INTERNATIONAL SOLAR ALLIANCE

Tripling Global Renewable Energy Capacity by 2030

SOLAR

Leading the Way

Foreword

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As we navigate the complexities of transitioning to a sustainable energy future, the International Solar Alliance (ISA) proudly presents this comprehensive report on the *Solar leading the way for the Tripling of Global RE capacity by 2030*, prepared for the COP 28 summit. This document encapsulates the multifaceted landscape of solar adoption, highlighting the barriers and drivers, while demonstrating solar energy's importance in the Nationally Determined Contributions (NDCs), and its role in mitigating climate change and the tripling of RE capacity as announced by G20 New Delhi Leaders Declaration and the COP 28 presidency.

Solar energy offers a pathway towards a low-carbon, resilient, and inclusive global energy landscape. It spearheaded remarkable growth, achieving 226 GW installations in 2022, marking a substantial 38% surge from the preceding year. The projections for future solar capacities, spanning various long-term and short-term scenarios crafted by leading analysts, vividly illustrate one undeniable truth: solar is poised for exponential expansion. With the PV fleet scaling from 1 TW in 2022 to potentially reaching 10 TW by 2030 and soaring up to an ambitious 60 TW by 2050 in the most ambitious scenario, the projected trajectory of Solar's growth is exponential.

Yet, its realization faces diverse challenges across our world's diverse regions. Equitable growth across all regions remains imperative. While the Asia-Pacific region accounted for 56% of the total installed PV in 2022, the Middle East and Africa region merely represented 2%. Across high solar penetration nations, the imperative lies in managing the advancements achieved. Intermittency of solar power, grid upgrades, and storage integration emerge as pivotal challenges. Countries navigating this stage grapple with balancing Solar's promise with grid stability, necessitating sophisticated forecasting, storage solutions, and upgrades to energy infrastructure. Conversely, in low solar penetration regions, the struggle is rooted in initiation. From initial investments and regulatory frameworks to fostering technical expertise and resource assessment, these nations face the pivotal task of laying foundations for a solar-powered future. Empowering these regions demands strategic investments, capacity building, and a supportive policy environment.

Addressing these technological barriers requires a concerted global effort, collaboration, and a shared commitment to innovation. It calls for harmonizing policies, fortifying regulatory frameworks, and leveraging advancements in grid management and storage technologies.

As the ISA, we stand firm in our resolve to foster international collaboration, drive policy advocacy, and champion innovation. Our commitment to harnessing the immense potential of solar energy remains unwavering. We extend our gratitude to all nations, partners, and stakeholders contributing to this collective endeavour.

Acknowledgement

This report was developed under the guidance of Dr Ajay Mathur (Director General, International Solar Alliance) and Mr. Joshua Wycliffe (Chief Operations Officer, International Solar Alliance) and was authored by the team (Mr. Saba Kalam, Programme Specialist, International Solar Alliance; Mr. Abhishek Shah, Director, KPMG; Mr. Rushikesh Muthyal, Manager, KPMG; Mr. Abhishek Dhawale Consultant, KPMG).

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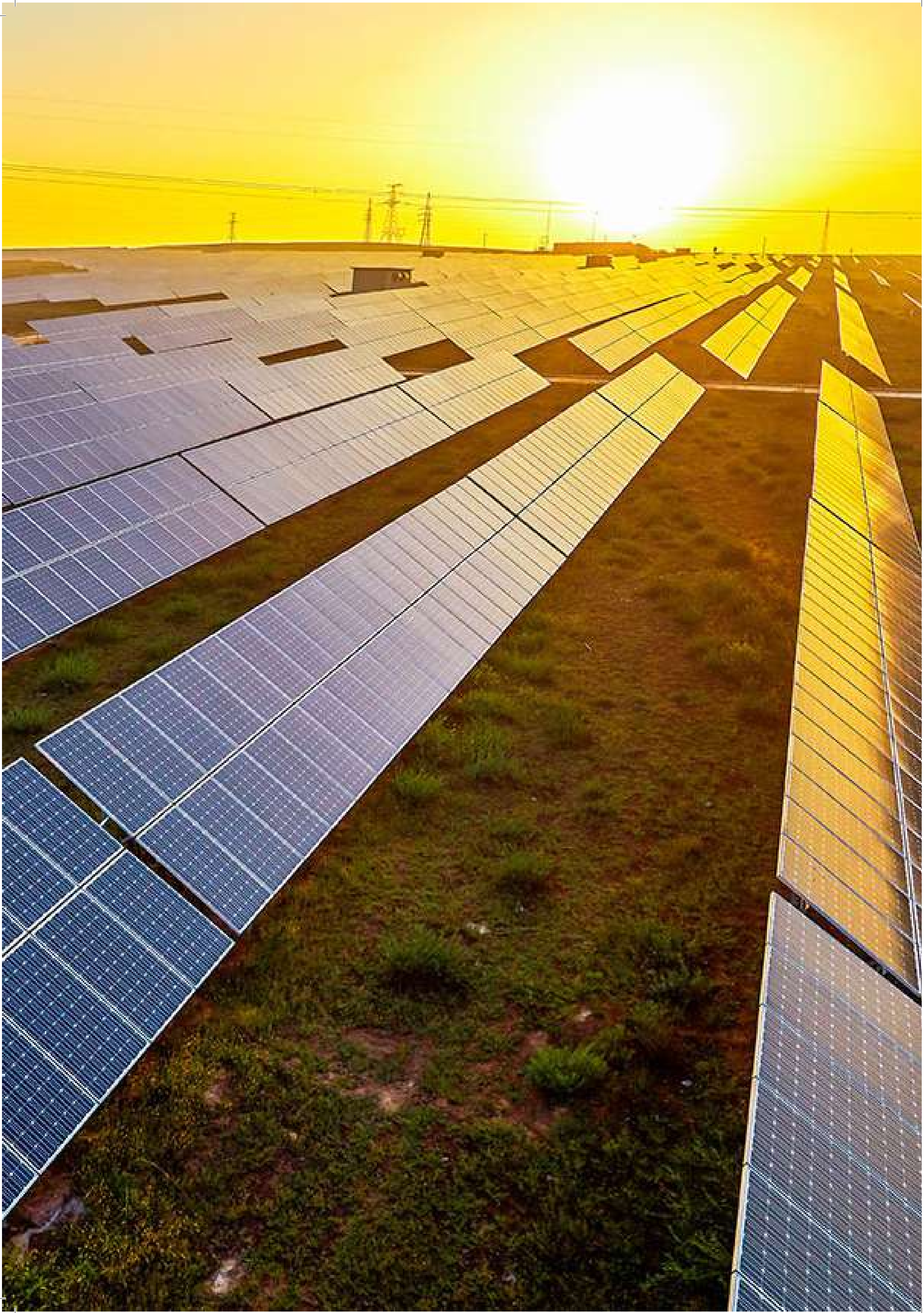

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Abbreviations

BAU	Business-As-Usual
BIPV	Building Integrated Photovoltaics
BNEF	Bloomberg New Energy Finance
CAGR	Compound Annual Growth Rate
CoP	Conference of Parties
CSP	Concentrated Solar Power
EV	Electric Vehicles
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
GHG	Global Greenhouse Gas
GW	Giga Watt
HJ	Hetero Junction
IBC	Interdigitated Back Contact
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
LAC	Latin America and the Caribbean
LDC	Least Developed Countries
MW	Mega Watt
NDC	Nationally Determined Contributions
PERC	Passivated Emitter Rear Cell
PV	Photovoltaic
RE	Renewable Energy
RPS	Renewable Portfolio Standards
SIDS	Small Island Developing States
TOPCon	Tunnel Oxide Passivated Contact
TW	Terra Watt
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America

Executive Summary

IPCC has identified the attainment of net-zero emissions by mid-century as a fundamental step towards limiting global warming to 1.5 degrees Celsius above pre-industrial levels. Moreover, the G20 New Delhi Leaders Declaration, adopted during the recent G20 Summit in India, encourages the **tripling of global RE capacity and doubling of energy efficiency rates by 2030** for all participant countries as an interim milestone towards the Net-zero targets. The **COP 28 presidency has also taken up the same mission** as the G20 and asked the participating countries to move towards the tripling of RE capacity.

The International Solar Alliance (ISA) is actively supporting its member countries to accelerate the adoption of solar energy and **support the tripling of RE capacity as announced by G20 New Delhi Leaders Declaration and the COP 28 presidency**. As we approach the COP 28, it is crucial to understand the role of solar energy in mitigating climate change and leading us towards a sustainable future powered by solar energy.

- **Tripling RE capacity to about 11 TW is consistent with a pathway to global net zero by 2050:** RE sources, including solar, wind, hydro, and geothermal power have the capacity to reduce emissions, stimulate economic growth, enhance resilience, and foster international cooperation. Solar power, in particular, has gained significant recognition due to its scalability, cost-effectiveness, and minimal carbon footprint. As of the first quarter of 2023, the world had approximately ~1.2 terra watt (TW) of installed solar photovoltaic (PV) capacity, a significant increase from a mere 40 GW in 2010. The solar PV market continued its record-breaking streak, with new capacity installations totaling approximately 226 giga watt (GW) in 2022. This reaffirms the pivotal role of solar energy in the global transition toward achieving the tripling of RE capacity by 2030.

- **Regional pathways differ, some need to nearly triple and some need to more than triple RE capacities:** The distribution of solar energy adoption varies greatly among different regions. In 2022, the top five countries in terms of capacity added were China, the United States, India, Brazil, and Spain, accounting for approximately 66% of the newly installed capacity. Regionally, the Asia Pacific region experienced the highest increase in solar installed capacity, primarily driven by developments in India and China, adding approximately 116 GW in 2022. China continued to lead in new renewable energy investments, followed by Europe and the United States. However, Africa and the Middle East only represented a small fraction (1.6%) of global investment in renewables.

- **~16x energy storage capacity and sector coupling will be required to meet RE tripling goals:** The widespread adoption of solar energy is crucial in addressing climate change and transitioning to a sustainable energy future. The global adoption of solar energy is driven by a combination of technological advancements, sectoral investments, policy support, economic incentives, environmental concerns, and societal awareness. However, there are also barriers that impede its global growth, including the lack of storage integration, insufficient regulatory support, and limited financial incentives, among others. Accelerating the adoption of solar energy to achieve the tripling of RE capacities by 2030 will require substantial efforts by various stakeholders including governments, industry players, and communities.

- **Solar a global success story, towards TW scale installations annually:** To support the tripling of global RE capacity by 2030 and subsequently meet the Net zero target, global installed solar PV capacity would need to reach 600GW/year from 2023 to 2030 and by 1000GW/year from 2030 to 2050. The following measures can be undertaken to achieve accelerated solar deployment.

    - Provide robust policy support through stable and long-term measures
    - Invest in grid infrastructure to accommodate higher levels of solar energy
    - Promote domestic manufacturing of solar components
    - Streamline permitting and approval processes for solar project development
    - Facilitate technology transfer and knowledge-sharing among countries
    - Encourage industries to commit to carbon neutrality targets that prioritize solar energy

- **Governments and Industries need to act fast; Investments in solar to be increased to ~2x:** To support the tripling of global RE capacity by 2030, annual investments in solar are expected to increase to ~$500 billion from the current levels of ~ $300 billion. Innovative financing tools and business models will further unlock investments in solar

    - Implementing innovative financing instruments like green bonds, dedicated climate funds, etc.
    - Commercial financial institutions need to make strong energy transition commitments.
    - Unlocking institutional investors can help attract unprecedented investment flows
    - Planned transition of subsidies from fossil fuels to solar energy
    - Enhancing the flow of foreign direct investments (FDIs) and improving blended finance
    - Ensure an efficient mobilization of investment and cooperation between all stakeholders

- **Only 19% of the total 195 Parties have quantified solar capacity targets mentioned in the NDCs. Encouraging countries to have solar specific NDCs can improve solar adoption**

    - Align policies with NDC targets to demonstrate a clear commitment to achieving these targets
    - Develop a standardized NDC format to ensure consistency and facilitate the tracking and monitoring of NDC progress.
    - Guarantees are essential to at least private sector investment in geographies that are seen as medium risk investment opportunities.
    - Grants, interest-rate subventions, and capital cost subsidies will enable solar investments (and thus create a policy and capacity demand) in geographies seem as high-risk investment opportunities.
    - Co-ordination between multiple agencies on-ground for seamless flow of data

- Mandate the inclusion of dominant RE technologies (solar, wind, and hydro, etc.) in the NDCs

- **Unlocking solar technology potential:** Tunnel oxide passivated contact (TOPCon) and hetero junction (HJ) technologies are expected to be ahead of passivated emitter rear cell (PERC) with efficiencies of 24% and 26% respectively in 2023, with a likely increase of 10%+ in the next 10 years. Therefore, there is need to expedite the implementation of novel solar technologies and other advanced technologies

  - Emphasizing research and development in newer high-efficiency solar technologies like TOPCon, HJ, interdigitated back contact (IBC), perovskites, etc.
  - Incorporating solar panels into vehicles, building facades, or through agrovoltaics
  - Additionally, Concentrated Solar Power (CSP) can be integrated with existing coal plants

- **Tripling RE capacity provides opportunity for ~10 million of additional jobs; Enhancing education, training, and capacity building programs is the key to meet the agenda**

  - Align workforce planning among all stakeholders, including labor agencies, labor unions, etc.
  - Identify critical skill gaps and workforce needs in advance
  - Ensure solar targets are reflected in educational programmes and resources, such as university curricula, vocational training institutions, etc.
  - Invest in reskilling and upskilling measures for vulnerable communities and those in fossil fuel industries


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01 Introduction

In the battle against climate change, the International Solar Alliance (ISA) is supporting its member countries across various policy and finance initiatives to accelerate solar energy adoption and **support the tripling of RE capacity as announced by G20 New Delhi Leaders Declaration and the COP 28 presidency**. The alliance is playing a pivotal role in advocating and facilitating the adoption of solar energy on a global scale. As we move towards the Global Stock Take (GST), it is essential to comprehend the significance of Nationally Determined Contributions (NDCs) and role of solar energy in mitigating climate change and paving the way towards a sustainable, solar-powered future.

The objectives of this report are:

A. To track the progress of solar energy and its contribution towards NDC commitments

B. To identify the barriers and challenges in the adoption of solar energy

C. To recommend possible solutions and best practices to accelerate solar capacity implementation and achieve the tripling of global RE capacity by 2030.

It is further expected that the insights and recommendations from this report will be taken up for discussion during the conference of parties (COP) 28.

