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LOW-COST FINANCE FOR THE ENERGY TRANSITION

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

LOW-COST FINANCE FOR THE ENERGY TRANSITION

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FOREWORD

The global energy transition has reached a critical juncture, at which the deployment of technologies such as green hydrogen, energy storage and offshore wind need to be scaled up rapidly; yet rising interest rates are increasing the cost of capital for project financing, highlighting the profound importance of low-cost finance to the success of the transition.

Over the past decade, the world has witnessed the accelerating development and deployment of solar photovoltaic (PV) and onshore wind technologies, the associated costs of which have declined dramatically - by 88% for utility-scale solar PV and 68% for onshore wind - according to IRENA's *Renewable power generation costs in 2021* report.

Whilst sustained policy support, ongoing technology maturation and innovation, new business models and manufacturing capacity throughout supply chains have contributed to this achievement, the cost of capital has played an integral role in the increasing competitiveness of solar PV and onshore wind. According to IRENA's *World Energy Transition Outlook*, USD 150 trillion in cumulative investments will be required by 2050 to scale up renewable power generation, electrify end-use sectors and deploy the technologies required to meet the 1.5°C target of the Paris Agreement.

The financial resources allocated by the public sector to support the transition are inherently limited, and much of the overall investment required will need to be mobilised from the private sector, including from national and international financial institutions. The active engagement of the private sector in the journey to net-zero is therefore vital, particularly in providing low-cost capital to finance energy transition projects in a time of tightening monetary policy.

This report, prepared by IRENA in conjunction with India's G20 Presidency and in close collaboration with the Ministry of New and Renewable Energy (MNRE) of India, offers valuable insights concerning access to low-cost finance for the energy transition and the deployment of critical technologies in particular. The recommendations in this report provide the foundations of a tool box for enhancing collaboration among stakeholders, with the aim of financing energy transition projects with low-cost capital in G20 countries and beyond.

Francesco La Camera
Director-General, IRENA

FOREWORD

India is a global energy transition leader, with major renewable energy deployments and ambitious long-term goals, that has achieved significant progress in making renewable energy and energy efficiency measures more accessible and affordable. India aims to reach about 50% of cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, reflecting both its commitment to the 2015 Paris Agreement and its stated ambition to reach net-zero emissions by 2070.

The energy transition is one of the key priorities for India's G20 Presidency under its theme, *Vasudhaiva Kutumbakam* (one Earth, one family, one future). A core component of this priority is low-cost finance for the transition that will support the development of new and emerging energy technologies - particularly in developing countries.

This report, developed by IRENA in collaboration with the Ministry of New and Renewable Energy (MNRE) under the Energy Transition Working Group of India's G20 Presidency, highlights the importance of low-cost finance in driving the deployment of critical technologies such as hydrogen, offshore wind and energy storage. While solar PV and onshore wind are mature technologies, markets for offshore wind are now opening up in emerging economies, including India. Access to low-cost capital will therefore play a significant role in financing energy transition projects for G20 countries and beyond, while collaboration between public and private sectors will help to catalyse institutional capital flows.

This report indicates that to achieve the 1.5°C climate goal of the Paris Agreement, the overall share of renewable energy in the primary energy mix will need to rise to as much as 75%, requiring an annual investment of over USD 4.4 trillion. To enable an energy system aligned with the 1.5°C target, investment in energy transition technologies needs to scale up considerably, complemented by a simultaneous redirection of investment away from fossil fuels. The bulk of investment will need to focus on renewable energy, energy efficiency, electrification and enabling infrastructure.

Mapping and understanding the drivers behind financing costs and conditions are crucial to gaining insights regarding differences by technology and country. Understanding which markets and technologies are exposed to higher costs of capital allows stakeholders to identify where problems might arise and investigate what is driving higher costs in different markets and for different technologies.

India is at a vital juncture in shaping its future energy system and is strongly engaged in the global energy transition. I am confident that the combined efforts of IRENA, MNRE and other stakeholders will make a positive contribution to long-term planning for the energy sector in India, and hope that this report under India's G20 Presidency will help in fostering a new phase of co-operation to further the global energy transition agenda.

Bhupinder S. Bhalla
Secretary, Ministry of New and Renewable Energy, Republic of India

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AEL	alkaline
BECCS	bioenergy with carbon capture
BNDES	Brazil Economic Development Bank
BoS	balance of system
CAMMESA	Argentine Wholesale Electricity Market Clearing Company
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CfDs	contracts-for-difference
CFPP	coal-fired power plant
CICERO	Centre for International Climate Research
CO_2	carbon dioxide
CoC	cost of capital
CPI	Climate Policy Initiative
CSP	concentrating solar power
DAC	direct-air capture
DFI	development finance institution
EIA	Environmental Impact Assessment
EPC	engineering, procurement and construction
EU	European Union
EV	electric vehicle
FiT	feed-in tariff
FODER	Fund for the Development of Renewable Energy (Fondo para el Desarrollo de Energías Renovables)
G20	The Group of Twenty
GDP	gross domestic product
GoA	Government of Argentina
GoI	Government of Indonesia
GWh	gigawatt hour
IBRD	International Bank for Reconstruction and Development
IEA	International Energy Agency
IFC	International Finance Corporation
IPP	independent power producer
KfW	Kreditanstalt für Wiederaufbau
$kgCO_{2eq}$	kilogrammes of carbon dioxide equivalent
kgH_2	kilogramme of hydrogen
kWh	kilowatt hour
LCOE	levelised cost of electricity
MDB	multilateral development bank
MSP	Maritime Spatial Planning
MWh	megawatt hour
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
PEM	proton exchange membrane
PES	Planned Energy Scenario
PPA	power purchase agreement
PV	photovoltaic
R&D	research and development
SDG	Sustainable Development Goal
USD	US dollar
WACC	weighted average cost of capital

EXECUTIVE SUMMARY

The energy transition requires significant annual investment if governments around the world are to achieve the 1.5°C climate target they committed to under the Paris Agreement. To reach and sustain these volumes over the coming decades, it is essential to ensure that low-cost finance for the energy transition is available to emerging market economies and advanced economies alike.

The factors that drove down the costs of solar and wind power over the past decade offer important insights into the framework conditions and policies needed to scale up the new and emerging technologies needed for the energy transition, as well as the vital role of low-cost finance.

Solar and wind power offer a case study for the importance of co-ordinated policies to spur deployment, technological innovation and supply chain growth, and the importance of low-cost finance in driving the deployment of those technologies required for the next stage of the energy transition. Government policies and industry innovation that drove down technology costs and improved system performance, were supported by de-risking policies that worked hand in hand with reduced technology risk and increased developer experience to drive down the cost of capital to very low levels, helping finance solar and wind power projects among the Group of Twenty (G20) members and beyond.

The lessons learnt from the success of solar photovoltaic and onshore wind can be used to accelerate the scale-up of hydrogen, offshore wind and battery storage – critical technologies for the next stage of the energy transition.

Policies need to support innovation – particularly during the early research and development, and demonstration phases – in order to foster commercially mature solutions with improved performance and reduced costs. Thereafter, policies need to shift gear to support accelerated deployment, supply chain manufacturing and the economies of scale that drive cost reductions during project implementation. A stable policy environment that includes policies to de-risk projects is then crucial in unlocking the volume of low-cost finance that would further reduce power generation costs and improve the competitiveness of emerging technologies. In this context, small-scale and modular technologies with low barriers to entry in manufacturing can achieve significant learning rates. Thus, investments in learning represent an important policy lever to drive down costs and improve performance. In retrospect, this inter-connection between learning, performance and costs has been underestimated by policy makers over the past decade as they considered the potential of new and emerging technologies.

Crucially, enabling innovative frameworks that reduce the transaction costs of technology transfers and facilitate foreign direct investments have played a key role in accelerating the deployment of new and critical low-carbon technologies in emerging markets.

Effective policy design that includes such innovative environments - which has proved successful for wind and solar - can foster local private ecosystems across multiple dimensions such as enabling technologies, business models, market design and system operation.

Today, most renewable power generation technologies are mature and cost competitive.

Thanks to the progress sustained over the past decade, renewable power generation technologies, notably solar photovoltaic and onshore wind power, have become mature and competitive. Economies of scale in both installations and manufacturing capacities have been achieved and the costs of renewable energy equipment across the supply chain dramatically reduced. This has led to renewables' improved cost competitiveness over fossil-fuel-based electricity generation. The key drivers behind this progress include improved technological maturity, continued innovation in technologies and business models, enhanced system integration and operational performance, increased manufacturing and assembling capacities, and reduced labour costs. The improved financing conditions as markets mature, plus reduced operation and maintenance costs, have also helped lower costs.

Yet, some technologies, such as offshore wind, hydrogen electrolysers, energy storage and heat pumps, which have become increasingly critical to the global energy transition compatible with the 1.5°C Paris Agreement, would need to be deployed at much faster speeds as well as greater scales. Over the past years, their costs have also been declining, although they remain relatively high. Therefore, lowering financing costs would be helpful to boost investment and thereby accelerate deployment.

To achieve the 1.5°C climate goal under the Paris Agreement, the overall share of renewable energy in the primary energy mix will need to rise to as high as three-quarters, and an annual investment of over USD 4.4 trillion[1] will be required.

This requires acceleration of end-use electrification to fully capture the benefit of renewable power, which is increasingly the lowest-cost form of electricity. Electricity's share of the energy system must expand far beyond the current 20% to reach half of final energy by 2050 in a 1.5°C-compliant energy system. In the short term, the technologies for direct use of electricity such as electric vehicles (EVs), heat pumps or electric cooking, which are readily available, will need to be deployed at a faster rate and greater scale. For indirect use of electricity, green hydrogen is expected to grow in the near term to 2030, but most of the scale-up and use will occur in the 2030-2050 time frame; however, planning must begin now to enable end-use technologies utilising hydrogen, as well as the expansion of infrastructure to harness this potential. To enable an energy system aligned with the 1.5°C target, investment in energy transition technologies needs to scale up considerably, complemented by a simultaneous redirection of investment away from fossil fuels. The bulk of investment will need to focus on renewable energy, energy efficiency, electrification and enabling infrastructure.

[1] *This figure is consistent with the analysis conducted for the 2022 edition of the World Energy Transition Outlook. IRENA is in the process of updating this analysis for 2023, and initial previews of the results suggest this figure has grown to over USD 5 trillion per year. The final results will be released later in 2023.*

The majority of the funds required for the energy transition will have to come from the private sector.

Capital needs to be urgently mobilised from the domestic and international capital resources of the private sector. Domestic financial markets are critical sources of capital for financing the energy transition since they provide diversified funding sources, access to local equity capital and corporate bond markets, and much-needed local-currency financing to avoid currency risk and help mitigate macroeconomic shocks. This is especially true in developing markets, where international institutional investors may be reluctant to invest, when local investors or lenders – local banks, pension funds and insurance companies – are not involved themselves in the project financing. International players tend to be concerned with market information asymmetry regarding project risk assessment.

In order to ensure policy and regulatory frameworks work to unlock these sources of private sector finance, it is critical to understand the dynamics shaping the renewable energy financing cost differences between markets. Knowledge of the risk-return profiles that the private sector, particularly institutional investors, are seeking helps the public sector identify the role it needs to play to mitigate risk factors that might otherwise raise the cost of capital to punitive levels that discourage investment.

As a result, the public sector is a critical catalyst in engaging and attracting private sector investors and project developers under conditions that ensure low costs of capital.

Governments can set the conditions for private sector actors to build and finance a viable pipeline of transition–oriented projects. For example, in a blended finance structure, the public sector strategically provides small amounts of concessional public capital to mitigate certain risks that private sector capital cannot (yet) absorb, or for which they would demand a very high price (rate of return). This approach sees public and, sometimes, philanthropic actors providing concessional capital (*i.e.* capital at below-market rates or terms) to alter the risk-return profile of an investment, so that private capital is attracted at lower cost, and/or better terms. The resulting structure blends both types of capital and allows each party to the transaction to achieve its specific objectives.

In this regard, G20 members have a wealth of experience in facilitating access to low-cost finance in different markets and can share valuable knowledge on innovative financing solutions to reduce the cost of capital. This report presents four case studies including Argentina, Brazil, India and Indonesia, as examples, to showcase best practices in lowering the cost of capital among G20 members and offer some generic lessons learnt that can be useful for the other countries.

Innovation is vital if governments are to scale up new and critical energy transition technologies. Along with economies of scale as markets grow, innovation is one of the main levers available to reduce technology costs, accelerate market penetration and unlock required financial resources.

Effective innovation frameworks incorporate co-ordinated policies and actions to drive innovations in four areas – namely, enabling technologies, business models, market design and system operation – to address the key challenges facing a specific technology in its scale-up. Additionally, they can also be designed to help reduce the transaction costs of technology transfers and facilitate foreign direct investments or the creation of local private sector ecosystems.

The role of these four dimensions varies based on technology development. For a more mature technology such as fixed-bottom offshore wind, the lack of transparent goals and a "fit-for-purpose" regulatory environment may be the primary obstacles to accessing low-cost capital and the investment needed for project development. As various renewable energy options compete for markets and power purchase agreements, governments would do well to help new technologies in order to scale up the deployment, as well as ensure compliance with the 1.5°C target over the next decades. Governments can provide certainty and support research and development, manufacturing and deployment efforts by creating clear, long-term goals and policy frameworks for offshore energy technologies. This will provide a positive signal to private developers, research institutions and financial actors. More specifically, focusing on policies that promote integrated marine spatial planning reduces the time and cost of permitting and ensures investments in critical grid infrastructure are made in sequence with expansion plans, which will greatly contribute to the adoption of offshore wind solutions.

For green hydrogen, the prospect of significant global trade arising from support policies on the supply and demand sides introduces new considerations. For instance, to help the scale-up of green hydrogen, a transparent and internationally accepted certification system will help accelerate the development of a global hydrogen market with buyers' and sellers' assurance of the provenance of the hydrogen. To put certification systems in place, common methodologies and taxonomies to determine which conditions a green hydrogen project must meet to be considered sustainable are required. Furthermore, it is important to emphasise that green hydrogen certification is not limited to hydrogen as an end product but can rather be the beginning of a much longer value chain extending towards chemical and steel industries and international shipping.

Mapping and understanding the drivers behind financing costs and conditions are crucial to gaining insights regarding differences by technology and country.

Understanding which markets and technologies are exposed to higher costs of capital allows stakeholders to identify where problems might arise and investigate what is driving higher costs of capital in different markets and for different technologies. This can then allow industry and policy makers to work together to identify the policies and actions needed to allow low-cost capital to flow to the investment needs of the energy transition in a timely manner. For instance, it may yield greater benefits in some markets for policy makers to provide exchange rate risk insurance, rather than concessionary loans, if international developers can help source low-cost finance for projects developed with local partners.

By informing policies that address the specific identified risks driving finance premiums, knowledge will help mitigate capital premiums associated with such risks. This can significantly reduce the costs of electricity generation, given the capital-intensive nature of most renewable power generation technologies and the fact that fuel costs are low or often zero. Policies, measures and innovative financing schemes to reduce projects' risk profiles and unlock a lower cost of capital will therefore be beneficial for G20 members, and others, with financing challenges. Among the key drivers behind the cost of capital differentials, particularly for debt, country risks and off-take risks are usually the most important – and hence the largest barriers to mobilising capital to accelerate the energy transition – in several G20 members. Other determinants of the cost of capital can include local financial sectors' experience in financing energy transition technologies and the standardisation (or lack thereof) of financial products, counter-party risk, permitting process certainty, grid access challenges, the variation in risk between projects and (to a lesser extent) technologies or the involvement of development banks.

INTRODUCTION

Climate finance, green development and lifestyle for the environment (LiFE) are among the key priorities of India's presidency of the Group of Twenty (G20), under its chosen theme, *Vasudhaiva Kutumbakam* ("One Earth, one family, one future"). A core component of these priorities is the aim to advance the progress of a just energy transition by facilitating access to climate finance and technologies in developing countries.

In this context, the Energy Transition Working Group, under the leadership of India's G20 presidency, has identified six priority areas. Priority II focusses on low-cost finance for the energy transition.

Low-cost finance in the global energy transition

The world has faced multiple challenges in recent years, including the economic fallout from the COVID-19 pandemic, global supply chain problems, the current energy crisis, slowing economic growth and high inflation. At the same time, the extent of global climate change has become increasingly obvious and the scientific evidence overwhelming. Unprecedented heatwaves in Europe, widespread flooding in Asia, wildfires in North America and the worst drought on record in the Horn of Africa are just some of the recent extreme weather events that have been linked to climate change.

There has also been progress – specifically in the energy transition. As highlighted in the report *Global landscape of renewable energy finance 2023* published jointly by the International Renewable Energy Agency and Climate Policy Initiative (IRENA and CPI, 2023), global financial commitments to investment in the energy transition reached USD 1.3 trillion in 2022, a record high. Even so, the current pace of investment is still not sufficient to put the world on track to meet the climate and socio-economic development goals of most countries, or commitments under the Paris Agreement. Therefore, there is a growing recognition among governments, businesses and people alike of the need for urgent action to accelerate the energy transition towards a net-zero future.[2] There is also a realisation that doing so would provide economic opportunities in terms of jobs, local development and technological innovation, with benefits to societies, humankind and nature.

There is a growing consensus that the best route to achieving the 1.5°C climate target is an energy transition based overwhelmingly on the scaling-up of energy efficiency measures;

[2] *In the context of this report, references to "net zero" refer to the greenhouse gas emissions of the energy sector.*

the direct use of renewables in transport, industry and buildings' and renewables-based electrification. Importantly, many of these technologies and measures are available today, albeit with their deployment at different levels in different markets. The developments of recent years have demonstrated the clear benefits of a renewables-based energy pathway in terms of enhancing energy security, reducing the negative impacts of fossil fuel price volatility and contributing to energy affordability. Renewable power generation technologies have become increasingly cost competitive with fossil fuels, helping to keep down energy costs while also allowing countries to reduce import dependency.

The energy transition at a crossroads: Lessons learnt and new challenges

Countries around the world have embarked on an ambitious and essential transformation of their energy sectors in order to avoid dangerous and costly climate change, protect ecosystems, and improve social and environmental outcomes for their citizens. However, progress remains uneven across sectors and countries. The growing urgency of the task ahead calls for a clear assessment of the challenges and the lessons learnt from the energy transition to date.

One clear message from solar and wind power technologies of the past decade is that conventional wisdom has been a poor guide to how far and how fast small, modular technologies can scale, innovate and decline in costs.

Globally, the costs of renewables have fallen over the last decade and more, with declines in the costs of solar and wind power being particularly large (IRENA, 2022a).[3] Several energy transition trends show that despite the impact of COVID-19, supply chain challenges and the fossil fuel price crisis in 2022, the energy transition is remarkably resilient and is accelerating. For example, by the end of 2022, renewable capacity reached new heights, exceeding 3 300 gigawatts (GW) of total installed capacity (IRENA, 2023a) for the first time (see Chapter 1). The rate of heat pump installations has skyrocketed in a number of countries that are particularly vulnerable to the effects of the current gas supply crunch (*e.g.* Germany, Poland). Sales of EVs rose by an estimated 57% in 2022 to over 10 million (Counterpoint, 2023). As a reaction to the challenge of fossil fuel supply disruptions in 2022, some jurisdictions are proposing new policies that will help accelerate the energy transition in the short to long term (*e.g.* through the Inflation Reduction Act in the United States and the REpowerEU/Fit for 55 package in the European Union).

The challenge the world now faces is that the rate of deployment of renewables and associated infrastructure, levels of funding and the inclusiveness of the transition (*e.g.* energy access) all remain below what is required by the 1.5°C pathway (IRENA, 2023b). To achieve the climate targets agreed to by countries under the Paris Agreement, scaling up the deployment of renewable energy, energy efficiency measures and other facilitating technologies (*e.g.* electricity storage, grid expansion, EV charging, *etc.*) is critical (see Chapter 2). This requires at least USD 4.4 trillion/year of investments in energy transition technologies (IRENA, 2022b).

Access to funding in many emerging and low-income economies is not sufficient, and often too costly to accelerate the energy transition at the necessary rate. Lowering the cost of capital for financing the energy transition has therefore become more crucial than ever. In this regard, although country-specific circumstances vary, country risk or policy risk is often identified as the primary impediment for international institutional capital flows.[4]

A project's risk profile is crucial to the cost of finance. In general, less-risky projects will be able to tap into larger pools of capital, with lower debt costs and more favourable terms (*e.g.* longer "tenors", which is to say the lengths of loans). Lenders will also be prepared to lend larger amounts, reducing the need for more expensive equity capital. At the same time, less risky projects will also require lower equity rates of return. The difference can be substantial, with the weighted average cost of capital differing by as much as a factor of five or six between an advanced economy and an emerging market economy (see Chapter 3). To this structural problem can be added the current, increasing macroeconomic risks and the rising interest rates being used to try and combat inflationary pressures.

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[3] *With the commodity price inflation seen in 2022, renewable energy equipment and total project costs were not immune to cost increases, or delays as developers hoped for prices to ease. However, this increase was generally modest in absolute terms, and with the massive increase in fossil fuel prices in 2022, the economic case for renewable power improved dramatically.*

[4] *See World Energy Transition Outlook (IRENA, 2021a) for an explanation of the range of risk factors.*

The importance of innovation in the energy transition cannot be under-estimated, whether that is in terms of technology performance, business models, market design or system operation. Appropriate innovation frameworks are needed at each stage of the technology deployment pathway; from incipient research and development activities to market- and finance-enabling processes, through to achieving commercial deployment and the scale-up required (Chapter 4). They can also be designed to reduce the transaction costs of technology transfers.

The private sector has stepped up its investments in energy transition projects. The public sector has not been idle, either, as it set the policy frameworks needed for the growth to date. The public sector has also acted to reduce the risk profile of energy transition projects. It has endeavoured to provide a stable long-term policy framework and business environment conducive to giving the private sector confidence to invest in large, long-lived energy transition assets. The public sector has thereby helped to attract private investors and developers to build and finance pipelines of bankable projects for the energy transition. Its role will continue to be crucial in the future, particularly when it comes to well-designed public support that reduces the risk profile of energy transition investments, to allow private developers to access lower-cost debt and equity.

Beyond policies and measures to attract private investment, multilateral public funds and policies could be more actively channelled towards technologies and countries/regions that are currently not able to attract private capital (Chapter 5). The public sector can also step up its role in providing concessional finance, that helps “crowd in” private sector capital. This “blended” finance approach to catalysing institutional capital at scale towards the energy transition will need to be given greater attention to mobilise the financial resources required for the transition.

In addition to more traditional de-risking products, a more comprehensive way of defining risk is needed. Amid climate change, it is not just the private risk profile of a project that matters. Policy makers need to adjust risk through policies that account for the external risks associated with the negative impacts of climate change on the environmental, planetary and social sphere. For instance, what are the risks associated with leaving a large

part of the population out of the energy transition and locked in underdevelopment? What are the risks of the Sustainable Development Goals not being met? Taking these risks into account suggests that public funds, including those that flow from the Global North to the Global South, need to play a much larger role in addressing the imbalance between private investors' risks and economy-wide risks of falling short in the energy transition.

Chapter 1 of this report considers the historical cost trends and investments in both traditional renewable power generation technologies (*e.g.* bioenergy for power, geothermal and hydropower) and solar and wind power technologies, which have come into their own in the last decade. The cost and investment trends for two critical technology groups for the next phase of the energy transition - hydrogen electrolysers for green hydrogen production and battery electricity storage technologies - are also covered.

Chapter 2 summarises IRENA's 1.5°C-compliant energy pathway. It lays out the transformation of the energy sector and the technologies and fuels that will allow a transition of the energy sector to 2050. It discusses the technology deployment needs and the required financial investments to achieve this pathway.

Chapter 3 discusses the current landscape of financing costs for solar and wind power technologies. It highlights the very large differences in financing costs for solar and wind technologies between advanced and emerging economies, as well as some of the drivers of these differences.

Chapter 4 discusses the importance of innovation frameworks in driving technology improvements that reduce project risks, but also in business models and system operations, as well as the role of policies to set the enabling conditions for a low-risk project environment, such as the role of standards and certification systems.

Chapter 5 looks at the inter-related roles that the public and private sectors must play in the energy transition and the blended finance approaches to catalyse institutional capital at scale into the energy transition. It identifies relevant case studies from G20 Members that could be extrapolated and scaled up in other countries.

Finally, this report ends with a summary of the conclusions and a set of recommendations for the G20 to consider.

CHAPTER 1
HISTORICAL COST AND INVESTMENT TRENDS FOR RENEWABLES AND LOW-CARBON TECHNOLOGIES IN THE G20

This chapter presents cost reduction trends and historical investment data for renewable power generation technologies, energy storage and hydrogen electrolysers. It also highlights the importance of technological innovation and economies of scale, as well as the lessons learnt from the successes of solar and wind that demonstrate the importance of low-cost finance in scaling investments and achieving rapid cost reductions.

KEY MESSAGES

- The period 2010-2022 witnessed a dramatic reduction in the cost of generating electricity from solar photovoltaic (PV), onshore wind, offshore wind and concentrating solar power (CSP).
- This cost reduction was driven by a virtuous cycle of policies that supported deployment, reducing costs and leading to more countries adopting renewable energy and/or expanding their support.
- With increased economies of scale in both installations and manufacturing capacities, as well increased automation of production processes, the costs of renewable energy equipment have been trending downward, leading to improved cost competitiveness for renewables.
- Among the other key drivers behind this progress were performance improvements and materials cost reductions from technology innovation, increased developer experience, lower operation and maintenance (O&M) costs from greater competition and operational experience, increased competition among suppliers and developers, and improved financing conditions as markets matured.
- Today, onshore wind and utility-scale solar PV are typically the lowest-cost sources of new electricity generation.
- Costs have also fallen for critical energy transition technologies which are globally important, but for which deployment is less advanced. These include offshore wind, hydrogen electrolysers, heat pumps and batteries – albeit their cost reductions have

not been as significant as for solar PV. Focussing on offshore wind, electrolysers and batteries, we see that:

- Offshore wind experienced a decade of rapid progress in terms of cumulative installed capacity from a low base, technological improvements, increased turbine size and swept area, and increased project size. This was achieved as projects were deployed in deeper waters and further from shore, particularly in Europe, to open up greater deployment and access better wind resources.
- In the period 2010-2021, the global weighted average levelised cost of electricity (LCOE) of newly commissioned offshore wind projects fell by around 60%. In Europe and China, offshore wind is now cost competitive, but new markets require some time to develop local supply chains and installation capabilities, and achieve economies of scale in O&M, before achieving competitiveness.[5]
- The costs of the two most popular electrolysers in commercial markets - alkaline (AEL) and proton exchange membrane (PEM) hydrogen electrolysers - declined by 61% and 68%, respectively, between 2005 and 2020. This trend in equipment cost declines is likely to continue, supported by ambitious government targets for renewable hydrogen as an energy carrier, a storage medium (for grid flexibility and seasonable energy storage) and industrial feedstock; and by manufacturing economies of scale, technology innovation and greater competition among suppliers. Demand pull will also drive technology innovations and other manufacturing cost reduction drivers as developers gain experience in delivering large numbers of projects.
- Batteries, with their ability to provide a multitude of services in the electricity sector, are a key technology. They are used in EVs, but can help shift variable solar and wind generation in time, provide standalone renewable off-grid systems, and flexibility in electricity markets and other "ancillary" grid services.
- Behind-the-meter batteries dominated the early stage of market growth, often paired with distributed solar PV, but the market for utility-scale solutions is also growing rapidly. In some cases, grid-scale deployments are allowing solar and wind projects to reduce their grid connection needs and/or bypass connection delays. However, in the energy transition, they hold great potential to allow grid operators and/or distribution companies to manage very large shares of variable renewable energy if the right regulatory structure is in place.
- Continued technology innovation for electricity battery storage will help to reduce materials use and costs, improve system performance and drive down total project costs. This is an ongoing process, and is both necessary and likely, given the dynamic research and development (R&D) efforts underway as deployment scales.

5 *There is a stronger element of regional "learning-by-doing" with offshore wind than for PV and onshore wind. This means there is a slightly longer lead time between new market development and achieving international benchmark best-practice costs for offshore wind; this is in contrast to onshore wind and solar PV, where international developers can bring their experience and purchasing power to bear rapidly.*

- Looking forward, the lessons learnt from the success of solar and onshore wind could accelerate the potential scale-up of these new and critical technologies, particularly in the Group of Twenty (G20) countries. Crucially, it should be noted that:

  - Innovation is a constant for renewable energy technologies. Once a commercially mature solution is developed and deployed, it will continuously evolve to reduce the cost of manufacturing and to improve performance.
  - Small modular technologies with low barriers to entry in manufacturing can achieve significant learning rates (cost reductions for every doubling in cumulative production). This makes learning investments to drive down cost and improve performance an important policy lever.
  - Analysts, research institutions, industry and policy makers have consistently underestimated the ability of all actors to improve small, modular renewable power generation technologies' performance, innovate in manufacturing, scale up supply chains and drive down costs. Almost every "ambitious" scenario from a decade ago underestimated solar PV and wind power cost reduction potentials.

1.1 RENEWABLE POWER GENERATION, BATTERY STORAGE AND HYDROGEN ELECTROLYSERS

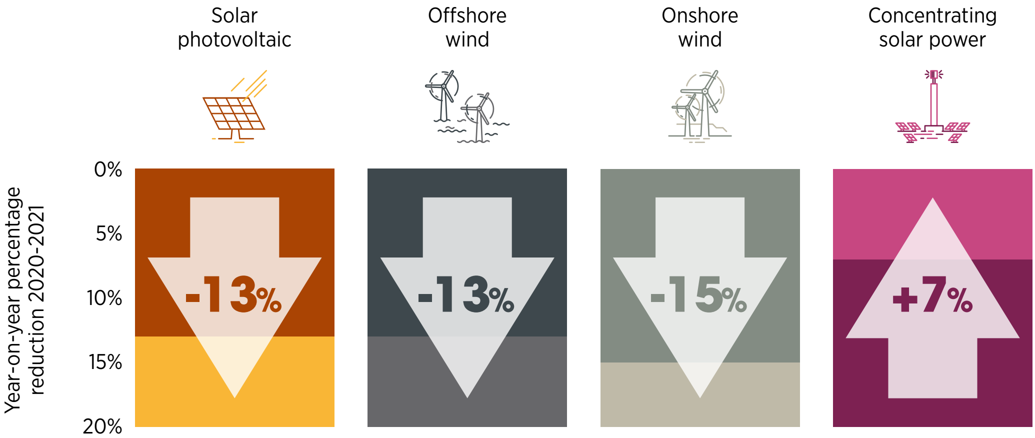
The period 2010-2021 saw remarkable cost reductions for solar and wind power technologies. A combination of targeted policy support and industry drive has given rise to a virtuous cycle of increased deployment, technology improvements and cost reductions driving further deployment growth. Renewable electricity from solar PV and wind power went from an expensive niche in 2010 to competing directly with fossil fuels for new capacity.[6]

The competitiveness of renewables continued to improve in 2021. Data from the IRENA Renewable Cost Database and analysis of recent power sector trends affirm their essential role in the journey towards an affordable and technically feasible net-zero future.

The global weighted average LCOE of new utility-scale solar PV projects commissioned in 2021 fell by 13% year-on-year, from USD 0.055/kilowatt hour (kWh) to USD 0.048/kWh (Figure 1.1). The global weighted average LCOE of new onshore wind projects added in 2021 fell by 15%, year-on-year, from USD 0.039/kWh in 2020 to USD 0.033/kWh in 2021. The offshore wind market saw unprecedented expansion in 2021 (21 GW added), while the global weighted average cost of electricity fell by 13% year-on-year, from USD 0.086/kWh to USD 0.075/kWh.

[6] *Country-level cost data are available for the renewable power generation cost trends in individual G20 countries. However, individual country data are not typically available for electrolysers and battery storage technologies, so global data or country snapshots will be provided to address this data gap.*

Figure 1.1 Change in global weighted levelised cost of electricity by technology, 2020-2021



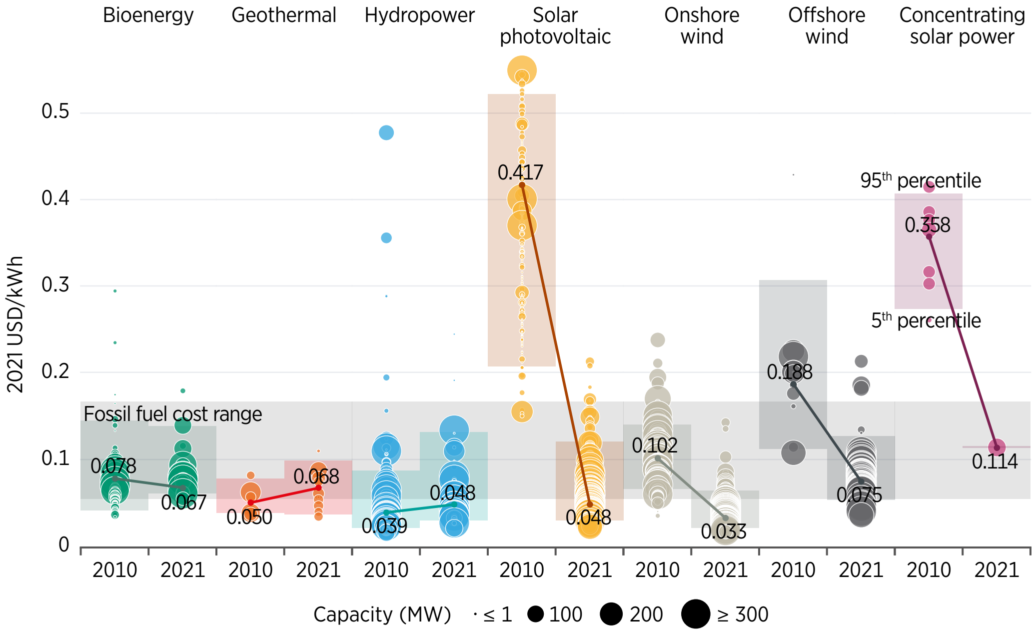
Source: IRENA, 2022a.

