

The cover image is a composite of two photographs. The top half shows a rural landscape with two large white wind turbines on a hillside under a blue sky with scattered clouds. The bottom half, separated by a diagonal white line, shows a large array of blue solar panels in a field. The overall theme is renewable energy.

iea

International  
Energy Agency

# Renewables

## 2021

Analysis and forecast to 2026

# INTERNATIONAL ENERGY AGENCY

---

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

Please note that this publication is subject to specific restrictions that limit its use and distribution. The terms and conditions are available online at [www.iea.org/t&c/](http://www.iea.org/t&c/)

This publication and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

Source: IEA. All rights reserved.  
International Energy Agency  
Website: [www.iea.org](http://www.iea.org)

## IEA member countries:

Australia  
Austria  
Belgium  
Canada  
Czech Republic  
Denmark  
Estonia  
Finland  
France  
Germany  
Greece  
Hungary  
Ireland  
Italy  
Japan  
Korea  
Luxembourg  
Mexico  
Netherlands  
New Zealand  
Norway  
Poland  
Portugal  
Slovak Republic  
Spain  
Sweden  
Switzerland  
Turkey  
United Kingdom  
United States

The European Commission also participates in the work of the IEA

## IEA association countries:

Brazil  
China  
India  
Indonesia  
Morocco  
Singapore  
South Africa  
Thailand

Revised version, December 2021.  
Information notice found at:  
<https://www.iea.org/corrections>  
<http://www.oecd.org/about/publishing/corrigenda.htm>



# Abstract

Renewables 2021 is the IEA's primary analysis on the sector, based on current policies and market developments. It forecasts the deployment of renewable energy technologies in electricity, transport and heat to 2026 while also exploring key challenges to the industry and identifying barriers to faster growth.

Renewables are the backbone of any energy transition to achieve net zero. As the world increasingly shifts away from carbon emitting fossil fuels, understanding the current role renewables play in the decarbonisation of multiple sectors is key to ensuring a smooth pathway to net zero.

While renewables continued to be deployed at a strong pace during the Covid-19 crisis, they face new opportunities and challenges. This year's report frames current policy and market dynamics while placing the recent rise in energy and commodities prices in context. In addition to providing detailed market analysis and forecasts, Renewables 2021 also explores trends to watch including storage, producing hydrogen from renewable electricity, stimulus packages, aviation biofuels and residential heating.

# Acknowledgements, contributors and credits

This study was prepared by the Renewable Energy Division in the Directorate of Energy Markets and Security. It was designed and directed by Heymi Bahar, Senior Analyst.

The report benefited from analysis, drafting and input from multiple colleagues. The lead authors of the report were, Yasmina Abdelilah, Heymi Bahar, Trevor Criswell, Piotr Bojek, François Briens, Jeremy Moorhouse and Grecia Rodríguez Jiménez, who was also responsible for data management. The report also benefited from analysis and drafting from Kazuhiro Kurumi and Kartik Veerakumar.

Paolo Frankl, Head of the Renewable Energy Division, provided strategic guidance and input to this work. Valuable comments, feedback and guidance were provided by other senior management and numerous other colleagues within the IEA, in particular, Keisuke Sadamori and Laura Cozzi.

Other IEA colleagues who have made important contributions to this work include:

Nadim Abillama, Ali Al-Saffar, Carlos Alvarez Fernandez, Lucila Arboleya, Elisa Asmelash, Praveen Bains, Christophe Barret, Jose, Bermudez Menendez, Sylvia Beyer, Toril Bosoni, Stéphanie Bouckaert, Davide d'Ambrosio, Peter Fraser, Astha Gupta, Ilkka Hannula, César Alejandro Hernandez, Joerg Husar, Kevin Lane, Stefan Lorenczik, Dionisia Lyngopoulou, Yannick Monschauer, Apostolos Petropoulos, Kristine Petrosyan, Uwe Remme, Luis Fernando Rosa, Michael Oppermann, Gabriel Saive, Jacopo Tattini, Jacob Teter, Nicole Thomas, Aad Van Bohemen, Peerapat Vithayasrichareon, Timothy Goodson, Ariane Millot, Fabian Voswinkel, Brent Wanner, Daniel Wetzel.

Timely data from the IEA Energy Data Centre were fundamental to the report, with particular assistance provided by Mathilde Daugy, Julia Guyon, Nick Johnstone, Julian Prime, Céline Rouquette and Roberta Quadrelli.

This work benefited from extensive review and comments from the IEA Standing Group on Long-Term Co-operation, IEA Renewable Energy Working Party, members of the Renewable Industry Advisory Board (RIAB) and experts from IEA partner countries and other international institutions. The work also benefited from

feedback by the IEA Committee on Energy Research and Technology, IEA Technology Collaboration Programmes (IEA TCPs).

Many experts from outside of the IEA provided valuable input, commented and reviewed this report. They include:

Countries:

Austria (Austrian Energy Agency), Belgium (Federal Public Service Economy), Brazil (Empresa de Pesquisa Energética), Canada (Natural Resources Canada), Chile (Ministry of Energy), People's Republic of China (Energy Research Institute – ERI), Colombia (Unidad de Planeación Minero Energética), European Union (European Commission – DG Energy), Finland (Ministry of Economic Affairs and Employment), France (Ministry of Ecological and Solidarity Transition), Italy (National Agency for New Technologies, Energy and Sustainable Economic Development ENEA), Ireland (Sustainable Energy Authority – SEAI), Japan (Ministry of Economy, Trade and Industry - METI), Spain (Institute for Energy Diversification and Energy Saving - IDAE), Switzerland (Federal Office of Energy), United States (Department of Energy).

Technology Collaboration Programme (TCPs):

Bioenergy TCP, Heat Pumping Technologies (HPT) TCP, Hydropower TCP, Photovoltaic Power Systems (PVPS) TCP, Solar Heating and Cooling TCP, SolarPACES TCP, Wind Energy TCP.

Other Organisations:

Abengoa Solar, Acciona Energía, American Clean Power Association (ACPA), American Wind Energy Association (AWEA), Amrock Pty Ltd, Australian Energy Market Operator (AEMO), Council on Energy, Environment and Water (CEEW), Electric Power Development Company (JPOWER), Électricité de France (EDF), ENEL, Energy Insights Ltd, European Bank for Reconstruction and Development (EBRD), European Commission, European Geothermal Energy Association (EGEC), European Bioenergy (AEBIOM), EA Energy Analyses, European Heat Pump Association (EHPA), European heating industry (EHI), European Renewable Energy Foundation (EREF), European Renewable Ethanol Association (EPURE), European Solar Thermal Industry Federation (ESTIF), First Solar, FTI Consulting, General Electric (GE), Gestore dei Servizi Energetici (GSE), Global Wind Energy Association (GWEC), Iberdrola, Institute of Energy Economics Japan (IEEJ), International Hydropower Association (IHA), International Renewable Energy Agency (IRENA), National Renewable Energy Laboratory (NREL), Neste, Ørsted, POET, Queen's University, REN21, Siemens

Gamesa, Solar Power Europe, SPV Market Research, TECSOL, SOLISART, United Nations Economic Commission for Europe (UNECE), US Grains Council, Università Degli Studi di Firenze, Vestas, WindEurope, World Bank, World Bioenergy Association.

The authors would also like to thank Justin French-Brooks for skilfully editing the manuscript and the IEA Communication and Digital Office, in particular Jon Custer, Astrid Dumond, Merve Erdem, Christopher Gully, Jad Mouawad, Barbara Moure, Jethro Mullen, Julie Puech, Robert Stone and Therese Walsh for their assistance. In addition, Ivo Letra from the Office of Management and Administration supported data management.

Questions or comments?

Please write to us at [IEA-REMR@iea.org](mailto:IEA-REMR@iea.org)

# Table of contents

<b>Executive summary</b> .....	<b>14</b>
Improved policies and COP26 climate goals are set to propel renewable electricity growth to new heights .....	14
Despite rising prices, solar PV will set new records and wind will grow faster than over the previous five years .....	15
Asia is set to overtake Europe as India and Indonesia lead renewed growth in global demand for biofuels.....	16
Renewable heat has gained some policy momentum, but its market share is not set to increase significantly .....	16
High commodity and energy prices bring significant uncertainties .....	17
Supported by the right policies, recovery spending on renewables could unleash a huge wave of private capital .....	18
Faster growth of renewables is within reach but requires addressing persistent challenges..	18
Renewables' penetration in to hard-to-decarbonise sectors is slowly emerging and promises a bright future .....	19
Renewables need to grow faster than our forecasts to close the gap with a pathway to net zero by 2050.....	19
<b>Chapter 1. Renewable electricity</b> .....	<b>21</b>
Forecast summary .....	21
Renewable capacity additions are set to grow faster than ever in the next five years, but the expansion trend is not on track to meet the IEA Net Zero by 2050 Scenario.....	21
Growing policy momentum worldwide is driving our forecast upward .....	22
Government-led auction capacity is in slight decline, but is compensated by robust corporate PPA activity .....	24
Top-10 countries continue to dominate renewables expansion, indicating that more diversity is needed .....	25
Solar PV breaks new records in our forecast, despite rising prices.....	26
Low wind conditions and droughts in key markets hamper more rapid growth of renewable generation in 2021 .....	30
Achieving the IEA Net Zero by 2050 Scenario requires policy makers to significantly increase their ambition for all renewables .....	34
Country and regional analysis .....	35
China .....	35
United States.....	37
Asia Pacific.....	40
India.....	41
Japan.....	45
Korea .....	46
ASEAN .....	47
Australia .....	50



Europe .....	52
Germany.....	54
Spain .....	56
France .....	58
The Netherlands.....	60
Turkey .....	62
Poland .....	64
Italy.....	65
United Kingdom.....	67
Denmark.....	68
Belgium .....	69
Latin America .....	71
Sub-Saharan Africa.....	78
Middle East and North Africa .....	81
References .....	84
<b>Chapter 2. Biofuels.....</b>	<b>89</b>
Forecast summary .....	89
Biofuels recover in 2021 despite high costs.....	89
Asia to surpass European biofuel production before 2026 .....	90
Ethanol and renewable diesel lead biofuels growth.....	91
Four policy discussions to watch that will help double biofuel growth rates .....	91
Demand and supply .....	93
Asia surpasses European biofuel demand and supply.....	95
Different fuels for different parts of the world.....	96
Fuel demand and government policies are driving different supply outcomes in different regions.....	98
Biofuel demand growth doubles in the accelerated case .....	102
Biofuels need to expand faster to align with the IEA Net Zero by 2050 Scenario .....	105
Trade.....	107
Renewable diesel and biojet lead growth in net trade .....	108
Singapore climbs to second largest exporter, while top importers remain the same .....	109
Ethanol and biojet import demand drives trade growth in the accelerated case .....	110
References.....	111
<b>Chapter 3. Renewable heat.....</b>	<b>114</b>
Recent trends.....	114
Global progress on conversion to renewable heat has been limited .....	114
Policy update.....	115
Renewable heat has gained some policy momentum, but not enough to put the heat sector on track to meet climate ambitions.....	115
Outlook to 2026.....	122



Buildings.....	123
Industry.....	125
References.....	129
<b>Chapter 4. Renewable energy trends to watch .....</b>	<b>133</b>
What is the impact of increasing commodity and energy prices on solar PV, wind and biofuels? .....	133
Wind and solar PV .....	133
How do commodity prices affect the investment costs of solar PV and onshore wind?.....	134
Rising energy prices and trade policies put additional upward price pressure on wind and solar.....	138
Despite rising equipment prices, wind and solar remain competitive .....	140
How much will renewable energy benefit from global stimulus packages? .....	145
Focus on the EU Recovery and Resilience Facility .....	148
Could the green hydrogen boom lead to additional renewable capacity by 2026? .....	151
How rapidly will the global electricity storage market grow by 2026? .....	154
Are conditions right for biojet to take flight over the next five years?.....	157
Condition 1 – Confidence in biojet .....	158
Condition 2 – Costs.....	159
Condition 3 – Policies.....	160
Condition 4 – Production.....	161
Condition 5 – Feedstock sustainability.....	162
Are renewable heating options cost-competitive with fossil fuels in the residential sector? .....	163
Upfront costs .....	163
Operating costs .....	165
Overall cost-competitiveness of heating technologies .....	166
References.....	168
<b>General annex.....</b>	<b>172</b>
Abbreviations and acronyms.....	172
Units of measure .....	173

## List of boxes

Box 2.1	India has tripled ethanol demand over the past five years, putting it on track to be the world’s third-largest ethanol consumer by 2026 .....	100
---------	---	-----

## List of figures

Figure 1.1	Average annual renewable capacity additions and cumulative installed capacity, historical, forecasts and IEA Net Zero Scenario, 2009-2026 .....	22
------------	---	----

Figure 1.2	IEA five-year renewable capacity forecasts by country/region, main case, 2021 and 2021 .....	23
Figure 1.3	Renewable electricity auctioned capacity by country/region, 2015-2021 (left) and by technology and corporate PPAs, 2015-2021 (right) .....	24
Figure 1.4	Auction-awarded renewable capacity by contract duration, 2017-2021 .....	25
Figure 1.5	Top-ten countries' share of total installed renewable capacity, historical and main case forecast, 1991-2026 .....	26
Figure 1.6	Annual capacity additions of solar PV, wind and other renewables, main and accelerated cases, 2020-2026 .....	27
Figure 1.7	Solar PV and onshore wind capacity additions, actual and forecast by country/region, 2015-2026 .....	28
Figure 1.8	Hydropower and wind electricity generation growth in selected markets, 2015-2020 average and 2021 .....	30
Figure 1.9	Renewable electricity generation by technology, 1990-2026 (left) and share by technology, 1990-2026 (right) .....	31
Figure 1.10	Share of wind, solar PV, hydropower and all renewables in total electricity generation, 2000-2026 .....	32
Figure 1.11	Wind and solar PV generation curtailment by country .....	33
Figure 1.12	Average annual capacity additions by technology, actual, forecasts and IEA Net Zero Scenario, 2015-2026 .....	34
Figure 1.13	China renewable capacity additions, 2009-2026 (left) and non-fossil energy target proposals for 2030 (right) .....	35
Figure 1.14	United States renewable capacity additions, 2008-2026 (left) and solar PV and wind PPA capacity and average contract price, 2014-2020 (right) .....	37
Figure 1.15	United States solar and wind capacity additions, 2017-2026 (left) and low-carbon electricity target, 2020-2030 (right) .....	39
Figure 1.16	Asia Pacific renewable capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right) .....	41
Figure 1.17	India renewable capacity additions, 2009-2026 (left) and national targets for 2022 and 2030 (right) .....	42
Figure 1.18	India renewable capacity awarded via auctions, 2018-2021 (left) and DISCOMs' overdue payments to generators, 2019-2021 (right) .....	43
Figure 1.19	Japan renewable capacity additions, 2009-2026 (left) and renewable energy capacity targets, 2019-2030 (right) .....	45
Figure 1.20	Korea renewable capacity additions, 2009-2026 (left) and average revenue per MWh by technology, 2017-2020 (right) .....	47
Figure 1.21	ASEAN renewable capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right) .....	49
Figure 1.22	Australia renewable capacity additions, 2009-2026 (left) and renewables curtailment, Q1 2019-Q2 2021 (right) .....	50
Figure 1.23	EU member states installed renewable capacity and capacity expected in 2030 based on submitted NECPs .....	52
Figure 1.24	Europe renewable capacity additions by country, 2009-2026 (left) and capacity growth by technology, 2015-2026 (right) .....	54
Figure 1.25	Germany renewable capacity additions, 2019-2026 (left) and onshore wind auctions (right) .....	55
Figure 1.26	Spain renewable capacity additions, 2019-2026 (left) and comparison of auction prices and wholesale electricity prices, 2018-2021 (right) .....	57
Figure 1.27	France renewable capacity additions, 2009-2026 (left), and auction results, 2019-2020 (right) .....	59
Figure 1.28	Netherlands renewable capacity additions, 2009-2026 (left) and share of budget award by technology, 2016-2020 (right) .....	61
Figure 1.29	Turkey renewable capacity additions, 2009-2026 (left) and solar PV auction results, 2021 (right) .....	63

Figure 1.30	Poland’s renewable capacity additions, 2009-2026 (left), and estimated PV and wind capacity additions resulting from renewable energy auctions, 2017-2021 (right) .....	64
Figure 1.31	Italy renewable capacity additions, 2009-2026 (left) and FER auction results, 2019-2021 (right) .....	66
Figure 1.32	United Kingdom renewable capacity additions, 2009-2026 (left), and CfD auction results (capacity and strike prices), 2021-2026 (right) .....	67
Figure 1.33	Denmark renewable capacity additions, 2009-2026 (left) and types of policy driver by technology, 2021-2026 (right) .....	69
Figure 1.34	Belgium renewable capacity additions, 2019-2026 (left) and historical and forecast solar PV additions by region, 2011-2026 (right) .....	70
Figure 1.35	Latin America capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right) .....	71
Figure 1.36	Brazil renewable capacity additions, 2019-2026 (left) and awarded auction and spot market prices, 2018-2021 (right) .....	72
Figure 1.37	Chile renewable capacity additions, 2019-2026 (left) and non-conventional renewable generation historical share and future target and demand by type (right) .....	74
Figure 1.38	Mexico renewable capacity additions, 2019-2026 (left) and Argentina renewable capacity additions, 2019-2026 (right) .....	76
Figure 1.39	Colombia renewable capacity additions, 2019-2026 (left) and capacity awarded by auctions, 2019 and 2021 (right) .....	77
Figure 1.40	Sub-Saharan Africa renewable additions by country, 2019-2026 (left) and additions by technology and country, 2015-2026 (right) .....	79
Figure 1.41	MENA renewable capacity growth by technology, 2009-2026 (left) and by country, 2021-2026 (right) .....	82
Figure 1.42	MENA solar PV growth, 2009-2026 (left) and awarded bid prices, 2014-2022 (right) .....	83
Figure 2.1	Biofuel demand growth and share of total demand by fuel (left) and region (right), main case, 2021-2026 .....	90
Figure 2.2	Biofuel demand and share of total biofuel demand in the accelerated case versus the main case by fuel (left) and by region (right) .....	92
Figure 2.3	Biofuel demand by region (left) and by fuel (right), main case, 2018-2026 .....	93
Figure 2.4	Biofuel supply and demand growth by region and fuel, main case, 2022-2026 .....	94
Figure 2.5	Biofuel regional demand (left) and supply (right), main case, 2018-2026 .....	95
Figure 2.6	Biofuel demand growth by fuel (left) and share of fuel demand growth by region (right), main case, 2021-2026 .....	97
Figure 2.7	US ethanol fuel supply (left) and Asian biodiesel and renewable diesel supply (right), main case, 2019 and 2026 .....	99
Figure 2.8	Biofuel demand growth by region and fuel in the accelerated case, 2021-2026 ...	102
Figure 2.9	Biofuel production growth by region in the accelerated case (left) and total production shares by region in the main and accelerated cases (right), 2021-2026 .....	103
Figure 2.10	Biofuel demand in the main case, accelerated case and the Net Zero Scenario, 2014-2026 .....	105
Figure 2.11	Net trade by fuel and net trade share of demand by fuel, main case, 2020 and 2026 .....	109
Figure 2.12	Top five global exporters and importers of biofuel in 2026 compared with 2021, main case .....	110
Figure 2.13	Net trade in 2021, 2026 main case and 2026 accelerated case .....	111
Figure 3.1	Renewable and non-renewable heat consumption and heat-related CO <sub>2</sub> emissions in buildings and industry, world, 2010-2020 .....	115
Figure 3.2	Increase in renewable heat consumption by energy source (left) and country/region (right), 2009-2026 .....	122

Figure 3.3	Renewable heat consumption and share of total heat demand in buildings and industry, 2014-2026.....	123
Figure 3.4	Increase in renewable heat consumption in buildings, and share of modern renewables and traditional uses of biomass in buildings heat demand, selected regions, 2015-2026.....	125
Figure 3.5	Contribution of different factors to changes in renewable electricity consumption in industry, selected regions, 2021-2026.....	126
Figure 3.6	Increase in renewable heat consumption in industry and share of renewables in industrial heat demand, selected regions, 2015-2026.....	127
Figure 3.7	Growth in renewable heat consumption and global cumulative heat-related CO <sub>2</sub> emissions in the IEA outlook and Net Zero Emissions Scenario, world, 2021-2026.....	129
Figure 4.1	Monthly commodity and freight price indexes, 2020-2021.....	134
Figure 4.2	Utility-scale PV and onshore wind investment cost structure by component and by commodity breakdown.....	135
Figure 4.3	Utility-scale PV and onshore wind, total investment cost change by commodity and freight input, from average 2019 prices.....	136
Figure 4.4	Impact of high commodity price scenario on forecast total investment costs and CAPEX, onshore wind and utility-scale PV, 2015-2026.....	138
Figure 4.5	Average wholesale electricity prices and LCOE of utility-scale solar PV and onshore in 2020 and in high commodity price scenario in Germany, United Kingdom and Spain.....	140
Figure 4.6	Demand decline in response to high prices, selected countries, 2021.....	142
Figure 4.7	Biofuel prices and feedstock costs in selected markets, ethanol (left) and biodiesel (right), 2017-2021.....	143
Figure 4.8	Global government clean energy stimulus in response to Covid-19, allocated up to October 2021.....	145
Figure 4.9	Global government clean energy spending by sector and technology, allocated up to October 2021.....	146
Figure 4.10	Government clean energy approved spending by region and share of renewables, allocated up to October 2021.....	147
Figure 4.11	Estimated renewable capacity additions resulting from approved government spending, depending on private financing leverage, to be commissioned over 2021-2026.....	148
Figure 4.12	EU RFF funding allocation by country and share of clean energy.....	149
Figure 4.13	EU RFF fund allocation by sector and between renewables.....	150
Figure 4.14	EU RFF fund allocation by renewable technology or fuel.....	150
Figure 4.15	Global installed electrolyser capacity in 2020 and projects planned for commissioning, 2021-2026 (left) and additional renewable capacity for electrolysis, 2021-2026.....	151
Figure 4.16	Additional renewable capacity according to planned and announced green hydrogen projects.....	152
Figure 4.17	Global planned electrolyser capacity and estimation of additional renewable capacity by country/region.....	153
Figure 4.18	Concentrated solar power, pumped hydro and batteries, installed storage capacity in 2020 and 2026.....	154
Figure 4.19	CSP, PSH and battery storage capability in 2020 and 2026.....	156
Figure 4.20	PSH storage capability, 2021-2030.....	157
Figure 4.21	Fossil jet and biojet fuel production cost ranges.....	159
Figure 4.22	Annual SAF demand range over the main and accelerated cases compared with capacity potential.....	160
Figure 4.23	Investment cost range for selected residential space and water heating technologies and regions.....	164

Figure 4.24	Average annual operating cost range for selected space and water heating technologies and regions .....	165
Figure 4.25	Levelised cost of heating for consumers, for selected space and water heating technologies and countries.....	166

## List of tables

Table 2.1	Main and accelerated case policy and assumption summary.....	106
Table 3.1	Recent policy updates encouraging the uptake of renewable heat .....	117
Table 4.1	Reductions in material processing due to high energy prices, commodities used in renewables equipment, selected examples .....	138
Table 4.2	Trade measures targeting wind and solar PV equipment .....	139

# Executive summary

## Improved policies and COP26 climate goals are set to propel renewable electricity growth to new heights

**Additions of renewable power capacity are on track to set yet another annual record in 2021, driven by solar PV.** Almost 290 gigawatts (GW) of new renewable power will be commissioned this year, which is 3% higher than 2020's already exceptional growth. Solar PV alone accounts for more than half of all renewable power expansion in 2021, followed by wind and hydropower.

**The growth of renewable capacity is forecast to accelerate in the next five years, accounting for almost 95% of the increase in global power capacity through 2026.** We have revised up our forecast from a year earlier, as stronger policy support and ambitious climate targets announced for COP26 outweigh the current record commodity prices that have increased the costs of building new wind and solar PV installations. Globally, renewable electricity capacity is forecast to increase by over 60% between 2020 and 2026, reaching more than 4 800 GW. This is equivalent to the current global power capacity of fossil fuels and nuclear combined. Overall, China remains the leader over the next five years, accounting for 43% of global renewable capacity growth, followed by Europe, the United States and India. These four markets alone account for 80% of renewable capacity expansion worldwide.

**China and the European Union are set to overshoot their current targets, setting the stage for a more ambitious growth trajectory.** China's commitment to reach carbon neutrality before 2060 has led to new nearer-term targets, such as 1 200 GW of total wind and solar PV capacity by 2030. We forecast that China will reach this target four years early thanks to the availability of long-term contracts, improved grid integration, and the cost competitiveness of onshore wind and solar PV compared with coal generation in many provinces. The trajectory of renewable capacity growth over the 2021-26 period indicates that renewable power growth in the European Union as a whole is set to outpace what the current National Energy and Climate Plans (NECPs) envision for 2030. This trend supports the ambition of reaching the stronger targets being finalised under the "Fit for 55" programme. Rapid deployment is being driven by member countries implementing larger auction volumes, corporations contracting for more renewable electricity, and consumers continuing to install large amounts of solar panels.

**Improving competitiveness, ambitious targets and policy support are putting renewable power on course for new highs in India and the United States.** Relative to existing capacity, renewable power is growing faster in India than any other key market in the world, with new installations set to double over our forecast period compared with 2015-20. Solar PV is expected to lead the way, driven by competitive auctions aimed at achieving the government's ambitious renewable power target of 500 GW by 2030. Over the 2021-26 period, the expansion of renewable capacity in the United States is 65% greater than in the previous five years. This is the combined result of the economic attractiveness of wind and solar PV, increased ambition at the federal level, the extension of federal tax credits in December 2020, a growing market for corporate power purchase agreements, and growing support for offshore wind.

## **Despite rising prices, solar PV will set new records and wind will grow faster than over the previous five years**

**Even with surging commodity prices increasing manufacturing costs for solar PV, its capacity additions are forecast to grow by 17% in 2021.** This will set a new annual record of almost 160 GW. Solar PV alone accounts for 60% of all renewable capacity additions, with almost 1 100 GW becoming operational over the forecast period in our main case, double the rate over the previous five years. In a significant majority of countries worldwide, utility-scale solar PV is the least costly option for adding new electricity capacity, especially amid rising natural gas and coal prices. Utility-scale solar projects continue to provide over 60% of all solar PV additions worldwide. Meanwhile, policy initiatives in China, the European Union and India are boosting the deployment of commercial and residential PV projects.

**Onshore wind additions through 2026 are set to be almost 25% higher on average than in the 2015-2020 period.** Global onshore wind additions doubled in 2020, reaching an exceptional level of almost 110 GW. This was driven by an acceleration in China as developers rushed to complete projects before subsidies expired. While annual additions in the coming years are not expected to match 2020's record, we forecast that they will average 75 GW per year over the 2021-2026 period.

**Total offshore wind capacity is forecast to more than triple by 2026.** By then, offshore wind additions are expected to account for one-fifth of the global wind market, a major milestone. Global capacity additions of offshore wind are set to reach 21 GW by 2026, thanks to rapid expansion in new markets beyond Europe



and China. This includes large-scale projects that are expected to be commissioned in the United States, Chinese Taipei, Korea, Viet Nam, and Japan.

**The expansion of dispatchable renewables is critical to support the integration of more wind and solar, but their growth is forecast to slow slightly.** The expansion of hydropower, bioenergy, geothermal and concentrated solar power accounts for only 11% of renewable capacity expansion worldwide over our forecast period. Relatively higher costs, lack of policy support and limited remuneration of flexible and dispatchable renewables discourage their expansion.

## Asia is set to overtake Europe as India and Indonesia lead renewed growth in global demand for biofuels

**Following a historic decline last year amid global transport disruption, total biofuel demand is on course to surpass 2019 levels in 2021.** In our main case, annual global demand for biofuels is set to grow by 28% by 2026, reaching 186 billion litres. The United States leads in volume increases, but much of this growth is a rebound from the drop caused by the pandemic. Asia accounts for almost 30% of new production over the forecast period, overtaking European biofuel production by 2026. This is thanks to strong domestic policies, growing liquid fuel demand and export-driven production. Recent Indian ethanol policies and blending targets for biodiesel in Indonesia and Malaysia are responsible for most of the growth in Asia. India is set to become the third largest market for ethanol demand worldwide by 2026.

## Renewable heat has gained some policy momentum, but its market share is not set to increase significantly

**Since the start of 2020, heat from renewable sources has benefited directly or indirectly from several policy developments, mostly in Europe.** Under current policies, renewable heat consumption, excluding traditional uses of biomass, is expected to increase by one-quarter during the 2021-26 period. Its share of global heat consumption is only forecast to rise from 11% in 2020 to 13% in 2026. Fossil fuels are set to continue meeting much of the growing global demand for heat, leading to a 5% increase in heat-related CO<sub>2</sub> emissions over our forecast period.

**The lack of policy and financial incentives for renewable heat is preventing faster growth.** Globally, more than one-third of heat consumption is not covered by any financial incentive for renewables, and more than half is not subject to any renewables-related regulatory measures. The fragmented nature of heat markets

and local characteristics of heat demand partly explain the limited national policy coverage. This makes greater collaboration with subnational actors necessary.

## High commodity and energy prices bring significant uncertainties

**Rising commodity, energy and shipping prices have increased the cost of producing and transporting solar PV modules, wind turbines and biofuels worldwide.** Since the beginning of 2020, prices for PV-grade polysilicon more than quadrupled, steel has increased by 50%, aluminium by 80%, copper by 60%, and freight fees have risen six-fold. Compared with commodity prices in 2019, we estimate that investment costs for utility-scale solar PV and onshore wind are 25% higher. In addition, restrictive trade measures have brought additional price increases to solar PV modules and wind turbines in key markets such as the United States, India and the European Union.

**Around 100 GW of contracted capacity risks being delayed by commodity price shocks.** Equipment manufacturers, installers and developers are absorbing cost increases in different ways, with some sectors being more heavily affected than others. Smaller companies are more exposed because of their more limited finances. Higher prices for solar PV and wind plants pose a particular challenge for developers who won competitive auctions anticipating continuous reductions in equipment prices. If commodity prices remain high through 2022, three years of costs reductions for solar and five years for wind would be erased. The increased costs would require over USD 100 billion of additional investment to install the same amount of capacity. This is equivalent to increasing today's annual global investment in renewable power capacity by about one-third.

**But higher natural gas and coal prices have improved the competitiveness of wind and solar PV.** For corporations, fixed-price renewable energy contracts serve as a hedge against higher spot prices for fossil fuel energy. For governments, higher electricity prices have not brought higher subsidies for wind and solar PV, as around 90% of all wind and PV projects have long-term fixed-price purchase agreements.

**Rising prices are slowing biofuels' growth by more than 3 percentage points in 2021 as policies changed in key markets.** Compared with average 2019 prices prior to the Covid-19 crisis, biofuel prices had increased between 70% and 150% across the United States, Europe, Brazil and Indonesia by October 2021, depending on the market and fuel. In response, governments have lowered blending mandates in Argentina, Colombia, Indonesia and Brazil, reducing

demand. We estimate these actions have reduced demand by 5 billion litres in 2021 compared with a scenario in which mandates remained unchanged or were increased as planned.

## Supported by the right policies, recovery spending on renewables could unleash a huge wave of private capital

**Renewables – including electricity, heat, biofuels and biogas – account for just 11% of governments’ economic recovery spending on clean energy.** Renewables are expected to receive USD 42 billion, led by solar PV and offshore wind. But greater public spending on renewable power could mobilise more than USD 400 billion of total investment. If appropriate enabling policies and regulatory frameworks were implemented, almost 400 GW of additional renewable projects – led by solar and wind -- could be deployed over our forecast period, equal to the entire installed power capacity of the Middle East. However, the level of private sector contribution will depend on the effectiveness of the policies and implementation measures supporting the new investment.

**Despite their important role in decarbonising key sectors, biofuels and biogas were allocated less than USD 5.5 billion of government economic recovery spending.** Renewable heat technologies also saw a limited public funding. Both industries would strongly benefit from enhanced recovery stimulus programmes.

## Faster growth of renewables is within reach but requires addressing persistent challenges

**Governments need to address four main barriers to accelerate renewables deployment.** For wind and solar PV projects in advanced economies, various challenges to permitting and grid integration have led to lower-than-planned capacity being awarded in government auctions. In emerging and developing economies, stop-and-go policies, the lack of grid availability and risks concerning off-takers’ financial health are hurting investor confidence, resulting in elevated financing rates. Lack of remuneration and targeted policy support for flexibility are an issue in all countries. In addition, challenges concerning social acceptance of wind and hydropower projects caused an increasing number of countries to delay or cancel planned projects.

**In our accelerated case, annual renewable capacity additions in the next five years could be one-quarter higher than in our main case, reaching more than 380 GW per year on average.** Our accelerated case assumes that governments

address the above-mentioned policy, regulatory and implementation challenges in the next 12-24 months. Moreover, the stabilisation and eventual decline of commodity prices and increasing volumes of affordable financing from the private sector all contribute to the accelerated growth of renewable electricity capacity.

**Biofuels demand growth could more than double between 2021-2026 in our accelerated case.** Increasing biofuel demand and production hinges on stronger policies that address cost, sustainability and technical limitations. India, the European Union, the United States, China and other countries are all considering or implementing strengthened biofuels policies. However, relatively higher cost of biofuels compared with gasoline or diesel in most markets remain a key challenge, limiting policy ambition or how well biofuels compete with other emission reduction technologies. Uncertainty over the availability of sustainable feedstocks and technical constraints are also important barriers.

## Renewables' penetration in to hard-to-decarbonise sectors is slowly emerging and promises a bright future

**Policy momentum supporting the production of hydrogen from renewables and biojet has stimulated a large number of projects.** If realised, planned projects indicate that global electrolyser capacity for hydrogen could stimulate the deployment of 18 GW of additional wind and solar PV capacity in the 2021-2026 period. While this would account for only 1% of forecast growth of renewables in our main case, the fulfilment of the entire announced electrolyser capacity pipeline could bring an additional 475 GW of wind and solar PV capacity in the longer term, the equivalent of one-third of total installed variable renewable capacity today.

**Biojet technology is ready to fly but policies to stimulate demand lag behind.** Global biojet demand is set to range from 2 billion to 6 billion litres by 2026 in our main and accelerated cases. The success of biofuels mainly depends on policy discussions in the United States, Europe and potentially China. Given the low absolute volumes proposed, feedstock sustainability will likely not prove a constraint over the next five years. However, increasing the diversity of feedstock supply from waste remains critical to achieve rapid expansion in the medium-term.

## Renewables need to grow faster than our forecasts to close the gap with a pathway to net zero by 2050

Globally, annual renewable power capacity additions through 2026 in the IEA's [Net Zero Emissions by 2050 Scenario](#) are 80% higher than in our main

**case.** For solar PV and wind, average annual additions would need to be almost double what we see in our main case forecast over the next five years.

**For biofuels, annual demand growth needs to quadruple.** To align with the Net Zero Emissions by 2050 Scenario, countries would need to implement existing and planned policies while also strengthening them before 2026. These policies must ensure that biofuels are produced sustainably and avoid negative impacts on biodiversity, freshwater systems, food prices and food availability. Policies must also incentivise greenhouse gas reductions, not just biofuel demand. For net zero by 2050, renewable heat demand growth needs to almost triple from the main case.

**To get renewables on track with net zero by 2050, governments not only need to address current policy and implementation challenges but also increase ambition for all renewable energy uses.** Governments can build on the momentum of competitive solar and wind, but they must also significantly strengthen their policy focus on dispatchable renewable electricity and renewable energy use in buildings, industry and transport. Governments should also consider targeting much more economic recovery spending on renewables while also putting in place policies and regulations enabling higher mobilisation of private capital.

# Chapter 1. Renewable electricity

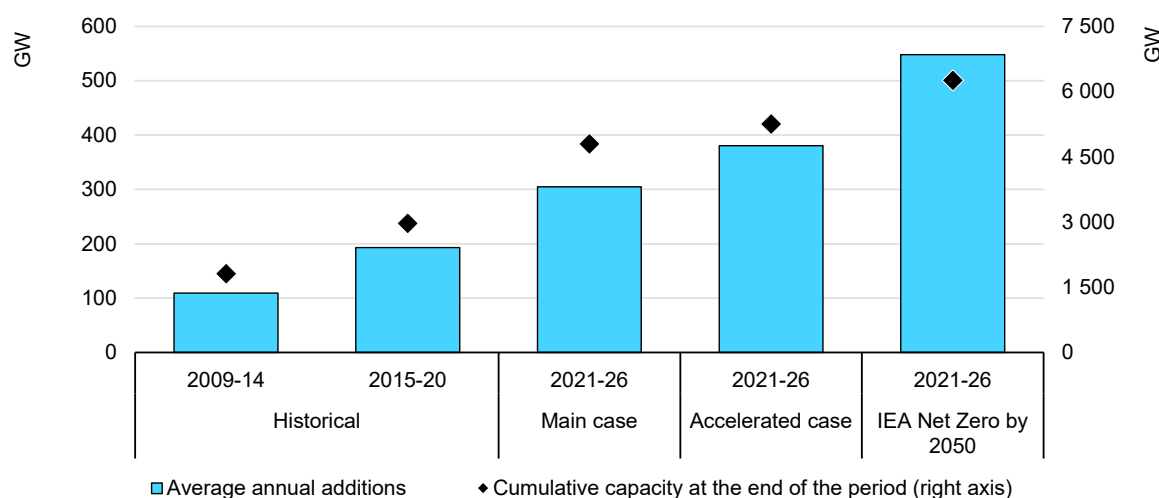
## Forecast summary

### **Renewable capacity additions are set to grow faster than ever in the next five years, but the expansion trend is not on track to meet the IEA Net Zero by 2050 Scenario**

Annual additions to global renewable electricity capacity are expected to average around 305 GW per year between 2021 and 2026 in the IEA main case forecast. This implies an acceleration of almost 60% compared to renewables' expansion over the last five years. Continuous policy support in more than 130 countries, ambitious net zero goals announced by nations accounting for almost 90% of global GDP, and improving competitiveness of wind and solar PV are all driving this expansion. Nonetheless, despite this growing support, renewables face a range of policy uncertainties and implementation challenges, including those relating to financing, permitting, social acceptance and grid integration. Current increases in commodity prices have put upward pressure on investment costs, while the availability of raw materials and rising electricity prices in some markets pose additional challenges for wind and solar PV manufacturers in the short term. However, the impact of volatile commodity and transport prices on demand are expected to be limited, as high fossil fuel prices improve the competitiveness of wind and solar PV further (see Chapter 4 for more detailed analysis).

Our accelerated case assumes that governments address policy, regulatory and implementation challenges in the next couple of years. The stabilisation and eventual decline of commodity prices to levels observed over 2015-2019 and more affordable financing from the private sector also contribute to the accelerated growth of renewable electricity in this case. Accordingly, annual renewable capacity additions are a quarter higher than in our main case, reaching over 380 GW on average over 2021-2026. However, the gap between both our main and accelerated case forecasts and the trajectory necessary to meet Net Zero by 2050 remains significant. Annual capacity growth under the IEA Net Zero Scenario during 2021-2026 needs to be 80% faster than in our accelerated case, implying that governments need to not only address policy and implementation challenges, but also to increase their ambition.

**Figure 1.1 Average annual renewable capacity additions and cumulative installed capacity, historical, forecasts and IEA Net Zero Scenario, 2009-2026**



Source: IEA (2021a), [Net Zero by 2050](#).

## Growing policy momentum worldwide is driving our forecast upward

Globally, we anticipate renewable capacity to expand by over 1 800 GW, or over 60%, in our main case forecast to 2026, accounting for almost 95% of the increase in total power capacity worldwide. Overall, People’s Republic of China (hereafter ‘China’) remains the leader, accounting for 43% of global growth, followed by Europe, the United States and India. These four markets alone provide almost 80% of renewable capacity expansion worldwide. We have revised the forecast up from last year, with China alone accounting for about 60% of the revision. For China, last year’s forecast reflected the phase-out of subsidies at the end of 2020 and the resulting policy uncertainty for onshore wind and solar PV. However, China’s subsequent commitment to net zero by 2060 has led to new targets, such as 40% of all electricity consumed to be from non-fossil generation by 2030 and a capacity target of 1 200 GW wind and solar PV by the same year, all reflected in our updated forecast.

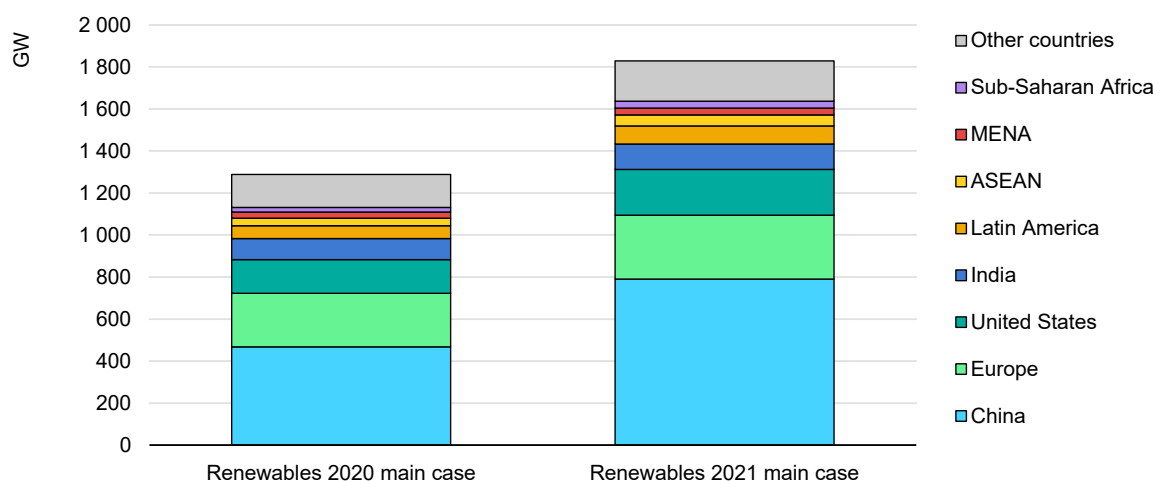
In Europe, the upward revision stems from larger auction volumes in most EU member countries to accelerate deployment towards 2030 renewable energy targets, a growing market for corporate power purchase agreements (PPAs) and the increasing attractiveness of self-consumption for distributed PV. The economic recovery plan for Europe, which will provide over EUR 800 billion (USD 940 billion) in the form of loans and grants, should partly contribute to facilitating the financing of renewables. Our main case renewable capacity growth trajectory shows that



the European Union is set to overachieve the country plans for 2030 stated in current National Energy and Climate Plans (NECPs), supporting higher targets under the “Fit for 55” programme (55% emissions reduction by 2030), which is expected to be finalised in 2023 or 2024.

In the United States, favourable wind and solar PV economics, and increased ambition at the federal level drive renewables to new highs. The continuation of federal tax credits in December 2020, a growing corporate PPA market and increasing federal and state-level support for offshore wind all drive higher capacity additions in our main case forecast.

**Figure 1.2 IEA five-year renewable capacity forecasts by country/region, main case, 2021 and 2021**



IEA. All rights reserved.

Notes: ASEAN = Association of Southeast Asian Nations; MENA = Middle East and North Africa. Renewables 2020 forecast covers the period 2020-2025; Renewables 2021 forecast covers the period of 2021-2026.

An improved policy environment and higher targets in multiple countries in Asia Pacific result in more optimistic renewable capacity growth in the region. In India the forecast is slightly revised upward, especially for solar PV, due to deployment acceleration towards the government’s ambitious renewables target of 500 GW by 2030 and additional policies introduced to improve the attractiveness of distributed PV. Higher renewable energy targets for 2030 in Japan, improved incentive schemes providing stable remuneration for solar PV developers in Korea and increased capacity targets in Viet Nam all support our higher forecast.

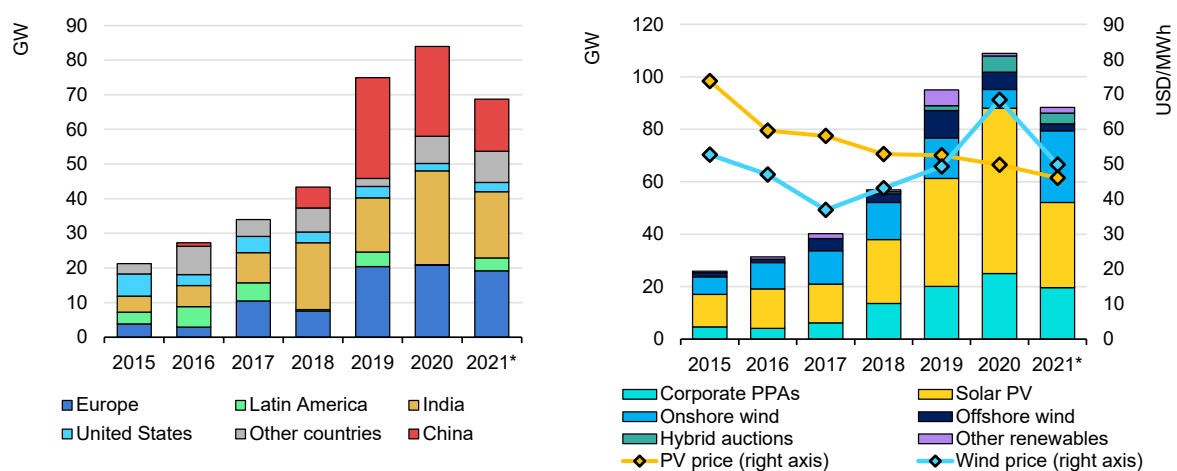
In Latin America, resumed competitive auctions following delays due to the Covid-19 crisis remain a key driver for utility-scale wind and solar PV development. In addition, deployment outside government policy schemes through bilateral contracts is rising in the region, especially in Brazil and Chile, leading to upward revisions for variable renewables.

In sub-Saharan Africa, faster commissioning of large hydropower plants to meet financing and construction deadlines, new auctions and project announcements lead to a higher forecast. In the Middle East and North Africa our forecast is slightly higher compared with last year. Although solar PV's competitiveness drives renewables expansion in the region, the faster pace is challenged by slower electricity demand and insufficient grid infrastructure.

## Government-led auction capacity is in slight decline, but is compensated by robust corporate PPA activity

Between January and November 2021 globally awarded auction capacity fell by 11% compared with the same period in 2020. The end of the central solar PV auction scheme in China played a critical role in this decline. Excluding China, governments around the globe awarded 4% more auction capacity in the first 11 months of this year compared with the same period last year as countries in Latin America resumed tendering capacity. Corporate PPAs partially compensated for lower auction capacity, especially in Europe and North America – their volumes remained robust from January to November 2021 and are on track to reach record procurement by the year end. Global average contract prices from government-led auctions continued to decline for PV this year thanks to low bids in India and the Middle East, while onshore wind contract prices increased in 2019 and 2020 due to more capacity auctioned in Europe, where average prices are higher than in Latin America and India.

**Figure 1.3 Renewable electricity auctioned capacity by country/region, 2015-2021 (left) and by technology and corporate PPAs, 2015-2021 (right)**



IEA. All rights reserved.

