specific types of solar projects on a regional level through loans to national development banks;
- replicate models for online deal development, such as the CPI's FAST-Infra platform (Déséglise et al. 2021) for infrastructure projects;
- explore strategies to mobilize capital for solar-specific private financial intermediaries that help scale private sector companies involved in off-grid and decentralized solar solutions; and
- develop and promote guidance for project promoters on key elements of feasibility studies to demonstrate the technical and financial viability of proposed solar projects.

Engage rating agencies to review and/or develop innovative rating tools for emerging market blended finance funds. Rating agencies do not traditionally rate emerging-market blended-finance funds, and institutional investors are hesitant to invest in funds that do not have credit ratings. To unlock and scale institutional capital, collaborate with rating agencies to develop streamlined and potentially subsidized rating methodologies for these funds. Engage with the Net Zero Asset Owners Alliance and other stakeholders to build and demonstrate demand for the ratings.

Support global scale-up of vendor finance. Vendor financing is a useful mechanism for large manufacturers to support the expansion of a key market segment when banks are reluctant to provide working capital to customers. It also provides an important potential vehicle for addressing future supply-side equipment constraints, given the extremely rapid global scaling of solar.

Vendor finance in the solar industry is still underused. Global manufacturers of solar panels and batteries could be encouraged to frontload investment in the rapid expansion of their market that will result from the global trend to decarbonize electricity and accelerate renewable energy deployment. Vendor finance involves manufacturers using their own funding to assist the expansion of their market; actions can include supporting the supply chain with inventory finance, partnering with banks to support end-user credits through loss pooling, and setting up in-house consumer finance capabilities. Vendor finance may also allow pooled assets to be securitized, thus bringing new capital into solar projects.

Global efforts to expand vendor finance could be coordinated through regional leads (e.g., regional development banks, the U.S. Export-Import Bank), in partnership with governments and their national development banks, as well as private banks and investment groups that focus on supply chain investment. Vendors would be required to meet a minimum requirement of technical and installation quality.

Vendor finance actions could include the following:

- Regional development banks and national governments could engage with solar and battery manufacturers to ensure understanding of vendor finance advantages based on planning for production expansion, while global and regional banks offer loss pooling and other market support.
- Wholesalers and industry organizations could identify bottlenecks in inventory and working capital finance and define key points of support and specific interventions, including foreign exchange, terms, and loans.
- Commercial banks could transfer their expertise from large-scale vendor finance programs in other sectors into the solar sector.

CONCLUSION

Scaling solar investment to meet global goals requires national governments and central banks to aggressively address policy and regulatory barriers to solar investment, to help build momentum in project pipelines and manage political, financial, and other investment risks. It also requires that DFIs and commercial banks implement dedicated programs and platforms to help move solar investment and deployment to scale. The solution pathways outlined in this roadmap highlight priority actions by market segment, and the solution cases and country examples illustrate implementation experiences and lessons.

Finally, a new level of multilateral collaboration is needed to tackle barriers to scaling solar that cannot be effectively addressed on a country-by-country basis. The “Recommendations” section of this roadmap calls for new, more ambitious forms of international collaboration to accelerate the pace and scale of solar deployment. Advancing solar energy’s critical role in climate mitigation, energy access, and the global clean energy transition must be a priority for all governments and intergovernmental processes.

APPENDIX A. CASE STUDY: BANGLADESH'S SOLAR HOME SYSTEMS PROGRAM TO DEVELOP OFF-GRID SOLAR

Bangladesh is one of the world's most densely populated countries (*CIA World Factbook* 2020), with more than 166 million people in a land area smaller than that of Greece (10.6 million inhabitants) in 2021 (World Bank 2022a). Its economy is growing rapidly, and so is its demand for energy. Between 2008 and 2018, energy generation more than doubled; the number of electricity consumers jumped 178 percent, and the energy access rate nearly doubled, from 47 to 90 percent (Moazzem and Ali 2019). Growth in the country's gross domestic product and power supply recently outpaced growth in population, and electricity access has continued to improve. However, to sustain its current economic growth rate of over 7 percent per year, Bangladesh needs around 34 gigawatts of power by 2030 (*Himalayan Times* 2018)—nearly 50 percent more than its capacity of 23.8 gigawatts in 2021 (IRENA 2022a).

As of 2020, 98 percent of Bangladesh's power came from fossil fuels, with natural gas supplying 60 percent of the country's electricity (IRENA 2022a). As its gas reserves have been depleted, the government has shifted to importing liquid oil fuels and coal (GoB 2013), worsening pollution and straining the country's finances (Nicholas and Ahmed 2020). The Energy Policy Institute at the University of Chicago has ranked Bangladesh as the country with the world's worst air pollution every year since 2018 (Air Quality Life Index 2022; Hasnat 2022).