With only one CSP plant commissioned in 2021, compared to two in 2020, deployment remains limited and year-to-year cost changes volatile. Noting this caveat, the average cost of electricity from the single new CSP plant was around 7% higher than the average in 2020.

However, rising commodity prices and supply chain difficulties made their presence felt in 2021 in a number of markets, and have been more generalised in 2022. The country weighted average total installed costs of utility-scale solar PV increased year-on-year in three of the top 25 markets worldwide, while for onshore wind this was true for seven of the top 25 markets in 2021.

In 2010-2021, the cost reductions for solar and wind power were particularly impressive. The period witnessed a seismic shift in the balance of competitiveness between renewables and incumbent fossil fuel and nuclear options. The global weighted average LCOE of newly commissioned utility-scale solar PV projects declined by 88%, of onshore wind and CSP by 68% and of offshore wind by 60% (Figure 1.2).

Figure 1.2 Global weighted average and project-level LCOE of newly commissioned utility-scale renewable power generation technologies, 2010-2021



Source: (IRENA, 2022a).
Note: kWh = kilowatt hour; MW = megawatt.

Utility-scale solar PV cost reductions in the G20

The global weighted average LCOE of utility-scale PV plants declined by 88% between 2010 and 2021, from USD 0.417/kWh to USD 0.048/kWh. In 2021, the year-on-year reduction was 13%. At an individual country level, the weighted average LCOE of utility-scale solar PV declined by between 75% and 90% in the period 2010-2021. During this period, solar PV capacity grew about 21-fold, with over 843 GW installed by the end of 2021.

IRENA has assessed the drivers of this reduction in the cost of electricity (IRENA, 2022a), showing that there have been cost reductions from all cost components. However, solar PV module costs declined so rapidly that between 2010 and 2021, module cost declines (of 91% since 2010) contributed 45% to the reduction in LCOE from utility-scale PV. The costs of other hardware components have also declined during the period. Indeed, taken together, cost reductions in inverters, racking and mounting, and other balance of system[7] (BoS) hardware contributed another 17% to the LCOE reduction during the 2010-2021 period.

[7] *The BoS for solar PV projects is defined as all costs excluding the modules and inverters.*

As solar PV technology has matured, the relevance of BoS costs has also increased. This is because module and inverter costs have historically decreased at a higher rate than non-module costs, increasing the share of total installed costs taken by BoS (IRENA, 2018). Engineering, procurement and construction (EPC), installation and development costs, when combined with other soft costs, were responsible for 26% of the LCOE decline over the 2010-2021 period.

The rest of the reduction can be attributed to: improved financing conditions as markets have matured; reduced O&M costs; and an increased global weighted average capacity factor, driven by a shift to sunnier markets between 2010 and 2013, which has been sustained.

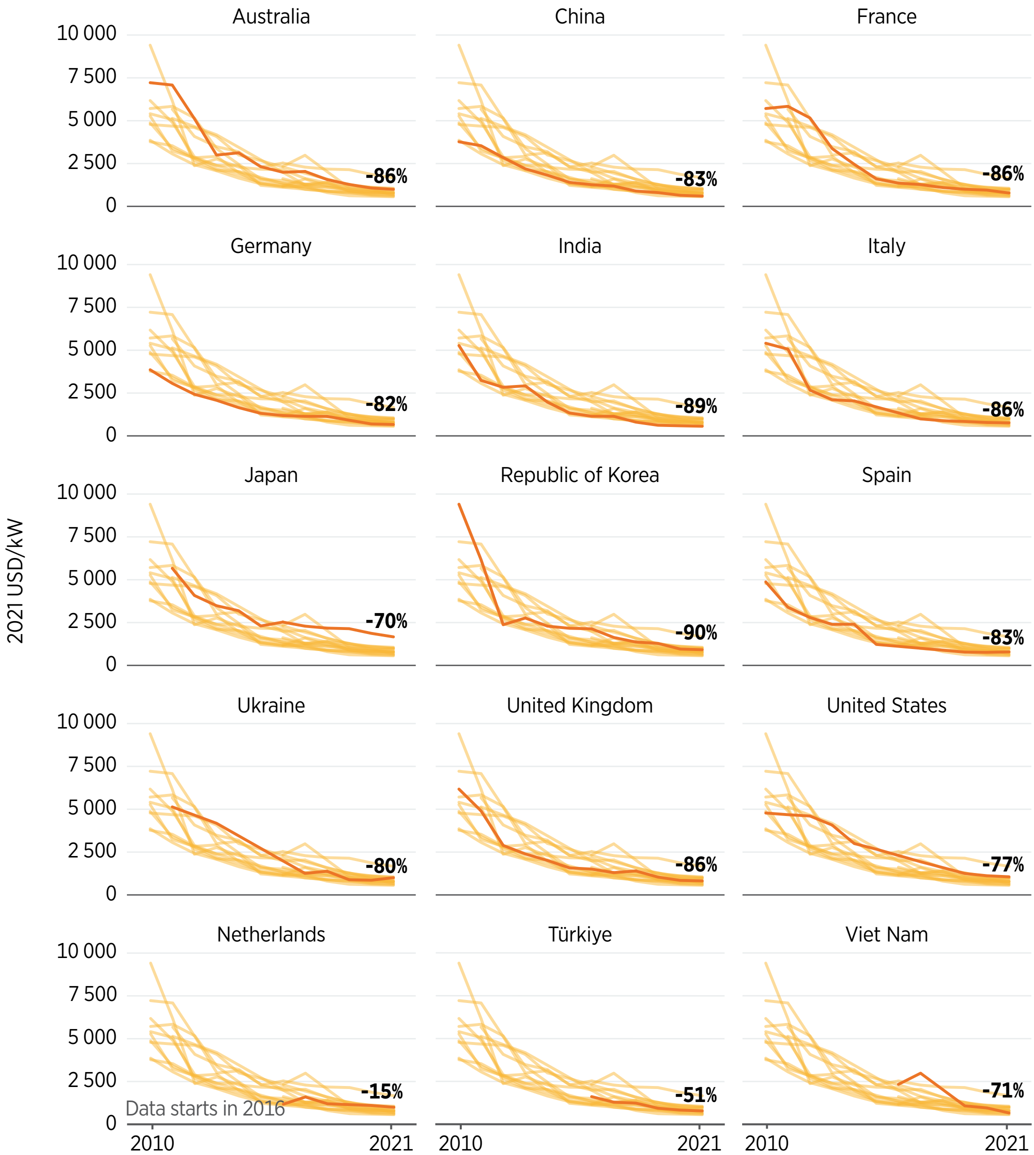
The global capacity-weighted average total installed cost of utility-scale projects commissioned in 2021 was USD 857/kW (13% lower than in 2019 and 81% lower than in 2010). During 2021, the 5th and 95th percentile range for all projects fell within a range of USD 571/kW to USD 1 982/kW. The 95th percentile value was 18% lower than in 2020, while the 5th percentile value declined by 4% between 2020 and 2021.

Solar PV total installed cost reductions are related to various factors. The key drivers of lower module costs are the optimisation of manufacturing processes, reduced labour costs and enhanced module efficiency. Furthermore, as project developers gain more experience and supply chain structures continue to develop in more and more markets, declining BoS costs have followed. This has led to an increased number of markets where PV systems are achieving competitive cost structures, with falling global weighted average total installed costs.

However, 2021 was a difficult year for solar PV. Supply chain disruptions in 2021 meant that the yearly cost reduction rhythm slowed, compared to previous years. Despite this, total installed cost reductions of between 4% and 11% still occurred in 2021 across all major historical markets, such as China, India, Japan, the Republic of Korea, the United States and Germany. This compares to a broader 2020 year-on-year total installed cost decline of between 5% and 25% among these markets.

Projects with very competitive cost structures led to a weighted average total installed cost of USD 590/kW in 2021 for India, a value 6% lower than in China. This differential was 22% during 2019 and 8% in 2020. This results from Chinese costs having declined 19% between 2019 and 2020 and another 7% in 2021, compared to 5% in India in both 2020 and 2021. During the latter year, total installed costs in Germany declined 4% (a considerably lower reduction than the 23% decline that occurred during 2020). A similar trend could be observed in the Republic of Korea, where total installed costs also fell by 4% in 2021 after falling by a quarter between 2019 and 2020 (Figure 1.3).

Figure 1.3 Utility-scale solar PV total installed cost trends in selected countries, 2010-2021



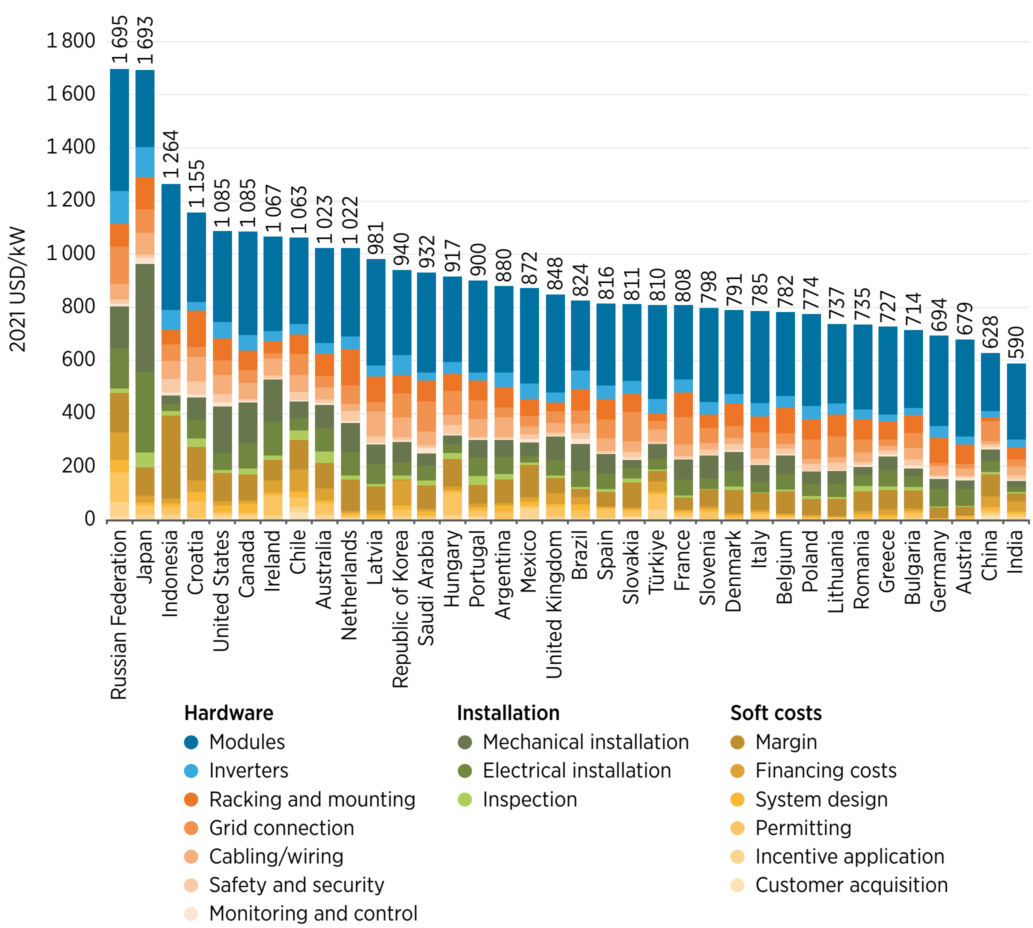
Source: (IRENA, 2022a).
Note: kW = kilowatt.

While solar PV has become a mature technology, regional cost variations do persist across the G20 (Figure 1.4). These differences remain not only for the module and inverter cost components, but also for the BoS. At a global level, cost reductions for modules and inverters accounted for 61% of the global weighted average total installed cost decline between 2010 and 2021. This means that BoS costs are therefore also an important contributor to declining global weighted average total installed costs. Between 2010 and

2021, 14% of the global reduction came from lower installation costs, 7% from racking, 3% from other BoS hardware (*e.g.* cables, junction boxes, *etc.*) and 16% from a range of smaller categories. The reasons for BoS cost reductions relate to competitive pressures and increased installer experience, which has led to improved installation processes and soft development costs. BoS costs that decline proportionally with the area of the plant have also declined as module efficiencies have increased.

A better understanding of cost component differences among individual markets is crucial to understanding how to unlock further cost reduction potential, and also where in the value chain local and imported investment occurs. Obtaining comparable cost breakdown data, however, is often challenging, and relate to differences in the scale, activity and data availability of markets. Despite this, IRENA has expanded its coverage of this type of data, collecting primary cost breakdown information for additional utility-scale markets.

Figure 1.4 Detailed breakdown of utility-scale solar PV total installed costs by country, 2021



Source: (IRENA, 2022a).
Note: kW = kilowatt.

Onshore wind cost trends in the G20

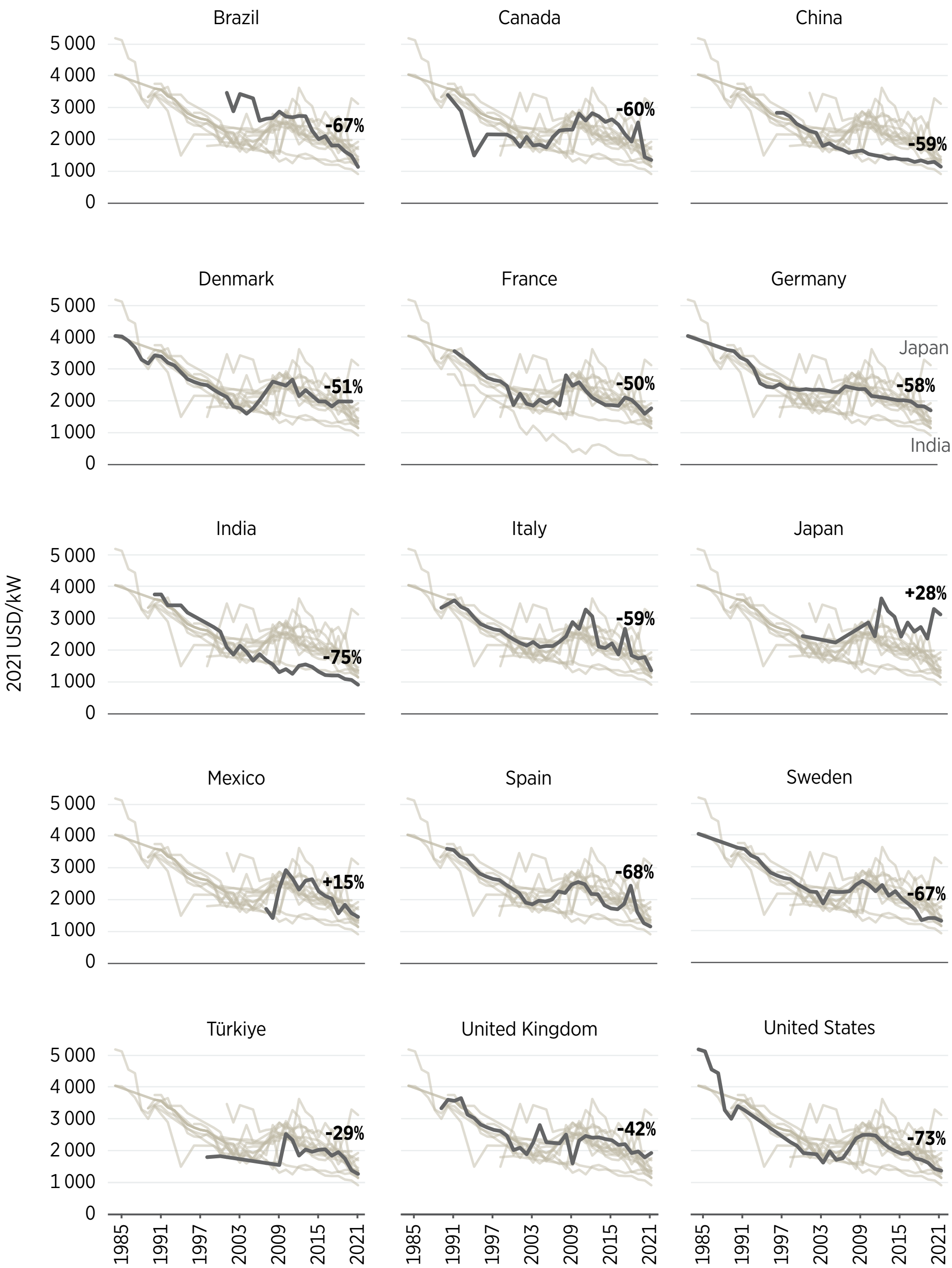
Onshore wind has become a significant contributor to renewable power generation as costs have fallen significantly as the market has matured and the technology constantly improves. Between 2010 and 2021, onshore wind's global weighted average LCOE fell 68%, from USD 0.102/kWh to USD 0.033/kWh. In 2021, the LCOE fell 15%, year-on-year.

The global weighted average total installed cost of onshore wind fell 35% between 2010 and 2021, from USD 2 042/kW to USD 1 325/kW. In 2021, average onshore wind turbine prices ranged between USD 780/kW and USD 960/kW, while the global total installed cost of newly commissioned onshore wind were down 5% on its 2020 value of USD 1 397/kW, albeit with some markets experiencing increased costs. Wind turbine prices, outside China, increased in 2021 and into 2022, suggesting total project costs may increase in 2022 given the lag between contract prices and the commissioning of projects.

Looking at the historical data in individual countries with the longest time series data (Figure 1.5) saw a range of cost reductions – from 75% to just 15% – but these comparisons need to be treated with caution, given the differing start dates for the first available data (IRENA, 2022a).

Japan, for example, saw a 28% increase between 2000 and 2021. However, the more competitive, established markets show large reductions in total installed costs over longer time periods than newer markets. India (1990-2021), followed by the United States (1984-2021), had the highest decrease in total installed costs, with reductions of 75% and 73% over their respective time frames. Spain (1990-2021) saw a reduction of 68% and Brazil (2001-2021) and Sweden (1984-2021) both saw a reduction of 67%, respectively, while Canada (1990-2021) saw a reduction of 60% and China (1996-2021) and Italy (1989-2021) both saw a reduction of 59%, respectively. Germany saw a reduction of 58%.

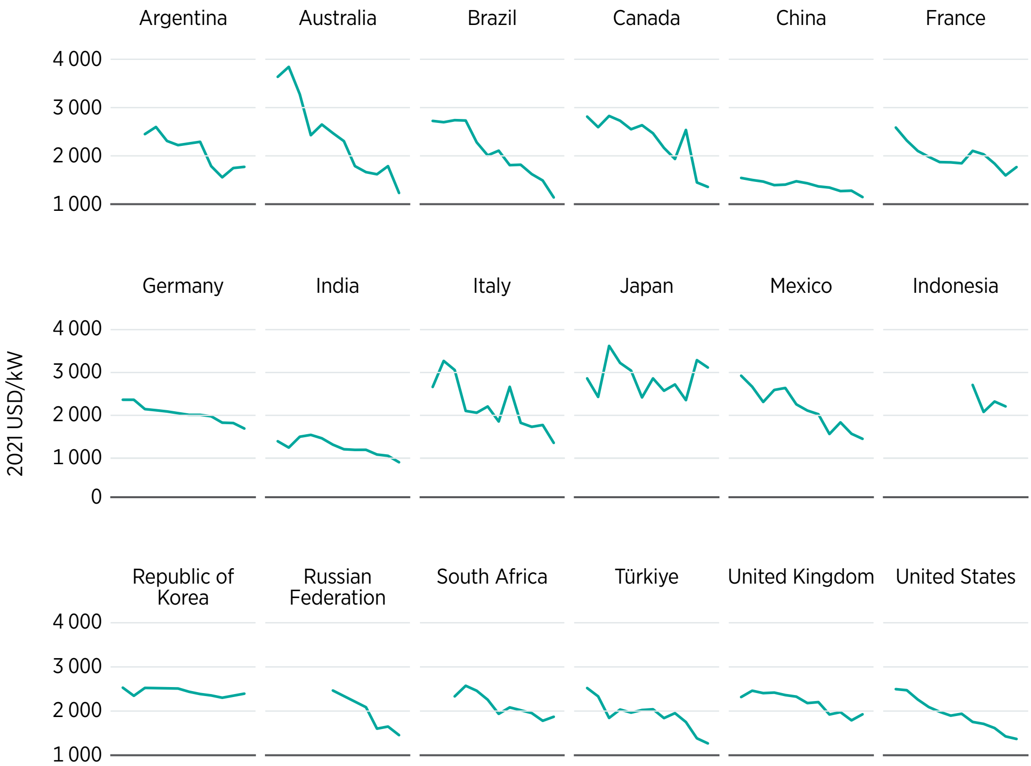
Figure 1.5 Weighted average total installed costs of newly commissioned onshore wind projects by country, 1984-2021



Source: (IRENA, 2022a).
Note: kW = kilowatt.

The data for country-level weighted average total installed project costs for newly commissioned projects in newer and smaller markets tend to be more volatile. Figure 1.6 presents the cost data for 18 of the G20 countries for which IRENA has time series data. It is clear from these data, that different G20 countries have very different cost structures, and in some cases experience cost reductions over time.

Figure 1.6 Weighted average total installed costs of newly commissioned onshore wind projects in 18 of the G20 countries



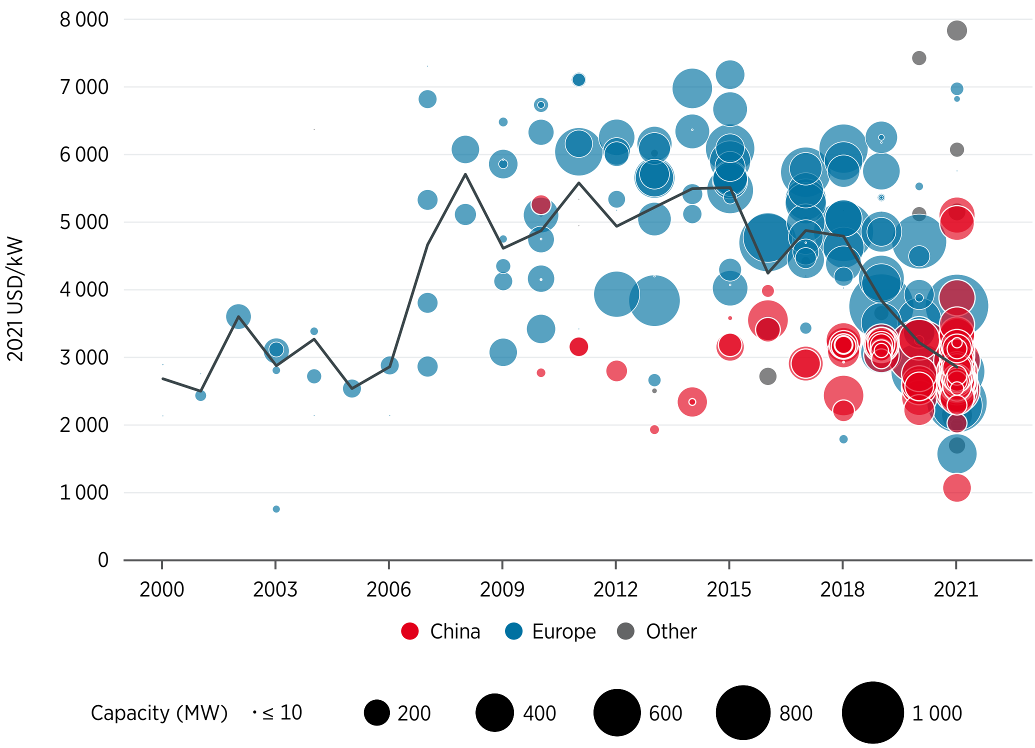
Source: (IRENA, 2022a).
Note: kW = kilowatt.

Offshore wind cost trends in the G20

Offshore wind technology has matured rapidly since 2010. Indeed, there was an 18-fold increase in cumulative deployed capacity between 2010 and 2021, from 3.1 GW to 55.7 GW (IRENA, 2022a). However, at the end of 2021, offshore wind made up just under 7% of the total cumulative global wind capacity. Yet, plans and targets for future deployment have been expanding, as costs have decreased, and the technology has headed further towards maturity.

Compared to onshore wind, offshore wind farms have higher total installed costs. Installing and operating wind turbines in the harsh marine environment offshore increases costs. The global weighted average total installed cost of offshore wind farms increased from around USD 2 685/kW in 2000 to over USD 5 712/kW in 2008. It then bounced around the USD 5 250/kW mark for the period 2008 to 2015 (Figure 1.7), as projects moved farther from shore and into deeper waters. The global weighted average total installed cost then began to decline after 2015, falling relatively rapidly to USD 2 858/kW in 2021.

Figure 1.7 Offshore wind projects and global weighted average total installed costs, 2000-2021



Source: (IRENA, 2022a).
Note: kW = kilowatt; MW = megawatt.

The relatively thin market for new offshore wind projects in most countries means that annual weighted average costs at a global and country level can be quite volatile, given the very site-specific nature of offshore wind. Table 1.1 includes the country- and region-specific annual weighted average total installed costs where data are available for 2010 and 2021.

In the United Kingdom, which had the second-largest added offshore wind capacity in 2021 (2.3 GW), the project-specific weighted average total installed cost was USD 3 057/kW. That year, all the regions and countries listed in Table 1.1 experienced a decrease in weighted average total installed costs. As for solar PV and onshore wind, commodity cost inflation and supply chain disruptions in 2022 and into 2023 are likely to see projects – outside China, at least – experience cost increases. The extent to which these can be mitigated remains to be seen.

Table 1.1 Weighted average total offshore wind installed costs by country and region

	2010			2021		
	5TH PERCENTILE	WEIGHTED AVERAGE	95TH PERCENTILE	5TH PERCENTILE	WEIGHTED AVERAGE	95TH PERCENTILE
	(2021 USD/KW)					
Asia	2 981	**4 680**	5 240	1 859	**2 876**	6 917
China	2 912	**4 638**	5 152	2 406	**2 857**	3 474
Japan	5 113	**5 113**	5 113	5 201	**5 550**	6 030
Republic of Korea*	n.a.	**n.a.**	n.a.	5 238	**6 278**	7 317
Europe	3 683	**4 883**	6 739	1 859	**2 775**	6 917
Belgium*	6 334	**6 334**	6 334	3 371	**3 545**	3 876
Denmark	3 422	**3 422**	3 422	2 289	**2 289**	2 289
Germany*	6 739	**6 739**	6 739	3 603	**3 739**	4 452
Netherlands**	4 299	**4 299**	4 299	1 695	**2 449**	6 424
United Kingdom	4 225	**4 753**	5 072	2 363	**3 057**	6 495

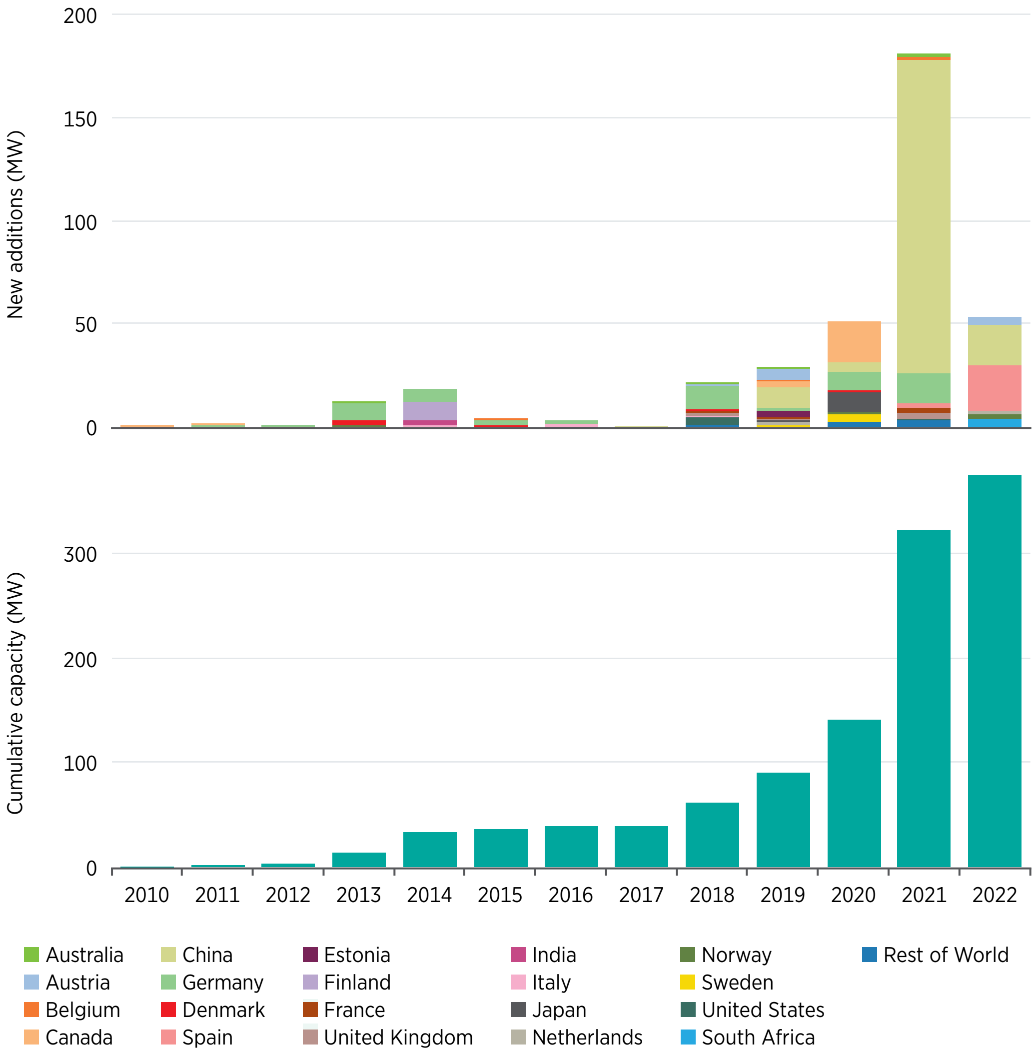
Source: IRENA Renewable Cost Database, cited in (IRENA, 2022a).
Note: kW = kilowatt.

Owing to the improved cost competitiveness of renewables, we are seeing technologies that will help facilitate the renewable-centric energy transition follow a similar path, such as battery storage, and others that are in the process of pushing down the learning curve, such as hydrogen electrolysers.

1.1.1 Hydrogen electrolysers cost trends

Historically, the market for hydrogen electrolysers was essentially minimal, with data showing that the total operational installed capacity only exceeded 323 megawatts (MW) in 2021 (BNEF, 2022a). The project pipeline suggests that new capacity added could rise to 1.3 GW in 2022, with most of this in the Asia-Pacific region. It could then grow to 2.2 GW in 2023, as Europe deploys significant capacity. The years 2024 and 2025 could see 3.3 GW and 8.7 GW added, respectively, but with a deep valley of lower additions then starting in 2026, before growing to as much as 13 GW of new capacity added in 2030.

Figure 1.8 Trends in hydrogen electrolyser capacity, 2010-2022



Based on: (IEA, 2022).
Note: MW = megawatt.