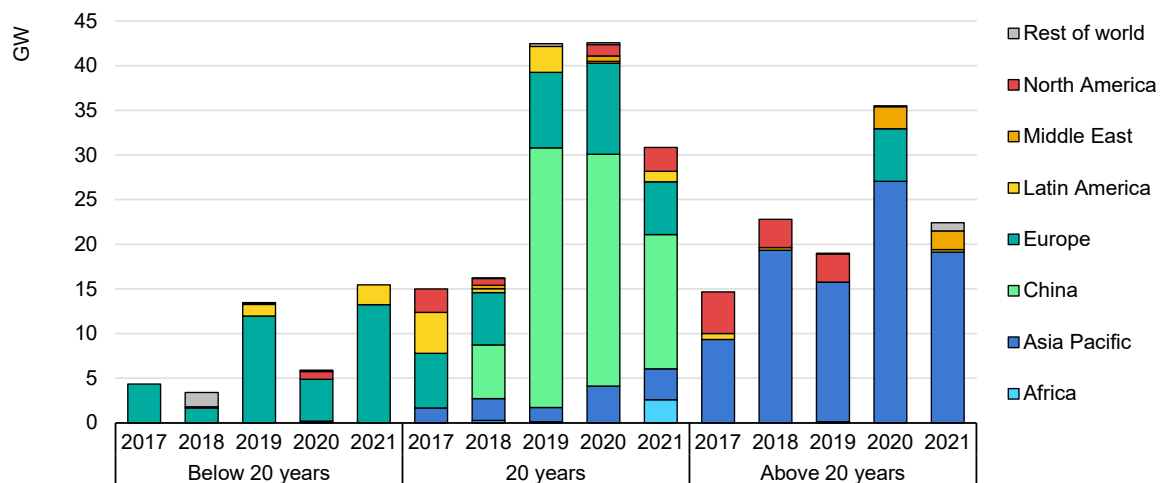
\* January to October.

Note: PPAs = power purchase agreements. Wind and solar PV price refers to global weighted average from auctions and excludes prices for corporate PPAs, for which the data are not complete.

Source: Corporate PPA volumes from BNEF (2021a).

Long-term contracts play a key role in facilitating the financing of wind and solar PV projects globally. Government-led auctions usually provide 20-year PPAs, accounting for almost half of all awarded contracts from 2017 to 2021. In India the standard contract duration is 25 years, as longer contract periods help developers offset risks associated with offtakers’ financial health, providing firm pricing for financing. Between 2019 and 2021 the volume of contracts shorter than 20 years increased in Europe, mostly due to the United Kingdom’s offshore contracts for difference, which are for 15 years. Shorter contracts encourage developers to prepare for market prices at an earlier date, while also providing flexibility for other revenue streams (e.g. bilateral PPAs) with large consumers over the remaining years of the plant’s operation.

**Figure 1.4 Auction-awarded renewable capacity by contract duration, 2017-2021**

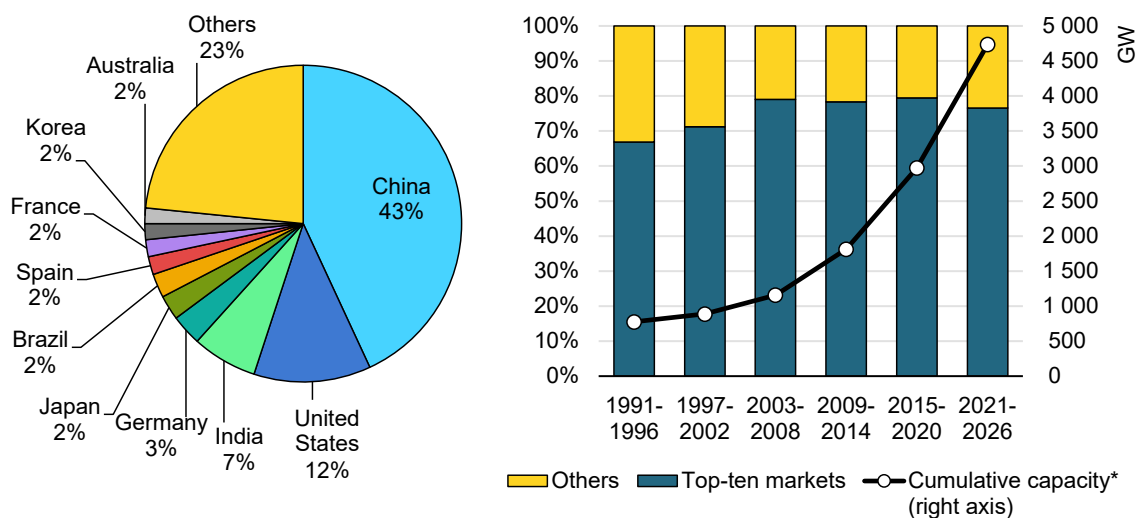


IEA. All rights reserved.

## Top-10 countries continue to dominate renewables expansion, indicating that more diversity is needed

Ten countries account for almost 80% of all renewable capacity growth over the period 2021-2026. China alone provides almost 45% of all renewables expansion in our forecast, followed by the United States, India and Germany. Since 1990, worldwide renewable capacity has more than quadrupled, but the top ten growth markets have more or less remained the same. Even though there remains tremendous economic and resource potential in countries outside the ten largest, these markets have seen their share stay static since the early 2000s, a trend expected to continue over the forecast period.

**Figure 1.5 Top-ten countries' share of total installed renewable capacity, historical and main case forecast, 1991-2026**



IEA. All rights reserved.

\* Cumulative capacity = installed renewable capacity at the end of each five-year period.

## Solar PV breaks new records in our forecast, despite rising prices

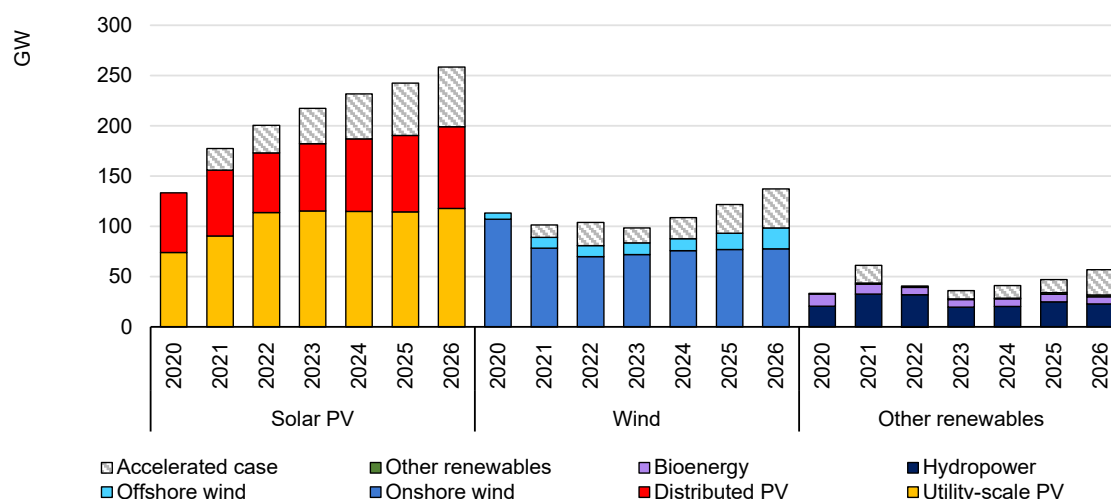
Additions of renewable power capacity are on track to set yet another annual record in 2021, driven by solar PV. Almost 290 gigawatts (GW) of new renewable power will be commissioned this year, which is 3% higher than 2020's already exceptional growth.

In our main case forecast for 2021-2026, we expect annual average renewable capacity additions to reach 305 GW, 58% higher than the figure for the last five years. Despite surging commodity prices increasingly affecting solar PV investment costs (see Chapter 4 for further analysis), we expect the annual market to grow by 17% year-on-year to almost 160 GW in 2021 with additions reaching almost 200 GW in 2026. In the significant majority of countries worldwide, utility-scale solar PV provides the lowest cost of adding new electricity capacity, especially in the context of increasing natural gas prices.

Overall, solar PV alone accounts for almost 60% of all renewable capacity additions, with almost 1 100 GW becoming operational over the forecast period in our main case. The expansion of solar PV capacity in the next five years is expected to be almost double that of the previous five years. Utility-scale projects continue to provide over 60% of all solar PV additions worldwide. Annual additions of distributed PV are increasing thanks to policy initiatives in China, the

European Union and India stimulating the deployment of commercial and residential projects.

**Figure 1.6 Annual capacity additions of solar PV, wind and other renewables, main and accelerated cases, 2020-2026**



IEA. All rights reserved.

Under the accelerated case, total growth of global solar PV capacity could be 22% higher with annual additions growing continuously, reaching almost 260 GW by 2026. The upside is largest in key markets such as China, Europe, the United States and India, but considerable growth potential remains in nascent markets such as sub-Saharan Africa and the Middle East. However, reaching the accelerated case will require the major markets to address their persistent challenges. These are the highlights:

**China:** Clarify the rules around the new renewable portfolio standard and green certificate scheme for utility-scale and large-scale commercial applications. Continue support for residential solar PV following the phase-out of incentives in 2021.

**United States:** Extend investment tax credits and the monetisation of credits through a direct-pay scheme.

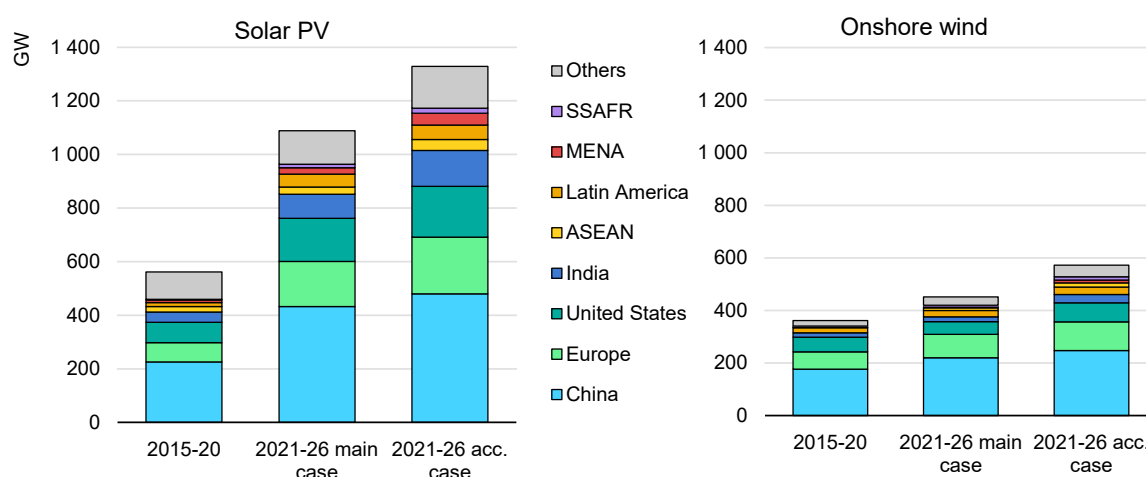
**India:** Improve the distribution companies' financial health, reducing delays in signing PPAs following solar PV auctions, accelerate grid expansion and improve the remuneration for distributed PV applications.

**European Union:** Increase auction capacity and improve participation rates in utility and large commercial-scale auctions via smoother permitting procedures when these are required for bidding. Increase support for distributed solar PV through the EU resilience and recovery fund.

**Japan:** Smooth the transition to the feed-in premium (FIP) scheme to build up a declining project pipeline from the former feed-in tariff (FIT).

**Middle East and North Africa:** Increase the frequency of auction rounds, and speed up bidder selection and contractual negotiations to accelerate utility-scale PV rollout. More rapid expansion of transmission and distribution grids allows the connection of additional solar PV capacity.

**Figure 1.7 Solar PV and onshore wind capacity additions, actual and forecast by country/region, 2015-2026**



IEA. All rights reserved.

Note: acc. case = accelerated case; ASEAN = Association of Southeast Asian Nations; MENA = Middle East and North Africa; SSAFR = sub-Saharan Africa.

Global onshore wind additions reached almost 108 GW in 2020, driven by acceleration in China as developers rushed to complete projects before the expiry of subsidies. Our forecast expects lower onshore wind growth through the forecast period, averaging 75 GW a year. Still, this is almost 25% higher than average annual additions between 2015 and 2020. China, Europe and the United States together account for 80% of global onshore wind expansion over 2021-2026.

In general, the challenges of permitting, social acceptance, grid connection and integration combined to limit faster onshore wind growth. These challenges prevent developers from participating in wind-specific or technology-neutral auctions, especially when permitting and grid connection agreements are required for participation. In addition, higher steel and transport costs have seen turbine prices rise by 10-25% in several markets, increasing challenges associated with project financing and profitability. In our accelerated case, global onshore wind capacity growth is almost 30% higher, assuming that governments tackle social acceptance and expand network capacity faster and tackle grid integration challenges. In addition, the accelerated case assumes countries introduce higher

auction capacity or increase auction participation as a result of smoother permitting. In this case, annual additions reach 110 GW by 2026, slightly higher than the record level achieved in 2020.

The offshore wind market is forecast to accelerate in 2021, with additions reaching 11 GW, almost double compared with last year. This is driven by expansion in China, as developers rush to secure expiring national subsidies. Despite China's growth slowing through to 2026, offshore annual capacity additions reach 21 GW globally thanks to rapid expansion in new markets beyond the United Kingdom, Germany, Belgium, Denmark and the Netherlands. Large-scale projects are expected to be commissioned in France, Chinese Taipei, Korea, Viet Nam, Japan and the United States in the next five years, pushing our forecast up. Cumulative offshore capacity is forecast to more than triple by 2026, reaching almost 120 GW. The share of offshore capacity in overall annual wind additions reaches over 20% in the main case, up from 5% in 2020, breaking a record at the end of our forecast period. However, faster offshore and onshore grid expansion in the United Kingdom and the European Union, rapid cost decline and strong provincial-level policies in China, and the early-commissioning of large-scale pipeline in the United States together could push cumulative global offshore wind capacity to 134 GW in 2026 in the accelerated case.

The growth of dispatchable renewables such as hydropower, bioenergy, geothermal and CSP slows by 5% compared with expansion over 2015-2020. Relatively higher investment and generation costs compared with wind and solar PV, the lack of policy support and limited recognition of the flexibility of dispatchable renewables prevent their faster expansion. For hydropower, annual additions are volatile according to the commissioning deadlines of large reservoir projects in China, India and Turkey. These three large markets drive our main case forecast of 153 GW over 2021-2026, which is similar to the deployment achieved in the last five years. Considering long environmental permitting and construction times, the upside for hydropower remains limited in the next five years.

Expansion of bioenergy for power capacity is expected to slow by 10% over the forecast period. China provides almost 60% of this new capacity due to waste-to-energy projects driven by growing urbanisation. Beyond China, supply chain challenges, lack of policy support and relatively high generation costs contribute to the slowdown in expansion. Despite its great resource potential, geothermal growth is limited to less than 5 GW over 2021-2026, representing only 0.2% of our forecasted renewable capacity expansion. Limited policy support to address the technology's pre-development risks hampers investment in large-scale geothermal projects. For CSP, we expect less than 3 GW to be commissioned by 2026. Relatively high investment costs, lack of dedicated auctions and competition from solar PV and battery storage projects prevent faster expansion of CSP.

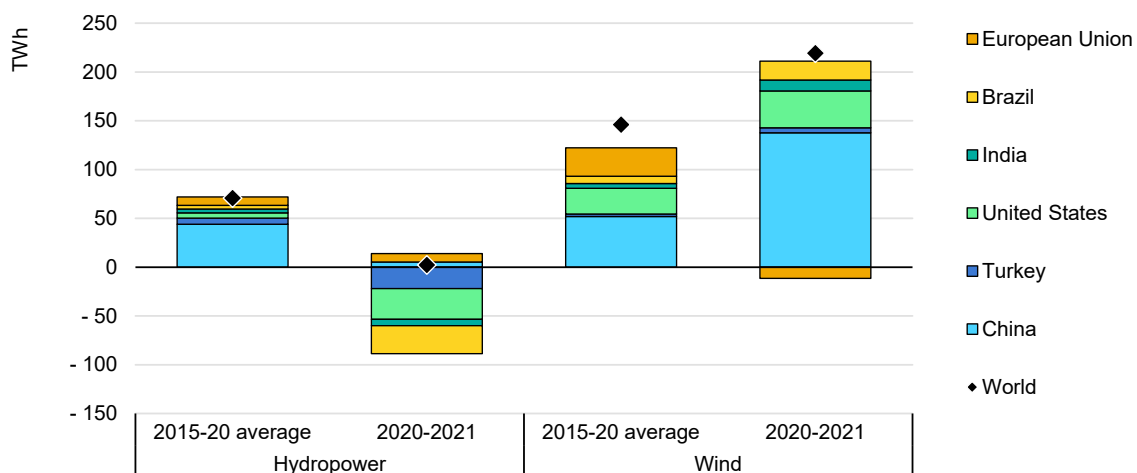


## Low wind conditions and droughts in key markets hamper more rapid growth of renewable generation in 2021

In 2021 renewable electricity generation is forecast to increase year-on-year by 6% and reach over 7 900 TWh, slightly higher than the average annual growth rate observed during 2015-2020. Conversely, the expansion rate of cumulative capacity in 2021 is faster over the same time period. This decoupling is mainly due to weather conditions in key markets affecting wind and hydropower generation. Without these conditions, renewable electricity generation would be up by almost 9% in 2021 compared with 2020.

Severe drought conditions in Brazil, the United States, China and Turkey have limited global hydropower generation. As a result, our forecast expects hydropower generation to remain stable compared with 2020, ending the annual increases seen since 2001. Wind electricity generation is expected to increase by 14%, or almost 220 TWh, worldwide in 2021; however, geographical variations due to adverse weather conditions prevent much faster annual growth. The European Union is set to see wind generation decline by 3% due to low wind conditions. This is the first annual decline in more than three decades, compared with 10% (or 30 TWh) average growth per year between 2015-20. Strong capacity growth and normal wind conditions in Brazil, China, India and the United States make up for slowing growth in other key markets.

**Figure 1.8** Hydropower and wind electricity generation growth in selected markets, 2015-2020 average and 2021

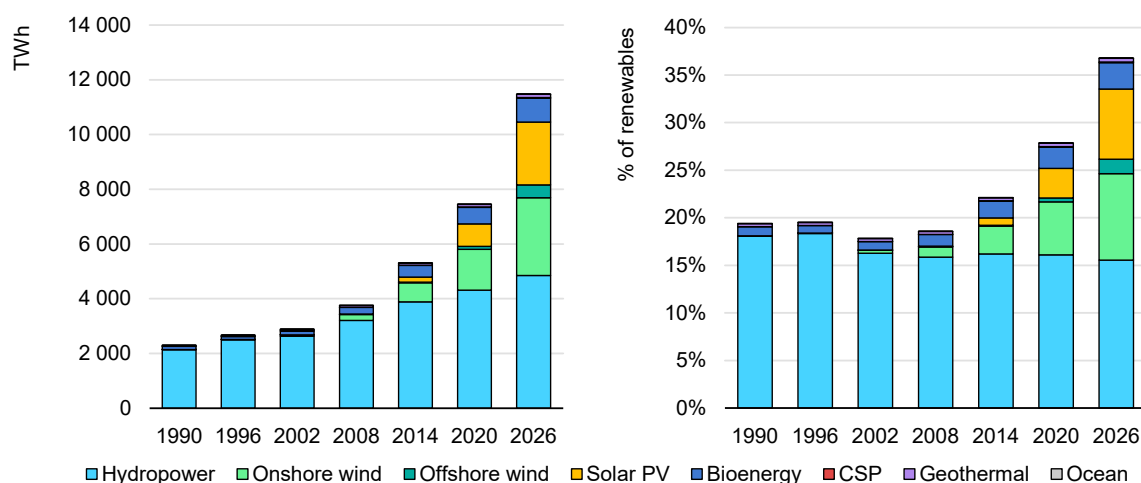


IEA. All rights reserved.

In our main case, renewable electricity generation is forecast to increase by almost 52% in the next five years, reaching over 11 300 TWh by 2026, two-thirds faster

than the growth seen during 2015-2020. As a result, renewables are expected to account for almost 37% of global electricity generation by 2026 to become the largest source of generation. While hydropower remains the largest source of renewable generation, its share of global electricity generation declines slightly to 15.6%. Over the forecast period, non-hydro renewables are expected to account for the majority of renewable generation globally for the first time. Meanwhile, output from variable renewables (solar PV and wind) more than doubles, their share reaching almost 18% of global generation to surpass hydropower. Offshore wind sees the fastest growth in the next five years (240%) among all renewables, reaching 1.5% of total generation by 2026.

**Figure 1.9 Renewable electricity generation by technology, 1990-2026 (left) and share by technology, 1990-2026 (right)**



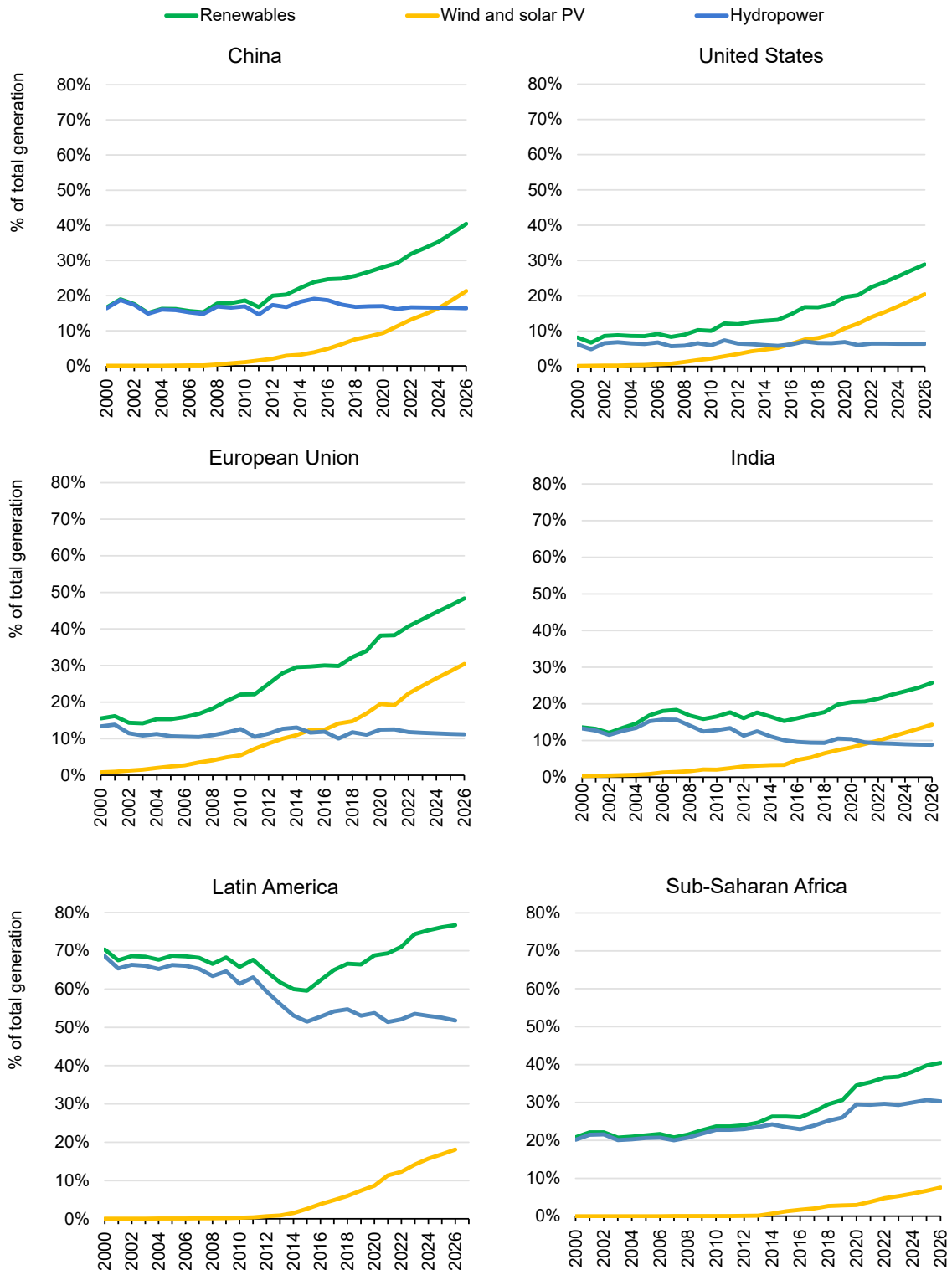
IEA. All rights reserved.

Note: CSP = Concentrated solar power

Sources: IEA analysis based on total electricity generation from IEA (2021b), [World Energy Outlook 2021](#).

In China, the United States, India, the European Union and Latin America, the share of hydropower in the generation mix is expected to decline over the forecast period, as generation from wind and solar PV drives growth. Sub-Saharan Africa sees all renewables growing, the share of hydropower and variable renewables both forecast to expand, contributing to electrification in a region where energy access remains a challenge. In Latin America the share of renewables is forecast to reach over 75% by 2026, driven by growing output from variable renewables, although hydropower remains the largest source of generation in the region. Wind and PV generation increases offset hydropower's declining share in the region. In the European Union and China we expect renewables to account for 50% and 40% of their respective generation mix by 2026. The acceleration of wind and solar PV generation in India and the United States drives the share of renewables in both markets to a record 30% at the end of the forecast period.

**Figure 1.10 Share of wind, solar PV, hydropower and all renewables in total electricity generation, 2000-2026**



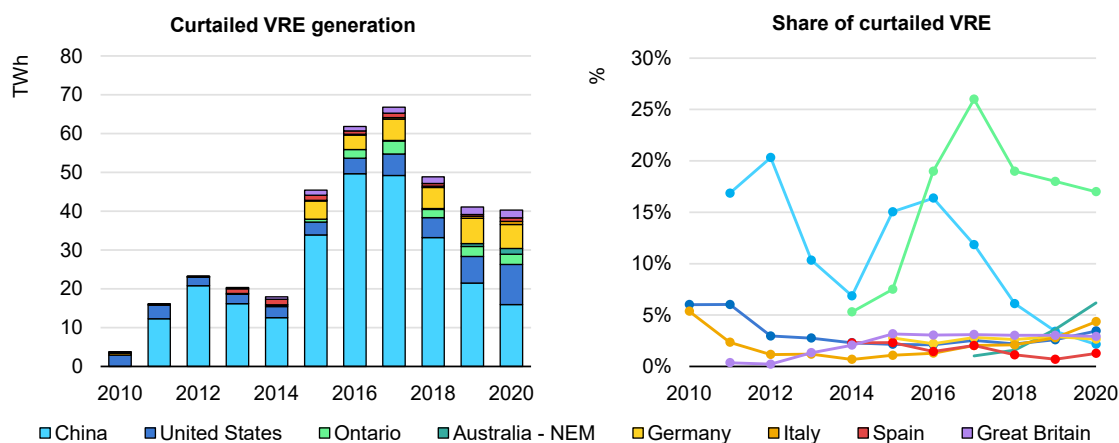
IEA. All rights reserved.

Sources: IEA analysis based on total electricity generation from IEA (2021b), [World Energy Outlook 2021](#).

The rapid expansion of wind and solar PV increases system integration challenges. As a result, policy priorities should be revised in the next five years to ensure secure and cost-effective system integration of larger shares of variable renewables. In order to ensure system operations during periods of oversupply, grid operators have chosen to curtail,<sup>1</sup> constrain or “dispatch down” renewables, mostly solar PV and wind. New load patterns caused by the Covid-19 demand shock resulted in an increase in curtailment in countries where wind and solar PV generation reached record levels during certain hours of the day. In the United States, Australia, Spain and Italy the share of dispatched-down wind and solar PV increased last year while remaining stable in Germany and Great Britain. Despite relatively lower demand growth and record levels of wind and solar PV expansion, curtailment continued to improve in China thanks to the commissioning of additional interprovincial transmission capacity and improved market operations.

Growing system integration challenges and ambitious clean energy targets call for improved grid and market operations, appropriate market design, better forecasting and the efficient operation of interconnectors. As the proportion of generation from variable renewable energy (VRE) grows rapidly, greater dispatchable renewable generation – such as hydropower, bioenergy, geothermal and CSP – and investment in new grid infrastructure are needed.

**Figure 1.11 Wind and solar PV generation curtailment by country**



IEA. All rights reserved.

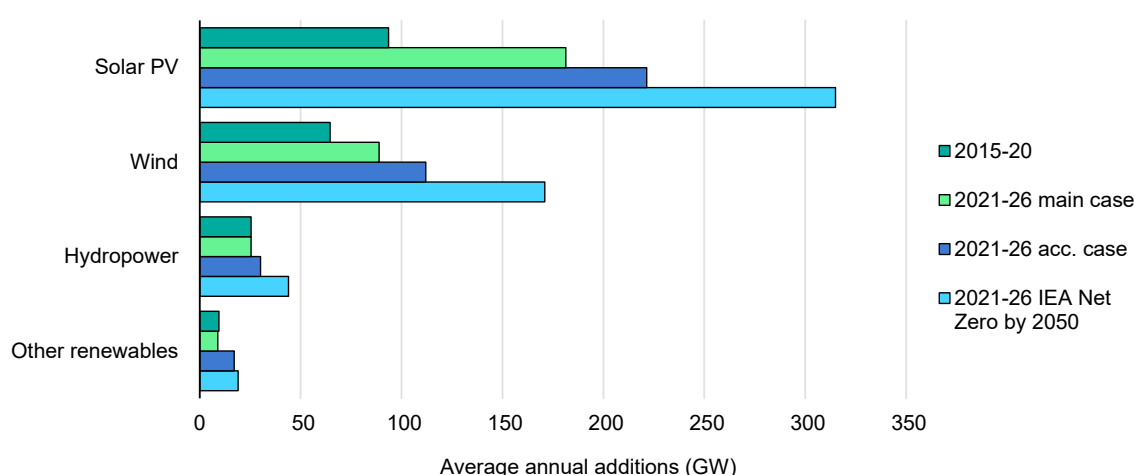
Notes: NEM = National Electricity Market; VRE = variable renewable energy. The graphs represent officially reported curtailed or constrained energy and also combine various curtailment schemes depending on the country.  
Sources: Bundesnetzagentur (2020), Netz- und Systemsicherheit; China Energy Portal (2021), 2020 Wind Power Installations and Production by Province; LBNL (2021a), Curtailment Data; IESO (2020), 2020 Year in Review; AEMO (2021), Statistical Reporting Streams; GSE (2020), Rapporto delle Attivita 2019; REE (2021a), El sistema eléctrico español síntesis; REF (2020), Balancing Mechanism Wind Farm Constraint Payments.

<sup>1</sup> The terms curtail, constrain and dispatch down all refer to instructing a renewable electricity generator to produce less electricity than it could at that moment. This can occur for system-wide reasons (e.g. inertia requirements, ramping limitations, contractual arrangements such as priority dispatch) and because of local network limitations or constraints (e.g. grid congestion, faults).

## Achieving the IEA Net Zero by 2050 Scenario requires policy makers to significantly increase their ambition for all renewables

Overall, the forecast for renewable generating capacity remains significantly below the level required for the Net Zero Scenario. For solar PV, average annual additions need to almost double in the next five years compared to what we see in our main case forecast. While solar PV is already one of the most competitive technologies in the market today, policy and regulatory support needs to scale up extensively.

**Figure 1.12 Average annual capacity additions by technology, actual, forecasts and IEA Net Zero Scenario, 2015-2026**



IEA. All rights reserved.

Note: acc. case = accelerated case.

To achieve the Net Zero Scenario, wind additions also need to more than double those in our main case. Although onshore wind generation costs are cheaper than fossil-fuel alternatives in most countries, non-economic barriers including permitting and social acceptance hamper faster expansion. Hydropower, including pumped-storage projects, also faces non-economic barriers and market design challenges despite its potential to provide much-needed flexibility to integrate larger shares of wind and solar PV. Other renewables such as bioenergy, CSP and geothermal can also provide dispatchable electricity, but policy support remains limited and costs remain significantly higher compared with variable renewables. Reaching net zero requires the deployment of a portfolio of all renewable technologies, including those that can provide dispatchable low-carbon electricity.

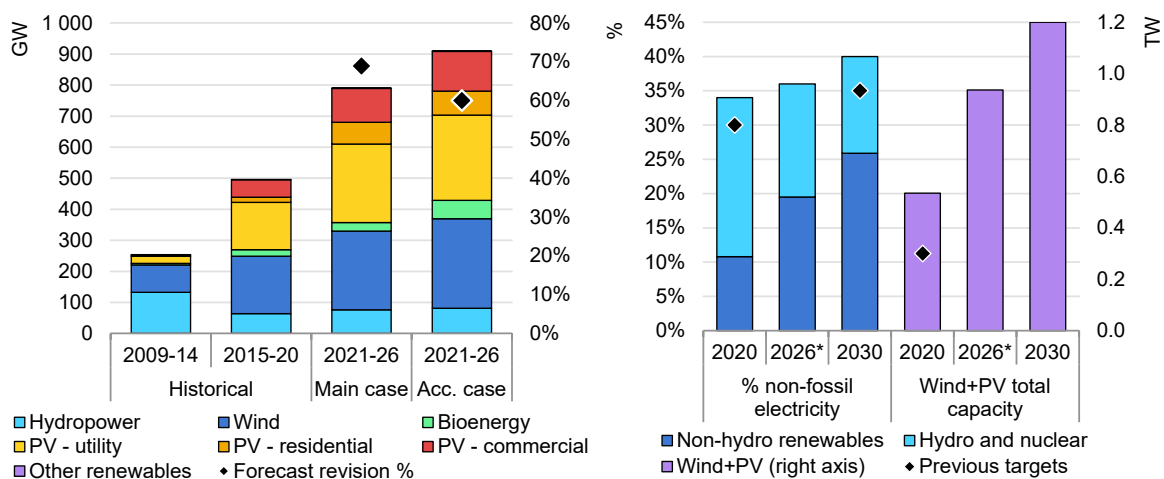
# Country and regional analysis

## China

### China's climate ambitions and higher 2030 targets boost renewables

In the main case, renewable electricity capacity in China is expected to increase by almost 800 GW, or 85%, over the period 2021-2026, led by solar PV and wind. China's forecast is revised upwards by almost 70% from last year's, driven by newly proposed renewable energy targets designed to accelerate non-fossil energy growth in line with the government's Net Zero by 2060 target. China has set a goal of achieving 40% of electricity consumption from non-fossil generation by 2030, five percentage points higher than the country's previous target. In addition, the president announced that China's wind and solar PV capacity is to reach 1 200 GW also by 2030, more than doubling the country's current fleet. Previously, China surpassed its renewable energy targets in both the 12th and 13th five-year plans. With wind and solar PV capacity reaching over 1 220 GW by 2026, our main case forecast expects China to reach its announced target earlier than 2030.

**Figure 1.13 China renewable capacity additions, 2009-2026 (left) and non-fossil energy target proposals for 2030 (right)**



\* 2026 values are estimated according to 2030 trajectory.

Notes: Acc. case = accelerated case. Forecast revision shows the change in the forecast since last year's report.

Given their large untapped potential and competitiveness, utility-scale solar PV and wind are expected to provide two-thirds of China's renewable capacity

expansion in the next five years. With FITs and central renewable capacity auctions ending in 2020/21, centrally set renewable portfolio standards are expected to guide China's provinces to achieve a certain share of hydro and non-hydro renewables in their consumption every year to reach 40% non-fossil electricity (including nuclear) by 2030.

After the phase-out of onshore wind and solar PV subsidies in 2020, developers have two remuneration options: 1) a 20-year power purchase contract at the provincial benchmark coal power price, ranging from USD 45 to 60 per MWh; or 2) selling electricity in the provincial wholesale power pools and receiving green certificates as a premium from the newly established renewable portfolio standard (RPS) and green certificate system. In most provinces, utility-scale onshore wind and solar PV projects can achieve reasonable returns with a 20-year fixed price contract at provincial coal prices. Thus, the forecast expects the significant majority of developers to choose the first option because uncertainty over liquidity and price volatility in the newly established wholesale and green certificate markets may result in higher project risks.

For residential solar PV, offshore wind and CSP, subsidies remain available until the end of 2021. As a result, the main case forecast expects a boom in annual residential solar PV and offshore wind installations in 2021, doubling from last year to reach over 18 GW and 8 GW respectively. However, their growth beyond this year is expected to slow after the phase-out of subsidies. CSP deployment is expected to be limited despite the subsidy deadline, as many projects struggle with technical challenges, high investment costs and poor project returns.

In the accelerated case, renewable capacity growth could be 15%, or 120 GW, higher than our main case, mainly driven by faster solar PV and wind deployment. The implementation pace of China's ongoing policy and market reforms in the next five years is critical to unlocking additional renewable capacity. Policy transition from a fixed-price FIT for wind, bioenergy and Concentrated solar power, and competitive auctions for solar PV, to a variable-price RPS and green certificate scheme for all technologies poses several challenges to onshore wind and PV developers as these markets are nascent with high price volatility.

Overall, growing market participation is expected to provide more stable remuneration and also to help alleviate ongoing curtailment challenges through cost-reflective dispatching and improved electricity trading across provinces. In addition, regulation enabling corporate PPAs or bilateral contracts between large consumers and developers could unlock further large-scale wind and PV capacity. For residential and commercial/industrial PV, growth could be 15% higher than anticipated, depending on policy reforms providing stable remuneration and the increased availability of affordable financing. Offshore wind upside depends on faster cost reductions and the resolution of supply chain challenges.

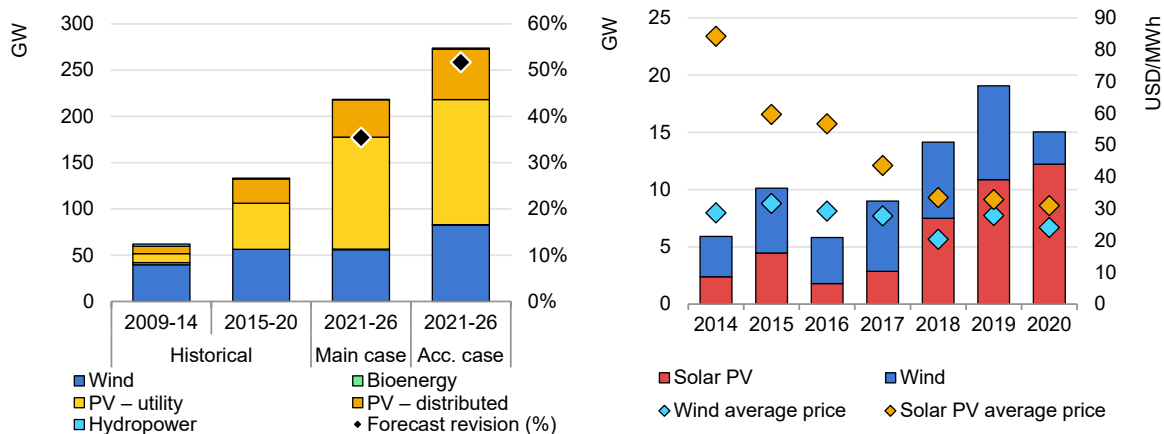
## United States

### Favourable economics and increased ambition at the federal level drive renewables to new highs

The United States' renewable capacity is forecast to increase by 65% in the main case, adding over 200 GW from 2021 to 2026, the third-largest market behind China and Europe. The expansion is driven by state-level targets, federal tax incentives and the increasing economic attractiveness of corporate procurement of renewable electricity. More than three-quarters of the growth is from solar PV and the remainder is almost exclusively from wind.

We have revised our forecast up by over 35% for three main reasons. The first is faster than expected growth in 2020 and the expectation that this pace will continue thanks to continuously improving economics and a growing project pipeline. This is partially due to strong demand for corporate PPAs, even in 2020. Both solar PV and onshore wind saw record-breaking growth in 2020 (19.2 GW and 16.9 GW respectively) despite the lockdowns, equipment delays and social distancing measures resulting from the Covid-19 pandemic. Second, in December 2020 the federal government extended the investment tax credit (ITC) and the production tax credit (PTC) for two years and one year respectively. Third, the forecast anticipates larger offshore wind additions, as federal and state ambitions ease previously onerous permitting challenges, unlocking development pipelines.

**Figure 1.14 United States renewable capacity additions, 2008-2026 (left) and solar PV and wind PPA capacity and average contract price, 2014-2020 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. Prices include federal investment and production tax incentives.

Sources: IEA analysis based on data from the US LBNL and BNEF. PPA volumes are from: LBNL (2021b), *Tracking the Sun* and (2021c) *Land-Based Wind Market Report* and BNEF (2021a), *Global Corporate PPA database*; pricing is from US LBNL (2021a), *Tracking the Sun* and *Land-Based Wind Market Report*, combined with BNEF (2021c), *US PPA and Offtake Pricing database*.

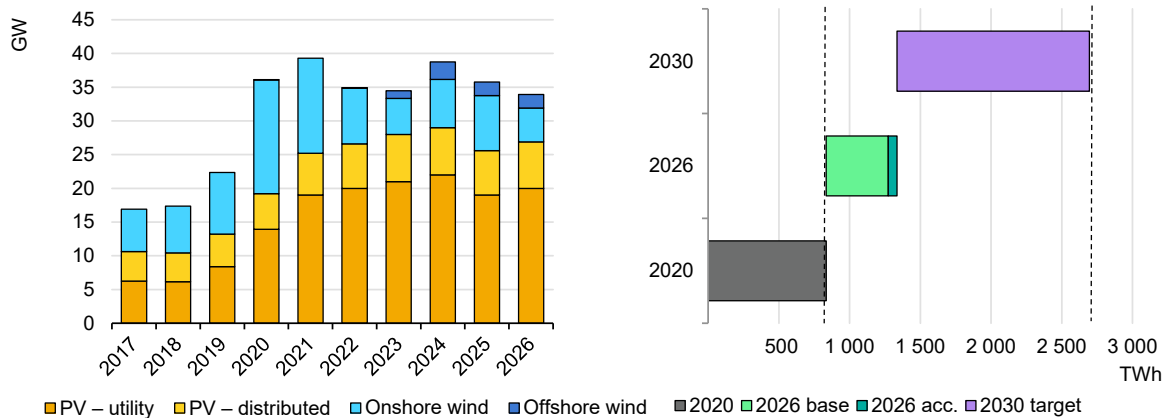


The main case assumes that federal tax incentives are phased down as planned. Thus, the pace of annual growth in solar PV and wind is expected to fluctuate in line with the step down of federal tax incentives. However, the impact on capacity additions is expected to be seen more acutely in the wind market than in solar PV. Onshore wind capacity expands by 48 GW over the forecast period. After record-breaking new wind capacity additions in 2020, growth slows slightly in 2021 due to the decrease in the PTC and continues the downward trend to 2023. Then increased PTC rates passed in 2019 and 2020 lead to higher additions in 2024 and 2025. Policy uncertainty clouds the final year of the forecast, as qualification for the PTC is currently scheduled to end this year, affecting additions in 2026. For solar PV, the impact is less pronounced. Additions are expected to decline in 2025, in line with the reduction in the ITC to 10% in 2024, but rebound in 2026 as the industry adjusts to the new economics.

Distributed PV is also expected to be affected by the ITC step-down, with the largest impact on the residential segment as the tax incentive reduces to 0% beyond 2025. Nonetheless, residential systems account for two-thirds of the growth in distributed PV capacity, driven by net metering schemes, an increase in home renovation projects and the desire for self-sufficiency following severe weather-related events recently. Policies aimed at improving the permitting process for community solar should boost the forecast for commercial systems, but interconnection delays remain a challenge.

Installed offshore wind capacity is forecast to reach almost 8 GW by 2026. The first large-scale offshore wind farm received final federal approval and closed financing this year. Seabed lease auctions, coupled with tax and certificate incentives (ocean renewable energy certificates [ORECs]) and long-term PPAs give developers firm financials for future project development. The recently announced federal target of 30 GW of new offshore wind by 2030 will be challenging to meet unless permitting processes continue to be streamlined, vessel constraints are addressed and new areas are developed.

**Figure 1.15 United States solar and wind capacity additions, 2017-2026 (left) and low-carbon electricity target, 2020-2030 (right)**



IEA. All rights reserved.

Notes: acc. case = accelerated case. The federal goal is for a carbon-free electricity sector by 2035. The intermediary goal of 80% by 2030 is also shown. The right graph shows the amount of additional renewable generation needed to hit the 80% 2030 goal. 2026 base case, 2026 acc. case and 2030 target are the additional generation values required to meet the 2030 goal.

Sources: IEA analysis based on IEA data and EIA (2021a), *Annual Energy Outlook 2021*.

The United States faces three key challenges to greater solar PV and wind expansion. First is policy uncertainty beyond current incentive schedules and the monetisation of tax credits. Qualification for the ITC and PTC is scheduled to end in 2024 and 2021 respectively. The demand for tax equity – the way to monetise federal production tax credits – has grown rapidly, driven by a larger pipeline of wind and solar PV projects. At the same time, the federal corporate tax cut in 2017 has contributed to a decline in the availability of tax equity. While an extension of the ITC and PTC – including an option for the direct payment of federal tax credits – is being discussed, it has yet to be approved. Second, increasing commodity prices are having an impact on overall project economics, potentially delaying investment decisions in both sectors. Third, limits to the availability of transmission and distribution infrastructure are leading to increased interconnection wait times. The recently passed Infrastructure Investment and Jobs Act includes funding for transmission infrastructure upgrades, but it is unclear how many of these upgrades will be completed within the forecast period.

Additional risk factors putting upward pressure on the price of solar PV equipment are: 1) a filed petition proposing to extend the anti-dumping duties (currently at 239%) to four countries in Southeast Asia, which could affect a significant amount of crystalline silicon cell and silicon module imports; 2) project delays resulting from bans on importing cells and modules containing silicon from certain companies in Xinjiang, China; and 3) raw material price increases (SEIA, 2021).

In the accelerated case, renewable capacity growth in the United States could reach almost 275 GW during 2021-2026, 26% higher than in the main case, if federal tax incentives are extended and monetised using a direct-pay scheme rather than just as tax equity. Both potential drivers depend on the final text of budget reconciliation, currently being negotiated. Higher growth would also result from increased grid capacity from upgraded networks as outlined in the Infrastructure Investment and Jobs Act. However, state-level policies need to align with federal ambitions to meet the stated federal clean energy targets for 2030: only 21 out of 50 states have carbon-free electricity goals; and Rhode Island is the only state that aims to achieve a carbon-free sector by 2035 (CESA, 2021).