Bangladesh has abundant renewable energy resources, including solar, wind, biomass, hydro, biogas, marine energy, and geothermal (Hossain and Rahman 2021). Solar energy represents a particularly important resource, since Bangladesh has more than 300 sunny days per year, with high levels of solar radiation (Lipu et al. 2013). Since 2008 the Government of Bangladesh has sought to diversify its energy sources. It began by adopting a Renewable Energy Policy that encourages and facilitates both public and private sector investment in renewable energy (GoB 2008). The policy exempts investors from corporate income tax for five years or more depending on a project's impact. It also enables utilities and consumers to purchase up to 5 megawatts of electricity generated from renewable energy projects (GoB 2008). Bangladesh has also supported off-grid solar power for parts of the country that are hard for the grid to reach. To achieve Bangladesh's target, under Sustainable Development Goal 7, of reaching universal energy access by 2030, approximately 10 percent of the country's remote and rural areas will have to depend on off-grid renewable energy (Hossain 2015).

Off-grid solar home systems (SHS) were introduced in Bangladesh in the 1990s by local organizations such as Grameen Shakti, the solar subsidiary of Grameen Bank. Financing came from the International Finance Corporation (IFC) in 1995 via the IFC / Global Environment Facility (GEF) Small and Medium Enterprise program (IFC 2007), and from the World Bank in 2008. In 2005, the government created the Infrastructure Development Company Limited (IDCOL), a state-owned, nonbank financial institution tasked with financing renewable energy infrastructure in Bangladesh (Matin et al. 2015). By 2018, more than 4.1 million SHS devices had been installed in Bangladesh, offering 20 million people access to electricity. By 2020, 97 percent of Bangladesh's population had access to electricity (Cabraal et al. 2021).

Since 2013, with funding from the World Bank, GEF, and other development finance institutions, IDCOL has disbursed $504 million in credit and $97 million in grants to participating partner organizations (IDCOL 2021), such as Grameen Shakti. These organizations have been instrumental in installing SHS in homes across Bangladesh. IDCOL provides the organizations with financing through low-interest loans and credits, and they, in turn, offer microfinance loans and direct subsidies to end users. End-use customers have various payment options and can access collateral-free loans to make payments (Ashden Winner 2022). This financing model has made investing in SHS affordable.

The program demonstrates how a public-private partnership for solar energy development can leverage financing vehicles such as subsidies, low-interest loans, and microfinance models. Several other enabling conditions have contributed to success in Bangladesh:

- The government's long-term commitment, engagement, and patience, as well as its clear targets and time lines for energy access and solar deployment, its consistent tariff and tax policies, and its solar incentives to clarify pricing.
- Continued financial commitment and support from multilateral development banks.
- An innovative financing model that enabled partner microfinance institutions to provide affordable financing to people who would not qualify for ordinary loans or credit from commercial banks.

Although the Bangladesh SHS program lifted millions of people out of energy poverty, its performance has slumped since 2015 (Hellqvist and Heubaum 2022). SHS sales peaked in 2013 at 816,000 SHS installations, but they had plummeted to 3,500 by 2018 (Cabraal et al. 2021). Customers defected, in part, because grid expansion—which was not coordinated in advance with SHS businesses, IDCOL, and other market actors—reduced demand for off-grid systems. Customers newly hooked up to the grid defaulted on their loan payments, depriving IDCOL and its partner organizations of expected revenue (Hellqvist and Heubaum 2022). In addition, competition arose from other government programs that provided subsidized and free solar systems, undermining the commercial model of purchasing for credit. Instead of borrowing, customers could get free SHS provided by companies under the government's social safety net programs, with the costs covered by the government (Hossain 2018). Third, reductions in the available subsidies reduced customer interest in the SHS program. IDCOL and its partners have not been able to continue to grow the SHS customer base in the face of shifting government policies and eroding demand.

While Bangladesh's experience has shown that microcredit financing can be successfully used to scale up SHS, recent setbacks point to the ongoing need to match policy and financing schemes with market developments. Grid expansion planning needs to be carried out with time frames sufficiently long for markets to adapt. Exit strategies are needed for public subsidies, and planners must balance support for the poorest with changing preferences and growth in consumer demand. To continue enabling affordable electricity access throughout Bangladesh, the SHS program would need to be recalibrated based on grid expansion planning and a larger and more active commercial solar sector.

APPENDIX B. CASE STUDY: TONGA'S EXPERIENCE SCALING UP UTILITY-SCALE SOLAR

Tonga consists of 171 islands, in five main island groups in the southern Pacific Ocean. According to the 2016 World Risk Index, Tonga is the second-most climate-vulnerable country in the world (GCF 2022). Tonga does not produce any fossil fuel–based energy and historically has relied heavily on imported petroleum products. With diesel meeting around 87 percent of the country's grid-connected electricity demand, Tonga's economy is extremely vulnerable to the volatility of oil prices. In 2022, 98 percent of Tongans have access to electricity (GoT 2022).

To improve national energy security and ensure energy access, the Government of Tonga made a strategic effort to decarbonize the energy sector by promoting renewable energy and energy efficiency. In 2008 it passed the Renewable Energy Act, and two years later it implemented the Tonga Energy Roadmap 2010–2020 (TERM). In 2021 the Tonga roadmap was updated as TERM-PLUS. The country's total installed renewable energy (wind and solar) power generation capacity increased from 0.1 gigawatts (GW) in 2011 to 7.8 GW in 2021; of this, 80 percent came from solar (IRENA 2022a). In 2020, solar generated 7.1 gigawatt-hours (GWh) of electricity (IRENA 2022b), accounting for 10 percent of the country's total electricity generation, and utility-scaled solar contributed to 95 percent of the total solar energy generation (IRENA 2022a). By 2021, solar generation in Tonga had reached about 7.6 GWh.