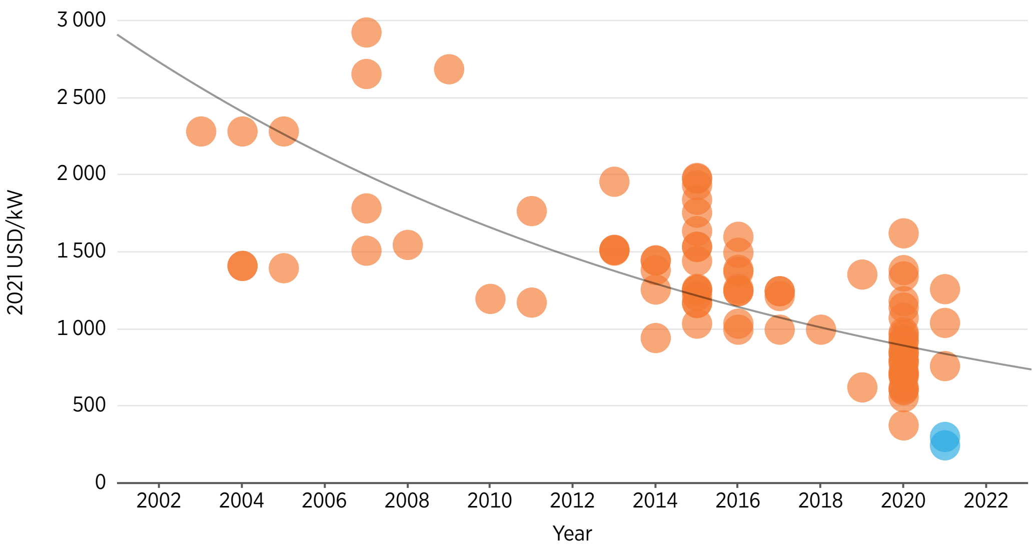
As the cost of renewable electricity has fallen, interest in renewable hydrogen[8] as an energy carrier and storage medium has grown. Electrolysers have been commercially deployed since the beginning of the last century. The main commercial technologies are alkaline (AEL) and proton exchange membrane (PEM) electrolysers.

AEL electrolyser cost trends

AEL electrolyser costs have fallen over time. Between 2003 and 2005, they ranged between USD 1 396/kW and USD 2 283/kW, while by 2021, they ranged between USD 248/kW to USD 1 261/kW. The trendline suggests a 61% reduction in costs between 2005 and 2020. A number of very low EPC quotes have been seen in China (blue dots in Figure 1.9) but are not directly comparable with projects in other countries.

The data presented here are from primary data sources quoting industry data, news reports, OEM (original equipment manufacturer) quotes, company reports or cost data from grant reporting. They exclude references to costs based on secondary data. Additionally, any reference where the source of the cost data was unexplained is excluded. The available information represents 86 data points. These are a mixture ranging from representative costs to individual electrolyser project costs, or manufacturers' quotes for projects.

Figure 1.9 Cost trends for alkaline electrolysers, 2003-2021



Source: (IRENA, 2022c).
Note: kW = kilowatt.

[8] *Renewable hydrogen can be produced from renewable electricity in electrolysers that process water into hydrogen. These electrochemical devices split water into its constituent components, yielding hydrogen and oxygen by the passage of an electrical current.*

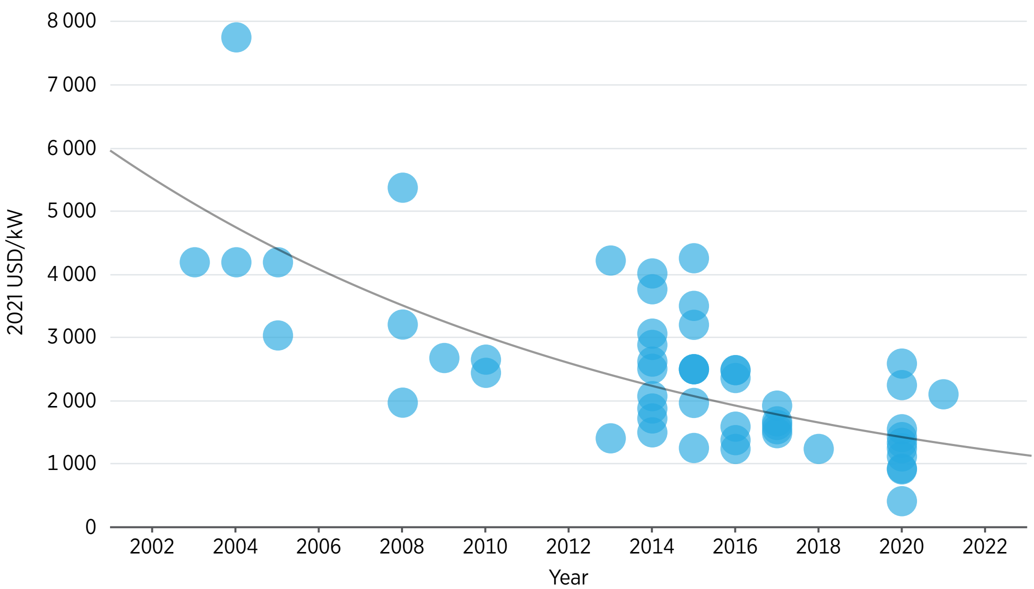
PEM electrolyser cost trends

The data available to IRENA for PEM represent 54 data points. PEM electrolyser costs are currently higher than those for AEL, as the former are costlier to produce today and are manufactured on a smaller scale. Part of the cost premium is explained by a more expensive bill of materials, involving costly transition metals. Starting from a higher level, PEM costs have fallen more rapidly than those for AEL, however.

PEM electrolyser costs ranged from USD 3 044/kW to USD 7 761/kW between 2003 and 2005 (Figure 1.10). By 2020, they had fallen 68% to between USD 420/kW and USD 2 598/kW. PEM cost data in 2021 were very limited; however, the cost fell to an estimate of USD 1 223/kW.

The average size of new PEM projects added in 2020 was just 2.5 MW, dropping to just 0.9 MW if the 20 MW Air Liquide project in Canada is excluded. **Therefore, even before addressing manufacturing scale and R&D efforts to reduce costs and improve performance, increasing the size of projects would help provide economies of scale at the project level and reduce costs.**

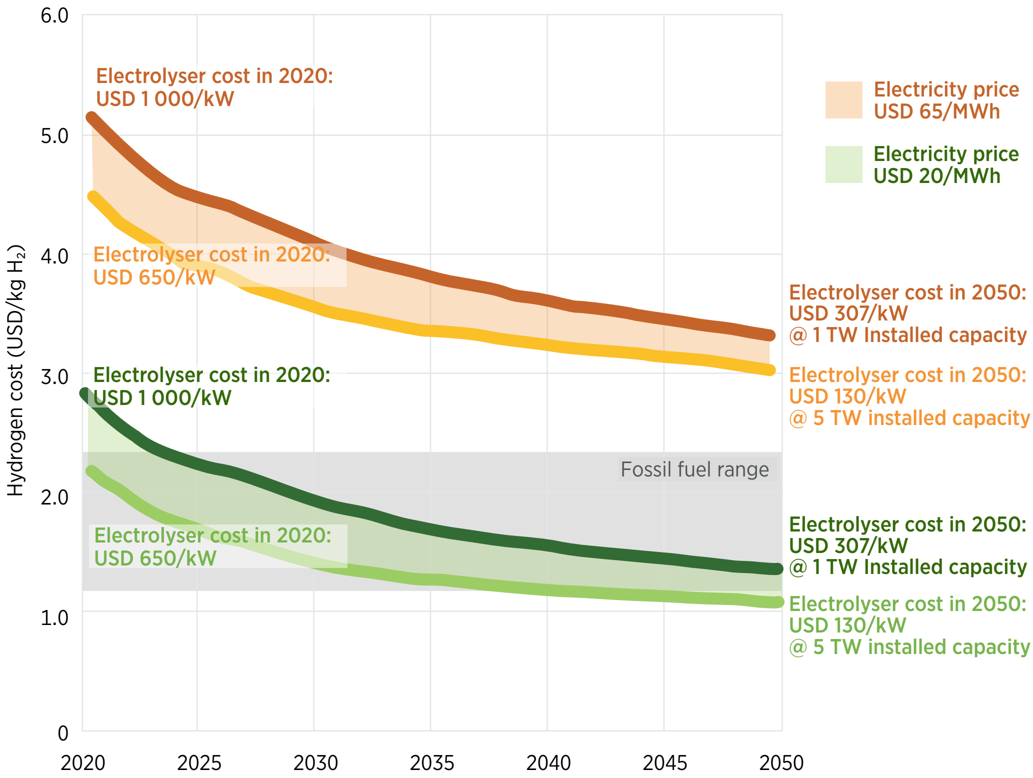
Figure 1.10 Cost trends for proton exchange membrane electrolysers, 2003-2021



Source: (IRENA, 2022c).
Note: kW = kilowatt.

Electricity is the dominant cost for on-site production of green hydrogen, but the journey to lower renewable costs is already underway. As illustrated in Figure 1.11, cost reductions in electrolysers must go hand-in-hand with low electricity costs to achieve low-cost green hydrogen. If rapid scale-up takes place in the next decade, green hydrogen is expected to start becoming competitive with blue hydrogen by 2030 in a wide range of countries – *e.g.* those with electricity prices of USD 30/megawatt hour (MWh) – and in applications.

Figure 1.11 Green hydrogen production as a function of electrolyser deployment, installed cost and electricity price, constant over the period 2020-2050



Source: (IRENA, 2018).
Note: Efficiency at nominal capacity is 65%, with a lower heating value (LHV) of 51.2 kilowatt hour/kilogramme of hydrogen (kWh/kgH_2) in 2020 and 76% (at an LHV of 43.8 kWh/kgH_2) in 2050, a discount rate of 8% and a stack lifetime of 80 000 hours. The electrolyser investment cost for 2020 is USD 650-1000/kW. Electrolyser costs reach USD 130-terawatt.

1.1.2 Behind-the-meter and utility-scale battery storage costs trends

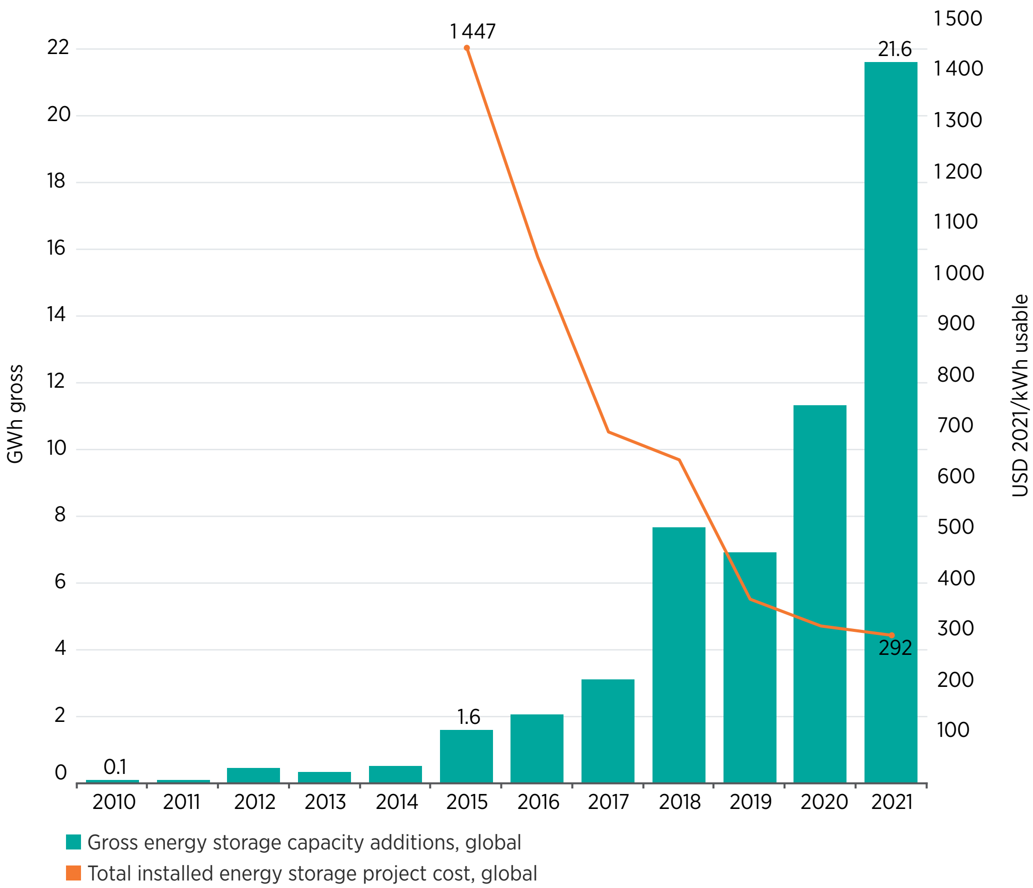
Another technology that is becoming increasingly crucial to the energy transition is stationary battery electricity storage, in order to complement and facilitate the rapid rise of installed electricity generation capacity of solar PV and wind. Stationary storage can help balance supply and demand, provide ancillary electricity market services and more (IRENA, 2017, 2018). In short, electricity storage will play a growing and crucial role in enabling the next phase of the energy transition as the shares of variable renewable energy technologies continue to increase globally.

Battery storage technology has played - and will continue to play - a prominent role in decarbonising transport and the electricity system (IRENA, 2022c). Battery storage costs have fallen rapidly in recent years. Available data for representative datasets of the price of lithium-ion (Li-ion) cells show them declining by about 98% between 1991 and 2018 as global manufacturing has scaled up. During this period, performance improvements have centred on improving energy density (which more than tripled) and specific energy (which almost tripled).

As cell cost declines occurred for Li-ion cells and battery packs, the range of services they can economically provide has expanded (IRENA, 2018). The cost of battery systems per kWh for stationary applications can be higher than those for mobile applications, however. This is due to the additional pack and battery management system costs required for managing the more challenging charge/discharge cycles to which they are subjected (IRENA, 2018).

Globally, the costs of a fully installed and commissioned energy storage project declined 80% between 2015 and 2021 (Figure 1.12), as new annual capacity additions increased from 1.6 gigawatt hour (GWh) gross capacity to 21.6 GWh gross capacity in 2021, a 13-fold increase.

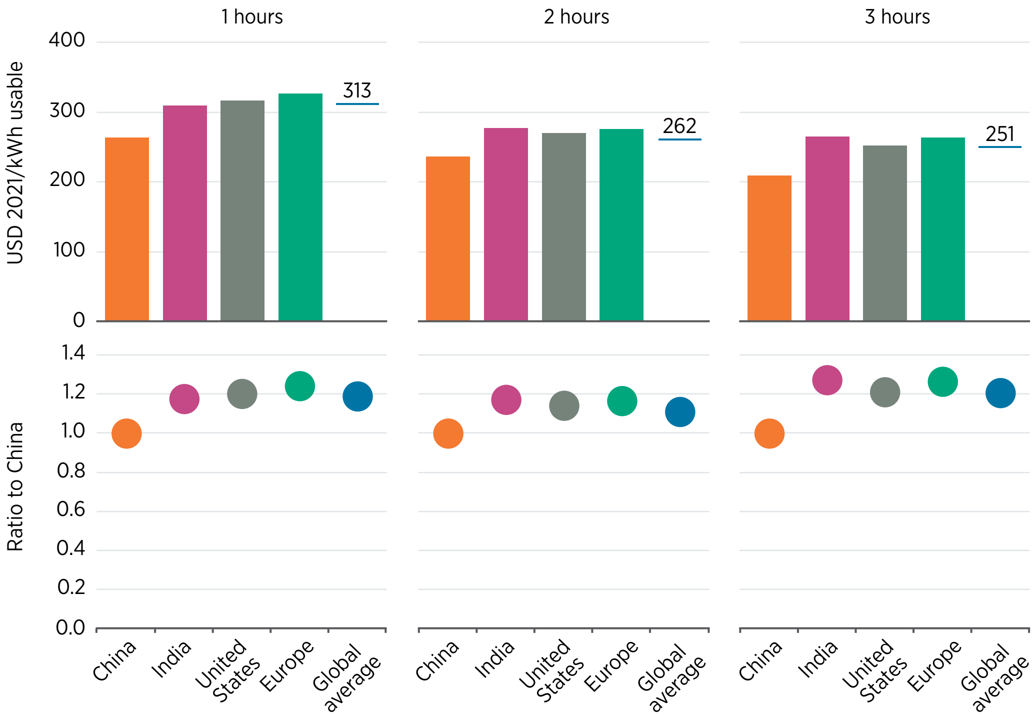
Figure 1.12 Global gross battery storage capacity additions by year and total installed energy storage project cost, 2010-2021



Based on: IRENA (2022a); (BNEF, 2022a); (Lazard, 2021) and (EIA, 2021).
Note: GWh = gigawatt hour; kWh = kilowatt hour.

Some data are available for turnkey utility-scale battery storage system prices in major markets. Though these costs exclude EPC, grid connection and developing costs, they can provide a sense of the cost differences by market. As the duration of the system increases from one to three hours, the global weighted average turnkey system cost decreases 20% from USD 313/kWh to USD 251/kWh (Figure 1.13).

Figure 1.13 Turnkey battery storage system prices by market and duration, 2021

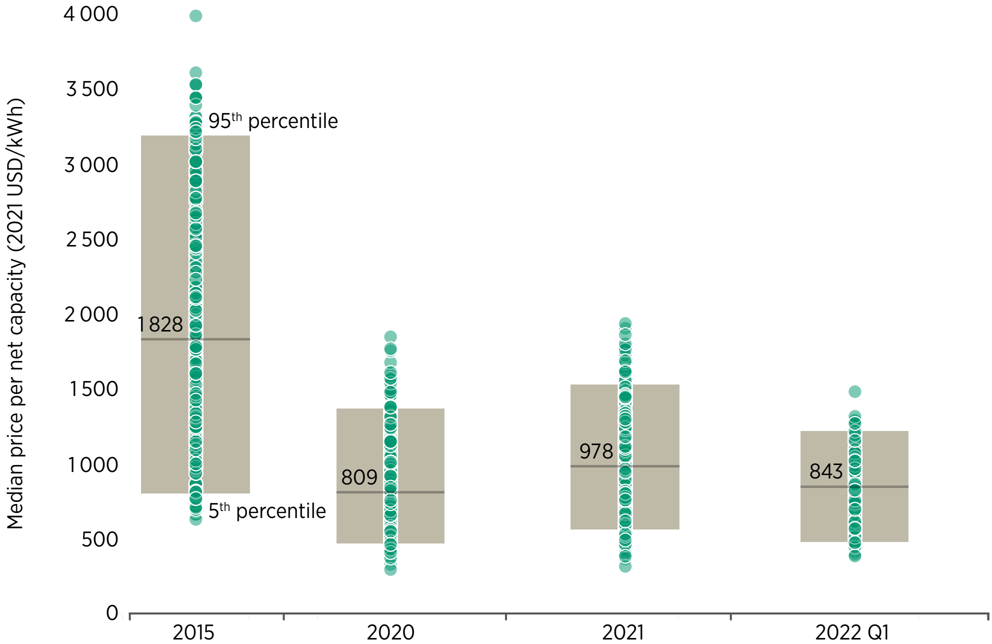


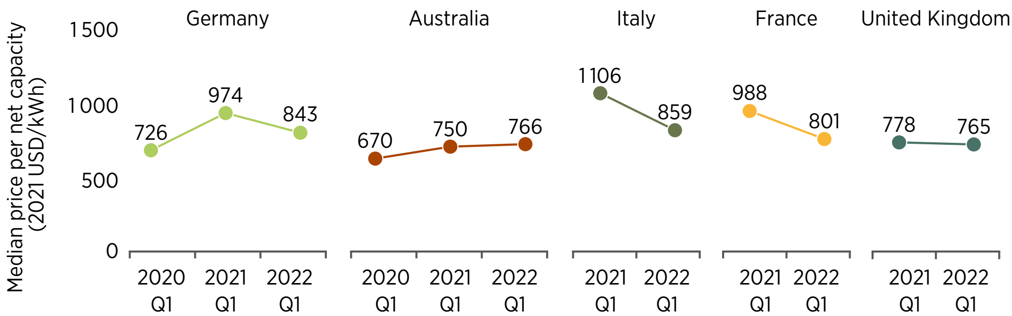
Source:(BNEF, 2022b).
Note: kWh = kilowatt hour.

Small-scale battery storage systems are often associated with PV, enabling an increase in self-consumption, or, potentially, in response to incentives from grid operators and/or distribution companies to manage grid feed-in. Time series data for small-scale residential battery systems in Germany, suggest prices fell by 71% there between 2014 and 2020, to USD 809/kWh in 2020. During 2021, the price increased by a fifth, to USD 978/kWh. Preliminary Q1 2022 data see prices falling again to USD 843/kWh – still higher than in 2022, but a 70% decline from 2014 and 54% compared to 2015.

Data for Australia and the United Kingdom suggest prices somewhat lower than those experienced in Germany for small-scale residential battery storage systems, while those in Italy and France are somewhat more expensive – similar to their experience with rooftop solar PV pricing (Figure 1.14). Between Q1 2021 and Q1 2022, however, prices in Italy and France declined 22% and 19%, respectively. The price decline in Germany during that period was 13%, with UK costs relatively flat during this time frame.

Figure 1.14 Behind-the-meter lithium-ion battery storage cost trends for residential systems by country, 2015-2022





Source: (IRENA, 2022a).
Note: kWh = kilowatt hour.

1.2 INVESTMENT TRENDS BY COUNTRY FOR RENEWABLE POWER GENERATION AND GLOBALLY FOR BATTERY STORAGE AND ELECTROLYSERS

This section charts the investment trends for the established renewable power generation technologies and the new and critical technologies for facilitating the energy transition (storage and hydrogen electrolysers).

Global investment in renewable power generation by year and technology

With falling costs, investment trends in renewables need to be examined with a critical eye, as trends in absolute currency values mask the dramatical fall in costs per kW for solar and wind power technologies.

This section presents the data for the ”value of investment of new renewable capacity” added in a year. It is the total installed cost multiplied by the deployment. This is not therefore, an estimate of the actual expenditure in a year, given disbursements for a project happen as the project is developed and constructed. For solar PV, with its short construction times, the time shift is relatively modest, but becomes larger for onshore wind, offshore wind and, especially, hydropower. It is worth noting that the definition of investment here differs from the definition of investment in IRENA's and CPI's *Global landscape of renewable energy finance 2023* (IRENA and CPI, 2023). The landscape report tracks investment values in the year of the financial investment decision, which can be anywhere from half a year on average for solar PV to up six or seven years for offshore wind and hydropower. Each investment metric provides different insights and neither is "correct." The "value of investment of new capacity added" is used in this report for consistency with the World Energy Technology Outlook investment numbers provided in Chapter 2.

Figure 1.15 shows the trends in the value of investment of new renewable capacity added by year. In 2010, when new renewable capacity additions totalled 88 GW, the investment value of all the renewable capacity newly commissioned in that year was USD 221 billion. In 2021, three times that level of new renewable power generation capacity was commissioned, but the value of the investment had only increased to USD 353 billion.

Three major drivers impacted the value of investment of newly added capacity for solar PV between 2010 and 2021. First, the global weighted average total installed cost fell 82% over this period. Second, deployment accelerated dramatically, and third, there was shift from deployment being dominated by the relatively more costly rooftop PV, to utility-scale projects. For utility-scale and distributed solar PV, in 2010, the 17.5 GW of capacity added required USD 92 billion (42% of the total). Approximately three-quarters of the value of investment of capacity added in that year derived from distributed, rooftop, solar PV. By 2021, new capacity additions had risen to 137 GW, while investment needs rose to USD 130 billion (37% of the total). In contrast to 2010, in 2021 utility-scale solar PV dominated deployment capacity (95 GW) and accounted for 63% of total solar PV investment (USD 82 billion).

In 2010, 31 GW of new onshore wind power capacity was added, with an investment value of USD 66 billion. By 2021, new onshore wind power capacity additions had had more than doubled to 72 GW, requiring investment of USD 95 billion, given the global weighted average cost of onshore wind fell by 35% in this period. Over the same period, the value of the investment in new offshore wind capacity grew more than 12-fold, from USD 4.5 billion to USD 57 billion, as capacity additions grew from 900 MW in 2010 to almost 20 GW in 2021.

Hydropower, CSP and bioenergy for power all saw their investment peak in 2013. For hydropower, the peak was in terms of new capacity deployed (46 GW), investment (USD 70.6 billion) and share of total investment in renewable power generation (26%).

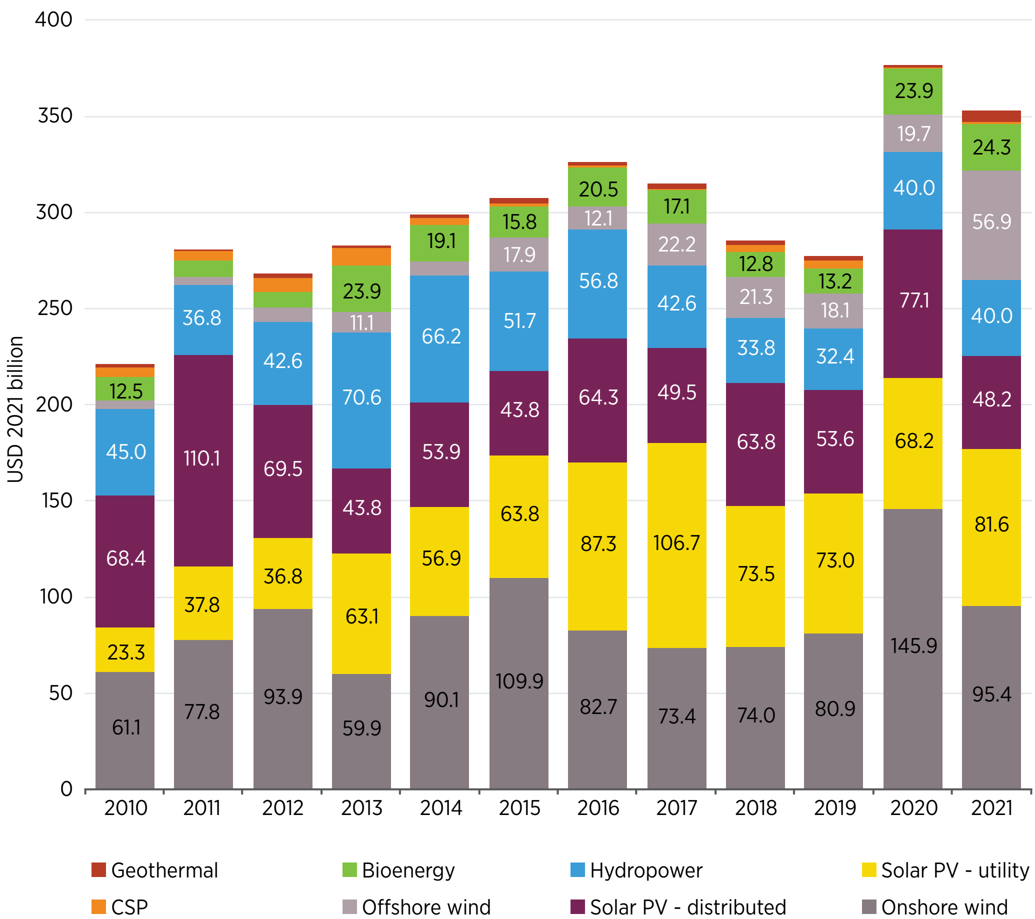
In 2010, new hydropower capacity additions of 34 GW required investment of USD 45 billion (20% of the total), while this fell to 18.7 GW of new capacity added, requiring investment of USD 40 billion in 2021 - some 11% of the total. For hydropower, the global weighted average total installed cost grew by 62% between 2010 and 2021, to USD 2 135/kW in 2021.

CSP capacity additions and investments peaked in 2013, at 1.3 GW and USD 9.3 billion, while investment in 2019 was USD 3.5 billion before declining to less than USD 1 billion in 2021. Investment in bioenergy also peaked in 2013, at around USD 24 billion, up from USD 13 billion in 2010. In 2021, investments in bioenergy for power were around USD 24.3 billion, or 7% of the total. Driven by modest new capacity additions, investment in geothermal ranged from a low of around USD 0.8 billion in 2011 to a high of USD 6.1 billion in 2021, which saw the largest new capacity commissioned in a single year this decade.

Figure 1.16 shows the trends in investment by technology (bars) and the associated annual new capacity deployment (lines). This makes obvious the dramatic increase in utility-scale solar PV deployment relative to the total investment needed. The trend is a little less evident for distributed solar PV, but is significant, nonetheless. For instance, USD 1 million invested in utility-scale solar PV in 2010 yielded 202 kW of capacity, while by 2021, this had increased almost sixfold, to 1 168 kW. The same comparison for distributed solar PV saw a quintupling in capacity yielded for the same USD 1 million invested, from 186 kW in 2010 to 874 kW in 2021.

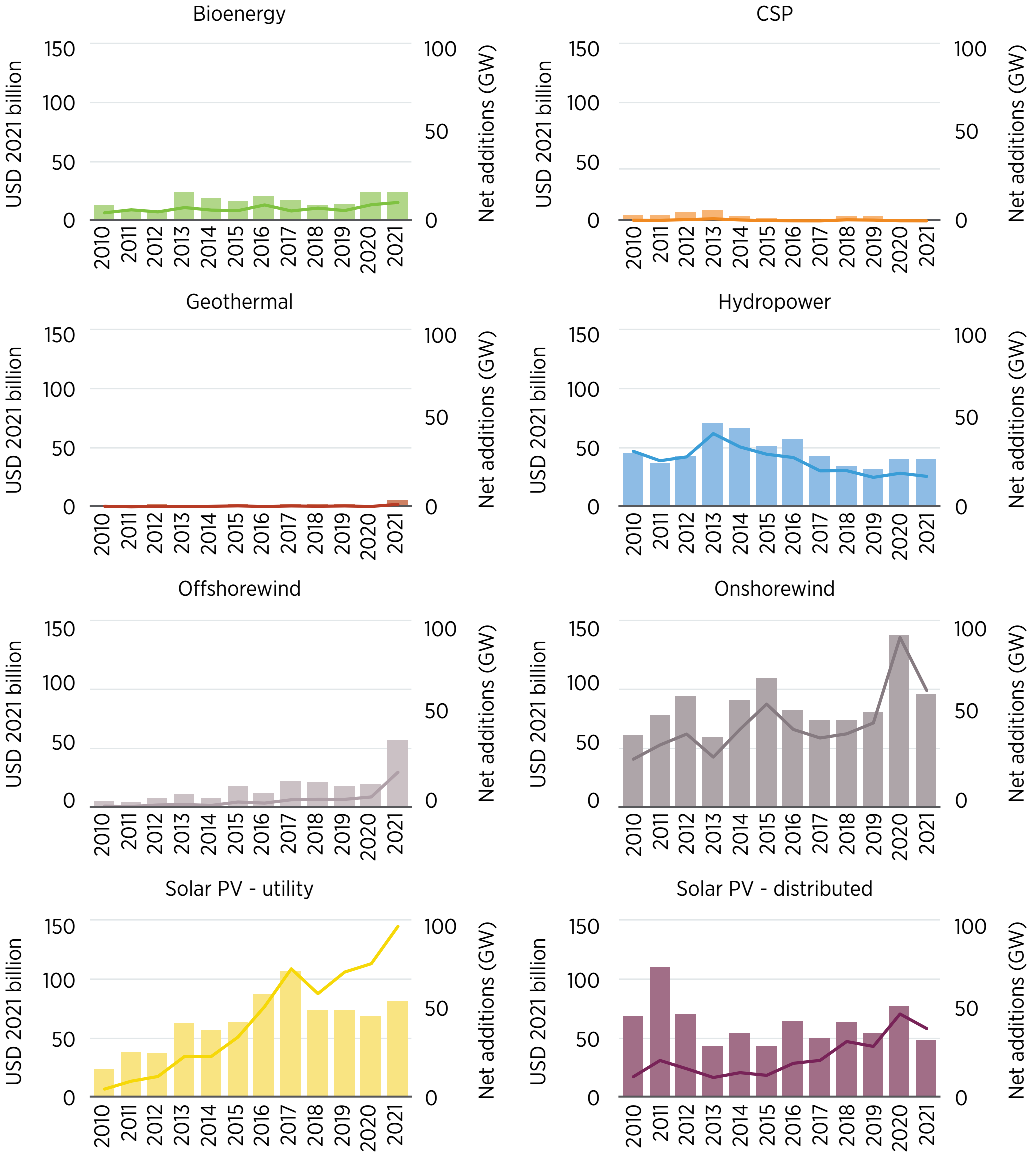
The trend for onshore wind and offshore wind is more modest, the yield of capacity added in 2010 from USD 1 million was 204 kW of offshore capacity and 487 kW of onshore capacity, while by 2021 these figures had risen to 350 kW and 755 kW, respectively.

Figure 1.15 Investment value of new renewable capacity added by year, 2010-2021



Based on: (IRENA, 2022a, 2023a).
Note: CSP = concentrating solar power; PV = photovoltaic.