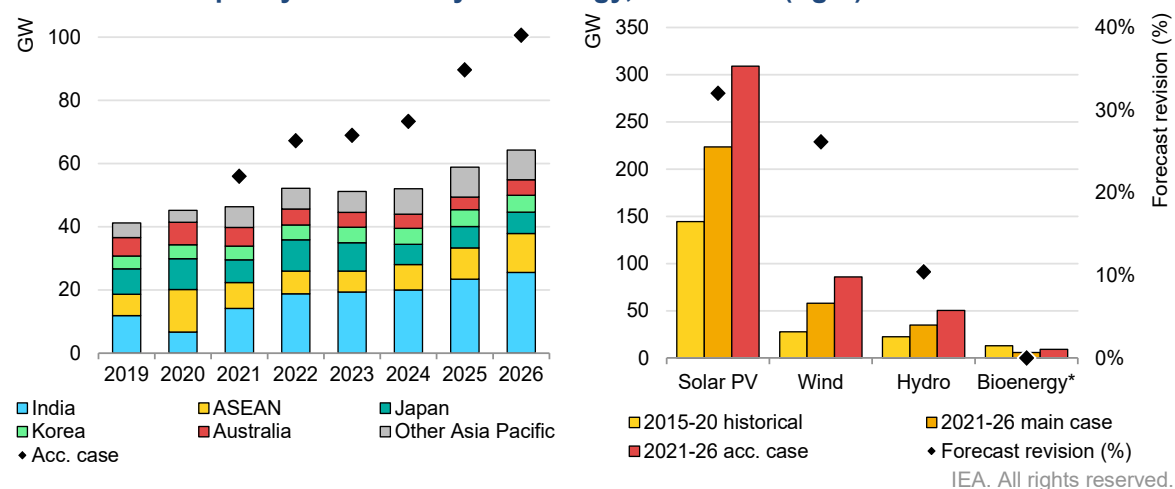
## Asia Pacific

### Solar PV leads the deployment of renewables in the region, driven by auctions in India, FITs in Japan and new policies expected in ASEAN countries

The Asia Pacific region (excluding China) is expected to add almost 330 GW of renewable capacity during 2021-2026 in the main case, representing almost 70% growth. Solar PV leads the deployment (68% share), followed by wind (18%) and hydropower (11%). The forecast is 27% higher than last year, with annual additions in 2026 42% higher than in 2020. India accounts for almost 40% of the region's renewable capacity expansion over the forecast period thanks to the continuation of auctions and improving incentives for distributed PV. Continuous acceleration is expected in ASEAN countries, led by Viet Nam and with the Philippines and Indonesia both becoming increasing sources of growth thanks to implementation of new auction and FIT schemes. Beyond ASEAN, in our main case forecast capacity additions in Japan slow after 2022-2023 due to a smaller FIT project pipeline, and in Australia due to grid integration challenges.

In the accelerated case, renewables growth in Asia Pacific is around 40% higher than in the main case. Achieving higher growth will require faster and smoother implementation of new support policies (especially in ASEAN countries and Japan), increased investment in grid development (in Australia, ASEAN countries and India), reducing risks to investors by easing permitting rules, introducing more bankable PPAs (in ASEAN countries) and resolving land acquisition challenges (in India and ASEAN countries).

**Figure 1.16 Asia Pacific renewable capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right)**



\* Bioenergy forecast revision is -7%.

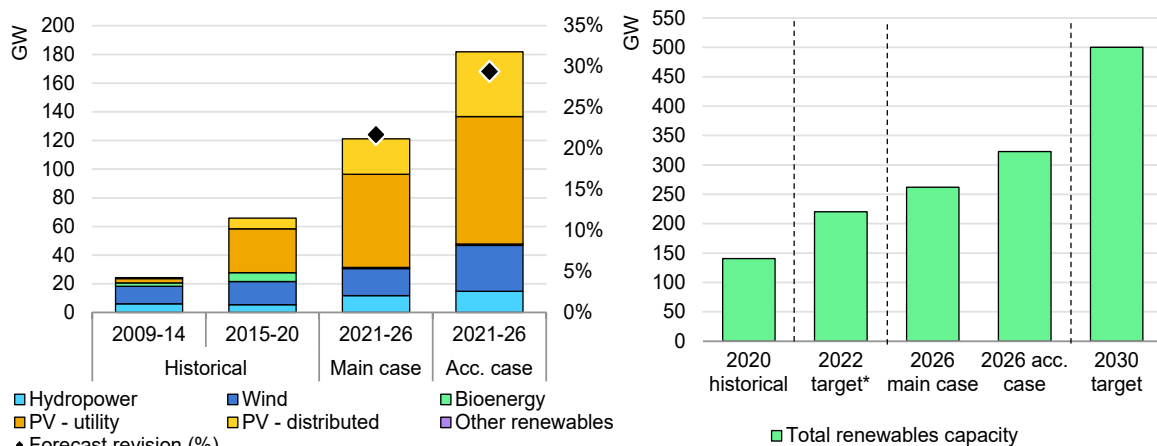
Notes: ASEAN = Association of Southeast Asian Nations; Asia Pacific excludes China; acc. case = accelerated case.

## India

### Renewables expansion in India accelerates, but reaching targets on time requires persistent challenges to be resolved

India is expected to add 121 GW of renewable capacity over 2021-2026, an 86% increase on existing capacity, making it the third-largest growth market globally after China and the United States. Solar PV leads this deployment (74%), followed by onshore wind (16%) and hydropower. India's forecast is revised upwards, but this is mostly due to accelerating capacity additions at the end of the forecast period following the dip in 2020, as some policy improvements have offset increasing challenges. The financial health of India's distribution companies (DISCOMs) remains a critical challenge, leading to delays in signing PPAs with auction winners and putting some projects at risk of delay and cancellation. Progress in the agricultural distributed PV scheme (KUSUM) and high oversubscription in recent PPA auctions drive additional expansion. Reduced mobility and supply chain challenges due to Covid-19 led to a 44% drop in renewable installations in 2020. At the same time, India maintained its firm support for renewables by contracting a record level of solar and wind capacity to reach its ambitious renewable capacity target for 2022 (175 GW), which excludes large hydropower. During COP26, India announced new 2030 targets of 500 GW of total non-fossil capacity and 50% renewable electricity generation share (more than double the 22% share in 2020), as well as net zero emissions by 2070. These further confirm the country's commitment to energy transitions.

**Figure 1.17 India renewable capacity additions, 2009-2026 (left) and national targets for 2022 and 2030 (right)**



\* Includes large hydropower

Notes: Acc. case = accelerated case. National targets for 2022 exclude large hydropower.

IEA. All rights reserved.

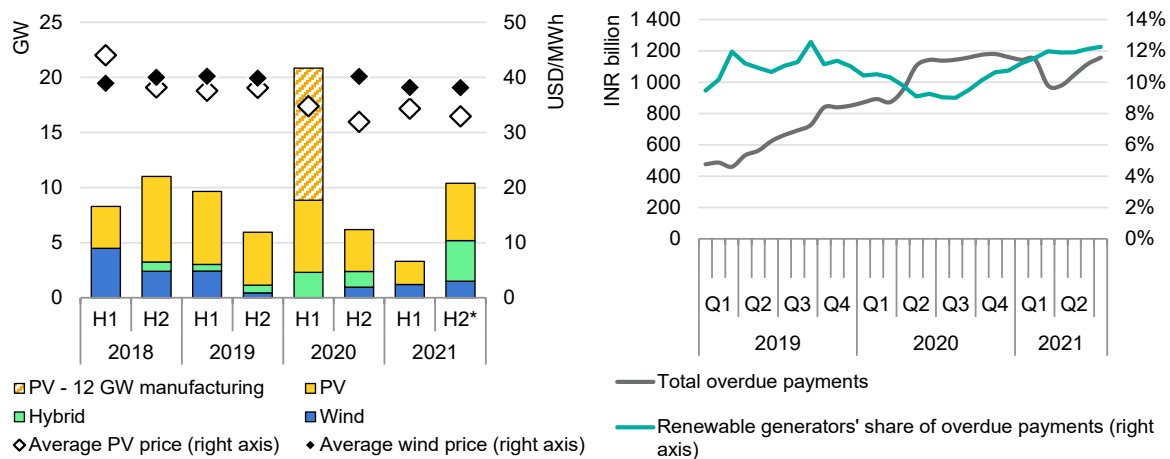
In April-May 2021 India reintroduced movement restrictions around the country to contain the increasing spread of Covid-19 infections. Although restrictions were much less severe than during the first Covid-19 wave last year, they still led to a slowdown in economic activity and increased logistical challenges. As a result, developers have faced construction delays, while reduced electricity demand has put additional strain on the DISCOMs’ financial health. As a relief measure, the government extended commissioning deadlines by two and a half months for projects already under construction. The combination of additional construction delays and the deadline extension is expected to push the commissioning of projects planned for this year into 2022.

The DISCOMs’ poor financial health remains the greatest challenge to faster renewable deployment in India. The government’s financial aid in 2020 put overdue payments on a downward trend in Q1 2021, improving the companies’ finances. Following the second wave of restrictions, their total overdue payments started to rise again in Q2 2021. As a result, they are postponing the finalisation of wind and solar PV PPAs while seeking to renegotiate downwards the contract prices already awarded in competitive tenders. For instance, developers of 12 GW of solar PV awarded at USD 41/MWh in a manufacturing-linked auction held in January 2020 are facing challenges to the signing of the PPA, delaying expansion in our forecast.

The Indian government announced a new stimulus programme (USD 41 billion over the next five years) to support the DISCOMs in the installation of smart and prepaid meters to reduce losses and decrease their revenue gap. In order to

improve their financial health further, the government introduced new guidelines enabling them to terminate PPAs with coal plants after 25 years. This will help them reduce fixed capacity payments, and enable greater flexibility in adapting to system needs and renewable energy mandates. This change may affect almost a third of India’s coal fleet of around 210 GW and facilitate the procurement of more renewable energy.

**Figure 1.18 India renewable capacity awarded via auctions, 2018-2021 (left) and DISCOMs’ overdue payments to generators, 2019-2021 (right)**



IEA. All rights reserved.

\* Comprises July-October data.

Note: PV – 12 GW manufacturing = national solar PV manufacturing-linked auction from January 2020.

Sources: (left) BNEF (2021b); Bridge to India (2021); (right) PRAAPTI (2021).

National and state-level auctions continue to be the main driver of utility-scale PV and onshore wind capacity growth. Solar PV auction volumes slowed from January to October in 2021 following the cancellation of a 6.4 GW auction in Andhra Pradesh due to disputed contract rules. For wind, more capacity has been contracted this year than in 2019 and 2020 combined. Hybrid auctions requiring multiple renewable technologies to provide more dispatchable power are emerging rapidly. From January to October 2021 the volume contracted from these auctions was already higher than historical levels. Recent changes in auction rules, for example lifting the price cap, have improved competition and almost all auctions conducted since H2 2020 have been oversubscribed. Our forecast expects auctions to continue at the level of about 14-16 GW annually, resulting in capacity additions of about 10-13 GW of utility-scale PV and 3 GW of wind per year until 2026.

Rising solar PV equipment costs are putting additional stress on developers who aggressively bid in auctions, betting on further continuation of earlier cost

reductions. Equipment cost inflation may lead to project delays and cancellations. Cost increases and trade policy are also putting upward pressure on solar PV pricing over the forecast period. After the record low PV price of USD 27/MWh observed in the December 2020 auction, tariffs rebounded to USD 34/MWh on average in H1 2021 partly due to rising prices. In addition, developers winning public auctions from April 2021 are obliged to use the modules produced by domestic manufacturers. From April 2022 the duty on modules imported from large manufacturing countries, including China, will increase from 14% to 40%. As imports cover 80% of India's annual capacity additions, local content requirements and trade policy are expected to lead to higher prices in the short term while India increases its manufacturing capabilities. For wind, prices mostly remain unchanged, sitting in the range of USD 38-40/MWh since 2018. Price reductions are elusive because of persistent challenges in finding available land, risks related to securing grid connection and delays in signing PPAs. Without increased assistance from state and central governments in land procurement, accelerating wind deployment remains challenging, resulting in flat capacity additions until 2026.

India's distributed PV capacity additions are expected to grow steadily over the forecast period following a 20% decline in 2020 from 2019. Cost attractiveness and continued policy support are expected to drive deployment. Increasing the PV system capacity limit eligible for net metering from 10 kW to 500 kW and a new proposal for more favourable rules for commercial installations should stimulate growth in the commercial sector. However, several major challenges persist. DISCOMs remain hesitant to support faster adoption of distributed PV due to fears of losing revenue from reduced energy sales caused by self-consumption and incurring higher grid costs. Financing options for small commercial and residential consumers remain limited due to high transaction costs, lack of specialised financial products and the difficulty of establishing a credit rating. Public awareness also remains low, which altogether leads to subdued deployment despite high economic attractiveness in many Indian states. In addition, the KUSUM programme supporting solar PV deployment in rural areas for agricultural consumers has a target of commissioning about 31 GW of PV capacity until 2024. However, due to financing and implementation challenges, we expect about 10 GW of this PV capacity to come online over 2021-2026.

In the accelerated case, renewables deployment in India during 2021-2026 is 50% higher, putting the country firmly on the pathway towards achieving the government's 2030 targets. Distributed PV deployment is about 82% higher in the accelerated case, conditional on assuring the DISCOMs' full support by offering them financial incentives, improved remuneration schemes that fairly allocate grid

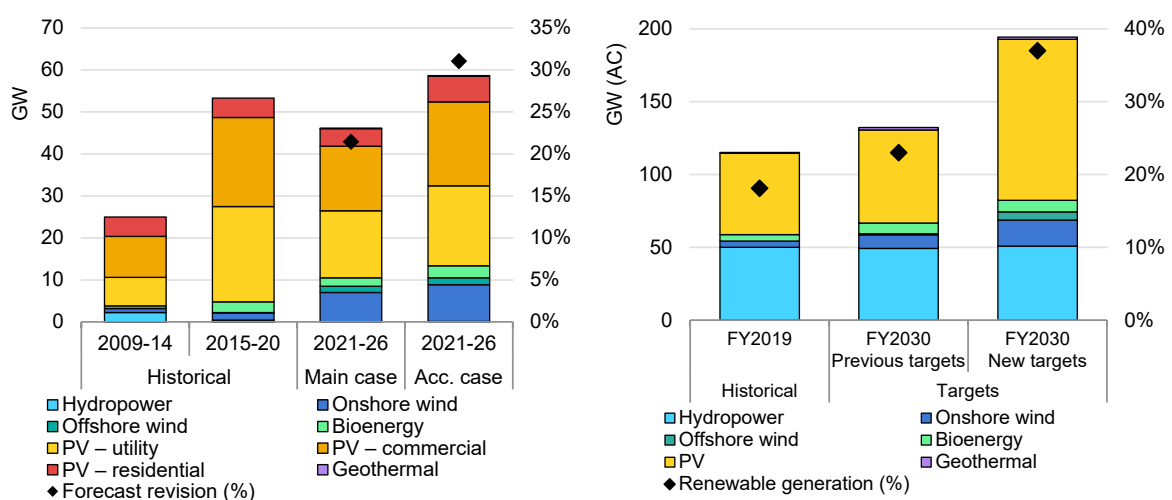
costs and innovative business models that provide them with benefits. For consumers, new financial products and education campaigns will be needed to increase public demand. Upside potential in the KUSUM programme also exists if financing and implementation challenges are resolved. Utility-scale PV and wind installations could be 37% and 70% higher respectively compared with the main case. The accelerated case also assumes that delays in DISCOMs signing PPAs with auction winners are reduced, thus speeding up investment. More support from central and state governments in identification of suitable sites for wind and solar PV, and providing grid connections, are essential elements of the accelerated case, speeding the development of large-scale projects, especially in onshore wind.

## Japan

### Revised renewable targets for 2030 drive faster expansion

Renewable capacity in Japan is expected to increase by 46 GW over 2021-2026 in the main case, or 35%, led by solar PV and wind. The forecast is revised upwards almost 20% from last year, driven by higher renewable electricity targets in Japan's new Strategic Energy Plan (from 22-24% of electricity generation to 36-38% by 2030 [METI, 2021a]) and the remaining large FIT project pipeline, which is mainly for solar PV and wind. Overall, our main case forecast for renewables is in line with Japan's higher targets.

**Figure 1.19 Japan renewable capacity additions, 2009-2026 (left) and renewable energy capacity targets, 2019-2030 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case; FY = financial year (April-March); AC = alternating current. Japan's official renewable energy capacity targets are announced in AC while our solar PV forecast is in direct current.

Sources: based on METI (2021a); METI (2021b).



Despite the higher targets and upward forecast revision, Japan's renewable capacity growth is expected to slow down over the forecast period compared with the previous five years. This is mainly due to a lower FIT pipeline of utility-scale and distributed PV projects for commissioning over 2024-2026. Still, the majority of solar PV expansion over the forecast period will be led by the commissioning of previously approved FIT capacity (18.5 GW AC as of June 2021 [METI, 2021c]) in addition to auction projects. In June 2020 the Japanese government approved a FIP scheme starting from 2022 (METI, 2021d). While FIP implementation details remain a forecast uncertainty, we expect additional utility-scale PV growth from the new scheme.

Japan's wind market is expected to add 8 GW over the forecast period, almost tripling the cumulative wind capacity by 2026. The forecast is driven by the commissioning of FIT-approved onshore wind projects rushing to meet a project completion deadline, with grid connection and environmental permitting remaining key challenges. The offshore wind market is still at an early stage of development, but thanks to the government's ambitious target for offshore wind deployment and supporting measures, including a FIT and sea area designation for construction, this market is expected to reach 1.5 GW over the forecast period.

In the accelerated case, renewable capacity growth could be almost 30% higher than our main case. This will require a higher completion rate of already approved FIT projects and smooth transition to the FIP scheme, enabling additional solar PV capacity to become operational. For onshore wind, faster permitting and grid connection could enable additional growth.

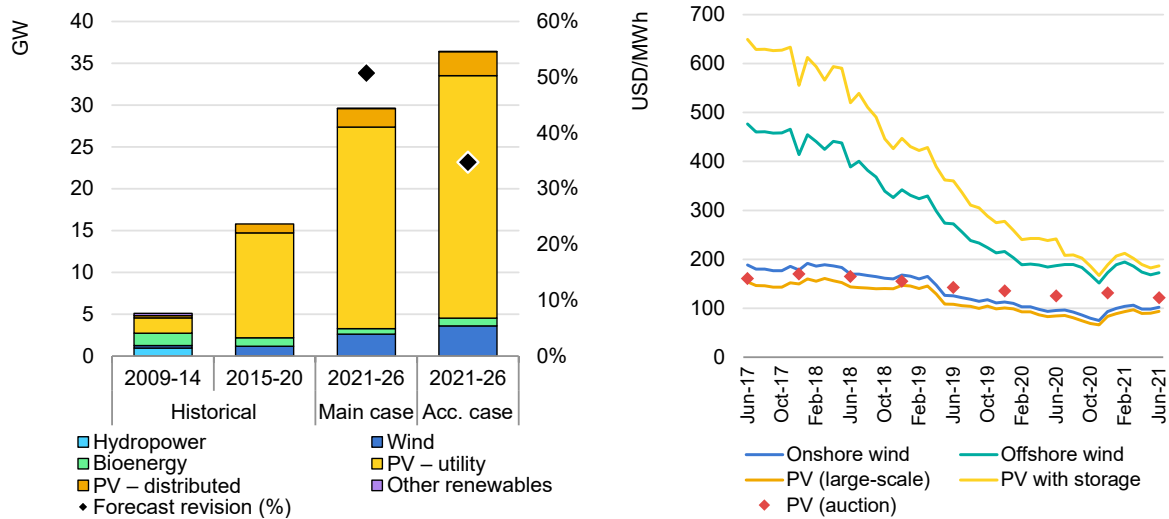
## Korea

### Recent policies providing stable remuneration for solar PV are critical to our forecast

Korea's renewable capacity is expected to double in the main case, expanding by almost 30 GW during 2021-2026. Solar PV accounts for 90% of the country's renewable expansion over the forecast period. We have revised our forecast up by 50% from last year, driven by rising auction volumes with fixed-price contracts for utility-scale and commercial PV, as well as a FIT mechanism for residential PV. Korea's cumulative wind capacity is expected to almost triple by 2026, with offshore wind providing the majority of the expansion. Unlike solar PV, wind projects are not eligible for fixed-price contracts, instead relying on wholesale market revenues and RECs, both of which have declined over the last four years. According to our estimates, remuneration for all large-scale renewable energy projects has halved since June 2017. Future remuneration remains the largest

forecast uncertainty for technologies beyond solar PV, for which fixed-price auctions provide revenue stability.

**Figure 1.20 Korea renewable capacity additions, 2009-2026 (left) and average revenue per MWh by technology, 2017-2020 (right)**



IEA. All rights reserved.

Notes: The average revenue excluding PV (auction) is calculated using the system marginal price (SMP) and weighted REC price. Offshore wind assumes projects with a total interconnection distance more than 15 km. PV (auction) prices reflect biannual average awarded prices. Acc. case = accelerated case.

Sources: Based on IEA (2020a); KNREC (2021); KPX (2021a); KPX (2021b).

In the accelerated case, renewable market growth could be 23% higher than in our main case, driven by higher auction volumes for solar PV and a growing corporate PPA market. For wind, social acceptance challenges need to be addressed, while higher REC prices or new policies providing further revenue stability would contribute to faster expansion.

## ASEAN

### Viet Nam continues to lead capacity growth in ASEAN, although new deployment is spreading throughout the region

Renewable capacity in ASEAN is expected to increase by 52 GW during 2021-2026, representing growth over current capacity of more than 65%. We have revised this main case forecast upwards by almost 50% compared to last year. This is mostly attributable to an onshore wind investment boom in Viet Nam anticipated in 2021 due to an expiring FIT scheme and the release of draft national long-term energy plans with higher wind capacity targets. In addition, more widely an acceleration in hydro and geothermal deployment is expected towards 2026, with a few large-scale projects coming online in Malaysia and Indonesia.

Solar PV accounts for around half of total renewables capacity growth in ASEAN, followed by wind. Low availability of land due to high population density and a mountainous landscape in many countries in the region remains a significant challenge for developing large-scale solar PV and onshore wind projects. Therefore, onshore wind development is likely to be limited outside Viet Nam and distributed PV applications are expected to cover almost 60% of total PV growth during 2021-2026. While offshore wind potential is robust and land availability does not pose challenges, relatively high costs are expected to constrain deployment.

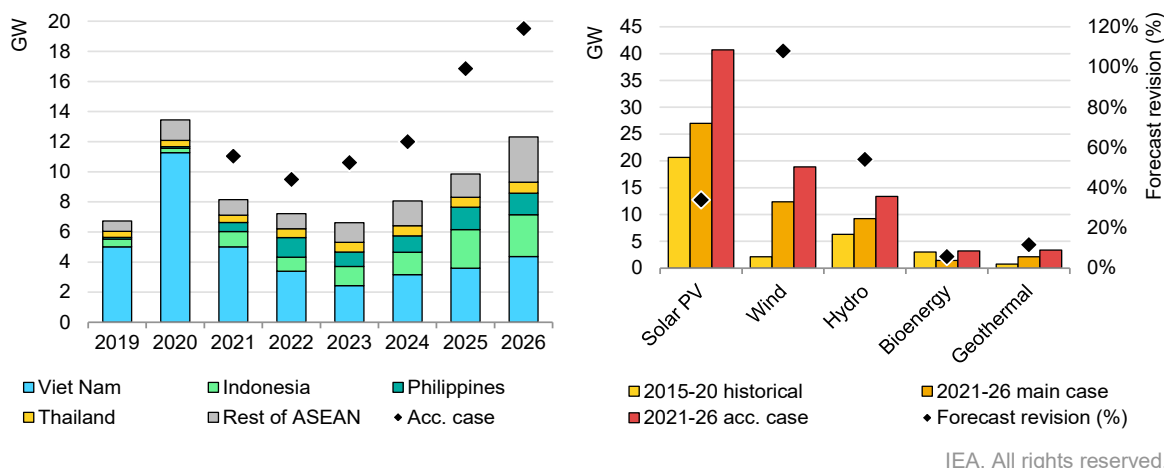
**Viet Nam** alone provides over 40% of all ASEAN's renewable capacity expansion over the forecast period in the main case. Following the deployment boom in utility-scale solar PV projects in 2019, and distributed solar PV in 2020 due to policy incentive deadlines, our forecast expects a similar trend for wind this year as a generous FIT expires. Further deployment of both wind and PV will depend on the implementation timeline of the country's planned auction scheme. It is expected that auctions will mostly target wind capacity, based on the new draft national Power Development Plan (PDP8), which assumes 11 GW of new wind capacity until 2030, but only 2 GW of PV. Utility-scale solar PV deployment is expected to slow due to system integration challenges, with growth limited mostly to distributed installations.

In **Indonesia** the acceleration of renewables growth is expected in the second half of the forecast period, with solar PV, hydro and geothermal dominating the additions. Growth expectations are based on the new draft national energy plan (RUPTL 2021-30), which targets almost 5 GW of PV capacity additions until 2030, a fivefold increase compared to the previous plan. Planned introduction of a FIT and auction schemes are principal drivers of the acceleration of PV deployment, bypassing current regulation that requires renewable generators to compete with subsidised coal plants, reducing the economic attractiveness of renewable projects. Bilateral PPAs with the state-owned utility (PLN) are expected to stimulate the commissioning of several large-scale hydropower and geothermal projects towards 2026.

In the **Philippines** an RPS was introduced in 2020, with auctions planned to ensure cost-effective procurement of renewable energy. The first 2 GW auction is planned for Q4 2021. Auctions are expected to accelerate capacity growth in the coming years, towards achieving the 35% generation share target in 2030. Apart from limited policy support outside the planned auction scheme, main challenges to faster deployment are lengthy permitting procedures, grid connection delays and limited financing available from international institutions due to local ownership rules for renewable projects.

Renewables development remains stable in **Thailand** as there is limited room for new power generation capacity. The situation is further exacerbated by growing imports of hydropower from Laos contracted through a long-term PPA. Commercial PV installations are expected to drive capacity growth during 2021-2026. Steady growth in utility-scale and commercial PV supported through auctions and net metering quotas is expected in **Malaysia**, while the private PPA market will continue to drive rooftop and floating PV installations in **Singapore**.

**Figure 1.21 ASEAN renewable capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right)**



Notes: Rest of ASEAN comprises Brunei, Cambodia, Laos, Malaysia, Myanmar and Singapore. Acc. case = accelerated case.

IEA. All rights reserved.

In the accelerated case, renewable capacity additions in ASEAN are 52% higher than in the main case, with solar PV and wind providing the greatest upside potential. Faster implementation of new auction support schemes in Viet Nam, Indonesia and the Philippines and increased investment in grid infrastructure, especially in Viet Nam, are needed to achieve this faster expansion. Creating a more investor-friendly regulatory and market environment through implementation of standardised bankable PPAs and faster permitting is necessary to propel local and international investment in the region. Maintaining a long-term vision for support schemes with clear rules and targets is needed to achieve the accelerated case, as policy and regulatory uncertainties can stall project development, as observed in Viet Nam and the Philippines during the transition from FITs to auctions. In addition, relaxation of local content and project ownership requirements in countries like Indonesia and the Philippines could lead to lower renewable costs, improving their competitiveness against conventional generators and attracting more international financing.

During COP26, Viet Nam, the Philippines and Indonesia (conditional on international assistance) joined a commitment to cease the utilisation of and support for unabated coal power generation by 2040. Furthermore, Viet Nam

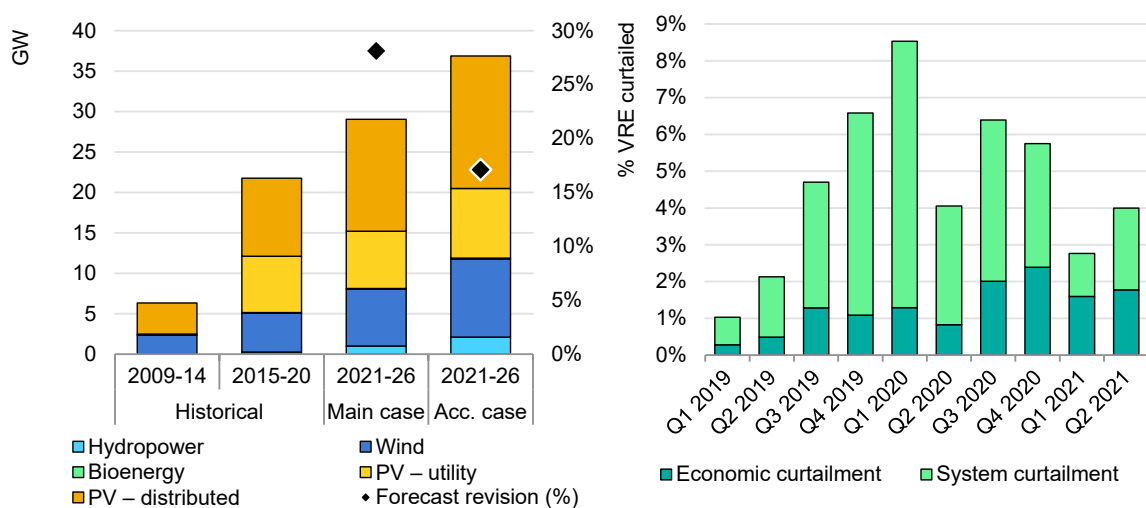
announced a net zero emissions target by 2050 and Thailand by 2065, joining Malaysia, Indonesia, Singapore, Laos and Cambodia who announced their net zero targets before COP26. Announced pledges signal a commitment of ASEAN countries to clean energy transitions, which are expected to drive renewable capacity growth in the region in the long term.

## Australia

### Distributed solar PV drives growth as large-scale installations await network upgrades

Australia’s renewable capacity is forecast to increase by nearly 30 GW, or 75%, in the main case during the period 2021-2026. For large-scale renewables, growth is driven by current policies to achieve renewable energy targets at both federal and state levels and by increased corporate buying. Low PV system prices and financial incentives are driving distributed PV installations. We have revised the forecast up by over 25% from last year thanks to network upgrades and state policies establishing Renewable Energy Zones (REZs) for large-scale renewables development. However, until these improvements are realised, grid integration challenges remain, leading to increased interconnection lead times and high volumes of curtailment. Australia’s recently released net zero roadmap for carbon neutrality by 2050 indicates a heavy reliance on clean energy technologies, including “ultra-low cost” solar PV (Australian Government, 2021).

**Figure 1.22 Australia renewable capacity additions, 2009-2026 (left) and renewables curtailment, Q1 2019-Q2 2021 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.  
Source: (right) AEMO.

Distributed solar PV provides nearly 50% of total growth, adding almost 14 GW of new capacity through the forecast period. Favourable economics due to relatively low system costs, support from the small-scale certificate scheme at the federal level and FITs at the state level drive expansion. However, distributed PV capacity additions have caused system integration challenges across multiple networks. In response, the Australian Energy Market Commission introduced new rules allowing distribution companies to charge fees for exported energy, leading to lower additions during the forecast period.

Utility-scale solar PV and onshore wind are forecast to grow by over 7 GW each during 2021-2026. The two main drivers of growth are: 1) energy revenue awarded via state-level auctions or PPAs with state and local governments, energy retailers, utilities and businesses; and 2) certificate revenues via the federal Large-scale Renewable Energy Target (LRET) programme. PPAs emerge as a key driver, with volumes increasing in order to hedge against wholesale price volatility and to meet state-level portfolio standards. LRET, which ends in 2030, has met its target, resulting in an oversupply of certificates and leading to converging certificate values. Thus, the effectiveness of LRET as an ongoing driver of capacity growth remains a forecast uncertainty. In addition, network challenges remain. Connection delays have extended project timelines and developers have increasingly self-curtailed existing projects to avoid grid penalties. REZs are expected to unlock additional grid capacity and enable more renewables development. The first REZ and associated projects are scheduled to be realised by the middle of the decade, boosting solar PV and wind deployment at the end of the forecast period.

The accelerated case sees nearly 30% higher additions than in our main case. In this case additional capacity could come from new auctions to achieve state-level targets or to procure capacity for REZs. Continued upgrades to synchronisation for existing installations and the timely implementation of planned network expansion ease investor concerns, eliminating project delays and backlogs. Distributed PV additions should achieve higher growth if energy export tariffs do not significantly affect the overall economics of the installation. The country has large ambitions for hydrogen from renewable energy, which could add substantial capacity at the end of the forecast period.

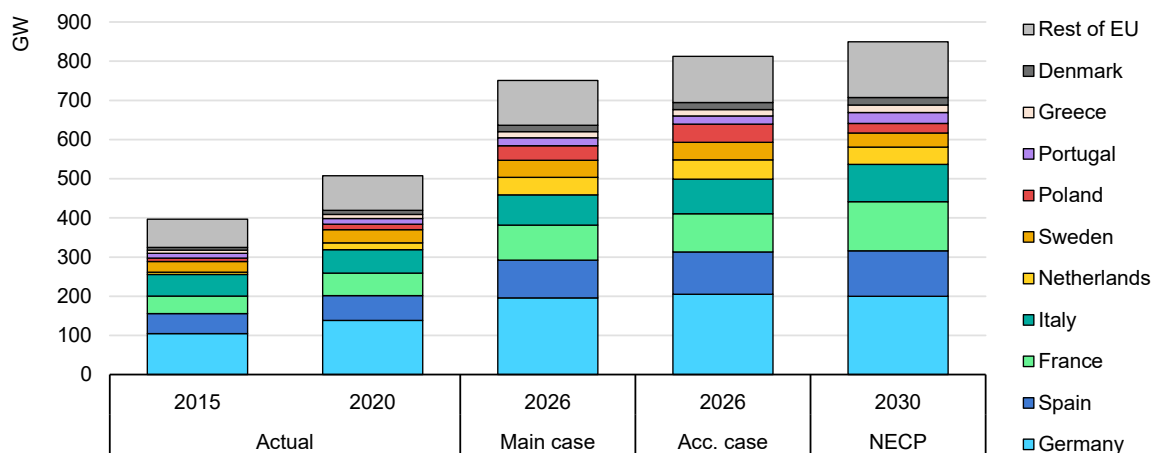
## Europe

### Stronger policy support drives faster utility-scale growth, while the increasing attractiveness of distributed PV exceeds our expectations

Europe’s renewable capacity is forecast to expand by 45% in the main case from the addition of 300 GW, led by solar PV and wind. Three-quarters of the growth is from seven countries: Germany, Spain, France, the Netherlands, Turkey, the United Kingdom and Poland. Government-held auctions remain a critical policy driver of utility-scale growth in most markets. An increasing proportion of the growth is expected to come from corporate PPAs due to the competitiveness of wind and solar PV with wholesale electricity prices and the private sector’s sustainability goals.

For countries in the European Union, the 2030 renewable energy targets set out in the NECPs remain a key policy underpinning renewable electricity capacity growth. These targets are part of a larger climate and energy framework, which currently sets a target of at least 32% of final energy consumption at the EU level to be from renewables by 2030. By 2026 the European Union’s renewable capacity is expected to reach 750 GW, expanding by 40 GW per year on average. If this pace continues, the bloc will be on track to not only meet, but to exceed current renewable capacity plans for 2030 stated in NECPs. This trajectory is even more likely in the accelerated case.

**Figure 1.23 EU member states installed renewable capacity and capacity expected in 2030 based on submitted NECPs**



IEA. All rights reserved.

Note: Acc. case = accelerated case, NECPs = National Energy and Climate Plans  
Source: IEA analysis based on NECPs.

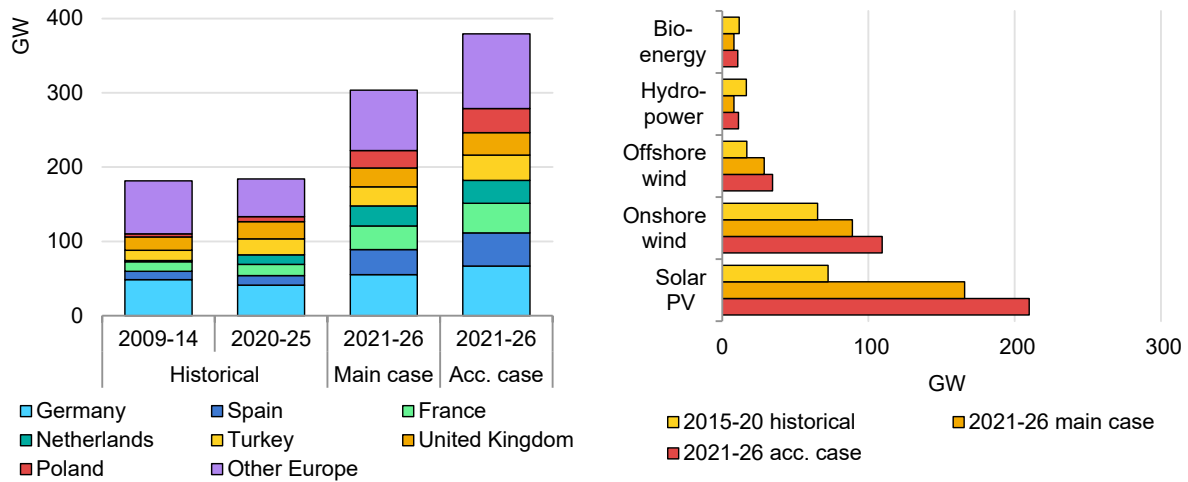
The 2030 target is likely to be raised; however, the final amount and when that would be reflected in member states' NECPs remain a forecast uncertainty. In July 2021 the European Commission proposed to update the EU target from 32% to 40% to align renewable policy with raised ambitions for emissions reduction (55% emissions reduction by 2030 and climate neutrality by 2050). Given the deadline for finalising the new target is May 2024, the main case assumes that the impact on capacity additions would occur after 2026 in order to allow member states to update their individual targets and policies, in line with the current governance. However, the accelerated case assumes swifter implementation of policies in each country in anticipation of new EU targets and due to increased national ambitions. Still, annual capacity additions are expected to fluctuate due to permitting and social acceptance challenges, which create lulls in the project pipeline. In some markets, this has resulted in auctions being undersubscribed or postponed.

Overall, the forecast is 19% higher compared to last year. A majority of the upwards revisions is from wind and utility-scale solar PV due to increased policy support under auction schemes. Over the past year, governments have announced new auction schedules or have extended current ones (e.g. Germany, Spain), in some cases with more capacity earmarked than in their previously announced plans (e.g. Turkey, Poland). The main driver for this is to accelerate growth towards 2030 targets. Furthermore, in several auction rounds held over the past year, more solar or wind capacity has been awarded than previously expected, while the subscription rates exceeded our expectations in some cases. Accordingly, we have modified the assumptions about future auctions.

In addition, distributed PV accounts for 40% of our upward capacity revisions for Europe. We assumed that the economic uncertainty due to the Covid-19 crisis would shift the financial priorities of both individuals and small/medium-sized enterprises in some countries. However, Europe installed 14 GW of distributed PV in 2020, the highest level since 2011 and higher than we forecast (9.7 GW). In addition we see regulatory changes and higher retail electricity prices in key markets making self-consumption and net metering more attractive. Over the forecast period, we expect the average annual pace to remain between 12 GW and 15 GW.



**Figure 1.24 Europe renewable capacity additions by country, 2009-2026 (left) and capacity growth by technology, 2015-2026 (right)**



IEA. All rights reserved.

Notes: Europe comprises EU member states, United Kingdom, Turkey, Norway and Switzerland. Acc. case = accelerated case.

Compared to the previous five-year periods, solar PV growth is expected to surpass wind. Increasing economic attractiveness resulting from distributed PV policies and corporate PPAs supports this trend. Growth of both hydropower and bioenergy is projected to be lower than the previous five-year period. The permitting process for hydropower projects is typically a challenge in Europe, with few available sites, and the economics of bioenergy remain challenging without further government support. In the accelerated case, Europe’s renewable expansion is about a quarter higher than in the main case. In addition to increasing 2030 ambitions, this would require countries to alleviate permitting and social acceptance challenges to enable higher participation in auctions, to expand grid capacity more quickly and to implement policies that improve the attractiveness of distributed PV.

## Germany

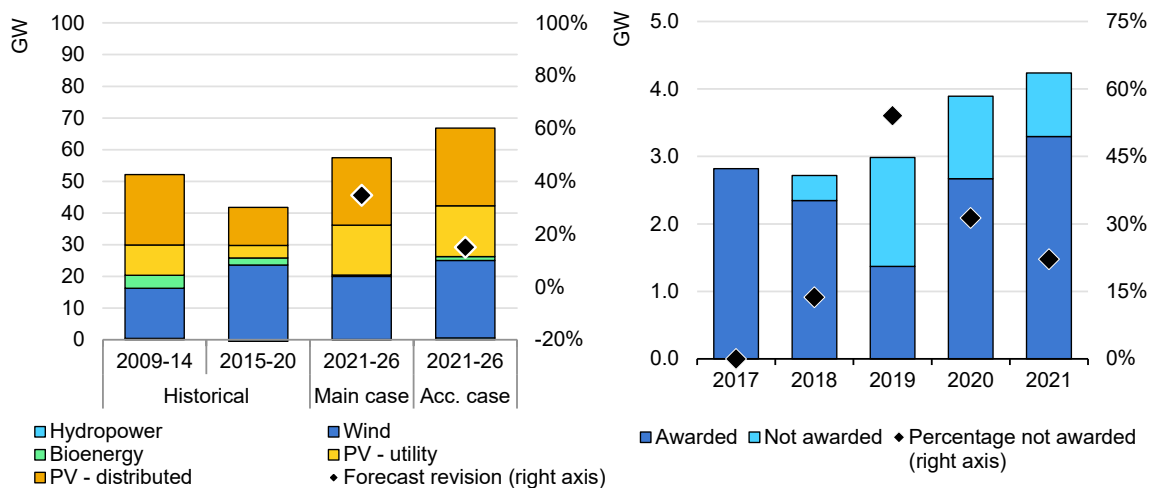
### New auctions accelerate utility-scale growth, but the impact of new self-consumption policies on large commercial PV is a major uncertainty

Germany’s renewable capacity is forecast to increase by more than 40% (57 GW) over 2021-2026, led by solar PV and followed by onshore wind, offshore wind and bioenergy. Growth is mostly driven by support policies to meet long-term climate

goals. Government-held auctions drive most of the utility-scale renewables, while distributed PV deployment is supported by FITs and self-consumption with remuneration for excess generation.

Our forecast is revised upwards by 35% compared to last year, mostly due to a 5 GW increase in auction volumes announced in April 2021. The government decided that the amount of capacity to be auctioned in 2022 will increase from 1.9 GW to 6 GW for solar PV and from 2.9 GW to 4 GW for wind. Also supporting the more optimistic forecast are the impacts from new regulations to ease permitting for onshore wind under the new Renewable Energy Sources Act (EEG 2021), which entered into force in January 2021.

**Figure 1.25 Germany renewable capacity additions, 2019-2026 (left) and onshore wind auctions (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.  
Source: Bundesnetzagentur (2021).

Distributed PV leads Germany’s expansion, accounting for 36% of the growth in renewable capacity, led by the commercial segment. However, a key forecast uncertainty is the impact of two new policies under EEG 2021 to increase self-consumption in the commercial segment. First, the new regulation stipulates that commercial PV projects between 300 kW and 750 kW may sell only up to 50% of their generation on a monthly basis. If the owner wants to sell more than 50%, they must compete in annual auctions capped at 300 MW per year. Monthly additions in this segment dropped from 125 MW per month under the previous policy when all generation was eligible to be sold, to 35 MW per month after the new policy entered into force in March 2021. Notably, an opposite trend is expected for smaller systems (10-30 kW), where the surcharge on self-consumed

electricity was removed in EEG 2021. Following this change, average additions doubled from 35 MW per month to 75 MW per month in 2021 compared with last year. The main case assumes that the increase in economic attractiveness of self-consumption drives growth in this segment.

The forecast for onshore wind is revised upwards in part due to the regulatory reforms aimed at tackling permitting challenges, which have previously caused auctions to be undersubscribed. Since 2017 only 13 GW out of the 17 GW offered were awarded in auctions because social acceptance and litigation issues have made obtaining a permit, which is required to bid in an auction, a lengthy process. However, annual subscription rates have been increasing since 2019 and two out of the three auctions in 2021 were fully subscribed. The main case forecast expects new reforms that increase the benefits to local communities will improve social acceptance and, consequently, permitting and subscription rates. EEG 2021 guarantees that a proportion of revenues from wind farms will go to local communities, taxes will be paid at the place of installation rather than at company headquarters, and local residents will be eligible for reduced electricity tariffs. Nonetheless, the continued decommissioning of older wind turbines for which support is expiring remains a downside risk to the forecast. An additional 3.5 GW of renewable capacity is also set to come from offshore wind and bioenergy, both driven by auction schemes.

Overall, renewables growth in the accelerated case could be 16% faster than the main case, with greater economic attractiveness for self-consumption in distributed PV, improved economics for repowering and increased social acceptance of onshore wind projects, and more rapid development of the offshore wind project pipeline.

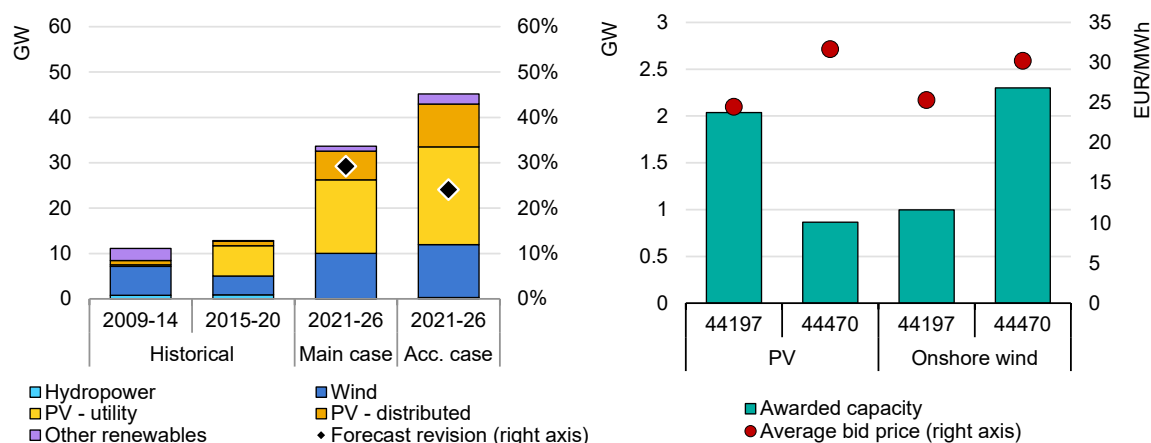
## Spain

### Auctions for renewable capacity resume, but regulatory uncertainty poses a risk to growth from corporate PPAs and merchant projects

Renewable electricity capacity in Spain expands by 52% between 2021-2026 from the addition of 34 GW in the main case, almost entirely from solar PV and wind. Overall, our forecast is 27% higher than last year due to the allocation of EU stimulus to incentivise distributed PV and higher than expected wind capacity awarded in the second round of auctions, held in October 2021. Only 1.5 GW was earmarked for onshore wind in the second round; however, 2.3 GW was awarded to compensate for unallocated capacity in other categories that were

undersubscribed. The impact on investor confidence of recent regulatory changes – which put a levy on the revenues of low-carbon generation exposed to the wholesale market – remains a forecast uncertainty, especially for future corporate PPAs and merchant activity.