1.1. Role of NDCs in achieving the tripling of global RE capacity and Net-Zero targets

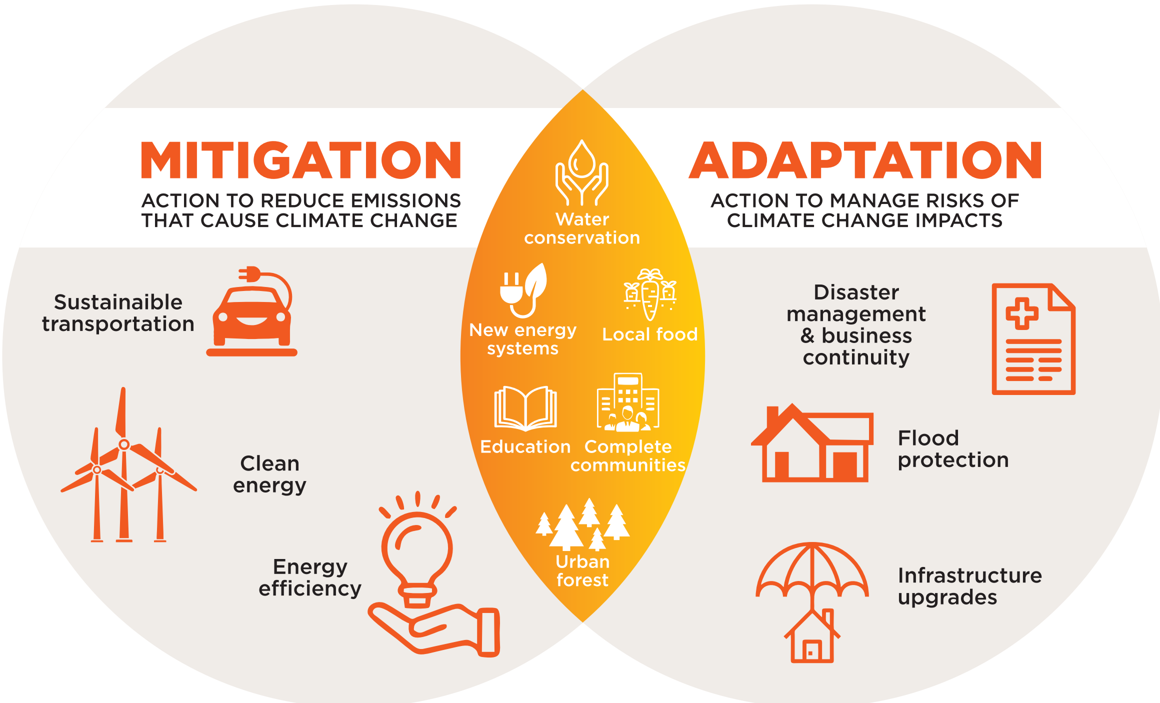
Nationally Determined Contributions (NDCs) are a cornerstone of the Paris Agreement, a historic international treaty adopted in 2015 aimed at limiting global warming to well below 2 degrees Celsius above pre-industrial levels. Each participating country, known as a Party, submits its NDCs, which are individualized, voluntary climate action plans. These contributions outline the country's specific targets, policies, and measures to reduce greenhouse gas emissions, adapt to the impacts of climate change, and promote sustainable development. The key aspects of NDCs are (i) Emission Reduction Targets, (ii) Mitigation and Adaptation actions, and (iii) Timeframes and Monitoring. NDCs help articulate a country's commitment to reduce emissions, promote specific mitigation measures such as increased RE capacity, energy efficiency, reforestation, etc., and set deadlines to achieve these commitments through regular monitoring and reporting.

NDCs promote global coordination and cooperation, providing a transparent platform for countries to communicate their commitments and align their efforts towards a common goal of limiting global warming.

Their flexibility and ambition foster broader participation, enable countries to revise and enhance their commitments over time, and attract financial support for sustainable initiatives, such as solar energy projects.

Furthermore, NDCs encompass not only **mitigation measures but also adaptation strategies, making them instrumental in strengthening resilience to climate impacts**. Through regular reporting and transparency,

Figure 1: Examples of mitigation and adaptation measures under NDCs



NDCs ensure accountability, enhance trust among nations, and drive the necessary adjustments to meet global climate goals.

Net-zero, on the other hand, represents a state where the greenhouse gases emitted into the atmosphere are balanced by the gases removed or offset, signifying zero net emissions. In essence, the emissions produced are entirely compensated for by actions that remove an equivalent amount of greenhouse gases from the atmosphere, effectively stabilizing the global temperature.

Net-zero emissions are imperative to limit global warming and stay within the boundaries outlined by the Paris Agreement. The Intergovernmental Panel on Climate Change (IPCC) has identified achieving net-zero emissions by mid-century as essential to limiting global warming to 1.5 degrees Celsius above pre-industrial levels. Achieving net-zero emissions is pivotal in averting the most catastrophic impacts of climate change such as habitat loss, species extinction, and other ecological disruptions caused by climate change. More and more countries have, therefore, started to set Net-zero targets for themselves in addition to the NDC commitments, as seen in the figure below.

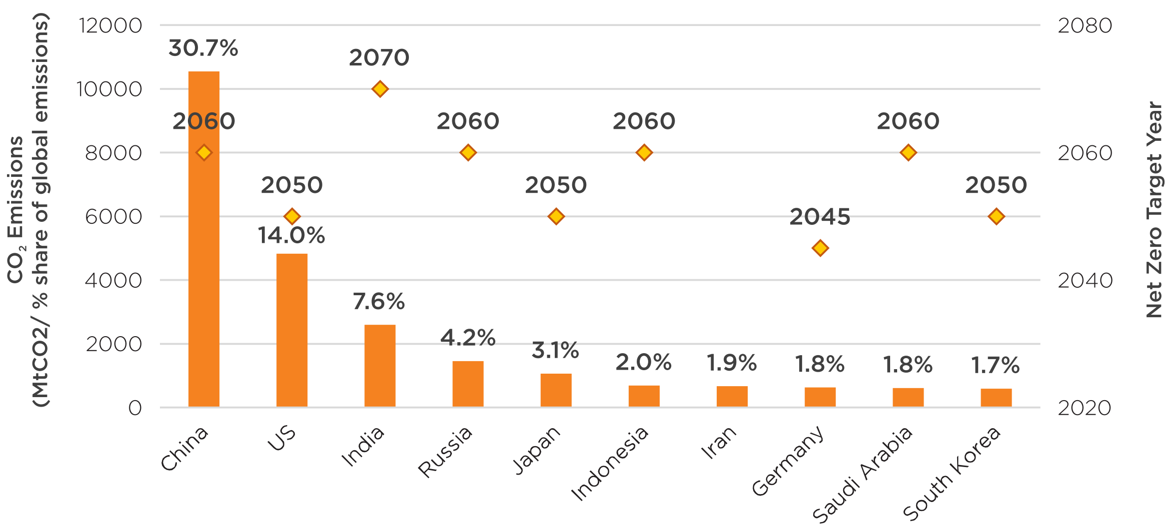


Figure 2: CO_2 emissions and Net-Zero Targets for the Global Top 10 Emitters as of 2022

Source: World Bank CO_2 emissions data and Country Net-Zero Targets

Moreover, the G20 New Delhi Leaders Declaration, adopted during the recent G20 Summit in India, encourages the **tripling of global RE capacity and doubling of energy efficiency rates by 2030** for all participant countries as an interim milestone towards the Net-zero targets. The COP 28 presidency has also taken up the same mission as the G20 and asked the participating countries to move towards the tripling of RE capacity. Therefore, updating the NDCs will be vital to achieve the tripling of global RE capacity and Net-zero targets.

1.2. Global Climate Stocktake and its importance

The UN Climate Change Conference (COP28) will mark the conclusion of the first-ever global stocktake, a process that allows countries and stakeholders to assess their progress towards meeting the goals of the Paris Climate Change Agreement. Unfortunately, it is clear that we are not on track to limit global warming to 1.5 degrees Celsius, and time is running out for meaningful action. At COP28, governments will decide on the future of the global stocktake, which could be used to increase ambition in their next round of climate action plans in 2025.

A transformation of systems is required for the stocktake, which adopts a comprehensive approach encompassing the entire society and economy, prioritizing climate resilience and development that aligns with low greenhouse gas emissions. These endeavours must be sustained for several decades, promoting sustainable development and the elimination of poverty. Additionally, the stocktake highlights a widening disparity between the requirements of developing nations and the assistance provided and mobilized for them, necessitating the release and reallocation of trillions of dollars towards climate action and climate-resilient development.

Throughout the initial week of the COP28 conference, the High-Level Committee responsible for the stocktake will arrange top-level deliberations which will provide valuable insights for the political outcome, which will encapsulate crucial political messages, highlight potential opportunities, commendable practices, and obstacles to overcome in order to bolster climate action. The aim is to assist governments in formulating more ambitious national climate action plans by 2025.

With a similar aim in mind, ISA has undertaken a solar-specific Global Stocktake to understand and highlight the progress in the solar sector along with the barriers that the countries face in achieving their climate targets, in particular the targets that can be achieved through the widespread adoption of solar and support in meeting RE tripling targets by 2030.

1.3. Role of Solar Energy in achieving the NDCs and Net-Zero

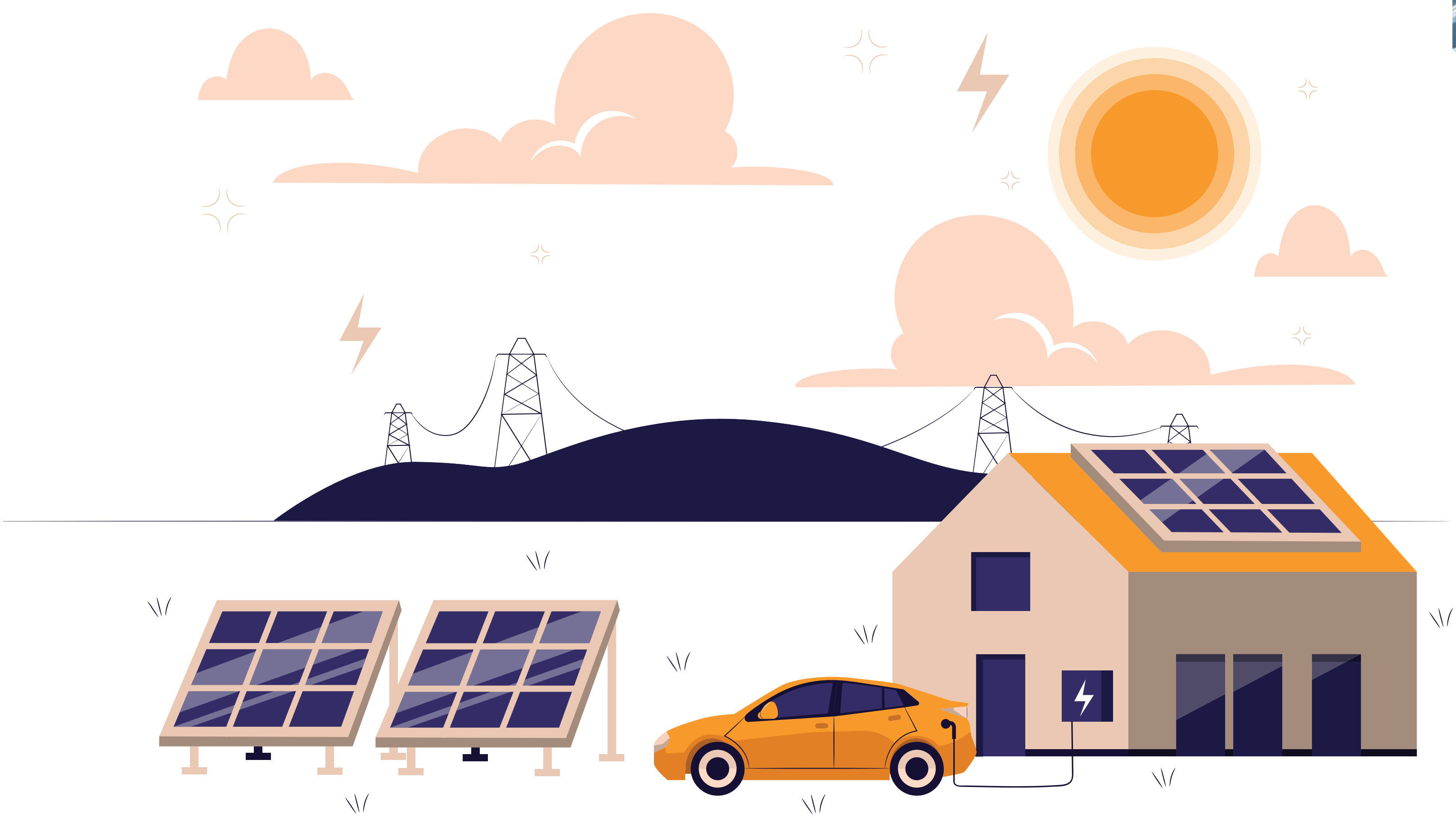
Renewable energy sources such as solar, wind, hydro and geothermal power play a pivotal role in achieving the NDCs. Their capacity to reduce emissions, stimulate economic growth, enhance resilience, and foster international cooperation aligns seamlessly with the objectives of NDCs.

Renewable energy sources are at the forefront of efforts to reduce greenhouse gas emissions. Many NDCs include specific targets for increasing the share of renewable energy in the national energy mix. Solar power, in particular, has gained prominence due to its scalability, cost-effectiveness, and minimal carbon footprint. By transitioning from fossil fuels to renewables, countries can significantly lower their carbon emissions, moving towards Net-zero. Moreover, Solar has a direct impact on the 3 key sectors of the NDC commitments, namely, energy, industry, and agriculture. While the energy aspect is clear, solar can also help industries decarbonise their power procurement and solutions such as solar pumps could directly affect the agricultural output. Solar energy also has an indirect impact on the transport sector by providing cleaner energy for the charging of EVs (cars, 2-wheelers, buses, etc.) thereby creating an indirect economy-wide impact helping achieve the NDC commitments.

Table 1: Direct and indirect impacts of solar energy on the broad sectors mentioned under NDC commitments

	Direct Impact	Indirect Impact	No Impact
Energy Supply			
Renewable energy generation	✓		
Grid improvement		✓	
Energy efficiency improvement		✓	
Shift to low- or zero-carbon fuels	✓		
Transport			
Energy efficiency improvement		✓	
Shift to more efficient modes of transport	✓		
Electrification	✓		
Shift to low- or zero-carbon fuels	✓		
Building			
Energy efficiency improvement		✓	
Shift to low- or zero-carbon fuels	✓		
Industry			
Energy efficiency improvement		✓	
Shift to low- or zero-carbon fuels	✓		
Agriculture			
Improved management of manure and herds			✓
Improved agricultural productivity	✓		
Improved cropland management	✓		
Agroforestry			✓

	Direct Impact	Indirect Impact	No Impact
LULUCF			
Afforestation, reforestation, and revegetation			✓
Sustainable forest management			✓
Reduced deforestation and forest degradation			✓
Land restoration			✓
Forest conservation			✓
Waste			
Waste recycling		✓	
Waste reduction		✓	
Waste-to-energy			✓
Composting			✓
Improved landfill system			✓



NDCs often emphasize the need for energy transition and diversification. According to the Global Carbon Atlas, in 2019, electricity and heat production accounted for 42% of global CO2 emissions, illustrating the potential need for energy transition to clean electricity. Renewable energy technologies provide an opportunity to reduce dependence on finite fossil fuel resources, enhance energy security, and create a more resilient energy infrastructure. Diversifying the energy mix with renewables contributes to the achievement of NDCs by ensuring a reliable and sustainable energy supply.