Figure 1.16 Investment value and new capacity added by renewable power technology, 2010-2021



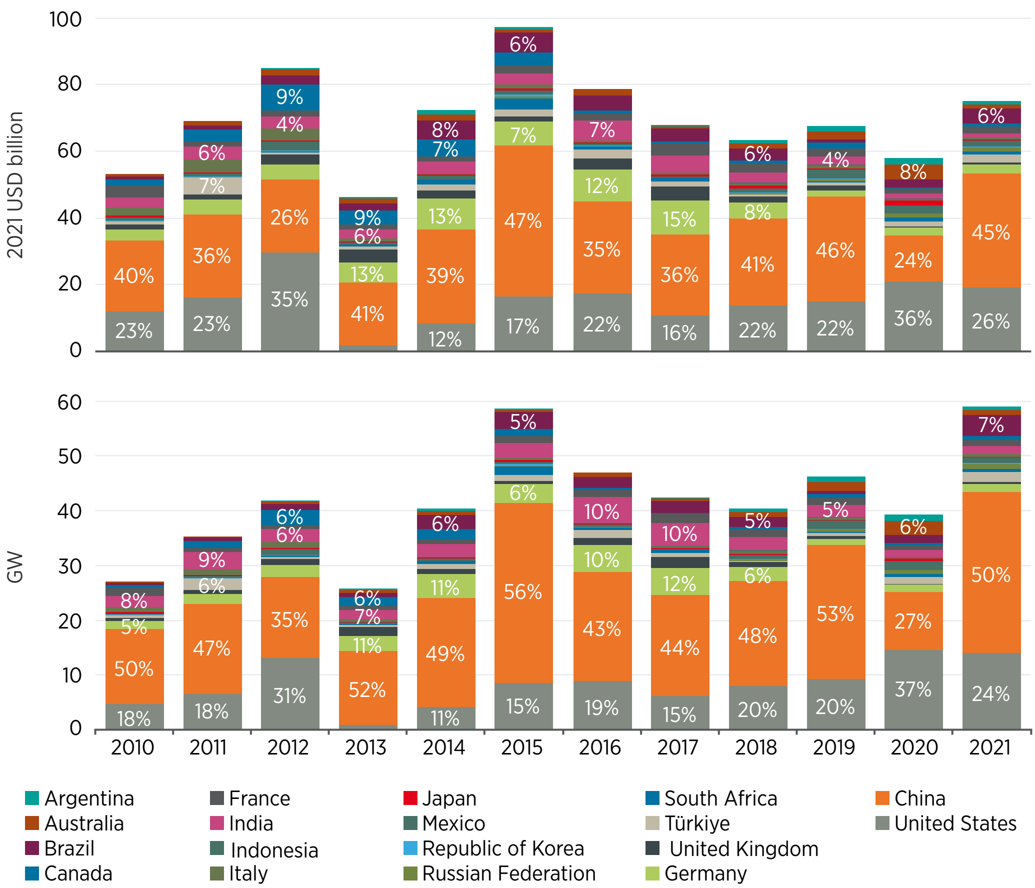
Based on: (IRENA, 2022a, 2023a).
Note: CSP = concentrating solar power; GW = gigawatt; PV = photovoltaic. Bars represent the investment value and lines the capacity additions.

Figure 1.17 presents the total investment value of new capacity added trend for onshore wind power in the G20, as well as the share of each G20 country in the total. As can be seen, the volatility in deployment volumes (lower half of the figure) drives the major trends in annual investment, but this transitions over time to result in more deployment for proportionately less investment, given the decline in the total installed costs in most G20 markets over time. In 2010, around 17 GW of capacity additions in the G20 necessitated

USD 53 billion in investment. By 2021, G20 countries added around 59 GW of capacity, but that necessitated just USD 75 billion. Between 2010 and 2021, annual new capacity additions increased by 118%, but the investment needs rose by only 41%.

China and the United States represent the two largest markets for both capacity and investment over the period 2010 to 2021. Together, China and the United States accounted for 68% of the capacity additions in 2010 (18 GW) and 63% of the investment value of new capacity added (USD 33 billion). The slightly lower share of investment than capacity is explained by the lower-than-average total installed costs in China, being only partially offset by the inverse of this in the United States. By 2021, the United States had reduced its total installed costs to much closer to the global average in 2010 and as a result accounted for 24% of the capacity additions and 26% of the investment value of new capacity added. In 2021, China and the United States accounted for 74% of the new capacity additions (43 GW) and 72% (USD 53 billion) of the investment value of new capacity.

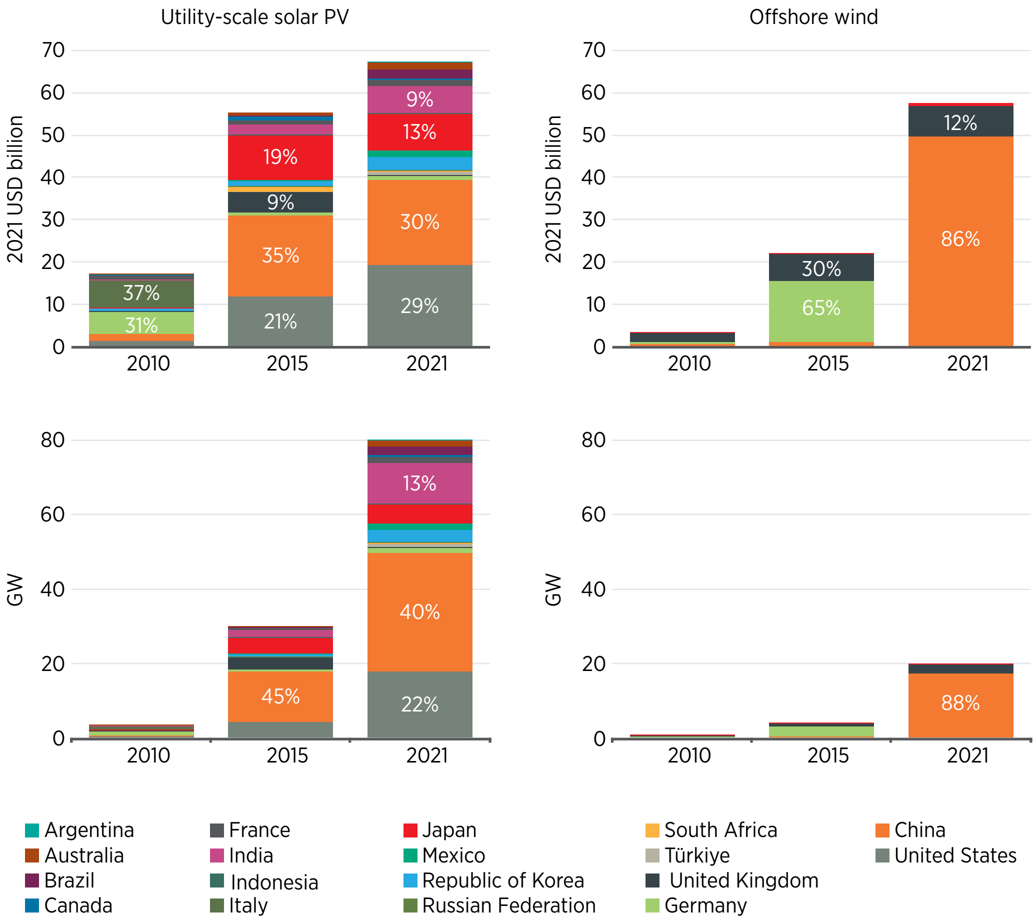
Figure 1.17 Total G20 investment for newly added onshore wind capacity in onshore wind power by year, 2010-2021



Based on: (IRENA, 2022a, 2023a).
Note: GW = gigawatt.

For utility-scale solar PV investment trends, the results are more pronounced than for onshore wind given the larger percentage reduction in total installed costs (see section 1.1 and [IRENA, 2022a] for details). Annual utility-scale capacity additions of solar PV increased 23.4-fold between 2010 and 2021, but the total annual investment value of new capacity added only increased 3.9-fold over the same period (Figure 1.18). Offshore wind total installed costs have also fallen, but remain between three and fourfold higher than utility-scale solar PV in most major markets. As a result, although the amount of capacity per dollar invested has increased, the sizeable new capacity additions, driven by China in 2021, necessitated around USD 58 billion in capital.

Figure 1.18 Total G20 investment in utility-scale solar PV and offshore wind power, 2010, 2015 and 2021

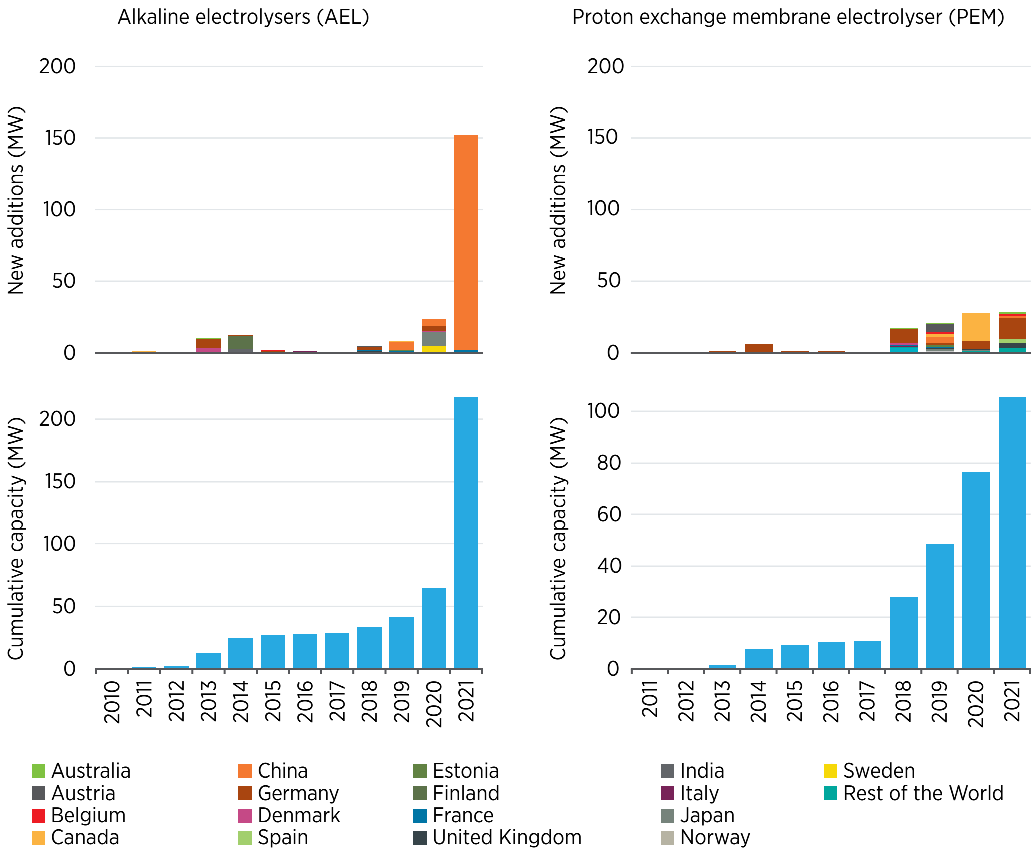


Based on: (IRENA, 2022a, 2023a).
Note: GW = gigawatt; PV = photovoltaic.

1.2.2 A global overview of investment trends in hydrogen electrolysers, with country-level analysis if data can be identified

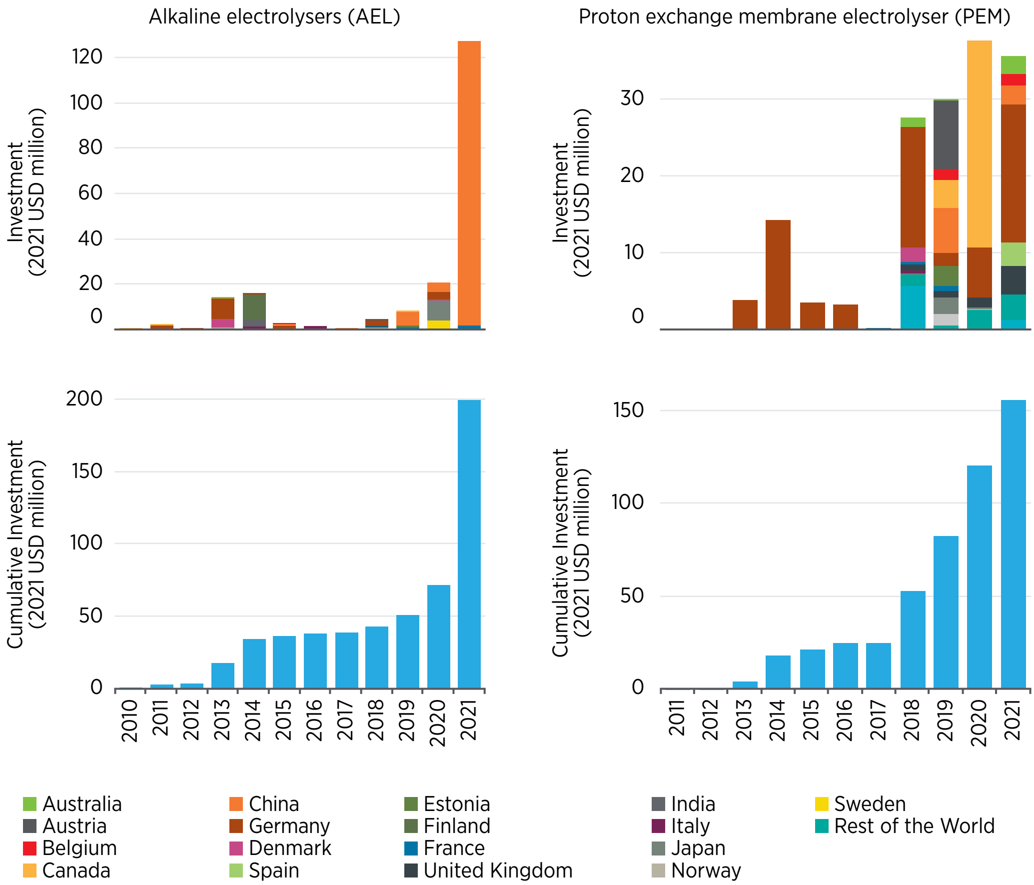
By 2021 the global cumulative investment in AEL electrolysers was estimated to be around USD 200 million since 2010 and for PEM electrolysers it was USD 156 million (Figure 1.19). Between 2020 and 2021, AEL electrolyser investment value of capacity added increased tremendously by 128% which was a result of China's added capacity of 152 MW in 2021. PEM electrolyser global investments in 2021 were mainly led by investments in Germany, the United Kingdom and Spain. Germany had the highest PEM electrolyser added capacity in 2021 where it has tripled its capacity from almost 5 MW in 2020 to 14.8 MW in 2021. The PEM electrolyser investments had somewhat decreased in 2021 when compared to 2020 as Canada - which had the highest PEM electrolyser added capacity in 2020 (20 MW) - had no added capacity in 2021.

Figure 1.19 Global cumulative capacity in hydrogen electrolysers, 2010-2021



Based on: (IEA, 2022).
Note: MW = megawatt.

Figure 1.20 Global annual and cumulative investments for new capacity additions for alkaline and proton exchange membrane electrolysers, 2010-2021

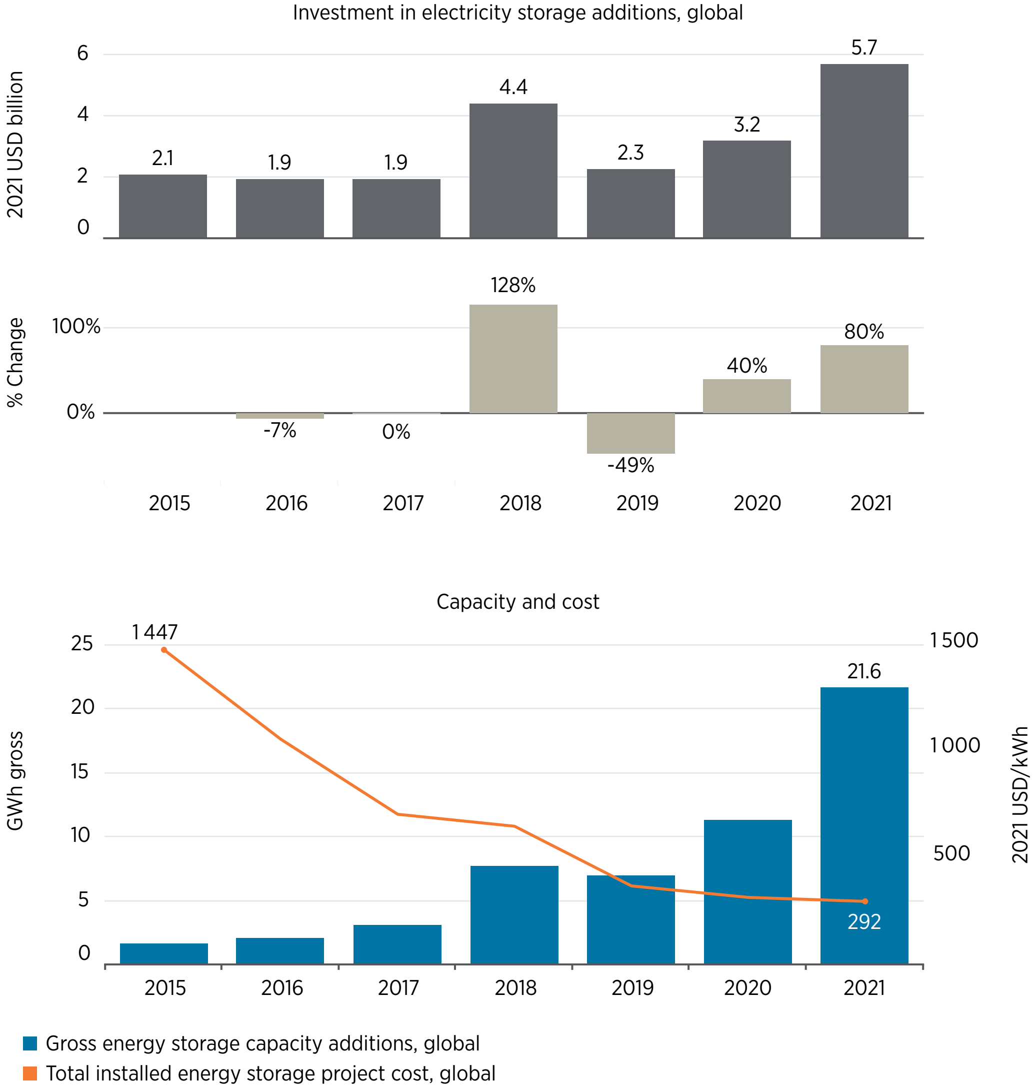


Based on: (IEA, 2022).

A global and country-level overview of investment trends in battery storage

Between 2015 and 2021, the increased maturity of battery electricity storage technologies has meant a decline in costs as the electricity storage capacity additions grew every year between 2015 and 2021 – with the exception of 2019, which was followed by a year of significant growth. Between 2020 and 2021, investment grew 80%, after having increased 40% between 2019 and 2020. During 2019, the annual investment in storage had roughly halved, as capacity additions declined 10% from its value in 2018, driven by a much faster cost decline of 43% between 2018 and 2019.

Figure 1.21 Global investment in battery electricity storage additions, 2015-2021



Based on: (BNEF, 2022b, 2022a); Lazard (2021) and (EIA, 2021).
Note: The cost in USD/kWh is for the "useable" proportion of the battery, not its gross capacity.
GWh = gigawatt hour; kWh = kilowatt hour.

CHAPTER 2
PROJECTED INVESTMENT NEEDS FOR THE GLOBAL ENERGY TRANSITION

Chapter 1 shows how renewable costs have increasingly become competitive and historical investments have, in turn, risen significantly. This chapter shows how renewables will be a key driving force to advance the global energy transition into the future, thanks to the dramatic reduction in costs, as well as technological improvements, a need to reduce emissions, among other factors. In turn, investment will need to scale significantly. To shed light on the types of technologies and investments needed, and provide policy and decision makers with a perspective on what is required, the following sections provide a detailed overview of IRENA's view on technologies for a 1.5°C pathway, and the levels of investment required to achieve it.

2.1 THE ENERGY TRANSITION: A 1.5°C PATHWAY

KEY MESSAGES

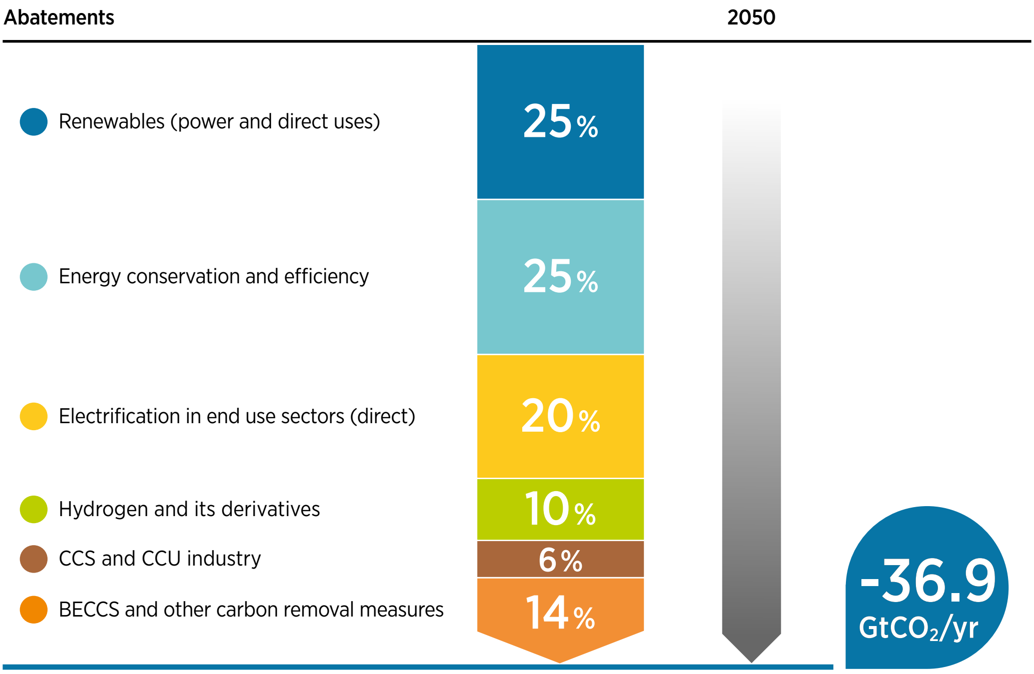
- The overall share of renewable energy in the energy mix will need to rise substantially to meet the 1.5°C target, driven by higher shares of renewable electricity and electrification, but also end-use renewables, biofuels and green hydrogen. In recent years the share of renewable energy in final energy consumption has been in the range of 17-18%; this will need to increase to as much as 80%. An additional benefit of electrification is that is can also improve energy-efficient energy use, thereby also reducing energy intensity.
- Renewable power is increasingly the least-cost form of electricity. The direct-use of electricity must rise in the energy system far beyond the current share of 20% and reach half or more of final energy by 2050 in a 1.5°C-compatible energy system. In parallel, this must be coupled with growth in the share of renewables in the electricity system to represent as much as 90% of electricity generation. Solar and wind will make up as much as two-thirds of this generation.
- Direct use of electricity is the key enabling technology in the short term. Electrification technologies like EVs, heat pumps or electric cooking are readily available and can be deployed at scale now, with significant increases needed by 2030. Renewables are the least-cost form of electricity in most markets, and electrification must be paired with build-out of clean electricity.

- Energy efficiency is a key measure and must more than double when viewed in terms of the energy intensity improvement rate to almost 3% per year, up from a recent historical range of 1.2-1.8% per year.
- Clean hydrogen, namely in the form of green hydrogen produced from renewable-based electrolysis, has a key role in certain challenging sectors, such as industry and shipping. Growth is expected in the near term to 2030, but most of the scale-up and use will occur in the 2030-2050 time frame; however, planning must begin now to enable end-use technologies utilising hydrogen, and expansion of infrastructure to produce, store and transport, and convert hydrogen to harness this potential.
- Not all energy-related carbon dioxide (CO_2) emissions can be avoided by 2050, therefore there is a need for some CO_2 to be removed and stored. This can be done using a variety of removal measures such as carbon capture and storage (CCS), and carbon capture, utilisation and storage (CCUS) or negative emission measures such as bioenergy with carbon capture and storage (BECCS), direct-air capture, reforestation and afforestation, among others.

To set a course on a 1.5°C-compatible pathway, the energy transition urgently needs to accelerate; therefore, a holistic, multi-faceted approach is necessary. This includes scaling up renewable energy, energy efficiency, related energy transition technologies and infrastructure, structural and behavioural change, and other measures. Investment in these solutions will also need to accelerate, and significant investment needs to shift from fossil fuels into energy transition technologies.

IRENA analysis shows that a combination of renewables (both power and end use, electrification and fuels such as hydrogen) and energy efficiency, can provide 80% of the CO_2 reductions needed to align the world on a 1.5°C pathway (see Figure 2.1).

Figure 2.1 Energy-related CO_2 emissions reductions by category in the 1.5°C Scenario by 2050



Source: (IRENA, 2022b).
Note: BECCS = bioenergy with carbon capture and storage; CCS = carbon capture and storage; CCU = carbon capture and utilisation; $GtCO_2$/yr = gigatonnes of carbon dioxide per year.

Energy intensity will need to improve and should be considered a first principle. Attention must be paid across the end-use sectors. In buildings major investments in energy-efficient renovation and electrification are needed. In transport, massive deployment of smart charging points for EVs - which are more efficient than internal combustion engines - will be needed in cities and along highways, along with investment in "avoid, shift and improve" principles. In industry, the best-available technologies and circular economy principles are required. Overall, the rate of energy intensity improvement must rise more than double current rates to as high as 3% per year, up from a recent historical range of 1.2-1.8%.

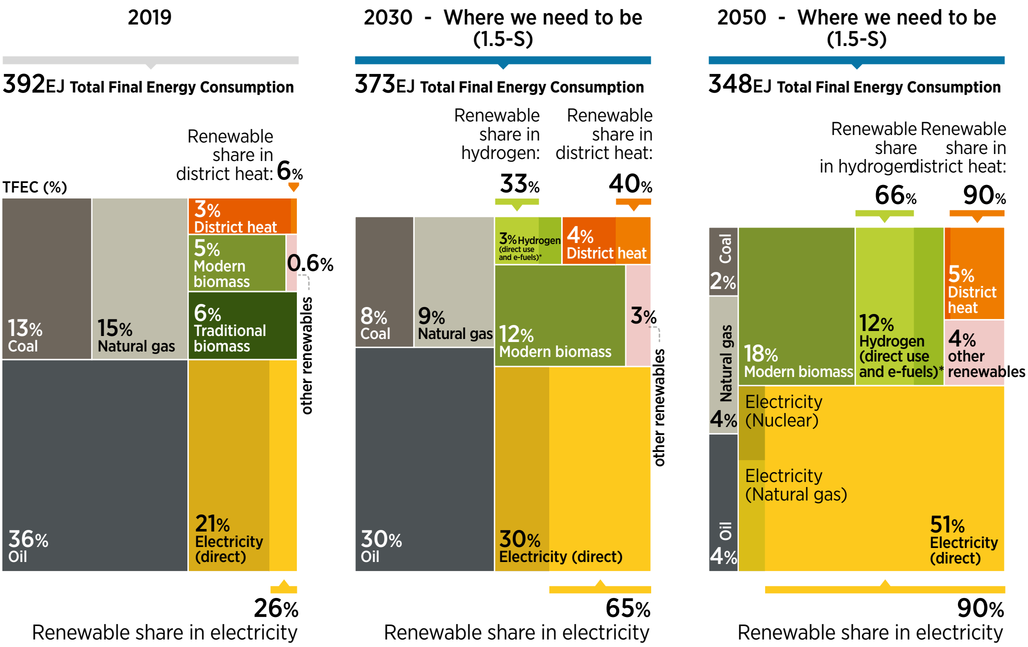
Electrification will be the key enabling solution for reaching 1.5°C. By 2030, global electricity demand will need to rise to in excess of 30 000 terawatt hours (TWh), and by 2050 to over 75 000 TWh. Renewables are to supply over half of all electricity by 2030 and as much as 90% by 2050, requiring thousands of gigawatts of new renewables-based generation capacity. For instance, just in the short term, offshore wind capacity will need to grow to 380 GW by 2030, an increase of around six-fold compared to the 58 GW that was in operation as of 2021. This upsurge will require annual additions averaging 35 GW per year in this decade, compared with just an average of 3 GW per year from the previous decade.

The stock of electric cars will need to grow significantly, from an estimated 10 million sold per year globally in 2022 to well over 100 million sold per year around mid-century.

Clean hydrogen and biofuels will play key roles. Clean hydrogen roadmaps and plans, new or modified infrastructure and implementation of projects must all accelerate. For instance, in the short term clean hydrogen will need to rise to 19 exajoules (EJ) of supply by 2030. It and its derivatives, such as green ammonia and methanol, would see their share of energy consumption increase to around 3% in final energy, from under 0.1% today. Sustainable use of biofuels is important in some sectors, such as industry, heating and certain transport modes. In industry, policy makers should dedicate special efforts to the cement, iron and steel, and chemical sectors. Dedicated policies and funds will be needed to accelerate the transformation of these sectors.

The share of renewables in the world's energy supply needs to grow sharply. Policy makers will have to place greater emphasis on the decarbonisation of end-use sectors. Renewable solutions will include direct and indirect electrification (*e.g.* via green hydrogen), end-use renewables, more efficiency and other measures. Figure 2.2 shows how the energy mix can transform in final energy from one that is predominantly fossil fuel based, to one in 2050 in which direct electrification comprises more than half, renewable direct uses and heat for over a quarter, and green hydrogen for 8% – all while reducing energy demand compared to 2019, largely due to energy efficiency measures, structural change and electrification.

Figure 2.2 Breakdown of total final energy consumption by energy carrier in 2019, 2030 and 2050 in the 1.5°C Scenario



Source: (IRENA, 2022b).
Note: 1.5-S = 1.5°C Scenario; EJ = exajoule; TFEC = total final energy consumption.

The transition will require a global commitment and all countries will need to play their part. The Group of Twenty (G20) must play an important role in catalysing action and securing concrete global commitments towards meeting the 1.5°C goal. The G20 represents the world's highest emitters today – and for many, the highest historic emitters, accounting for around 80% of global emissions. It is of particular importance that the four largest members of the G20 – China, India, the European Union and the United States – representing around 60% of global emissions must take action as their role is crucial.

2.2 DETAILED INVESTMENT NEEDS FOR THE TRANSITION

KEY MESSAGES

- To enable an energy system aligned with the 1.5°C target, investment in energy transition technologies and related infrastructure will need to rise to over USD 130 trillion by 2050 in the 1.5°C Scenario, complemented by a simultaneous redirection of investment away from fossil fuels. The bulk of investment will need to focus on renewable energy, energy efficiency, electrification and enabling infrastructure.
- Overall investment in the energy system will need to increase by about one-third to 2050 in the 1.5°C Scenario compared to the Planned Energy Scenario, led by higher initial investment needs for some energy transition technologies and their associated enabling infrastructures. However, savings in fuel costs generally results in lower overall energy costs. Therefore, the target of investment will need to shift towards higher upfront investment costs but lower overall energy costs in the longer term. Therefore, cost of finance is very important (see next chapter).
- Roughly half of the investment in the 1.5°C Scenario will be required in renewables – both direct use and on the supply side – and electrification, and a further one-third for energy efficiency. The remainder is split between investment in fossil fuels and CO_2 removal.

Funding the energy transition at the pace required to keep the world on a climate-safe pathway will require a substantial increase in investments over their current level, and over the level envisaged in governments' current plans (the Planned Energy Scenario [PES]). The climate-safe pathway will also require a reallocation of capital towards sustainable solutions, an even greater activation of the private sector and the expanded use of debt financing. The required shifts are entirely achievable. However, policy support in the energy sector and beyond remains crucial to keep the pace of the energy transition on track with global climate goals.

Sharp adjustments in capital flows and a reorientation of investments are necessary to align the global energy sector with the 1.5°C target. IRENA analysis shows that, up to 2050, over

USD 130 trillion[9] will need to flow into an energy system that prioritises technology avenues compatible with a 1.5°C pathway. Over 80% of the USD 130 trillion total must be invested in energy transition technologies, including efficiency, renewables, end-use electrification, power grids, flexibility, hydrogen and innovations designed to help emerging and niche solutions become economically viable.

The analysis also shows that cumulative investments of over USD 24 trillion should be redirected globally from fossil fuels to energy transition technologies in the period to 2050. This shift, plus increased investments in energy transition technologies, correspond to an increase in energy transition investments from USD 1.8 trillion in 2019 to USD 4.4 trillion per year until 2050. While the annual funding requirement is large – averaging USD 4.4 trillion – it represents 20% of gross fixed capital formation in 2019, which is equivalent to about 5% of global gross domestic product (GDP).

Current government strategies already envisage significant investment in energy amounting to USD 98 trillion by 2050. In the Planned Energy Scenario, investment needs alone require a 50% increase in annual energy investment, which in 2019 amounted to USD 2.1 trillion. Substantial funds will flow towards modernisation of ailing infrastructure and meeting growing energy demand. The breakdown of financing for technology under the 1.5°C Scenario, however, differs significantly from current plans.

Of the investment to reach the 1.5°C Scenario, around one-third is needed in energy efficiency, with a quarter required for renewables (power and direct use) and a little over one-fifth in electrification (Figure 2.3). These three areas will represent over 80% of the required investment, with the remainder largely channelled to solutions in fossil fuels.