**Figure 1.26 Spain renewable capacity additions, 2019-2026 (left) and comparison of auction prices and wholesale electricity prices, 2018-2021 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. In the right graph, the average bid price represents the weighted average winning auction price of onshore wind and solar PV.

The main policy driver for capacity growth in Spain is government-held auctions, which resumed in 2021 after three years of delay. The first round was in January and achieved relatively attractive weighted average prices for utility solar PV and onshore wind of EUR 24.47/MWh and EUR 25.31/MWh, respectively. However the awarded prices increased by 29% and 19%, respectively, in October's second round, in part due to the increase in commodity prices. The forecast contains two main uncertainties related to project realisation under auctions. First, securing financing may be a challenge given the low bid prices and relatively short contract lengths of 12 years. Second, projects still need to obtain grid connection permits, which can be in short supply and expensive due to the existence of a secondary market where permits can be sold at a higher value. To free up capacity for new projects, the government introduced regulations last year stipulating the expiry of permits if certain project development milestones are not met.

Spain's onshore wind and utility-scale solar PV forecast is also driven by a pipeline of projects outside the auction process, with revenues from corporate PPAs and the wholesale market. However, Royal Decree-Laws 17/2021 and 23/2021, passed in October 2021, recuperate a proportion of the revenues of low-carbon electricity generators from sales linked to the wholesale market; this action was

taken to avoid excessive increases in consumer electricity bills in response to high natural gas prices. The new law is set to last until 31 March 2022; however, it could be extended if gas prices remain high. The main case expects this regulation and uncertainty surrounding the length of time it will remain effective to slow new contract signing and to delay financial closure of projects outside the auction scheme.

Distributed PV accounts for 19% of Spain's renewable capacity growth, driven largely by self-consumption in the commercial segment. We have revised this forecast upwards due to higher than expected growth in 2020 and newly announced plans to allocate EU stimulus money to increase self-consumption. Spain's recovery plan earmarks EUR 450 million towards investment grants for distributed PV and another EUR 110-220 million for storage systems.

In the accelerated case Spain's renewable capacity growth is 35% higher than the main case, due to increased deployment outside auctions. This depends on clarification of the length of time that Royal Decree-Law 17/2021 revenue recuperation lasts, providing investors with the visibility needed to plan future investment. Higher distributed PV growth could occur if additional EU stimulus is allocated to self-consumption. Spain plans to apply for another EUR 70 billion in the form of loans to support the energy transition and some could be earmarked to support self-consumption from solar PV.

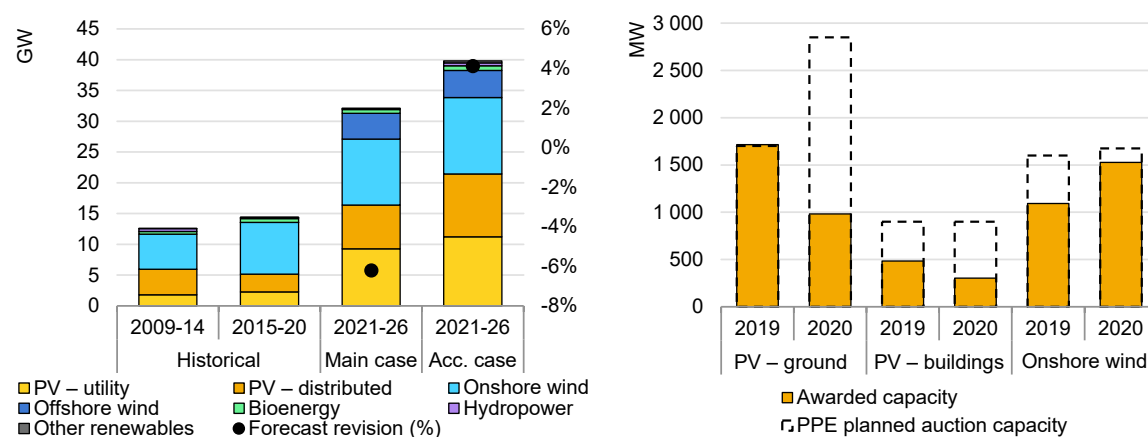
## France

### Despite growing policy ambition, implementation challenges lead to a downward forecast revision

France's total installed renewables capacity is projected to grow by 55% (32 GW) during 2021-2026 in the main case. Solar PV and wind account for almost all of this growth, with annual capacity additions averaging 2.7 GW and 2.4 GW respectively over the forecast period. Three-quarters of wind additions are anticipated to be onshore, while utility- and commercial-scale segments continue to represent the large majority of PV developments. Compared to last year, we have revised France's outlook for 2021-2026 slightly downwards, based on: 1) the postponement and downward adjustment of auction capacity initially scheduled for 2020-2021; 2) the undersubscription of recent auction rounds for ground-mounted PV and onshore wind; 3) a high rate of cancellation among PV projects awarded in the past; 4) limited land eligibility for PV and wind projects; and 5) ongoing permitting bottlenecks, partly due to limited administrative resources.

Expansion is largely steered by the country’s multiannual energy plan (PPE), updated in 2020, which sets technology-specific targets for 2023 and 2028, as well as indicative auction schedules. Large solar PV and wind projects benefit from sliding FIPs awarded through competitive tenders, while FITs support smaller wind projects and residential-scale PV. In 2021 the government published the schedule for seven new technology-specific auction schemes, which replace the previous schemes ending in the same year. These new schemes aim for 29.9 GW of renewable energy capacity over the period 2021-2026 (16.4 GW of PV and 10.2 GW of onshore wind).

**Figure 1.27 France renewable capacity additions, 2009-2026 (left), and auction results, 2019-2020 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

Annual solar PV additions are expected to more than triple from 2020 levels during the forecast period, enabled by previous tenders for utility-scale and commercial projects, as well as the new auction frameworks. While the latter offer potential for more rapid growth, multiple PV tenders have suffered undersubscription since 2018, mostly due to permitting challenges, leading to a downward revision of auctioned capacity targets. In addition, awarded projects have faced a high cancellation rate during the past two years, while complex administrative procedures cause very long project lead times – about four years to develop a ground-mounted plant (France Territoire Solaire, 2021). Supportive policy updates for solar PV were confirmed in October 2021, including the extension of FIT eligibility to larger projects, tax cuts and PV installation obligations on new warehouses, supermarkets and parking canopies. Despite these improvements, investor confidence might be challenged by the recent retroactive revision of FITs already awarded to projects between 2006 and 2010.

Onshore wind growth is anticipated to accelerate, largely driven by rising auction volumes under the new auction schemes. The new auction specifications include supportive updates, in particular an extension to project eligibility and the reduction of administrative delays during the selection process. However, land constraints remain a critical challenge. High spatial concentration of projects in regions with the greatest wind potential has led to rising local opposition in recent years, despite stringent heritage, landscaping and environmental limitations. Restricted areas around military radars were extended in 2021, potentially exacerbating permitting issues.

France's offshore wind capacity is expected to take off in 2022 with the full commissioning of the 480 MW project in Saint-Nazaire, a decade after the tender was held in 2012. By the end of 2026, offshore capacity is expected to reach 3.7 GW, with seven large projects expected to come online. Projects have faced significant delays related to extended litigation while the government renegotiated contracts to prevent windfall profits. In addition, in April 2021 France launched a call for tender for a floating offshore wind project with a capacity of up to 270 MW. Under the accelerated case, France's renewable capacity additions reach 40 GW during 2021-2026 – a quarter more than in the main case. Assuming the full subscription of the new auction schemes, lower abandonment rates for awarded projects, and the rapid uptake of residential PV and corporate PPA projects, solar PV capacity could expand almost a third more than in the main case, potentially meeting the 2023 PPE target. With greater auction participation, an additional 1.6 GW of onshore wind is also achieved in the accelerated case, assuming that land constraints and social acceptance challenges are overcome, and the permitting procedure is streamlined. The Ministry of Ecological Transition recently announced a set of measures, including mapping of wind zones and a better tracking of projects, which could help achieve a more regionally balanced deployment of onshore wind – hence potentially reducing social opposition challenges.

## The Netherlands

**Solar PV leads capacity additions, but grid availability and competition with carbon capture for future subsidy budget allocation remain forecast uncertainties**

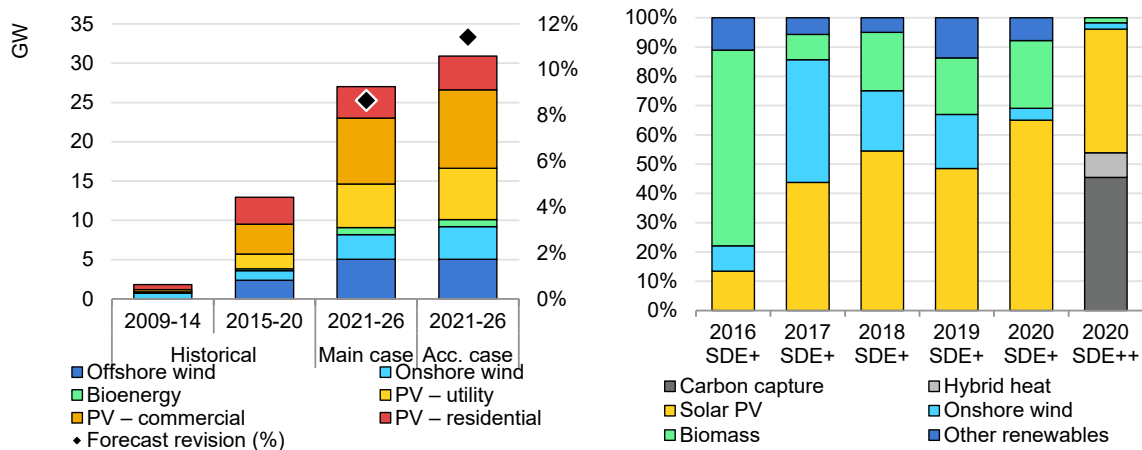
The Netherlands' renewable capacity is forecast to increase by over 27 GW over the forecast period in the main case, more than doubling the currently installed capacity. Capacity awarded in the SDE+ and SDE++ auction rounds, completed tenders for offshore wind and the net metering policy for PV projects under 15 kW



are the primary factors for growth. We have revised the forecast up by nearly 10% from last year due to a large amount of PV capacity being awarded in the first SDE++ auction round held at the end of 2020, more than previously anticipated.

The amount of subsidies available for renewables in upcoming auctions remains a principal forecast uncertainty during 2021-2026. In the first SDE++ round last year, over 50% of the total subsidy was awarded to carbon capture and storage and heat pumps, leaving less budget available for wind and solar PV. The continuation of this trend poses challenges to faster expansion of renewables. In addition, our forecast expects that the onshore renewable generation target of 35 TWh by 2030 is likely to be achieved prior to that year and could lead to a re-evaluation of onshore renewables incentives (IEA, 2020b).

**Figure 1.28 Netherlands renewable capacity additions, 2009-2026 (left) and share of budget award by technology, 2016-2020 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. Two auctions took place per year. 2016, 2017, 2018 and 2019 values are combined results. In 2020, two auctions were held, the final SDE+ round and the first SDE++ round, resulting in the broken-out values in the right figure. Offshore wind totalling over 5 GW was tendered 2015-2021.

Source: (right) IEA analysis based on data from Netherlands Enterprise Agency (RVO) (2020), Verplichtingen SDE per technologie.

Solar PV accounts for two-thirds of the Netherlands' renewable capacity expansion in the forecast period, led by distributed PV. The country awarded nearly 3.6 GW in the latest SDE++ auction round held in 2020, with rooftop applications winning 97% of all PV projects. Auction results over the period 2018-2020 indicate a large PV pipeline of nearly 12 GW eligible for subsidies. In addition, our forecast expects demand for residential projects to remain strong in 2022 and 2023 before the remuneration under the net metering scheme is reduced.



For utility-scale solar PV and onshore wind projects, grid availability and permitting present a key challenge for greater growth. The regional grid operator has stated that regions in the central and eastern Netherlands have no remaining grid capacity due to a backlog of solar PV and wind projects. Connection delays are expected over the forecast period (TenneT, 2021). Reduced network availability has already contributed to lower participation of onshore wind projects in auctions, as developers must prove grid availability at the time of their bid. Thus, the main case forecast expects substantially lower onshore wind additions over 2024-2026 after the commissioning of previously awarded projects. Driven by previously allocated capacity, offshore wind is forecast to add 5 GW during 2021-2026, accounting for nearly two-thirds of the country's total wind expansion.

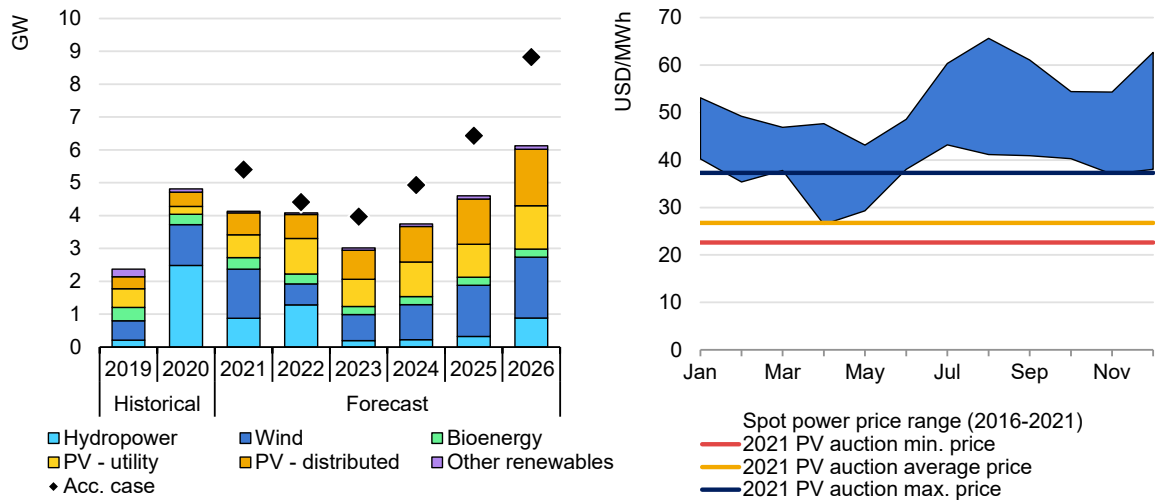
The accelerated case sees higher additions on the assumption that grid congestion issues are addressed, freeing up space for new large-scale projects, especially utility solar PV and onshore wind installations. In addition, the following factors are also considered in the accelerated case: 1) similar or larger budgets for SDE++ and faster cost declines leading to more capacity and 2) an extension of the 100% net metering credit, which was proposed but not passed, would lead to higher deployment of residential PV.

## Turkey

### Growth shifts from hydropower to low-cost solar PV and wind, but annual additions remain volatile for onshore wind

Turkey's renewable electricity capacity is expected to increase by over 26 GW, or 53%, during 2021-2026 in the main case. Solar PV and wind are anticipated to provide nearly 80% of Turkey's renewable capacity expansion, mostly driven by FITs and auctions for utility-scale renewables, and monthly net metering for distributed solar PV projects. Driven by the commissioning of large hydropower projects and a FIT deadline for onshore wind, Turkey's annual additions doubled last year compared with 2019. However, a reduced hydropower pipeline is expected to result in lower growth over 2021-2026. In December 2020 the government extended the FIT application deadline for onshore wind to June 2021, resulting in higher additions this year in our forecast. However, wind additions are expected slow significantly between 2022 and 2024 due to delayed auctions and project permitting timescales, leading to a reduced project pipeline. Additions recover through to 2026, driven by additional wind auctions with higher capacity compared with historical levels.

**Figure 1.29 Turkey renewable capacity additions, 2019-2026 (left) and solar PV auction results, 2021 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

Following the solar PV auction (1 GW single plant) in 2019 at USD 70/MWh, Turkey held a second PV auction in April 2021 awarding 74 projects at an average price of USD 27/MWh. With the lowest bid price at USD 23/MWh, awarded contracts are competitive with or lower than average wholesale electricity prices over the last five years. At these prices, our forecast assumes tenders for an additional 1 GW are to be held in coming years. However, the project completion rate at these prices remains a forecast uncertainty in view of macroeconomic challenges, exchange rate volatility and high interest rates. Large-scale commercial PV projects are expected to support the forecast as large consumers seek bill savings in the face of increasing retail electricity prices. Geothermal capacity is expected to increase by 0.5 GW over the forecast period, driven by the continuation of the FIT.

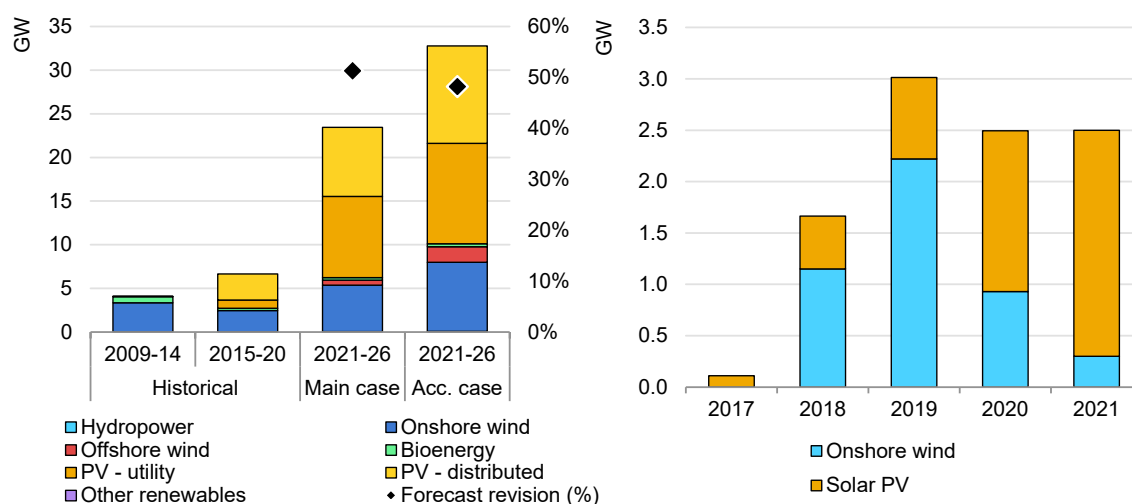
In the accelerated case, renewables growth is over 30% higher than in the main case. Solar PV has the largest upside, with higher auction volumes and faster project completion rates, while improving financing conditions should facilitate additional growth for both utility-scale and distributed solar PV projects. Moreover, new regulations enabling hybrid projects and the introduction of corporate PPA regulations are assumed to unlock additional onshore wind and PV projects at competitive prices. The upside for geothermal remains high if affordable financing is available, reducing pre-development risks and unlocking additional projects in the pipeline.

## Poland

### Renewable capacity growth triples during 2021-2026 compared to 2015-2020, but annual additions are volatile due to policy changes

Poland is expected to add 23 GW of renewable capacity over 2021-2026 (71% growth) in the main case. Solar PV accounts for almost 75% of the growth, followed by onshore wind. In addition, Poland's first offshore wind turbines are expected to start operations in 2026, adding close to 1 GW of capacity. Poland has requested about EUR 3.7 billion of grants and loans through the European Union's Recovery and Resilience Facility to stimulate development of offshore wind, which should help the development of port infrastructure and ensure timely commissioning of approved projects. Our forecast is around 50% higher than last year's, due to faster than expected growth of distributed PV, progress on offshore wind project approval and much higher overall renewables deployment in 2026 compared to 2020.

**Figure 1.30 Poland's renewable capacity additions, 2009-2026 (left), and estimated PV and wind capacity additions resulting from renewable energy auctions, 2017-2021 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

Source: (right) IEA analysis based on Urząd Regulacji Energetyki (2021).

Auctions remain the principal driver of utility-scale PV and wind deployment. In October 2021 the Renewable Energy Act was amended, extending auctions from 2021 to 2027 and introducing long-term plans for auction volumes, which should encourage project development. The act also facilitated investment in small installations, which is expected to result in faster growth of distributed PV capacity.

The investment subsidies driving distributed PV growth since 2019 are expected to be scaled down in 2022. Regulators are also planning to replace the generous net metering scheme with net billing from 2022. Although the final rules are yet to be announced, current plans indicate a reduction in remuneration, leading to a slowdown in annual distributed PV growth compared to 2020-2021, especially in the residential segment.

The first seven offshore wind projects in Poland, with a total capacity of about 6 GW, were approved in Q2 2021 via contracts for difference. The projects are expected to come online during 2026-2030, with additional capacity planned to be awarded through auctions starting in 2025. However, onshore wind project development remains constrained by a law prohibiting construction of turbines at a distance from the nearest residential building of less than ten times the height of the turbine. Current rules prohibit project development even in areas with strong local community support, and are expected to result in a significant slowdown in annual deployment after 2022.

In the accelerated case, capacity additions are 40% higher, with the biggest upward potential being in onshore wind and distributed PV. Achieving more rapid capacity growth will require the expansion of auctions for large-scale systems, the softening of restrictions for onshore wind turbine placement and ensuring the profitability of installations under the new distributed PV remuneration scheme. Increased investment in transmission and distribution grids will also be required to enable the system integration of higher wind and solar PV capacity. In addition, updating national strategic documents for long-term power sector development would provide renewables developers with greater visibility, encouraging investment.

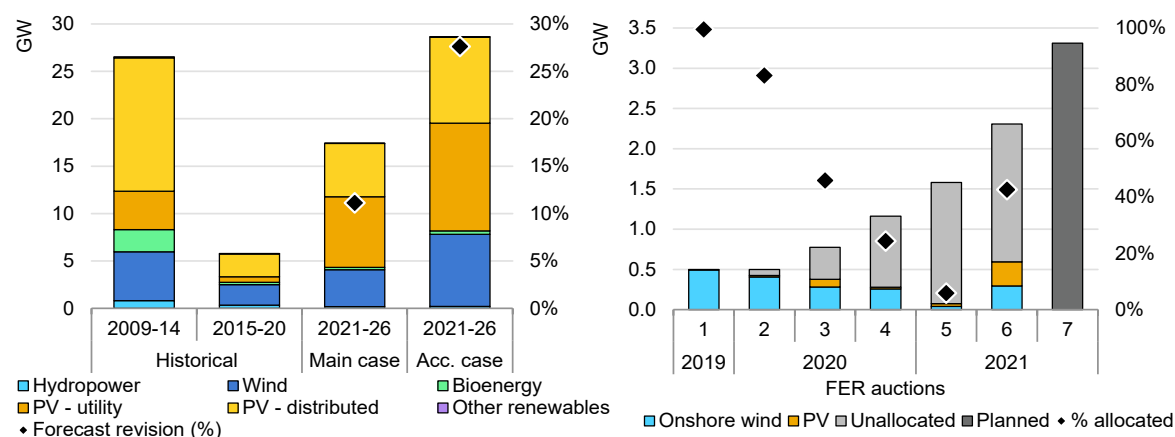
## Italy

### Solar PV leads the revival of the Italian renewables market, but lengthy permitting procedures put 2030 targets at risk

Renewable capacity in Italy is forecast to grow by 17 GW, or 30%, over the period 2021-2026 in the main case. Solar PV accounts for three-quarters of this growth, split between utility-scale and distributed applications. Auctions, bilateral PPAs and merchant projects are driving utility-scale PV expansion. For distributed applications, the main drivers continue to be the net billing scheme and generous tax incentives in the residential sector, and self-consumption with a guaranteed selling price for exported power in the commercial and industrial segments. We expect renewables growth in Italy to continuously accelerate towards 2026, to reach the targets set out in the NECP. In addition, the renewable electricity sector is expected to receive around EUR 4.7 billion in grants from the European Union's

Recovery and Resilience Facility, the largest among all EU members, which should contribute to project financing. According to the NECP, cumulative installed solar PV and wind capacity should almost double to 2030, which requires faster growth, similar to the capacity additions observed during 2009-2014.

**Figure 1.31 Italy renewable capacity additions, 2009-2026 (left) and FER auction results, 2019-2021 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

Source: (right) IEA analysis based on Gestore Servizi Energetici (2021).

In 2019 Italy launched a new auction programme (FER) with the aim of contracting about 5 GW of new solar PV and onshore wind capacity through seven auctions by 2021. However, the six auctions held since the programme launched saw only about 2 GW out of the planned 4 GW being contracted. The main challenge holding developers back from participating is the complicated and lengthy permitting process and the restriction on using agricultural land in submitted projects. In Q4 2021 the government is due to auction all the unallocated capacity (3 GW), but the participation rate remains a key forecast uncertainty.

The long and complicated permitting process remains the main challenge to more rapid renewables deployment in Italy. Many projects are abandoned during the permitting process, which can take up to six years. More than 100 GW of renewable capacity is stuck at various stages of the administrative process. In July 2021 a simplification decree was enacted, aimed at streamlining various administrative processes. However, the impact of the new policy remains uncertain. In addition, limited land availability and growing social acceptance challenges further hamper faster growth of renewables.

In the accelerated case, renewable capacity additions are 65% higher, putting the country on a path to exceeding current 2030 targets for solar PV and wind.

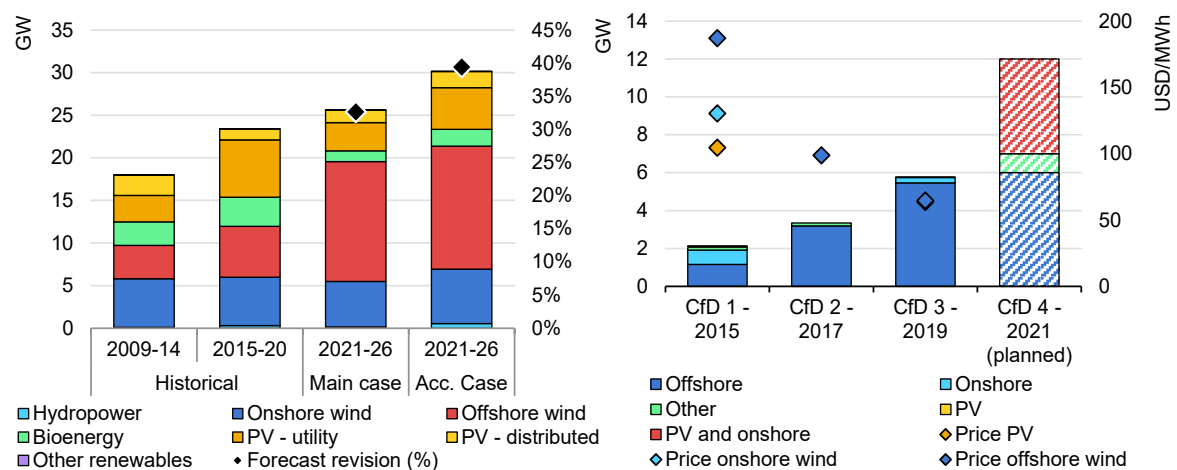
Achieving faster growth requires the effective streamlining of permitting processes, strong investment in transmission and distribution grids to integrate additional variable renewable capacity and a higher success rate at auctions.

## United Kingdom

### Offshore wind remains the main tool for power sector decarbonisation on the road to net zero emissions

Renewable capacity in the United Kingdom is expected to grow by almost 26 GW, or 50%, during 2021-2026 in the main case. Offshore wind accounts for more than half of all renewables growth, making the United Kingdom the second-largest global growth market for offshore wind after China. The forecast is one-third higher than last year due to accelerating deployment of projects awarded in contract for difference (CfD) auctions towards the end of forecast period and low additions in 2020. In 2019 the United Kingdom adopted a binding net zero GHG emissions target for 2050, with an interim target of a 78% emissions reduction compared to 1990 levels by 2035. Currently the renewables capacity target is specified only for offshore wind, with 40 GW planned to be installed by 2030, quadrupling the current installed capacity of 10 GW.

**Figure 1.32 United Kingdom renewable capacity additions, 2009-2026 (left), and CfD auction results (capacity and strike prices), 2021-2026 (right)**



Note: Acc. case = accelerated case, CfD = contract for difference.  
Source: (right) GOV.UK (2021), Contracts for Difference.

CfD auctions remain the main driver of growth, with almost 11 GW of renewable capacity awarded in three auction rounds conducted in 2015, 2017 and 2019, 10 GW of which was for offshore wind. The fourth CfD round is planned for Q4

2021, with a record 12 GW of total capacity, 5 GW of which is expected to be allocated to onshore wind and PV projects, leading to a rebound in their additions over 2023-2025.

Development of distributed PV is expected to remain limited due to relatively low financial incentives in the Smart Export Guarantee scheme introduced in 2020, replacing a FIT. The scheme mandates power suppliers to purchase exported electricity from systems with a capacity of up to 5 MW at retailer-set tariffs. Currently tariffs range from around 50% to 100% of average wholesale electricity prices (USD 40-70/MWh). Such remuneration levels limit the economic attractiveness of investment in distributed PV, as costs in the United Kingdom remain relatively high due to low average solar irradiation.

Corporate PPAs are expected to be an increasingly important driver of utility-scale PV and onshore wind growth, resulting in 0.3-0.5 GW of new capacity annually. Procuring renewable electricity directly allows companies to fulfil their emissions reduction goals and provides a hedge against volatile market prices.

In the accelerated case, renewables capacity growth in the United Kingdom during 2021-2026 is almost 20% higher than in the main case, with the main upside potential identified in onshore wind and utility-scale PV. The main challenges include long permitting processes and the lack of grid availability. Current rules for onshore wind require lengthy changes in local zoning plans, and in England individuals can easily block projects even if the majority of the local community backs them. For utility-scale PV, more financial support is required, as costs of generation are higher than for wind. Continued inclusion of PV in CfD auctions, as planned for the fourth round, will be a crucial enabler of faster growth. In addition, offshore wind projects would also benefit from a streamlined permitting schedule.

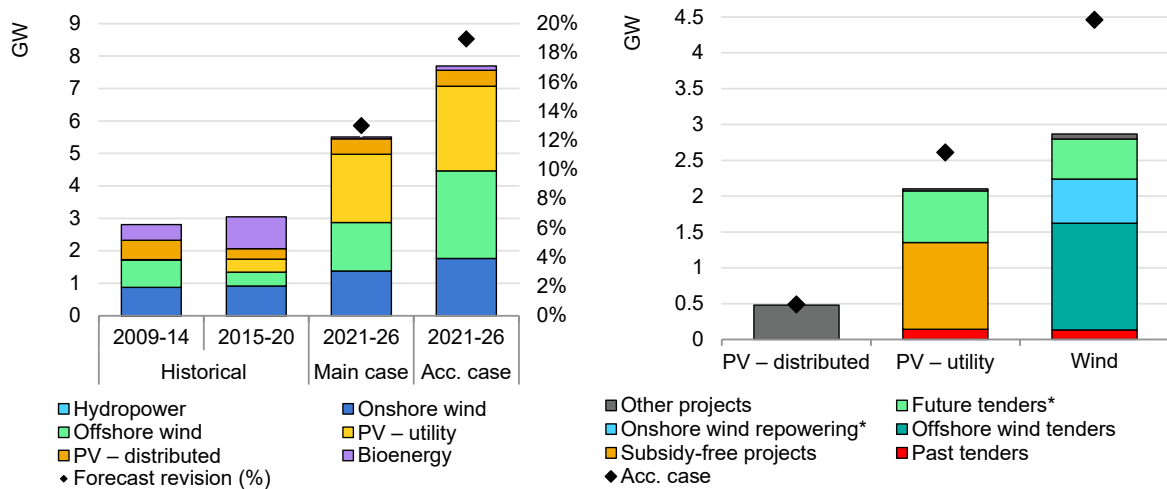
## Denmark

### Auctions and subsidy-free projects expand solar PV capacity, while wind still leads forecast growth

Denmark's renewable electricity capacity is expected to increase by 55% over 2021-2026 in the main case, led by wind and solar PV, with the rate of growth accelerating compared to the previous decade. We have revised Denmark's forecast up by 13% from last year, mainly driven by offshore wind auctions, future technology-neutral tenders and subsidy-free utility-scale solar PV projects.



**Figure 1.33 Denmark renewable capacity additions, 2009-2026 (left) and types of policy driver by technology, 2021-2026 (right)**



IEA. All rights reserved.

\* Future tenders and onshore wind repowering assumption.

Note: Acc. case = accelerated case.

Source: (right) ENERGINET (2021), Energi Data Service.

Three large offshore wind projects totalling 1.5 GW are expected to come online in the forecast period. The repowering of older turbines and greenfield projects through technology-neutral tenders are set to drive onshore wind expansion. In addition, our forecast expects the commissioning of utility-scale solar PV projects without subsidy through merchant revenues, bilateral contracts and PPAs. Distributed PV sees sustained growth through the use of real-time self-consumption models.

In the accelerated case, renewables growth could be 40% higher than in the main case, with offshore wind having the largest upside. Higher capacities in technology-neutral tenders, the faster commissioning of projects in the pipeline and additional plants delivering electricity for green hydrogen production could bring an additional 1.2 GW of offshore wind.

## Belgium

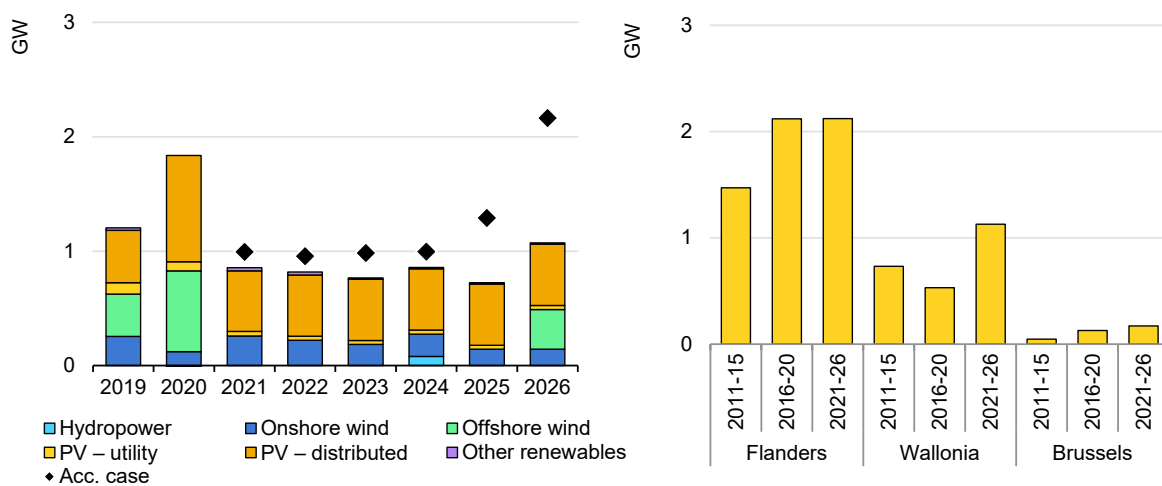
Annual additions slow after the deployment boom in 2019 and 2020, the next large-scale offshore wind project coming online in 2026, while lower remuneration hampers PV growth

Renewable electricity capacity in Belgium is expected to increase by 40% over 2021-2026 in the main case, with solar PV and wind together accounting for almost all of this growth. Four separate Green Certificate (GC) programmes – one



from the federal government covering only offshore wind and three regional government programmes – drive renewable expansion over the forecast period. In the federal scheme for offshore wind, the minimum guaranteed price for GCs varies depending on the wind farm and offshore domain concession. GC banding factors remain attractive for PV systems above 40 kW in the Flanders region, propelling growth of both commercial and utility-scale PV projects over the forecast period. For distributed solar PV, real-time self-consumption and incentives reducing investment costs (such as rebates) for the residential segment in the Flanders region drive capacity growth. However, this is hampered by a new policy introduced in 2021 reducing the remuneration for the residential sector, leading to a decline in PV additions. Following the commissioning of large-scale offshore wind projects in 2019 and 2020, our forecast expects no additions until 2026 when the federal government opens new offshore areas.

**Figure 1.34 Belgium renewable capacity additions, 2019-2026 (left) and historical and forecast solar PV additions by region, 2011-2026 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. Other renewables include bioenergy, CSP, geothermal and marine energy.

Sources: (right) Energie Commune, Flanders, Wallonie energie SPW (2021), Brugel.

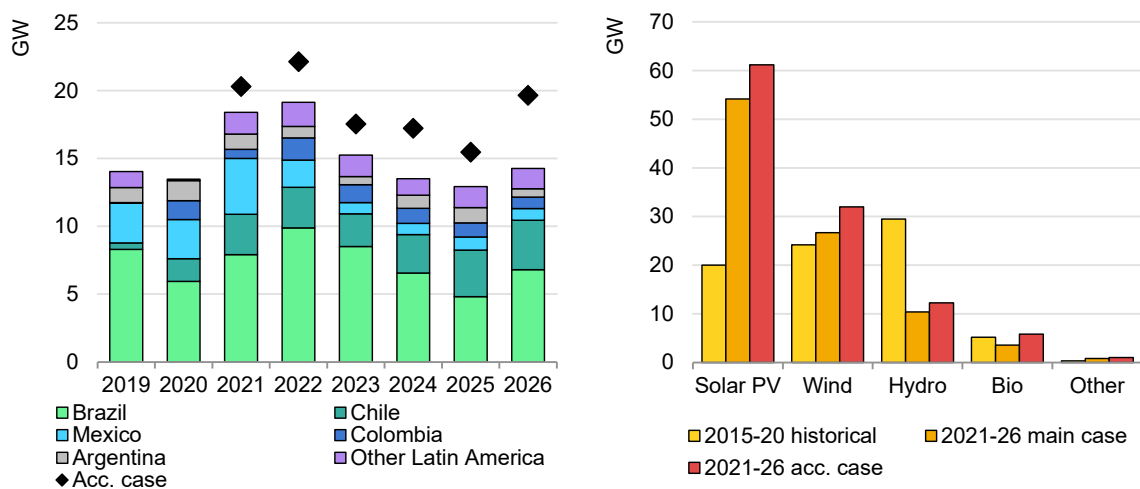
In the accelerated case, renewables growth could be 45% higher than in the main case. Distributed PV and offshore wind hold the largest upside potential. This case assumes that capital subsidies and incentives for reducing the investment costs of PV continue during the forecast period. In addition, the more rapid commissioning of new offshore wind projects leads Belgium to reach the 4 GW target by 2030, coming online in 2025 and 2026. There is further upside for utility-scale and commercial PV with the introduction of additional auctions in the Flanders region, following the allocation of 33 MW of solar PV in 2021. Finally, the

Belgian recovery and resilience plan investment sees an upside potential for new offshore wind projects via the “Energy Island” in 2026.

## Latin America

Renewable capacity in Latin America is expected to increase by 34%, or 96 GW, during 2021-2026 in the main case, as growth shifts from large-scale hydropower to solar PV. Variable renewables together account for 84% of the regional expansion. Brazil remains the largest market in Latin America; however, the country’s proposed remuneration reduction for distributed PV in 2023 slows the region’s overall annual additions. Although competitive auctions remain an important driver for utility-scale wind and solar PV development, their pace has slowed since 2018. As equipment prices fall, deployment outside government policy schemes is rising, especially in Brazil, Chile and Mexico. Policy and regulatory uncertainties remain critical challenges to growth in the region, while greater investment in transmission will also be required to avoid project delays caused by system constraints.

**Figure 1.35 Latin America capacity additions by country, 2019-2026 (left) and capacity additions by technology, 2015-2026 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

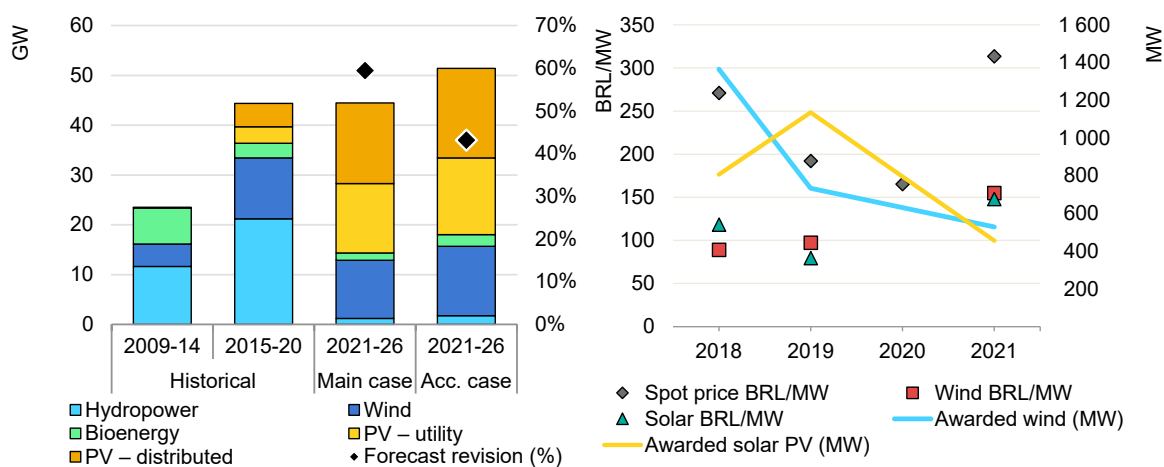
## Brazil

*Distributed PV and market activities outside government-led auctions are driving expansion*

In the main case, Brazil’s renewable capacity is expected to increase by almost 45 GW, or 30%, during 2021-2026, with solar PV and wind comprising almost 95%

of the anticipated additions. We have revised Brazil's forecast up by 60% from last year's market report. Power market reform and grid use tariff exemptions for renewables have led to increasing amounts of capacity being procured through the deregulated market via PPAs with utilities or businesses. Average spot market prices have exceeded awarded auction prices in the last three years, potentially indicating a better business case in the deregulated market. The growing share of free-market projects is supplemented by auction capacity and increasing amounts of distributed PV installations. New hydropower capacity makes up only 3% of all additions, a steep decline on previous years' additions, as developing the country's remaining large-scale hydropower potential remains difficult due to social acceptance and environmental challenges. Brazil announced two new revised targets at COP26. The first is a revised emissions reduction target of 50% by 2030 (up from 43%), while the second is a revised net zero target year of 2050, ten years earlier than the previous commitment. These revisions indicate policy momentum beyond the forecast period.

**Figure 1.36 Brazil renewable capacity additions, 2019-2026 (left) and awarded auction and spot market prices, 2018-2021 (right)**



IEA. All rights reserved.

Note: Brazil postponed auctions for new capacity in 2020, hence the missing data points on the right. Acc. case = accelerated case.

Sources: (right) ANEEL (2021a), Leiloes de energia da ANEEL e CCEE viabilizam R\$ 4 bi de investimentos em renovaveis; ANEEL (2021b), Leilao de Energia Nova A-5 atrai mais de R\$ 3 biloes em investimentos; CCEE (2021), Relatorios.

Solar PV expands by over 30 GW, representing nearly 70% of all additions in the main case, with the majority being distributed PV projects. A proposed change in net metering compensation (phasing down the value of surplus energy that can be offset against distribution, regulatory, and operation and maintenance tariffs) is anticipated to begin in 2023, leading to lower additions. Systems installed within 12 months of the new rules being passed will not be affected by the new structure;

thus the forecast anticipates a rush of new installations in 2022 should the new legislation be approved. Even with the change, the market is expected to average over 2 GW of additions per year from 2023 to 2026 thanks to lower costs.

The “free” (unregulated) market becomes a primary driver of growth for utility-scale PV and onshore wind. Uncertainties over future demand have resulted in lower government auction capacity, as decreased demand leads regulated utilities to procure less renewable capacity via auctions. Currently 85% of the pipeline of onshore wind and utility-scale solar PV projects is being developed outside the regulated market. However, approved changes to grid use tariffs, and higher commodity prices and fluctuating currency exchange rates remain key challenges to higher market growth for both technologies. Increasing solar PV and wind equipment prices were reflected in the latest auction round – they were one of the reasons that the awarded prices in 2021’s auctions were nearly twice as high as those awarded in 2019.

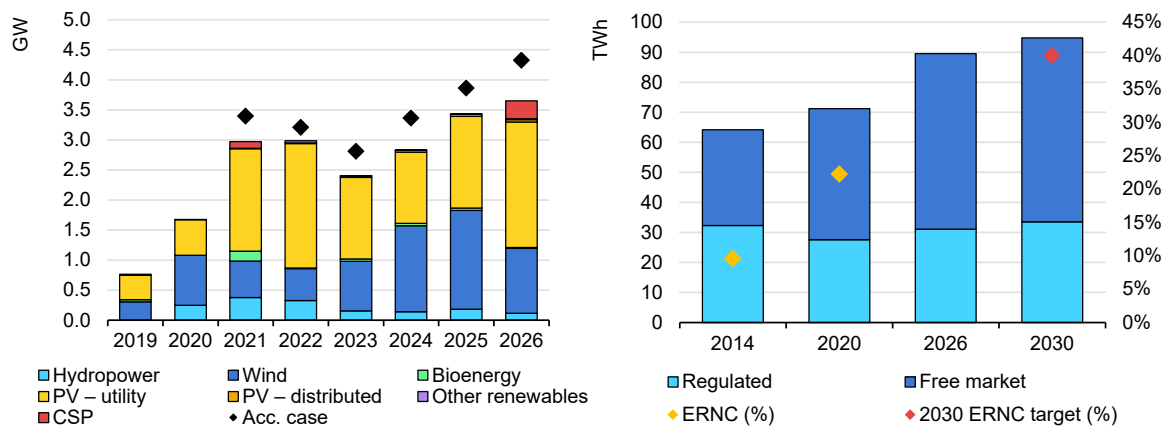
The accelerated case sees over 15% higher additions across all technologies. Lowering the demand threshold for participation in the deregulated market would lead to even higher shares of renewables signing contracts in the free market. In addition, faster recovery of electricity demand following the slowdown in economic activity due to the Covid-19 crisis, could lead to additional renewable capacity being procured via government-run and private auctions, and hence more rapid expansion of wind and solar PV. Finally, the prolonged drought affecting hydropower production could lead to a greater focus on non-hydro resources.

## Chile

### *Higher targets, competitive renewables and bilateral contracts lead to a raised forecast*

Chile’s renewable capacity is forecast to more than double in the main case, with the commissioning of 18 GW over 2021-2026. Utility-scale PV and onshore wind together account for almost 90% of this expansion. Our forecast is driven by the country’s new goal to increase the share of electricity generated by non-conventional renewables’ (ERNC) share in electricity generation from around 23% today to 40% in 2030. Auction schemes, competitive contracting in the deregulated power market and, most recently, the country’s hydrogen strategy are all expected to drive renewables expansion.

**Figure 1.37 Chile renewable capacity additions, 2019-2026 (left) and non-conventional renewable generation historical share and future target and demand by type (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case. ERNC = Non-conventional renewables which excludes large-scale hydropower.  
Source: Comisión Nacional de Energía (2021), Previsión de demanda eléctrica.

Auctions have historically driven utility-scale renewables expansion in Chile. Of the 4 GW contracted between 2015 and 2017, almost 40% became operational. After postponing the auction in 2020 due to the Covid-19 crisis and reducing the auction volume because of lower forecast demand, this year only 2.3 TWh were awarded to solar, wind and storage projects (against an original objective of around 9.3 TWh by 2027). With an estimated 700 MW of solar and 330 MW of wind, these projects should start delivering electricity to the grid no later than 2026. In this latest auction, the lowest bid was from a PV project, which submitted a price of USD 13.32 /MWh, setting the record as the lowest bid in Latin America.