NDCs also recognize the potential of RE projects to contribute to economic growth and job creation and include policies to promote renewable energy investments. These projects not only stimulate local economies but also align with sustainable development goals, fostering inclusive growth. Additionally, distributed renewable energy systems, like off-grid solar installations, provide reliable access to electricity in vulnerable communities, improving their resilience to climate-related disruptions and enhancing their quality of life.

As countries continue to strengthen their commitments and actions under the Paris Agreement and work towards their Net-zero targets, the integration of RE into NDCs will remain a critical strategy for achieving a sustainable and low-carbon future.

02
Global review of NDCs, Solar targets and current implementation status

Achieving a climate-resilient trajectory aligned with the Paris Agreement hinges upon the global transition of the energy sector towards sustainable sources. A substantial increase in the adoption of renewable energy, improved energy conservation practices, and the electrification of key sectors like heating and transportation can collectively contribute to realizing 70% of the potential for emissions reduction (with 25% attributable to renewable energy, 25% to enhanced energy efficiency, and 20% to sectoral electrification)[1]. In light of its crucial contribution to the attainment of global climate objectives, this section places particular emphasis on the solar energy elements within the Nationally Determined Contributions (NDCs).

2.1. Broad review of NDCs and presence of solar targets

Since the ratification of the Paris Agreement, a total of 194 Parties have submitted their Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). These NDCs outline the respective Parties' strategies for reducing emissions and increasing the adoption of renewable energy sources. In the year 2022, 35 countries provided updated NDCs, although not all of them included specific targets for the deployment of renewable energy. As of 2022, 183 Parties

1 International Renewable Energy Agency (IRENA) (2021)." NDCs and Renewable Energy Targets In 2021"

incorporated renewable energy components into their NDCs, but only 149 of them had established quantified targets for renewable energy[2,3]. Among these targets, 118 primarily emphasize renewable energy in the power sector, while 30 explicitly reference renewables in the context of heating, cooling, or transportation. Notably, only 13 Parties have pledged a specific percentage of renewables within their broader energy portfolios. Moreover, only 65 Parties have targets that mention Solar.

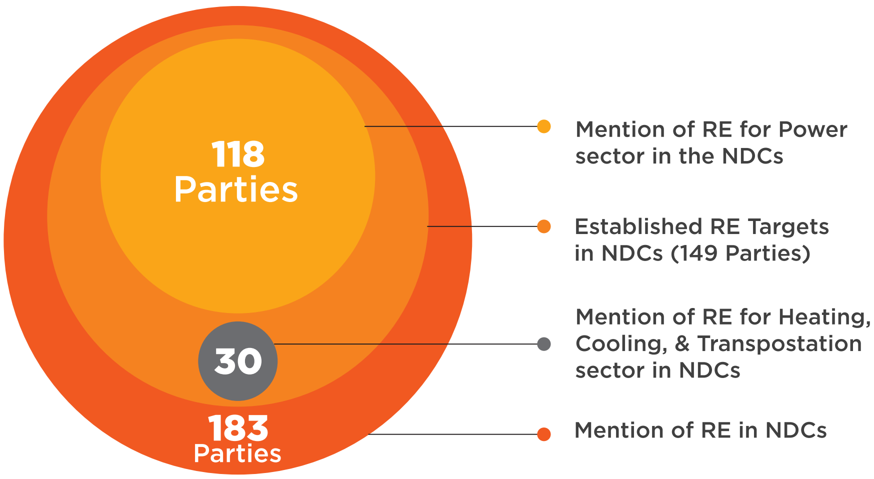


Figure 3: Mention of RE in the NDCs

On Track (12 Countries)	Lagging (25 countries)		No Specific Solar Targets (28 countries)	
• India	• Sri Lanka	• Niger	• Australia	• Guinea
• China	• Singapore	• Zimbabwe	• Cambodia	• Burundi
• Bangladesh	• Vanuatu	• Benin	• Uzbekistan	• Sierra Leone
• Uruguay	• Bhutan	• Rwanda	• Nepal	• Republic of Congo
• Grenada	• Turkey	• Seychelles	• Myanmar	• Guinea Bissau
• Morocco	• Armenia	• Eritrea	• Mongolia	• Bosnia Herzegovina
• Angola	• Cuba	• Eswatini	• North Korea	• Barbados
• Senegal	• Belize	• Comoros	• Laos	• Nicaragua
• Namibia	• Haiti	• Gambia	• Tonga	• United Arab Emirates
• Burkina Faso	• St. Kitts and Nevis	• Liberia	• Egypt	• Oman
• Nigeria	• Sudan	• Lesotho	• Tunisia	• Saudi Arabia
• Togo	• Ghana	• Djibouti	• Malawi	• Yemen
		• Sao Tome and Principe	• Mozambique	• Palestine
			• Mauritania	
			• Democratic Republic of Congo	

Figure 4: Countries with mention of "Solar" in the NDCs

2 Renewable Energy Policy Network for the 21st Century (REN21) (2023). "Renewables 2023 Global Status Report – Global Overview"

3 International Renewable Energy Agency (IRENA) (2023). "World Energy Transitions Outlook 2023"

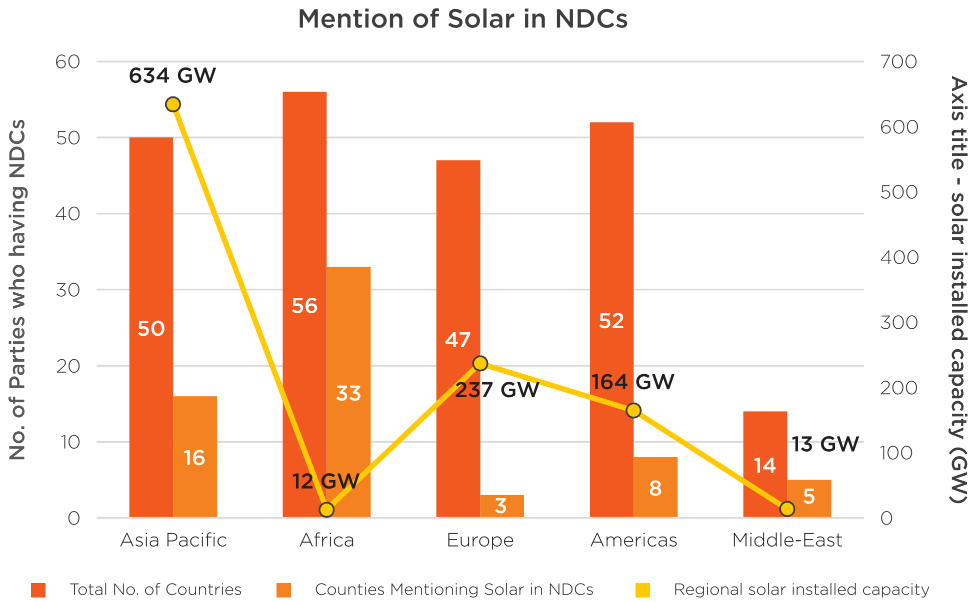


Figure 5: No. of countries/parties in a region vs the parties mentioning "Solar in the NDCs, along with the regional solar installed capacity

Policies aimed at decarbonization indirectly promote the utilization of renewable energy and encompass measures such as greenhouse gas emission reduction targets, commitments to achieve climate neutrality, and policies for achieving net zero emissions. As of May 2023, a total of 146 countries have announced or adopted a net zero emissions target[2]. The integration of renewable energy sources is crucial in attaining the goal of net zero emissions, and 94 countries have established both a net zero emissions target and an economy-wide target for renewable energy[2].

The transition towards sustainable energy sources necessitates more ambitious commitments, particularly from developed nations, and heightened international collaboration to amplify financing for climate and renewable energy initiatives, particularly in countries most impacted by climate change, namely small island developing states and least developed countries. Additionally, as non-binding pledges, the targets outlined in Nationally Determined Contributions (NDCs) must align with national energy plans and renewable energy objectives.

2.2. Global Solar Capacity Addition Requirements to achieve Tripling of RE

Over the past decade, there has been a remarkable increase in global solar capacity. This growth has been driven by factors such as falling solar panel prices, improved technology, and supportive policies.

By the end of Q1 of 2023, the world had approximately ~1.5 TW of installed solar photovoltaic (PV) capacity, a significant increase from just 40 GW in 2010. Annual resource-wise capacity additions in 2022 highlight the dominance of solar among all other RE sources globally, with 44% of all RE capacity installed being solar, followed by wind (24%).

Although the absolute share of hydropower is still the highest (~50%), solar has shown a drastic growth in the past decade from ~1% in 2010 to 15.5% in 2022. This trajectory underscores the accelerating adoption of solar energy worldwide.

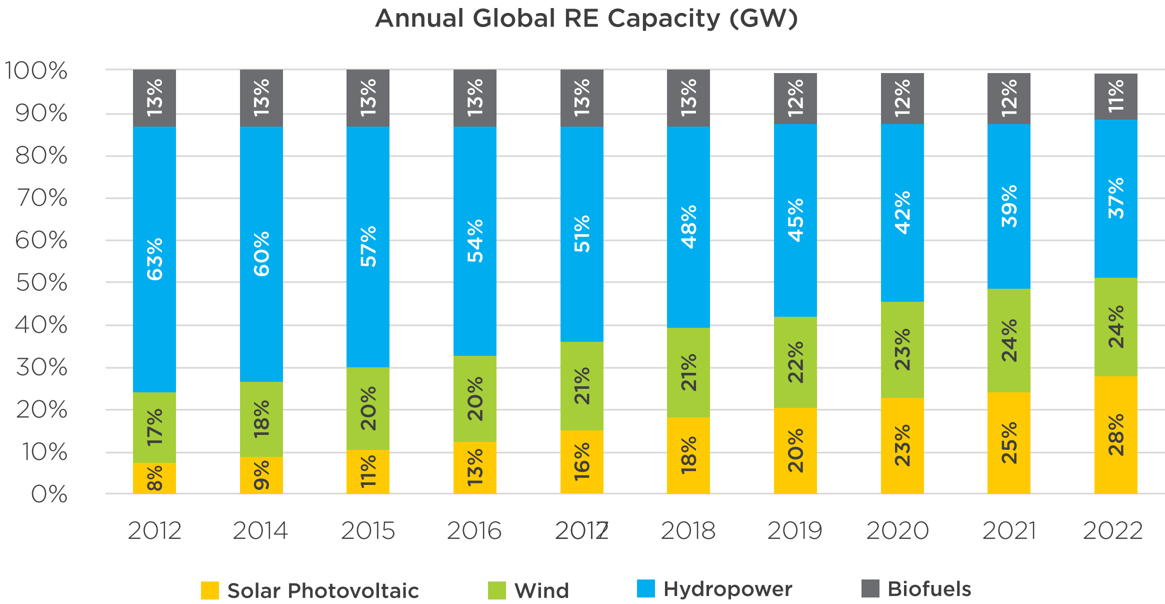


Figure 6: Annual Source-wise RE Capacity Share (till 2022)

Source: BNEF RE source-wise capacity data

To meet the target of limiting global warming to 1.5°C, it is necessary to significantly increase the capacity of renewable power generation across all countries. The extent of penetration of different renewable energy technologies will vary depending on their technical resource potential and cost competitiveness in the market. The majority of deployment is expected to occur in the G20 countries, which are projected to account for over 80% of global renewable installed capacities by 2030. The renewable capacity of G20 countries will need to increase nearly four times to reach 9,400 GW by 2030, and ten times to reach nearly 24,900 GW by 2050, compared to the levels in 2020, in order to align with the 1.5°C pathway[4]. The G20 New Delhi Leaders Declaration, adopted by the G20 leader countries on 9th September 2023 during the recent G20 Summit in India, encourages the tripling of RE capacity and doubling of energy efficiency rates by 2030 for all participant countries. During the special forum of the G20 Presidency, known as 'From G20 to COP28', COP28 President Dr. Sultan Al Jaber called on the world to unite, act, and deliver in order to achieve the goal of keeping the global temperature increase to 1.5 degrees Celsius. The COP28 president also highlighted the alignment between the G20 and COP28 visions, reiterating the need for a fair and inclusive energy transition, emphasizing the importance of doubling adaptation finance, replenishing the green climate fund, tripling the global RE capacity by 2030 and delivering the promised $100 billion this year.

To achieve this ambitious 1.5 C goal, various organizations have estimated the installed capacity of solar PV by 2030, all of them expecting the installed capacity for Solar PV to grow from 1 TW in 2022 to more than 5 TW in 2030. The International Energy Agency (IEA), in the latest Next Zero Roadmap report, anticipates grid-connected solar PV to reach 6.1 TW, higher than the 5.7 TW, 5.4 TW and 5.1 TW as estimated in the BNEF and IRENA and University of Technology, Sydney (UTS) scenarios, respectively. The Lappeenranta University of Technology (LUT) scenario has assumed an extraordinary growth of Solar PV reaching 10.2 TW by 2030. Even after 2030, the solar capacity will need to grow at substantial rates to stay within the 1.5 C temperature increase.

4 International Renewable Energy Agency (IRENA) (2023). "World Energy Transitions Outlook 2023"

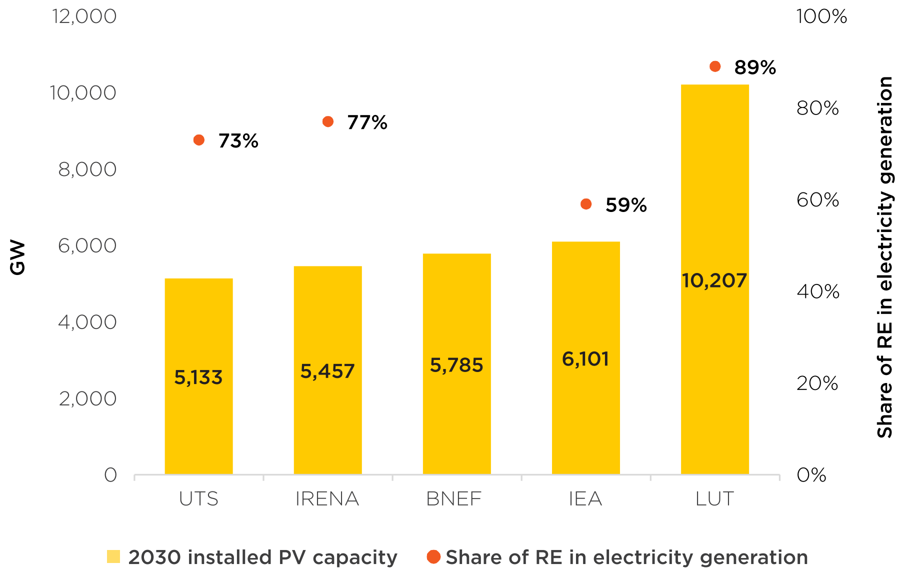


Figure 7: Scenarios for total installed capacity of solar PV in 2030

Source: BNEF RE source-wise capacity data

Moreover, to support this large capacity addition requirement year-on-year, significant developments would need to be made in the manufacturing capacity across all components of solar PV. In 2022, China emerged as the predominant force in global solar PV manufacturing. Over the past decade, the module manufacturing capacity of solar PV worldwide has experienced a remarkable surge, skyrocketing from approximately 25 GW in 2010 to an impressive 656 GW in 2022. Notably, China has accounted for a staggering 83% of this production. Furthermore, an additional 300 GW of manufacturing capabilities have already been announced, indicating a clear intention to prevent other entities from acquiring significant market shares.