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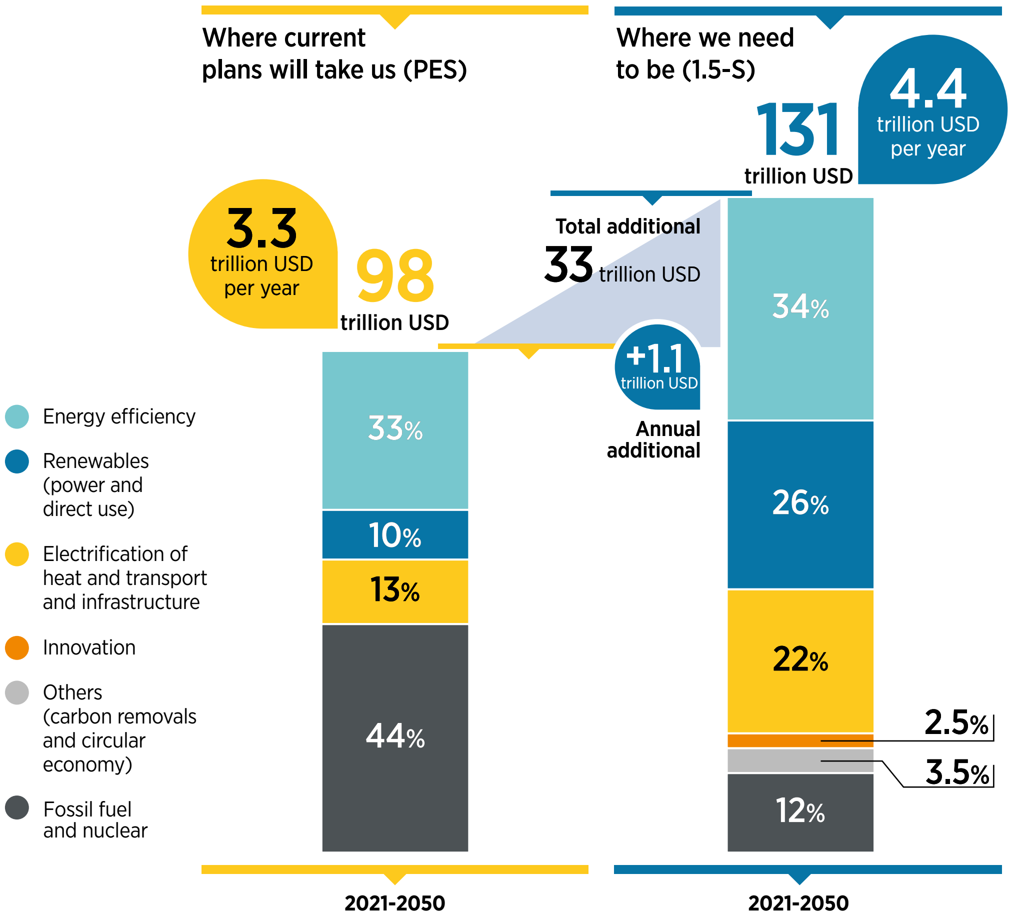
9 *This figure is consistent with the analysis conducted for the 2022 edition of the World Energy Transition Outlook. IRENA is in the process of updating this analysis for 2023, and initial previews of the results suggest this figure has increased. The final results will be released later in 2023.*

Figure 2.3 Total investment by technology, PES and the 1.5°C Scenario, 2021-2050



Source: (IRENA, 2022b).
Note: 1.5-S = 1.5°C Scenario; PES = Planned Energy Scenario.

The nature of investment needs varies by sector. In buildings, much of the investment is needed in energy efficiency - including retrofits to the building envelope, heating and cooling, efficient appliances and the requirement that new construction are generally at, or near, zero-energy standards. Investment is also required in heat pumps, solar thermal systems, clean cooking and other technologies.

Transport investments will need to focus on electric mobility in the road segment, including the adoption of EVs and related charging infrastructure. Energy efficiency measures would also account for a large share, and should adopt the "avoid, shift and improve" principle. Certain transport modes, such as aviation and shipping, will require investment in sustainable biofuels as well as green hydrogen and its derivatives.

Industry investments are diverse, ranging from efficiency using best available technologies, to principles of circular economy and direct use of renewables such as sustainable bioenergy. Clean hydrogen is also needed, the majority of which should be supplied via the green route, *i.e.* renewable-electricity-based electrolysis. Industry will also require some level of CO_2 removal.

Finally, on the supply side, significant investment is required in the power sector, which will need to become predominantly renewables based. This will require significant investment in renewable power capacity as well as related infrastructure such as grids and storage. For instance, investment in offshore wind must also scale considerably requiring USD 114 billion in investment per year to 2030 in capacity, along with significant additional investment in related grids and energy flexibility. Also on the supply side, investment is needed to produce and transport clean hydrogen, namely from areas with strong renewable power potential to areas of demand. Significant investment would be required in electrolyser capacity and hydrogen infrastructure averaging USD 133 billion per year to 2030 and higher sums in the longer term. More detail on the level of investment in select energy transition technologies can be found in Figure 2.4.

Figure 2.4 Annual average investments in energy transition technologies in power and end uses, historical and in the 1.5°C Scenario

Power

		Annual average investments USD billion/yr: Historical 2017-19	Annual average investments USD billion/yr: 1.5°C Scenario 2021-50
Power generation capacity	Hydro - all (excl. pumped)	22	85
	Biomass (total)	13	69
	Solar PV (utility and rooftop)	115	237
	CSP	3	84
	Wind onshore	80	212
	Wind offshore	18	177
	Geothermal	3	24
	Marine	0	59
Grids and flexibility	Electricity network	271	600
	Flexibility measures (*e.g.* storage)	4	133

Continues next page

End uses and district heat

		Annual average investments USD billion/yr	
		Historical 2017-19	1.5°C Scenario 2021-50
Renewables end uses and district heat	Biofuels - supply	2	87
	Renewables direct uses and district heat	31	84
Energy efficiency	Buildings	139	963
	Industry	45	354
	Transport	65	157
Electrification	Charging infrastructure for electric vehicles	2	131
	Heat pumps	12	102
Innovation	Hydrogen - electrolysers and infrastructure	0	116
	Hydrogen-based ammonia and methanol	0	45
	Bio-based ammonia	0	22
	Bio-based methanol	0	12
Carbon removals	Carbon removals (CCS, BECCS)	0	65
Circular economy	Recycling and biobased products	0	25

Source: (IRENA, 2022b).
Note: BECCS = bioenergy with carbon capture and storage; CCS = carbon capture and storage; CSP = concentrating solar power; PV = photovoltaic.

The G20 represents the largest economies globally, accounting for around 80% of global GDP. Countries in the G20 will not only need to significantly increase their own levels of investment in energy transition technologies, but will also need to help enable the scaling up of financing in developing and emerging economies. The G20 countries can also invest in learning to create the economies of scale needed in key emerging energy transition technologies to transition in certain challenging sectors.

CHAPTER 3
LOW-COST FINANCE FOR RENEWABLE POWER: MAPPING THE COST OF FINANCE FOR SOLAR AND WIND POWER PROJECTS

Drawing upon IRENA's insights on the cost of capital for solar and wind projects around the world obtained through surveys, this chapter discusses the relevance to the Group of Twenty (G20) countries. It covers approaches to assessing the overall cost of capital for projects; the importance of costs of debt and equity, as well as the share of each; the results for G20 countries (where available) of the survey for the cost of capital for solar photovoltaic (PV) and wind power; drivers of low-cost finance and high-level implications for policy makers.

KEY MESSAGES

- The costs of financing for renewable energy projects play an important role in project development and vary depending on a number of factors such as financing structure, technologies and market conditions, as well as country risk premiums. Mapping and understanding the drivers behind financing costs and conditions are therefore crucial to gaining insights regarding differences by technology and country, for instance, in terms of financing costs. Given the capital-intensive nature of most renewable power generation technologies and the fact that fuel costs are low or often zero, the weighted average cost of capital (WACC) used to evaluate the project - often also referred to as the discount rate - has a critical impact on the levelised cost of electricity (LCOE).
- Over time, an assumed WACC used for analysis and modelling could change. Having more accurate WACC assumptions is therefore critical in terms of understanding and estimating renewable energy cost of capital.
- The insights drawn from IRENA's survey for the cost of capital for solar and wind power show that variations across countries are influenced by such key factors as cost of equity and debt, as well as debt-to-equity ratios. More work would be required to survey stakeholders on the drivers of the differences in these factors between markets to inform policy makers on potential courses of action to unlock greater access to low-cost financing.
- Policy makers shall consider various models for renewable energy projects integrating tailored grants, equity, debt, mezzanine financing, refinancing mechanisms, green bonds, guarantees or other de-risking instruments, *etc.*

The cost of capital for renewable power generation

The cost of capital (CoC) for renewable power generation technologies is a very important driver of total costs. The CoC is a major determinant of the cost of electricity from renewable power generation technologies. For instance, for a representative solar PV project or onshore wind project, the total cost of electricity (LCOE) increases by 80% if the CoC is 10% rather than 2%. Access to low-cost finance reduces the cost of energy to consumers and unlocks the potential for greater deployment. The CoC for a renewable energy project will differ based on a range of different drivers, the three most important of which are:

- The country where the project is located: the so-called "country risk premium" represents the general cost over a risk-free rate (usually the cost of borrowing of the US government) due to country political, institutional and regulatory risks. These can be a major driver of CoC differences.
- Off-take risk: Where the revenues of a project are secured through a bilateral contract of some sort, the investors' perceived risk in relation to their ability to pay will influence the expected rate of return. This can also be influenced by regulatory risks, where the off-taker is a public entity. Where international developers are involved, exchange rate risk also has an impact, although hedging can mitigate this risk, at a cost.
- Technology risk: Different technologies have different risk profiles, based on the technology maturity, the level of experience to date in specific markets, the developer's experience and also with respect to resource confidence (*e.g.* the extent to which on-site solar irradiation data is available), although this latter factor is not as important as it once was, thanks to the growth in global experience.

Other factors are also important, including the size of the domestic financial market (and its depth), developer experience, transmission access and cost allocation rules, *etc.* Construction risk also remains important for offshore wind, hydropower, geothermal and concentrating solar power, but is not a major driver of risk for solar PV and onshore wind.

As a result of the differing CoC drivers, individual projects of a specific technology in a given country might be expected to vary, while variations between countries and technologies could be larger.

Given the crucial nature of access to low-cost finance in achieving the required mobilisation of capital to support the energy transition, understanding the current CoC and its drivers is vitally important for policy makers, energy researchers and energy modellers. Understanding which markets and technologies are exposed to higher costs of capital allows stakeholders to identify where problems might arise, and investigate what is driving higher costs of capital in different markets and for different technologies. This can then allow industry and policy makers to work together to identify the policies and actions needed to allow low-cost capital to flow to the investment needs of the energy transition in a timely manner.

Given that reliable, differentiated financing data by country and technology has not been readily available to stakeholders, despite the vital importance of the CoC to calculating the cost of energy, IRENA, together with International Energy Agency (IEA) Wind and ETH Zurich, undertook a survey to collect reliable data for individual countries across all regions.

3.1 COST OF CAPITAL FOR SOLAR AND WIND POWER PROJECTS IN 2021

The survey results yielded a cost of capital range of between 1.1% and 12%. The CoC values for 2020-2021 revealed by the survey ranged from a remarkable minimum of 1.1% for onshore wind in Germany, to over 12% for solar PV and onshore wind in Ukraine (Figure 3.1). Other countries with a high CoC include Mexico, Egypt and Tunisia. Values for onshore wind peak at 12.2% in the Ukraine, and for offshore they peak at 8.1% in Viet Nam.

The simple average of the regional CoC from respondents for utility-scale solar PV was 3.9% in China, 6.1% in other Asia-Pacific, 4% in Western Europe, 7.7% in Eastern Europe, 8.7% in the Middle East[10] and Africa, 6.6% in Latin America and 5.4% in North America.

The simple average of the regional CoC for onshore wind was 3.0% in China, 7.2% in other Asia-Pacific, 3.3% in Western Europe, 7.2% in Africa, 6.4% in Latin America and 5.1% in North America.

The simple average of the regional CoC for offshore wind was 2.8% in China, 7.1% in other Asia-Pacific, 4.2% in Western Europe and 5.2% in North America.

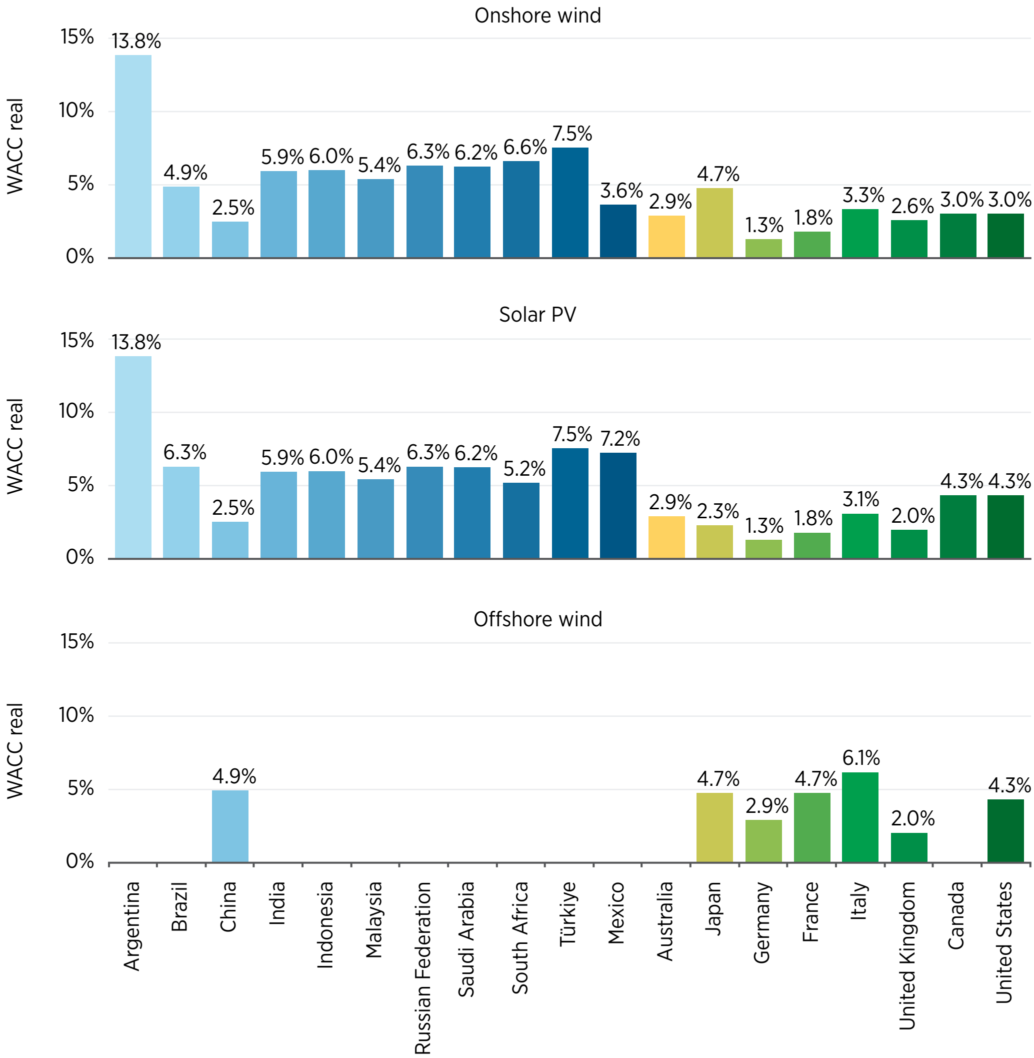
IRENA then used these survey results to calibrate a benchmark model of the cost of finance for utility-scale solar PV, and onshore and offshore wind, for projects commissioned in 2021.[11] The results are presented in Figure 3.1 for the G20 countries.

The importance of the country risk premium in determining the CoC can be seen by the generally higher CoC for solar PV and onshore wind projects in the non-OECD (Organisation for Economic Co-operation and Development) members of the G20. Interestingly, there is not the same variability for offshore wind, although the markets for offshore wind are fewer and important CoC differences remain between offshore wind markets.

[10] *The average reflects the fact that no respondents offered COC estimates for the Gulf Council countries, which have dramatically lower borrowing costs and very competitive markets for new PV capacity auctions that in turn place significant pressure on lending and equity margin expectations.*

[11] *See (IRENA, 2022a) for more details on the methodology.*

Figure 3.1 Benchmark average cost of capital by technology for projects commissioned in 2021



Source: (IRENA, 2022a).
Note: Benchmark WACC values are derived from capital market data, but have been calibrated with the IRENA survey results of finance sector experts. PV = photovoltaic; WACC = weighted average cost of capital.

Important considerations when assessing the benchmark cost of capital data

Project finance data are almost always proprietary in nature - even when public financing is secured – so few options have been available to collect CoC data. IRENA's survey has been instrumental in providing new CoC benchmarks given the improvement in overall financing conditions (*cf.* lower interest rates) and the risk premiums for renewable energy technologies in particular in the past decade, whether due to support schemes and/or technology maturity.[12]

IRENA and its partners conducted the surveys based on a single specific CoC metric, which is most relevant for investors and policy makers; namely the nominal "cost of capital after tax", often also referred to as nominal "post-tax WACC" (Equation 1). The terms K_D and K_E denote the cost of debt and the cost of equity, respectively; L denotes the leverage (or debt share) and T denotes the tax rate.[13]

$$CoC = K_D \times L \times (1 - T) + K_E \times (1 - L) \quad \textit{(Equation 1)}$$

These rates are expressed in nominal terms here, meaning that they are not adjusted for inflation. Respondents noted a mix of solutions, financing in local currency, US dollars or euros. IRENA and its partners conducted an online survey and semi-structured interviews with finance sector experts, banks, financial intermediaries, project developers and financial advisors in order to obtain CoC data for solar PV, and onshore and offshore wind power generation technologies for 45 countries on six continents.

Some important findings were that:

- Almost 9 out of 10 (88%) of responses discussed projects that were financed via the "project finance" route, with 6% financed from the developers' balance sheet and another 6% via other routes.
- Around half of the responses noted that the project included some kind of merchant exposure. In some cases, this was limited to exposure to market after long-term (20-25 years) fixed-price contracts-for-difference (CfDs), but in other cases project developers had to "go to market" prior to financial close to find corporate off-takers for much shorter tenures.
- Revenues are secured by a range of mechanisms. With upfront capital costs dominating the cost of electricity, renewable power generation projects typically need to demonstrate that they have secured sufficient revenues over an extended period of time (typically less than the economic lifetime, however) to be able to access finance on reasonable terms. The means by which these revenues were secured varied, but were predominantly power purchase agreements (PPAs), which can be with governments (or government-backed financial vehicles to provide a de-facto sovereign guarantee), utilities or corporate buyers; feed-in tariffs (FiTs) and contracts-for-difference (CfDs).

On this last point, the contractual details of all these approaches to securing revenues can vary in important ways, including their duration, pricing arrangements (*e.g.* nominal or indexed to inflation, capped or uncapped, currency of payment, penalty clauses, *etc.*), volumes, responsibilities relative to the market, *etc.* See: (IRENA *et al.*, 2020) for more

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12 *For more information about the survey methodology and results, see (IRENA, 2023d; and IRENA, 2022a).*

13 *For a more detailed discussion of the components of the cost of debt and equity see Annex I.*

details. The responses most commonly mentioned by respondents for securing revenues were: PPA (43%) with either a government entity or corporate buyer as off-taker, followed by FiTs (22%) and CfDs (14%). There is also an emerging complexity in the structure of off-take arrangements, with CfDs or government PPAs covering a portion of the plant's output and merchant exposure anticipated to be hedged with corporate PPAs. Given that corporate or utility PPAs tend to have shorter durations than those provided by governments, this portion of the output might need to be offered to the market more than once over the lifetime of the asset.

Implications for policy makers from the survey of the CoC include:

- A major CoC determinant is the macroeconomic environment, such as the prevailing risk-free interest rates. Interest rate rises in 2022 will undoubtedly have an impact on CoC for new projects being financed in 2022 and in 2023. However, it remains to be seen to what extent this impacts the average CoC for projects that will be commissioned in 2023 and 2024. Additionally, the higher CoC in 2023 is unlikely to reduce the competitiveness of renewables in markets where natural gas prices and thermal coal prices remain at elevated levels.
- Experience in financing and standardisation matters. Across many markets, capital seems abundant and sound projects have not had difficulty securing financing in recent years - in part because of new capital providers (*e.g.* pension funds) increasing the availability of funds. This trend has reduced the CoC for renewable power projects. This has not been exclusively an OECD trend but efforts to ensure the benefits of this pass through into as many markets as possible warrant greater examination.
- The impact of the variation in risk between projects and (to a lesser extent) technologies tends to be captured primarily in the debt share available to projects, that is to say less risky projects have higher debt ratios. To a lesser extent, higher risk is reflected in the cost of equity, and even less frequently in the cost of debt, which is often relatively standardised within a market. Given that risk varies between countries and technologies, and debt is lower in cost, further work is warranted to examine how to ensure risks are minimised and the debt share maximised in emerging markets.
- For the cost of debt, differences in the country risk seem to be the primary distinguishing factor. In practice, this means investment decisions are structured around the level of debt that the project risk profile can support - from the financier's perspective. Then, the target rate of return on equity is scaled to reflect the risk profile the developer expects, but is also influenced by what the market will support in terms of overall electricity cost. It is clear that a stable regulatory environment is beneficial to achieving a low CoC.
- Development banks can lower the CoC significantly. In the early stages of emerging markets and many low-income countries, financing is usually facilitated by multilateral development banks. Sovereign guarantees are either unavailable, or do little to reduce risk. In contrast, the merchant components are relatively small, if present at all. De-risking policies can therefore be very important (via grants, concessional finance, off-take guarantees, exchange rate insurance, *etc.*), lowering the CoC and reducing insurance costs. In developed markets, public investment and development banks have also played a large role, such as the Kreditanstalt für Wiederaufbau (KfW).

- Funding from public and concessional sources is, however, scarce and therefore needs to be used intelligently to "crowd in" the maximum amount of private sector sources of capital as possible.
- Mature markets, with good investment climate, supportive policy frameworks, stable regulatory environments and financial systems, and with extensive experience of renewable energy projects, can see very high debt shares, allowing some of the very competitive CoC results observed (*e.g.* in Western Europe) given the exceptionally low-interest rate period in 2020-2021.
- More work is required to identify exactly what factors are driving differences in the cost of debt and equity between different markets beyond country risk premiums, and would be beneficial in crafting policies to ensure the lowest practical cost of finance for projects.

CHAPTER 4
ENABLING INNOVATIVE FRAMEWORKS TO ACCELERATE THE DEPLOYMENT OF NEW AND CRITICAL LOW-CARBON TECHNOLOGIES

Innovation has played a primary role in the cost reductions for the renewable energy technologies highlighted in Chapter 1, as well as in their market penetration. Innovative solutions have focussed on not only technological developments but also new business models or system integration approaches. They can also play a key role in minimising the cost of financing for renewable energy projects and technologies that facilitate the energy transition (*e.g.* battery storage and hydrogen electrolysers). This can in turn ensure that the technologies needed to reach the decarbonisation goals by 2050 are seeing adequate flows of the required investment, discussed in Chapter 2.

Given the wide scope of innovations and their potential benefits, this chapter explores challenges in defining effective innovation frameworks that can accelerate market deployment of new and critical low-carbon technologies for the energy transition. Innovation frameworks consist of co-ordinated sets of actions and activities to support the market development of a targeted technology via policy, standards and regulation, business models and complementary infrastructures. They can be present at any stage of technology deployment, from incipient research and development (R&D) activities to market- and finance-enabling processes. They can reduce the transaction costs of technology transfers, facilitating foreign direct investments or the creation of local private ecosystems. Innovation frameworks are thus one of several essential areas that need to be supported to achieve stable technology market conditions, reduce investor risks and associated high rates of returns, and ultimately lower the financing cost for the energy transition.

One example of an innovation framework is the Enabling Measures Roadmaps for Green Hydrogen for Europe and Japan. The framework is developed through the World Economic Forum's Accelerating Clean Hydrogen Initiative and IRENA's Collaborative Framework on Green Hydrogen. Some of the key activities under this initiative include the identification of barriers and related enabling measures to scale up hydrogen markets, the identification of innovation priorities and the creation of a forum for relevant stakeholders to share knowledge and learn from each other (IRENA and WEF, 2021).

KEY MESSAGES

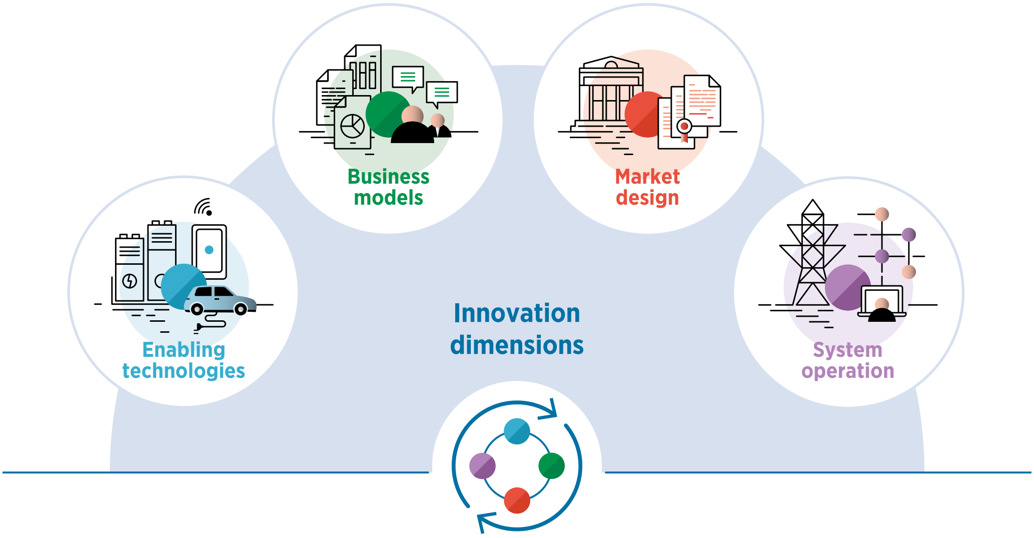
- For a technology to gain market share, it is crucial to develop policies, formulate standards and regulations, and promote collaborative efforts between relevant stakeholders.
- The key challenges for low-carbon technologies can be addressed by designing **co-ordinated sets of actions and innovations across four dimensions**: *enabling technologies, business models, market design and system operation*.
- The role of the dimensions varies based on technology development. Assessment of the three technologies covered in this chapter (solar PV, offshore wind and green hydrogen) reveals different innovation needs.
- **Solar PV market design and business model reinforcement:** As the most mature technology, solar PV requires support to ensure a self-sustained market[14] in cases where public support is limited. This includes aspects such as grid access, grid management, smart grid models, rural electrification, capacity building or techno-economic guarantees for new business models.
- **Offshore wind market design and regulation:** Speeding up project development, especially the permitting process, is the pivotal aspect. Innovation in this area would significantly reduce the time to implement a project and accelerate technology deployment.
- **Hydrogen market design and business models:** A harmonised definition of green hydrogen (*hydrogen taxonomy*) is essential for creating a market. Additionally, it is critical to have a single, global, transparent and reliable system for certifying hydrogen production. Such a system should be established to support the investment decision-making process for green hydrogen projects and related initiatives.

This chapter focuses on three low-carbon energy technologies (solar PV, green hydrogen and offshore wind) representing different levels of maturity. Figure 4.1 presents the dimensions for a systemic innovation approach.

The discussion on solar PV focuses on past measures that enabled its deployment, as well as how to self-sustain a mature market. For green hydrogen and offshore wind, focus is on current and future challenges. The discussion investigates the following key dimensions: enabling technologies, business models, market design and system operation.

[14] *A "self-sustained" market is defined as one that does not require public support. In such markets, the public role is limited to ensuring adequate functioning and transparency of the market.*

Figure 4.1 Innovation dimensions under the systemic innovation approach



Source: (IRENA, 2019).

For each technology that the chapter focuses on, it discusses the most relevant dimension in detail, giving examples of measures taken by the Group of Twenty (G20) countries. This requires identifying barriers and technology objectives first. With these inputs, dedicated alternatives are presented, including relevant information across the four dimensions indicated above. The combination of technologies allows us to draw on the lesson learnt from PV, which can serve as a valuable overview input for addressing the challenges that lie ahead for offshore wind and hydrogen.

4.1. LESSONS LEARNT ACROSS ALL FOUR INNOVATION DIMENSIONS FOR PV TECHNOLOGIES

For solar PV, innovations in technology and business models have evolved together with reduction in technology cost (Figure 1.2). This has not only accelerated technology adoption but also influenced policy initiatives implemented by governments. From a general point of view, efforts on innovation in solar PV have been, and continue to be, determined by the following pillars:

- Definition of medium- and long-term targets for PV development
- Design of sustainable financial support mechanisms
- Targeted efforts to reduce PV costs and improve performance to help define the R&D agenda
- Actions for electricity system upgrades to incorporate large shares of PV production (*i.e.* transmission and distribution networks)

The above four areas are a result of a SWOT (strengths, weaknesses, opportunities and threats) analysis for PV technologies and include aspects that can evolve from threats to opportunities depending upon the specific context – for example, fossil fuel price. In the context of high fuel prices, *i.e.* the 1970s oil crises or the instability of natural gas supply in 2022, solar PV has made significant progress. In the 1970s, many countries adopted R&D programmes with the aim of making PV systems commercially available (*enabling technologies dimension*). Today, rooftop and utility-scale PV markets have grown significantly as solutions to reduce the impact of high fossil gas prices (*market design and business models*) (Hyun Jin Julie Yu, 2016).

Innovation priorities for PV technologies have been defined based on the combined evolution of demand-side (*consumers*), supply-side (*industry*) and R&D policies. Consequently, the development of national PV markets has been accompanied by mechanisms to provide support in these three areas to achieve long-term energy targets. Historically, industry has received support through financial mechanisms including grants or cash incentives, whereas on the demand side, feed-in tariffs (FiTs) have been a primary instrument. Meanwhile, R&D has followed a classic linear innovation model, moving from R&D investments to demonstration and commercialisation.

International players have adopted different strategies for the three elements of R&D, supply side and demand side. These strategies explain the role of different innovations in recent decades. The strategies followed by some G20 Members, along with their results, are explored below.

What can be learnt from the PV experience?

Different G20 Members have adopted different strategies to foster investment in low-carbon energy technologies. While Germany and Japan were pioneers in setting up an internal ecosystem including R&D, supply and demand, China opted for a strategy that focussed on building an export-focused industry (Hyun Jin Julie Yu, 2016). However, these approaches evolved over time depending on the specific context. This is the case for China, which promoted the domestic market to level out lower international demand. Other general aspects, such as fossil fuel prices, can also modify the definition of enabling frameworks.

In summary, the solar PV experience is defined by rapid changes depending on the status of technology, mostly in terms of cost. Pioneering countries that contributed to technological maturity faced fierce global competition, resulting in other countries taking the lead. For these pioneering countries, the lack of competitiveness with the countries of the *second wave* has resulted in significant economic losses. This was the case of Germany, but also other countries, such as Spain, which dedicated considerable economic resources to accelerate the internal demand, setting FiT schemes that led to unaffordable windfall profits. Furthermore, some markets suffered job losses because imports cost less than national production. In other cases, to address the lack of competitiveness, countries set up market barriers via standards and certification to reactivate the demand for local PV manufacturers. In yet other cases, the national industry took a strategic decision to focus on highly skilled sectors, such as silicon refining or equipment production, to offset decreases in competitiveness in more mature sub-sectors.

In addition to strategic decisions on competitiveness, it is fundamental to implement consistent policies to capitalise investments in R&D, as well as in the supply and demand sectors. This will help to facilitate the decarbonisation of energy systems and achieve economic development. Today, the competitive prices of PV require enabling frameworks that facilitate business models, including establishment of energy communities (defined as collective and citizen-driven energy actions to achieve energy independency, reduce carbon emissions and fuel poverty, as well as contribute to the local economy) and the provision of guarantees for power purchase agreements. Those are the final steps in the classic linear innovation model. R&D efforts should nevertheless continue to keep improving efficiencies and reducing costs.

Box 4.1 Key messages for PV: Public support

- Today, solar PV is a readily available and mature technology, which is cost competitive as a replacement for fossil-fuel-based technologies. However, significant potential remains untapped.
- Before achieving competitiveness, governments set up mechanisms to support R&D activities and investments. In some cases, these measures were not properly designed and led to unstable policy frameworks.
- After achieving competitiveness in an individual market, support should shift towards facilitating a self-sustaining market, where financial support is replaced by more important aspects, such as grid strengthening to maintain ongoing new access opportunities, grid management and opportunities for new business models and actors to sustain deployment on the path to very high shares of solar and wind.
- Market deployment of solar PV is centred around the smart operation of electricity supply based on digital solutions. Grid management and flexibility sources should be the focus of the enabling framework for the years ahead.
- Cost reduction targets should receive continued attention, given they are a key element of the enabling framework for solar PV. However, this will require further data collection and detailed analysis, due to the importance of grid integration at very high shares of solar and wind.
- As PV technologies provide greater geographical coverage, rural electrification and capacity building will become the cornerstones of an enabling framework for this technology.