Tonga was the first Pacific Island country to implement a policy to promote renewable energy (REEEP 2022). Its 2008 law promotes enhanced research and development, enables the "licensing of persons involved in the design, research, installation and management of renewable energy projects and streamlining of permitting," and establishes feed-in tariffs (Climate Laws 2008). Revisions to the law in 2010 provided a mechanism for private sector entities to invest in independent power producers (IPPs) and engage with the state-owned Tonga Power Limited (TPL) under a power purchase agreement (PPA) (GoT 2022).

The TERM aimed to decarbonize and reform the country's energy sector. It outlined a renewable energy pathway for 2010–20 and identified solar as the most promising renewable alternative, despite challenges with grid integration (GoT 2010; UN 2022). The Arup Group, which helped prepare the TERM, estimated that Tonga could supply 58 percent of its energy with renewables by 2020 and 91 percent by 2030, while improving the grid's cost efficiency, stability, and reliability (Arup 2022). As part of this ambitious renewable energy plan, Arup foresaw a role for hybrid solar, wind, and battery energy storage solutions as part of a microgrid on Tongatapu, Tonga's main island and home to around 74 percent of the population (Tonga Census 2021), to balance out the grid and provide greater grid resilience to extreme weather and events (Create Digital 2018).

Tonga fell short of achieving the goals in the TERM, largely due to disruptions related to the COVID-19 pandemic (PCREEE 2021). In 2021, Tonga's updated roadmap (TERM-PLUS) set a new ambitious goal to raise the renewable energy share in the electricity mix to 70 percent by 2025 and 100 percent by 2035 (GoT 2022; PCREEE 2021). The country's implementation of TERM-PLUS has had to contend with the Hunga Tonga–Hunga Ha'apai volcanic eruption and tsunami on January 15, 2022.

Tonga's Energy Department, part of the Ministry of Meteorology, Energy, Information, Disaster Management, Environment, Climate Change, and Communication, is responsible for the country's energy planning and development. Tonga's Electricity Commission regulates the country's power sector by setting tariffs for grid-connected electricity. TPL, under the oversight of the Ministry of Public Enterprises and the government cabinet, is the only company in Tonga that provides grid-connected electricity services—including generation, transmission and distribution, electricity retailing, and operation and maintenance. This state-owned enterprise serves

Tonga's four main island groups—all except the outlying Niuas. In 2020, TPL generated a total of 73.2 GWh, with nearly 13 percent coming from renewable energy, 38 percent more than in the previous year (TPL 2020).

The TERM clearly defined roles for the government, TPL, and the private sector in power and renewable energy development (UN 2022). Even though TPL is a state-owned enterprise and the Government of Tonga remains the arbiter in the market, the private sector has led renewable energy generation projects between 2018 and 2022 for construction and operation, following a competitive and transparent bidding and procurement process. Public funding, often in the form of grants, subsidizes the cost of the winning proposals for a given renewable energy IPP tender (UN 2022). Between 2011 and 2021, utility-scale solar capacity in Tonga increased dramatically, from 0 to 6 megawatts (MW), with six solar projects fully completed, due to the successful financing and implementation of large-scale solar projects with active participation from the private sector (IRENA 2022a; Fonua 2021).

Tonga's first large-scale solar project, the 1 MW Maama Mai solar facility on the island of Tongatapu, was commissioned in 2012 and funded by the New Zealand Aid Programme with a total of NZ$7.9 million (around US$4.4 million) (GoT 2022; TPL 2022). Since 2012, this solar farm has delivered an average of 1.88 GWh of electricity every year (TPL 2022). Tonga's second solar farm, La'a Lahi ("big sun") solar field, was initiated in 2012 on Vava'u Island. This 512 kilowatt (kW) solar photovoltaic (PV) facility was publicly funded by the UAE-Pacific Partnership Fund to meet 17 percent of Tonga's annual electricity demand at that time (PRDR 2022). The project, delivered in 2013 for operation by Masdar, a UAE renewable energy company, reduced the electricity tariff across Tonga by 1 percent, supplying up to 67 percent of grid demand during peak hours (IRENA 2015a).

In 2017, Tonga built its then-largest solar PV plant, the 2 MW Matatoa Solar Project, at a cost of $4.4 million. This project was funded by a private Chinese energy company, Singyes, based on a 2016 agreement to sell electricity to TPL for 25 years; the completion of this project increased Tonga's share of renewable energy in the power generation mix from 8 to 13 percent (Brown 2017; GoC 2017; GoT 2022). Since 2019, several other new solar projects in Tonga have been commercially financed by public-private partnerships. For example, in 2019 Tonga began construction of its second commercially financed public-private partnership between TPL and Sunergise, a New Zealand–based solar company with a Fiji office that received an equity investment from IFC in 2014. Sunergise will finance, build, and operate the solar farm and will sell the electricity to TPL for 25 years. This 6 MW solar farm, with three plants on the island of Tongatapu, is intended to provide enough energy to meet 15 percent of the country's electricity demand (based on 2020 levels).