Auctions are designed to supply regulated customers with loads under 2 MW, while non-regulated consumers above this demand threshold can procure electricity directly from the power market. Recent government forecasts indicate that non-regulated clients will account for almost all the expected demand growth in Chile. As a result, our forecast expects only 20% of solar and wind capacity to come from long-term electricity auctions (approximately 3.3 GW) and an additional 5.3 GW from special land auctions where the government allocates public land for renewable energy projects to address acquisition challenges, with the most recent awarding almost 2.8 GW in November (Ministerio de Bienes Nacionales, 2021). Another forecast driver for wind and solar PV is Chile's green hydrogen strategy, which estimates 5-8 GW of associated renewable capacity being developed by 2025 (Ministerio de Energía, 2020).

The first CSP project in Latin America, Cerro Dominador (110 MW), entered into operation this year, bringing with it 17.5 hours of storage and helping the grid integration of variable renewables. In addition, the Likana CSP project bid the lowest reported price worldwide (USD 34/MWh) in the recent government auction (SolarPaces, 2021).

The main barriers to renewables in the forecast are social acceptance of new plants and the availability of transmission and distribution capacity given the rapid increase in variable renewable generation. The expansion of renewable electricity generation technologies calls for a robust grid with good coverage. Slow transmission infrastructure expansion has caused project delays in the past and could slow the pace of expansion over the forecast period.

The accelerated case sees almost 15% higher additions over the forecast period thanks to the rapid increase of new renewable capacity associated with green hydrogen projects. It also sees greater growth in projects participating in the free market, and expects a faster resolution of transmission and distribution infrastructure bottlenecks.

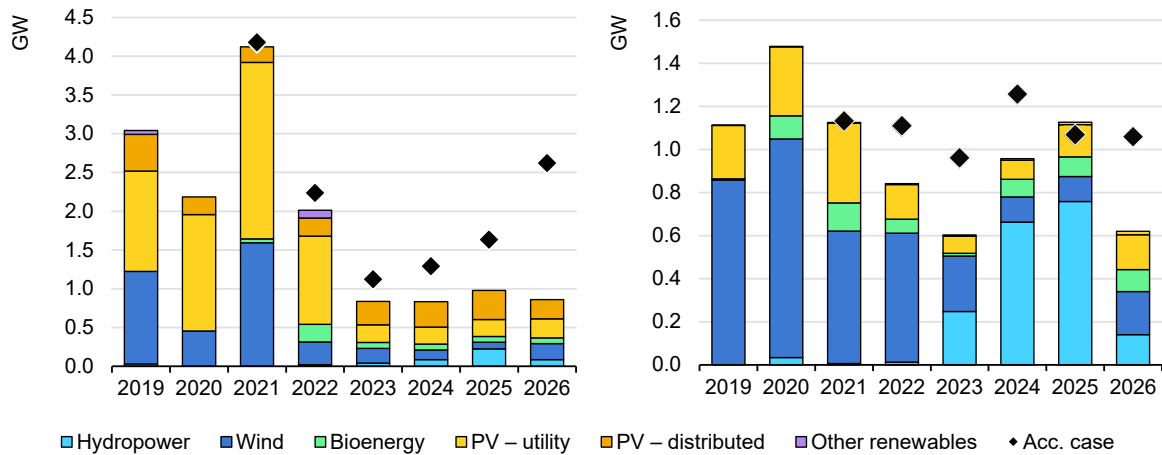
## Argentina and Mexico

### *Forecasts are revised downwards in both countries*

**Argentina's** renewable capacity in the main case is set to increase by 5 GW during the forecast period, equivalent to 32% growth. We have revised the forecast down by 6% from last year mainly due to the country's challenging economic environment. Hydropower dominates Argentina's expansion, with projects Jorge Cepernic, Presidente Nestor Kirchner and Brazo Aña Cuá beginning to come online in 2023, adding a combined 1.6 GW of capacity.

Long-term auctions (RenovAr) contracted 4.4 GW of wind and solar PV over the period 2016-19, driving recent renewable capacity expansion. However, the recent macroeconomic crisis and the pandemic have brought further financing challenges for renewables projects and delayed their commissioning. As a result, only a half of the wind and solar PV projects awarded in previous auctions were operational by mid-2021. In addition, almost a quarter of the auctioned projects missed their commissioning deadlines and were at risk of losing their power purchase contracts (Energía Estratégica, 2021). Following this development, the government has provided flexibility by extending the deadlines. Of the half of awarded projects yet to become operational, our forecast sees around 40% becoming operational, while the remainder are expected to be cancelled due to financing challenges.

**Figure 1.38 Mexico renewable capacity additions, 2019-2026 (left) and Argentina renewable capacity additions, 2019-2026 (right)**



IEA. All rights reserved.

Note: Acc. case = accelerated case.

The accelerated case sees almost 25% higher additions thanks to a rapid economic recovery leading to improved financing conditions, higher uptake of government extensions to commissioning deadlines for projects awarded in previous auctions, and the restart of auctions in an effort to reach the goal of 20% renewable generation by the end of 2025.

**Mexico's** renewable capacity is set to expand by over 9.5 GW during the forecast period in the main case, with utility-scale PV leading the expansion (4.3 GW), followed by wind (2.5 GW). However, the forecast is revised down compared to last year as a result of a changing policy environment. The cancellation of the green certificate auctions in 2018, proposed policies to change dispatch criteria in 2019 and uncertainty over the newly proposed electricity market rules and regulations in 2020 and 2021 have all reduced investor confidence.

Corporate PPAs, bilateral contracts and merchant activities outside government policy schemes are expected to drive 80% of the utility-scale wind and solar PV capacity growth in our forecast. Wind and PV projects offer competitive prices via bilateral contracts, meeting the increasing demand for commercial and industrial customers, which account for over 60% of total electricity demand in Mexico (Secretaria de Energía 2021). In addition, distributed PV capacity is expected to more than double during 2021-2026, driven by net metering and net billing, coupled with growing demand and rising electricity tariffs.

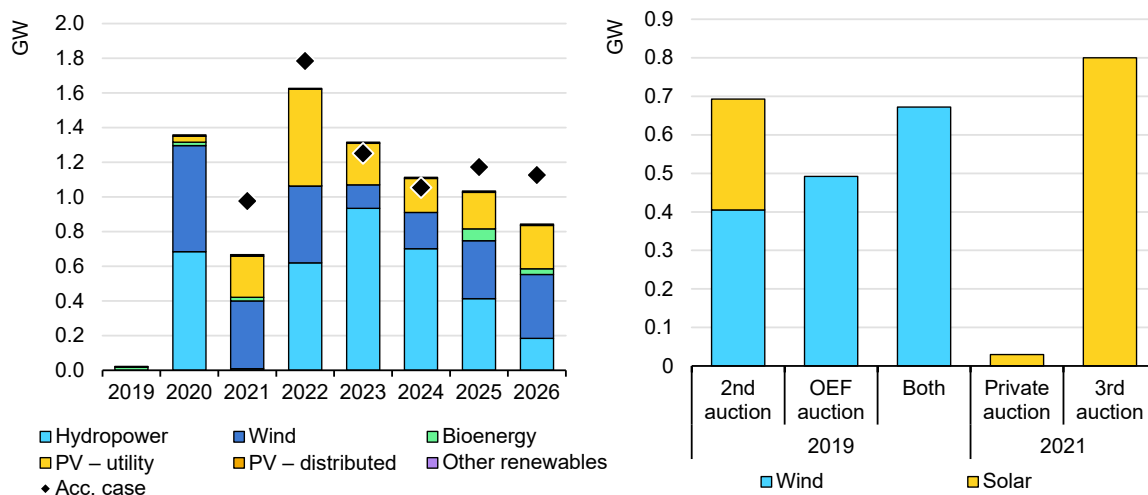
## Colombia

### *Government-led auctions drive development, but slow grid expansion poses challenges*

Colombia’s renewable capacity is forecast to expand by almost 50% (close to 7 GW) during 2021-2026 under the main case. This is primarily driven by competitive solar PV and wind auctions and the commissioning of the 2.4 GW Hidroitango hydropower project. Overall, renewables are expected to meet Colombia’s growing electricity demand, providing low prices. Wind and solar PV developers have secured almost 2.6 GW of capacity from energy, reliability and private auctions since 2019. The latest energy auction in October awarded almost 800 MW of solar capacity to deliver electricity by January 2023 (La Republica, 2021). In addition, three wind projects received contracts from the system operator in the reliability charge auction (OEF), a scheme to ensure electricity security, especially in times of drought.

For the later years of the forecast, we assume almost 1 GW of additional wind and utility-scale PV capacity, spurred by the continuation of the auction schemes. Considering its contracted projects and government plans, Colombia could reach its 2030 target of 4 GW of non-conventional renewable energy sources five year early.

**Figure 1.39 Colombia renewable capacity additions, 2019-2026 (left) and capacity awarded by auctions, 2019 and 2021 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. 2nd and 3rd auctions = the second and third of the government’s long-term energy auctions; Both includes the capacity of projects whose energy was committed in both auctions. Private auctions differ from long-term auctions primarily in that the PPAs can range from 5 to 25 years and the contracts can begin anytime between 2022 and 2025.

Source: BNamericas (2020).



However, transmission infrastructure construction delays due to Covid-19 in locations where major solar and wind projects are being developed remain a forecast uncertainty. Some projects are at risk of missing their commissioning deadlines. Insufficient port and road infrastructure has been an additional source of delays for new projects (BNAmericas, 2021).

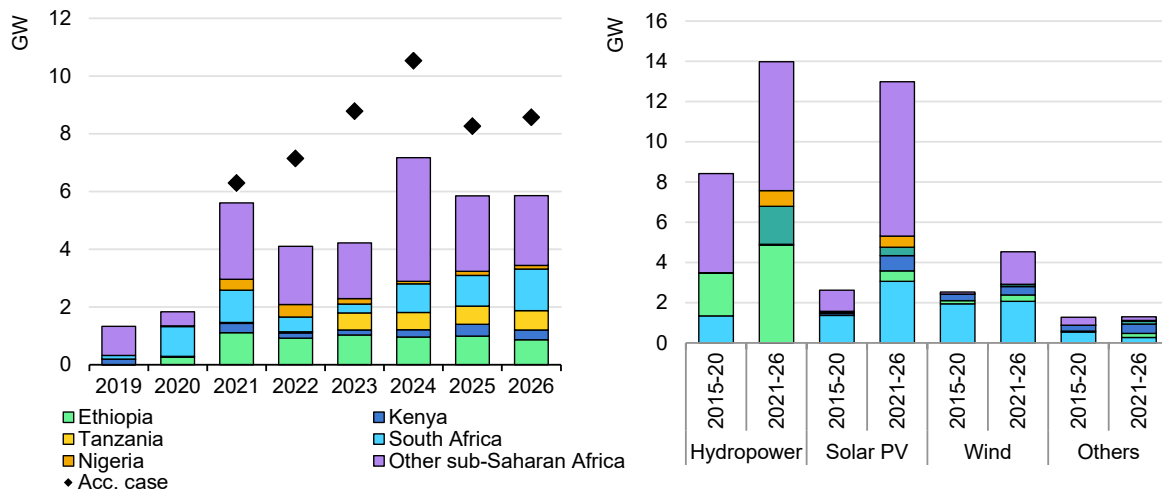
Renewable capacity growth could be 12% higher in the accelerated case from increased deployment outside auctions and higher capacities awarded in future government-led auctions. It assumes higher uptake of wind and solar capacity with the resolution of transmission infrastructure issues. Additionally, Colombia's goal to begin production of green hydrogen by 2030, which aims to have at least 1 GW of electrolysis installed, could spur additional development by the end of the forecast period.

## Sub-Saharan Africa

### Solar PV becomes an increasing driver of new capacity after large-scale hydropower, but the mismatch between policy and implementation prevents greater additions

Renewable capacity is expected to increase by 76%, or almost 33 GW, in sub-Saharan Africa from 2021 to 2026 in the main case, twice the amount of capacity additions in the preceding five-year period. Nearly half of the new additions are from large-scale reservoir hydropower projects, while solar PV and onshore wind represent the majority of the remaining growth over the forecast period. We have revised the forecast up by over 50% from last year due to large-scale hydropower projects receiving financing and meeting construction milestones, new auctions and tenders and new project announcements. Additions in the region rely heavily on government guarantees or backing from development banks. Ethiopia is expected to provide the largest growth in the region, followed by South Africa, Tanzania, Kenya and Nigeria.

**Figure 1.40 Sub-Saharan Africa renewable additions by country, 2019-2026 (left) and additions by technology and country, 2015-2026 (right)**



IEA. All rights reserved.

Notes: Acc. case = accelerated case. Others: Other renewable electricity technologies.

**South Africa** is forecast to add over 5 GW of capacity by the end of 2026, representing almost 30% of all non-hydropower capacity additions in the region. Annual additions in the country are expected to be stable in 2021 thanks to the commissioning of projects awarded in 2015 (REIPPP Round 4). However, growth is expected to slow for the next two years, before accelerating in 2024. The financial situation of the government utility (Eskom) and system constraints remain key barriers to higher growth as available funds are being allocated for upgrades and maintenance of the existing network, not for grid expansion, exacerbating low network availability (Eskom, 2021). Policy decisions facilitating public and private procurement drive the additions between 2021 and 2026. Utility-scale wind and solar PV additions are enabled by government auctions and municipal procurement. Increased commercial-scale PV capacity is expected to result from the lift on the licensing cap for embedded generation and tenders from private firms. At COP26, the South African government announced a revised nationally determined contribution to boost renewables by repurposing coal plants due for decommissioning within the next 15 years. It is supported by USD 8.5 billion of international concessional financing to be allocated over the next three to five years (Sunday Times, 2021).

**Kenya's** renewable capacity expands by over 75%, adding over 1.7 GW from 2021 to 2026. Capacity additions are enabled by long-term PPAs signed via the national FIT policy, with nearly 1.2 GW of combined wind and solar PV. The forecast is revised down slightly from last year due to the cancellation of previously announced projects. Low investor confidence is a barrier to greater additions in

Kenya. PPA renegotiations and long interconnection periods have extended project timelines. In addition, land acquisition, compensation and resettlement remain a challenge, a process that has previously prevented projects from being realised.

**Ethiopia's** renewable capacity more than doubles by 2026, with the country adding nearly 6 GW of new capacity. The Grand Ethiopian Renaissance Dam and the Genale-Dawa IV hydropower plants make up over 80% of the capacity additions. Foreign investment, tenders and bilateral PPAs with the government utility Ethiopian Electric Power Company have driven capacity additions previously and continue in the forecast period. Auctions held in 2019 and private investment are expected to drive solar PV additions, while international concessional financing helps drive wind development, with two major projects being funded in part by China and Denmark. However, tenders for additional wind or solar PV capacity have currently not been scheduled. Challenges to further development include land and physical grid infrastructure and access, while political concerns are also a risk, impacting areas for planned development.

**Nigeria** adds over 1 GW of new capacity through a combination of hydropower and solar PV plants. Government policies have placed an emphasis on developing connected mini-grids for schools and universities, while also prioritising the development of rural off-grid PV as part of the economic recovery from Covid-19. Utility-scale solar PV is enabled through private investment via public-private partnerships and PPAs with utilities, representing over 30% of the forecast. However, further development is hindered by policy uncertainties, as previously awarded PPAs were subsequently renegotiated, leading to numerous projects not being realised.

**Tanzania's** renewable capacity expands by over 2.5 GW, led by the commissioning of the 2.1 GW Julius Nyerere hydropower plant. New solar additions are aided by concessional financing and building developments along existing transmission infrastructure, easing connection concerns. New regulations enable independent power producers to sign PPAs in areas currently not served by the national grid, driving new off-grid capacity through the forecast period. After welcoming its first wind farm in 2020, Tanzania adds 100 MW of new wind capacity in the forecast period, enabled through negotiation with the government on land rights and power offtake. Policy uncertainty and infrastructure present challenges to growth. Previously announced auctions were cancelled and the majority of the country lacks access to the national grid.

West African nations, such as **Cote d'Ivoire**, **Senegal** and **Togo** install increasing amounts of solar PV and wind, with major developments backed by multilateral development banks.

Sub-Saharan Africa has tremendous solar PV and wind potential, in addition to vast hydropower resources. The accelerated case sees over 50% greater additions if stated government plans for new capacity are realised. In order to achieve this, governments must provide firm and transparent policies for project timelines, remuneration and land rights, while also investing in transmission infrastructure. Entering into more partnerships with development banks and private entities could increase investment in the region, helping address concerns associated with capital availability and offtaker risk. Further investment in off-grid solar PV through government programmes or from private firms would alleviate concerns over infrastructure availability while also increasing electrification rates.

## Middle East and North Africa

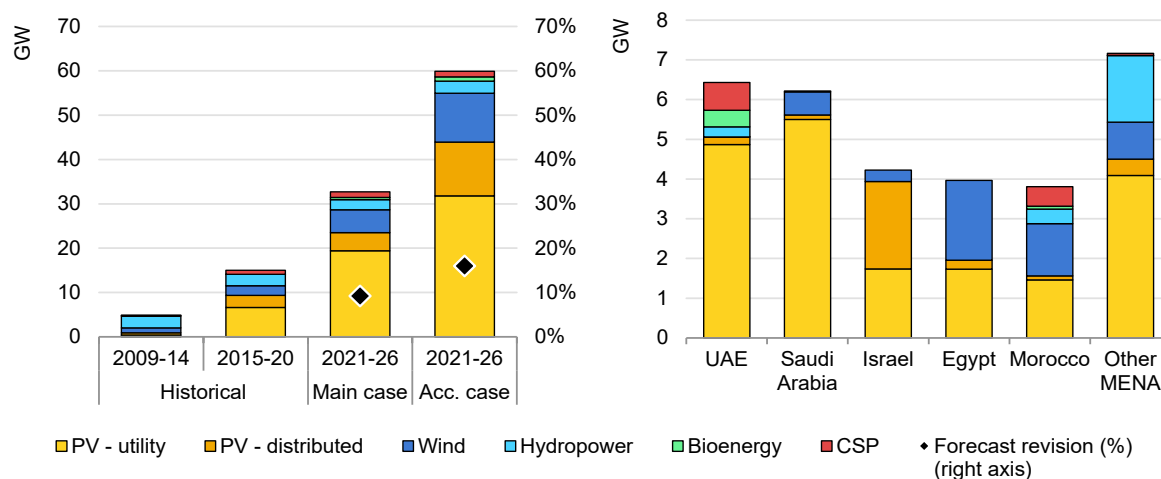
### Solar PV's competitiveness drives renewables expansion, but the pace is challenged by slower electricity demand and insufficient grid infrastructure

The pace of renewable capacity growth in the Middle East and North Africa (MENA) in the main case is expected to double over the next five years, compared to the last five years, from 15 GW to over 32 GW. More than three-quarters of the capacity expansion is concentrated in five countries: the United Arab Emirates, Saudi Arabia, Israel, Egypt and Morocco. One common driver is the cost-effectiveness of solar PV to meet climate goals and fossil fuel diversification needs. Solar PV accounts for more than two-thirds of the region's renewable capacity growth.

The share of MENA's solar PV growth taking place in net fossil fuel exporting countries is expected to increase from 40% over the previous five years to 67% over 2021-2026. The main reasons for this are the cost reductions achieved by competitive independent power producer auctions, in which awarded bid prices have fallen from USD 56/MWh in 2015 to USD 10.4/MWh in 2021. This trend can be attributed to falling system costs, good resource potential, favourable financing conditions and economies of scale. Awarded projects over the last year ranged from 600 MW in Qatar to 1.5 GW in Abu Dhabi. However, utilities' attempt to replicate or achieve lower prices may prolong contract negotiations and slow the pace of expansion (MEES, 2020). These bid prices depend on country-specific

conditions that may not be available in other markets, such as beneficial land costs and access to low-cost state-supported financing.

**Figure 1.41 MENA renewable capacity growth by technology, 2009-2026 (left) and by country, 2021-2026 (right)**



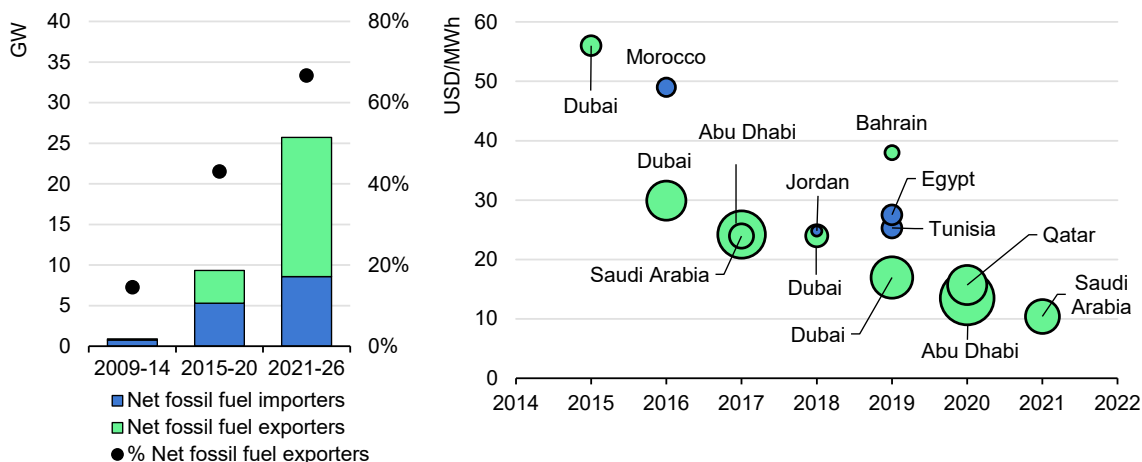
IEA. All rights reserved.

Note: Acc. case = accelerated case; UAE = United Arab Emirates; MENA = Middle East and North Africa.

There are two main challenges to faster growth in the region. The first is insufficient grid infrastructure to connect renewable plants and evacuate the power to demand centres. In Jordan and Tunisia auction plans have slowed, awaiting grid upgrades, while more rapid growth in distributed PV in Israel also requires an increase in distribution network capacity. Another emerging challenge in some countries in the region is the mismatch between supply and demand, with many countries having an overcapacity of supply due to slower demand growth following the Covid-19 crisis.

Renewable capacity in the **United Arab Emirates** is expected to increase by over 6 GW, led by solar PV and followed by CSP, bioenergy and hydropower. The forecast is slightly higher compared to last year due to higher than expected PV capacity awarded in the latest independent power producer auction, new government-owned PV projects at data centres and landfills, and progress in the development of waste-to-energy projects. The independent power producer competitive auctions remain a key policy driver for utility-scale PV growth; however, the implementation pace is uncertain. Slower than expected power demand and overcapacity are raising concerns over the timeline for future auctions. In addition, regulatory changes pose a downside risk to the distributed PV forecast. In 2020 the Dubai government capped the system size eligible for net metering at 2 MW and barred ground-mounted systems.

**Figure 1.42 MENA solar PV growth, 2009-2026 (left) and awarded bid prices, 2014-2022 (right)**



IEA. All rights reserved.

Notes: Net fossil fuel importers and exporters according to net trade in 2019. Bubble size = auction capacity.

Source: IEA (2021c), World Energy Statistics, [www.iea.org/statistics/](http://www.iea.org/statistics/).

**Saudi Arabia’s** renewable capacity is set to grow by over 6 GW, driven by renewable energy targets to diversify the power generation mix away from oil. More than 80% of the growth is from utility-scale solar PV via two procurement methods: competitive auctions for independent power producers, and unsolicited bilateral contracts with the utility. However, limited visibility over auction timelines and lengthy tender and contractual processes pose a risk to the pace of development.

**Israel’s**<sup>1</sup> renewable capacity is expected to more than double over the period 2021-2026 from the addition of 5.2 GW. More than half of the growth is from distributed PV, driven by a supportive policy framework comprising FITs, net metering, self-consumption with remuneration for excess generation, and competitive auctions. The forecast is more optimistic than last year due to an increase in 2030 targets for the share of renewables (up from 17% to 30%) and additional support for solar PV. In April 2020 the government earmarked ILS 6.5 billion (USD 2.1 billion) of Covid-19 stimulus to help deploy 2 GW of solar PV and introduced low-interest loans and FITs for systems installed on public buildings. Nonetheless, insufficient grid infrastructure may slow the growth of distributed PV, while land availability is a key challenge for utility-scale PV.

<sup>1</sup> The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

**Egypt's** renewable capacity is expected to increase by 68% (4 GW), led by onshore wind, followed by solar PV. The majority of the growth comes from unsolicited bilateral contracts with the state-owned utility. Recent developments under this scheme have increased the renewable capacity of planned projects. For instance, one developer received approval to increase their planned solar PV plant size from 200 MW to 500 MW and another will switch plans to build a 2.3 GW gas plant to 1.1 GW of wind. However, overcapacity and lower power demand due to Covid-19 have raised questions over the pace of plans for renewables under the other procurement policies. Last year, the government cancelled an independent power producer auction for 200 MW of solar PV and put caps on the amount of capacity eligible for net metering, a main driver of corporate procurement.

**Morocco's** renewable capacity is forecast to double during 2021-2026 with the addition of 3.8 GW, led by utility-scale solar PV, onshore wind, CSP and hydropower. The main drivers for growth are long-term renewable energy targets supported by competitive auctions for solar and wind, and having them managed by a dedicated institution (MASEN). In addition, an enabling regulatory environment that permits bilateral sales between large electricity consumers and self-consumption projects connected to transmission lines also supports new wind projects. However, a similar regulatory framework for the distributed grid is lacking implementation, which hampers faster PV growth in the commercial and residential segments.

In the accelerated case, MENA's renewable capacity expansion could be almost twice as high (57 GW) on the assumption that several challenges are addressed. More frequent auction rounds and more rapid bidder selection and contractual negotiations would accelerate utility-scale deployment. Regulatory frameworks that permit corporate PPAs, bilateral contracts and self-consumption could open up the potential for private investment outside auctions and having cost-reflective end-user tariffs could make the business case for such investment. Investment in grid upgrades would permit faster connection of planned projects and building interconnections would open up new demand markets.

## References

- AEMO (Australian Energy Market Operator) (2021), Statistical reporting streams. <https://aemo.com.au/energy-systems/electricity/national-electricity-marketnem/system-operations/congestion-information-resource/statistical-reporting-streams>. (accessed October 2021).
- ANEEL (Agencia Nacional de Energia Electrica) (2021a), Leiloes de energia da ANEEL e CCEE viabilizam R\$ 4 bi de investimentos em renovaveis, (accessed August 2021).

- ANEEL (Agencia Nacional de Energia Electrica) (2021b), Leiao de Energia Nova A-5 atraí mais de R\$ 3 bilhões em investimentos (accessed October 2021).
- Australian Government (2021). Australia's Long-term Emissions Reduction Plan. (accessed November 2021).
- BNamericas (2021), Concern mounts over Colombia power project delays <https://app.bnamericas.com/article/section/all/content/xiou9eovb-concerns-mounts-over-colombia-power-project-delays> (accessed September 2021).
- BNamericas (2020), The details behind Colombia's first private renewable energy auction <https://app.bnamericas.com/article/section/all/content/xoihlzql4-the-details-behind-colombias-first-private-renewable-energy-auction> (accessed September 2021).
- BNEF *Global Corporate PPA database* (2021a) (accessed November 2021).
- BNEF (Bloomberg New Energy Finance), 3Q (2021b), Global Auction and Tender Calendar and Results (accessed August 2021).
- BNEF *US PPA and Offtake Pricing database* (2021c) (accessed November 2021).
- Bridge to India, India RE Navigator, <https://india-re-navigator.com/utility> (accessed September 2021).
- Brugel (Brussels regulatory authority), <https://www.brugel.brussels/themes/energies-renouvelables-11> (accessed September 2021).
- Bundesnetzagentur (Germany's Federal Network Agency) (2021) [https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen\\_Institutionen/Ausschreibungen/Wind\\_Onshore/BeendeteAusschreibungen/BeendeteAusschreibungen\\_node.html](https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/Ausschreibungen/Wind_Onshore/BeendeteAusschreibungen/BeendeteAusschreibungen_node.html) (accessed September 2021).
- Bundesnetzagentur (Germany's Federal Network Agency) (2020), Netz- und Systemsicherheit [https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Berichte/2020/Quartalszahlen\\_Gesamtjahr\\_2020.pdf?\\_\\_blob=publicationFile&v=3](https://www.bundesnetzagentur.de/SharedDocs/Mediathek/Berichte/2020/Quartalszahlen_Gesamtjahr_2020.pdf?__blob=publicationFile&v=3) (accessed September 2021).
- CCEE (Camara de Comercializacao de Energia Electrica) (2021), Relatorios (accessed November 2021).
- CESA (Clean Energy States Alliance) (2021) <https://www.cesa.org/projects/100-clean-energy-collaborative/guide/table-of-100-clean-energy-states/> (accessed October 2021).
- China Energy Portal (2021), 2020 wind power installations and production by province [http://www.nea.gov.cn/2021-07/29/c\\_1310093667.htm](http://www.nea.gov.cn/2021-07/29/c_1310093667.htm) (accessed October 2021).
- Comisión Nacional de Energía, Previsión de demanda eléctrica, <https://www.cne.cl/en/tarificacion/electrica/prevision-de-demanda-electrica/>, (accessed September 2021).
- EIA (2021a), *Annual Energy Outlook 2021* (accessed September 2021).
- Energi Data Service <https://www.energidataservice.dk/collections/production-and-consumption>, (accessed September 2021).
- Energía Estratégica (2021) <https://www.energiaestrategica.com/por-carta-cammesa-pidio-a-martinez-resolver-contratos-pendientes-de-energias-renovables/>, (accessed September 2021).
- Energie Commune, <https://energiecommune.be/statistique/observatoire-photovoltaique/> (accessed September 2021).
- ENERGINET, <https://en.energinet.dk> (accessed September 2021).



- Eskom (2021), Transmission Generation Connection Capacity Assessment of the 2023 Transmission Network (GCCA – 2023) (accessed September 2021).
- Flanders, <https://www.vlaanderen.be>, <https://www.energiesparen.be/energiekaart/cijfers> (accessed September 2021).
- France Territoire Solaire (2021), Le parcours du combattant – développer un projet de centrale solaire au sol en France, <https://www.actu-environnement.com/media/pdf/news-37481-etude-france-territoire-solaire.pdf> (accessed November 2021).
- GOV.UK (2021), Contracts for Difference, <https://www.gov.uk/government/publications/contracts-for-difference/contract-for-difference> (accessed September 2021).
- GSE (Gestore Servizi Energetici) (2021), <https://www.gse.it/servizi-per-te/fonti-rinnovabili/fer-elettriche/graduatorie>, (accessed September 2021).
- GSE (Gestore dei Servizi Energetico) (2020), Rapporto delle attività 2020, GSE. [https://www.gse.it/documenti\\_site/Documenti%20GSE/Rapporti%20delle%20attivit%C3%A0/RA%202020.pdf](https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20delle%20attivit%C3%A0/RA%202020.pdf) (accessed September 2021).
- IEA (2020a), Korea 2020 Energy Policy Review, Paris. <https://www.iea.org/reports/korea-2020> (accessed September 2021).
- IEA (2020b), The Netherlands 2020 Energy Policy Review, Paris. <https://www.iea.org/reports/the-netherlands-2020> (accessed September 2021).
- IEA (2021a), Net-Zero by 2050 – A Roadmap for the Global Energy Sector, <https://www.iea.org/reports/net-zero-by-2050> (accessed October 2021).
- IEA (2021b), World Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2021> (accessed September 2021).
- IEA (2021c), World Energy Statistics and Balances 2021 (database) (accessed October 2021).
- IESO (Independent Electricity System Operator) (2020), 2020 year in review. <https://www.ieso.ca/en/Corporate-IESO/Media/Year-End-Data>. (accessed October 2021).
- KNREC (Korean New & Renewable Energy Center) (2021), Fixed price contract competitive bid selection status, [https://www.knrec.or.kr/business/rps\\_bidding.aspx](https://www.knrec.or.kr/business/rps_bidding.aspx) (accessed September 2021).
- KPX (Korean Power Exchange) (2021a), Weighted Average SMP (system marginal price) <http://epsis.kpx.or.kr/epsisnew/selectEkmaSmpSmpGrid.do?menuId=040201&locale=eng> (accessed September 2021).
- KPX (Korean Power Exchange) (2021b), Power market and electricity <https://www.kpx.or.kr/www/selectBbsNttList.do?key=19&bbsNo=136&searchCtgr=&pageUnit=10&searchCnd=all&searchKwd=&integrDeptCode=&pageIndex=1> (accessed November 2021).
- La Republica (2021), Ganadores de subasta de las energías renovables adquirieron obligación de 796,3 MW, Colombia, <https://www.larepublica.co/economia/ganadores-de-subasta-de-energia-renovables-adquirieron-obligacion-de-800-mw-3253267> (accessed September 2021).
- LBNL (Lawrence Berkeley National Laboratory) (2021a), Land-Based Wind Market Report, Berkeley, CA, (accessed September 2021).

- LBNL (Lawrence Berkeley National Laboratory) (2021b), Tracking the Sun, Berkeley, CA (accessed September 2021).
- LBNL (2021c) *Land-Based Wind Market Report* (accessed September 2021).
- MEES Middle East Petroleum and Economic Publication (2021), Volume 63. No. 41 - 09 Oct 2020. Publisher: Cyprus. (accessed September 2021).
- METI (Japan's Ministry of Economy, Trade and Industry) (2021a), Cabinet Decision on the Sixth Strategic Energy Plan. [https://www.meti.go.jp/english/press/2021/1022\\_002.html](https://www.meti.go.jp/english/press/2021/1022_002.html) (accessed October 2021).
- METI (2021b), Energy supply and demand in FY2019 [https://www.enecho.meti.go.jp/statistics/total\\_energy/pdf/gaiyou2019fyr.pdf](https://www.enecho.meti.go.jp/statistics/total_energy/pdf/gaiyou2019fyr.pdf) (accessed September 2021).
- METI (2021c), Renewable energy statistics in the FIT scheme, [www.fit-portal.go.jp/PublicInfoSummary](http://www.fit-portal.go.jp/PublicInfoSummary) (accessed September 2021).
- METI (2021d), FIP starts in April 2022 toward making renewables a main energy source in Japan <https://www.enecho.meti.go.jp/about/special/johoteikyo/fip.html>, (accessed September 2021).
- Ministerio de Energía (2020), National Green Hydrogen strategy [https://energia.gob.cl/sites/default/files/national\\_green\\_hydrogen\\_strategy\\_-\\_chile.pdf](https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf) (accessed September 2021).
- Ministerio de Bienes, Bienes Nacionales anuncia el mayor impulso de la década a las energías renovables, <https://www.bienesnacionales.cl/?p=40925> (accessed November 2021).
- PRAAPTI, Payment Ratification And Analysis in Power procurement for bringing Transparency in Invoicing of generators, <https://praapti.in/#> (accessed September 2021).
- REE (Red Eléctrica de España) (2021a), El sistema eléctrico español síntesis <https://www.ree.es/es/datos/publicaciones/informe-anual-sistema/informe-del-sistema-electrico-espanol-2020> (accessed September 2021).
- REE (Red eléctrica de España) (2021b) <https://www.ree.es/es/clientes/datos-acumulados-generacion-renovable> (accessed October 2021).
- REF (Renewable Energy Foundation) (2020), Balancing Mechanism Wind Farm Constraint Payments. <https://www.ref.org.uk/constraints/indextotals.php>. (accessed September 2021).
- RVO (Rikksdienst voor Ondernemend Nederland) (2020) Verplichtingen SDE per technologie (<https://www.rvo.nl/subsidie-en-financieringswijzer/sde/feiten-en-cijfers-sde-algemeen>) (accessed September 2020).
- Secretaria de Energía (2021), PRODESEN [https://www.gob.mx/cms/uploads/attachment/file/649612/PRODESEN\\_CAP\\_TULO-4.pdf](https://www.gob.mx/cms/uploads/attachment/file/649612/PRODESEN_CAP_TULO-4.pdf) (accessed September 2021).
- SEIA (Solar Energy Industries Association) and Wood Mackenzie, US Solar Market Insight Executive Summary, Q32021 <https://www.seia.org/research-resources/solar-market-insight-report-2021-q3> (accessed October 2021).
- SolarPaces (2021), Why Likana's 24-Hour Solar Bid under \$34/MWh Lost in Chile, <https://www.solarpaces.org/likanas-24-hour-solar-under-34-mwh-lost-chile-bid/> (accessed October 2021).

Sunday Times (2021). Cyril Ramaphosa secures 'historic' COP26 green financing deal (<https://www.timeslive.co.za/politics/2021-11-02-cyril-ramaphosa-secures-historic-cop26-green-finance-deal/>). (accessed November 2021).

TenneT (2021). TenneT expects structural congestion, as referred to in Article 9.5 of the Electricity Grid Code, in the 150kV grid in Flevoland and Gelderland during the period 2021-2029. <https://www.tennet.eu/news/detail/tennet-expects-structural-congestion-as-referred-to-in-article-95-of-the-electricity-grid-code-in/> (accessed September 2021).

Urząd Regulacji Energetyki (2021) <https://www.ure.gov.pl/pl/oze/aukcje-oze/ogloszenia-i-wyniki-auk> (accessed September 2021).

Wallonie energie SPW , <https://energie.wallonie.be> (accessed September 2021).

# Chapter 2. Biofuels

## Forecast summary

Global demand for biofuels is set to grow by 41 billion litres, or 28%, over 2021-2026 in the main case. The recovery to pre-Covid-19 demand levels accounts for one-fifth of this demand growth. Government policies are the principal driver of the remaining expansion, but other factors such as overall transport fuel demand, costs and specific policy design influence where growth occurs and which fuels grow quickest. The combination of these influences pushes Asian biofuel production past that of Europe during the forecast period. Policies in the United States and Europe help demand for renewable diesel (also known as hydrogenated vegetable oil [HVO] in Europe) to nearly triple.<sup>1</sup> The factors influencing biofuel demand are all subject to uncertainty. For example, some governments have responded to the current high price of feedstock by relaxing or delaying biofuel blending mandates, with the effect of reducing demand. However, over the medium term, major policy discussions in the United States, Europe, India and People's Republic of China (hereafter 'China') hold the promise of a more than doubling of biofuel demand growth in the accelerated case.

### Biofuels recover in 2021 despite high costs

Rising prices are slowing biofuels' growth, but according to our forecast, demand in 2021 nevertheless recovers from the lows seen in 2020 during the Covid-19 crisis. Brazil, Argentina, Colombia and Indonesia are managing climbing feedstock and biofuel costs by temporarily reducing or delaying blending mandates. We estimate these actions to reduce demand by 3%, or 5 billion litres, in 2021 compared to a scenario where mandates remained unchanged or were increased as planned. By August 2021 biofuel prices had increased by between 70% and 150% across the United States, Europe, Brazil and Indonesia,<sup>2</sup> depending on the market and fuel, from average 2019 prices (see Chapter 4 for more details). For comparison, crude oil prices increased by 40% over the same time period.

While overall biofuel demand returns to 2019 levels this year even with slower growth, the recovery is uneven. Ethanol demand remains 4% below 2019 levels

---

<sup>1</sup> Biodiesel, also called fatty acid methyl ester (FAME), and renewable diesel, also known as hydrogenated vegetable oil (HVO), can both be blended with diesel fuel. Renewable diesel has the same chemical composition as fossil diesel and so is fully compatible with existing diesel engines. Biodiesel has a different chemical composition to fossil diesel and so blending is limited. Europe, for example, limits blends to 7%.

<sup>2</sup> Based on US ethanol, Brazilian ethanol and biodiesel, Indonesian biodiesel and EU biodiesel. EU ethanol in August 2021 averaged 7% higher than average 2019 values, but has since climbed to a 33% increase (IHS Markits, 2021a).

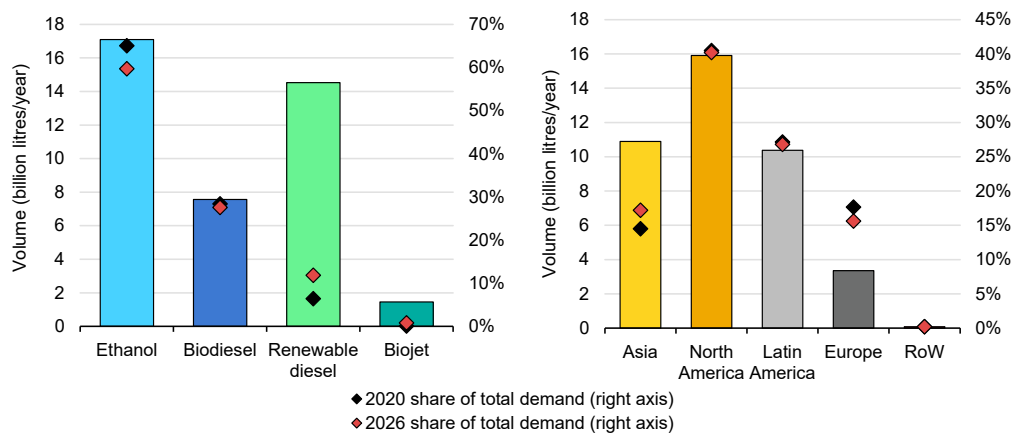
in 2021 and does not fully recover until 2023. High ethanol prices in Brazil and lower gasoline demand in the United States relative to 2019 levels are both driving lower ethanol volumes in 2021. By 2023 US and European gasoline demand has recovered from Covid-19 disruption, but remains well below 2019 levels (IEA, 2021c). Increasing energy efficiency, surging electric vehicle sales and behaviour change all contribute to lower demand. Lower gasoline demand reduces ethanol volumes under current policies. However, ethanol demand recovery in Brazil and growing demand in Asia eventually offset declines in the United States and Europe in 2023.

By comparison, in 2021 biodiesel, renewable diesel and biojet, expand well beyond 2019 levels, albeit from a low base for biojet. The combined demand for these fuels in 2021 is up 15%, or 7 billion litres, from 2019 levels. Renewable diesel demand in the United States and Asian biodiesel demand are responsible for the majority of this growth.

## Asia to surpass European biofuel production before 2026

Asia surpasses total European biofuel production in the forecast period thanks to strong domestic policies, growing liquid fuel demand and export-driven production. Asian countries account for nearly one-third of new production over the forecast period. Blending targets for biodiesel in Indonesia and Malaysia and India's ethanol policies are responsible for most of this growth. North American biofuel demand grows the most by 2026; however, 40% of this growth is demand recovery following Covid-19 declines. The United States and Brazil remain the largest centres for both biofuel demand and production.

**Figure 2.1 Biofuel demand growth and share of total demand by fuel (left) and region (right), main case, 2021-2026**



IEA. All rights reserved.

Sources: Argus Direct (2021a), CNMC (2021), CSET (2021), Department of Agriculture (2021), EIA (2021b), EIA (2020), EPA (2021), IEA (2021d), IHS Markits (2021a), Ministère de la Transition Écologique (2020), Ministério de Mins e Energia (2021), Statistics Canada (2021)

## Ethanol and renewable diesel lead biofuels growth

Renewable diesel demand nearly triples between 2020 and 2026, primarily thanks to policies in the United States and Europe. However, in absolute volume, ethanol demand growth surpasses that of renewable diesel. The majority of renewable diesel growth is concentrated in the United States and Europe. In both regions renewable diesel competes well in a policy environment that values GHG reductions and places limits on some biofuel feedstocks, as it can be produced with a low GHG intensity using wastes and residues. It has a further benefit in that it can be blended at higher levels than biodiesel.

Ethanol and biodiesel growth remains robust, however, thanks to demand in Latin America and Asia, and recovery from Covid-19 declines. In Asia, India's efforts to reach 20% ethanol blending by 2025 support global ethanol demand growth, while Indonesia's 40% blending mandate planned for 2022 stimulates biodiesel expansion. In both countries, growing transport fuel demand over the forecast period, in combination with mandates, accelerates biofuel demand. Similarly, in Latin America, Brazil's biofuel policies combined with growing gasoline and diesel demand drive up biofuel use.

## Four policy discussions to watch that will help double biofuel growth rates

The outcomes of policy discussions in the **United States, Europe, India** and **China** will have a profound impact on biofuel prospects over the next five years. Overall biofuel demand growth could more than double to near 9% a year in the accelerated case. If implemented, policies under discussion in these countries would account for two-thirds of this growth. In this case, Asia accounts for the largest upside and surpasses Brazil to become the second-largest biofuel producer globally. Biojet demand also expands considerably, growing by almost 6 billion litres by 2026, higher than the demand growth for renewable diesel over the last five years (see Chapter 4 for a full analysis of biojet's potential over the next five years).

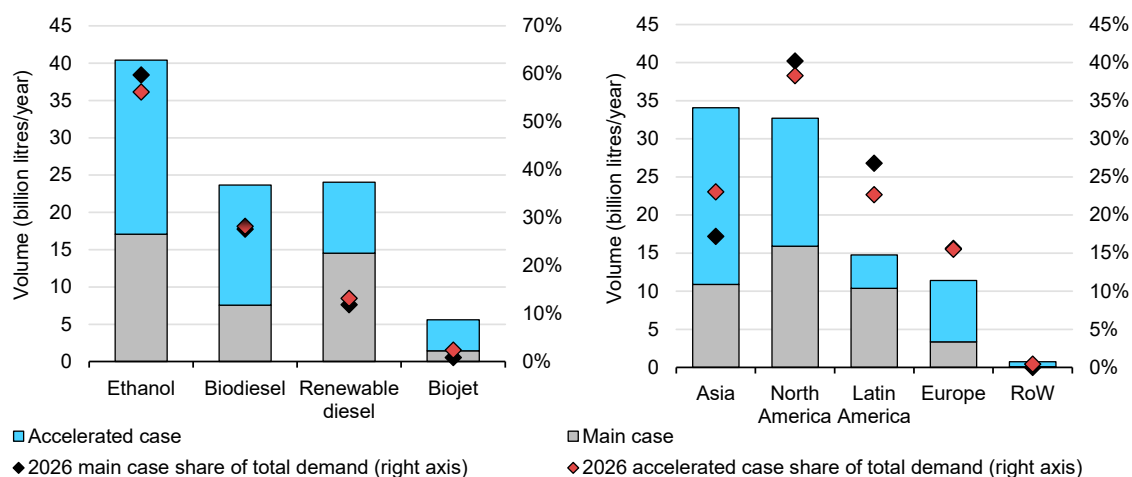
In the **United States**, the Sustainable Aviation Challenge sets a goal for the airline industry to use 11 billion litres of sustainable aviation fuel (SAF) by 2030 (Office of Energy Efficiency & Renewable Energy, 2021), equivalent to 15% of current jet fuel demand.<sup>3</sup> To support this goal the government is working on a SAF tax credit linked to GHG intensity. The United States also plans to outline rule-making for

---

<sup>3</sup> SAFs are jet fuels that are certified for use in commercial jet aircraft and that meet GHG and other sustainability criteria, and are also made from raw materials other than fossil fuels, such as wastes and agricultural residues.

the Renewable Fuel Standard (RFS) later this year (Office of Information and Regulatory Affairs, 2021b). SAFs qualify for credits under the RFS.