Box 4.2 Delivering global energy transition infrastructure

IRENA's *World Energy Transition Outlook* highlights the importance of enhancing capacity across the full spectrum of infrastructure required to ensure the success of the global energy transition. Transition infrastructure comprises a multitude of areas in which progress must be made to achieve the 1.5°C target, from physical infrastructure, financial systems, and international trade networks and regulations, to knowledge generation, innovation, and both human and institutional capacities. Combined progress in these areas will serve to set the foundations of an international ecosystem that both facilitates the transition to, and sustains, a sustainable global energy paradigm.

These vital physical and institutional foundations must be approached holistically in order to support the efficient integration of an increasing share of variable renewable energy in the global power mix, and ensure deployment growth occurs without delay. IRENA considers transition infrastructure in a way that includes much more than the physical capacities required to deploy more renewable power generation, upgrade existing power system infrastructure, implement smart grids and ramp up domestic manufacturing facilities for key components; it also encompasses vital capacities in the areas of policy making, regulation, trade, and human capital and skills, as well as new institutional architecture.

The recent reforms to the permitting process for renewables within the European Union are a case in point, as they are necessary to complement the physical infrastructure development required to decarbonise electricity and utilise green hydrogen in the region.

Leveraging institutional capacity among financial institutions represents another key aspect of transition infrastructure that is vital to achieving a renewable-powered future. Low-cost capital availability is essential to the implementation of energy transition projects; new institutional structures are therefore required to rationalise risk assessments, provide more investor certainty, and more effectively manage the real or perceived risks associated with energy transition projects among investors.

Another vital component of transition infrastructure is the enhanced international architecture required to ensure the global energy transition is delivered in an inclusive, just and equitable way. This includes governments ensuring the energy transition has the framework, means and capacities to address energy poverty challenges, create new, quality job opportunities, equip human capital with appropriate skill sets, and sustain the resultant economic development in a climate-safe way.

To achieve these goals, international cooperation must be strengthened across the public and private sectors, and the collaborative efforts of international organisations ramped-up, in order to assist those countries around the world that require the most support to build their capacities. This, in turn, will serve to underpin efforts to achieve an equitable and sustainable global energy transition.

4.2. ENABLING INNOVATION MATRIX FOR OFFSHORE WIND AND GREEN HYDROGEN

Enabling innovative frameworks or matrices can lead to significant reductions in the financial cost for low-carbon technologies. Among others, they can help demonstrate cost reduction potential, better shape the role of public support as well as public-private co-operation, showcase successful experiences or mitigate financial risks. Here, we focus on two key technologies for the energy transition - offshore wind and green hydrogen - and examine a specific challenge for each of them: market design and permitting dimension for offshore wind, and market creation in the case of hydrogen.

4.2.1 Speeding up offshore wind projects: Market design and permitting

Offshore wind is a valuable alternative to cost-effectively provide electricity to densely populated coastal and inland areas. This is due to the offshore location of the installations, their high energy output per square metre and their ability to quickly scale up to gigawatts. Developments in turbine technologies, as well as foundations, installation, operation and system integration, have made possible the move into deeper waters farther from shores, reaching sites with greater energy potential. Over the past 5-10 years, offshore wind has matured into a technically proven and competitive solution, making it the most advanced technology among offshore renewables (IRENA, 2021b).

From an enabling technology perspective, wind turbines have been increasing in size and rated capacity due to continuous R&D and the increasingly clear economic advantages of larger turbines. Recent projects have average turbine sizes of 8-9 MW, but new turbines with higher-rated capacities exist – a 15 MW prototype is being tested and has already been announced for production by 2024. With regard to foundations, fixed forms have been dominant and can be deployed cost-effectively up to a depth of 60 metres in water. Floating foundations have been gaining traction given they can be deployed at depths of above 60 metres in water. These foundations could also be applicable for turbines, even for medium-depth sites (30-50 metres). There are continuous R&D efforts to produce wind turbines with higher power generation capacities and greater efficiency. IRENA has reported increasing weighted average capacity factors for projects commissioned in Europe over the period 2010-2021, moving from 39% to 48%. This trend is observed in other regions but at different pace. For example, the weighted average capacity factor for projects commissioned in China in 2021 was 37% (IRENA, 2022a).

While offshore wind has witnessed positive trends that support project deployment, there are challenges that hamper the realisation of such projects. A key challenge in this regard is the need to speed up permitting schemes for offshore wind projects. The challenge has been identified through consultation with countries and stakeholders.[15]

Permitting, which falls under the market design dimension, refers to the environmental and administrative permits to install and operate offshore wind projects. In most countries, the first step in permitting is generally to obtain a license to conduct preliminary investigations, followed by several other permits: permit for seabed leasing, authorisation to exploit the energy source or generate electricity, a grid connection agreement and permission for any work that should be done onshore to support the installation of offshore turbines (ETC, 2023).

Permitting follows two major approaches: (1) a centralised (one-stage) model, wherein governments have full discretion in the Environmental Impact Assessment (EIA), site feasibility (geographical/geotechnical surveys), stakeholder engagement and consent

[15] *This is also true of onshore wind in many markets.*

for offshore wind development; and (2) a decentralised (two-stage) model, which gives developers an opportunity to participate in the processes. Both approaches are valid, although the choice is largely determined by the political, fiscal and cultural backdrop within a country.

There are a few **key barriers** to address within permitting. Some of them are as follows:

- **The different types and numbers of permits needed to secure an offshore wind project site.** On average, a minimum of seven permits are required. For example, in the Republic of Korea, permits include EIA, an occupancy implementation plan, a marine traffic safety examination, a cultural heritage survey, onshore permits for onshore facilities and construction plan approval.
- **The long and elaborate permitting process results in many projects getting stuck in the pipeline.** Projects take an average of 2.25 years to secure consent after submitting their plans. In some cases, this can be up to 9.5 years. For example, in Japan, the complex EIA alone can take up to 8 years to complete.
- **Delay in project implementation due to opposition by environmental groups.** This challenge largely arises due to the public perception of offshore wind projects and the environmental concerns raised by environmental associations or climate groups surrounding them. Prolonged legal battles often result, due to concerns surrounding biodiversity, bird life, endangered marine life and habitats, all of which may be indirectly impacted by services posing potential hazards to the local ecosystem. For example, in the United Kingdom, the Norfolk Boreas offshore wind farm received written opposition from 85 parish councils claiming the onshore cable route required for the project would be disruptive to their homes. The decision regarding consent was delayed by five months and further delays occurred due to COVID-19 lockdowns.

Given below are a few suggested **potential solutions** to speed up permitting processes:

- **Establishing dedicated centralised authorities and single focal points that can work with offshore wind developers to streamline the siting and permitting process.** The adoption of a single contact point or one-stop-shop model is a key solution to a more streamlined permitting process, which is fairer, more transparent and more efficient. Such a process can be made possible by having a single contact point in the administration to co-ordinate all relevant authorities. For example, in the European Union, the Renewable Energy Directive, REDII, requires Member States to designate a single contact point ("one-stop shop") for granting permits. This contact point covers the operation of renewable generation assets. As another example, in South Korea, a new licensing system (including a one-stop-shop approach) was introduced with the aim to reduce the period for project development by more than two years.
- **Promote active dialogue between local authorities, communities and industry for shared understanding of priorities during the consenting and construction stages of wind projects.** Active dialogue between communities and industry throughout a wind project's life cycle will be beneficial for local stakeholders during the consenting process. Local communities can provide additional information, which can help to de-risk offshore wind projects. Through active dialogue, governments can manage

offshore wind projects in a manner that recognises all users and balances competing interests. For example, WindEurope, the European association for the promotion of wind power, sees the involvement of communities as key to creating acceptance and support for wind projects.

- **Mandated maximum lead times to grant permits to offshore wind energy plants, for example, three years for offshore wind projects, with additional discretionary time allowances under extraordinary circumstances.** Mandated lead times are necessary because they can help to prevent prolonged litigation and reduce government bureaucracy, resulting in efficient processing of applications. In December 2022, the European Union issued new rules, under which Member States must speed up permitting for all new wind energy projects. They must now grant permits to repowering projects within six months, including the EIA and grid permits. If repowering results in a capacity increase of less than 15%, the grid connection should be permitted within three months.

Another challenge to address is the low utilisation of Maritime Spatial Planning (MSP) to support the effective use of offshore resources. MSP brings together all ocean users from energy, industry, government, regulation, conservation, protection and recreation to formulate best practices and devise optimal decisions on how to use marine resources efficiently. For example, Belgium has been a pioneer in integrating offshore wind in MSP. Its 2014-2020 MSP allowed for the allocation of 7% of the country's territorial waters for developing and deploying offshore wind projects. Furthermore, Belgium's new marine spatial plan for 2020-2026 provides a useful example of how the country unlocked 2 GW of offshore wind potential in a densely crowded marine area through a multiple-use approach (IRENA, 2021b).

Regarding critical infrastructure, grid connectivity should be given due consideration. There have been calls to consider investing in joint power transmission lines across political borders. For example, transmission system operators from Denmark (Energinet) and Germany (50 Hertz) will jointly operate a hybrid offshore asset comprising two wind parks – one located in each country – using a 400 MW joint cross-border interconnected transmission line. New power transmission high-voltage direct current and DC technologies should also be considered that can increase grid flexibility and make it more manageable, enable the integration of a higher share of renewables in the grid, and minimise power losses (Elia Group, 2022). For example, the UK's Dogger Bank Wind Farm will have a 2.6 GW high-voltage direct current system, which will be developed over three phases in 2023, 2024 and 2025.

In summary, for mature technologies such as fixed-bottom offshore wind, the lack of transparent goals and fit-for-purpose regulation are the primary obstacles to investment and project development. Clear and long-horizon policy frameworks for offshore energy technologies will send a positive signal to private developers, research institutions and financial actors. **Focusing on policies that improve permitting protocols, promoting the use of MSP and allowing for investments in critical grid infrastructure will significantly accelerate the adoption of offshore wind solutions globally and among the G20 Members in particular.**

Box 4.3 Speeding up offshore wind projects: Key messages

- A major bottleneck to faster deployment of offshore wind projects relates to long permitting processes. Some of the key challenges that hamper the permitting process include the variety of permits (seven per project on average) to be acquired before a project's initiation and the long permitting lead times required (2.25 years on average), which restrict many projects to their pipeline phase.
- There is a need for increased focus on developing advanced regulatory frameworks for maritime spatial planning and to avoid conflict of use.
- It is important to develop joint projects that establish cross-border infrastructure, especially offshore grids.
- The private sector must be consulted on regulatory developments, especially in the context of tendering and permitting processes.
- Innovation in permitting can minimise project delays. An innovative solution that has gained traction in the discussion is the development of energy islands, such as those in the North Sea.
- In most North Sea countries, site selection and pre-investigation are undertaken by public authorities, and the costs for onshore connection are borne by the transmission system operator. This reduces expenses and risks for project developers. Auctions should be the default support mechanism for new offshore wind installations.

4.2.2 Creating a hydrogen market: Market design and business model dimension

Green hydrogen is widely acknowledged as a key energy vector for countries to achieve carbon neutrality by 2050. It is to play a key role in hard-to-decarbonise sectors such as industry. According to IRENA's 1.5°C Scenario, described in the *World Energy Transitions Outlook*, green hydrogen and its derivatives will need to account for 12% of final energy use by 2050, and together with electricity, it will need to represent 63% of final energy consumption. Achieving decarbonisation globally will require installing 5 000 GW of hydrogen electrolyser capacity by 2050, compared with only 0.3 GW of installed capacity in 2020.

From a broad perspective, the innovation dimensions for hydrogen, as with any other technology, can include aspects such as enabling technologies, market, business models and system operation. Some of these aspects were already discussed for wind and solar PV.

Several barriers impede green hydrogen's full contribution to the industrial sector. These barriers include cost, technical barriers, policy-related barriers, lack of demand and carbon leakage risk. Policy makers can adopt industrial policies that address barriers and oblige or support a shift away from fossil fuel dependency for hard-to-abate sectors.

For hydrogen, the enabling technologies dimension is, to some extent, addressed – or, at least, to the extent that allows market creation – since green hydrogen production is based on mature technology, namely, electrolysis. Yet, the technology would be more affordable, and confidence would be increased, through R&D efforts to improve electrolysers' performance or support the deployment of pilot projects.

Concerning the market dimension, the 2050 carbon neutrality targets set a certain level of hydrogen demand for the coming decades. However, challenges such as identification of high-value applications, policies to accelerate fuel shifts in industry or targets for trade facilities are yet to be defined and implemented more clearly.

Cost and infrastructure are other critical components of the enabling framework for hydrogen. With decline in renewable power generation costs and faster deployment of renewable generation, green hydrogen could become a major energy transition tool. However, further reductions in renewables' costs, as well as improvements in the costs of electrolysers and the balance of plant costs, are needed. Also required are financial mechanisms to support both supply push and demand pull. Options include implementing carbon contracts for differences or phasing out free Emissions Trading System (ETS) allowances for grey hydrogen.

Still, one of the most significant challenges faced by hydrogen today is the necessity to cultivate certainty among market participants via electrolyser and green hydrogen standards and certification. Today, grey hydrogen produced from fossil fuels dominates the market (98%). This means that for green hydrogen to gain relevance, markets must incorporate tracking instruments that guarantee the origin of the hydrogen and distinguish green from grey hydrogen. A market for green hydrogen trade will rely on verifiable

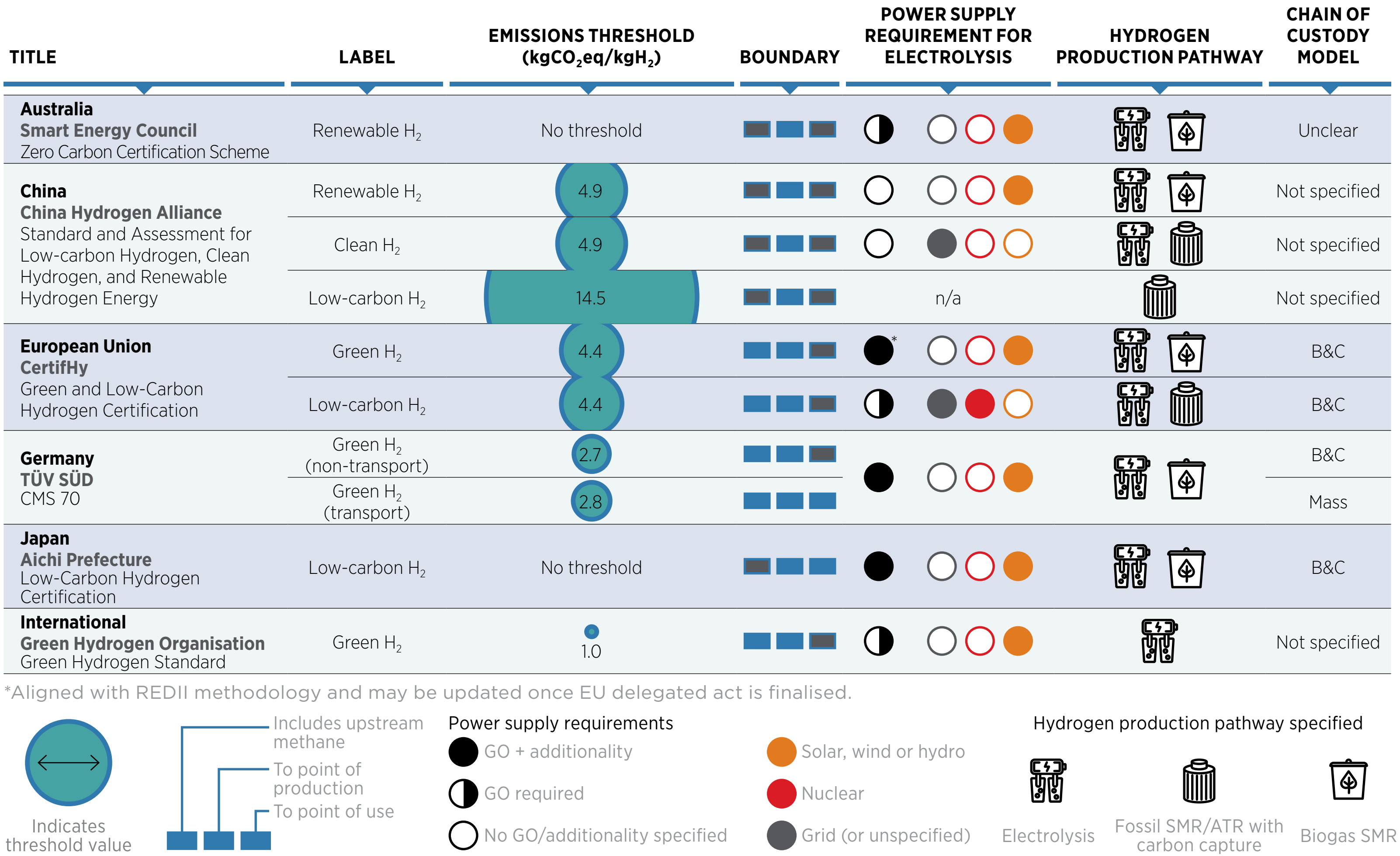
information on production methods. A trustworthy certificate can ensure consumers that the purchased hydrogen (or its derivatives) has the renewable or low-carbon characteristics that the seller claims. As an example, ÜV Rheinland offers a Carbon-Neutral Hydrogen certification standard (H2.21), which allows manufacturers, distributors, and users of carbon-neutral hydrogen to document its environmentally friendly production.

Certificates can therefore enable the creation of low carbon (including green and blue) hydrogen markets by allowing for the verification of low-carbon hydrogen use, as opposed to unabated use of fossil fuel based hydrogen. Furthermore, hydrogen certificates can be used by downstream industries, such as those producing ammonia and steel, to market their products as having used green hydrogen. Certifying hydrogen is therefore an important step in creating markets for green hydrogen and industries using hydrogen as feedstock.

Globally, there exist several certification systems for green hydrogen. Many of these focus on domestic trade (IRENA, 2023c). Having multiple certification systems presents a challenge: cross comparing the hydrogen certified by each individual system. However, different boundaries, labels and methodologies can render certificates inapplicable in different jurisdictions. Enabling an international hydrogen market, therefore, requires certificates to be harmonised globally. This means agreeing on taxonomies, accounting methodologies, boundaries, energy and fuel sources to ensure continuity in hydrogen certification.

Figure 4.2 provides an overview of voluntary mechanisms for different G20 Members. As can be seen, there is no harmonisation on, for example, emission thresholds, which range from 2.8 kilogrammes of carbon dioxide equivalent per kilogramme of hydrogen ($kgCO_{2eq}/kgH_2$) in Germany for green hydrogen to up to 14.5 $kgCO_{2eq}/kgH_2$ for low-carbon hydrogen in China. In addition, labels are not the same across markets – since some markets use the term *renewable* while others use the term *green.* This gives a clear idea of the challenges ahead for the creation of a robust market.

Figure 4.2 Summary of voluntary market mechanisms with published technical criteria



Source: (IRENA, 2023c). *Note:* EU = European Union; kgCO$_{2eq}$/kgH$_2$ = kilogramme of carbon dioxide equivalent per kilogramme of hydrogen.

Apart from global harmonisation of certificates, there is also a need for a transparent international registry that tracks the number of certificates issued in a system. This will build trust and confidence in a market and prevent double counting of certificates. Such a system should result from a collaborative and international effort that considers the needs of both importing and exporting countries. It could also address carbon "leakage", where hydrogen production is moved to countries with more lenient regulations. Importing countries, therefore, have an incentive to develop such a system and comply with it to access market requirements, and ensure that green hydrogen has a positive contribution to global decarbonisation goals. Yet, potential exporting countries should prioritise domestic renewable energy targets and domestic hydrogen demands before supplying an international demand.

Of the G20 Members, 17 countries and the European Union have national hydrogen strategies published or under development (IRENA, 2022e). This represents a high level of ambition for G20 Members wishing to advance the use of hydrogen. Existing certification schemes are also highly concentrated in G20 Member jurisdictions, as illustrated in Figure 4.3.

Figure 4.3 Map of organisations working on hydrogen certification

Source: (IRENA, 2023c).
Note: * under development. BEIS = Department for Business, Energy and Industrial Strategy; CEN = European Committee for Standardization; CENELEC = European Committee for Electrotechnical Standardization; JTC = Joint Technical Committee; RED II = Renewable Energy Directive II.
Disclaimer: This map is provided for illustration purposes only. Boundaries and names shown on this map do not imply the expression of any opinion on the part of IRENA concerning the status of any region, country, territory, city or area or of its authorities, or concerning the delimitation of frontiers or boundaries.

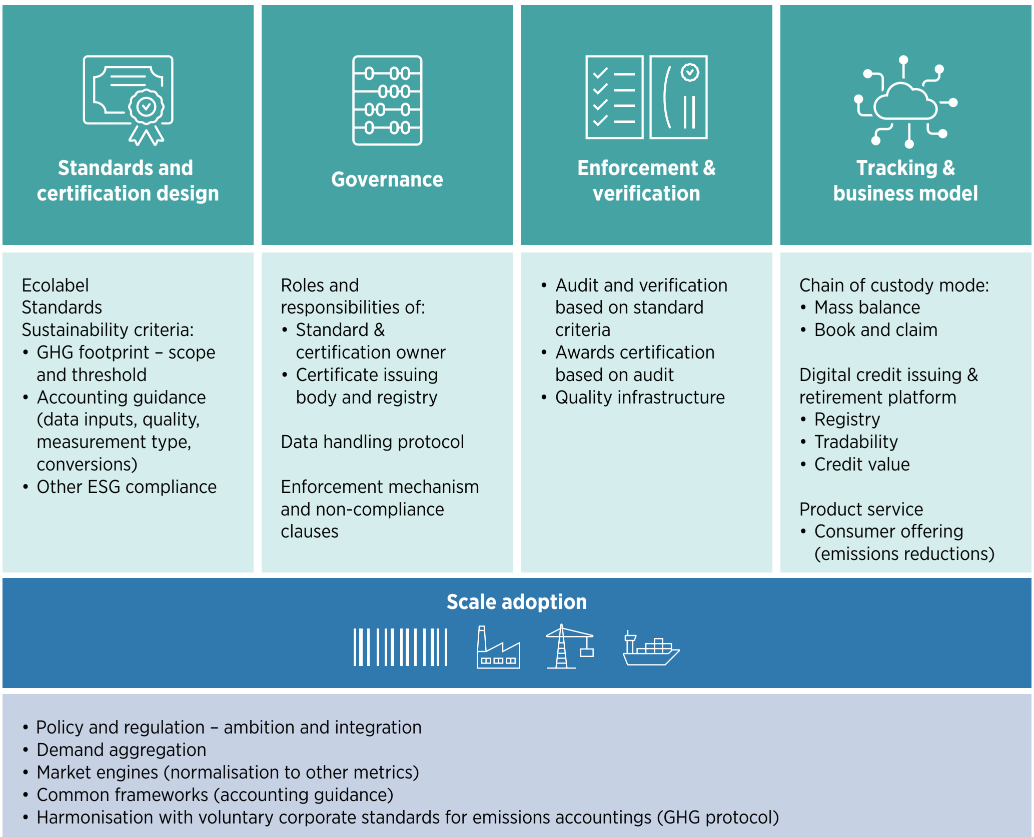
In Australia, the Smart Energy Council's Zero Carbon Certification Scheme issued its first green hydrogen certificate for a hydrogen refuelling station in Canberra in 2022. It is an industry-led certification scheme with plans to certify ammonia production in Australia, and is working with the Green Hydrogen organisation to develop a global standard for green hydrogen (Smart Energy Council, 2022).

The China Hydrogen Alliance also has a green hydrogen standard, which has equal carbon emission thresholds for renewable and clean hydrogen, but has an added requirement of using renewable energy for producing renewable hydrogen (CEIC, 2021).

In Brazil, TUV Rheinland has issued the first green hydrogen certificate in Latin America for a green hydrogen producer (FuelCellsWorks, 2022).

Certificates must be designed to ensure transparency. Not only will this make them more informative for policy makers and end users relying on them, but this can potentially minimise costs in auditing and verification. The report "Creating a Global Hydrogen Market: Certification to Enable Trade", dives deeper into the design elements to create a robust certification system (IRENA, 2023c). Figure 4.4 underscores the key elements of a robust certification system.

Figure 4.4 Key operational components for a hydrogen certification system



Source: (IRENA, 2023c).

To conclude, a transparent and collaborative certification system is needed to activate a global hydrogen market. However, certification alone will not facilitate international hydrogen trade; it is but a necessary step to accelerate hydrogen's uptake. Common methodologies and taxonomies can further unlock investment in green hydrogen projects. They make it easier to determine which conditions must be met by a green hydrogen project to be considered sustainable. Furthermore, it is important to emphasise that green hydrogen certification is not limited to hydrogen as an end product, but it can be the beginning of a much longer value chain extending towards chemical and steel industries, and international shipping.

Box 4.4 Key messages for creating a hydrogen market

- Policies to promote hydrogen's use in industry require carbon pricing mechanisms, technological mandates, support schemes and market creation.
- A harmonised definition of green hydrogen is essential. A consensual definition of green hydrogen should be developed, based on a transparent methodology to avoid market fragmentation. Developed countries should play a leading role. A global single system for the certification of hydrogen production should be implemented to ensure a proper account of hydrogen quantities and avoid double-counting effects.
- Certificates should be designed in such a manner that they are informative and can be easily understood by policy makers and end users.
- A transparent and reliable certification system is needed to minimise any additional cost due to the certification system itself, and to allow traceability across the hydrogen value chain.
- A taxonomy for sustainable green investments is required. Capital-intensive green hydrogen projects can benefit from funding mechanisms under a robust taxonomy that helps companies, investors and policy makers by defining the conditions according to which a green hydrogen project may be considered sustainable.

CHAPTER 5
MOBILISING LOW-COST PRIVATE CAPITAL FOR THE ENERGY TRANSITION IN G20 COUNTRIES

This chapter[16] outlines the role that the private sector must play in the energy transition. Also, it discusses the blended finance approaches to catalyse the flow of capital to the energy transition at scale from institutional investors. It identifies relevant case studies from the Group of Twenty (G20) Members that could be extrapolated and scaled up in other countries. These case studies will focus on government interventions to attract private financing and foreign direct investment, and developing domestic financing markets to scale commercially feasible renewable energy decarbonisation technologies.

KEY MESSAGES

- Both the private sector and the public sector have a critical role to play in advancing the energy transition agenda. Neither can do without the other. The philanthropic sector can also make useful concessional contributions to de-risking energy transition initiatives and projects.
- The energy transition is a "higher-hanging fruit" that no individual party can achieve in isolation. It requires the participation of all parties. This calls for closer collaboration in the form of partnerships to address distinct and well-defined challenges between all three sectors. Such partnerships must generate jointly developed action plans with accountability and ownership for measurable outcomes.
- Stronger collaboration is also desirable between governments in the Global North and those in the Global South. If the energy transition is not solved for all, it is not solved for anyone.

[16] *Note that given the complexity of the challenges in ensuring the lowest cost of capital for energy transition projects across the globe, the analysis in this chapter is necessarily limited and focuses on how to mobilise private capital through public-private partnership in the G20, especially through blended financing. IRENA's recent report, "The global landscape of renewable energy finance, 2023", presents a broader coverage of the relevant topics, including the limitations of using public funds for de-risking investments, and the need to direct public funds to regions and countries where a much stronger role for public financing is needed (IRENA and CPI, 2023).*

No country should be left behind. Promises made in the Paris accord regarding annual transfers of funds from developed countries to developing countries should be honoured.

- The private sector sees a broad range of attractive investment opportunities in the domain of the energy transition, which can significantly benefit from the sector's investment capital and rigorous resource allocation, especially now that the financial resources of the public sector globally are, and will likely for some time remain, under pressure due to macroeconomic headwinds. However, private sector institutional investors controlling trillions of dollars can often act only on opportunities in investment-grade countries, and they invariably need to deploy capital in larger amounts. This creates a shortage of necessary investment capital for non-investment-grade or unrated countries, smaller and riskier projects, and more nascent decarbonisation technologies designed in, and for, developing countries. Blended finance can play an important role in addressing this disconnect between capital and needs. The G20 may consider endorsing blended finance as an important tool towards achieving lower-cost finance for the energy transition.
- The public sector plays a critical catalysing role by providing a conducive and predictable enabling environment for long-term investment decisions of the private sector, and by engaging and attracting private investors and developers to build and finance pipelines of bankable energy transition projects. If resources permit, it can also support technology and programme development for scaling up the use of renewable energy resources.
- The case studies in this chapter – taken from G20 Members – illustrate that well-designed public sector support, which reduces risks for private sector investors and improves their financial returns, can play a central role in global efforts to address developing countries' adaptation and mitigation needs. In some case studies, forms of blended finance are being successfully applied at scale. These case studies merit close review for possible replication in other countries, customised to cater to specific local and regional differences.

5.1 THE ROLE OF THE PRIVATE SECTOR IN ACCELERATING THE ENERGY TRANSITION

It is universally recognised that public sectors will drive the energy transition. Traditionally, the public sector in both developing and developed countries formulates enabling policies, regulations and financing frameworks to try to achieve climate finance at scale.

As the energy transition accelerates, it has increasingly become critical for the public sector to effectively leverage investment capital at scale as well as the private sector's resourcefulness to accelerate the related processes. More importantly, the public sector needs to take swift actions in this regard, as it takes time for capital commitments to translate into newly built and operational sustainable climate-resilient infrastructure.

We should also note the quantum of need for private sector investment capital. In the *Global landscape of renewable energy finance, 2023* report, IRENA and the Climate Policy Initiative state that while global investments in energy transition technologies reached a record USD 1.3 trillion in 2022, this pace of investment is far from sufficient to put the world on track to meet climate and socio-economic development goals (IRENA *et al.*, 2023).

5.1.1 The private sector and other relevant actors

It is important to highlight that the "private sector" is far from a monolithic phenomenon, just like the public sector. Private sector organisations active in climate finance range from corporations, international and domestic banks, project developers and asset owners such as pension funds, to insurance companies, sovereign wealth funds and asset managers (who/which help manage asset portfolios). Asset managers include mutual funds managers, private equity and private credit funds, impact investment funds, infrastructure investment funds and venture capital funds. These private sector actors are guided by their respective risk tolerance, capital allocation and return expectations, motivations and fiduciary duties. Asset managers use the financial terminology prevailing in the sector and possess different levels of sophistication in their climate finance, energy transition and developing market approaches.

Additionally, there are development finance institutions (DFIs) that may have sovereign operations (*e.g.* World Bank), private sector operations (*e.g.* International Finance Corporation [IFC] as part of the World Bank, the Dutch development bank FMO, the German development finance institution DEG) or both (*e.g.* Asian Development Bank), as well as development agencies (*e.g.* the United States Agency for International Development; the UK Foreign, Commonwealth and Development Office). Both DFIs and development agencies are sources of private sector and concessional financing. They have all expressed ambitions to lead and participate in the climate finance space and energy transition.

Finally, the philanthropic sector also plays an important role, since it is a significant source of concessional capital, ranging from non-repayable grants, guarantees and first-loss tranches, to low-cost debt financing.

5.1.2 Macroeconomic headwinds

The pandemic-induced economic demand shock, coupled with supply chain disruptions hindering world trade, led to a significant slowdown of the global economy in 2020-2021. Several countries, mostly from the developed world, introduced fiscal stimuli to shore up consumers' spending power, which, paired with relatively relaxed monetary policies, eventually unleashed inflationary pressures in late 2021. The onset of the Ukraine crisis in February 2022 led to sharp spikes in energy and food prices, compounding other key factors, such as drought. Several central banks eventually decided to raise interest rates to rein in inflation.

These economic conditions are currently leading to several headwinds:

- While volatility of higher oil and gas prices is a boon for oil and gas exporters and traders, the populations of importing countries are struggling to pay higher energy bills, while those living in poverty are affected most. In some cases, governments have yielded to consumer pressure to increase fossil fuel subsidies, entrenching fossil fuels further in their economic system.

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- In several countries, natural gas is considered a critical transition fuel, easing the transition from fossil fuels such as coal and oil. However, natural gas has shown price volatility over recent years, especially in European and Asian markets. In the short term, and probably in the medium term, market uncertainties might be greater for natural gas. There has been a year-over-year decline in the volume of foreign direct investments into developing countries. There is some evidence that institutional investors in the Global North, hurt by recent financial market declines and inflation, are concerned about geo-political risks generating additional market volatility. They are increasingly adopting a “risk-off” attitude towards developing markets. This is slowing down the reallocation of private sector institutional capital into investment opportunities afforded by sustainable infrastructure and climate mitigation and adaptation, especially in developing countries.
- Globally, interest rates are increasing – to different degrees – making it more expensive to issue green and sustainable bonds and bank financing for climate transactions. Capital markets, fundraising and debt financing are needed the most when bond issuers or borrowers can least afford these expenses. Additionally, equity capital continues to be the scarcest resource available.
- On a positive note, a significant amount of investment capital continues to flow into innovative early-stage “climatech” business models and technologies, including in developing countries (PwC, 2021), and the economics of renewable power generation in many markets, with higher fossil fuel prices, have never been more compelling.