The dominance of the Chinese market can be attributed to the remarkable ability of local companies to capitalize on economies of scale. China has implemented infrastructure and industrial policies that have established an integrated supply chain with significant economies of scale. China's industrial policies, specifically targeting solar PV, have fostered continuous innovation throughout the entire supply chain.

The imbalanced concentration of the solar PV supply chain has prompted the European Union, Turkey, India, and the United States to implement policy incentives in order to support domestic solar PV production. However, the diversification of solar PV manufacturing can only be achieved if production costs decrease to ensure competitiveness with the lowest-cost producers, such as China, in both the short and long term. As of 2021, Thailand, Vietnam, and Malaysia have emerged as manufacturing and assembly hubs, collectively accounting for approximately 9% of cell and module production. Furthermore, Japan, India, and Singapore currently contribute to 10.5% of cell production and 7.6% of module production.

In conclusion, significant manufacturing capacities, diversification of solar PV supply chain, and simultaneous solar PV capacity additions will be vital to achieve the global NDC targets by 2030 and 2050.

03

Regional pathways in meeting RE tripling targets by 2030

On a global scale, renewables are anticipated to evolve into the new foundation of energy generation. In 2022, the world witnessed a significant acceleration in the growth of renewable installed capacity, with an impressive addition of 348 GW[5]. This increase in renewable energy penetration can be attributed to several factors, including the installation of new photovoltaic (PV) systems, an overall upsurge in electricity demand, government incentives, and a heightened awareness of the imperative to transition to cleaner energy sources.

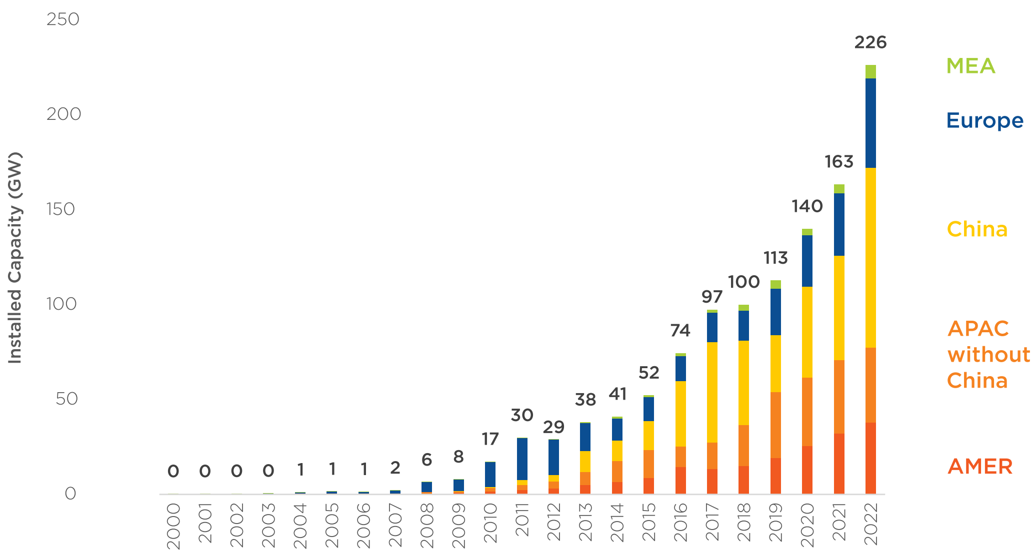


Figure 8: Global installed solar capacity from 2012-2022
Source: World Solar Reports 2023

5 REN21, (2023). "Renewables 2023 Global Status Report"

Notably, the solar sector has emerged as a dominant force in the renewable energy landscape, gaining substantial traction in recent years. The solar PV market, in particular, continued its record-breaking streak, with new capacity installations totalling around 226 GW in 2022[6]. This reaffirms the pivotal role of solar energy in the global transition toward sustainable power generation.

But the shift to solar energy has been uneven across regions. The top five countries by capacity added (in 2022, descending) were China, the United States, India, Brazil, and Spain, together comprising around 66% of newly installed capacity (up from 61% in 2021). The leading countries for cumulative solar PV capacity remained China, the United States, Japan, India, and Germany, while the leading markets for per capita capacity continued to be Australia, the Netherlands and Germany. China continued to lead in new renewable energy investments in 2022, followed by Europe with 11%, and the United States with 10%. While Africa and the Middle East combined represented only 1.6% of global investment in renewables[7].

The report has focussed on a regional assessment to understand the growth of solar in the world and to identify the barriers and the drivers to the adoption of solar. This section comprises of a broad assessment of the various regions of the world such as the Americas, Europe, Middle-East, Africa, and Asia Pacific.

3.1 Asia Pacific (APAC)

The Asia-Pacific region encompasses a vast geographical expanse, characterized by a rich tapestry of landscapes, societies, cultures, religions, and economies. Among the 58 countries within the region, there is a notable diversity, including 11 high-emission nations, 11 Least Developed Countries (LDCs), 17 Small Island Developing States (SIDS), and nine classified as fragile states. This region is currently undergoing rapid transformations in terms of economic development, population growth, urbanization, social dynamics, and technological progress, all of which are closely tied to its abundant natural resources.

While all the countries in the Asia Pacific region, have committed to NDCs under the Paris Agreement, the United Nations Development Programme (UNDP) is actively supporting 27 countries in the preparation of second-generation Nationally Determined Contributions (NDCs). As of June 15, 2022, 20 of these countries (74%) had submitted updated or new NDCs as part of their commitment to the Climate Promise initiative. Additionally, 39 countries in the region have submitted net-zero pledges.

It is noteworthy that over half of the world's population resides in the Asia-Pacific region. This dynamic region also holds a significant role in global greenhouse gas (GHG) emissions, contributing to 42.4% of the world's total emissions. Among these emissions, the top 11 high-emitting countries are responsible for 40.8% of the world's total GHG emissions.

6 ISA, (2023). "World Solar Reports 2023"
7 REN21, (2023). "Renewables 2023 Global Status Report"

In 2022, the Asia Pacific region saw in increase of ~116 GW of solar installed capacity. The five countries with highest shares of total solar installed capacity are China (393 GW), Japan (83 GW), India (63 GW), Australia (~30 GW), and Republic of Korea (24 GW). These 5 countries contribute to ~95% of the annual solar installations the region.

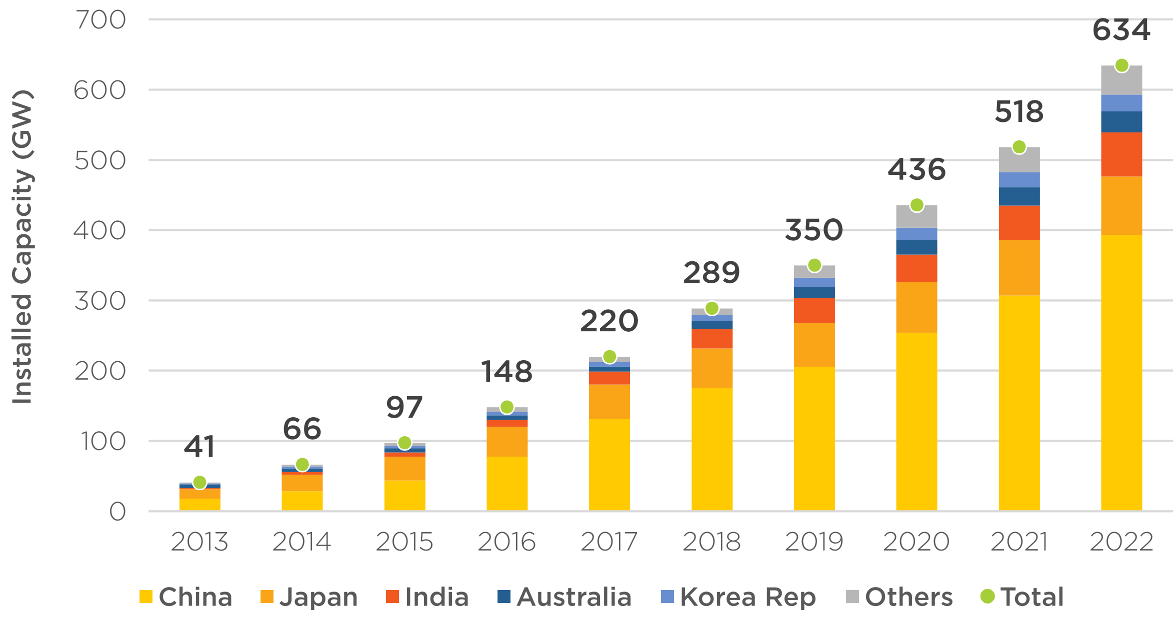


Figure 9: Global installed solar capacity from 2012-2022
Source: IRENA RE Statistics 2023

- China is the most dominant country in the world when it comes to solar energy, both in the total installed capacity and the manufacturing capacity. The country's solar installations have grown at a compound annual growth rate (CAGR) of 25% in the last 5 years, from 130 GW in 2017 to 393 GW in 2023. China contributed to 64% of the global solar capacity addition in 2022 and also increased its investments in the renewables sector to United States Dollar (USD) 274 billion, which makes up 55% of the global investments in the sector.

- Japan also holds a prominent position as the market leader in the Asia Pacific region, with a substantial 83 GW of solar PV capacity installed at the end of 2022, marking a notable increase from 49.5 GW in 2017. This growth has been achieved at a commendable CAGR of 11%. The Japanese government has implemented a series of measures to promote solar PV, including mandating that 60% of new residential buildings include rooftop PV systems and deregulating land zoning to allow PV installations on agricultural land.

India has experienced remarkable expansion in its solar PV capacity, reaching 63.2 GW in 2022, up significantly from 18.3 GW in 2017. This growth was driven by a focus on local manufacturing and significant policy push from the government. India has set an ambitious goal of achieving 50% of its cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

- Australia has seen substantial growth in its solar PV capacity, reaching 29.7 GW in 2022, compared to 7.3 GW in 2017, which is a CAGR of 32%. In 2021, Australia established a new global record by achieving 1 kilo watt (kW) of installed solar PV capacity per capita.
- Republic of Korea has also grown consistently at a CAGR of 30% to reach 24 GW of solar installed capacity in 2022. In the 9th Basic Plan for Long-term Supply, Korea has announced RE to account for 34% of the total power capacity by 2030, of which 34 GW is expected to be fulfilled by solar.

3.2 Europe (EU)

The recent global energy crisis, marked by supply chain disruptions, price fluctuations, and geopolitical tensions, has underlined the critical nature of energy security. European nations are working towards enhancing their energy security by reducing their dependence on fossil fuel imports and expanding the array of energy sources through renewable energy projects. This commitment is exemplified by energy-related policies like the European Union's REPowerEU initiative, which seeks to bridge the gap between regional energy supply and demand by fostering the adoption of renewable energy sources. These efforts are pivotal in ensuring a more secure and sustainable energy future for the region. UNDP's Climate Promise initiative is supporting 18 of the 54 countries in the region to update/revise their NDC submissions and to prepare second-generation NDCs. Of these 54 countries, 46 have already submitted second-generation NDCs and 5 more are under process.

Europe has made substantial contributions to the production of renewable fuels, accounting for 18% of the global production. Moreover, the share of renewables in the region's total electricity generation has seen remarkable growth, increasing from 25% to 36% over the span of a decade. In 2022, Europe continued its impressive growth in the field of solar photovoltaic (PV) capacity, adding a remarkable 45 GW to its installed capacity, reaching a total of ~237 GW. Several countries within Europe played a significant role in this growth with Spain leading the region with 8.1 GW, followed by Germany with 7.5 GW, Poland with 4.9 GW, the Netherlands with 3.9 GW, and France with 2.9 GW of additional solar PV capacity[8]. These efforts collectively reinforce the region's commitment to expanding solar energy and advancing its transition to cleaner and more sustainable energy sources.

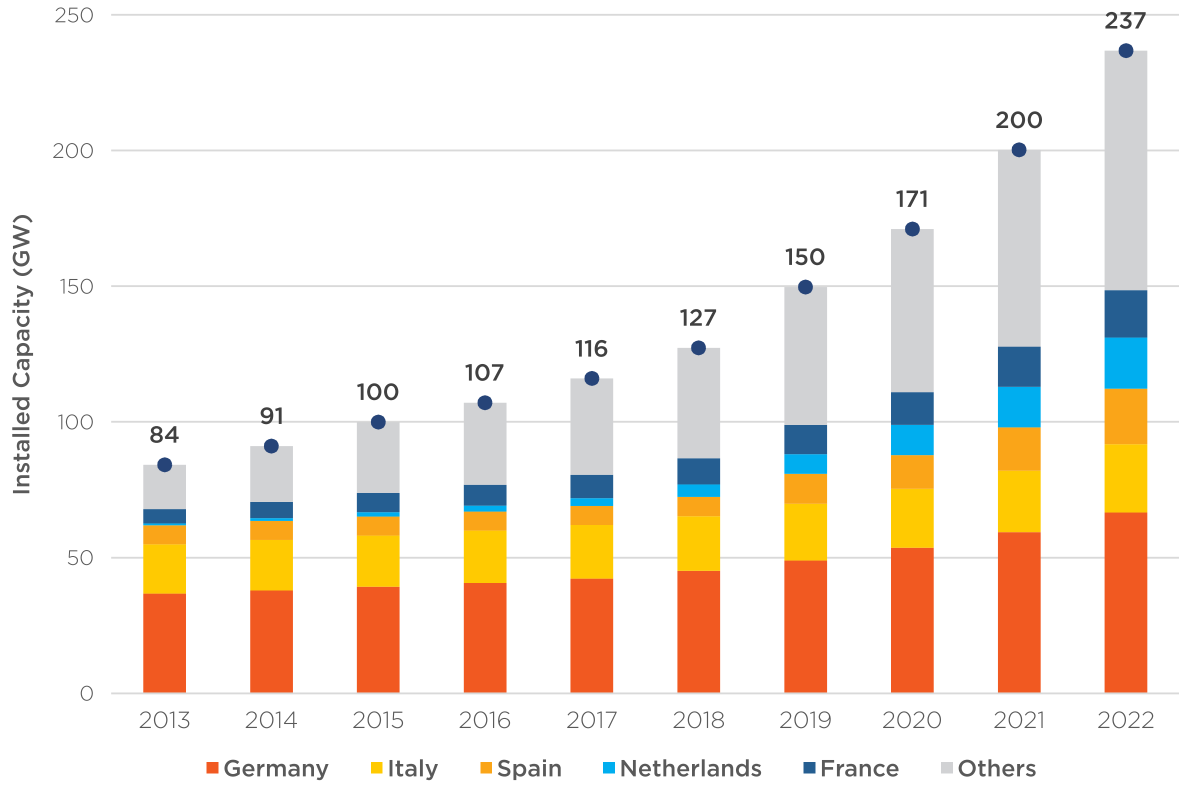


Figure 10: Solar installed capacity trends with 5 largest capacity countries in Europe
Source: IRENA RE Statistics 2023

- Germany stands as the market leader in the European region, with its total solar PV installed capacity growing from 42 GW in 2017 to 66 GW in 2022, at a Compound Annual Growth Rate (CAGR) of 10%. The country has committed to boosting renewable energy in final energy consumption, targeting at least 32% by 2030.