Development finance institutions have played a significant role in financing Tonga's solar deployment. For example, since 2012 the Asian Development Bank (ADB) has been one of the largest financing sources for Tonga's power sector, with almost $100 million invested through multiple projects (ADB 2022b). The ADB, International Union for Conservation of Nature, International Renewable Energy Agency, UN Economic and Social Commission for Asia and the Pacific, World Bank, and other international donors have provided technical assistance for utility-scaled solar projects, including advisory support to help build a competitive tender process in Tonga to attract private sector participation (ADB 2019; GoT 2022).

Tonga increasingly relies on solar energy deployment to maintain energy access for its full population, to improve its energy security, and to mitigate climate change. The Government of Tonga's long-term energy sector planning, ambitious target setting, and implementation of Tonga's TERM and TERM-PLUS energy roadmaps have helped this small island country create enabling market conditions for renewables, including solar, and attract public and private capital at scale; these actions can be replicated by other countries with similar conditions. Some challenges remain in Tonga, such as high maintenance costs for major solar projects, the limited capacity of the current grid to integrate more renewable energy, and obstacles to land acquisition. More international collaboration and support, such as PPA capacity-building; more dialogue among donors, the government, and the private sector; and more platforms to de-risk financing to support local and international investors could help further grow the market and scale solar (GoT 2022). Installation of additional battery storage systems is also needed to ensure that Tonga achieves its renewable energy targets (Fonua 2021).

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APPENDIX C. CASE STUDY: ARGENTINA'S AUCTION SCHEME TO BOOST SOLAR ENERGY

Between 2018 and 2022, Argentina's renewable energy capacity increased from 700 megawatts (MW) to 5.1 gigawatts (GW), and its solar capacity increased from 8 MW to nearly 1.1 GW (IRENA 2022f; Kind 2022). By 2022, solar contributed 2.5 percent of Argentina's total energy capacity, mostly from on-grid solar (IRENA 2022g). Total solar capacity in Argentina is expected to reach 2.6 GW in 2030 (BMI 2021a). Argentina's largest driver for pursuing solar is its growing demand for electricity and a widening energy deficit that has driven up energy imports (Parikh 2016; Technavio 2022). The planning and policies of the Government of Argentina (GoA) have made it possible to rapidly scale solar.

In 2006, the GoA legalized 15-year feed-in tariffs for all renewable sources and set a goal to have 8 percent of the country's electricity mix come from renewable resources by 2016. In 2009, to support this goal, Energía Argentina (ENARSA), the national energy company, launched the GENREN renewable energy auction, aiming to deploy 1 GW of renewable energy capacity, including 20 MW of solar, by 2016 (IRENA 2015b). In addition, the GoA passed a regulation in 2011 that allowed renewable energy developers to negotiate premium tariffs directly with the government and Argentina's grid operator, the Compañía Administradora del Mercado Mayorista (CAMMESA, Wholesale Electricity Market Administrative Clearing Company) (BMI 2013). These early efforts helped attract foreign investors for solar. However, between 2009 and 2015, only 320 MW of renewable capacity was added (Kind 2022); this was due in part to Argentina's investment environment, which did not attract long-term investments for development of renewables at scale. Investors worried about Argentina's declining foreign reserves, exchange rate devaluation, and funding constraints on renewable energy incentives (BMI 2013). In addition, of the new renewable capacity, only 1 percent was solar (IRENA 2022g), since the GoA considered solar energy as more an option to improve rural electrification than a utility-scale opportunity (Research and Markets 2012).

Argentina's deployment of renewable energy, including solar, swung into gear in 2015 with the election of President Mauricio Macri, who was determined to revive the country's economy by seeking foreign investment, especially in renewables (Parikh 2016). In 2015, the government enacted Law 27191 on Renewable Energy, which created targets, incentives, and funds to promote renewable energy deployment. The law set a national target for renewable energy sources to supply 20 percent of the country's electricity consumption by 2025. The law also mandated that, for major users of the wholesale electric markets and for users with power demands of at least 300 kilowatts, renewable energy sources should account for at least 20 percent of their total electricity consumption by 2025. Targeted large consumers could either produce renewable energy themselves or purchase it from other producers through power purchase agreements (PPAs) (GoA 2015). The government's goal was to reach a total of 10 GW of renewable energy capacity with an expected average annual investment of $1.5 billion by 2025 (Menzies et al. 2019).

The Law on Renewable Energy also created policy incentives to attract international investors, including fiscal incentives and competitive and transparent market regulations (World Bank 2018b). Examples of fiscal incentives for independent power producers (IPPs) included a refund of the value-added tax, an extension of income tax loss credits, and a tax deduction for all financial expenses for renewable energy projects. In addition, the law included incentives to build local supply chains for renewable energy projects, such as import duty exemptions for local suppliers and manufacturers, and tax credits for locally supplied capital expenses for IPPs (IEA 2018).