The next section discusses how the private sector will respond to these investment needs and macroeconomic challenges in the coming years, as it allocates capital for the best possible risk-adjusted returns, and what the public sector can do to catalyse private sector climate finance at scale and with urgency.

5.1.3 Sources of capital

Two different distinctions exist in terms of capital: international versus domestic, and commercial versus concessional.

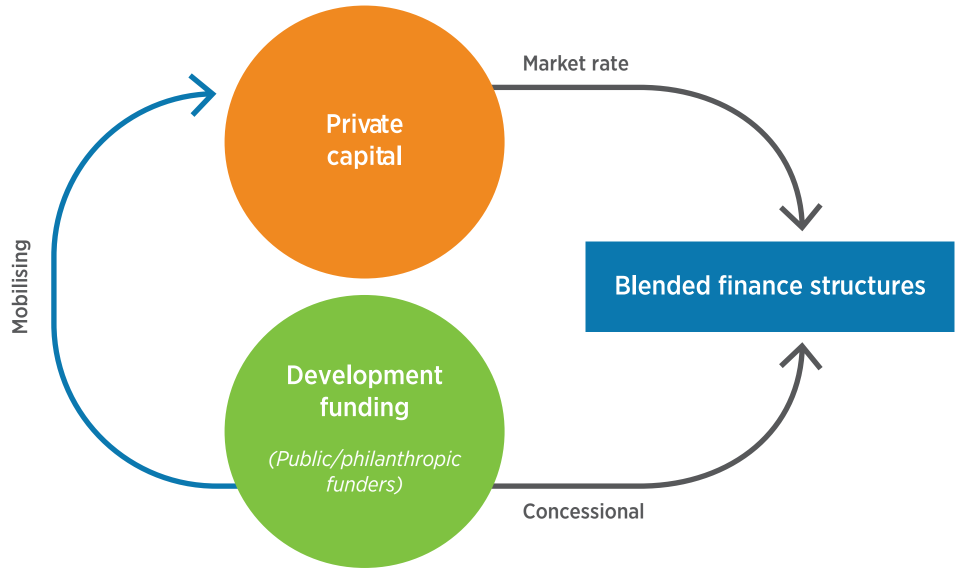
Domestic financial markets are a critical source of capital for financing the energy transition. This is because they provide diversified funding sources, access to local equity capital and corporate bond markets, and much-needed local-currency financing to prevent currency risk and help mitigate macroeconomic shocks. They are also critical because international institutional investors are reluctant to invest in projects in developing markets when local investors or lenders – local banks, pension funds and insurance companies – are themselves not involved in project financing. International players tend to be concerned with information asymmetry regarding project risk assessment in the market.

In 2021, global pension fund assets stood at USD 56.6 trillion (TAI, 2022), whereas the global insurance sector managed USD 41.6 trillion in the same year (Statista, n.d.). However, these institutional investors do not invest in small-scale or unprofitable projects, and they often cannot invest in non-investment-grade or unrated developing countries. Their primary aim is to invest on behalf of pension and insurance policy holders, which carries a fiduciary duty and is tightly regulated from a capital adequacy perspective. By 2022, the world's sovereign wealth funds managed USD 10.6 trillion. These institutional investors, therefore, collectively manage well over USD 100 trillion of assets.

Another relevant distinction to be drawn is that between commercial and concessional capital. The energy transition involves important projects that necessitate balancing investments' risk-return profiles. Some projects needed to achieve the global energy transition but are yet to be profitable. They remain at small scale and are in developing countries – two inhibiting factors preventing institutional investors, such as pension funds, from participating in such investments. Considering the constrained public sector resources of these projects, the private sector will need to contribute at scale to make the energy transition a reality. Large asset owners, such as pension funds and insurance companies making long-term capital investments, have a unique role to play given the energy transition's financial heft.

There is, therefore, a need to tailor projects to institutional investors' requirements. The purpose – and transformative impact – of blended finance is to crowd in private sector capital where it is the most needed. Government interventions, as well as those of DFIs or philanthropic foundations, can set in motion relatively risky projects that have the potential to generate positive, measurable social and environmental impacts. Figure 5.1 shows the fundamental workings of a blended finance structure. Public and philanthropic actors provide concessional capital (*i.e.* capital below market-conform terms) with the aim of pivoting investments' risk-return profiles, such that private capital providers will be enticed to invest their commercial capital, on normal market-conform terms. The resulting structure blends both types of capital and allows each party to the transaction to achieve their specific objectives.

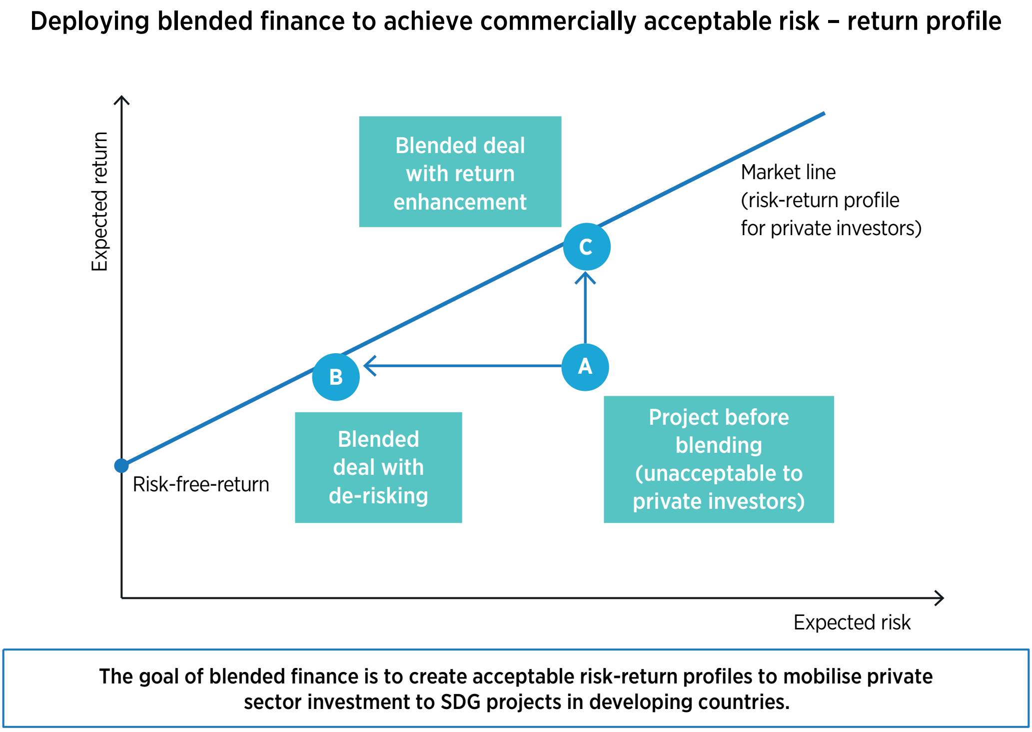
Figure 5.1 Fundamental workings of blended finance



Source: (Convergence, 2021).

Figure 5.2 shows the basic approaches to structuring blended finance so as to create acceptable risk-return profiles for institutional investors, in order to enable them to allocate capital to these projects. This is accomplished by either de-risking or, less frequently, by return enhancement; sometimes this is accomplished using a combination of both. Typical de-risking instruments may include (partial) risk guarantees, first-loss positions, grants, technical assistance, subordinated debt or junior equity. While these de-risking instruments are typically deployed to de-risk clean energy investments where capital is not flowing at scale, they can also be applied to unlock new sources of capital, such as domestic clean energy bond issuance in developing countries. Last but not least, return enhancement can be created by giving investors priority rights to cash flows generated.

Figure 5.2 Basic structuring approaches in blended finance



Source: (Convergence, 2021).
Note: SDG = Sustainable Development Goal.

Concessional funding is therefore considered a strategic risk mitigation tool and an enabler to address market imbalances in order to mobilise private funding towards sustainable development in developing countries. Nonetheless, a caveat exists: blended financing intervention makes sense if:

a. There is clear additionality, *i.e.* a project would not happen at all or would not happen quickly enough without blended finance, *i.e.* based on market forces alone; and

b. The subsidy element involved in the intervention is as minimal as possible (so-called "minimum concessionality") so as not to distort the marketplace and waste public resources. The finite nature of concessional capital also informs the latter requirement, be it of public or philanthropic origin,[17] and concessional capital must be used as efficiently and effectively as possible.

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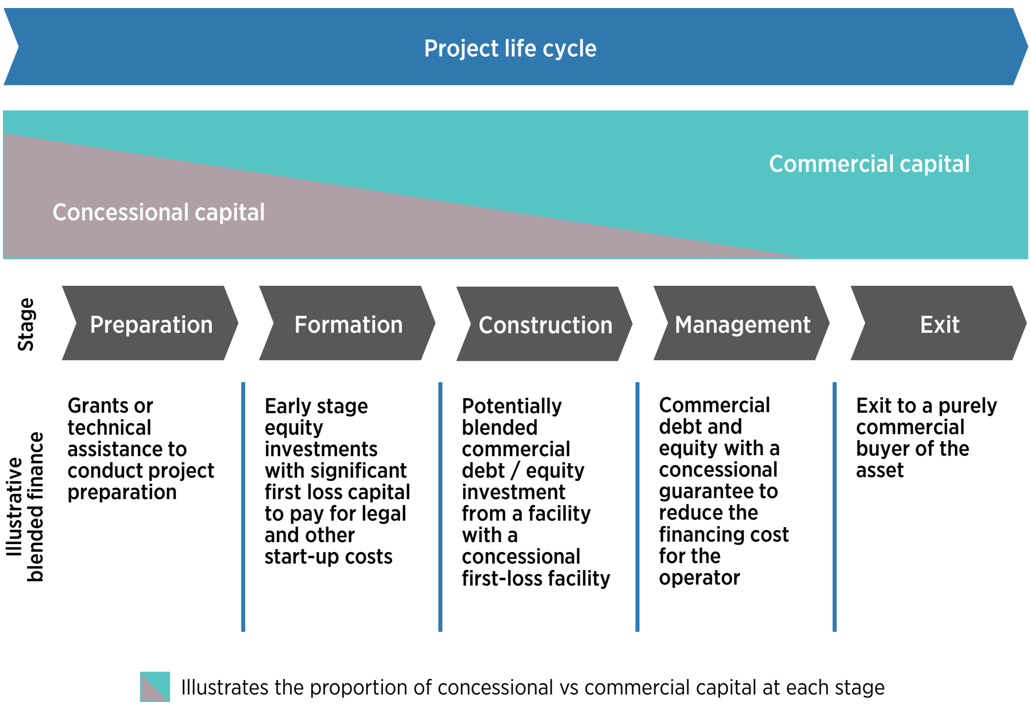
[17] *Official development aid totalled USD 179 billion in 2021, according to a recent report by the Organisation for Economic Co-operation and Development. However, global philanthropy in support of sustainable development is estimated to be approximately USD 50 billion. Individual governments' concessional support to domestic development projects is added to infer the total concessional capital available globally.*

Sources of commercial versus concessional capital for financing sustainable infrastructure vary depending on the infrastructure's business development cycle. Figure 5.2 conceptually highlights how the relationship between commercial and concessional capital changes as sustainable infrastructure moves from the early project development and preparation phases, advances through formation and construction, proceeds into the management phase and eventually exits (via appropriate exit strategies). In the early high-risk stage of project development, concessional capital providers may provide grants or technical assistance to conduct project development and preparation. Thereafter, concessional and commercial capital providers may share in the early-stage equity investment to pay for legal and other start-up expenses.

Commercial capital providers will take the lead once a project has been sufficiently de-risked in the construction phase; a concessional capital provider may, however, still absorb the first loss should a project fail. Finally, during the operation and maintenance phase (which sometimes lasts decades) and the eventual exit, commercial parties control projects.

Figure 5.3 Blended finance across project life cycle

- Blended finance can be used to support full project life cycle until project reaches commercial viability
- Blended finance can be tailored to each stage - minimise concessionality



Source: (Convergence, 2021).

5.1.4 Country risk as the primary impediment for international institutional capital flows

The majority of private sector borrowers in most countries eligible for official development assistance are deeply speculative in terms of credit risk. As shown in Table 5.1, the rated countries have a median rating of B+, whereas the investment-grade cut-off is BBB-. This disregards the 65 countries as of 2020 that were not rated at all. By convention, most “good” private sector companies, including successful developers of energy transition projects, within a country rated B+ are rated, or considered equivalent to, one to three levels below the sovereign credit ceiling. This is too low for international institutional investors, since it makes the probability of default and expected loss too high. Many international institutional investors are prohibited, by their fiduciary duty, investment charter or other organisation restrictions, from investing in any non-investment-grade instrument.

Table 5.1 Distribution of countries on the OECD DAC List, 2018-2020

COUNTRY CLASSIFICATION	NUMBER
Least developed countries	47
Other low income	2
Lower middle income	38
Upper middle income	58
Total	145

SOVEREIGN RISK RATING	NUMBER
A- or better	3
BBB	10
BB	16
B	45
CCC or worse	6
Unrated	65
Median rated	**B+**

Source: OECD DAC; (Convergence, 2021).
Note: DAC = Development Assistance Committee.

The sovereign risk rating (or the lack thereof) can impede institutional investors from even considering energy transition projects in developing countries, let alone allocating capital to them at scale. Once this barrier to investment has been overcome, institutional investors can begin to weigh anticipated returns relative to a plethora of risks, depending on geography, sector and project size (*e.g.* regulatory risk, off-take risk, foreign exchange risk, to name a few), as highlighted in section 3.

5.1.5 Proposed blended finance initiatives

As highlighted in the previous section, an important driver of the persistent USD 4 trillion investment gap is the country risk associated with developing countries. Blended finance offers two ways, often in concert, to overcome this impediment:

1. A **portfolio approach** creates diversification through aggregation, which helps to reduce risk. In practice, this means pooling multiple loans in one portfolio, which helps diversify risks across borrowers, countries, sectors and currencies. Consequently, the default of one borrower in the portfolio would have minimal impact on the portfolio's overall performance. This portfolio approach alone can improve credit rating by one to two levels. The aggregation approach also helps bring total investment tickets to a size that institutional investors prefer. They invest at least USD 100 million per transaction, often larger.

2. **Subordination** of concessional capital can improve the risk profile for an institutional investor. For example, a portfolio may benefit from being funded by two tiers of capital, where the junior capital effectively absorbs losses until it has been depleted (*e.g.* "first-loss tranche"). The higher the percentage of concessional capital, the higher the cushion to absorb losses. If the default and losses do not materialise, the junior capital is returned, possibly with positive returns. Much of the same effect can be achieved through partial risk guarantees.

Once the country risk hurdle has been overcome, other root causes of high perceived or real risks and the related high cost of project financing in developing countries need to be tackled. These apply to energy transition projects as well. Many energy transition investments are more capital intensive than traditional infrastructure. For example, a renewable energy project may have a higher upfront cost but lower operating costs than a coal plant of equal size. This high capital requirement relative to non-climate-friendly infrastructure means that energy transition projects are disproportionately impacted by high costs of capital: small changes in interest rates have compounding effects on project costs over time, and lowering financing costs can, therefore, have significant price benefits for projects' end beneficiaries (electricity consumers).

High cost of capital can result in higher prices for end users (or the need for energy subsidies to offset those costs), and they can also result in projects not being built. The private sector can make risky investments – provided risks are seen to be manageable – as long as the expected returns compensate for the actual or perceived risks taken. Relatively higher sovereign and project risk premiums translate into higher return expectations on the part of investors. If return expectations appear unachievable, the proposed energy transition investments will attract little, if any, contribution from the private sector.

Blended finance offers the potential to create a vehicle or a series of vehicles on a national or sub-regional level to break the persistent negative feedback loop between high perceived risk, high cost of capital and limited investment in energy transition projects, especially in developing countries. The issue of high costs of capital is the most pronounced in developing countries, especially developing countries with high vulnerability to climate, other non-financial shocks and economic shocks.

Given the substantial impact of cost of capital on the viability of energy transition projects, the blended finance vehicle should be designed to deploy strategies to reduce risk and lower financing cost to unlock greater private sector investment flows:

- Against this backdrop, blended finance would need to have a combination of the following product capabilities: project preparation facility and technical assistance should be a key part of its design; this would be to bring technical and financial expertise to projects and create standards that reduce transaction costs. The project preparation component should be grant funded and provide project structuring assistance to improve bankability, including strengthened contracts and agreements, clear processes for securing permits and land rights, and improvements to businesses plans. Energy transition projects can be poorly structured - a dedicated facility will help prepare projects for commercial finance and complement and increase the effectiveness of the vehicle's other product offerings.
- Guarantee products can be developed in multiple ways (partial or full, first loss or second loss) and typically leverage high levels of private sector investment. Guarantees can enable significant leveraging of private investment with only a modest commitment.
- Direct co-investment at senior or subordinate levels can help lower risk and crowd in private sector investment.

Direct investment can also be in the form of bridge financing, or loan products specifically designed to support the aggregation and securitisation of assets for refinancing by commercial investors.

Governments have a critical role to play in convening all necessary parties to design, incubate and implement such a blended finance vehicle, as highlighted in section 5.2.

5.2 THE PUBLIC SECTOR AS STRATEGIC CATALYST FOR THE ENERGY TRANSITION

5.2.1 Introduction

The public sector plays a catalysing role in the energy transition by providing a conducive and predictable enabling environment for long-term investment decisions of the private sector. It is also serves as a catalyst by engaging and attracting private investors and developers to build and finance pipelines of bankable energy transition projects. Lastly, it can support technology and programme development for scaling up the use of renewable energy resources.

Well-designed public sector support that reduces private investors' risks and improves their financial returns can play a central role in global efforts to address developing countries' adaptation and mitigation needs.

This chapter identifies relevant case studies from G20 Members, notably from Argentina, Brazil, India and Indonesia, that could be extrapolated and scaled up in other countries. These case studies show how well-designed government interventions can attract private financing and foreign direct investment, and help develop domestic financing markets to scale commercially feasible renewable energy decarbonisation technologies.

It should be noted that Argentina's RenovAr programme, Brazil's Economic Development Bank (BNDES) and Indonesia's accelerated phase-out of coal-fired power plants each use one or more concessional blended finance approaches to mobilise private sector financing capital and, thereby, help the respective countries to achieve their desired development outcomes.

5.2.2 Case study: Argentina's RenovAr

How to create bankable sustainable infrastructure opportunities, sponsored by the private sector, taking advantage of the country's wealth of renewable energy resources by de-risking its adverse macroeconomic conditions, which hinder the scaling of renewable energy generation via an auction model.

Structure of the RenovAr Programme

In 2015, Argentina had a less than 2% share of renewable energy sources in its power generation mix compared with the renewable-energy-based power generation of its neighbouring countries, whereas 60% of electrical power came from fossil fuels, of which some was imported. The RenovAr programme aimed to turn the country's abundant renewable resources into reliable power generation.

Programme launched: May 2016.

Programme goals as a percentage of electricity matrix: Increasing the share of renewable-energy-based production to 8% in 2017 and 16% in 2025.

Programme goals as the billion US dollars target: USD 17-20 billion in direct investments.

Entity responsible for renewable energy auctions: CAMMESA (Argentine Wholesale Electricity Market Clearing Company) – the wholesale energy market administrator – is the off-taker and signatory to power purchase agreements (PPAs) awarded to private independent power producers (IPPs).

Description of the RenovAr Programme

The country's adverse macroeconomic environment and lack of robust renewable energy regulation made it difficult to attract and mobilise private sector capital, both international and domestic. In this regard, the Government of Argentina (GoA) needed to develop a reliable institutional foundation to attract private capital. Argentina's Congress enacted the Renewable Energy Law No. 27191 in September 2015.

The law allowed the creation of the Fund for the Development of Renewable Energy (FODER or Fondo para el Desarrollo de Energías Renovables). The World Bank's Banco de Inversión y Comercio Exterior (BICE) – or the International Bank for Reconstruction and Development (IBRD) - administered the FODER Fund as its trustee. The IBRD provides guarantees, in an aggregate amount of USD 480 million, to cover the risk of the government's failure to fund the FODER in the event that the FODER should pay eligible renewable energy projects a put price where IPPs exercise the put option under their respective FODER trust adhesion agreements (World Bank, n.d.). It means the IBRD guarantee indirectly mitigates country risks, including lack of payments, change in policy and regulation, and convertibility and transferability risks.

The guarantee is limited to a maximum of USD 500 000 per megawatt at the sub-project level. In the medium term, the guarantee allowed Argentina to rebuild a positive track record with investors.

FODER's primary financing and de-risking instruments were (1) ongoing PPA payments and liquidity support, and (2) termination payment obligations arising from the IPPs' rights to sell their project (a put option) to FODER if adverse macroeconomic or sector risks materialise.

Private sector investors were interested in returning to Argentina's market after years of absence. They were nevertheless cautious given (1) Argentina's track record in the last years of significant policy reversal and non-compliance with contractual undertakings (*i.e.* political risk); and (2) their lack of recent experience financing renewable energy projects in the country.

The novelty of the RenovAr scheme is its comprehensive approach to mitigating country risks for investors and developers. A decisive feature of Argentina's RenovAr support programme is a multi-level safety net of payments and solvency guarantees to leverage investors' confidence and reduce prices. On one level, in addition to entering a PPA with CAMMESA, successful bidders join FODER. A second-level guarantee is offered as a put option mechanism aimed at mitigating the primary risk factors inherent to the country (country and policy risks). Developers are allowed to transfer project assets to FODER if CAMMESA fails to pay for the supplied energy for four consecutive months (or six non-consecutive months within any 12 months). In turn, generators are entitled to receive compensation from FODER, the value of which can be based on investment audits or pre-defined per megawatt schemes.

Creating a market for renewable investments

Private sector financiers and investors welcomed the risk mitigation instruments provided by the GoA via FODER and backed by the World Bank's guarantee via IBRD. The GoA and the World Bank helped build a bridge between the government and the private sector, which led to new investments in a critical sector.

The RenovAr programme opened a space for private sector investment and innovation, helping Argentina meet its renewable energy goals while leveraging private capital and avoiding public debt.

In 2016, the first renewable energy auction was held. It aimed to attract 1 000 MW worth of new projects and was completed with 123 bids for 6 346 MW – a signal of confidence from local and international developers. Wind capacity was nearly six times oversubscribed (3 469 MW), whereas solar capacity was nine times oversubscribed (2 813 MW). Winning projects received contracts for a 20-year term. The selected projects were completed in a time frame of two years.

Thereafter, given the significant participation of developers and low bidding prices, the GoA decided to hold an extension of the firstround of auctions (called **RenovAr 1.5**) in mid-November 2016 for an additional 400 MW of wind and 200 MW of solar PV capacity. Only companies that qualified in the first round of auctions but failed to win a contract could participate in RenovAr 1.5. This round saw wind projects awarded amounting to 765 MW and solar PV projects totalling 516 MW, distributed across the country.

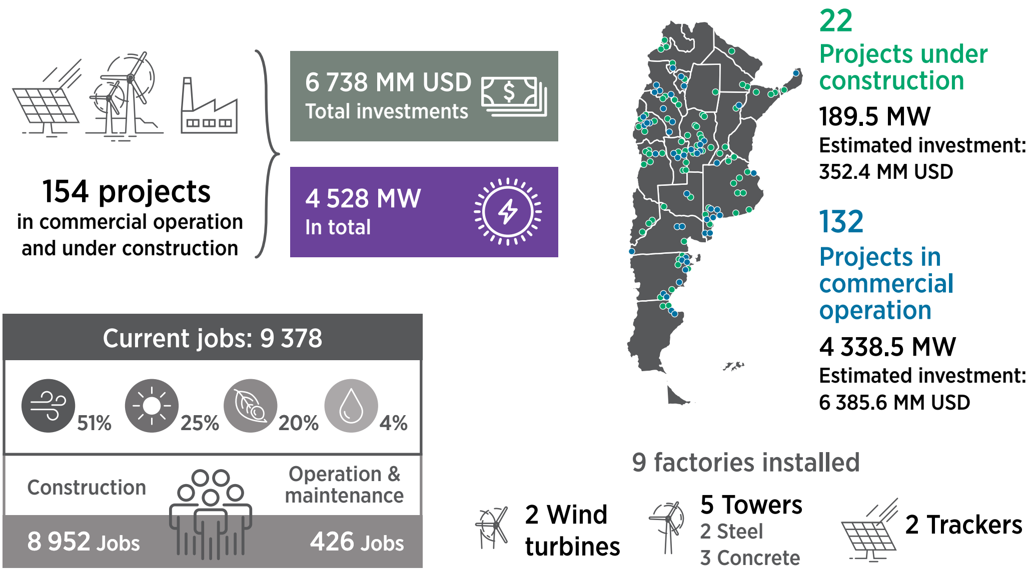
In a second auction round in 2017 (**RenovAr 2**), The government sought to contract 1.1 GW of renewable energy projects. It was announced that wind projects participating in the auctions would have to demonstrate the use of wind turbines manufactured in Argentina. A total of 1 200 MW were auctioned, resulting in 1 400 MW of total renewable energy contracted.

In 2019, the GoA held the RenovAr 3 auction round, called "**MiniRen**", for procuring renewable power capacity. Approximately 400 MW of renewable capacity were opened for competition. This round saw 259 MW awarded in long-term PPAs.

Impact on the energy matrix and results

RenovAr's successful implementation by 2025 will help fulfil 16% of Argentina's reduction commitments under the Paris Agreement and will help the country achieve the UN Sustainable Development Goals (Greenmap, n.d.). The RenovAr programme has already contributed to making renewables the cheapest energy source in the country.

Figure 5.4 RenovAr results



Source: (Greenmap, n.d.).
Note: MW = megawatt.

5.2.3 Case study: The Brazilian Development Bank (BNDES)

How a former development agency was converted into a state-owned financial institution and resulted in a more flexible organisation to raise and invest funds in infrastructure, while being less exposed to politically motivated requests. The BNDES plays a fundamental role in stimulating the expansion of infrastructure and industrial sectors in Brazil.

The BNDES (or the Bank) was established as a development agency in Brazil on 20 June 1952. Subsequently, in 1971, it was converted by law into a state-owned financial institution. This resulted in an organisation with greater flexibility to raise and invest funds across different industry sectors of the country, besides being less exposed to political interference. The Bank's current vision is "to be Brazil's sustainable development bank", and its mission is "to facilitate solutions that contribute to investments for the sustainable development of the Brazilian nation."

The BNDES has become the government's most important financial institution to support and mobilise capital to develop productive investments in Brazil. The Bank aims to promote and commit to local and regional development and scale innovation, supporting industry sectors and projects that would require reducing the gap between the public and private sectors and the social and environmental landscape.

Table 5.2 shows a comparative analysis of the BNDES and other multilateral DFIs.

Table 5.2 Comparison of the BNDES and international development banks, 2021[1]

	BNDES	CDB	DBJ	KDB	KfW	EIB	COFIDE
Location	Brazil	China	Japan	South Korea	Germany	Luxembourg	Peru
Rating (Moodys/S&P)	Ba2 / BB-	Aa3 / AA-	A1 / A	Aa2 / AA	Aaa / AAA	Aaa / AAA	Baa3 / BBB
Assets (BRL bn)	737	15 084	1 070[2]	1 567	3 553	3 589	18.1
BIS ratio (%)	40.2	11.7	16.8	14.9	23.9	32.3	30.1
NPS (%)	0.2	0.8	0.5	1.7	n/a	0.4	6.6
ROA[3] (%)	4.5	0.5	0.2	0.4	0.3	0.5	n/a
ROE[4] (%)	28.4	5.4	1.3	2.9	6.0	3.4	1.9

1 *Source:* Annual 2021 reports of the banks available on their websites.
2 Amount disclosed for fiscal year 2021 converted to BRL with base date of 12.31.2021.
3 ROA (return on assets).
4 ROE (return on equity).
Source: (BNDES, 2022).
Note: BIS = Bank for International Settlements; BNDES = Brazil Economic Development Bank; BRL = Brazilian real; CDB = China Development Bank; COFIDE = Corporacion Financiera de Desarrollo S.A; DB = development bank; DBJ = Development Bank of Japan; EIB = European Investment Bank; KDB = Korea Development Bank; KfW = Kreditanstalt für Wiederaufbau.

Structure and impact of the BNDES

The BNDES has two fully owned subsidiaries: FINAME and BNDESPAR. The three entities are together called the BNDES system (the System):

a. FINAME's resources are earmarked for financing purchases, sales operations, Brazilian machinery and equipment exports, and imports of goods produced overseas. Its activities are developed in collaboration with the parent company, BNDES.

b. BNDESPAR is a business corporation that carries out the capitalisation of undertakings controlled by private groups while abiding by BNDES's plans and policies. It is also responsible for strengthening Brazil's capital markets by expanding the offer of securities and democratising the ownership of BNDES's capital.

The System has evolved into an effective financing platform to increase investments, employment and exports, especially helping micro, small and medium sized companies to access financing and expand their investor base.

BNDES effectively:

i. Acts to help micro, small and medium sized companies overcome restrictions to access financing and investors.

ii. Resolves the market gap by financing infrastructure projects that require long-term capital. Hence, the BNDES completes the market and makes projects financeable.

iii. Offers preferential interest rates compared with private financial markets, allowing a greater quantum of projects to be financed.

iv. Steps in as the catalyser to the development of the domestic financial market by incentivising competition among private financial institutions through reducing spreads and cost of capital. This enables greater domestic capital mobilisation.

As of today, BNDES:

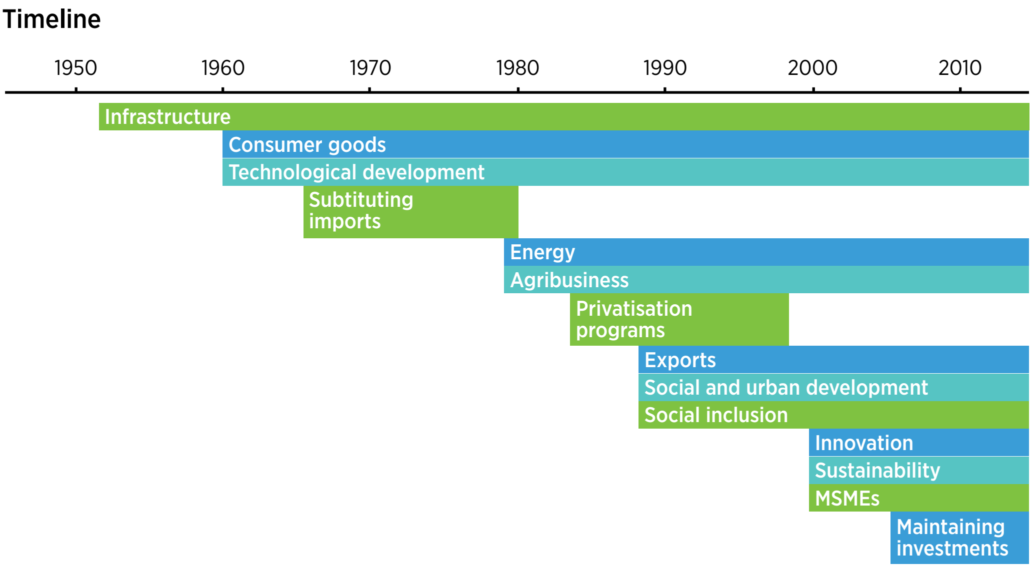
a. Serves a wider range of sectors of the Brazilian economy - from infrastructure, industry, agriculture and trade, to services. It also promotes and supports the development of innovation, a green economy, exports and capital markets.

b. Considers provisions for allocating resources in different forms – from subsidies, grants and state guarantees of its obligations, to tax incentive structures.

Figure 5.5 illustrates the 50-year evolution of the Bank's growing financing in different sectors of Brazil's economy.