**Figure 2.2 Biofuel demand and share of total biofuel demand in the accelerated case versus the main case by fuel (left) and by region (right)**



IEA. All rights reserved.

In the **European Union**, the “Fit for 55” package includes a proposal for a transport GHG intensity requirement that would double the existing renewable energy target for transport of 14% by 2030 (European Commission, 2021a). The package also includes a proposed 2% SAF blending mandate by 2025 under the ReFuelEU Aviation initiative (European Commission 2021c) and a 2% GHG improvement for shipping under FuelEU Maritime (European Commission, 2021d).

Although biofuels and bioenergy received scant attention in **China’s** outline of its 14th Five-Year Plan, the country plans to peak emissions before 2030. As part of that plan, China plans to vigorously promote alternatives like advanced liquid biofuels and SAF (The State Council of the Peoples Republic of China, 2021). According to IEA analysis, biofuels play an important role in achieving emission reductions in China.

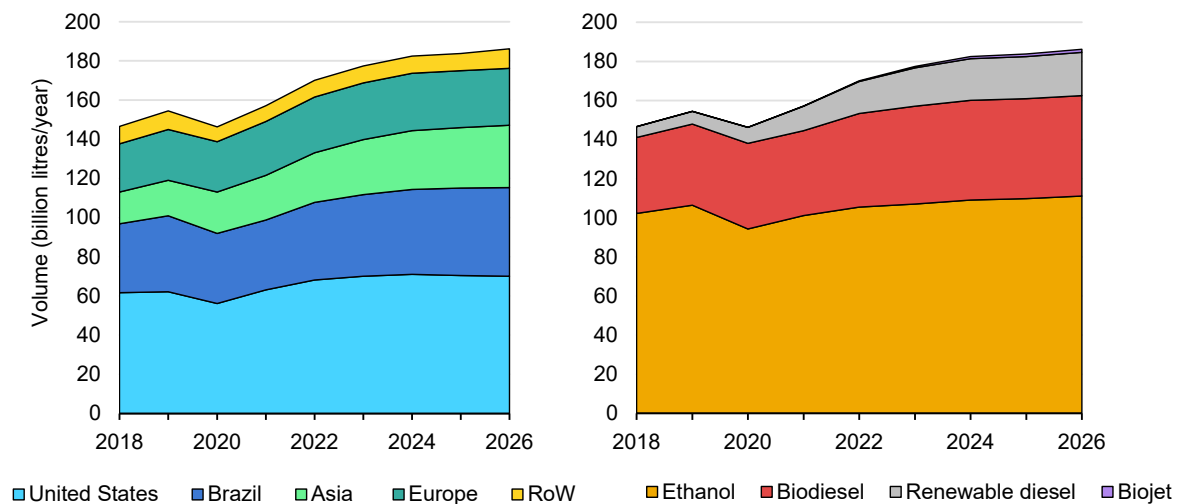
**India** will find it challenging to implement its 20% blending mandate in just five years, but even reaching 11% blending would make it the world’s third-largest ethanol market behind the United States and Brazil.

## Demand and supply

Biofuel demand grows at an average of 4% annually over the forecast period to reach 186 billion litres by 2026 in the main case, an increase of 41 billion litres from 2020. Brazil and the United States remain the largest markets for biofuels. They also account for the greatest expansion of demand in the next five years.

At the end of the forecast period, ethanol and biodiesel make up 87% of all biofuel demand globally, eight percentage points lower than today. The market sees both geographical and fuel shifts. Asia surpasses Europe to become the third-largest regional demand centre in 2024. Policies in Europe and the United States drive demand for renewable diesel and biojet, growing the global share of these fuels from 5% of total biofuel demand in 2020 to 13% in 2026.

**Figure 2.3 Biofuel demand by region (left) and by fuel (right), main case, 2018-2026**

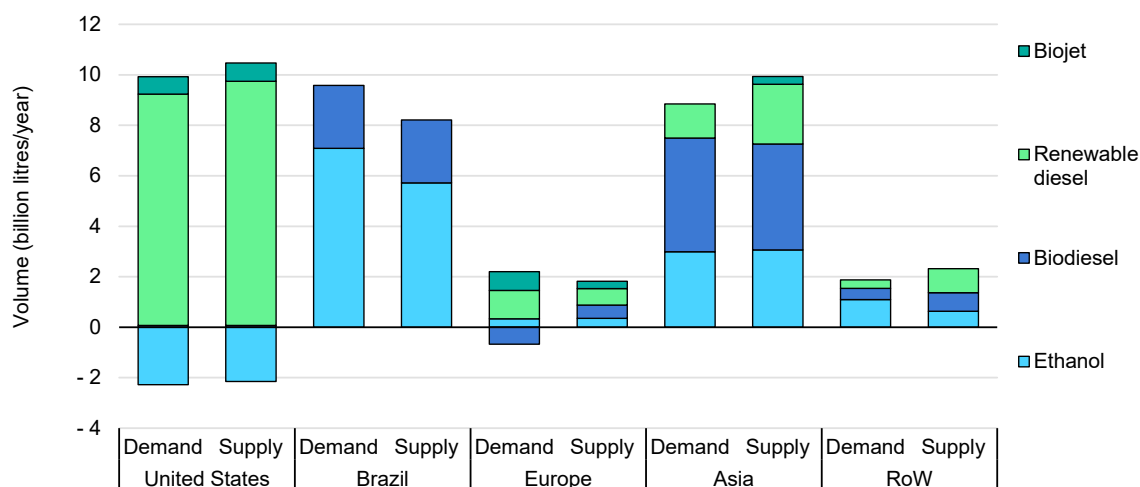


IEA. All rights reserved.

New supply, beyond the recovery in 2021, primarily comes online to support increasing local demand. However, Asia sees a greater increase in production than in demand, as Asian countries support increasing local demand and expand exports of renewable diesel and biojet to serve North American and European markets. Total Asian supply grows by 40% between 2022 and 2026. In the United States ethanol supply declines because of lower domestic demand. Increasing exports only partially offset the pace of this decline. In Europe ethanol supply keeps up with demand, while domestic biodiesel production expands, substituting some imports despite an overall decline in demand.



**Figure 2.4 Biofuel supply and demand growth by region and fuel, main case, 2022-2026**



IEA. All rights reserved.

In Brazil biofuel demand grows by 27% between 2022 and 2026, an increase of 10 billion litres. However, nearly half of this growth is ethanol demand returning to 2019 levels. Growing liquid transport fuel demand, mandates for 27% ethanol and 15% biodiesel blending, and consumer ethanol purchases beyond the mandated amounts are the main drivers of growing consumption. RenovaBio, a transport GHG intensity policy, supports both increasing biofuel demand and GHG reductions along the biofuel supply chain. Sugar cane ethanol generally performs better under the regulation compared with domestic corn ethanol production. Both perform better than imported US corn according to RenovaCalc, Brazil’s analytical tool used to generate certificates of energy intensity for biofuel production.

Across countries and regions, the interplay between policy, transport fuel demand, and prices for feedstocks and fuels drive the major trends in the forecast. Global transport fuel demand recovers from the Covid-19-related demand lows of 2020, but in many countries ethanol and biodiesel demand never return to 2019 levels as vehicle efficiency, electric vehicle purchases and behaviour change reduce demand for liquid transport fuels. Falls in demand for gasoline are more pronounced than for diesel. Feedstock prices have also delayed a number of national policies. Our forecast assumes the high feedstock prices of 2021 and government responses are temporary, although feedstock price increases do slow biofuel demand over the coming years in some markets (see Chapter 4 for more details). Biofuel policies are also increasingly rewarding fuels with better GHG emission profiles and lower environmental impacts, and introducing competition amongst fuels; this is shifting the types of fuels used in some regions.

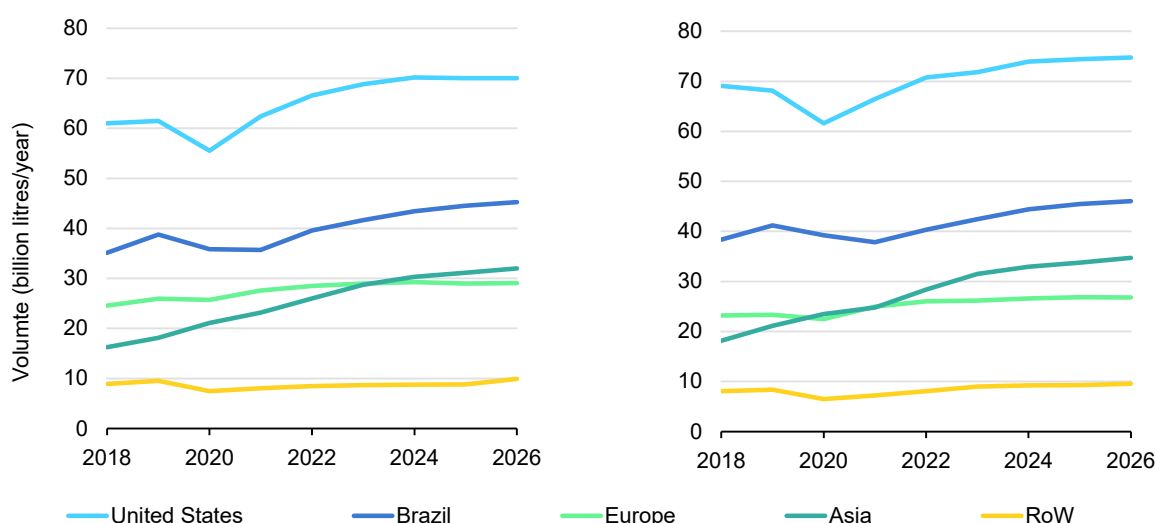
## Asia surpasses European biofuel demand and supply

The **Asia Pacific** region accounts for 27% of new demand and 29% of new supply over the forecast period – enough to surpass European demand and production. Most new production comes online to satisfy the 11 billion litres of new Asian demand over the forecast period. India and Indonesia drive much of this growth. In India the government has brought forward its 20% ethanol blending target to 2025 from an initial 2030 target. This forecast assumes India achieves 20% blending in some locations by 2025, but total blending averages 11% because of blending compatibility constraints in the vehicle fleet. This blend rate still nearly doubles ethanol demand in India, which increases by 3.4 billion litres by 2026. Ethanol supply increases to match India’s demand, since it plans to satisfy domestic demand with local production.

In **Indonesia** biodiesel demand grows by 38% as the government increases its biodiesel mandate and continues to subsidise biofuel consumption. In April 2021 Indonesia delayed implementing its 40% biodiesel blending target, citing high biodiesel prices as a major concern. Our forecast assumes that in 2022 feedstock and biofuel prices return to their average level over the past five years and Indonesia continues to increase biodiesel blending, lifting annual demand by 3 billion litres by 2026.

China and Singapore are building renewable diesel and biojet supplies to service export markets, adding to the production totals in the rest of Asia that service domestic demand. In total 2.5 billion litres of new renewable diesel capacity is planned for export. In Singapore, for instance, Neste is planning to expand capacity by 1.7 billion litres by the end of 2022 (Neste, 2021a).

**Figure 2.5 Biofuel regional demand (left) and supply (right), main case, 2018-2026**



IEA. All rights reserved.

Biofuel demand prospects in **Europe** remain weak, with only 13% growth expected over the forecast period. This is in part because liquid fuel demand is declining. In the major demand markets of Germany, France and Spain diesel demand declines by 4% and gasoline by 11% between 2022 and 2026 (IEA, 2021c). Policies such as the Renewable Energy Directive (RED II), and member country efforts to meet it, are intended to increase the share of renewable energy in transport. However, RED II allows for double counting of some fuels, which reduces the total quantity of fuels required to meet it. For instance, countries can count every unit of biogas, renewable electricity to power vehicles and advanced liquid fuels as two or more units towards compliance with RED II targets (European Commission, 2021b). The Fit for 55 package includes changes to the RED II that would do away with most multipliers. The impact of this and other changes are considered in the accelerated case (see below for further detail). Demand growth is primarily for renewable diesel and ethanol, although there is scope for increasing biodiesel production if it replaces imports.

To satisfy **Europe's** growing demand, albeit at a slow pace, Spain, France, the Netherlands, Italy, Finland, the United Kingdom and Sweden all add new renewable diesel production over the forecast period. This growth includes both refinery conversions and dedicated projects. In France, for instance, Total is planning a USD 590 million conversion of its Grandpuits refinery to produce renewable diesel, biojet and bioplastics by 2024 (Total Energies, 2020). In the Netherlands Neste is preparing for biojet production at its Rotterdam facility, which currently produces primarily renewable diesel (Neste, 2021b).

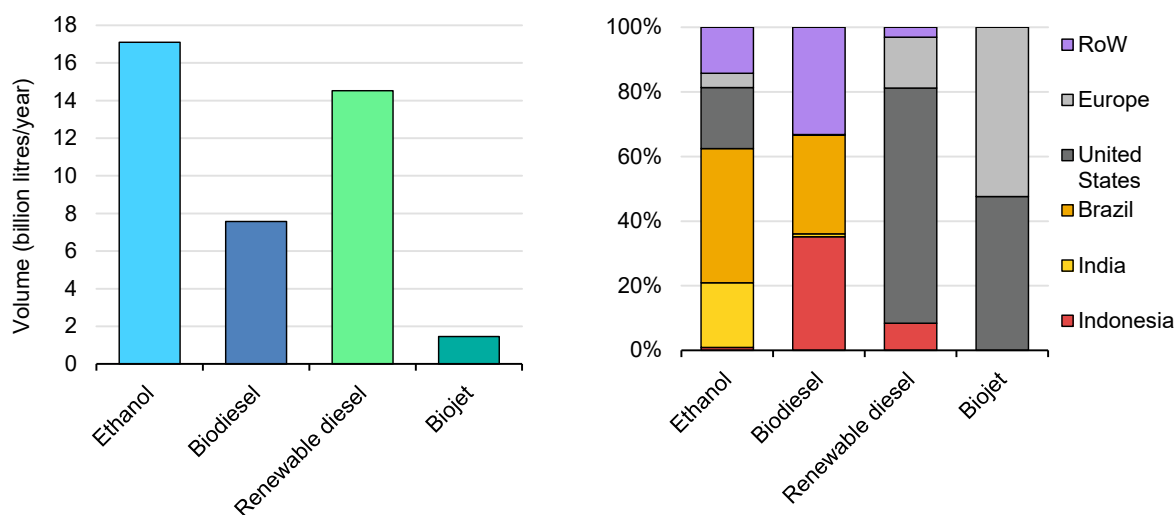
## Different fuels for different parts of the world

Ethanol and renewable diesel account for nearly four-fifths of the 41 billion litres of new demand between 2021 and 2026, with biodiesel making up most of the remainder. In addition, in the main case biojet grows by 1.5 billion litres, more than ten times 2021 estimated demand levels, but still less than 4% of new biofuel demand. However, 20% of the total growth in demand for biofuel, nearly 8 billion litres, is the recovery from Covid-19 demand impacts. Total new demand is therefore 32 billion litres over 2021-2026. This overall scale of growth is similar to the 32 billion litres of new biofuel demand created over the last six years. Ethanol and biodiesel demand expands most in Asia, and renewable diesel and biojet demand expands most in North America and Europe.

The United States and Europe, for example, account for 90% of renewable diesel demand growth and nearly all biojet demand. Renewable diesel competes well in these markets, where policies prioritise GHG performance, fuel suppliers and

consumers value its performance characteristics, and refinery closures open up potential for conversion to biofuel production.

**Figure 2.6 Biofuel demand growth by fuel (left) and share of fuel demand growth by region (right), main case, 2021-2026**



IEA. All rights reserved.

In the **United States** renewable diesel and biojet account for 78% of forecast growth. However, when excluding ethanol’s recovery, the share jumps to nearly 100%. The RFS and the blender’s tax credit, as well as low-carbon fuel standard credits in California, continue to drive renewable diesel expansion. The blender’s tax credit is due to end in 2022, but has been extended four times in the past and an extension is included in the US Build Back Better bill. California’s low-carbon fuel standard, the federal RFS and airport or airline commitments also drive biojet demand in the main case to 0.7 billion litres by 2026. The United States has also announced the Sustainable Aviation Fuel Grand Challenge and a proposed sustainable aviation tax credit to support it; however, the tax credit was not approved at the time of writing and thus remains a forecast uncertainty. The tax credit proposes a minimum 50% reduction in lifecycle GHG emissions compared to conventional aviation fuels (The White House, 2021). Which lifecycle GHG values the United States chooses will have a significant impact on the fuel feedstocks that would be eligible for the credit. For example, the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), an agreement under the International Civil Aviation Organization, specifies life-cycle GHG factors that would make corn-based alcohol to jet fuel and US soybean oil-derived jet fuel ineligible, since life-cycle emissions for these two pathways do not meet the 50% improvement threshold (ICAO, 2021a).

Domestic renewable diesel and biojet supply in the United States meet most new demand, but some imports are still likely to be required over the forecast period. Despite high feedstock costs, there is little evidence of project cancellations to date; only CVR Energy has delayed conversion of its Wynnewood refinery to renewable diesel because of the high cost of feedstocks, with a delay until spring 2022 (S&P Global, 2021). Nevertheless, fat, oil and grease feedstock availability remain the primary risk to the expansion of renewable diesel production (EIA, 2021b).

The US government's sustainable aviation announcement, including existing and new funding of USD 4.3 billion to support sustainable aviation projects, also prompted a number of SAF agreements (Office of Energy Efficiency & Renewable Energy, 2021).

In contrast to renewable diesel and biojet, ethanol and biodiesel growth is concentrated in just three countries, Brazil, India and Indonesia, which account for 64% of ethanol and biodiesel demand growth. All three have significant domestic feedstocks, growing gasoline and diesel demand and a desire to reduce fossil fuel imports. In contrast, China has pulled back from its earlier 10% ethanol blending ambitions and only Shanghai has a biodiesel mandate. Biofuel demand in China grows in line with gasoline and diesel demand, at just under 2% per year.

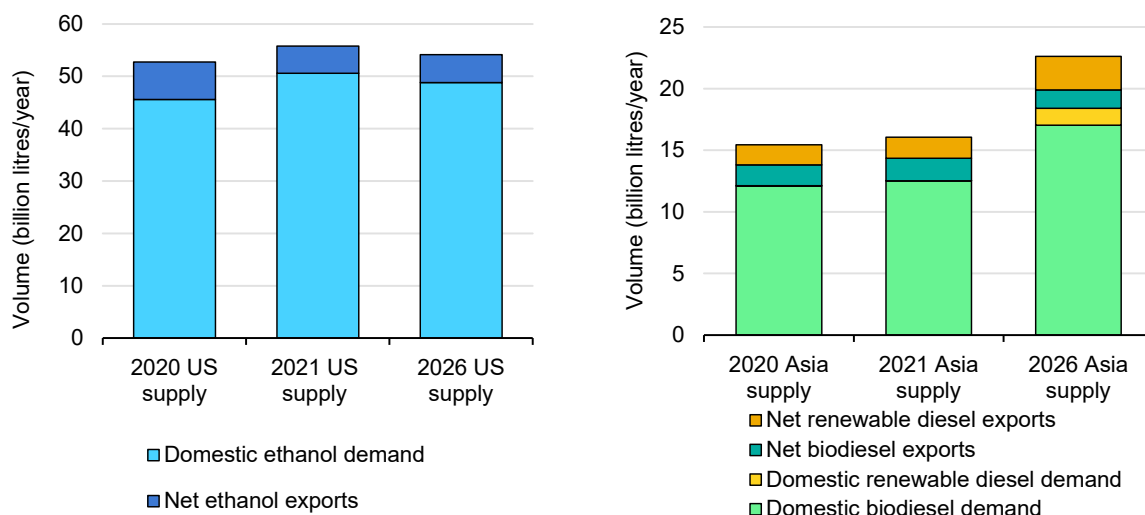
## **Fuel demand and government policies are driving different supply outcomes in different regions**

The combination of transport fuel demand, biofuel policies and trade policies help explain why different fuels are growing in some areas and not others. In the United States gasoline demand is declining and future increases in the RFS remain forecast uncertainties. It is also affected by countries with growing ethanol demand slowing policy deployment or seeking to limit biofuel imports by focusing on domestic production.

US ethanol supply increases from 2020 Covid-19 lows, but then declines by 4% between 2022 and 2026, tracking a similar decline in domestic ethanol demand of 4.5%. The demand for ethanol follows the gasoline market since ethanol blending is expected to remain near 10%, as E15 and E85 uptake has been limited. The US Court of Appeals also ruled in early July that the Environmental Protection Agency exceeded its authority in lifting restrictions on E15 sales during summer months. This ruling, if upheld, would make it more difficult to sell 15% ethanol blends during summer months, limiting opportunities to increase blending beyond 10% (Argus, 2021b). At the time of writing, the US government had not modified

renewable fuel volume targets under the RFS for 2023 and following years, nor had it set retrospective targets for 2020/21. Updates are expected in December 2021.

**Figure 2.7 US ethanol fuel supply (left) and Asian biodiesel and renewable diesel supply (right), main case, 2020 and 2026**



IEA. All rights reserved.

For the United States, exports are unlikely to make up for declining domestic demand since governments of growing demand centres show a preference for domestic production. For instance, India plans to expand domestic ethanol demand, places limits on ethanol fuel imports and is financially supporting new production. At the same time, Colombia has lowered its ethanol mandate, which then limits export opportunities for other countries. China’s willingness to import US ethanol increases import demand, but overall exports remain near 2021 levels since this increase is offset by declines in other markets. The accelerated case below explores ethanol supply prospects assuming that US domestic demand increases in parallel with more favourable trade policies.

In contrast with US ethanol, the combination of growing fuel demand, increasing mandates and increasing export markets combine to support significant growth in the production of biodiesel and renewable diesel in Asia. Together this is expected to grow by 41% between 2021 and 2026.

### **Box 2.1 India has tripled ethanol demand over the past five years, putting it on track to be the world's third-largest ethanol consumer by 2026**

India is on track to surpass China as the world's third-largest ethanol consumer by 2026. In January 2021 India brought forward its 20% ethanol blending target with gasoline from 2030 to 2025, and is aiming to start selling 20% blends in 2023. India is supporting ethanol because it helps reduce oil imports, reduces air pollution and provides economic and employment opportunities for farmers. Lifting ethanol demand is also aligned with a net zero pathway according to IEA analysis.

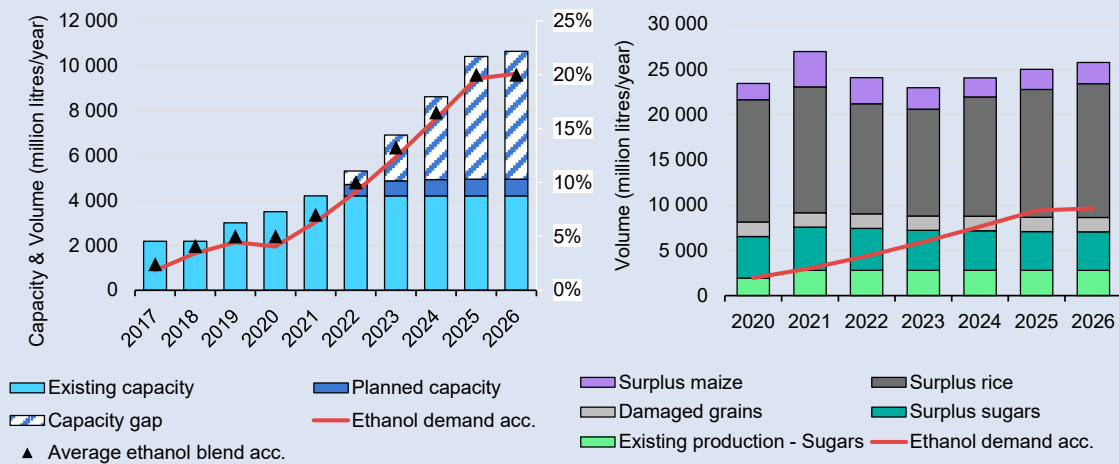
India has already made impressive progress in increasing ethanol blending. Between 2017 and 2021 India tripled ethanol demand to an estimated 3 billion litres in 2021. Ethanol blending rates with gasoline have also increased. In 2017 blending stood at 2%, and by the summer of 2021 it had reached 8% blending, putting India on track to achieve 10% blending by 2022. India has also increased its policy commitment. In pursuit of its 20% target, the country has set guaranteed prices per litre of ethanol according to feedstock; established financial support for new ethanol capacity; released an ethanol roadmap; and is planning to mandate flex-fuel vehicles that can operate on higher ethanol blends.

#### **What will it take for India to achieve 20% blending?**

There are, nevertheless, significant challenges India must overcome to achieve its 20% target. Vehicle compatibility, GHG and sustainability criteria, feedstock availability, and maintaining incentives at the right level will all require dedicated attention. Fortunately, there are examples from other countries for India to draw upon. In our accelerated case we assume India meets these challenges and achieves its 20% blending target in 2025.

A large segment of India's existing vehicle fleet may have compatibility issues with fuel blends above E10 (NITI Aayog, 2021). Retrofits are an option, but the scale of the undertaking may make that impractical. Flex-fuel vehicles or vehicles otherwise compatible with 20% blends will need to be made available and consumers will need to be convinced to purchase them. There is also a co-ordination challenge, as flex-fuel vehicles will need to be sold before E20 is broadly available. Brazil offers an example, since flex-fuel vehicles now make up 80% of gasoline-fuelled vehicles and Brazil's ethanol blend rate averages near 50% (IEA, 2019).

### Ethanol demand in the accelerated case compared with capacity, (2017-2026) (left) and production potential based on feedstock (right), India, 2020-2026



IEA. All rights reserved.

Note: The right-hand graph compares estimates of ethanol production potential from different feedstocks with ethanol demand in the accelerated case.

Sources: IEA analysis based on OECD, IHS Markit and NITI Aayog data.

Clear GHG performance requirements and sustainability criteria will also help ensure ethanol production reduces emissions and avoids other impacts. India estimates that ethanol blending has reduced its GHG emissions by 19 Mt CO<sub>2</sub>-eq since 2014 and its ethanol roadmap notes the need to supplement sugarcane, a water-intensive crop, with less water-intensive feedstocks (MoPNG, 2021; NITI, Aayog 2021). The United States, Brazil and the European Union all offer examples of how to develop and implement these frameworks. The United States, for example, has a minimum GHG threshold as part of its RFS and the European Union provides broader sustainability criteria for fuels.

Surplus sugar, maize, corn, rice and damaged grains should be more than sufficient to provide for proposed demand according to current production and consumption data (NITI Aayog, 2021). However, surpluses can quickly become deficits, as India experienced with maize in 2015 as a result of the 2015/16 drought (OECD, 2021). China, which had targeted 10% ethanol blending based on surplus agricultural stocks, quietly moved away from this target once the surpluses declined. Feedstock diversity and investing in technologies that use wastes can help minimise feedstock availability concerns.

India will also need to regularly modify incentives to ensure ethanol is competitive under its current incentive structure, while also ensuring there are sufficient funds to pay for those incentives. India is currently guaranteeing fixed rates for ethanol according to the feedstock it is produced from. In November 2021 India increased its incentive rates by between 1 and 2% to encourage production (CCEA, 2021).



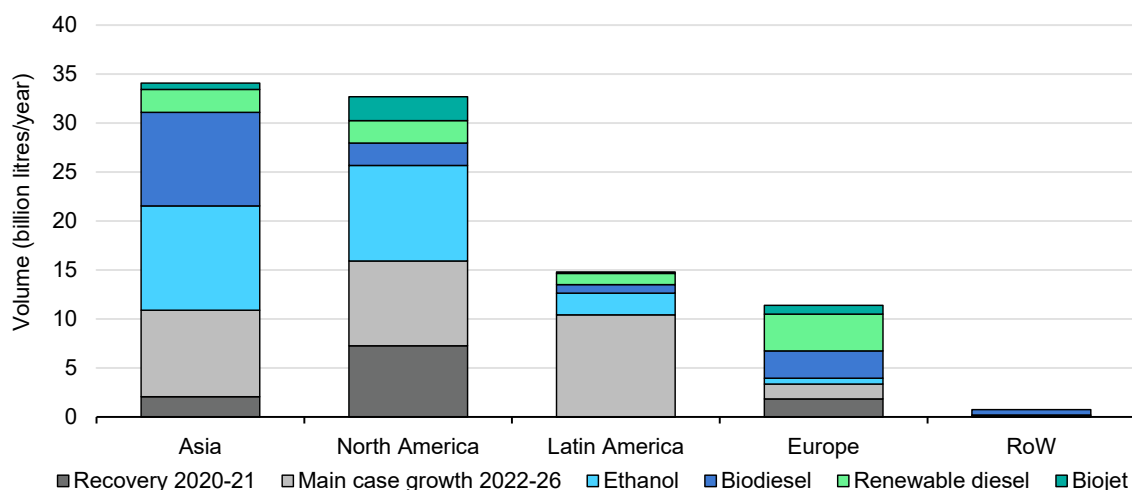
The incentive structure and funding system will need to be carefully structured. Here, too, India can learn from other examples. Indonesia for instance has scaled back its biodiesel blending ambitions because of high costs, a situation India would like to avoid. India may also look to other models, such as targets with credit trading, as applied under the US RFS.

These are significant challenges, especially with only four years to overcome them. Success will require applying lessons from other jurisdictions and long-term commitment.

## Biofuel demand growth doubles in the accelerated case

In the accelerated case, biofuel demand grows by an average of nearly 9% annually, amounting to 94 billion litres of new demand by 2026. This scale of growth relies on governments implementing proposed policies according to their indicated date and accelerating existing policies. Ethanol has the greatest potential for additional growth, followed by biodiesel, renewable diesel and biojet. Regionally, biofuel demand grows the most in Asia, followed by North America, Latin America and then Europe.

**Figure 2.8 Biofuel demand growth by region and fuel in the accelerated case, 2021-2026**



IEA. All rights reserved.

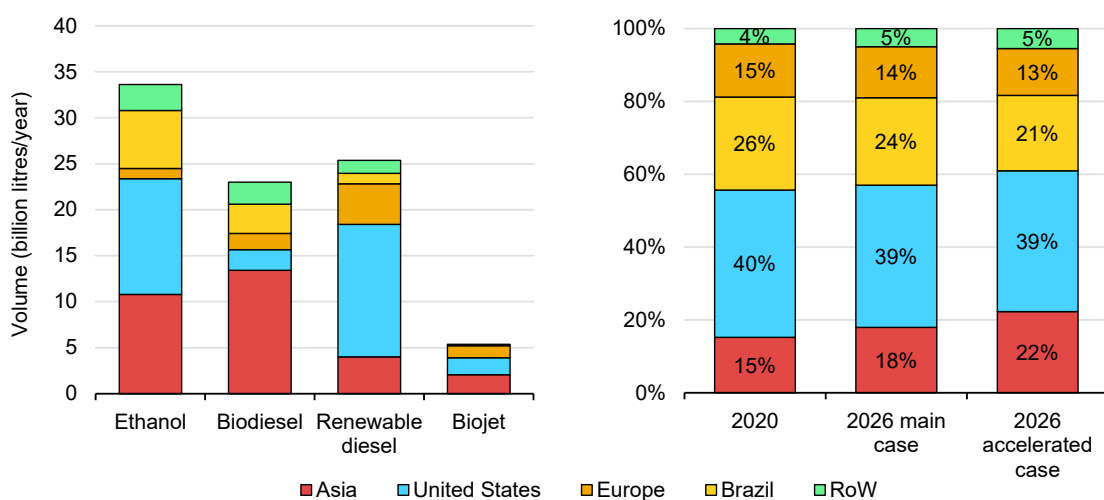
In Asia under the accelerated case, the combination of growing transport fuel demand and increasing blending mandates leads to a 17% average annual growth

rate. India, Indonesia and China drive this demand, primarily for ethanol and biodiesel. India meets its 20% ethanol blending target, Indonesia expands blending to biojet and China introduces modest blending requirements for ethanol, biodiesel and biojet.

Domestic production meets most of this new demand, increasing Asia's share of global biofuel production to 22% by 2026, ahead of Brazil. Asia also expands renewable diesel and biojet production to supply growing demand in Europe. However, the scale of demand growth in some countries, including India and China, is likely to require some imports to help keep costs in check and increase the likelihood of achieving domestic blending targets. This relaxing of trade barriers prompts additional supply from countries like the United States.

In North America, a more ambitious RFS in the United States and dedicated support for biojet in the United States and Canada could see biofuel demand grow by 55% by 2026. Given the United States' large transport fuel demand, relatively small changes can lead to large volume increases. In the accelerated case, a 2 percentage point increase in ethanol blending translates into 8 billion litres of new demand, equal to one-fifth of ethanol growth in the rest of the world in this case. Ethanol production satisfies domestic demand and exports an additional 7 billion litres. Biojet blending also increases to 3% in the United States by 2026, which brings the country over a quarter of the way to the proposed 11 billion litre goal in the Sustainable Aviation Fuel Grand Challenge.

**Figure 2.9 Biofuel production growth by region in the accelerated case (left) and total production shares by region in the main and accelerated cases (right), 2021-2026**



IEA. All rights reserved.

In the European Union, member states implement policies aligned with the Fit for 55 proposals, especially the ReFuelEU Aviation proposal. Our forecast expects Europe's biofuel demand to expand by 11 billion litres, driven by the implementation of ReFuelEU Aviation, which calls for a 2% biojet blending mandate by 2025 and 5% by 2030, and a revised RED II. The revised directive proposes a number of important changes, including a GHG intensity target instead of a renewable content target, changing multipliers, new minimum requirements for advanced fuels, and requirements for renewable non-biogenic fuels.

The European Commission expects its proposals to double the renewable energy content of fuels by 2030 from the existing 14% target based on the existing calculation methodology (European Commission, 2021a). However, this does not mean that biofuel demand will double. Under the proposals, GHG intensity reductions are rewarded, not biofuel volumes. Should member states focus on GHG intensity reductions, as Germany currently does, then biofuels will compete with all other eligible reduction options such as electric vehicles. In addition, liquid biofuels are blended with gasoline and diesel, the demand for which are in decline. Biofuels must also increasingly be produced from renewable non-biogenic fuels, which depend on technologies in the early stages of development, or wastes and residues like used cooking oil, which are in high demand. Despite this, the forecast expects a modest increase in biofuel demand in Europe under the accelerated case, primarily from renewable diesel, since it can be blended at higher levels than ethanol and biodiesel, performs well on GHG intensity and can be produced from wastes and residues.

Expanding renewable diesel demand and production will increase competition for compliant feedstocks, which may drive up costs. Increasing targets for both road transport and aviation will also contribute to competition for fuels, most notably between renewable diesel and biojet.

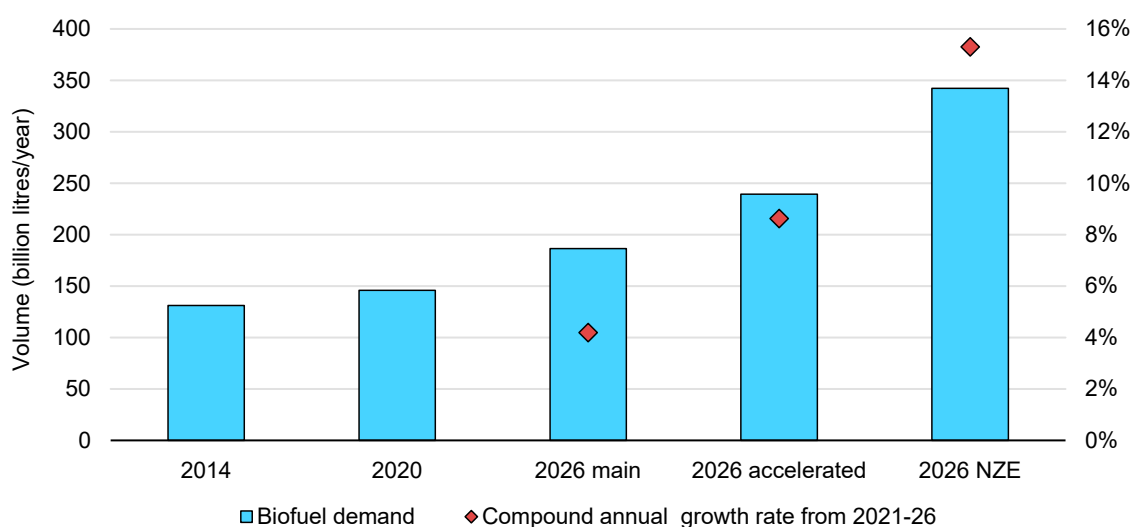
Marine fuels offer another potential growth area for biofuels. The International Maritime Organization (IMO) has committed to the long-term target of reducing absolute international shipping-related GHG emissions by 50% by 2050 (versus the 2008 level) and to reduce CO<sub>2</sub> emissions per transport activity by 40% by 2030. To help achieve this target, the IMO announced in June 2021 that ships must calculate their energy efficiency intensity, and the organisation expanded technical support and collaboration efforts to accelerate low-carbon pathways for the industry. The IMO expects to update its GHG strategy in 2023 (IMO, 2021).

Beyond the IMO, regional and country-level policies and programmes can also support GHG reduction in marine fuels. The European Commission's proposed FuelEU Maritime programme, for example, would require a 2% decline in the GHG intensity of marine fuels by 2025 (European Commission, 2021d). Efforts at the Port of Rotterdam also increased biofuel blending in its supplies to between 0.5% and 2% in 2019. Biofuels accounted for 0.1% of the fuel used for global shipping in 2019, equivalent to 0.8% of total biodiesel demand. See *Renewables 2020* for an in-depth analysis of marine fuel's potential for GHG reductions (IEA, 2020).

## Biofuels need to expand faster to align with the IEA Net Zero by 2050 Scenario

Biofuel demand must nearly double from our main case or expand by over 40% from the accelerated case to align with the IEA Net Zero Scenario. Liquid biofuels expand in the Net Zero Scenario to 2026 primarily to reduce emissions in road transport and to a lesser extent for planes and ships.

**Figure 2.10 Biofuel demand in the main case, accelerated case and the Net Zero Scenario, 2014-2026**



Note: NZE = Net Zero by 2050 Scenario.

IEA. All rights reserved.

To align with the Net Zero Scenario, countries would need to implement existing and planned policies, and then strengthen them before 2026. These policies must also ensure that biofuels are produced sustainably and avoid the risk of negative impacts on biodiversity, freshwater systems, and food prices and availability. In addition, policies must incentivise GHG reductions, not simply biofuel demand, so that every litre of biofuels used reduces emissions relative to fossil fuels as much as possible.

The following policy summary table provides details for major biofuel markets, including notable policy changes for selected countries in the main and accelerated cases. The analysis is based on policy assumptions for demand, supply and trade for 61 countries.

**Table 2.1 Main and accelerated case policy and assumption summary**

Country or region	Main and accelerated case policy and assumption summary
United States	<p><b>Main case:</b> No significant changes to the RFS or other existing policies. Ethanol blending remains near 10% and exports remain near 2020 levels for the forecast period. Renewable diesel expands according to planned capacity additions for projects in advanced development stages. Biodiesel blending remains near 3%. Biojet supply and demand reach 0.7% blending of domestic jet use according to planned biojet capacity additions for projects in advanced development stages.</p> <p><b>Accelerated case:</b> An accelerated version of the RFS increases domestic biofuel demand, with ethanol reaching 12% blending and biodiesel expanding to 4%. Renewable diesel expands to 7% blending, requiring additional capacity beyond projects in advanced development stages. Biojet expands to 3% blending, just over one-quarter of the way to the Sustainable Aviation Grand Challenge goal. US ethanol production increases to meet both domestic demand and satisfy net export demand. This is possible within existing ethanol capacity. By 2026 the United States produces sufficient renewable diesel, biojet and biodiesel for domestic demand, with some excess capacity for exports.</p>
Brazil	<p><b>Main case:</b> Brazil maintains mandatory ethanol blending and hydrous ethanol purchases expand so that total blending reaches 57% by 2026. Biodiesel remains at B15, but there is little growth in renewable diesel and biojet.</p> <p><b>Accelerated case:</b> Brazil achieves its B15 blending target as in the main case, but accepts renewable diesel and co-processing so additional growth flows to renewable diesel, achieving 2% blending in 2026. Ethanol blending expands marginally more quickly, achieving 59% blending in 2026, up from 57% in the main case. Part of the total ethanol blend is a continuation of Brazil's 25% (premium gasoline) to 27% (regular gasoline) blending requirements. Hydrous ethanol sales (100% ethanol) make up the remainder of ethanol demand. Brazil produces sufficient ethanol, biodiesel, renewable diesel and biojet to meet domestic demand. Exports continue but at lower than historical rates, assuming that there is long-term preference for sugar production if India diverts sugar production to ethanol.</p>
India	<p><b>Main case:</b> India achieves 11% ethanol blending on average across the country by 2026 and all fuel ethanol is produced domestically. E20 is available starting in 2023. Biodiesel blending remains near 0.4%.</p> <p><b>Accelerated case:</b> India achieves its 20% blending mandate in 2025 and makes progress towards its 5% biodiesel blending ambitions, reaching 3% by 2026. India continues to support domestic production. India allows fuel ethanol imports up to 20% of demand.</p>
China	<p><b>Main case:</b> No significant changes to ethanol or biodiesel policy. Ethanol blending remains near 2% and biodiesel at 1%. Ethanol imports remain near 2020/21 levels. Biodiesel exports remain near 2020 levels and renewable diesel exports expand according to planned project additions in advanced development stages.</p> <p><b>Accelerated case:</b> We assume China's 14th five-year plan includes a modest role for biofuels, targeting 4% blending for ethanol, 3% for biodiesel and renewable diesel, and a 1% SAF target for domestic aviation by 2026. China continues to allow ethanol imports from the United States and other countries for up to 10% of demand. Exports continue for biodiesel and renewable diesel.</p>
Indonesia	<p><b>Main case:</b> Indonesia achieves 40% biodiesel blending by 2026, the majority from biodiesel, while renewable diesel makes up three percentage points of the 40% blend. There is no ethanol or biojet production or use. Exports remain near 2020 levels.</p> <p><b>Accelerated case:</b> Indonesia meets a B40 mandate for biodiesel with an additional 5% from renewable diesel. It also enforces its SAF blend mandate, reaching 2% by 2025. Exports decline by 2026 as nearly all production is directed towards domestic demand.</p>

Country or region	Main and accelerated case policy and assumption summary
Europe	<p><b>Main case:</b> EU member countries implement RED II or achieve domestic targets if more stringent, and non-EU countries achieve domestic targets. Biojet expands according to country-level targets. Countries without targets achieve 75% of the ReFuelEU aviation 2% by 2025 target. Germany's biodiesel and ethanol blending remains steady, while renewable diesel expands to 2.5%. France expands ethanol blending, biodiesel blending remains flat, renewable diesel blending expands to 2% and biojet reaches 2% blending by 2025. In Spain ethanol and biodiesel blending remain flat, but renewable diesel and biojet expand to 3% blending and 0.5% blending respectively according to planned additions. Finland, Netherlands and the United Kingdom all reach near 10% ethanol blending. Sweden reaches 3% biojet blending. In Italy renewable diesel blending expands to 5%.</p> <p><b>Accelerated case:</b> The European Union sets a 2% SAF target as envisaged in the ReFuel proposal for fuel use, increasing demand threefold from the main case. As per the ReFuel proposal, feed and food crop-based fuels are not eligible, there is no cap on waste oils and fats, and fuels must otherwise meet the requirements of RED II Annex IX, Part A or Part B. Germany sees no biojet in accordance with its plan to focus on renewable non-biogenic fuels. The European Commission also implements its proposed changes to RED II, focusing on a 13% improvement in the GHG intensity of transport as presented in the Fit for 55 proposal. The European Union maintains and strengthens sustainability requirements for biofuels, which limits some imports. The United Kingdom establishes a 1% SAF target by 2025.</p>
Other countries	<p><b>Main case:</b> Canada implements its Clean Fuel Standard in 2022, but Malaysia's B20 mandate is delayed until 2023. Thailand makes progress on its E20 target, reaching 15% blending by 2026, while biodiesel expands to 10% based on government support plans. Singapore's renewable diesel and biojet production expands to fill domestic shortfalls in the rest of the world. Argentina's biodiesel blending remains at 5%, and ethanol at 12%. Colombia returns to 10% ethanol blending by 2022, while biodiesel blending remains at 10% over the forecast period.</p> <p><b>Accelerated case:</b> Canada follows the United States in supporting SAF, Malaysia expands biodiesel blending for the industrial sector to 20%, Argentina reinstates its 10% biodiesel blending requirement and Colombia pursues 13% biodiesel blending. Thailand achieves 20% ethanol blending by 2026 and allows 10% ethanol imports.</p>

## Trade

Absolute net trade<sup>4</sup> volumes of biofuel remain the same in 2021 and 2026 at near 18 billion litres. While net trade volumes remain the same, net trade as a share of demand declines by two percentage points to 10% by 2026.

The United States, the Netherlands and Singapore remain the top three biofuel net exporting countries, and Canada, Sweden and the United Kingdom the top importing destinations over the forecast period. While the Netherlands and Singapore are important export centres, biofuel production in these countries still

<sup>4</sup> This analysis uses the terms net trade, net exports and net imports, which account for countries or regions with a net surplus or deficit in biofuel supply. It does not include other trading activity that may occur to accommodate short-term demand/supply mismatches or trade through countries where fuels are ultimately destined for another market. For example, in 2018 Canada imported 370 million litres of biodiesel and exported 270 million litres. In this case, Canada had net imports of 100 million litres in 2018.

depends on imported feedstocks. The Philippines joins the top five net importers in 2026, thanks to increasing ethanol imports.

Countries with renewable diesel and biojet demand rely the most on trade to satisfy that demand. In 2026, 21% of global renewable diesel demand and 31% of global biojet demand is satisfied through trade.

## Renewable diesel and biojet lead growth in net trade

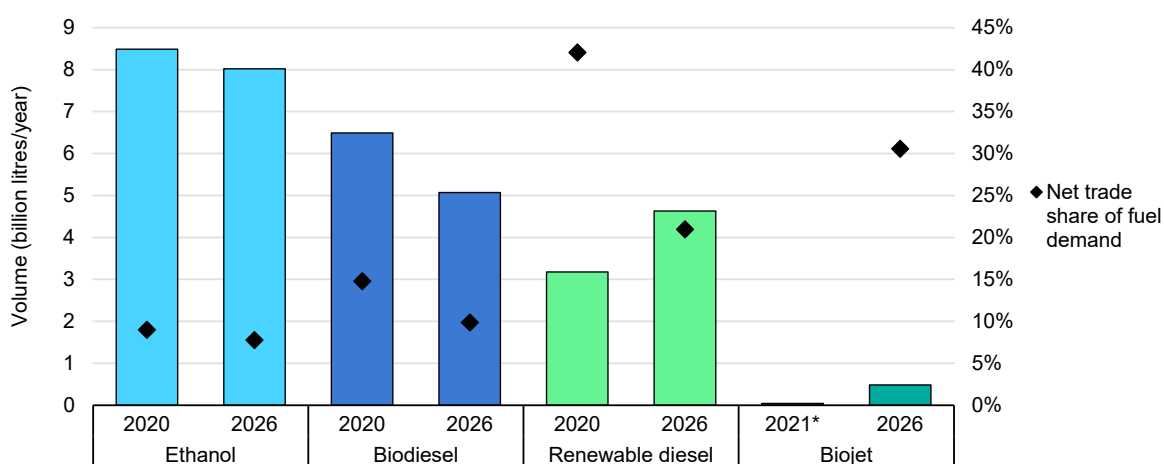
Global net trade remains stable, although there are increases in renewable diesel and biojet trading, balanced by declines in ethanol trading. Renewable diesel and biojet net trade expands by 60% between 2021-2026, mainly for imports to Europe and the United States. While domestic production satisfies most of their domestic demand, especially in the United States, imports, primarily from Asia, are expected to fill the gaps. Net trade in ethanol and biodiesel on the other hand decline by 13% over the forecast period. The existing large ethanol markets of Brazil and the United States remain net exporters; however, new demand centres such as India intend to be self-sufficient, limiting trade growth prospects. Biodiesel trade declines slightly because of increased domestic production in Europe. However, this production may still be based on imported feedstocks. Overall, ethanol and biodiesel account for 82% of net trade of all biofuels in 2020, declining to 72% by 2026.