In May 2016, the government launched the RenovAr program with design support from the International Finance Corporation. RenovAr created competitive renewable energy auctions with 20-year PPAs. The first auction was planned in the same year to acquire 1 GW of renewable energy capacity, including 300 MW of solar energy from projects between 1 and 100 MW (Meyers 2016; Kind 2022). The tender process was designed with transparent and specific rules for bidders' qualifications and project selection, as well as detailed criteria for assessment and award of the winning bid (Greenmap 2022).

To support the auction process and attract private investment, RenovAr contains an embedded guarantee scheme that enhances the bankability of the contracts and protects IPPs against several types of risks. The Fund for the Development of Renewable Energy (FODER) provides payment guarantees for project finance, with a first tranche of US$819 million in 2016. The Law on Renewable Energy mandates that the amount of funds available every year be at least 50 percent of the savings from using renewable energy to replace fossil fuels. This provides a legal foundation to guarantee funding to deploy renewables in the country (GoA 2015; IEA 2018). With support from the World Bank, FODER also offers guarantee mechanisms to mitigate off-taker risk, ensuring that IPPs that sell electricity to the utility will be paid from FODER if the utility does not provide timely payment. The IPPs also can avoid early termination of the contracts by transferring project assets to FODER if needed in the case of contract arbitration (Menzies et al. 2019). Finally, an optional Sovereign Default Guarantee is available to cover nonpayment of any sovereign obligation—money owed in hard currency by the government under the contracts—up to the amounts guaranteed by the World Bank (World Bank 2018b; Bauza 2022; Kind 2022). This guarantee was offered in the first three rounds of auctions to eligible projects based on their bid price and other competitive variables, and each project could request coverage of up to $500,000 per MW (Kind 2022). The Sovereign Default Guarantee helped boost investors' confidence throughout the process, from tender to design and contracting phases (Kind 2022). FODER's guarantee mechanisms established a safety net for the renewable energy auctions the GoA launched the following year (Menzies et al. 2019).

Argentina received a massive response to its first renewable energy auction (Saurabh 2017); the bids offered on installed capacity were more than six times the requested amount (Braud 2018). In 2021, 15 percent of Argentina's electricity demand came from renewable energy sources (excluding hydropower plants larger than 50 MW) (Kind 2022). Although solar energy still accounted for only 1.6 percent of electricity generation in Argentina in 2022 (Kind 2022), the auction scheme effectively boosted solar investment and deployment. During the first three rounds of auctions (Round 1, Round 1.5, and Round 2), 950 MW of solar was planned, and the final contracted capacity was 1,732 MW, with a total of 41 winning bidders. Round 3 of the auctions in 2019 added 12 new solar projects, with a total of 108 MW. In addition, the Corporate PPA Market, which is for commercial and industrial users of more than 300 kW, has added 17 projects, with a total of 214.5 MW (Kind 2022).

Argentina has abundant solar radiation levels and extensive available lands to deploy solar photovoltaic, and its renewable energy auctions have given momentum to solar deployment and investment (Bragagnolo et al. 2022); however, momentum has installed since 2018 due to surging inflation, external debt, and an economic slowdown. No further significant long-term investment has been attracted since then (Kind 2022). Although the RenovAr program has helped make renewable energy the cheapest unsubsidized source of energy in Argentina, the program has suffered from delayed payments of nearly $2 billion from utilities, due to demand for electricity slumping along with economic growth after 2019 (Greenmap 2022). Argentina's limited planned investment in upgrading and expanding its transmission and distribution system is another impediment to scaling solar quickly enough to reach the country's renewable energy goals (BMI 2020). Furthermore, despite the strong forecasted growth of wind and solar through 2030, fossil fuels are expected to continue their domination in Argentina's energy mix through the decade (BMI 2021b). Political winds have shifted as well, creating additional uncertainties. At the end of 2020, President Alberto Ángel Fernández announced a major policy change to relaunch the oil and gas economy, and the government has provided $5 billion in subsidies to encourage companies to exploit the country's major shale deposits (Bloomberg Law 2021; Burnett 2021).

Argentina's future solar development relies heavily on the country's commitment to integrate renewable energy into its planning and its ability to attract long-term infrastructure investment for solar power generation and transmission. Policies prioritizing oil and gas could further constrain the availability of financial resources to support renewable energy development (Bragagnolo et al. 2022).

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APPENDIX D. CASE STUDY: ZAMBIA'S EXPERIENCE ATTRACTING INVESTMENT IN SOLAR GENERATION AND TRANSMISSION AND DISTRIBUTION

The Republic of Zambia, located in the central and southern part of sub-Saharan Africa, is classified by the World Bank as a low-income country, with a per capita gross national income of $1,040, a total population of almost 19 million in 2021, and a fast-growing economy. Approximately half (44.5 percent) of the population had access to electricity in 2020, including 14 percent of the rural population (World Bank 2022a).

Wood fuel is the largest source of energy in Zambia, accounting for more than 70 percent of the country's total energy supply (SEforAll 2022). For electricity, Zambia remains largely dependent on hydropower, which accounted for 79.3 percent of the total installed electricity generation capacity, 3.2 GW, in 2021 (IRENA 2022a). Before 2013, there were no solar energy facilities deployed in Zambia. Between 2013 and 2021, solar photovoltaic (PV) installations expanded rapidly, from only 60 kilowatts to 96 megawatts (MW), with most of the capacity added in 2019 (IRENA 2022a). Annual generation of 150 gigawatt-hours from solar PV still accounts for only 1 percent of Zambia's total electricity generation.