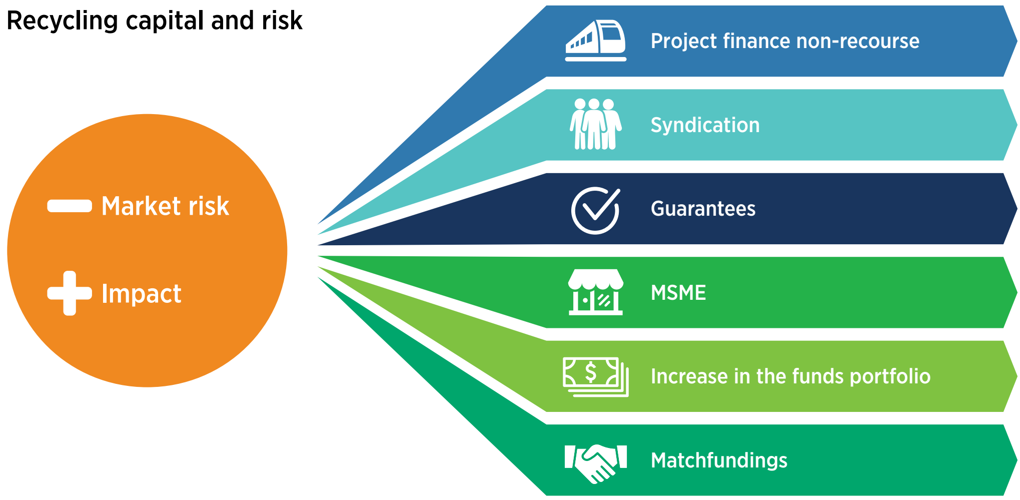
Figure 5.6 depicts BNDES's conceptualisation of product offering, risk and impact.

Figure 5.5 Evolution of BNDES's growing financing by sector over the 50-year time horizon



Source: (BNDES, 2022).
Note: MSMEs = micro, small and medium enterprises.

Figure 5.6 BNDES's conceptualisation of product offering, risk and impact



Source: (BNDES, 2022).
Note: MSME = micro, small and medium enterprise.

BNDES and ESG landscape

The impact of climate change has prompted the Bank to reformulate and emphasise strategic sectors in the climate change and finance agenda. As per the September 2022 Investors Presentation[18]: "Our recent advancements in the ESG agenda reinforce BNDES' role in fostering sustainable development."

The BNDES was the first Brazilian bank to issue a green bond for USD 1 billion internationally in 2017. It was the first bank to locally issue a green bank note of BRL 1 billion in 2020. The BNDES has broadened its environmental, social and governance (ESG) funding capacity with the Sustainability Bond Framework, which incorporates new environmental categories and includes social ones. The Sustainability Bond Framework reinforces the importance attributed by the BNDES to the ESG theme and meets the growing demand from investors.

Moody's Investor Services has re-affirmed BNDES's ESG ratings as A1+.[19]

The BNDES has committed to the following sectors, in alignment with the UN Sustainable Development Goals (UN SDGs): (1) Renewable energy and energy efficiency; (2) Sanitation and recovery of brownfields; (3) Corporate social investments, social and productive inclusion, and microcredit; (4) Recovery and preservation of biomass; and (5) Urban sustainability, mobility, healthcare, education and public safety.

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[18] *See https://ri.bndes.gov.br/. Also, to learn more about the BNDES's role as a national sustainable development bank, see: https://ri.bndes.gov.br/sustentabilidade/*

[19] *Learn more about BNDES' ESG rating and access the complete report at: https://ri.bndes.gov.br/sustentabilidade/rating-asg/.*

Given below is BNDES's share of contributions to Brazil's sustainable development as of Q3 2022:

a. 68% of BNDES's loan portfolio, representing BRL 238 billion (approximately USD 47 billion), is linked to projects supporting green economy and social development.

b. Disbursement linked to SDGs reached BRL 15.3 billion (approximately USD 3 billion), equivalent to 91% of the total disbursements.

c. Disbursements linked to Brazil's Nationally Determined Contributions: BRL 3.5 billion (approximately USD 700 million). Total emissions of approximately 78.2 million tonnes of carbon dioxide equivalent (tCO_{2eq}) avoided through the Bank's operations.

5.2.4 Case study: India taps capital markets with sovereign green bonds

IREDA's role in India's Energy Transition

India's total energy consumption ranks third in the world, and the demand is only going to increase with high economic growth, coupled with industrialisation and population growth. According to the International Energy Agency (IEA), India's energy demand will see the highest jump in the next two decades. The migration to more affordable and cleaner energy sources becomes paramount in the country's pursuit of sustainable development.

India understood and adopted this viewpoint at an early stage and established itself as a leader in renewable energy adoption. The country's renewable energy sector has seen unprecedented growth driven by national targets of 175 GW of renewable energy capacity by 2022 and 500 GW of non-fossil fuel capacity by 2030. India ranked third on the Renewable Energy Attractive Index in 2021, and its solar and wind power base is the fourth largest in the world. The country's capacities are some of the fastest growing among the top five countries promoting and advancing renewable energy (EY, 2021). The comprehensive policy framework designed by the Indian government has ensured that the national targets are well supported.

In promoting renewable energy, one critical success factor has been the establishment by the Ministry of New and Renewable Energy of a renewable-energy-focussed non-bank finance corporation in 1987: the Indian Renewable Energy Development Agency Limited (IREDA) has been serving India's renewable energy sector and the government's ambitions for the past 35 years. It has helped commission approximately 20 GW of renewable energy capacity in the country through financing to renewable energy developers. This is the highest capacity commissioned by a financier in India. IREDA continues to pioneer new and emerging technologies (battery energy storage system, green hydrogen electrolysers, e-mobility, waste to energy) by introducing policies for financing in these new technologies to promote their use. It has also become the preferred agency through which DFIs across the world contribute to green project financing in India.

India Sovereign Green Bond Issuance

Building on IREDA's success, sovereign green bonds are a next logical step to showcase India's commitment to building a low-carbon economy, mobilise private sector capital for sustainable development and lower the cost of capital for green projects by tapping into new investors. During the 2021 United Nations Climate Change Conference (COP26), India set net-zero emissions targets to achieve by 2070, and the country will need to invest an estimated USD 10 trillion between 2022 and 2070 to achieve them. Thus far, overall green bond issuance in India has grown significantly to USD 18.3 billion cumulatively, with 2021 being the banner year with a record issuance of USD 7 billion.

On 7 January 2023, the Reserve Bank of India announced that on 25 January and 8 February 2023, respectively, it would launch its inaugural auction of 5- and 10-year sovereign green bonds, which total up to INR 160 billion (approximately USD 1.93 billion) (RBI, 2023). This comes on the heels of the Indian finance minister announcing the plan to issue sovereign green bonds in the 2022-2023 budget, to tap the domestic debt market to finance green infrastructure projects. India follows Singapore, Hong Kong and Indonesia as an Asian issuer of sovereign green bonds.

India Green Bond Framework

The overall governance of green bond issuance was laid out in a recently issued Framework for Sovereign Green Bond Issuance by the Government of India[20] ("Framework"). Among other things, the Framework created a Green Finance Working Committee, which will select public sector projects for green financing from those submitted by several government departments.

The Framework is designed to comply with the four components and key recommendations of the International Capital Market Association's Green Bond Principles (ICMA, 2021), which recommend the delineation of a clear process and disclosure by issuers to enable investors and banks and others to understand the green bonds' characteristics. The four core components as outlined by the ICMA Green Bond Principles are (1) use of proceeds, (2) project evaluation and selection, (3) proceeds management and (4) reporting.

The Framework was also given a "medium green" rating in a second opinion by the Centre for International Climate Research (CICERO). This rating provides a positive view that this Framework entails a significant step towards the long-term vision of a low-carbon and climate-resilient future, yet scope for improvement remains. The CICERO noted, for example, that the principles for selecting green projects for some sectors are generic, which might potentially increase the risk of financing projects that are not completely green or create adverse climate-related impacts.

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[20] *Specifically, the Government of India will use the proceeds raised from sovereign green bonds to finance and/or refinance expenditure (partially or fully) for eligible green projects falling under "Eligible Categories" defined in Table 1 of the Framework.*

The green bond proceeds are earmarked for financing public sector projects that will help reduce the carbon intensity of the Indian economy, such as solar, wind and small hydro projects (less than 25 MW). Importantly, projects for both climate change mitigation and climate change adaptation qualify.

Projects to be considered for financing will include those focussed on renewable energy, energy efficiency, clean transportation, climate change adaptation, green buildings, sustainable management of living natural resources and land use, sustainable water and waste management, pollution prevention and control, and conservation of terrestrial and aquatic biodiversity.

The Green Finance Working Committee will, under its Terms of Reference specified in the Framework, identify new projects every year and ensure that the bond proceeds are allocated within 24 months from the date of issuance.

25 January and 9 February: Inaugural Sovereign Green Bond Issuance

On 25 January, the Indian government sold INR 80 billion of securities, comprising INR 40 billion each of 5- and 10-year notes, at a pricing that was slightly lower than similar maturity sovereign bonds issued previously by the government (Mazumdar, 2023). The USD 1.93 billion-equivalent bond offering on January 25 and the follow-on offering of USD 2 billion-equivalent bonds on 9 February will constitute only 1% of the government's overall borrowing this year. However, as the government begins to raise meaningful amounts through green bond issuance, it could reduce the supply from non-green bonds, thereby lowering the overall yield of government bonds.

The bulk of the issue was bought by local banks and insurance companies, with some participation from foreign banks as well. Demand from foreign institutional investors was more restrained, possibly due to their general preference for USD-denominated debt (Dhutia, 2023).

Investment in green bonds qualifies towards the Reserve Bank of India's so-called statutory liquidity ratio, which refers to the minimum percentage of deposits that local commercial banks are required to invest in liquid assets such as government bonds. Insurance companies were allowed to classify the green bonds as infrastructure investments. Meanwhile, investment in sovereign green bonds will also be designated as specified securities under the "Fully Accessible Route" for foreign investors, where unlimited investment is allowed.

5.2.5. Case Study: International Co-operation in Indonesia and Developing a Sukuk Market

In Q4 22, Indonesia and a group of leading economies launched the new Just Energy Transition Partnership at the G20 Leaders' Summit in Bali. The partnership is an important step forward for international co-operation on financing clean energy transitions in emerging economies.

Indonesia's International Co-ordinated Capital Mobilisation and the Green Sukuk Market Development

Indonesia is the world's fifth-largest greenhouse gas emitter. Last year, coal mining contributed about 5% of the country's GDP and 12% of all export income. Indonesia derives 60% of its electricity generation from coal, and this creates structural challenges to transitioning away from this fossil fuel (IEA, 2022).

However, Indonesia has ratified the Paris Agreement and is committed to stepping up climate change mitigation and adaptation activities. The country has committed to reducing emissions by around 32%, equivalent to 2.87 gigatonnes of carbon emissions, by 2030 and to establishing a framework for reaching net-zero emissions by 2060.

Indonesia's energy transition dynamic is showcased with two intertwined case studies.

Case A – Accelerated phase-out of coal-fired power plants

The decarbonisation of Indonesia's power sector represents a cornerstone of the country's efforts to achieve its emissions-related goals. The endeavour of phasing out coal-fired power plants (CFPPs) will require a robust policy framework for the wider energy transition at the regional and national levels. There will be challenges related to the expanded deployment of renewable energy; for example, considerations at plant locations involving local stakeholders and increased efforts to build workforce's capacity to capitalise on the opportunities that will come.

Indonesia's national power utility, PLN (Perusahaan Listrik Negara), has 16 GW of CFPPs, which operate with strong, bankable long-term PPAs with fixed tariffs ensuring fixed returns to their owners, IPPs. The investment plan to continue the programme of phasing out CFPPs will require mobilising international capital from different DFIs, multilateral development banks (MDBs) and other agencies. The Government of Indonesia's (GoI's) principal development partners are the Asian Development Bank (ADB), IFC, the World Bank Group (WBG), the Japan International Cooperation Agency, German development co-operation through Kreditanstalt für Wiederaufbau (KfW) and the French Development Agency (AFD). The governments of Denmark, New Zealand, the United Kingdom and the United States also support the GoI on initiatives related to energy transition.

The investment plan must provide concessional financial support to local and regional stakeholders, while fostering opportunities for crowding in public and private financing to address the oversupply of electricity production from CFPPs.

The GoI quantifies approximately USD 5.2 billion in investments to retire just 2 GW of CFPPs. Of these investments, USD 1 billion are from the GoI and USD 600 million are provided in funding by the Climate Investment Fund (CIF) through the Accelerating Coal Transition (ACT) programme. They are together with USD 2.2 billion from the ADB, IFC and WBG, and over USD 1.3 billion in commercial co-financing.

The GoI describes the investment plan (table 5.3) to support Indonesia's CFPP retirement as a transformational change by addressing three critical pillars: (1) governance, (2) people and communities, and (3) infrastructure.

The scope of support from MDBs will range from working with the GoI to selecting plants to decommission and repurposing aspects of the plants to accelerate the retirement of the first 2 GW of baseload in a five-year framework. The MDBs' scope of support will, in parallel, include developing a just and inclusive approach to the workforce's transition to clean energy that is not limited to supporting replacement technologies, such as battery storage and solar PV. The scope will further include other initiatives for capacity building and training, and ancillary services for strengthening the grid network to handle variable renewable energy.

Table 5.3 Indonesia's proposed investment plan for the retirement of coal

		MDB SECTOR	ACT	MDB	OTHER/ PRIVATE	GOL[a]	TOTAL	PILLARS: Governance	PILLARS: People & communities	PILLARS: Infrastructure
COMPONENT 1: ACCELERATED RETIREMENT OF COAL PLANTS										
1.1	PLN RBL (early retirement of ~1 GW	ADB Public	50	600	300	[600]	1550	✓	✓	✓
1.2	PT SMI ETMCP - Facility 1 (PLN Sustainability-Linked Loan	ADB Public	50 1 (grant)	50	100	[250]	451		✓	✓
1.3	IPP CFPP early retirement programme	ADB Public	100	400	300[b]	N/A	800			✓
COMPONENT 2: GOVERNANCE, JUST TRANSISTION AND REPURPOSING										
2.1	PLN/MEMR Energy Transition P4R	WB Public	30 5 (grant)	400	0	[100]	535	✓	✓	✓
2.2	Just Transition & Repurposing Investment Propject (Phase 1 & 2)	WB Public	180 5 (grant)	415	0	[60]	660		✓	✓
2.3	PRIME STeP	ADB Public	9 (grant)	139	0	[21]	169		✓	
COMPONENT 3: SCALING UP RENEWABLE ENERGY & STORAGE										
3.1	Dispatchable Renewables Programme	IFC Public	70	140	350	N/A	560			✓
3.1	PT SMI ETMCP - Facilities 2 & 3 (Standby Facility & RE Loans)	ADB Public	100	100	300	N/A	500		✓	✓
	TOTAL		**600**	**2244**	**1350**	**[1031]**	**5225**			

Source: ADB, GoI (Ministry of Finance, PLN, PT SMI, Ministry of Education, Ministry of Energy and Mineral Resources) and WBG.

[a]GoI contribution figures subject to further discussion of program or project needs as well as annual budget approvals or endorsements. These numbers do not include broader MoF corporate support for implementing egencies such as PLN and PT SMI.

[b]To be confirmed in future market sounding.

Note: CFPP = Coal-fired Power Plant, ETMCP = Energy Transition Mechanism Country Platform, IPP = Independent Power Producer, P4R = Programme For Results, RBL = Results Based Loan, PRIME STeP = Skills Development and Center of Excellence on Energy Transition Program, RE = Renewable Energy.

Investment Financial Plan and Financial Instruments

Critical activities described in the above chart are built into the following components:

Component 1: Led by ADB, it encompasses early retirement of 1 GW, in turn accelerating renewable capacity expansion, providing training and increasing the number of women in the energy sector, and re-training of PLN workers impacted by the retirement of CFPPs.

Component 2: Led by the World Bank, it encompasses a multi-year Just Transition and Repurposing investment in CFPPs' retirement and coal mining to train the transitioning workers for new opportunities, promote wider community impacts and address alternative livelihood needs.

Component 3: Led by ADB and IFC, it encompasses scaling renewable energy and storage.

The terms and conditions of concessional funding, for example, senior and subordinated debt, pricing and tenor, will be tailored for each component to address their specific objectives and key performance indicators, while adhering to the DFI Enhanced Blended Concessional Finance Principles for Private Sector operations. For private sector projects, MDBs will most effectively retain flexibility in terms of approach, project selection and application of CIF funds to accelerate implementation and maximise impact on a project-by-project basis as well as across implementation plans.

Projects benefitting from public sector lending terms will follow the financial terms and conditions for public sector concessional loans for CIF financing that is fixed at financial closing. Table 5.4 shows the concessional lending terms for Indonesia's public sector.

Table 5.4 Indonesia's public sector concessional lending terms

	IDA-ONLY REGULAR SERVICE CHARGE [A]	APPLICABLE PERCENTAGE OF IDA-ONLY REGULAR SERVICE CHARGE [B]	APPLICABLE CIF LENDING RATE FOR TIER 3 COUNTRIES [C=A*B]	MATURITY (YEARS)	GRACE PERIOD (YEARS)	PRICIPAL REPAYMENTS
TIER 3A (USD)	1.22%	75%	0.92%	up to 20	8	Equal semi-annual installments after grace period
TIER 3B (USD)	1.22%	90%	1.10%	up to 30	8	Equal semi-annual installments after grace period

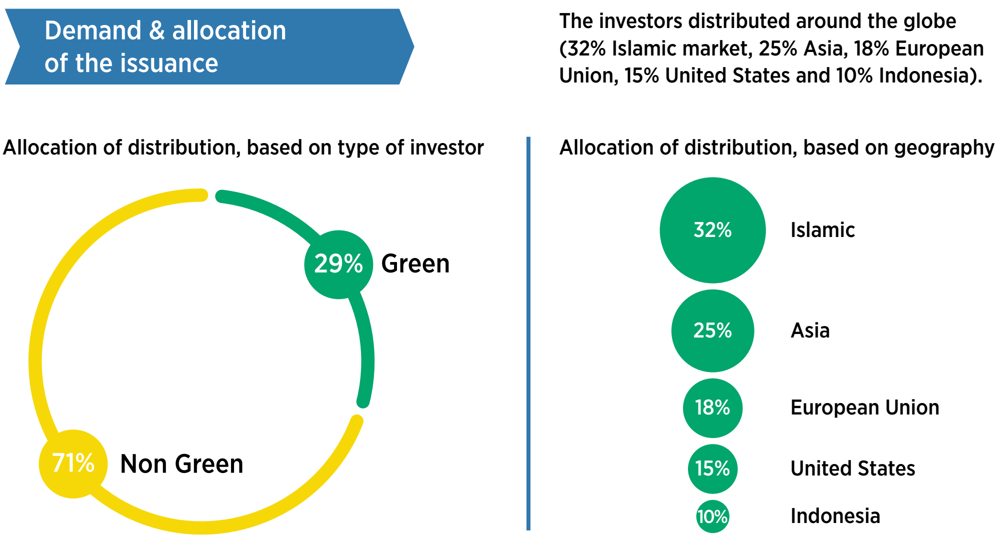
Source: World Bank. IDA Financial Products. Lending Rates and Fees. https://treasury.worldbank.org/en/about/unit/treasury/ida-financial-products/lending-rates-and-fees
Note: Tiering refers to Indonesia's pricing status for CIF as a lower middle-income country still qualifying for development assistance.
CIF = Climate Investment Fund; IDA = International Development Association.

The GoI's ambitious CFPP retirement programme underpins the case for effective government intervention and financial incentives.

Case B: Creating a market for Green Sukuk Bonds

Since 2020, Indonesia has registered three issuances of Sharia-compliant Sukuk bonds worth USD 2.5 billion on Nasdaq Dubai. The Sukuk list includes one issuance worth USD 1 billion for a 10-year tenor and two issuances worth USD 750 million with 5- and 30- year tenors. The Sukuk issuance has been welcomed by local and international investors, reaching oversubscription of nearly 6.7 times. Proceeds from Sukuk bonds are earmarked to finance economic and social development projects in Indonesia, and the USD 750 million five-year tenor is a green Sukuk earmarked for sustainable development projects. The Green Sukuk Bond Framework has received a second opinion from the CICERO.

Figure 5.7 Indonesia's Green Sukuk 2020 allocation



Source: (UNDP, 2020).
Note: SWF = sovereign wealth fund.

Table 5.5 Sukuk listings

Obligor	The Government of the Republic of Indonesia, represented by the Ministry of Finance
Issuer	Perusahaan Penerbit SBSN Indonesia III
Issuer rating	Baa3 Moody's (Positive) / BBB-S&P (Stable) / BBB Fitch (Stable)
Exp. issue rating	Baa3 Moody's / BBB- S&P / BBB-Fitch
Instrument	USD Wakala Trust Certificates ("Sukuk"), issued under a USD25 bn Trust Certificate Programme
Format. status	144A / RegS registered, senior unsecured
Maturity	Mar 1. 2023
Tranche	USD 1250 mm
Profit rate	3.750% p.a. (30/360)
Reoffer price / yield	100.000 / 3.750%
UST benchmark (price / yield)	2.375% 01/31/23 (98-22¾ / 2.655%)
Reoffer spread	+109.5 bp
Use of proceeds	General financing requirements in line with the Green Bond and Green Sukuk Framework
External reviewer	CICERO second party opinion
Other terms	USD200k/1k denominations, English and Indonesia law, Singapore and NASDAQ Dubai listing
Joint lead managers	ADIB, Citi (B&D), CIMB, DIB, HSBC

Source: (UNDP, 2020).

The GoI has 14 Sukuk listings, as shown in Table 5.5, These include the three issuances described above, valued at approximately USD 17.5 million. This is the largest list of Islamic Sukuk on Nasdaq Dubai. Still, Malaysia is the largest issuer of Sukuk bonds, amounting to approximately USD 142 billion, 80% of the country's private sector capital market.

The GoI's Sukuk bonds initiative is helping develop depth for the Islamic Sukuk financial product earmarked for sustainability, as well as highlighting the leadership of regional stock exchanges by attracting green investors. However, Indonesian corporates largely depend on bank loans for funding rather than bonds and Sukuk – because of the concept of default being untested in the country, and due to lack of standardisation and additional costs (legal, requirement of Sharia experts, *etc.*)

According to Fitch Ratings, Indonesia's onshore local-currency corporate Sukuk market has ample potential to grow because of the nascent debt-capital market, sizeable corporate funding needs, funding diversification push through both Sukuk and bonds, low but growing awareness of Islamic financing and the country's considerable Muslim population. Developing an Islamic finance ecosystem will require building an effective regulatory framework, providing additional incentives for corporate Sukuk issuers and investors, and raising awareness of debt capital-market funding.

However, it will take much more time develop the foreign-currency Sukuk market than the local-currency market, due to the limited record and more complex requirements from the country's risk management perspective.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

IRENA's detailed analysis of the energy transition in 2022 identified that the world will need to invest USD 131 trillion to achieve a 1.5°C pathway, one of the key Paris Agreement goals. This is about USD 33 trillion more than initially planned under current government policies. The 1.5°C pathway developed by IRENA is both technologically and economically feasible, and the global economy can commit to this level of investment. However, to achieve the energy transition at the least cost, access to low-cost capital is essential, particularly for emerging markets and developing economies.

Fortunately, the world does not start from scratch on this journey. Countries have already gained significant knowledge about many aspects of how to design, plan and execute a technology-driven transformation in the energy system. Over the past decade, renewable power generation technologies, specifically solar and wind power, have moved from an expensive niche to become, in most countries, the cheapest source of electricity today. This transformation was driven by a rapid scale up of deployment, improving performance and falling costs, with economies of scale and continuous technology innovations.

Support polices played a crucial role in creating this virtuous cycle of improved performance, falling costs and increased deployment. As a result, a future power system dominated by solar and wind power, which has the potential to decarbonise the end-use sectors through electrification (*e.g.* heat pumps or EVs), green hydrogen and the use of battery storage, to name a few of these critical technologies, can be envisaged.

Ensuring low-cost capital is available in sufficient quantities will be key to this transition. Renewable power generation capacity additions need to continue to accelerate to ensure that the share of renewables in the power mix grows rapidly to 2030. This suggests that not only must solar PV and onshore wind deployment be broadened and accelerated, but that of new and emerging renewable energy technologies, such as offshore wind power, as well. At the same time, those technologies that are needed to keep the grid operations stable and reliable as the share of variable renewable electricity in the power mix increases must rise in lockstep.

Despite the critical role that offshore wind, hydrogen electrolysers to produce green hydrogen, battery storage and others will play, they may not be as attractive as PV or onshore wind from an investor's perspective today. As a result, in new markets they are likely to face difficulty in accessing capital, especially at a low-cost. Their lack of access to low-cost capital in many markets poses a considerable challenge and therefore risk to delay the global energy transition under the 1.5°C pathway. Without proper attention to this issue, it could rapidly become a barrier, and not only in the Group of Twenty (G20), given rising interest rates over the last year.

To avoid missing the Paris Agreement goals, a holistic policy framework is needed to ensure these critical technologies for the energy transition scale down their cost curve supported by new innovations. This framework must include policies and measures to gain access to low-cost capital in the volumes needed. The lessons learnt by countries in the scale-up of solar PV and onshore wind power form a valuable resource to be shared and adapted for these new and emerging technologies that are critical to the next stage of the energy transition.

The synergies derived from co-ordinated deployment, innovation and de-risking policies will be crucial to scaling up public-private partnerships that are crucial to achieve the volume of investment funds needed. This is particularly important in the context where the private sector is becoming savvier about the investment risks and the need to make a reasonable return on their investment. Policies to reduce the transaction costs of technology transfers, facilitate foreign direct investment and the creation of local private ecosystems/supply chains where they make economic sense are also important.

The report highlights the following points:

- **There are lessons from the historical cost reduction seen for solar PV and onshore wind.** Since 2010, renewable power generation technologies, notably solar and wind power, have fallen significantly in cost. Technology innovation is constant, but today's solutions represent low technology risks. Even prior to the current fossil fuel crisis, cost-competitive renewable power generation typically undercut fossil fuels and their value has been proven in 2022, saving countries billions amid a global fossil fuel crisis. They have again proven beneficial for economy, environment and society. The policies and market development that succeeded in driving down costs and accelerating innovation, provide insights into how to manage the next stage of the energy transition.
- **Investment needs for energy transition are large, but within the means of the global finance system.** In the long run, renewables and energy efficiency will play the dominant role in accelerating the global energy transition process, which is pivotal to achieving the 1.5°C climate target under the Paris Agreement. However, this will require an annual investment, on average to 2050, of at least USD 4.4 trillion,[21] a significant portion of which will need to come from the private sector. Both commercial domestic and international sources of private sector capital need to therefore be urgently mobilised at scale.
- **Effective innovation frameworks are crucial components in accelerating the deployment of new and critical energy transition technologies, reducing financing**

[21] *Note that this figure is consistent with the analysis conducted for the 2022 edition of the World Energy Transition Outlook (IRENA, 2022b). IRENA is in the process of updating this analysis for 2023, and initial previews of the results suggest that this figure has grown to over USD 5 trillion per year (IRENA, 2023b). The final results will be released later in 2023.*

cost premiums and attracting investments. Such frameworks must include co-ordinated sets of actions across four dimensions – enabling technologies, business models, market design and system operation – to help address the key challenges and support the market development for a targeted technology and, thus, accelerate the energy transition. Even more, they can reduce the transaction costs of technology transfers and facilitate foreign direct investments or the creation of local private ecosystems.

- **Challenges of mitigating the cost of capital premiums.** Renewable energy financing cost differences between markets are primarily driven by non-technical variables, among which, country risk, exchange rate risk and off-take risks are usually the most important – and hence the largest barriers to mobilising low-cost capital to accelerate the energy transition – in a number of G20 members. Policies and measures, as well as innovative financing schemes to mitigate the cost of capital premium, would be beneficial for those G20 members with financing challenges and other developing countries to accelerate the energy transition.
- **The public sector cannot work in isolation. Partnerships between public, private and philanthropic sectors will be crucial.** Both the private sector and the public sector have a critical role to play in advancing the energy transition agenda. Neither can do without the other. The philanthropic sector can also make useful concessional contributions to de-risking energy transition initiatives and projects. The energy transition is a "higher-hanging fruit" that no one party in isolation can achieve. It therefore requires close collaboration between the parties in the form of partnerships on distinct and well-defined challenges between all three sectors, which generate jointly developed action plans with accountability and ownership for measurable outcomes.
- **The role of the public sector:** The public sector plays a critical catalysing role by providing a conducive and predictable enabling environment (policy framework) to drive long-term private sector investment decisions. An effective enabling environment will incentivise and facilitate private sector investors and developers' decisions in developing, financing and building the volume of projects needed for the energy transition. With the financial resources of the public sector, globally, increasingly restricted due to macroeconomic headwinds, the importance of leveraging limited public resources to unlock private sector investment is, even more than usual, crucial.
- **The role of the private sector.** The private sector sees attractive investment opportunities in the energy transition but will only invest if the projects meet the private sector's rigorous resource allocation models for directing their capital investments to projects with suitable risk-reward profiles. Non-investment-grade countries can have trouble accessing low-cost finance, as institutional investors with trillions of dollars under management are often restricted from investing in such markets. Similarly, smaller and riskier projects, and more nascent decarbonisation technologies designed in and for developing countries might also not have access to capital they need. In these cases, blended finance interventions by the public and philanthropic sectors can play an important role in solving for this disconnect between capital availability and cost, and the needs of developers and governments.
- **Low-cost financing instruments and case studies.** There are a variety of instruments and schemes that can be adopted to reduce the cost of financing. The case studies taken from G20 Members in this report illustrate that well-designed public sector

support which reduces private sector investors' risks can play a central role in reducing the cost of capital and facilitate emerging and developing countries mitigation plans. In some case studies forms of blended finance are being successfully applied at scale. These case studies merit close review for possible replication in other countries and/or with new and emerging technologies for the energy transition, customised to cater to specific local and regional differences.

- **G20 members have a wealth of experience in facilitating access to low-cost finance** in different markets and can share valuable knowledge on innovative financing solutions to reduce the cost of capital. Efforts at documenting cost of finance differential drivers and the sharing of examples and/or case studies, such as the ones included in the report, showcase best practices in lowering the cost of capital among G20 members and provide welcome insights.

Additionally, the report has made the following recommendations for the G20 members and more to take into consideration in their policy-making process.

- **The fossil fuel price shock of 2022 has reinforced the need for countries to stay on course in the energy transition and to scale up the deployment of renewables.** Renewables and energy efficiency represent the only true long-term hedge against fossil fuel price volatility and the macroeconomic damage of price shocks. The avoided fossil fuel import costs from renewable energy technologies, that have over the past decade of development become mature with low technology risks and high cost-competitiveness, ran into the tens of billions in 2022. Renewables, once installed, provide multi-decadal energy independence and, thus, minimise the effect of instability of international energy markets.
- **Countries should provide a range of policy incentives (economic, financial and regulatory as appropriate to a country's situation) to facilitate the development and deployment of the next set of critical technologies for the energy transition**, such as offshore wind, hydrogen electrolysers, battery electricity storage, heat pumps,

etc. Policy frameworks can include a range of elements, from certification standards to long-term contracts for the purchase of green hydrogen, and from improved permitting and marine spatial panning for offshore wind to ancillary service contracts that recognise the value of battery storage in integrating variable renewables in the power system.

- **Countries should build upon the lessons learnt from the success of solar PV and onshore wind** to accelerate the potential scale-up of these critical technologies in their own country-specific context. Peer-to-peer exchanges on policy frameworks, institutional and regulatory needs could be complemented by analysis from a range of stakeholders; from governments, international organisations and research institutions.
- **Innovation policies should be sustained over time**, particularly in supporting research and development, demonstration and early market roll-out to allow novel technologies to become commercially mature solutions. Countries could consider and build on the innovation framework proposed in this report as a holistic tool to devise their support schemes and address the specific challenges of each technology in their market.
- **The drivers of cost of capital differences between countries and technologies should be mapped in detail and stakeholders surveyed to understand the reasons for these differences.** With this knowledge of the reasons for cost differences, industry and policy makers could then work together to identify the policies, regulatory framework adjustments and other interventions needed to lower the cost of capital to energy transition technologies. This would allow low-cost capital to flow to the investment needs of the energy transition in a timely manner. By the same token, it would be advisable to work with multilateral development banks (MDBs) and other financial institutions involved in development and climate mitigation finance to understand the enhanced role they can play in lowering the cost of capital and growing the available pool of capital.
- **The role of the public sector is crucial to unlocking low-cost private sector capital for the energy transition.** The public sector should play an active role in creating a healthy financing environment for private sector investors and project developers. If that is achieved, the private sector will invest and build the energy transition projects needed. This is vital, given that the vast majority of the required investment in energy transition will need to come from the private sector.
- **Specifically, the public sector, including MDBs, should step up efforts to offer risk mitigation measures.** The provision of concessional funds by applying blended financing approach in collaboration with the private sector, as well as other risk mitigation measures related to off-taker or exchange rate risk are important levers. Adapting these products to country-specific needs could attract more private investments into the pool of resources dedicated to financing those critical energy transition technology projects and reduce the cost of capital.
- **Knowledge exchange is vital. The G20 members should take the opportunity to exchange knowledge and best practice** given there is a wealth of experience in facilitating access to low-cost finance in different markets and also in reducing the cost of capital, particularly for the private sector to take part in financing the global energy transition. IRENA is ready to help facilitate this and any other efforts to scale-up low-cost finance for existing and emerging energy transition technologies.

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