- Italy has also made noteworthy progress, with its total installed capacity reaching 25 GW in 2022, increasing at a 5% CAGR from ~20 GW in 2017. Italy has also set a target to increase renewable energy in final energy consumption to at least 32% by 2030.

- Spain has the second highest growth in the last 5 years jumping from ~7 GW in 2017 to 20.5 GW in 2022, at a CAGR of 24%. Recently, the country has also ramped up the RE generation targets to 81% of their requirement by 2030. This will require a total installed capacity of ~214 GW of RE by 2030, of which solar PV is expected to be 76 GW[8].

- Netherlands has significantly expanded its solar PV capacity, growing from ~3 GW in 2017 to 18.9 GW in 2022, boasting an impressive CAGR of 45%.

France has also experienced robust growth in its solar PV capacity, with the total capacity reaching 17.4 GW in 2022, an upsurge from 8.6 GW in 2017, showcasing a CAGR of 15%. France also aims to decrease the share of nuclear energy from 70% to 50% in its electricity mix by 2035 and close its coal plants by 2022.

8 Spain's Draft National Integrated Energy and Climate Plan (PNIEC), 2023

3.3 Americas (AMER)

The American continent is a vast land mass consisting of North America, Central America, South America, and the Caribbean where Central and South America are collectively termed Latin America. North America includes countries like the US, Canada, and Mexico whereas South America comprises countries like Brazil, Argentina Peru etc. Central America connects north and south regions encompassing countries like Guatemala, Panama, etc. and the Caribbean consists of numerous islands like Jamaica, Bahamas etc. The American continent, home to 650 million people, is incredibly diverse with wealth and prosperity coexisting alongside vulnerability and extreme poverty and offers a wide range of experiences, from the Arctic tundra of Canada to the tropical rainforests of the Amazon basin, making it one of the most geographically and culturally diverse regions on the planet.

Of the 33 countries in Latin America and the Caribbean (LAC), 16 are Small Island and Developing States (SIDS), one is a Least Developed Country, and four are high emitters with an average per capita income $7,243[9]. Overall, the American continent is responsible for 20% of global greenhouse gas (GHG) emissions, of which countries in North America contribute 81%[10]. Every corner of the region is impacted by climate change. Central America and the Caribbean are facing various threats such as increasingly intense hurricanes, that lead to economic losses and a surge of migration out of the hardest-hit areas, an increase in sea levels which may result in loss of infrastructure and natural resources, increased degradation of Amazon rain forest that could be a net contributor to the warming of the planets and a potential hotspot for future pandemics. At the same time, countries in this region lead the way to low-carbon development, exploring it as an opportunity to increase the long-term well-being of their citizens[11].

The American region (including North Central and South America) witnessed a solar PV capacity addition of 32 GW in 2022, an 8% increase compared with the preceding year's 29.7 GW capacity addition, to attain a cumulative solar PV installation of 164.4 GW in 2022. The top five countries in the cumulative solar PV installations are accountable for 96% of the total installations in the continent. The USA, being the dominating country, added 17.6 GW of solar PV in 2022, followed by Brazil (9.8 GW), Chile (1.8 GW), Mexico (1.2 GW), and Canada (0.7 GW). However, countries such as the USA, Mexico and Canada have seen a decrease in solar PV capacity addition compared to 2021.

9 The State of Climate Ambition June 2022.
10 Statistical Review of World Energy 2023, Energy Institute
11 Global climate promise, UNDP

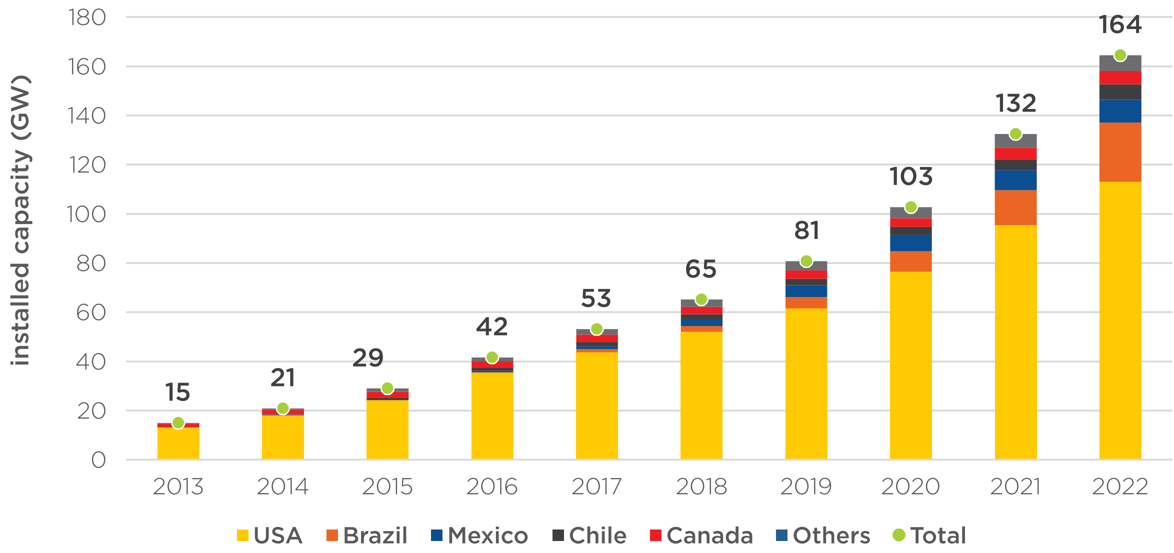


Figure 11: Solar installed capacity trends with 5 largest capacity countries in America[13]
Source: IRENA RE Statistics 2023

- The USA has installed 113 GW of solar PV as of 2022, 69% of the total installations in the region of America, with a CAGR of 21% from 2017 to 2022. The US set goals to achieve an economy-wide target of reducing its net greenhouse gas emissions by 50-52% below 2005 levels in 2030 and to reach 100% carbon pollution-free electricity by 2035[13].

- Brazil has increased the total solar PV installation significantly to reach 24 GW (15% of total installed capacity in America) in 2022 from 1.2 GW in 2017, with a remarkable CAGR of 82%. Brazil intends to reduce its greenhouse gas emissions by 2030 by 50% and commits to include 45% renewables in the energy mix by 2030[14].

- Mexico installed 9.3 GW of solar PV as of 2022, a share of 6% in the total installed capacity, with a CAGR of 53% from 2017 to 2022. Nevertheless, the addition of solar PV was at its peak in 2019 and observed a significant reduction in the succeeding years. In the updated NDC, Mexico framed mitigation targets, aiming for a 35% reduction in GHG emissions and the country plans to increase the clean energy production to 40 GW by 2030[15].

- The installed capacity of Chile hit 6.2 GW (4% share of total installed capacity in America) in 2022 with an annual growth rate of 28% from 2017, a 40% increase as compared with 2021. Chile set a mitigation target to reduce total black carbon emissions by at least 25% by 2030, with respect to 2016 levels and to include 20% non-conventional renewables in the energy mix by 2025[16].

- Canada accounted for a 3% share of solar PV in America and reached an installed capacity of 5.3 GW in 2022 with a minimum CAGR of 13% among the top five countries. As per the NDC, Canada has made plans to reduce GHG emissions by 40-45% below 2005 levels by 2030.

12 IRENA- Renewable Energy Statistics 2023
13 The United States of America Nationally Determined Contribution
14 NDC, Federative Republic of Brazil
15 Mexico-Climate Promise, UNDP
16 Chile's Nationally Determined Contributions Update 2020.

3.4 Africa

Africa is a region of great complexity, endowed with natural capital and biodiversity, and home to 1.13 billion people, one-third of the world's languages, and a rich and diverse culture. However, it is also plagued by conflict and other crises, which hinder basic activities such as food production, local economic development, and healthcare access. Of the 46 countries in sub-Saharan Africa, 32 are classified as Least Developed Countries (LDCs), six as Small Island Developing States (SIDS), and 33 as fragile states. As per the UNDP's Climate Promise report, published in July 2022, 40 out of the total 55 countries in Africa have submitted NDCs, with 5 more expected to submit. Of these, 44 are supported under the UNDP's Climate Promise and are on their way to submit second-generation NDCs, with 39 countries already having submitted them and 4 more expected to submit before the COP 28.

Access to electricity is a significant challenge in many parts of Africa. According to the IEA world energy outlook 2023, today there are around 600 million people without access to electricity in Africa and they constitute around 80% of the global population without access, most of them in sub-Saharan Africa. Political leaders are prioritizing renewable energy developments to improve energy access and electrification rates, particularly in remote and underserved areas. Renewable energy sources offer decentralized, off-grid solutions to bridge the energy gap, and Africa is experiencing significant growth in renewable energy installations, with solar photovoltaic (PV) projects, wind farms, and small-scale hydropower installations becoming more common. Off-grid solar solutions, such as solar home systems and mini-grids, also play a vital role in electrifying rural communities.

In 2022, Africa installed a total of 870 MW of new solar PV capacity additions, representing a ~10% increase from the previous year's 797 MW. In the African region, the leaders in terms of total solar installed capacity are South Africa, Egypt, Morocco, Algeria, and Kenya collectively boasting an impressive 9671 MW capacity, contributing to 77% of the total installed solar capacity on the continent[17].

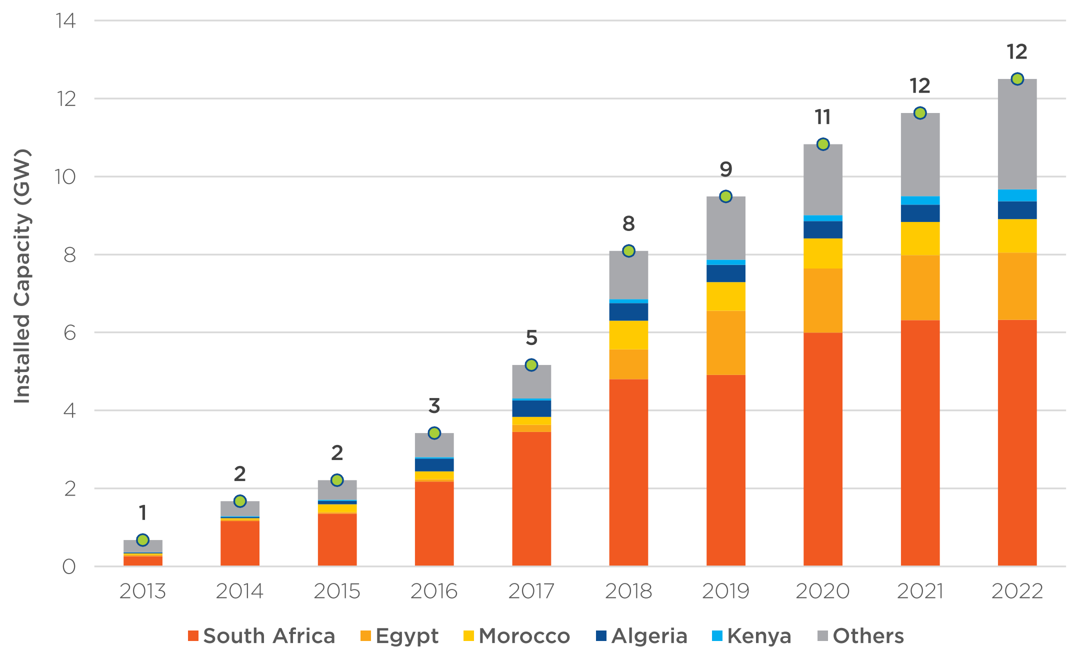


Figure 12: Solar installed capacity trends with 5 largest capacity countries in Africa

Source: IRENA RE Statistics 2023

17 IRENA (2023). "Renewable Energy Statistics 2023"

- South Africa has an installed capacity of ~6.2 GW, which is almost 50% of the current installed capacity for solar in Africa and has grown at a CAGR of 13% from 2017 to 2022. The country has set a RE target of 18 GW by 2030, where solar is expected to make up the majority share.

- Egypt has made remarkable progress, increasing its total installed solar PV capacity from 180 MW in 2017 to 1,724 MW in 2022, representing a compound annual growth rate (CAGR) of ~57%. The country has set an ambitious goal of reaching a 42% contribution of renewable energy capacity to its electric power supply by 2035, as outlined in the country's energy strategy document.

- Morocco has achieved a 6.8% share of the total installed solar PV capacity in Africa, reaching 854 MW capacity. Morocco has set its sights on a 52% share of renewable energy in its generation mix by 2030, with 20% coming from solar energy.

- Algeria holds a 3.7% share of the total installed capacity of solar PV in the African region. Its solar PV capacity has grown from 423 MW in 2017 to 460 MW in 2022, at a CAGR of 2%. Algeria aims to deploy solar photovoltaic, wind power, and thermal solar energy on a large scale by 2030.

- Kenya, contributing 2.5% to the total installed solar PV capacity in the African region, has seen impressive growth in its solar PV capacity, which has expanded from 46 MW in 2017 to 307 MW in 2022, at a CAGR of 46%.

3.5 Middle-East (MEA)

The Middle East comprises of 19 countries and is home to 394 million people, which includes four Least Developed Countries alongside several of the world's biggest oil and gas producers. The region is responsible for 7% of GHG emissions[18].

MEA also receives the highest solar radiation. Over the past decade, the region has increased its renewable energy capacity by a factor of ten. However, the temperature across the region is increasing faster than the global average. It is expected, that by 2100, the Middle East region could be affected by experiencing a 5^{0}C increase in average temperature above pre-industrial levels[19].

The Middle East has installed a total capacity of 13.4 GW of solar PV as of 2022 by adding 3.5 GW in 2022, a 55% increase in capacity addition compared with 2022. Countries with significant capacity additions in 2022 include Qatar (from 5 MW in 2021 to 805 MW in 2022) and Oman (from 155 MW in 2021 to 655 MW in 2022). However, Israel and UAE, the top two countries in the solar PV installed capacity, have experienced a reduction in capacity addition in 2022.