A severe drought in 2015 caused an energy crisis and forced Zambia to ration power and increase power imports by 178 percent (RES4Africa 2018), highlighting the need for more diversified and resilient electricity generation. A severe drought in 2019 plunged Zambia into an even more severe power crisis, focusing more attention on the need to generate more electricity from nonhydro renewables, especially solar energy. In 2005, the Government of Zambia had initiated Vision 2030, a plan to increase overall electricity generation capacity to 6 gigawatts (GW) and to meet 30 percent of Zambia's energy needs with renewable energy (excluding large hydro) by 2030 (UN 2021b). It calls for adding 600 MW of solar PV procurement by 2030 (World Bank 2019)—a sixfold increase in capacity from the current 96 MW. As part of its broader national development strategy and the goals of its SDG7 Energy Compact, the government also aims to expand electricity access to 100 percent of its urban population and 50 percent of its rural population by 2030 (UN 2021b). The investment needed to achieve these goals is estimated to be at least $4.7 billion.

In 1994, the Government of Zambia had already implemented the National Energy Policy (NEP) to open the power sector to private sector investment in order to promote electrification and energy access. The Zambia Electricity Supply Corporation (ZESCO), Zambia's state-owned utility, owns and operates more than 90 percent of the electricity sector generation and transmission and distribution (T&D) assets in the country and remains dominant in Zambia's electricity market as an off-taker. However, the NEP allowed independent power producers (IPPs), such as the Copperbelt Energy Company and North Western Energy Company, to operate on-grid and off-grid plants and sell power to ZESCO, as well as participating in the T&D market to provide services (Chimbaka 2016; UN 2021c). Despite these early power sector reforms, Zambia struggled to meet the increasing power demand, in part because tariffs did not keep pace with costs (Vagliasindi and Besant-Jones 2013).

In 2015, with $2 million provided by Power Africa and USAID Zambia (IRENA 2018), the International Finance Cooperation (IFC) jump-started the utility-scale solar market in Zambia through the IFC / World Bank Group Scaling Solar program. In 2015, IFC and Zambia's Industrial Development Corporation launched a competitive auction that attracted 48 solar developers, from which two winners were chosen (IRENA 2018). The first of the plants, the 54 MW Bangweulu project implemented by NEOEN/First Solar, was inaugurated in March 2019 with a feed-in tariff of 6.02¢/kWh, which will remain fixed for 25 years. More than 27,000 households are benefiting from the Bangweulu project. The second project, the 34 MW Ngonye plant with a feed-in tariff of 7.84¢/kWh, was implemented by Enel Green Power and began operating in August 2019 (USAID 2022).

The Government of Zambia completed development of its Renewable Energy Feed-in Tariff (REFiT) strategy in 2015 with support from USAID. Following the success of the competitive auction under the Scaling Solar program, in 2017 the Government of Zambia revised its national REFiT strategy and chose to utilize the Global Energy Transfer Feed-in Tariff (GET FiT) solar tender process designed initially to help East African countries launch IPP projects with support from the German government. The Zambia GET FiT solar program has been effective in further boosting the prospects of Zambia's utility-scale solar sector. The initial tender target for Zambia was 100 MW, but an additional 20 MW was awarded due to favorable results, including a high number of IPPs attracted and the low level of tariff achieved through a competitive auction (Vagliasindi and Besant-Jones 2013). The Zambia GET FiT solar program supported the utility-scale solar market in Zambia through a combination of instruments, including premium payment mechanisms, guarantee mechanisms to mitigate off-taker risks, and competitive debt and equity financing for private developers. No grant or concessional finance was included in GET FiT.

The GET Fit Zambia solar tender, the largest-single solar PV tender implemented in sub-Saharan Africa (excluding South Africa), is composed of six solar PV IPP projects totaling 120 MW, with the lowest tariff for successful bids at 3.99¢ per kilowatt-hour (kWh). This was the first time a tariff level below 4¢/kWh for solar tender had been achieved through a competitive public tender in sub-Saharan Africa (GET FiT Zambia 2022). Once successfully implemented, these utility-scale solar PV projects in Zambia will feed power into the grid at an average tariff of 4.41¢/kWh—much lower than the average tariff in Zambia today (GET FiT Zambia 2021).

Together, the GET FiT and Scaling Solar programs have implemented successful competitive auctions for more than 200 MW of utility-scale solar online in Zambia. However, through 2022, only the two Scaling Solar projects totaling 86 MW have been successfully financed and commissioned, and the second phase of Zambia's IFC/WBG Scaling Solar program has been suspended. The six GET FiT projects that total 120 MW have not yet been able to secure financing. These delays stem mainly from financial problems surrounding ZESCO, which is currently the main off-taker of large PPAs. Further competitive auctions for utility-scale solar PV projects, to reach the government's target of 500 MW of installed solar PV capacity, have been placed on hold due to concerns over ZESCO's financial standing and the challenge in securing sovereign repayment guarantees from the Government of Zambia due to restrictions imposed by the International Monetary Fund. ZESCO's financial stress could limit further large-scale development of solar projects in the short term (US DoC 2022). Addressing challenges with off-taker risks will remain key to scaling solar and other renewables in the country. Zambia is currently working with Africa GreenCo, a renewable energy buyer and seller that works to reduce energy prices and expand renewable energy supply across southern Africa, to mitigate off-taker risk and procure renewable energy at scale.