A number of factors – including domestic trade policy, biofuel policy design, domestic production capacity, biofuel costs and the scale of the market – influence the share of demand satisfied by trade for any given biofuel. For instance, in 2020 trade satisfied over 40% of global demand for renewable diesel, higher than ethanol and biodiesel. The United States and Europe account for nearly all renewable diesel imports since domestic capacity does not meet local demand, imports can count towards policy objectives and demand is growing for fuels that meet GHG and sustainability requirements. Given these circumstances, renewable diesel imports offer a competitive option to meet domestic policy requirements. Over the forecast period renewable diesel demand swells in Europe and the United States. The scale of new demand and favourable policy leads to new investment in domestic production. As domestic production expands, trade as a share of renewable diesel demand declines to 21% by 2026.

In contrast, ethanol trade satisfies just 9% of total ethanol demand in 2020. Trade's share is lower for ethanol since many countries have launched or continued to operate ethanol programmes to improve energy security, or to support domestic agriculture. The United States and Brazil, for example, launched ethanol support

policies in part to reduce reliance on imported oil. Domestic demand is therefore met primarily with local production based on ample feedstocks in both countries. Over the forecast period countries with sufficient existing or planned ethanol capacity to meet domestic demand, such as Brazil, or those aiming to be self-sufficient, such as India, drive growth in ethanol production and demand. As a result, ethanol trade as a share of demand remains low at 7% by 2026.

**Figure 2.11 Net trade by fuel and net trade share of demand by fuel, main case, 2020 and 2026**



IEA. All rights reserved.

\* Trade data unavailable for biojet in 2020. Data for 2021 shown.

## Singapore climbs to second largest exporter, while top importers remain the same

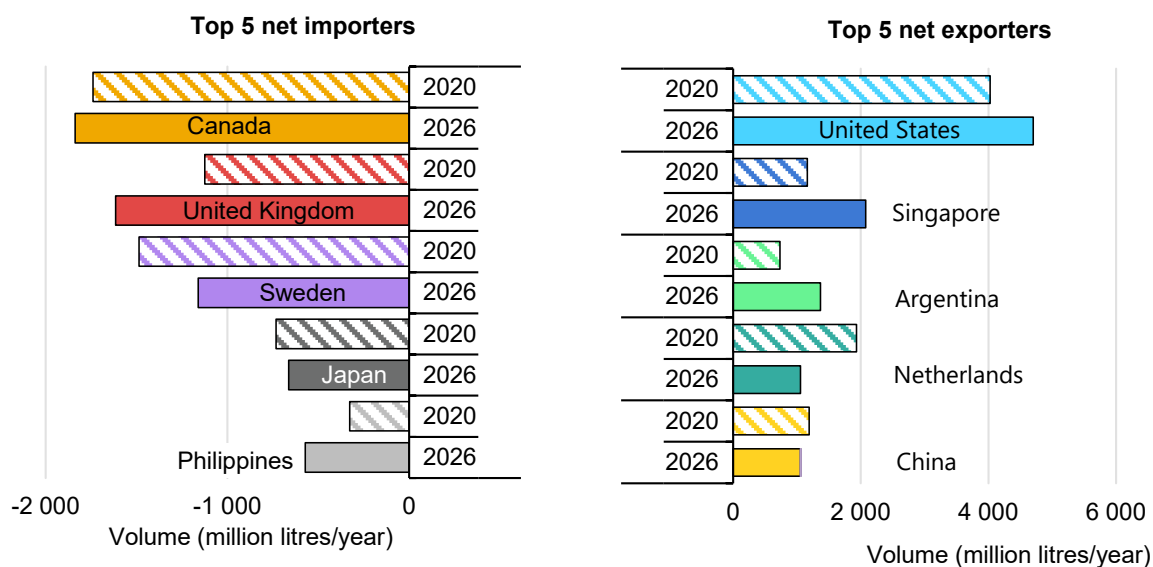
With significant ethanol capacity, slowing domestic demand and competitive ethanol prices, the United States is by far the world's largest biofuel exporter. As the United States adds to its own renewable diesel supply over the forecast period, imports decline, increasing net exports to 4.7 billion litres by 2026, up by 0.7 billion litres from 2020. In Singapore, growing global demand for renewable diesel and biojet increases exports by 78% by 2026. The Netherlands continues as a major renewable diesel and biodiesel exporter in Europe, but the country exports lower volumes in 2026 compared with 2020 as its own demand grows.

In 2026 Canada, Sweden and the United Kingdom remain significant net importers of biofuels. Canada's imports grow as it implements its Clean Fuel Standard, which will require reductions in liquid fuel carbon intensities, since new domestic production, supported by government programmes and private investment, does not keep up with demand. In the United Kingdom new demand is primarily met with domestic supply, but import growth is still needed to satisfy domestic demand



in 2026. Sweden continues to import biodiesel and renewable diesel to comply with its GHG intensity requirements on transport. Net imports in Sweden increase slightly from 2020 levels. The Philippines joins the top five import list as a stable ethanol blending requirement, increasing gasoline demand and a historically high import ratio lead to growing imports

**Figure 2.12 Top five global exporters and importers of biofuel in 2026 compared with 2020, main case**



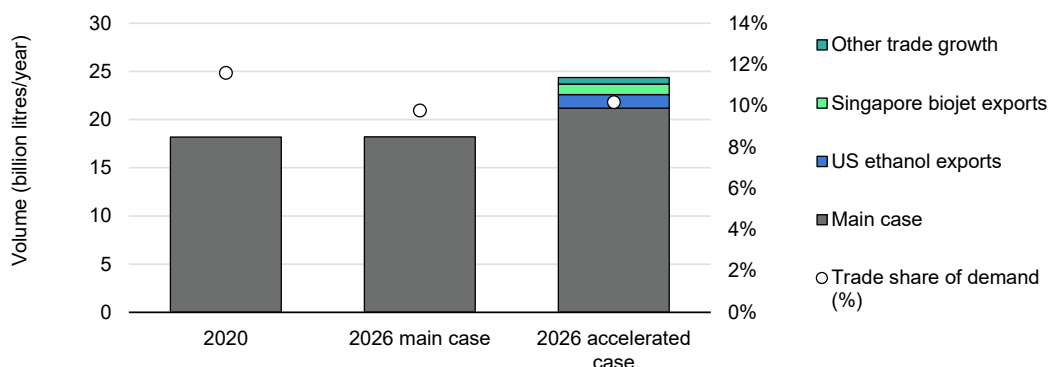
IEA. All rights reserved.

## Ethanol and biojet import demand drives trade growth in the accelerated case

In the accelerated case, demand for biojet and the relaxation of some trade restrictions for ethanol imports drive net trade in biofuels 16% higher than in the main case in 2026. Ethanol demand expands significantly in the accelerated case, primarily because of more progressive policies in India and China. Global ethanol net exports in 2026 expand by 25% over the main case on the basis that China continues to import at historical rates and India allows imports to meet up to 20% of fuel ethanol demand.

Countries and regions with biojet mandates offer another potential area for trade growth where demand outstrips local production capacity. In the United States and Europe, for example, both SAF mandates and stronger policies for road transport, whether GHG intensity or blending based, increase biojet and renewable diesel demand, beyond domestic supply capacity over the forecast time period. Imports of SAF alone expand to 2 billion litres a year by 2026 in the accelerated case.

**Figure 2.13 Net trade in 2021, 2026 main case and 2026 accelerated case**



IEA. All rights reserved.

In the rest of the world, Brazil also expands ethanol exports to meet growing global demand, and the Netherlands further expands renewable diesel and biojet production for regional markets in Europe.

## References

- Argus Direct (2021a) Data services, <https://direct.argusmedia.com/> (accessed September 2021).
- Argus Direct (2021b) US court rejects EPA rule expand E15 sales. <https://www.argusmedia.com/en/news/2230695-us-court-rejects-epa-rule-expanding-e15-sales>.
- CNMC (Comisión Nacional de los Mercados y La Competencia) (2021). Biocarburantes. <https://www.cnmc.es/ambitos-de-actuacion/energia/mercado-petroleo-biocarburantes#biocarburantes> (accessed September 2021).
- CSET (Center for Security and Emerging Technology) (2021) Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives 2035. [https://cset.georgetown.edu/wp-content/uploads/t0284\\_14th\\_Five\\_Year\\_Plan\\_EN.pdf](https://cset.georgetown.edu/wp-content/uploads/t0284_14th_Five_Year_Plan_EN.pdf) (accessed September 2021).
- Department of Agriculture (2021) India: Biofuels Annual, [https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual\\_New%20Delhi\\_India\\_06-07-2021](https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_New%20Delhi_India_06-07-2021). (accessed October 2021)
- EIA (Energy Information Administration) (2021b) U.S. Imports of Other Renewable Diesel Fuel. <https://www.epa.gov/fuels-registration-reporting-and-compliance-help/spreadsheet-rin-generation-and-renewable-fuel-0> (accessed September 2021).
- EIA (Energy Information Administration) U.S. (2020), Petroleum and Other Liquids, [www.eia.gov/petroleum/data.cfm](http://www.eia.gov/petroleum/data.cfm) (accessed September 2021).

- EPA (Environmental Protection Agency) (2021) Spreadsheet of RIN Generation and Renewable Fuel Volume Productino by Fuel Type for the Renewable Fuel Standard <https://www.epa.gov/fuels-registration-reporting-and-compliance-help/spreadsheet-rin-generation-and-renewable-fuel-0> (accessed September 2021).
- European Commission (2021a) Directive of the European Parliament and of the Council, COM(2021) (accessed September 2021).
- European Commision (2021b) Renewable energy – directive, targets and rules. (accessed September 2021).
- European Commission (2021c) Sustainable aviation fuels – ReFuelEU Aviation. (accessed September 2021).
- European Commission (2021d) Regulation of the European Parliament and of the Council on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC. <https://ec.europa.eu/info/law/better-regulation/> (accessed September 2021).
- ICAO (2021a) CORSIA Default Life Cycle Emissions Values for Corsia Eligible Fuels. <https://www.icao.int/environmental-protection/CORSIA/Documents/ICAO%20document%2006%20-%20Default%20Life%20Cycle%20Emissions%20-%20March%202021.pdf> (accessed October 2021).
- IEA (2021c), Oil Information (database), [www.iea.org/statistics](http://www.iea.org/statistics). (accessed September 2021).
- IEA (2021d), Monthly Oil Data Service (MODS), [www.iea.org/statistics](http://www.iea.org/statistics) (accessed September 2021).
- IEA (2020) Renewables 2020. <https://www.iea.org/reports/renewables-2020> (accessed October 2021).
- IEA (2019), Fuel Economy in Major Car Markets. <https://www.iea.org/reports/fuel-economy-in-major-car-markets>. (accessed October 2021)
- IHS Markit (2021a), Biofuels market (subscription service), IHS Markit, London. (accessed September 2021).
- IMO (2021) Initial IMO GHG Strategy. <https://www.imo.org/en/MediaCentre/HotTopics/Pages/Reducing-greenhouse-gas-emissions-from-ships.aspx> (accessed October 2021).
- Ministère de la Transition Écologique (2020) Chiffres clés des énergies renouvelables – Édition 2020, <https://www.statistiques.developpement-durable.gouv.fr/chiffres-cles-des-energies-renouvelables-edition-2020#:~:text=En%20croissance%20r%C3%A9guli%C3%A8re%20depuis%20plusieurs,%C3%A9nergie%20en%20France%20en%202019> (accessed September 2021).
- Ministério de Mins e Energia (2021) Dados estatísticos. <https://www.gov.br/anp/pt-br/centrais-de-conteudo/dados-estatisticos> (accessed September 2021).
- MoPNG (2021), Ethanol Growth Story – Fulfilling Aatmanirbhar Bharat Dream. [https://mopng.gov.in/files/uploads/Ethanol\\_Booklet\\_english.pdf](https://mopng.gov.in/files/uploads/Ethanol_Booklet_english.pdf) (accessed September 2021).
- Neste (2021a) Neste Singapore Expansion Project. <https://www.neste.com/neste-in-singapore-and-asia-pacific/journeytozerostories/singapore-expansion-project> (accessed September 2021).

- Neste (2021b) Neste to enable production of up to 500,000 tons/a of Sustainable Aviation Fuel at its Rotterdam renewable products refinery. <https://www.neste.com/releases-and-news/renewable-solutions/neste-enable-production-500000-tonsa-sustainable-aviation-fuel-its-rotterdam-renewable-products> (accessed September 2021).
- NITI Aayog (2021) Roadmap for Ethanol Blending in India 2020-25. <https://www.niti.gov.in/expert-committee-roadmap-ethanol-blending-india-2025> (accessed September 2021).
- Office of Energy Efficiency & Renewable Energy, US (2021) Sustainable Aviation Fuel Grand Challenge, <https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge>, (accessed September 2021).
- Office of Information and Regulatory Affairs, US (2021a) Renewable Fuel Standard Program: Annual volumes and Percentage Standards <https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202104&RIN=2060-AV11> (accessed September 2021).
- Office of Information and Regulatory Affairs, US (2021b) Volume Requirements for 2023 and Beyond Under the Renewable Fuel Standard Program <https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202104&RIN=2060-AV14> (accessed September 2021).
- OECD (2021a) Agricultural Outlook 2021-2030. <https://stats.oecd.org/viewhtml.aspx?QueryId=107144&vh=0000&vf=0&l&il=&lang=en> (accessed September 2021).
- S&P Global (2021) CVR delays Wynnewood renewable diesel conversion due to high feedstock prices. <https://www.spglobal.com/platts/en/market-insights/latest-news/electric-power/080521-cvr-delays-wynnewood-renewable-diesel-conversion-due-to-high-feedstock-prices>, (accessed September 2021).
- Statistics Canada (2021), Petroleum products by supply and disposition, monthly, Table 25-10-0081-01. <https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510008101> (accessed September 2021).
- Total Energies (2020) Energy Transition: Total is Investing More Than 400 Million To Convert Its Grandpuits Refinery Into a Zero-Crude Platform for Biofuels and Bioplastics. <https://totalenergies.com/media/news/news/energy-transition-total-investing-more-eu500-million-convert-its-grandpuits> (accessed September 2021).
- The State Council – The Peoples Republic of China (2021) Full Text: Action Plan for Carbon Dioxide Peaking Before 2030. [http://english.www.gov.cn/policies/latestreleases/202110/27/content\\_WS6178a47ec6d0df57f98e3dfb.html](http://english.www.gov.cn/policies/latestreleases/202110/27/content_WS6178a47ec6d0df57f98e3dfb.html) (accessed September 2021).
- The White House (2021) FACT SHEET: Biden Administration Advances the Future of Sustainable Fuels in American Aviation. <https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/09/fact-sheet-biden-administration-advances-the-future-of-sustainable-fuels-in-american-aviation/> (accessed September 2021).

# Chapter 3. Renewable heat

## Recent trends

### Global progress on conversion to renewable heat has been limited

Heat is the world's largest energy end use, accounting for almost half of global final energy consumption in 2021, significantly more than electricity (20%) and transport (30%). Industrial processes are responsible for 51% of the energy consumed for heat, while another 46% is consumed in buildings for space and water heating, and, to a lesser extent, cooking. The remainder is used in agriculture, primarily for greenhouse heating. Global heat demand declined by 2% in 2020, primarily due to the curtailment of economic activity as a result of the Covid-19 pandemic, while renewable heat consumption increased by over 3.5% year on year.

More than a quarter of global heat consumption takes place in People's Republic of China (hereafter 'China') – almost 70% of which is for industry – while the United States, the European Union, India and the Russian Federation ("Russia") together account for another 35%.

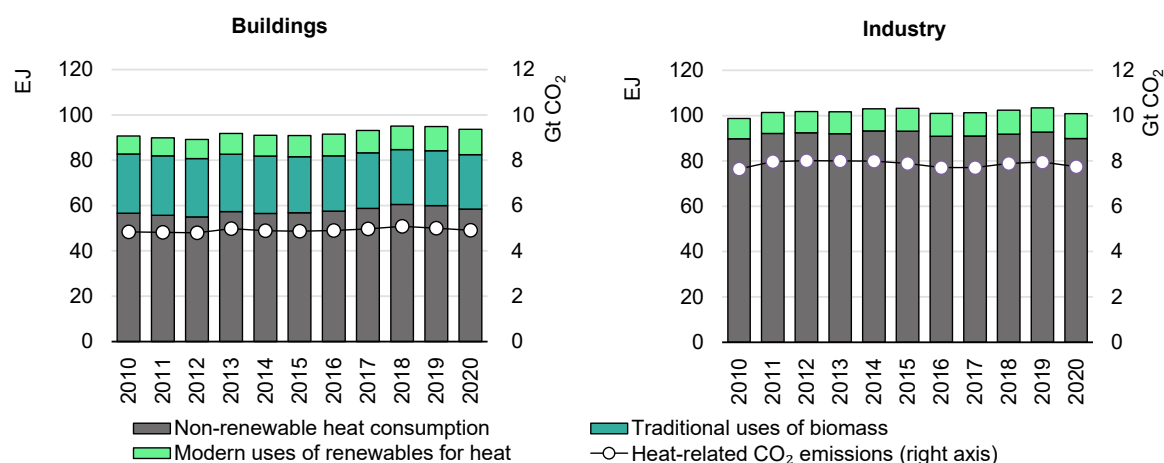
The supply of heat, which contributed more than 40% (13.1 Gt) of global energy-related CO<sub>2</sub> emissions in 2020, remains heavily fossil fuel dependent, with renewable sources (including traditional uses of biomass) meeting less than a quarter of global heat demand in 2020 – a share that has remained static during the past three decades. Excluding ambient heat, for which limited data are available at the global scale,<sup>1</sup> as well as traditional uses of biomass, modern renewables<sup>2</sup> contributed only 11% (23 EJ) of the energy used for heat in 2020, up from 10% in 2015.

---

<sup>1</sup> While data on ambient heat harnessed by heat pumps are [available for member countries of the European Union](#), data availability is still very limited for other regions of the world.

<sup>2</sup> In this report, "modern renewable energy" excludes traditional uses of biomass. Modern renewable heat covers the direct and indirect (e.g. through district heating) final consumption of bioenergy, solar thermal and geothermal energy, as well as renewable electricity for heat based on an estimate of the amount of electricity used for heat production and on the share of renewables in electricity generation. Although credited as a renewable heat source, ambient heat harnessed by heat pumps is not systematically accounted for in this report, due to limited data availability, especially for the industrial sector. Specific mention is made when ambient heat is included. For the sake of simplicity, "modern renewables" is referred to as "renewables" in the remainder of this report.

**Figure 3.1 Renewable and non-renewable heat consumption and heat-related CO<sub>2</sub> emissions in buildings and industry, world, 2010-2020**



Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), [World Energy Statistics and Balances 2021](#) (database); IEA (2021b), [World Energy Outlook 2021](#).

## Policy update

### Renewable heat has gained some policy momentum, but not enough to put the heat sector on track to meet climate ambitions

Despite heat accounting for a large share of final energy consumption, renewable heat has until recently received limited policy attention globally compared with other end-use sectors. In 2020 the number of countries with national regulatory policies for renewable heating and cooling was less than a sixth of those with regulatory policies for renewable electricity (REN21, 2021). More than a third of global heat consumption was not covered by any financial incentive for renewables, and more than half was not subject to any national or provincial renewables-related regulatory measures. At the end of 2020 only ten countries had renewable heat policies covering all sectors (residential and commercial buildings, public facilities and industry) (REN21, 2021). Designing policy for renewable heating and cooling can be a challenge due to the fragmented and diverse nature of heat markets and the local characteristics of heat demand. This makes collaboration with subnational actors necessary, and partly explains the limited national policy coverage.

At least 46 countries – the majority from the European Union – had a target in place to increase the share of renewables in the heating and cooling sector by 2020. However, while about half of these countries were able to achieve their 2020

ambition, many did not set out new targets (REN21, 2021). In the European Union (EU27), while member countries performed at different levels, the overall share of renewables in heating and cooling reached 22% in 2019, helping to meet the 2020 target of 20% renewable energy in total final energy consumption.

Since the start of 2020 renewable heat has benefited directly or indirectly from several policy developments, a number of them part of stimulus and recovery plans. Some measures consist of extending existing policies, while others implement new support schemes. The majority of recent policy developments have taken place in European countries (see table below). Among these new or updated policies are direct incentives, such as subsidies, tax incentives, rebates and loan programmes for renewable heating systems as well as for the electrification of heating (e.g. with heat pumps) in buildings and industry. Other measures include the implementation of a national CO<sub>2</sub> price, renewable mandates in building energy codes, and support for the expansion and conversion of district heating networks to renewable heat sources (e.g. solar thermal, biomass) and for the use of renewable-based hydrogen in high-temperature industrial processes (e.g. iron and steel). Various policies targeting energy efficiency in industry and buildings (e.g. retrofits) are also expected to play a key role in enabling new opportunities for renewable heat technologies where complementary measures exist.

Financial incentives remain the most common type of policy support to encourage renewable heat uptake globally, while regulatory measures are in most cases directed at new building construction. This is the case, for instance, with bans and restrictions on certain fossil fuel technologies, which are becoming increasingly prevalent in the buildings sector, and can indirectly stimulate the use of renewables for space and water heating (REN21, 2021). Beyond national policies, such as in Germany, France, Sweden, Slovenia and the United Kingdom, many of these bans are introduced at the municipal level, confirming the sustained dynamism of subnational jurisdictions in renewable heat policy making. Nevertheless, local governments often lack knowledge about renewable heat options and have limited experience in implementing renewable heat policies.

This recent increase in policy attention on renewable heat is welcome, but remains largely below the ambitions of the IEA Net Zero by 2050 Scenario.

**Table 3.1 Recent policy updates encouraging the uptake of renewable heat**

Country/ region	Policy update	Policy type and sector*
Austria	<ul style="list-style-type: none"> <li>In May 2021 the budget of the Austrian Climate and Energy Fund grant scheme for large solar thermal plants <a href="#">was increased to EUR 45 million</a> for the period until February 2023.</li> <li>(Styria): An <a href="#">amendment to the Styrian building law</a> came into force in October 2021. The new regulation requires that new large buildings are equipped with solar thermal or solar PV systems in proportion to their gross floor area.</li> </ul>	<p>Economic incentives (B, I)</p> <p>Regulation (B)</p>
Canada	<ul style="list-style-type: none"> <li>(Quebec): The <a href="#">2030 Plan for a Green Economy</a>, launched in November 2020:               <ul style="list-style-type: none"> <li>Commits to a 50% reduction in emissions related to heat for buildings by 2030 (and 60% for government buildings compared to 1990), to be achieved by way of support measures for heat electrification, with a budget of CAD 550 million.</li> <li>Targets 10% renewable natural gas in the network by 2030.</li> </ul> </li> <li>(British Columbia): From January to June 2021 the province <a href="#">doubled the rebates</a> available under the CleanBC Better Homes scheme for the replacement of fossil fuel heating with residential heat pumps.</li> <li>(British Columbia): The Greenhouse Gas Reduction (Clean Energy) Regulation <a href="#">was amended in 2021</a>, giving utilities the right to pay for and blend up to 15% renewable gas in their public gas supply. These changes support the target of 15% renewable gas use by 2030.</li> </ul>	<p>Targets, Economic incentives (B)</p> <p>Economic incentives (B)</p> <p>Regulation</p>
Denmark	<ul style="list-style-type: none"> <li>The <a href="#">Danish Climate Agreement for Energy and Industry 2020</a>, adopted in June 2020:               <ul style="list-style-type: none"> <li>Allocates DKK 2.5 billion in subsidies from 2020 to 2030 for electrification and energy efficiency improvements in industry, and DKK 2.9 billion for low-carbon gases.</li> <li>Lowers taxes on renewable electricity used for heat in buildings.</li> <li>Raises taxes on fossil fuels for heating.</li> <li>Allocates DKK 2.3 billion for the replacement of oil and natural gas boilers with “green” heat sources.</li> <li>Cancels the mandatory requirement binding consumers to use natural gas in some areas.</li> <li>Removes the requirement that some district heating plants have to generate both electricity and heat, making it easier to switch to renewable heat sources.</li> </ul> </li> </ul>	<p>Economic incentives, Regulation (B, I)</p>



Country/ region	Policy update	Policy type and sector*
Finland	<ul style="list-style-type: none"> <li>• <a href="#">Grants have been introduced</a> to support the phase-out of oil boilers in households and municipal buildings (EUR 45 million budget for 2020).</li> </ul>	Economic incentives (B)
France	<ul style="list-style-type: none"> <li>• The <a href="#">Heat Fund</a> has been continued in 2021, with an annual budget of EUR 350 million. The scheme has been extended to solar thermal projects (&lt; 250 m<sup>2</sup>) for space and domestic water heating. Geothermal projects under 1 000 MWh now benefit from a flat-rate grant.</li> <li>• New installations of oil-fired boilers <a href="#">will be banned</a> from mid-2022.</li> <li>• The new building code (RT2020) will come into force in 2022. It requires new buildings to be energy positive, which implies the integration of renewable energy systems.</li> <li>• The programme <a href="#">MaPrimeRenov</a>, launched in 2020, provides grants for energy efficiency and renewable heat in buildings. It <a href="#">replaced two previous programmes</a>. This change was made to simplify the administrative process. The scheme was extended in 2021.</li> </ul>	Economic incentives (B) Regulation (B) Regulation (B) Economic incentives (B)
Germany	<ul style="list-style-type: none"> <li>• The new <a href="#">Buildings Energy Act</a> (EEG) (in force since November 2020) replaced the Act on the Promotion of Renewable Energy in the Heat Sector (EEWärmeG). It limits the installation of oil-fired heating systems and fossil fuel boilers from 2026, and places tighter mandates on how much energy can be used in new buildings. The EEG also <a href="#">requires minimum shares of renewable energy</a> in heating and cooling for public buildings and new buildings.</li> <li>• The <a href="#">National Emissions Trading System</a> (nEHS) for heat and transport fuels was launched in 2021. The scheme will be phased in progressively, with a fixed price per tonne of CO<sub>2</sub>, rising from EUR 25/tonne of CO<sub>2</sub> in 2021 to 55 EUR/tonne of CO<sub>2</sub> in 2025, followed by auctions from 2026. The revenue from this scheme will finance a reduction in consumer electricity rates (via a decrease in the renewable electricity levy).</li> </ul>	Regulation (B) Economic incentives (B, I)
India	<ul style="list-style-type: none"> <li>• <a href="#">Guidelines</a> for biogas production were issued in April 2021, envisaging up to 10% biogas being blended into the domestic gas network.</li> </ul>	Regulation (B, I)
Italy	<ul style="list-style-type: none"> <li>• The <a href="#">110% Superbonus tax deduction</a> scheme for energy efficiency retrofits and heating and cooling system replacement (including heat pump installations) in the residential sector was extended until the end of 2022.</li> </ul>	Economic incentives (B)

Country/ region	Policy update	Policy type and sector*
Ireland	<ul style="list-style-type: none"> <li>In October 2021 the country announced the ambition to install <a href="#">600 000 heat pumps by 2030</a>, of which 400 000 are to be in existing buildings, as part of the National Development Plan 2021-2030.</li> </ul>	Target (B)
Lithuania	<ul style="list-style-type: none"> <li>The government is offering <a href="#">compensatory payments</a> to building owners for the replacement of inefficient or fossil fuel boilers with more efficient biofuel boilers or heat pumps. It has a budget of EUR 14 million from EU investment funds until 2022.</li> </ul>	Economic incentives (B)
Netherlands	<ul style="list-style-type: none"> <li>The <a href="#">Renewable Energy Transition Incentive Scheme</a> (SDE++) replaces and broadens the former SDE+ scheme to include renewable and low-carbon heat (geothermal, aquathermal, biomass and solar thermal systems as well as electric boilers, large-scale heat pumps and renewable gases). The next round of SDE++ will award EUR 11 billion of projects with public support of up to EUR 8 billion.**</li> </ul>	Economic incentives (B, I)
Poland	<ul style="list-style-type: none"> <li>Following a pilot phase started in 2019, Poland updated its <a href="#">District Heating</a> support scheme, which offers grants and loans for the integration of renewable energy and waste heat into district heat networks. The total budget for the programme is PLN 500 million, of which PLN 150 million is for grants and PLN 350 million is for loans.</li> </ul>	Economic incentives, Finance (DHC)
Portugal	<ul style="list-style-type: none"> <li>The <a href="#">More Sustainable Buildings</a> programme, launched in September 2020, offers investment grants for decarbonisation and energy efficiency in buildings, including for efficient air-conditioning and heating systems such as heat pumps and solar thermal. Following the success of the first phase, the initial EUR 4.5 million budget envelope was expanded, and a EUR 30 million budget is allocated to the second phase, which runs until the end of 2021.</li> </ul>	Economic incentives (B)
Romania	<ul style="list-style-type: none"> <li>In November 2020 the European Commission <a href="#">approved a EUR 150 million Romanian scheme</a> to support the construction of renewables-based district heating systems or the conversion of existing networks to renewable energy sources.</li> </ul>	Economic incentives (DHC)
Senegal	<ul style="list-style-type: none"> <li>The government introduced <a href="#">VAT exemptions for solar thermal and PV components</a> in summer 2020.</li> </ul>	Economic incentives (B, I)

Country/ region	Policy update	Policy type and sector*
Slovenia	<ul style="list-style-type: none"> <li>The final <a href="#">National Energy and Climate Plan</a> submitted in 2020 indicates a commitment to ban the installation of new heating oil boilers from 2023 at the latest.***</li> </ul>	Regulation (B)
Spain	<ul style="list-style-type: none"> <li>In September 2020 the country launched an <a href="#">investment grant scheme</a> focused on renewables-based thermal energy production.</li> <li>In June 2021 a further <a href="#">investment grant scheme</a> was launched for the implementation of renewable heat in the residential sector, within the framework of the Recovery Plan, endowed with EUR 200 million. The grants are available until the end of 2023.</li> </ul>	Economic incentives (B, I) Economic incentives (B)
United Kingdom	<ul style="list-style-type: none"> <li>The <a href="#">Ten-Point Plan for a Green Industrial Revolution</a>, launched in November 2020, sets a target of 600 000 heat pump installations per year by 2028 in residential and public buildings.</li> <li>The Domestic Renewable Heat Incentive Scheme (DRHI) <a href="#">was extended until March 2022</a>.</li> <li>In July 2020 the government announced a GBP 2 billion budget for the Green Home Grant scheme, which opened in September the same year. In November 2020 announcement was made to extend the scheme until March 2022 with an additional budget of GBP 1 billion. However, the programme <a href="#">was closed to new applicants a year early in March 2021</a>, with only a small fraction of the initial budget spent.</li> <li>In October 2021 the government confirmed that new gas boiler installations <a href="#">will be banned from 2035</a>.</li> <li>(Scotland): The <a href="#">Social Housing Net Zero Heat Fund</a>, launched under the Low Carbon Infrastructure Transition Programme, was allocated GBP 100 million over five years. It supports social landlords across Scotland with capital grant and loan funding for energy efficiency and low-carbon heating projects (including heat pumps, biomass boilers and connection to existing heat networks) in social housing.</li> <li>(Scotland): The SME Loan fund, launched in 2008, offers small and medium-sized enterprises based in Scotland interest-free loans of up to GBP 100 000 over 8 years and cashback grants for renewable or energy efficiency projects. A new scheme was allocated GBP 4 million in 2021.</li> </ul>	Targets (B) Economic incentives (B) Economic incentives, Finance (B) Regulation (B) Finance (B) Finance (I)

Country/ region	Policy update	Policy type and sector*
United States	<ul style="list-style-type: none"> <li>(California): In 2020 regulators <a href="#">allocated USD 45 million to incentives for electric heat pump water heaters</a> until 2025.</li> <li>(California): In August 2021 the California Energy Commission approved the <a href="#">2022 Energy Code</a>, which includes electric heat pumps as a baseline technology for new builds and requires new single family homes to be “electric-ready”. Pending approval by the state’s Building Standards Commission, the new code would take effect in January 2023.</li> <li>(New Mexico): The state’s solar tax credit, which expired in 2016, was <a href="#">reinstated in 2020</a>. Solar thermal water heaters are eligible for this support, which amounts to 10% of total installation costs.</li> <li>(Washington): The Commercial Property Assessed Clean Energy (C-PACER) programme <a href="#">went into effect in June 2020</a>. Under this scheme, renewable heat investments are eligible for loans that run with the property and are repaid through property taxes.</li> </ul>	<p>Economic incentives (B)</p> <p>Regulation (B)</p> <p>Economic incentive (B)</p> <p>Finance (B)</p>
European Union	<ul style="list-style-type: none"> <li>In 2020 the European Commission committed to a legally binding emissions reduction target of 55% by 2030 compared to 1990.****</li> <li>In July 2021 the European Commission proposed the “Fit-for-55” policy package, which will be discussed by the Council and the European Parliament over the next two years. Among key elements, the package proposes to set up a specific emissions trading system for buildings emissions, and to revise upwards renewable energy targets under the Renewable Energy Directive (REDII). The proposal requires member states to achieve at least 49% renewables in buildings energy use by 2030 and to increase the use of renewable energy in heating and cooling by 1.1 percentage points each year, alongside a ban on fossil fuels in district heating and cooling. An EU benchmark for the use of renewables in industry is also part of the proposal, including a certification system for renewable and low-carbon fuels. In addition, the European Commission proposed to set up <a href="#">risk mitigation frameworks</a> to help reduce the cost of capital for renewable heating and cooling projects.***</li> </ul>	<p>Targets (B, I)</p> <p>Targets, Economic incentives (B, I)</p>

\* “Economic incentives” include direct subsidies and grants, rebates, tax reliefs and other fiscal incentives, and feed-in-tariffs; “Finance” refers to loans; “Regulation” refers to mandates, bans, norms and codes. (B) = buildings; (I) = industry; (DHC) = district heating and cooling.

\*\* The SDE++ is also a tender-based sliding feed-in premium scheme that compensates the difference between the technology cost and the market price of the energy service. However, it is now allocated on the basis of avoided CO<sub>2</sub> emissions instead of renewable energy production. It also applies to industrial companies that generate renewable power, heat and gas for their own use.

\*\*\* Policies not enacted yet.

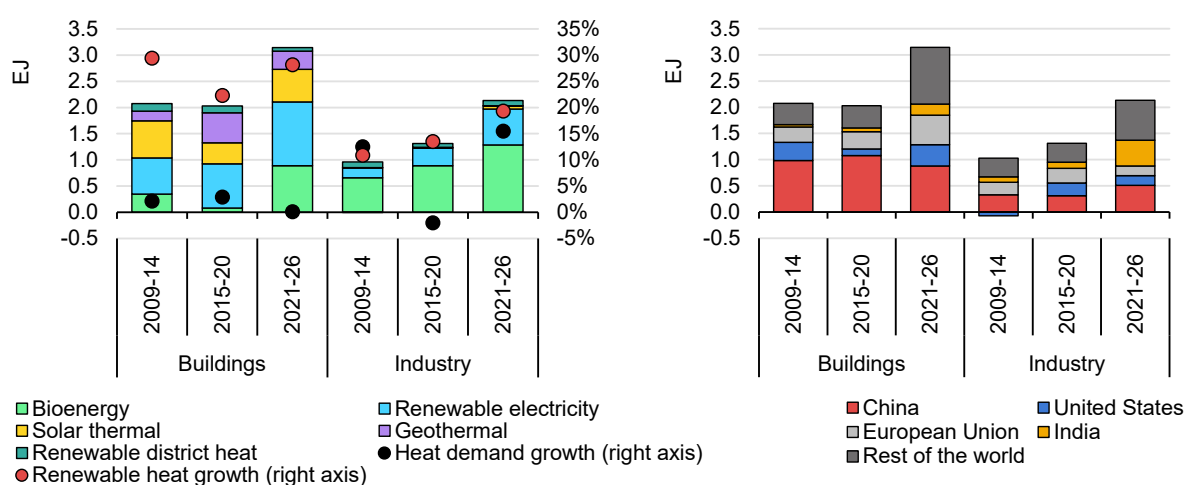
\*\*\*\* This target refers to CO<sub>2</sub> emitted within the borders of the European Union (production-based approach); it excludes embodied CO<sub>2</sub> emissions from foreign trade, in contrast to a footprint – or consumption-based – accounting approach.

Sources: Solarthermalworld (2021a, 2021b, 2021c); Building Times (2021); Gouvernement du Québec (2021); British Columbia (2021a, 2021b); KEFM (2020); Valtioneuvosto (2020); Ecologie.gouv (2021a, 2021b); Effy (2021); PrimesEnergie (2021); BMI (2021a, 2021b); ICAP (2021); Government of India (2021); Gov.ie (2021); Rödle & Partner (2021); Apva (2021); Netherlands Enterprise Agency (2021); Serwis Rzeczypospolitej Polskiej (2021); STEP (2021); European Commission (2020); Republika Slovenija (2020); IDEA (2021); Gov.UK (2021a, 2021b); BNEF (2021d); Energy Live News, (2021); Scottish Government (2021); Greentechmedia (2020); Reuters (2021); SolarReviews, (2021); The National Law Review (2021); Georisk (2021).

## Outlook to 2026

Considering the policy landscape as of September 2021, global heat demand is projected to expand by 17 EJ during 2021-2026. This increase of almost 9% is about three times larger than that during the decade 2011-2020. The industrial sector accounts for almost all of this growth, half of which occurs in China and India. Traditional uses of biomass are anticipated to decline slightly by 1.7 EJ (down 7%) over the outlook period, mostly in China and India, driven in part by the deployment of improved biomass cookstoves.

**Figure 3.2 Increase in renewable heat consumption by energy source (left) and country/region (right), 2009-2026**



IEA. All Rights Reserved

Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), [World Energy Statistics and Balances 2021](#) (database); IEA (2021b), [World Energy Outlook 2021](#).

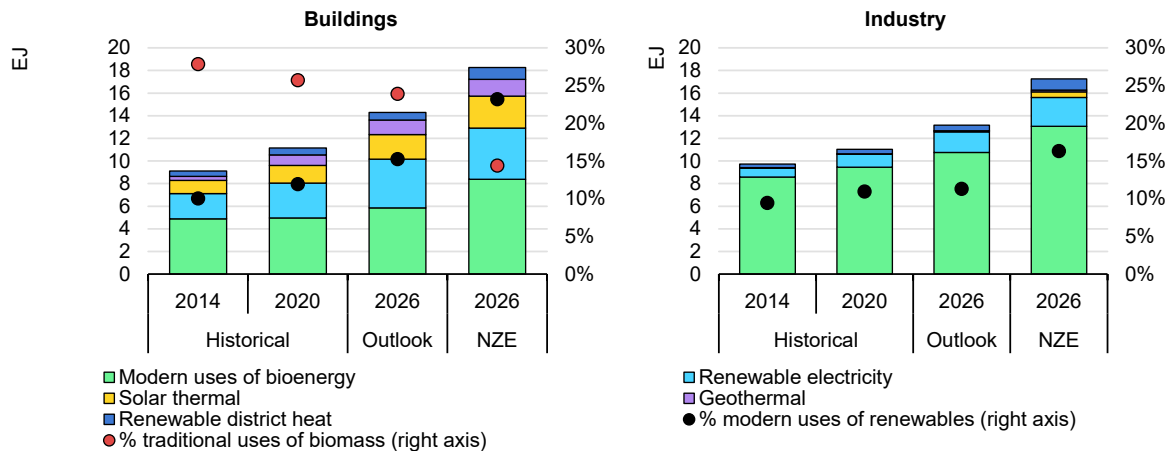
Global modern renewable heat consumption is expected to increase at a faster rate than heat demand, expanding by a quarter (an increase of 5.4 EJ)<sup>3</sup> in the next five years, with the majority of the growth occurring in the buildings sector. While the share of modern uses of renewables rises from 11% in 2020 to 13% in 2026, these investments fall short of containing non-renewable heat consumption. Fossil fuel consumption for heat is forecast to see a 5% increase in heat-related CO<sub>2</sub> emissions over the outlook period, equivalent to 0.6 Gt CO<sub>2</sub>.

For comparison, to align with the IEA Net Zero Emissions Scenario, renewable heat consumption would have to progress 2.5 times faster, combined with wide-

<sup>3</sup> This is excluding ambient heat harnessed by heat pumps, for which limited data are available globally, especially in the industrial sector.

scale behavioural change and much larger energy and material efficiency improvements in both buildings and industry.

**Figure 3.3 Renewable heat consumption and share of total heat demand in buildings and industry, 2014-2026**



IEA. All rights reserved

Notes: NZE = IEA Net Zero Emissions by 2050 Scenario. This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), [World Energy Statistics and Balances 2021](#) (database), IEA (2021b), [World Energy Outlook 2021](#).

## Buildings

The rising share of renewables in the power sector and heat pump deployment are the main drivers of renewable heat growth in buildings

Global heat consumption in buildings is expected to remain stable during the outlook period, since energy efficiency improvements counter growth in energy demand from an expanding building stock. Meanwhile, the use of renewable heat in buildings, including ambient heat, is projected to grow by almost 35%.

Renewable electricity is, as in the past decade, the largest contributor to this growth, owing primarily to the rising share of renewables in the power sector, and – to a lesser extent – increasing reliance on electricity for heat in buildings (via electric heat pumps and boilers). China, the United States and the European Union together account for two-thirds of the global increase in renewable electricity use for heat in buildings.

It will be crucial to anticipate the impacts of the greater electrification of heat on electricity demand patterns when planning future developments in the power sector, including grid infrastructure needs. While the electrification of heat increases electricity demand, it can also potentially contribute to the integration of

variable renewable electricity by providing demand-side flexibility, using (for instance) the thermal inertia of buildings and hot water tanks for load shifting.

While global data are limited, key markets for electric air-source heat pumps are expanding rapidly, including in the European Union, where heat pump sales have experienced double-digit growth over the past five years (EHPA, 2021). As this expansion continues, the amount of ambient heat harnessed by electric heat pumps in the buildings sector is expected to almost double during the outlook period, increasing by 1.1 EJ and making the second-largest contribution to renewable heat uptake in buildings after renewable electricity.

Modern bioenergy accounts for a fifth (0.9 EJ) of the projected increase in renewable heat use in buildings over 2021-2026. A third of the additional consumption takes place in sub-Saharan Africa, where improved cookstoves slightly alleviate the expansion of traditional uses of biomass, which continue to dominate heat supplies. Similarly, India and China together contribute another 30% of modern bioenergy growth in buildings, while the European Union is responsible for half of the remainder thanks to support for wood chip and pellet stoves and boilers in various countries, especially in Italy, France and Germany.

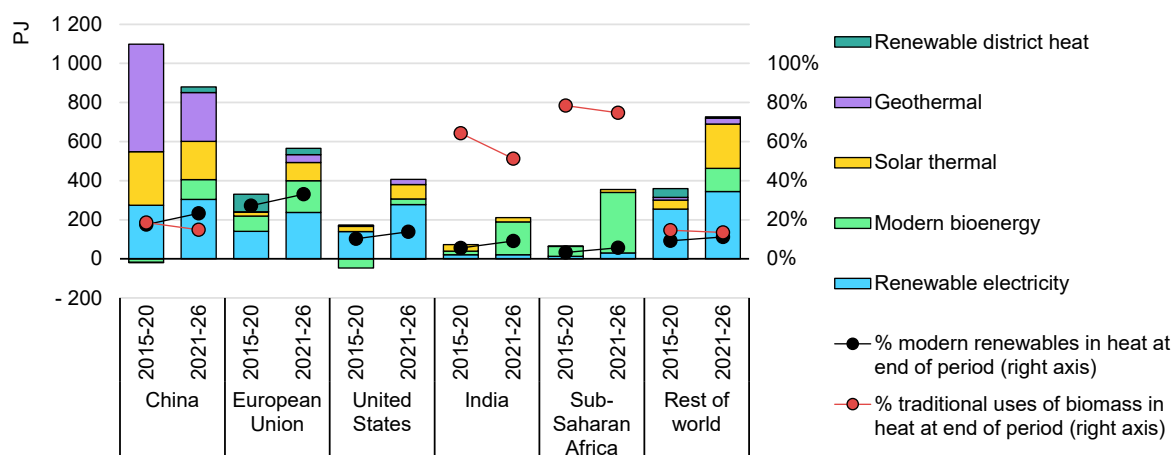
Notwithstanding a [4% year-on-year decline in new capacity additions in 2020](#), mostly due to market slowdown in China, the United States and India, solar thermal heat consumption in buildings is projected to expand by 40% over the outlook period (0.6 EJ). Despite its domestic market declining, China is anticipated to continue leading this consumption growth, followed by the Middle East, the European Union and the United States. Together, these regions represent almost three-quarters of the increase. In most of these large markets, however, limited policy support and increasing policy maker interest in the electrification of end uses mean that small-scale solar water heating systems face competition not only from heat pumps, but also from rooftop PV systems (IEA SHC, 2020). From this perspective, hybrid systems combining PV and thermal (PVT) technologies offer enormous potential. The global market for PVT systems saw rapid growth of 9% in 2020 (IEA SHC, 2021). While domestic solar water heaters still represent the large majority of installations, there is also growing interest in large-scale solar thermal systems connected to district heating networks.

Direct geothermal heat consumption is projected to increase by more than one-third globally, nearing 1.3 EJ by 2026. China dominates this trend, accounting for almost three-quarters of geothermal developments despite a contracting domestic market, followed by the European Union and the United States. Deep geothermal



heat has recently received growing interest from oil companies, for which it offers opportunities to diversify their activities while building on their drilling expertise.

**Figure 3.4 Increase in renewable heat consumption in buildings, and share of modern renewables and traditional uses of biomass in buildings heat demand, selected regions, 2015-2026**



IEA. All rights reserved

Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), [World Energy Statistics and Balances 2021](#) (database); IEA (2021b), [World Energy Outlook 2021](#).