18 Statistical Review of World Energy 2023, Energy Institute
19 Global climate promise- Arab states, UNDP

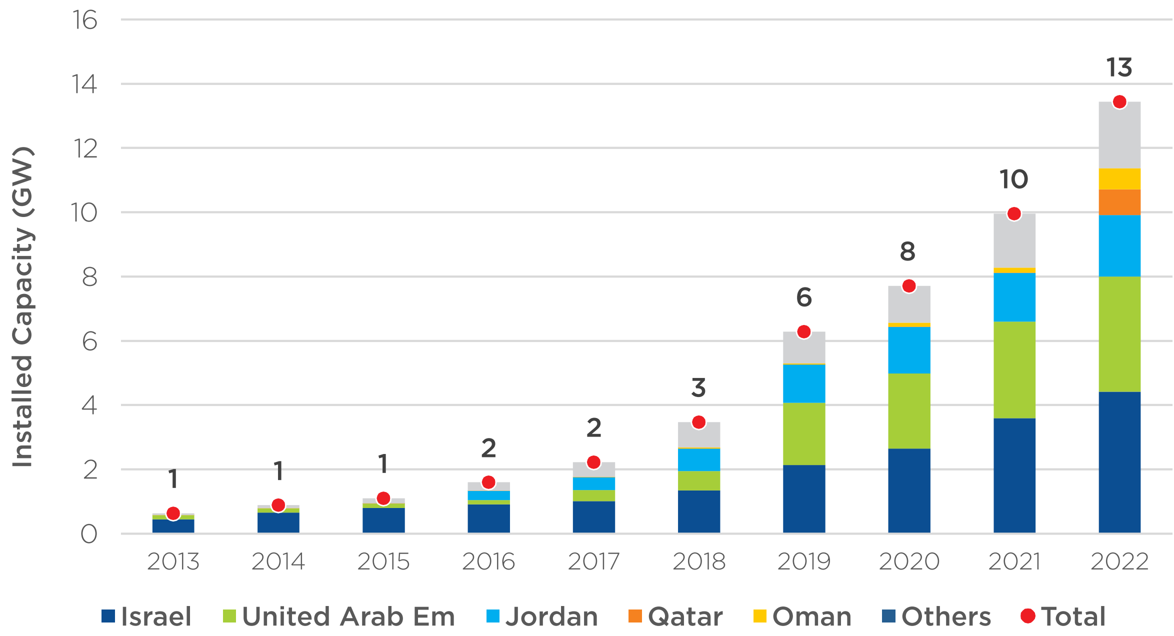


Figure 13: Solar installed capacity trends with 5 largest capacity countries in the Middle East

Source: IRENA RE Statistics 2023

- Israel installed 820 MW of solar PV in 2022 to reach a cumulative capacity of 4.4 GW, accounting for 33% of the installed capacity of solar PV in the Middle East region with a CARG of 34% from 2017 to 2022. The NDC of Israel includes a 27% unconditional absolute GHG emissions reduction by 2030 relative to 2015, supported by a target of 20% renewable energy share in 2025 and 30% in 2030[20].

- UAE contributes 27% of the total installed capacity of solar PV in MEA with a cumulative installed capacity of 3.6 GW as of 2022. The country observed an annual growth of 59% from 2017 to 2022 and an addition of 586 MW in 2022. As per the NDC submitted, the UAE is committed to achieving a 19% reduction by 2030 in economy-wide net GHG emissions, compared to 2019 levels aided by a plan to install 19.8 GW of clean energy sources (solar PV, concentrating solar-thermal power, and nuclear) by 2030[21].

20 Update of Israel's Nationally Determined Contribution under the Paris agreement, July 2021
21 Accelerating action towards a green inclusive and resilient economy- Third update of second NDC for the UAE, 2023

- Jordan increased the capacity of solar PV from 1.5 GW in 2021 to 1.9 GW in 2022, with a CAGR of 37% from 2017 to 2022. Jordan enhanced its commitment by raising its conditional greenhouse gas emissions reduction target to 31% by 2030 compared to Business-As-Usual (BAU). Renewable energy is expected to contribute 35% of electricity generation by the year 2030[22].

- Qatar, the country with the highest CAGR of 176% from 2017 to 2022, added 800 MW of solar PV in 2022 and reached a cumulative installed capacity of 805 MW. The State of Qatar set a target to reduce 25% of GHG emissions for the year 2030, relative to BAU. Furthermore, the country plans to transform renewable energy into a key driver for ecological and commercial benefits and promote decentralized renewable energy production[23].

- Oman increased the installed capacity of solar PV from 155 MW in 2021 to 655 MW in 2022, with an annual growth rate of 141% from 2017 to 2022. The country observed a significant increase in capacity addition from 26 MW in 2021 to 500 MW in 2022. Oman aims to slow GHG emission growth and reduce it by 7% in 2030, compared to the BAU scenario. In addition, the 2040 vision data published by Oman also set an ambitious target to raise the penetration of renewable energy in the energy mix to 20% in 2030 and up to 35-39% in 2040[24].

The countries across the world have made substantial progress in harnessing solar energy, highlighting their commitment to renewable energy and their role in the global transition toward cleaner and more sustainable energy sources.

22 Updated submission of Jordan's 1st Nationally Determined Contributions, 2021.
23 State of Qatar, Nationally Determined Contributions – 2023.
24 Sultanate of Oman, second Nationally Determined Contributions - 2021.

04
Barriers and Drivers to the adoption of Solar

The widespread adoption of solar energy is essential for addressing climate change and transitioning to a sustainable energy future. The adoption of solar energy on a global scale is driven by a combination of technological advancements, policy support, economic incentives, environmental imperatives, and societal awareness. These drivers collectively promote the growth of solar energy as a key component of sustainable energy systems. However, there are also several barriers that hinder its growth on a global scale. Addressing these barriers will not only improve the adoption of solar but will also help countries achieve their NDCs and emissions reduction targets through the rapid implementation of solar energy.

This section outlines the key barriers and drivers to the adoption of solar energy globally and also presents some recommendations categorized across various areas from investments to policy implementation.

4.1 Barriers and Challenges

Barriers can be categorized into technological, policy, economic, and social factors, each posing unique challenges to the expansion of solar energy[25,26].

Technological Barriers:

International power markets in the summer of 2023 have been at times afflicted by wholesale prices plummeting to negative levels. According to the IEA, the number of hours with power prices dropping below zero doubled in countries such as Germany and the Netherlands during the first half of 2023, relative to the same period in 2022. Other examples are California, which saw negative prices about 1% of the time and South Australia where wholesale electricity market prices were below zero almost 20% of the time in 2022.

25 International Energy Agency (IEA). (2020). "Renewables 2020: Analysis and Forecast to 2025."
26 Renewable and Sustainable Energy Reviews. (2019). "Barriers to the Adoption of Solar Energy: A Review."

This negative price phenomenon occurs when the grid experiences a 'congestion', which refers to a situation in which the grid cannot integrate the electricity produced by power plants. As a result, prices in wholesale power markets steeply decrease below zero and solar PV power plants have to temporarily shut down due to unexpectedly low or inexistant profit margins. Due to this 'economic curtailment', solar energy is wasted, especially during summer months. In addition, unaddressed volatility of energy prices and recurrent negative prices endanger investments in new solar PV assets.

To resolve this predicament, a massive push for flexibility measures is needed. In other words, heavily increasing the capacity to cover with dispatchable sources the potential intermittency of renewable energy sources. It comes in the form of more flexible operations, more flexible generation, stronger grids, more energy storage, demand response, hydrogen for renewable power, heat pumps, and faster uptake of electromobility.

Concerning power grids, traditional electricity networks were constructed to transport, distribute, and deliver electricity from centralized sources to end-consumers in a rather linear and inflexible fashion. The high penetration of variable and decentralized energy sources comes together with a set of technical challenges related to grids and the management of distributed power stations. With the incipient increase in power demand stemming from the electrification of the heating and transport sectors, grid capacity needs to be sizably reinforced, expanded both nationally and internationally, modernized, and digitalized.

Yet, several countries are already facing grid congestion problems, which cause delays in the development, commission, and entry into operation of solar projects. To avoid a scenario where grid constraints become the norm, governments and national transmission systems need to sizably increase the level of investments into grids and flexibility solutions such as energy storage to avoid existing limitations to exacerbate. The IEA's World Energy Investment Report 2023 highlighted that global investment on power grids has not yet significantly increased across the past years, relative to investments in renewable energy adoption. An insufficient increase of 8% was recorded in 2022, relative to 2021, but initial signs in 2023 reveal a flattening in spending efforts. The distribution of investments reveals that most of the spending is conducted by advanced economies and China, while investments into grids is rapidly falling in emerging and developing countries.

Massively promoting flexible resources, both on the demand side and the generation side is also fundamental. Hybrid solar projects coupling solar with energy storage or coupling solar and another complementary renewable energy source, such as wind offer an effective, flexible, and cost-efficient solution. When the sun does not shine, the wind blows, and when there is neither, storage serves as a flexible dispatchable source of power. Other grid-connected devices such as heat pumps, electric vehicles, home appliances and electrolysers can also enhance the flexibility of the electricity network. But also, flexibility is needed on the demand side, to shift energy consumption to off-peak hours by developing appropriate demand action plans including simple, non-market, price signals, such as the Time of Use grid tariffs or self-consumption schemes.

Lastly, boosting the diffusion of smart building technology. Energy renovation rates must be fast-tracked to digitalize buildings and make them increasingly responsive to grid price signals. Simultaneously, buildings should be equipped with battery storage or smart heat pumps to allow the increase of flexibility potential, and consumers should be allowed to limit the import or export of electricity at the grid connection point.

1. **Intermittency Management:** High-penetration countries often face challenges related to managing the intermittency of solar power. Solar generation varies with weather conditions and time of day, requiring advanced grid integration and energy storage solutions.

2. **Grid Upgrades and Inter-regional Transmission:** Extensive solar penetration can strain existing grids, necessitating substantial upgrades to accommodate the influx of intermittent energy. This includes investments in grid infrastructure, smart grid technologies, and grid-balancing measures such as load shifting, demand response, and time-of-use pricing to shift demand to solar hours.

3. **Storage Integration:** As solar penetration increases, the demand for effective energy storage solutions rises. Ensuring that grid-scale energy storage systems are seamlessly integrated with solar installations is essential to address the intermittency issue. Although energy storage is less critical in the initial stages of solar adoption, low-penetration countries should consider integrating storage technologies as they scale up their solar capacity.

4. **Advanced Forecasting:** High solar penetration countries require advanced weather forecasting and predictive analytics to manage and optimize solar power generation, ensuring grid stability and reliability.

5. **Electric Vehicle Charging Infrastructure:** High-penetration countries need robust EV charging infrastructure that can be powered by solar energy. With increased penetration of EVs, the need for solar energy as a clean power source becomes even more pronounced.

6. **Technical Skills and Expertise:** Building a skilled workforce capable of designing, installing, and maintaining solar installations is crucial. Low-penetration countries often lack the necessary technical skills and expertise.

7. **Resource Assessment:** Understanding solar potential and resource assessment is vital for low-penetration countries to make informed decisions about the feasibility and benefits of solar projects.

8. **Research and Development:** Investing in solar research and development is essential to improve technology, reduce costs, and adapt solar solutions to local conditions.

Policy and Regulatory Barriers:

1. **Subsidies and Incentives:** The availability and stability of government subsidies and incentives for solar installations vary widely across countries. Inconsistent policies can discourage investment and slow adoption.

2. **Regulatory Frameworks:** Developing and implementing the appropriate regulatory frameworks for solar energy is essential. Low-penetration countries may need to establish clear permitting processes, net metering policies, and quality standards.

3. **Net Metering and Grid Access:** Policies related to net metering and grid access can either support or hinder the growth of solar energy. Complicated regulations or unfavorable pricing structures can deter individuals and businesses from adopting solar.

4. **Trade Barriers:** Trade restrictions and tariffs on solar equipment and components can increase costs and limit market access for solar technologies. Resolving trade disputes and promoting international cooperation is essential.

5. **Default on PPAs:** Consumers defaulting on PPA payments poses a significantly high risk for the financial viability of the solar project. Regulations related to the imposition of high penalties on default are largely absent.

Economic and Financial Barriers:

1. **High Initial Costs:** The upfront costs of solar panel installation and equipment can be a barrier for individuals and businesses. Although prices have decreased over the years, financing options and incentives are crucial to making solar energy more accessible.

2. **Access to Financing:** Limited access to financing options, especially in developing countries, can hinder solar projects. Innovative financing models, such as solar leasing and power purchase agreements, can help address this challenge.

3. **Off taker Credibility:** The financial credibility of the off taker is vital to the success of PPAs for the utility-scale projects. Creditworthiness assessments and recuperations mechanisms should in place along with strict penalties for default. Usage of power purchase agreement (PPAs) as bankable documents should also be taken care of.

Social and Cultural Barriers:

Due to the societal nature of the incipient energy transformation, the acceptance of change is a fundamental component of the success of such metamorphosis. A wide array of social, economic, and environmental aspects of the solar revolution are under increasing scrutiny, and maintaining a positive social perception remains fundamental to the deployment of solar.

This covers a large set of factors starting from the very capacity of solar technologies to substitute fossil fuels and nuclear plants to meet future energy demands. But topics also cover the financial cost of solar, the opposition to utility-scale PV on the grounds of excessive land consumption, the existence of a synergic relationship between solar parks and natural ecosystems, the electricity production at night, the ability of solar to abate CO2 emissions, the availability of raw materials to secure solar technology supply, and many more.

All these factors may hinder and slow down the deployment of a multi-terawatt global solar fleet, and it majorly boils down to the concept of social acceptance by local communities. In particular, the global energy transition heightens the competition for land and its intended use. An especially pressing issue in countries with a high population density. The conundrum of NIMBYism (Not In My Backyard opposition) is present across any large-scale solar project, and within the energy sector, but is usually more associated with other energy generation technologies. At the same time, as solar is set to emerge as the primary source of electricity in many countries across the globe, societal acceptance towards solar technology must remain high.

Even today, there are cases of local communities disputing solar projects in their vicinities, despite fundamentally endorsing the expansion of renewable energy solutions. However, with solar being an energy technology that can be decentralized, a substantial part of the generation can take place on rooftops, car parks, traffic routes, public and commercial buildings, and which strongly alleviates the overall solar PV demand for land. Therefore, thanks to its versatility, solar is the technology with the highest acceptance rate in opinion surveys.

Additionally, the possibility of integrating solar into existing infrastructure by utilizing it as the shell of buildings (the so-called building integrated photovoltaics, BIPV) further minimizes its visual impact. Options range

from solar tiles to roofs, windows, facades, and balconies. Nevertheless, these solutions still necessitate the proactive participation of households and building owners. Preserving a high societal acceptance by effectively communicating the benefits of solar PV is an imperative task in the solar revolution.

While the deployment of rooftop solar is not contingent on a strong social acceptance, the construction of ground-mounted solar projects can face sizable opposition from local communities. It includes concerns over distributional justice (a fair sharing of costs and benefits) and trust among local stakeholders. Directly addressing these concerns and transferring the positive impacts of solar to local communities is critical to secure a just and equitable solar transformation.

Nevertheless, the strongest opposition is commonly related to space utilization by ground-mounted solar projects, even though research proves that large-scale solar PV can be deployed without any significant conflicts with agriculture or nature conservation and that large solar parks have lower land use impacts than other energy generation technologies[27]. When comparing land transformation and occupation requirements within the complete project life-cycle – material sourcing, manufacturing, transport, utilization, and end-of-life management – solar technology requires the least amount of land among renewable energy options. In addition, large-scale PV in areas of high solar irradiance also presents lower land requirements when weighed against some traditional energy sources such as coal, if impacts of surface mining such as mountain-top-removal practices are considered.