In addition to scaling up utility-scale solar into the grid, Zambia has striven to improve grid reliability and power trade in the region. In 2013, the World Bank and the Government of Zambia started the Electricity Transmission and Distribution System Rehabilitation Project in Lusaka, Zambia's capital. The goal is to increase the capacity of the T&D system, improving service to existing customers and connecting new ones. The scope of work includes rehabilitation of T&D networks, technical assistance, and project supervision, at an estimated cost of $210 million ($105 million from the World Bank, 65 million euros from the European Investment Bank [EIB], and $40 million from the Government of Zambia), and implemented by ZESCO (World Bank 2022b; *Africa Energy* 2015). However, the EIB has withdrawn from the project, causing setbacks and delays (*Africa Energy* 2021).

Zambia has also liberalized its power market. In late 2019, the government passed the Electricity Act and the Energy Regulation Act, both of which took effect the following year. They allow IPPs and other actors to play a larger role in the power generation and T&D markets through the existing grid (Nq'oma 2020). Private players can now own assets, obtain operation licenses, and qualify for concessional lending and multilateral guarantees (UN 2021c). The first intermediate power trader to come in under these two legal frameworks is GreenCo Power Services, created in 2020 as a subsidiary of Africa GreenCo and based in Lusaka. GreenCo Power Services plans to sell Zambia's clean energy to the competitive market in the Southern Africa Power Pool (SAPP),[2] with a 110 MW renewable energy portfolio funded by private investors. GreenCo's entry into Zambia's electricity market signals the government's commitment to creating a transparent and competitive electricity market (*Solar News* 2022).

Although it has liberalized its power market and is one of the very few countries in Africa that allows private players in the T&D market, Zambia still faces challenges in further enhancing its attractiveness and crowding-in private investment in T&D. These include off-taker risk from the single-buyer market dominated by ZESCO (UN 2021c) and the lack of clear targets and time lines for expanding T&D. Despite some setbacks, Zambia's experience demonstrates how an enabling policy environment with a competitive, well-designed, and efficiently implemented bidding process can attract private investment to procure solar energy and T&D infrastructure in developing and emerging markets.

APPENDIX E. CASE STUDY: EGYPT'S PATH TO GREEN HYDROGEN THROUGH SOLAR MARKET DEVELOPMENT

Egypt is on a path to build a pipeline of major green hydrogen projects, with $40 billion of investment committed from the government and a production capacity goal of 1.4 gigawatts (GW) by 2030 (*Energy & Utilities* 2022). The pipeline will include the world's largest green hydrogen project, with 100 megawatt (MW) electrolyzers that use electricity to break water into hydrogen and oxygen. That electricity comes as grid-supplied renewable energy—chiefly from solar and wind. The projects have attracted more than $10 billion in investment from the private sector (*Enterprise* 2022). Several factors have fueled Egypt's emergence as a global leader in green hydrogen. These include the growing potential demand for hydrogen at Egypt's marine ports; shippers are increasingly exploring the use of hydrogen to power equipment and vessels. In addition, Egypt's large-scale renewable energy projects provide cost-competitive and abundant renewable energy from the grid to produce green hydrogen. And finally, Egypt's feed-in tariff (FiT) and other policy reforms have created an enabling environment that attracts local and international private sector developers, equity investment, and technical expertise to help create new and dynamic green markets.

Egypt, the most populous country in North Africa with a population of about 104 million, achieved near universal electricity access in 2016 (World Bank 2022a). Egypt's solar photovoltaic sector has expanded rapidly in the last decade to meet its growing power demands, with installed capacity rising from 15 MW in 2011 to 1.66 GW in 2021, mainly due to deployment of utility-scale solar projects financed by independent power producers who received debt financing from international financial institutions, bilateral lenders, and commercial banks (IRENA 2022a).

Egypt's success in attracting this investment stemmed from power sector liberalization and regulatory reform to enable the investment environment, along with technical assistance and policy guidance from multinational institutions such as the World Bank Group and the International Monetary Fund.

Since 2014, the Government of Egypt has carried out significant structural reform in the power sector, including reducing fuel and electricity subsidies, which were estimated to equal 6 percent of Egypt's gross domestic product before the reform (Breisinger et al. 2019). Egypt also passed the Renewable Energy Law in 2014 to create a foundation for the country's renewable energy tenders and tax incentives. The law provides for competitive bidding, a 25-year FiT scheme for solar projects, and bilateral direct transactions between independent power producers and consumers. In 2015, Egypt also passed a new Electricity Law, implementing regulations that encourage energy efficiency and the generation of electricity from renewable sources, as well as allowing market competition for electricity generation and transmission and distribution.