In terms of preoccupations with biodiversity and ecosystem conservation, implementing best industry practices can turn ground-mounted solar parks into sanctuaries for fauna and flora to thrive. The literature reveals that the solar plant's shading effect can create positive impacts on microclimates, resulting in greater vegetation growth and higher species diversity[28]. Involving environmental experts at an early stage allows developers to factor in all environmental aspects of an installation and enables the ability to create on-site symbiotic relations between solar PV and wild species of plants and animals. Against this background,

27 Fthenakis, V., KIM, H.C., (2009), Land use and electricity generation: A life-cycle analysis, Renewable and Sustainable Energy Reviews., 13 (6–7), pp. 1465-1474.

28 Armstrong A., and al (2016), Solar Park microclimate and vegetation management effects on grassland carbon cycling, Environmental Research Letters, Volume 11, Number 7, DOI 10.1088/1748-9326/11/7/074016.

an appropriate choice of land for the solar park by project developers can be supported by government actions to identify and allocate the most suitable land types for such projects.

It is therefore paramount to rightly design and build large-scale solar plants to minimize competition for land and enable additional value creation on top of green electricity generation. For instance, integrated technological applications such as Agri-PV and Floating-PV present a compelling response to this predicament. Both solutions make intelligent use of space and can diversify income streams for farmers and landowners. PV panels offer a buffering effect to agricultural production facing extreme climatic events and can create optimal conditions for enhanced productivity. Numerous studies have shown that shading by PV panels decreases drought stress on plants, increases food and biomass production, reduces heat stress and protects plants against severe weather events. A wide set of benefits arises in artificial water bodies too: less water evaporation, increased efficiency of solar panels due to the cooling effect of water, synergies with hydro-power facilities, creation of new habitats under the Floating-PV platforms, reduced albedo effects in water bodies, and more.

1. **Awareness and Education:** A lack of awareness and understanding of solar energy's benefits and potential can impede adoption. Education and outreach efforts are essential to inform communities and dispel myths about solar power.

2. **Aesthetic Concerns:** Some individuals may resist solar installations due to aesthetic concerns, such as the appearance of solar panels on rooftops. Advancements in design and aesthetics can mitigate this barrier.

3. **Permitting and Local Regulations:** Lengthy and complex permitting processes, along with local regulations, can deter potential solar adopters. Streamlining these processes and offering standardized guidelines can facilitate growth.

4. **Cultural and Social Norms:** Cultural attitudes and social norms related to energy use and sustainability can influence the acceptance of solar energy. Promoting a cultural shift toward clean energy is a gradual but essential process.

Fossil fuel subsidies:

Prices for fossil fuels were strikingly high and volatile in 2022 as energy markets wrestled against the enormous hit caused by the Russian invasion of Ukraine, and the remnants of the COVID-19 pandemic. This tension in energy markets was even more prominent in Europe and other regions as Russia sharply reduced natural gas deliveries, causing energy prices to soar. In countries where the impact was profound, emergency aid packages were rolled out to shield consumers from astronomical prices, at the damaging expense of artificially maintaining fossil fuel market competitiveness against low-carbon and cheap alternatives. The IEA calculates that more than USD 500 billion were spent to lower energy bills in 2022, mainly in advanced economies, with around USD 350 billion of this in Europe[29].

Therefore, and even though the renewable uptake in 2022 was immense, the provision of explicit or implicit subsidies to hydrocarbons wind down the pace of the energy transition as the economic incentive to replace fossil technologies with renewables diminishes. It also comes at a fiscal burden for many countries: firstly, as a financial cost, considering that fossil fuel industries benefit from taxpayers' money; and secondly, as a societal cost, resulting from the burning of fossil fuels and the resulting release of greenhouse gas emissions which impose negative externalities (e.g. air pollution leading to higher public health spending) on society and the environment. Fossil fuel emissions are generally not priced and consequently not internalized by polluters, which enjoy as a result an indirect subsidy in the market. This further unrealistically maintains hydrocarbon prices low. It is also important to highlight that

29 IEA (2023), Fossil Fuels Consumption Subsidies 2022, IEA, Paris https://www.iea.org/reports/fossil-fuels-consumption-subsidies-2022, License: CC BY 4.0

low-carbon and cost-efficient technologies have a deflationary impact on energy prices in the long term, while subsidies to fossil fuels are only further driving prices up.

In other words, fossil fuel subsidies distort the efficient allocation of resources, which could be otherwise diverted to sustainable solutions that increase social and environmental welfare. The IEA estimates that explicit worldwide subsidies (undercharging for supply costs) to fossil fuel companies swelled to USD 1.4 trillion in 2022, by far the largest annual value ever witnessed. In comparison, fossil fuel subsidies in 2020 amounted to slightly more than USD 200 billion and had been on a three-year decline since 2018 (nearly USD 600 billion that year). According to the agency, this explicit subsidy amount is expected to fall over the years, if fuel prices recede in international markets, and temporary price support measures are eliminated. In terms of implicit subsidies (undercharging for environmental costs and forgone consumption taxes), the International Monetary Fund estimates a total of USD 5.7 trillion in 2022[30]. Therefore, global fossil fuel subsidies amounted to USD 7 trillion in 2022, which is equivalent to approximately 7.1% of world gross domestic product (GDP).

Nigeria's bold move to eliminate fossil-fuel subsidies

Solar power in Nigeria is currently experiencing a significant turning point. Despite being known as the epitome of neo-colonialism in Africa and the largest crude oil producer on the continent, Nigeria surprisingly lacks its own refineries. As a result, Nigerians have been burdened with exorbitant prices for gasoline and diesel fuel, which are imported from first world countries. To alleviate some of the financial strain caused by high fuel prices, the government has been providing subsidies for over three decades to keep pump prices low. However, these subsidies have been costing the government a staggering $522 million per month, amounting to $9.7 billion in 2022 alone for imported gasoline subsidies.

Upon assuming office in May 2023, Nigeria's new president, Bola Tinubu, made the bold decision to eliminate these subsidies. Consequently, the prices of gasoline and diesel skyrocketed by 175% overnight, causing significant disruptions to the nation's economy, particularly for a country heavily reliant on portable generators. Since then, prices have continued to rise.

In the wake of the government's decision to end fossil fuel subsidies, energy researchers at BloombergNEF promptly revised their projections. They now anticipate Nigeria to achieve a solar capacity of 1.6 gigawatts within a year, which is three times higher than their previous forecast.

Lagos, Nigeria's largest cities, has devised a comprehensive plan to ensure reliable electricity for all its residents by the end of 2036. This strategy hinges on the establishment of a localized electricity market that caters exclusively to the city, rather than relying solely on the national grid. Despite this, Lagos still intends to incorporate an off-grid component as part of its energy mix. Additionally, the city aspires to phase out fossil fuel generators, thereby bringing Nigeria closer to its ambitious goal of achieving carbon neutrality by 2060.

Source: https://cleantechnica.com/2023/11/08/nigeria-has-ended-fossil-fuel-subsidies-giving-solar-power-a-boost/

30 Black, S., and al. (2023), IMF Fossil Fuel Subsidies Data: 2023 update, Working Paper No. 2023/169.

With renewable electricity being much cheaper than fossil fuel power in many countries across the world today, the economic disadvantage of fossil fuel subsidies becomes evident. Consequently, this represents an opportunity to redirect investments and public spending to accelerate the advancement of renewables.

Addressing these barriers requires a collaborative effort involving governments, industry stakeholders, and civil society to create an enabling environment for solar energy adoption.

4.2 Drivers to the adoption of Solar

The primary drivers can be categorized into technological advancements, social awareness, policy support and economic and environmental benefits[1,31].

Technological Advancements:

1. **Improvements in Solar Technology:** Advances in solar panel efficiency, durability, and affordability have significantly boosted the attractiveness of solar energy as a viable and cost-effective energy source.
2. **Energy Storage Solutions:** Innovations in energy storage technologies, such as lithium-ion batteries and emerging alternatives, enable the efficient capture and utilization of solar power, making it a more reliable energy source.
3. **Smart Grids:** The development of smart grids allows for the seamless integration of solar power into existing energy infrastructure, enhancing grid stability and enabling more efficient energy distribution.

Policy Support:

1. **Feed-in Tariffs and Incentive Programs:** Many governments offer feed-in tariffs and financial incentives to promote solar energy adoption. These programs provide financial rewards to solar power producers, making solar installations more economically viable.
2. **Renewable Portfolio Standards (RPS):** Mandates requiring a certain percentage of a region's energy to come from renewable sources, including solar, encourage utilities to invest in solar energy generation.
3. **Net Metering:** Net metering policies allow individuals and businesses to sell excess solar-generated electricity back to the grid, offsetting energy costs and incentivizing solar installations.
4. **Tax Credits and Rebates:** Tax credits and rebates for solar installations lower the initial investment required, making solar energy more accessible.

Economic Benefits:

1. **Reduced Dependence on Fossil Fuels:** Solar energy reduces a nation's reliance on fossil fuels, enhancing energy security by diversifying the energy mix and reducing exposure to fossil fuel price fluctuations.

1. **Falling Solar Costs:** The decreasing cost of solar panels and equipment has made solar energy more competitive with conventional energy sources in many regions.

2. **Job Creation:** The solar industry is a significant source of employment, from manufacturing to installation and maintenance, contributing to local and national economies.

31 Renewable Energy Policy Network for the 21st Century (REN21). (2023). "Renewables 2023 Global Status Report."

Environmental Imperatives:

1. **Climate Change Mitigation:** The urgent need to reduce greenhouse gas emissions and combat climate change has driven the adoption of clean and renewable energy sources like solar.

2. **Air Quality Improvement:** Solar energy generation produces zero emissions, contributing to improved air quality and reduced health risks associated with pollution from fossil fuels.

Societal Awareness and Preferences:

1. **Environmental Awareness:** Growing awareness of environmental issues and a desire to reduce carbon footprints motivate individuals and organizations to adopt clean energy solutions.

2. **Consumer Demand:** Increasing consumer demand for clean and sustainable products and services has led to greater interest in solar energy.

3. **Corporate Sustainability:** Many businesses adopt solar energy as part of their sustainability initiatives and to meet corporate social responsibility goals.

4. **Local Energy Resilience:** Solar energy systems, especially in combination with energy storage, offer communities greater energy resilience during power outages and disasters.

5. **Energy Independence:** Solar energy empowers individuals and communities to generate their electricity, reducing dependence on centralized energy providers.

Moreover, the investments in the development of low carbon energy have proven to be a crucial driver as they have surpassed the investments in fossil fuels on a global scale this year. According to the International Energy Agency, clean energy is projected to receive a substantial investment of USD1.8 trillion in 2023, while coal, gas, and oil will receive USD1 trillion. Despite this shift in investment, the overall composition of energy sources used for electricity generation has not been significantly impacted.

In conclusion, the adoption of solar energy globally is driven by a synergy of technological progress, supportive policies, economic benefits, environmental considerations, energy security, societal preferences, and investments in the technology development. These drivers collectively contribute to the expansion of solar energy as a clean and sustainable power source.

05 Recommendations

In the last decade solar emerged as a leader amongst various renewable technologies and has played a key role in aligning climate goals. Although, the pace of solar growth is not sufficient to meet the climate goals and fulfil the NDC commitments. To accelerate solar adoption and the fulfilment of NDCs, governments, industry stakeholders, and communities may adopt the following recommendations under some key themes:

A. To support the tripling of global RE capacity by 2030 and meet the net zero target, global annual installed solar PV capacity would need to double from the 226 GW[32] in 2022 to 600GW/year until 2030[33]. The following measures can be undertaken to achieve accelerated solar deployment

- **Enhance policy support** by creating strong, stable regulatory framework and long-term policies that support solar energy, such as feed-in tariffs, tax incentives, rebates, and renewable portfolio standards/obligations. **Green finance mechanisms** and incentives for solar projects, including green bonds and investment tax credits should also be developed.
- **Invest in grid infrastructure** to accommodate higher levels of solar energy and facilitate its integration into the energy grid. **Creating inter-regional linkages** between the existing grid networks can substantially help absorb the effects of intermittency as outlined in the **One Sun One World One Grid (OSOWOG) mission**. Additionally, solar mini-/micro-grids can be deployed to improve the energy resilience in remote areas.
- **Streamline permitting and approval processes** for solar project development need to reduce administrative barriers and lower costs.
- **Facilitate technology transfer and knowledge-sharing** among countries to promote solar energy adoption in regions with lower access to resources. **Provide financial assistance** and support to developing nations for solar **infrastructure development and capacity building**.
- Industries could also participate by committing to **carbon neutrality targets** that include solar energy as a central component of the strategy.

32 BNEF Data
33 ISA World Solar Technology Report 2023

B. Moving towards the tripling of global RE capacity by 2030, annual investments in solar are expected to increase to ~$505 billion in 2030, from the current levels of ~ $300 billion, and may cumulatively increase to of ~$10 trillion by 2050. Innovative financing tools and business models will further unlock investments in solar.

- **Investments in renewable energy hit an all-time high in 2022** having crossed $590 billion, with solar energy attracting the majority investments at 52% of renewables. Having said that the investments are **insufficient to meet the set climate goals** and need to be increased significantly to tackle global climate change and accelerate clean energy transition.

- Moreover, these **investments are highly skewed in favour of advanced economies** that lie in the regions of Asia Pacific, Europe, and North America. The two regions i.e., Asia Pacific, and Europe and North America, accounted for 55% and 33% of global solar project development investment respectively in 2022. China alone witnessed investment worth $164 billion in solar projects. On the other hand, **developing regions of the Middle East, Africa, Latin America, and the Caribbean continue to lag** in the race for solar adoption. For more inclusive energy transition, **investments need to be more universal**.

- Between 2018 and 2022, solar capacity additions have seen an average growth rate of 21% while **solar investment has seen an average growth rate of 15%, lagging way behind the target growth rates required to meet net zero by 2050**. Along with the urgent need to guarantee an exponential increase in solar capacity expansion, it's also important to ensure that the solar industry expands equitably, particularly in regions with the highest rates of energy poverty.

- **Private finance has been a major contributor** to solar energy projects, accounting for more than **80% of the total investments between 2015 and 2022**, whereas the public sector contributed to the remaining investments. Though public finance has helped create an **enabling environment for private investors in solar space**, more needs to be done to facilitate the uptake of solar in underdeveloped and developing regions.

- **Fossil fuel subsidies distort the efficient allocation of resources**, which could be **otherwise diverted to sustainable solutions** that increase social and environmental welfare. The IEA estimates that explicit worldwide subsidies to fossil fuel companies swelled to **USD 1.4 trillion in 2022**, by far the largest annual value ever witnessed. In comparison, fossil fuel subsidies in 2020 amounted to slightly more than USD 200 billion and had been on a three-year decline since 2018. In terms of implicit subsidies, the International Monetary Fund estimates a total of USD 5.7 trillion in 2022, taking the global fossil fuel subsidies to USD 7 trillion in 2022 (~7.1% of world GDP). With solar electricity being much cheaper than that from fossil fuels in many countries, **investments and public spending may be redirected towards the development of RE sources**.