Building on this experience in scaling up utility-scale solar, the Government of Egypt set ambitious goals to pursue green hydrogen as a key strategy to further cut emissions, then implemented policies to enhance readiness for the large-scale green hydrogen pipeline. The government simplified the permitting process for green hydrogen projects to facilitate their establishment, operation, and management (Lepic 2022). In addition, it introduced incentives for new projects, including covering utility connection costs and reimbursing 50 percent of land allocation costs, and is considering adding special customs facilities for imports and exports (*Energy & Utilities* 2022; Jones 2022). The government has also worked to expand the scope of its investment law, offering tax deductions and other benefits to private companies that produce, store, or export green hydrogen and green ammonia in Egypt; investment cost deductions can reach 30–50 percent (Alhosainy 2022). Meanwhile, the European Bank for Reconstruction and Development is providing support to the Egyptian (as well as Moroccan) government to study green hydrogen development, including assessing how green hydrogen could play a role in decarbonization and mapping out low-carbon pathways (*Energy & Utilities* 2021). Egypt's success in attracting private sector investment in renewable energy has made the country a regional energy hub and a global green hydrogen leader.

APPENDIX F. LIST OF PARTICIPATING EXPERTS

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GLOSSARY

Agri-voltaics: The use of land areas for both solar photovoltaic power generation and agriculture.

Auction: A competitive bidding procurement process for electricity from renewable energy or where renewable energy technologies are eligible. The auctioned product can be either capacity (megawatts) or energy (megawatt-hours). (https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/Jun/IRENA_Renewable_Energy_Auctions_A_Guide_to_Design_2015.pdf)

Battery energy storage system (BESS): An electrochemical device that charges (or collects energy) from the grid or a power plant and then discharges that energy at a later time to provide electricity or other grid services when needed. (https://www.nrel.gov/docs/fy19osti/74426.pdf)

Concentrating solar-thermal power: A system that uses mirrors to concentrate solar rays. These rays heat fluid, which creates steam to drive a turbine and generate electricity. Concentrating solar-thermal power is used to generate electricity in large-scale power plants.

Development finance institution (DFI): A specialized development bank or subsidiary set up to support private sector development in developing countries. DFIs can be national or international, usually majority-owned by national governments and sourcing their capital from national or international development funds or benefiting from government guarantees. (https://www.oecd.org/development/development-finance-institutions-private-sector-development.htm)

Independent power producer (IPP): A corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for the generation of electricity for use primarily by the public, and that is not an electric utility. (https://www.ferc.gov/about/what-ferc/about/glossary#:~:text=Independent%20Power%20Producer,is%20not%20an%20electric%20utility)

Levelized cost of energy (LCOE): The cost of generating energy (usually electricity) for a particular system. It is an economic assessment of the cost of the energy-generating system, including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, and cost of capital. (https://www.nrel.gov/analysis/tech-lcoe-documentation.html)

Off-grid solar: A solar system not connected to or served by utilities. For the purpose of this roadmap, off-grid solar includes solar lighting devices and solar home system services and household applications that are typically below 50 kilowatts; mini-grid and/or commercial rooftop solar photovoltaic installations; and larger decentralized solar installations that are off the centralized electrical grid system for dedicated uses for rural health services and clinics, schools, and agriculture.

Official development assistance: Government aid that promotes and specifically targets the economic development and welfare of developing countries. (https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/official-development-assistance.htm#:~:text=Official%20development%20assistance%20(ODA)%20is,of%20financing%20for%20development%20aid)

Off-taker: The purchaser of a system's power and/or renewable attributes. In a power purchase agreement, a solar off-taker buys power from a project developer at a negotiated rate for a specified term without taking ownership of the system. (https://www.nrel.gov/docs/gen/fy16/65567.pdf)

Photovoltaics (PV): Electronic devices (solar cells) that convert sunlight directly into electricity.

Power purchase agreement (PPA): A long-term contract between sellers and buyers of electricity, defining each party's rights and responsibilities, as well as mechanisms for dispute resolution. (https://irena.org/events/2022/Aug/Capacity-Building-on-Design-of-Bankable-Power-Purchase-Agreements-in-AIS-SIDS)

Solar home system (SHS): A stand-alone solar system that is suitable for residential use.

State-owned enterprise (SOE): A body formed by the government through legal means so that it can take part in activities of a commercial nature. (https://corporatefinanceinstitute.com/resources/careers/companies/state-owned-enterprise-soe/)

Technical potential: The amount of renewable energy output obtainable by full implementation of demonstrated technologies or practices. (https://www.ipcc.ch/site/assets/uploads/2018/03/SRREN_Full_Report-1.pdf)

ENDNOTES

1. For more information on ISA's planned Blended Finance Facility, see https://isolaralliance.org/uploads/newsletter/ISA%20Newsletter%20June%202022.pdf.

2. SAPP, created in 1995 as an electricity power pool in the Southern Africa region, coordinates the planning and operation of the electric power system among member countries, represented by each country's electric power utility. Currently SAPP has 12 member countries, including Zambia (SAPP n.d.).

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ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.