- Ramping up investments requires new and innovative financing options. Innovation finance is an expression of two main trends in international development: increased focus on programs that deliver results and a desire to support cross-sectoral collaboration. This requires mutually reinforcing efforts by governments, financial institutions, and public and private investors.

- **ISA's Global Solar Facility** is one such innovative example that aims to catalyze solar **investments in Africa's underserved segments** and geographies, thereby unlocking commercial capital in the solar energy space. The Global Solar Facility is intended to promote high-potential solar technologies by **attracting private capital** into underserved African markets **while providing a payment and insurance mechanism as a first-loss guarantee**. The facility consists of three components to stimulate solar investment: Solar Payment Guarantee Fund, Solar Insurance Fund, and Solar Investment Fund. This facility can be further augmented to increase the on-ground impact.

C. Only 19% of the total 195 Parties have quantified solar capacity targets mentioned in the NDCs. Encouraging countries to have solar specific NDCs may accelerate solar adoption and help in meeting climate goals

- **Countries need to align policies with their NDC targets** to assure domestic stakeholders of their intentions to achieve the NDC targets. NDC fulfilment can be on track with the policy and regulatory support of the government. E.g., Indian government has supported the 500 GW RE target with appropriate policy push for solar, wind, energy storage, etc. through incentives, subsidies, and promotion of domestic manufacturing.
- **Standard NDC format may be developed** to have uniformity across all countries the NDCs could also be specific to technologies such as solar, wind, etc. rather than clubbing all sources together. This may help in accelerating adoption of specific technologies, and the tracking and monitoring of NDC's progress. The same has also been highlighted by several stakeholders in the Global Climate Stock Take Stakeholder consultations.
- **Guarantees are essential to at least private sector investment** in geographies that are seen as medium risk investment opportunities.
- **Grants, interest-rate subventions, and capital cost subsidies will enable solar investments** (and thus create a policy and capacity demand) in geographies seem like high-risk investment opportunities.
-
- Along with the standard NDC format, **the agency** within each country that is **responsible for submitting the biennial report** to the UNFCCC must **actively coordinate with the agencies responsible for the implementation and adaptation actions on ground**. Incorporating a standard NDC format will ensure a cohesive NDC update submission for the coordinating agency and **will result in aligned actions of the multiple stakeholders** on ground.
- **Mandate including targets for dominant RE technologies in the NDCs** such as solar, wind, hydro, etc. based on the resource assessment studies of a country. Such measures could provide a targeted approach for a technology to develop in a country. International organizations working on specific technologies such as ISA, UNFCCC, UNDP, etc. could help countries design such RE technology specific NDCs.

D. Novel solar technologies such as TOPCon, HJT and Perovskite along with sector coupling applications such as energy storage and green hydrogen need to be rapidly deployed to meet climate goals

- Large demand for clean energy in the future necessitates an increase in conversion efficiencies of solar cells. **TOPCon and HJT technologies** are expected to be **ahead of PERC with an efficiency of 23.8% and 24% respectively in 2023**, and likely to observe a 13% increase in efficiencies in the next 10 years. Mono PERC may be overtaken by higher efficiency technologies such as TOPCon, HJT, and IBC if cost-effective manufacturing is achieved. Focus on **R&D for newer high-efficiency solar technologies** such as TOPCon, HJT, IBC etc. will help **drive down costs and improve efficiencies and stability.**

- Chinese solar manufacturing capacity has a share of 86% of the global installed capacity and has grown ninefold since 2012. Therefore, **countries must promote domestic manufacturing** of solar components **to diversify supply chains and reduce trade dependence**, along with solar applications in agriculture, such as solar-powered irrigation and cooling systems, to enhance food security and rural development.
- **Integrating solar panels** in vehicles, building facades, or via agrovoltaics, enables **proper utilization** of the land space available. **Coupling of solar with energy storage technologies** such as batteries, pumped hydro and green hydrogen **improve the availability of solar energy** for round-the-clock supply to be used across various sectors.
- Research across materials science, module design, systems reliability, product integration, and manufacturing will be required to pave the way to multi-TW-scale PV deployment.
- **CSP** also provides a new prospect for the utilization of solar energy because of its **integration with existing coal plants for its ability to provide both heat and power**. Moreover, coal plants can be repurposed with CSP with fewer architectural changes in the existing coal power plants.

E. Tripling RE capacity provides opportunity for ~10 million of additional jobs; Enhancing education, training, and capacity building programs is the key to meet the agenda.

- Align workforce planning among all stakeholders, including labour agencies, labour unions, the wider solar industry, and educational institutions, to identify critical skill gaps and workforce needs in advance, and to design skill-building strategies accordingly.
- Ensure solar targets are reflected in educational programmes and resources, such as university curricula, vocational training institutions, occupational health and safety training institutions, and professional education programmes. ISA already has such initiatives in place such as the solar training programs, fellowships, STAR Centres, and the SolarX Challenge. These initiatives can be scaled up to improve their reach and impact.

- Invest in reskilling and upskilling measures for vulnerable communities and those in fossil fuel industries to ensure the employment benefits of the transition are extended to a wide subset of the population. Such measures need to be embedded in broader regional economic revitalisation programmes and investments

Incorporating these recommendations into national and regional energy strategies can help accelerate the global transition to solar energy, reduce greenhouse gas emissions, and while helping countries upgrade and achieve their NDC targets.

06 Annexure

Summary of NDCs for Parties that mention "Solar" in their NDCs

Country	Value
Angola	Installation of large-scale solar power plants (PV) 104 MW; Installation of small-scale solar panels for industries and solar villages of 2 MW-187 MW capacity; Installation of 2000 solar streetlamps
Armenia	Achieve 1000 MW of solar capacity before 2030; Achieve green energy share of at least 15% in 2030 in power generation mix;
Australia	Bring down solar electricity generation cost to $15/MWh through large scale solar by 2030-2035
Bangladesh	Achieve 1000 MW of utility-scale solar power capacity
Barbados	Retrofitting 3,000 low-income homes with solar PV by 2030 under the Roofs to Reefs Program
Belize	Install 40 MW utility-scale solar power by 2025; 85% renewable energy by 2030 by through hydropower, solar, wind and biomass leading to 44 ktCO2e of avoided emissions; Implement an interconnection framework to facilitate distributed RE power generation by 2022;
Benin	Installation of solar PV farms with a total capacity of 95 MWp
Bhutan	Installation of 71.11 MW of utility scale solar and wind energy (Solar - 17.38 MW in Sephu, 30.73 MW in Shingkhar; Wind - 23 MW in Gaselo); Install roof mounted solar PV on 300 rural households; Installation of more than 50 Solar Water Heating Systems (SWHS) of 1000 liters per day (LPD) capacity at various public institutions
Burkina Faso	Installation of 20 MW of PV solar connected to the network every 10 years (beginning in 2015)
Burundi	Installation of 7.5MW of solar capacity (unconditional); 50 off-grid public institutions using photovoltaic solar energy (total 200kW) (unconditional); Installation of solar power systems at 48 centers, 40940 households, 455 health facilities, 454 schools; Production of 48 MW of PV panels by 2025;
Cambodia	25% of RE share in the power and energy mix by 2030;

Country	Value
Cape Verde	Installing additional 150 MW by 2030; Installation of 29 MW solar power plants at Santiago, Boa Vista, Sal, Sao Vicente, etc. between 2022-2025;
China	Installation of 100 GW solar by 2020
Comoros	Installation of 14 MW solar by 2020
Cuba	Installation of 5,000 solar pumping systems in livestock; Increase share of RE generation in the electricity generation by 2030; Installation of 833,333 units of solar heaters in the residential and industrial sectors;
Democratic Republic of the Congo	Increase the RE installed capacity to 42.7 MW in 2030 (solar, wind, geothermal)
Djibouti	Develop three solar power plants (250MW) by 2025
Egypt	Installing additional renewable energy (RE) capacities to reach electric power contribution target of 42% by 2035 as per Egypt's Integrated Sustainable Energy Strategy 2035; (40% RE share by 2030) Installation of rooftop PV panels for electricity generation, 5,300 solar water heaters, and expand the use of LED lighting in residential sector by 2030;
Eritrea	Installation of 60 MW of large, grid-scale solar PV systems; Installation of 40 MW of solar/diesel mini grids;
Eswatini	Increasing the share of RE to 50% in the electricity mix by 2030; Installation of 55.85 ME of solar by 2030; Achieving 100% access to clean modern energy for cooking at household-level by 2030; Replacing conventional geysers with 1000 solar water heaters by 2030;
Gambia	Emissions reduction by 2025: • 0.122 MtCO2e by Energy saving appliances; • 0.0785 MtCO2e through combined wind, solar PV and Hydro; • 0.019 MtCO2e by installing solar water heating facilities on public buildings;
Ghana	Achieve 150-250 MW of utility scale solar installed capacity; Increase solar lantern replacement to 2 million rural non-electrified households;
Grenada	Installation of 10 MW solar capacity;
Guinea	Installation of an additional 47 MW of solar and wind power;
Guinea-Bissau	Increase in the share of RE in the electricity mix to 58% by 2030 (of which hydro - 40%); Installation of 90 MW of RE capacity by 2030;
Laos	Installation of 1 GW of total solar and wind capacity;
Lesotho	Achieve 40 MW of solar power;
Liberia	Develop large solar PV plants with IPPs; Installation of 10 MW of solar PV capacity with an output of 2 GWh/year by 2025 to reduce 0.52 Gg CO2e;
Malawi	Installation of 50000 solar PV systems and 20,000 solar water heaters by 2030;
Mauritania	Reach a cumulative installed additive capacity of 30,000 solar kit/fireplace in 2030;

Country	Value
Morocco	Installation of 1000 MW each of MV- and LV-level grid connected solar power plants by 2030; Installation of 300,000 low-energy light bulbs, 300,000 m2 of solar water heaters; Extension of National Solar Plan to 2,000MW by 2030 from CSP and solar PV; Development of the solar thermal field to reach 1,700,000 m2 by 2030;
Mozambique	Installation of 50,000 solar PV or wind lighting systems; Installation of 5000 solar PV systems for pumping water for domestic, community or public use;
Myanmar	30% renewables in rural electrification (mini-hydro, biomass, solar, wind and solar mini-grid technologies)
Namibia	Installation of 45 MW of solar rooftop systems and 40 MW of large-scale soalr power plants; Installation of 20000 solar water heaters;
Nepal	Develop 600,000 solar home system; Develop 1,500 institutional solar power systems (solar PV and solar pumping systems); Achieve 2,100 MW of solar energy by 2030 with grid capacity arrangements; Achieve 15% of clean energy share in the total energy demand and expand clean energy generation to 1500 MW by 2030;
Nicaragua	Increase the RE share in electricity generation to 60% in 2030; Increase the energy matrix up to 65% with renewable energy sources by 2030 (conditional);
Niger	Achieve the following by 2030: • Solar PV, large grid: conditional: 402 MW • Solar PV, small, insulated grid: 100 MW • Solar/diesel mini grid: conditional: 24 MW • Efficient Street lighting: conditional: 140,000 lamps; unconditional: 70,000 lamps • Solar streetlights: conditional: 40,000 lamps; unconditional: 8,000 lamps • Solar LED lamps: conditional: 71,000 lamps; unconditional: 40,000 lamps
North Korea	Installation of 1000 MW grid connected solar PV systems;
Oman	Target to derive 20% of electricity from renewables by 2027 in the National Energy Strategy; Installation of 2660 MW of RE by 2027; (79% solar, 21% wind)
Palestine	Generation of 20%-33% of electricity using solar PV b y 2040;
Republic of Congo	Achieve the following by 2030: • 1 MW of large solar PV; 450 solar/diesel mini grids (40 kW solar); • 100 residential solar water heaters; 400 solar home PV systems (400 W); 275 solar cottage PV systems (50 W); 8000 solar street lights;
Rwanda	Installation of 68 MWp of solar mini-grids in off-grid rural areas by 2030, according to the Rural Electrification Strategy;
Saint Kitts and Nevis	Installation of 35.7 MW of utility-scale solar PV capacity by 2030; Installation of 2x0.75 MW solar PV systems for desalination plants; Achieve 5% reduction in power demand by 2030 through solar water heaters;
Sao Tome and Principe	Achieve share of 13% Solar PV in the national electricity system through the installation of solar (32.4 MW), hydroelectric (14 MW) and biomass (2.5 MW);
Saudi Arabia	Achieve 50% if RE share in the energy mix by 2030; Building one of the world's largest green hydrogen facilities (Green Hydrogen - 650 tons/day, Green Ammonia - 1.2 million tons/year) at NEOM powered by 4 GW of RE (solar and wind);

Country	Value
Senegal	Achievement of an additional installed solar capacity of 100 MW, 100 MW in wind power, 50 MW biomass, 50 MW of CSP, by 2030 (conditional); Achievement of a cumulative installed solar capacity of 235 MW, 150MW in wind power, 314 MW in hydroelectricity in 2030 (unconditional);
Seychelles	Achieve 80% solar water heating for households by 2035
Sierra Leone	Improve energy efficiency; Increase access to grid connections by 42% in 2025; Increase share of off grid mini-grid and solar stand-alone systems by 27% and 10% respectively in 2030;
Singapore	Achieve at least 2 GWp of solar installed capacity by 2030, contributing to ~3% of the total electricity demand by 2030;
Sri Lanka	Establishment of 115 MW of solar power plants
Sudan	Establish 2140 MW of utility scale grid connected Solar and wind power plants of which 1000 MW on- and off- grid solar PV energy; 1000 MW grid connected CSP plants; 1.1 million Solar Home Systems by 2030;
Turkey	Reach 10 GW solar electricity generation capacity by 2030;
Togo	Electrify 555,000 households per Solar Kits by 2030, i.e. up to 85 MW of installed solar generation capacity in 2030
Tonga	Achieve 70% of RE share in the electricity generation by 2030 through solar, wind, and battery storage;
Tunisia	Triple the solar water heater distribution rate (220 m^2 of collectors per 1,000 inhabitants in 2030)
United Arab Emirates	Achieve installed clean power capacity, including solar and nuclear, of 14 GW by 2030 (~9 GW of solar); Achieve 54% reduction in total emissions of electricity generation through clean energy by 2030; Increase in the clean energy share to 50% of the installed power capacity mix by 2050 (30% target in 2030); Reduction of final energy demand by 40% by 2050 relative to BAU in 2050; (National Energy Strategy 2050)
Uruguay	Achieve 220 MW of installed solar power by 2025; 100 MW of solar water heaters for industrial/residential users;
Uzbekistan	Achieve 25% RE share of the total power generation by 2030 through 5 GW of solar, 3 GW of wind and 1.9 GW of hydropower plants;
Vanuatu	Install 10 MW grid connected solar PV by 2025; Adding 10 MW grid connected solar PV by 2030;
Yemen	Electrified Solar Home Systems in 110,000 rural household until 2025 (installed capacity around 5.5 MWp);
Zimbabwe	Increase the solar installed capacity to 300 MW by 2025;

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