## Industry

### Despite rising contributions from bioenergy and electricity, renewable heat consumption in industry fails to match expanding heat demand

Driven by economic growth, industrial heat consumption is projected to expand by 15% globally during 2021-2026, an increase of 16 EJ. Renewables are expected to account for only one-fifth of this growth. Fossil fuels supply the remaining four-fifths, leading to a 12% surge in annual heat-related industrial CO<sub>2</sub> emissions. By 2026 the share of renewables in industrial heat consumption is anticipated to remain near 11%, only 0.4 percentage points higher than in 2020.

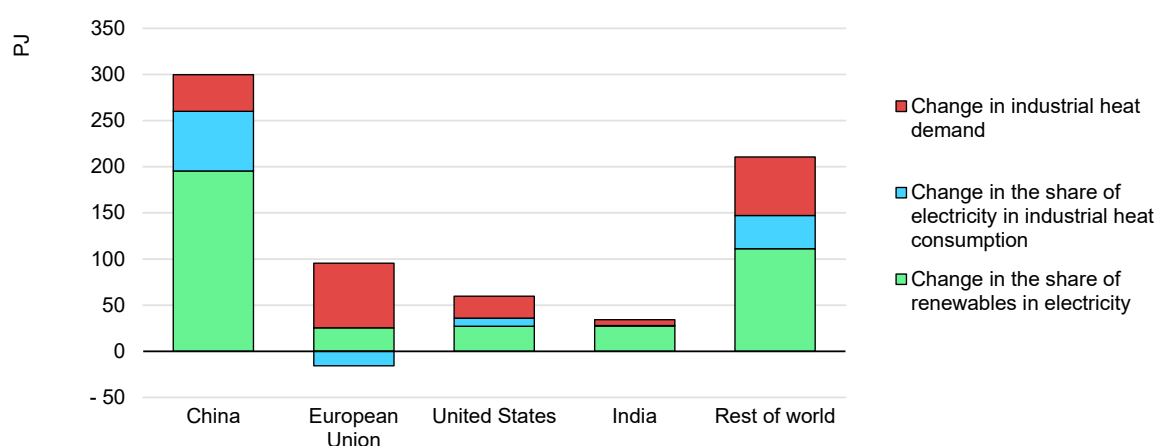
Bioenergy makes the largest contribution to renewable heat progression in industry, with consumption in 2026 projected to exceed 2020 levels by 1.2 EJ (up 14%). Half of this increase is expected to take place in India and Brazil – the two largest industrial bioenergy consumers – owing primarily to greater use of bagasse in the sugar and ethanol industries and biomass in the food industry. China, the United States and the European Union together are responsible for a further quarter of the additional industrial bioenergy consumption, due to the growth of



bioenergy-intensive subsectors like the pulp and paper industry, as well as expanding use of waste in the cement subsector.

The share of electricity in global industrial heat consumption is expected to make little progress over the outlook period, rising by less than half a percentage point to 4.5% in 2026. China contributes almost half of this slow electrification trend. Still, renewable electricity used for heat in industry is projected to expand by 60% (0.7 EJ) globally during 2021-2026, driven primarily by spillover effects from renewables uptake in power generation and, to a lesser extent, by the overall expansion of industrial heat demand. After China, the largest contributors are the European Union, the United States and India. Together these four markets are expected to account for almost 70% of the growth in renewable electricity use for industrial heat.

**Figure 3.5 Contribution of different factors to changes in renewable electricity consumption in industry, selected regions, 2021-2026**

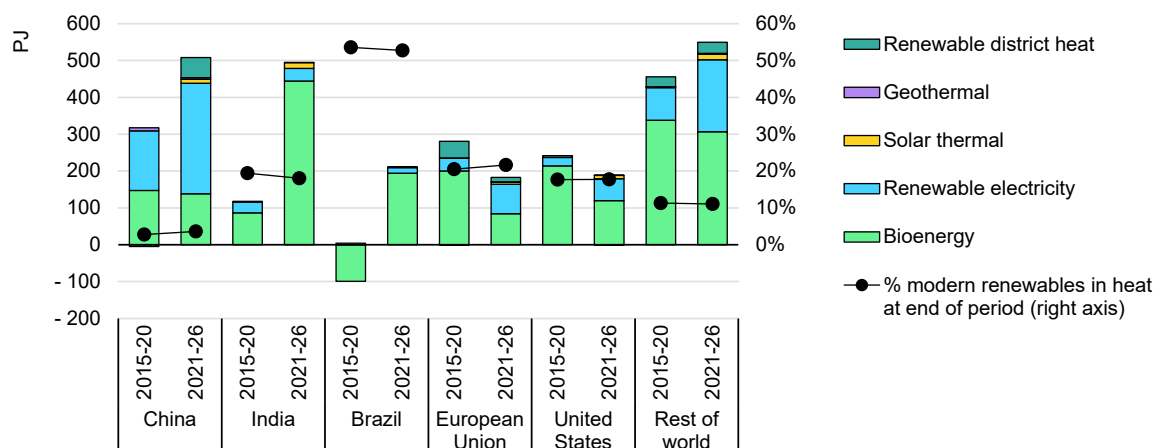


IEA. All rights reserved

Source: IEA (2021b), [World Energy Outlook 2021](#).

Despite its current negligible contribution (less than 0.02% of global industrial heat consumption), solar heat for industrial processes continues to see rising interest, with about 900 projects in operation worldwide by the end of 2020, representing more than 1.1 million m<sup>2</sup> of collector area and near 500 MW<sub>th</sub> of capacity (IEA SHC, 2021). Well suited to a number of industrial applications with low- to medium-temperature heat requirements, such as in the food, textile and chemical industries, the global potential for solar heat in industrial processes is largely untapped. From its low base, solar thermal heat consumption in industry is expected to triple during 2021-2026, an increase of 57 PJ, with the largest single contribution from India, followed by China, the United States, the European Union and South Africa.

**Figure 3.6 Increase in renewable heat consumption in industry and share of renewables in industrial heat demand, selected regions, 2015-2026**



IEA. All rights reserved

Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021c), [World Energy Statistics and Balances 2021](#) (database); IEA (2021b), [World Energy Outlook 2021](#).

Limited development of district heating and cooling is anticipated during the outlook period, with total global consumption expected to be 11% higher in 2026 compared to 2020, growth of 1.4 EJ, yet still meeting less than 7% of total heat demand. The share of district supplies from renewable sources is expected to remain low at around 8% globally. Most renewable district heating and cooling developments during the next five years are expected to take place in China and the European Union, benefiting mostly the industrial sector in the former case, and the buildings sector in the latter. While bioenergy and municipal waste account for the large majority of renewable district supplies, large-scale solar thermal systems and heat pumps are seeing growing interest. By the end of 2020, 262 large-scale solar district heating systems totalling 1.4 GW<sub>th</sub> were in operation worldwide, with Denmark in the lead, followed distantly by China and Germany (IEA SHC, 2021).

### Keeping up with ambitions in the IEA NZE Scenario requires much faster policy action globally in both industry and buildings

In the IEA Net Zero Emissions by 2050 Scenario, the use of modern renewable heat in buildings expands twice as fast as in our outlook, and almost three times as fast in industry.

The largest discrepancies are seen in modern bioenergy use, with additional growth of 5.1 EJ during 2021-2026 under the Net Zero Emissions Scenario compared to our outlook, almost evenly split between the industrial and buildings sectors. In industry, this gap comes primarily from greater use of municipal solid waste in the cement subsector, and greater reliance on on-site residues for pulp

and paper industries in the Net Zero Emissions Scenario. In buildings, the wider rollout of improved biomass cookstoves enables further substitution of traditional uses of biomass.

Assuming both more rapid penetration of renewables in power generation and greater electrification of heat through heat pumps and direct electric processes (e.g. induction or electric arc furnaces for secondary steelmaking), the Net Zero Emissions Scenario sees thermal uses of renewable electricity in industry expanding twice as fast as in our outlook. In buildings, behavioural changes and envelope retrofits completely offset additional electricity consumption associated with the massive deployment of heat pumps described in the Net Zero Emissions Scenario. The number of heat pumps installed in buildings globally is 50% larger than in our outlook by 2026, expanding to 600 million units by 2030, driven by the introduction of bans on fossil fuel boilers. By 2030 heat pumps meet 20% of energy demand for heat in buildings, up from 5% in 2019 (IEA, 2021c; REN21, 2021).

Direct solar thermal consumption grows more than 2.5 times as fast during 2021-2026 in the Net Zero Emissions Scenario than anticipated in our outlook, a difference of 1.1 EJ. The addition is both from the installation of solar thermal water heaters in buildings and the take-off of solar heat for industrial processes. Accordingly, the number of dwellings using solar thermal systems rises from 250 million in 2020 to 400 million by 2030, and up to 1.2 billion in 2050 (IEA, 2021c).

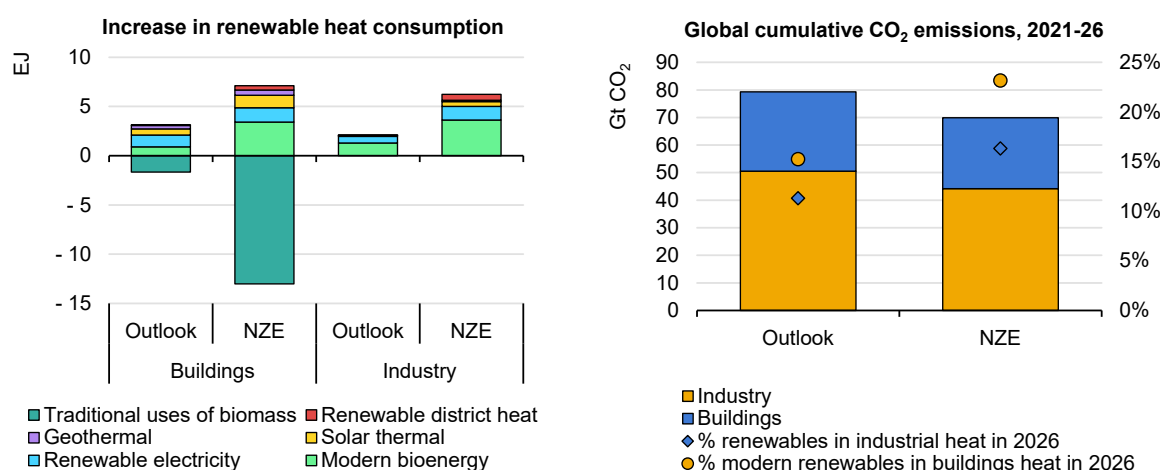
Finally, the Net Zero Emissions Scenario sees the exploitation of the decarbonisation potential of existing district heating networks far beyond our current projections, with more than a doubling of the share of renewables in global district supplies by 2026. Under these assumptions, renewable district heat consumption needs to grow six times faster than in our outlook, with contributions not only from bioenergy – the largest renewable source for district heat – but also from solar thermal and large-scale heat pumps.

In the longer term the Net Zero Emissions Scenario also sees a growing – yet limited – role for renewable gases such as biomethane and renewables-based hydrogen for heating, in specific contexts, both in buildings and industry. These renewables-based energy carriers can be introduced by progressive blending, taking advantage of existing gas infrastructure, and provided end-user appliances are compatible with blending levels. They can also be used in hybrid systems that combine electric heat pumps with gas boilers.

Beyond highlighting opportunities to expand the supply of renewable heat, the Net Zero Emissions Scenario emphasises the critical importance of simultaneously

containing heat demand through behavioural change, material efficiency and energy efficiency. For instance, the scenario's total global heat demand is 13% lower (9% lower in industry, 18% lower in buildings) than in our current projections for the year 2026. Targeting the substitution of traditional uses of biomass with more efficient cooking and heating technologies is also a critical element of the Net Zero Emissions Scenario to achieve progress towards more sustainable use of renewable sources. An important multidimensional policy gap remains to be addressed to bring heat-related CO<sub>2</sub> emissions in line with Paris Agreement ambitions.

**Figure 3.7 Growth in renewable heat consumption and global cumulative heat-related CO<sub>2</sub> emissions in the IEA outlook and Net Zero Emissions Scenario, world, 2021-2026**



IEA. All rights reserved

Note: This figure does not account for ambient heat harnessed by heat pumps.

Sources: IEA (2021a), [Net Zero by 2050](#); IEA (2021b), [World Energy Outlook 2021](#).

## References

- Apva (2021), Use of renewable energy sources in the homes of natural persons, replacing fossil fuel heat installations 2021-09 No KK-AM-KA03, [https://apvis.apva.lt/paskelbti\\_kvietimai/atsinaujinanciu-energijos-istekliu-t-y-silumos-siurbliu-oras-oras-oras-vanduo-zeme-vanduo-vanduo-vanduo-biokuro-katilu-panaudojimas-fiziniu-asmenu-gyvenamuosiuose-namuose-pakeiciant-iskastini-kuranaudojancius-silumos-irenginius-2021-09](https://apvis.apva.lt/paskelbti_kvietimai/atsinaujinanciu-energijos-istekliu-t-y-silumos-siurbliu-oras-oras-oras-vanduo-zeme-vanduo-vanduo-vanduo-biokuro-katilu-panaudojimas-fiziniu-asmenu-gyvenamuosiuose-namuose-pakeiciant-iskastini-kuranaudojancius-silumos-irenginius-2021-09), (accessed October 2021)
- BNEF (2021d), Reversal of U.K. Green Stimulus Flattens Heat Pump Outlook, <https://www.bnef.com/insights/26225/view> (accessed October 2021)
- BMI (2021a), The new Buildings Energy Act, <https://www.bmi.bund.de/EN/topics/building-housing/building/energy-efficient->

- [construction-renovation/buildings-energy-act/buildings-energy-act-node.html](https://www.renewableheat.org/construction-renovation/buildings-energy-act/buildings-energy-act-node.html) (accessed October 2021)
- BMI (2021b), Legal Framework and support schemes for renewable heat, [https://energie-fr-de.eu/fr/manifestations/lecteur/conference-en-ligne-sur-la-chaaleur-renouvelable.html?file=files/ofaenr/02-conferences/2021/210520\\_chaleur\\_renouvelable/Presentations/02\\_Katrin\\_Rosendahl\\_BMWi\\_DFBEW\\_OFATE.pdf](https://energie-fr-de.eu/fr/manifestations/lecteur/conference-en-ligne-sur-la-chaaleur-renouvelable.html?file=files/ofaenr/02-conferences/2021/210520_chaleur_renouvelable/Presentations/02_Katrin_Rosendahl_BMWi_DFBEW_OFATE.pdf), (accessed October 2021)
- British Columbia (2021a), Province doubles CleanBC home energy retrofit rebates, [https://archive.news.gov.bc.ca/releases/news\\_releases\\_2020-2024/2020EMLI0068-002140.htm](https://archive.news.gov.bc.ca/releases/news_releases_2020-2024/2020EMLI0068-002140.htm), (accessed October 2021)
- British Columbia (2021b), Province enables increased investments in renewable gas, hydrogen, <https://news.gov.bc.ca/releases/2021EMLI0046-001286>, (accessed October 2021)
- Building times (2021), Steiermarkt bringt Solarpflicht, [https://buildingtimes.at/recht\\_politik/steiermarkt-bringt-solarpflicht/](https://buildingtimes.at/recht_politik/steiermarkt-bringt-solarpflicht/) (accessed October 2021)
- Ecologie.gouv (2021a), Évolution du Fonds chaleur en 2021, <https://www.ecologie.gouv.fr/evolution-du-fonds-chaaleur-en-2021>, (accessed October 2021)
- Ecologie.gouv (2021b), MaPrimeRénov', <https://www.economie.gouv.fr/plan-de-relance/profils/particuliers/maprimerenov> (accessed October 2021)
- Effy (2021), L'interdiction d'installation de chaudières au fioul reportée à mi-2022, <https://www.effy.fr/pro/actualite/interdiction-installation-chaudieres-fioul-reportee-mi-2022>, (accessed October 2021)
- EHPA (2021), [http://www.stats.ehpa.org/hp\\_sales/country\\_cards/](http://www.stats.ehpa.org/hp_sales/country_cards/) (database) (accessed October 2021)
- Energy Live News (2021), Boris Johnson confirms ban on all new gas boilers by 2035, <https://www.energylivenews.com/2021/10/18/boris-johnson-confirms-ban-on-all-new-gas-boilers-by-2035/> (accessed October 2021)
- European Commission (2020), State aid: Commission approves €150 million Romanian scheme to support investments in district heating systems based on renewable energy sources, [https://ec.europa.eu/commission/presscorner/detail/en/IP\\_20\\_2033](https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2033) (accessed October 2021)
- Georisk (2021), Geothermal risk mitigation established by the EU's legislative arsenal for renewables in heating and cooling, <https://www.georisk-project.eu/press-release-geothermal-risk-mitigation-established-by-the-eus-legislative-arsenal-for-renewables-in-heating-and-cooling/> (accessed October 2021)
- Greentechmedia (2020), California moves to tackle another big emissions source: fossil fuel use in buildings, <https://www.greentechmedia.com/articles/read/california-moves-to-tackle-another-big-emissions-source-fossil-fuel-use-in-buildings> (accessed October 2021)
- Gouvernement du Québec (2021), 2030 Plan for a Green Economy, <https://www.quebec.ca/en/government/policies-orientations/plan-green-economy>, (accessed October 2021)

- Gov.ie (2021), Climate Action Plan 2021  
<https://www.gov.ie/en/publication/6223e-climate-action-plan-2021/> (accessed November 2021)
- Gov.UK (2021a), The ten point plan for a green industrial revolution,  
<https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution>, (accessed October 2021)
- Gov.UK (2021b), 28 April 2020: Changes to RHI support and COVID-19 response: notice of proposals, <https://www.gov.uk/government/publications/changes-to-the-renewable-heat-incentive-rhi-schemes/changes-to-rhi-support-and-covid-19-response> (accessed October 2021)
- Government of India (2021), Policy Guideline No.1 of 2021-PNG/GP,  
<https://satat.co.in/satat/pages/assets/download/Policy%20Guideline%20No.%201%20of%202021-PNGGP.pdf>, (accessed October 2021)
- ICAP (2021), German National Emissions Trading System,  
[https://icapcarbonaction.com/en/?option=com\\_etsmap&task=export&format=pdf&layout=list&systems%5b%5d=108#:~:text=Prices%20were%20set%20at%20EUR,\(USD%2062.82\)%20in%202025](https://icapcarbonaction.com/en/?option=com_etsmap&task=export&format=pdf&layout=list&systems%5b%5d=108#:~:text=Prices%20were%20set%20at%20EUR,(USD%2062.82)%20in%202025), (accessed October 2021)
- IDEA (2021), Para Energías Renovables en autoconsumo, almacenamiento, y térmicas sector residencial (RD 477/2021. PRTR), <https://www.idae.es/ayudas-y-financiacion/para-energias-renovables-en-autoconsumo-almacenamiento-y-termicas-sector> (accessed October 2021)
- IEA (2021a), Net-Zero by 2050 – A Roadmap for the Global Energy Sector,  
<https://www.iea.org/reports/net-zero-by-2050> (accessed October 2021).
- IEA (2021b), World Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2021> (accessed September 2021).
- IEA (2021c), World Energy Statistics and Balances 2021 (database) (accessed October 2021)
- IEA SHC (2021a), Solar Heat Worldwide 2021 <https://www.iea-shc.org/Data/Sites/1/publications/Solar-Heat-Worldwide-2021.pdf> (accessed October 2021).
- IEA SHC (2020), Solar Heat Worldwide 2020 <https://www.iea-shc.org/solar-heat-worldwide-2020> (accessed October 2021).
- KEFM (2020), Danish Climate Agreement for Energy and Industry 2020 – Overview,  
[https://kefm.dk/Media/C/B/faktaark-klimaaf tale%20\(English%20august%2014\).pdf](https://kefm.dk/Media/C/B/faktaark-klimaaf tale%20(English%20august%2014).pdf), (accessed October 2021)
- Netherlands Enterprise Agency (2021), Stimulation of sustainable energy production and climate transition (SDE++), <https://english.rvo.nl/subsidies-programmes/sde> (accessed October 2021)
- PrimesEnergie (2021), Ma Prime Rénov' fusion du Crédit d'impôt transition énergétique et l'aide Anah Habiter Mieux Agilité, <https://www.primesenergie.fr/maprimerenov> (accessed October 2021)
- REN21 (2021), Global Status Report 2021, [https://www.ren21.net/wp-content/uploads/2019/05/GSR2021\\_Full\\_Report.pdf](https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf) (accessed October 2021).
- Republika Slovenija (2020), Integrated national energy and climate plan of the Republic of Slovenia,

- [https://ec.europa.eu/energy/sites/ener/files/documents/si\\_final\\_necp\\_main\\_en.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/si_final_necp_main_en.pdf)  
(accessed October 2021)
- Reuters (2021), New California rules move state away from natural gas in new buildings, <https://www.reuters.com/legal/litigation/new-california-rules-move-state-away-natural-gas-new-buildings-2021-08-11/> (accessed October 2021)
- Rödle & Partner (2021), Italy 2021 Budget Law, <https://www.roedl.com/insights/tax-newsletter-italien/2121-03/italy-2021-budget-law> (accessed November 2021)
- Scottish Government (2021), Social Housing Net Zero Heat Fund, <https://www.gov.scot/publications/social-housing-net-zero-heat-fund---call-for-funding-applications---2021/> (accessed October 2021)
- Serwis Rzeczypospolitej Polskiej (2021), Program „Ciepłownictwo powiatowe” od 1 października na nowych zasadach, <https://www.gov.pl/web/nfosigw/program-cieplownictwo-powiatowe-od-1-pazdziernika-na-nowych-zasadach> (accessed October 2021)
- SolarReviews (2021), New Mexico’s solar tax credit is back with big savings, <https://www.solarreviews.com/blog/new-mexico-solar-tax-credit> (accessed October 2021)
- Solarthermalworld (2021a), Uncapped funding for large solar heat plants in Austria <https://www.solarthermalworld.org/news/uncapped-funding-large-solar-heat-plants-austria> (accessed October 2021)
- Solarthermalworld (2021b), Little known VAT exemption in Senegal, <https://www.solarthermalworld.org/news/little-known-vat-exemption-senegal> (accessed October 2021)
- Solarthermalworld (2021c), Europe holds top spot for SHIP incentives, <https://www.solarthermalworld.org/news/europe-holds-top-spot-ship-incentives> (accessed October 2021)
- STEP (2021), Consumers benefit from Deco’s advice as More Sustainable Buildings programme gets a relaunch in Portugal, <https://www.stepenergy.eu/support-mechanisms-consumer-advice-energy-efficiency-portugal/> (accessed October 2021)
- The National Law Review (2021), Keeping “PACE” in commercial real estate improvements: a primer on the new washington Commercial Property Assessed Clean Energy and Resiliency (C-PACER) program, Volume XI, Number 302, <https://www.natlawreview.com/article/keeping-pace-commercial-real-estate-improvements-primer-new-washington-commercial> (accessed October 2021)
- Valtioneuvosto (2020), Government reaches agreement on fourth supplementary budget proposal for 2020, press release 381/2020, <https://valtioneuvosto.fi/en/-/10616/hallitus-paatti-vuoden-2020-neljannesta-lisatalousarvioesityksesta>, (accessed October 2021)

## Chapter 4. Renewable energy trends to watch

### What is the impact of increasing commodity and energy prices on solar PV, wind and biofuels?

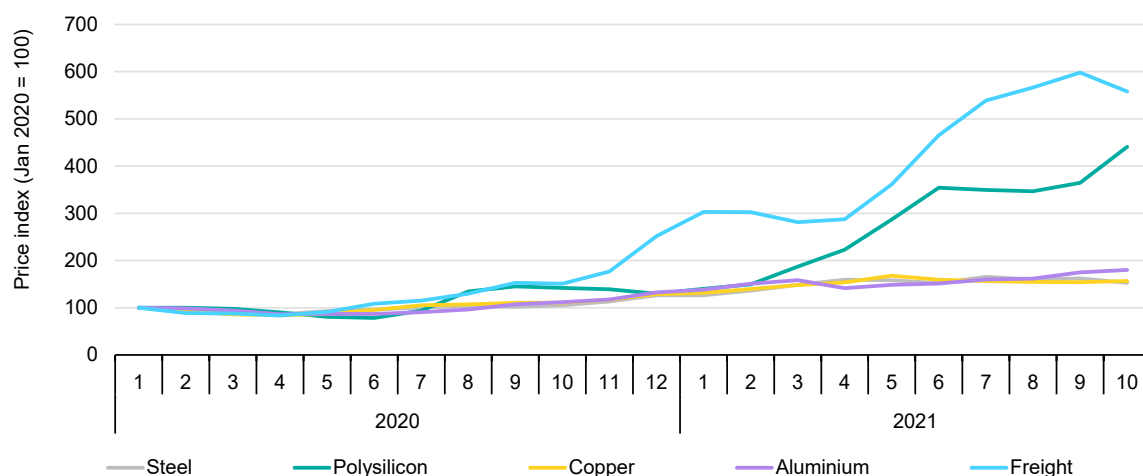
Rising commodity prices have increased the cost of producing solar PV modules, wind turbines and biofuels worldwide. This situation has short-term implications for equipment manufacturers, project developers and policy makers. Higher prices for solar PV and wind equipment have reversed the cost reduction trend that the industry has seen for more than a decade and may delay the financing of some projects already in the pipeline. While rising input prices have already resulted in policy change on biofuels in several countries, demand for wind and solar PV remains strong, as reflected in recent auction participation and corporate purchasing, even with rising prices. While uncertainty remains as to how long commodity prices will continue their upswing, the impact of rising material costs on the profitability of the renewable energy industry could have long-term implications for the cost of clean energy transitions.

#### Wind and solar PV

Prices for many industrial materials, and freight costs, have been on an increasing trajectory since Q1 2021, pushing up wind turbine and solar PV costs. Since the beginning of 2020 the price of PV-grade polysilicon has more than quadrupled, steel has increased by 50%, copper by 60% and aluminium by 80%. In addition, freight fees have increased almost sixfold, resulting in additional costs for the geographically dispersed supply chain of renewables. The reversal of the long-term trend of decreasing costs is already visible in the prices of wind turbines and PV modules, which have increased by 10-25% depending on country and region, erasing two to three years of cost reductions since 2018 from technology improvements. The exception, however, is in People's Republic of China (hereafter 'China') where wind turbine costs have continued to decrease in 2021, as demand declined following the 2020 deployment boom driven by the planned phase-out of subsidies.



**Figure 4.1 Monthly commodity and freight price indexes, 2020-2021**



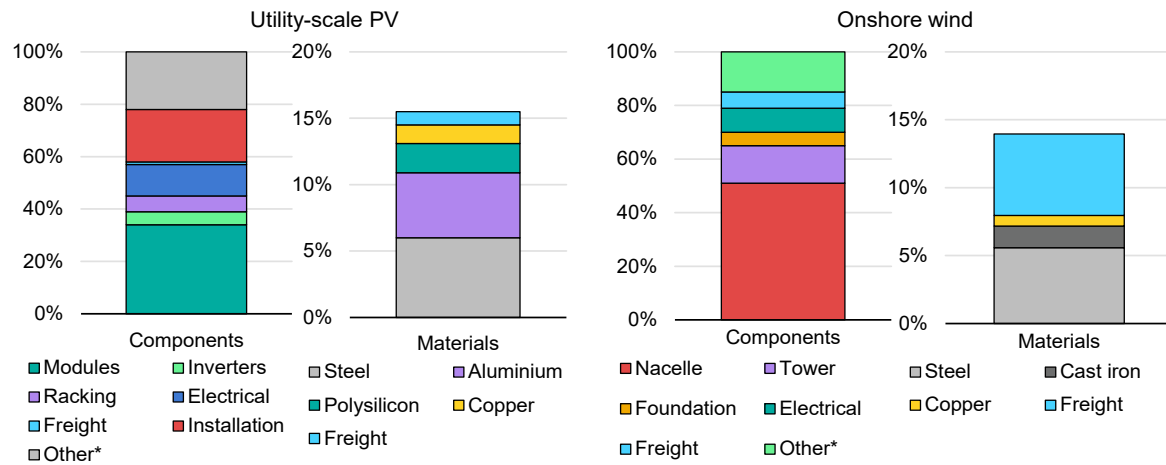
Notes: Steel – China domestic hot-rolled steel sheet spot average price; polysilicon – solar-grade silicon spot price; copper and aluminium – London Metal Exchange 3-month forward contracts; freight – WCIDCOMP Index.

Sources: IEA analysis based on Bloomberg LP (2021).

## How do commodity prices affect the investment costs of solar PV and onshore wind?

We estimate that key commodities and freight costs make up about 15% of total utility-scale solar PV and onshore wind investment costs. Solar PV’s largest cost component is the manufacturing and shipment of the module, which is directly affected by the price of polysilicon, steel and aluminium. Inverter and electrical installation costs depend on the price of copper, while all components are impacted by increasing freight rates. Steel contributes the most to the final cost of wind installations, as large quantities are used in manufacturing and construction of the tower, nacelle and mechanical equipment. Freight can make up to 6% of total onshore wind investment costs, as the transport of bulky elements with specialised ships is required.

**Figure 4.2 Utility-scale PV and onshore wind investment cost structure by component and by commodity breakdown**



\* Includes costs of project development, management and financing.  
Sources: IEA analysis, based on NREL (2019) (2020); IRENA (2020); BNEF (2021e).

Upfront capital and associated financing costs are 70-80% of the levelised cost of electricity generation for wind and 80-90% for solar PV. Thus, any increase in initial CAPEX greatly affects the profitability of the investment. We estimate that the overall investment cost of utility-scale PV and onshore wind plants could increase by around 25% due to the commodity and freight price surge, based on a comparison of average commodity prices between 2019 and 2021.

Increases in commodity prices do not immediately affect investment costs, as developers, manufacturers and other parts of the supply chain usually maintain stocks of materials and have contracts based on previous prices. However, the increase in raw material and logistics costs ultimately affects the whole value chain and could result in a higher cost of electricity generated at renewable installations. Different areas of the value chain, such as manufacturers, equipment installers and developers, can absorb cost increases in different ways, with some sectors being more affected than others. Additional hedging mechanisms, the sharing of costs or the strategic distribution of equipment are all options developers can use to minimise the impact of increased costs in the short term.

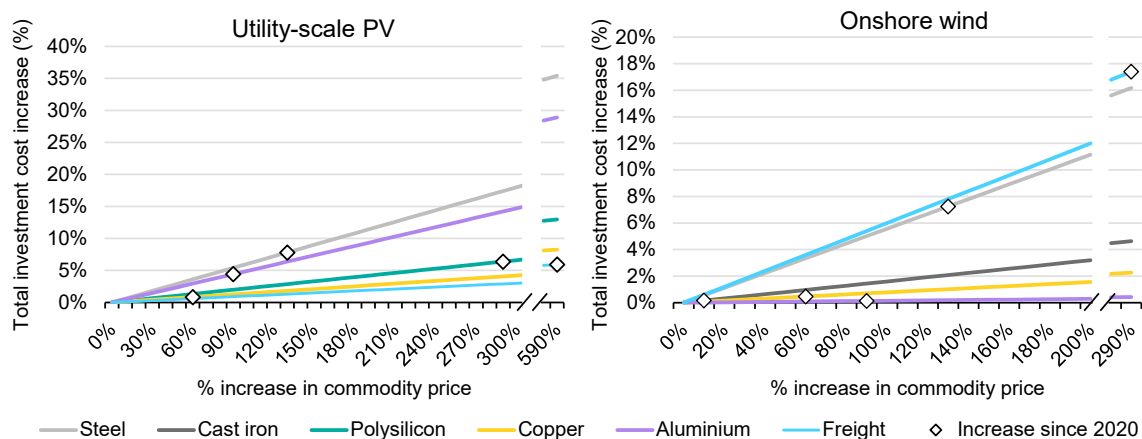
### Implications for manufacturers

Higher costs led to decreased equipment purchases in Q1 2021, as numerous manufacturers reported fewer orders because of higher input prices led them to adjusting the price of their finished products. While purchases increased in Q2 as buyers accepted the new market conditions, growing demand coincided with a

sharp increase in polysilicon prices. Higher costs have also resulted in wind equipment manufacturers reporting reduced margins, with some lowering their profit guidance by 50%.

In addition, many European and American wind turbine manufacturers have already announced price increases ranging from 10% to 25% for new orders. While manufacturers are reducing freight costs by sourcing equipment from countries closer to their assembly hubs, increased material costs could be felt downstream as manufacturers use hedging clauses to pass commodity price risk on to the buyer. China has not been insulated from rising commodity costs. Even though China produces around 80% of the world’s modules, higher commodity prices have driven solar PV system costs higher in that market. Chinese wind equipment prices, however, have hit record lows in 2021 due to fierce competition among suppliers left with manufacturing overcapacity after exceptionally high deployment in 2020.

**Figure 4.3 Utility-scale PV and onshore wind, total investment cost change by commodity and freight input, from average 2019 prices**



IEA. All rights reserved.

Notes: The increase in freight prices is significantly higher than for commodities. The baseline for all prices is the 2019 average.

### Implications for developers

Recent government-led competitive wind and solar PV auctions have already seen contract price increases partly due to high commodity and freight prices. In Brazil rising equipment prices have contributed to awarded prices being over 70% higher in 2021 auctions compared to those held in 2019. Nevertheless, the awarded prices are substantially below those awarded to natural gas-fuelled generation in Brazil’s emergency reserve auction held in October. In India auction prices for solar PV in Q3 2021 were 16% above the historical lows reached in Q4

2020, which may result in delays in signing PPAs with utility companies. The most recent renewables auction in Spain resulted in prices nearly 30% higher than those awarded in January 2021 due, in part, to increases in the cost of materials. These auction prices are, however, well below current wholesale prices in the country. Nascent renewables markets are also seeing higher prices. In Colombia final contract prices for solar PV at the auction held in November 2021 were almost 45% higher than those awarded in 2019, with these increases partially caused by higher investment costs.

Upward price trends for the equipment needed to build solar PV and wind power plants pose a challenge to developers who won bids in competitive auctions anticipating continuous declines in the cost of modules and turbines. The IEA estimates that around 100 GW of awarded but yet-to-be commissioned wind and solar PV capacity from 2019 and 2021 are at risk of the commodity price shock, potentially leading to commissioning delays. A prolonged increase in commodity and equipment prices could result in developers withholding equipment purchases until prices return to lower levels. Meanwhile, auction organisers, utilities and companies purchasing renewable electricity could also be reluctant to accept higher tariffs, delaying their procurement plans, especially in emerging and developing markets.

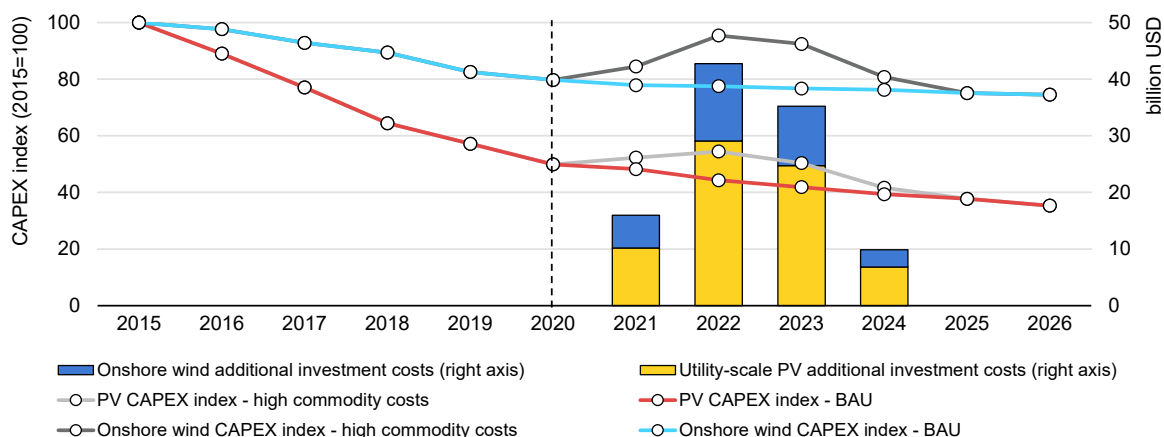
### Implications for onshore wind and solar PV investment globally

Despite rising costs and contract prices, wind and solar PV generation costs remain lower than fossil fuel alternatives, especially given current high natural gas and coal prices. However, if the prices of polysilicon, steel, aluminium, copper and freight remain at their current elevated levels throughout 2022 and manufacturers continue to increase equipment prices, as currently observed, global investment costs of wind and solar PV could increase further. This situation would erase almost three years of investment cost reductions for solar PV and five years for onshore wind. When compared with previous cost reduction trends, higher commodity and logistics costs could lead to investment costs increasing by USD 70 billion for solar PV and USD 35 billion for onshore wind over the forecast period, affecting the pace of deployment. Without these price increases, developers could build about 95 GW of additional solar PV and 25 GW of further wind capacity over 2021-2026.<sup>1</sup>

---

<sup>1</sup> In the case of onshore wind, China was excluded from the analysis due to specific market dynamics.

**Figure 4.4 Impact of high commodity price scenario on forecast total investment costs and CAPEX, onshore wind and utility-scale PV, 2015-2026**



IEA. All rights reserved.

Notes: BAU = business as usual. Onshore wind data exclude China.

## Rising energy prices and trade policies put additional upward price pressure on wind and solar

In addition to increased raw material, commodity and freight prices due to the economic recovery after the Covid-19 crisis, rising energy prices are also putting upward price pressure on renewables as manufacturers of materials critical for renewable energy equipment have curtailed production in Asia and Europe to avoid higher fuel and electricity costs. This situation further exacerbates an already strained material supply chain, leading to additional increases and volatility in prices for commodities such as aluminium, copper and steel.

**Table 4.1 Reductions in material processing due to high energy prices, commodities used in renewables equipment, selected examples**

Material	Type	Countries impacted	Start month, 2021
Aluminium	Shutdown	China	September
Zinc	Curtailment	China, Europe	September
Polysilicon	Curtailment	China, Europe	September
Magnesium	Shutdown	China	September
Steel	Curtailment	China, Europe	September

Source: Fast Markets (2021a), Fast Markets (2021b), Financial Times (2021), PV Tech (2021), Reuters (2021a), Reuters (2021b), TFI Global (2021)

In addition, trade measures due to concerns over the origin of equipment bring additional price increases to solar PV modules and wind turbines in key markets

such as the United States, India and the European Union. Both supply-side constraints and trade measures have a short- and medium-term impact on markets, increasing costs and affecting project profitability, especially for those projects that won auction bids prior to price increases, and also delaying investment.

**Table 4.2 Trade measures targeting wind and solar PV equipment**

Country/region	Measure	Detail	Start year
United States	Tariff	Import duty on cell/modules manufactured in China	2012/2018
European Union	Tariff	Variable tariff on PV-rated glass from China	2014
India	Import duty	40% duty on solar modules, 25% duty on cells	2022
United States	Anti-dumping	Import duty on wind equipment from India, Malaysia and Spain	2021
European Union	Anti-dumping	Steel wind towers from China	Pending
United States	Anti-dumping	Crystalline silicon PV products from China and Chinese Taipei	2015
Canada	Anti-dumping	PV modules and laminates from China	2015
United States	Anti-dumping	Utility-scale wind towers from Canada, China, Indonesia, Korea and Viet Nam	2013/2020
Australia	Anti-dumping	Wind towers from China	2019

Source: Australian Government (2020), CBSA (2015), European Commission (2020), European Commission (2021), Federal Register (2012), Federal Register (2013), Federal Register (2021), MNRE (2021), US Department of Commerce (2020), US ITC (2020), US Trade Representative (2018).

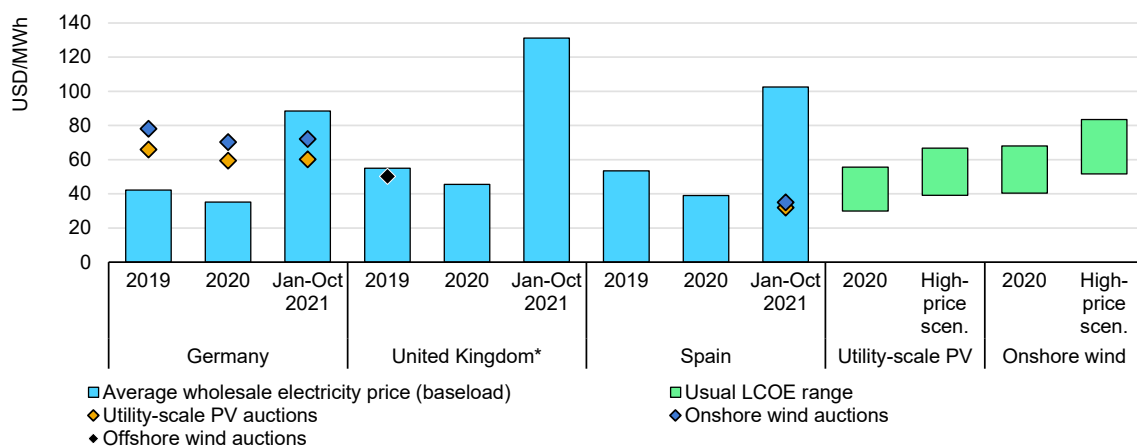
The rapid economic recovery from Covid-19 and higher commodity prices compared to pre-pandemic levels have contributed to rising inflation in many countries (IMF, 2021a). The OECD and the IMF expect inflation rate increases to peak at the end of this year before moderating in 2022; however, both organisations warn that uncertainties associated with the pace of the Covid-19 economic recovery may prolong inflation beyond their current forecasts (IMF, 2021a; OECD, 2021b).

In the event of inflation remaining above target levels, central banks may consider increasing interest rates. Higher rates translate into higher borrowing costs, affecting the total generation costs of renewable energy projects. Although the European Central Bank and the US Federal Reserve currently do not plan to raise their main interest rates in the short term, uncertainty over possible hikes presents a longer-term risk. Coupled with prolonged cost increases for equipment, this could have a material effect on investment in renewables, leading to increased costs for developers and governments and affecting the pace of deployment.

## Despite rising equipment prices, wind and solar remain competitive

Rising natural gas and coal prices have led average wholesale electricity prices to increase worldwide. In countries such as Germany, the United Kingdom and Spain, average wholesale electricity prices from January to October 2021 more than doubled compared with values observed in 2019 and 2020. Higher natural gas and coal prices have improved the competitiveness of wind and solar PV, despite historic equipment price increases due to high commodity and energy prices. For corporations, fixed-price renewable energy contracts have served as a hedge against higher spot market prices, increasing the value of such bilateral agreements. For governments, higher electricity prices are not translated into higher subsidies for wind and solar PV, as almost 90% of all wind and PV projects have long-term fixed-price PPAs either through FITs or CfDs.

**Figure 4.5** Average wholesale electricity prices and LCOE of utility-scale solar PV and onshore in 2020 and in high commodity price scenario in Germany, United Kingdom and Spain



IEA. All rights reserved.

\* Wholesale prices excluding Northern Ireland.

Notes: scen. = scenario; High-price scenario comprises LCOE calculation with assumption of high commodity prices, as described in the previous paragraphs of this chapter.

Sources: IEA analysis based on Bloomberg LP, IRENA (2020).

### The long-term implications of price increases

Although it is too early to assess the medium- and long-term implications of commodity price increases on the deployment of wind and solar PV, so far higher prices have had limited impact on demand for new capacity. Governments have made no major changes in their policies or cancelled auctions, both of which are crucial to ensure the continued deployment of renewables. In addition, corporate buying is on pace to break another year-on-year record, demonstrating the cost-

competitiveness of renewable resources, even with a slight increase in prices in some markets. Should commodity and freight prices moderate in the near future, the cost reduction trend of wind and solar PV would continue, and the long-term impact on the demand for solar PV and wind may be minimal. However, there is a risk of a prolonged period of high commodity prices, inflation and rising interest rates increasing the cost of clean energy transitions and slowing the pace of wind and solar PV capacity expansion.

## Biofuels

Feedstock costs have been driving up biofuel prices, causing an estimated 3% decline in global demand in 2021. A number of factors are causing this price increase, including growth in demand for soybeans and corn in China, weather impacts, climbing shipping costs and, to a lesser extent, biofuel demand itself. In response, governments have lowered blending mandates in Argentina, Colombia, Indonesia and Brazil, reducing biofuel demand. These impacts are likely to be short-lived should prices decline in the coming years. The significant planned expansion of renewable diesel projects, for instance, remains on track and governments seem willing to reinstate mandates if prices come down. However, the prospect of high feedstock and biofuel costs does present a risk to supportive policies under discussion in the United States, Europe, India, China and Indonesia.

### *Short-term impacts*

In mid-July **Argentina** passed a law to reduce the biodiesel blend rate from the original 10% to 5% because of high crop costs. The law also authorises the government to reduce the biodiesel blend rate to 3%, and to halve the ethanol volume entering the fuel sector from corn ethanol if necessary.

The **Colombian** government reduced its ethanol blending mandate from 10% to 4% from April 2021, with the aim of returning blending to 10% in September 2021. However, in August, Colombia extended the 10% blending mandate to January 2022. The reduction was in part because of a sugar cane shortage due to excessive rains, as well as high US ethanol import costs.

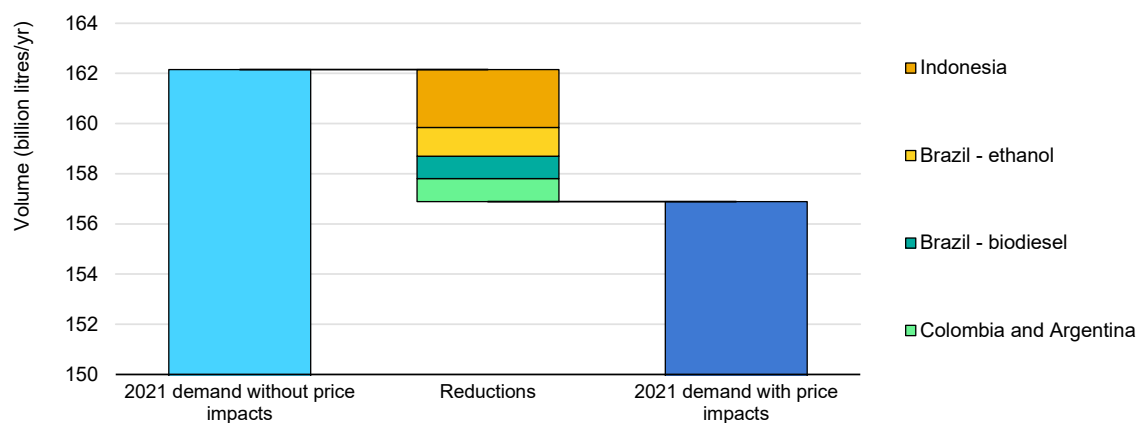
**Indonesia** has continued to delay increasing its biodiesel mandate from 30% to 40% as initially planned. High palm oil and biodiesel costs are part of the reason for the delay.

In response to high costs, **Brazil's** mines and energy ministry reduced its biodiesel blending mandate to 10% from 13% for July and August. It then increased the



mandate to 12%, but is considering reducing it again to 10%. High costs are also part of the reason for reduced sales of hydrous ethanol in Brazil, as consumers have switched from buying ethanol to gasoline.

**Figure 4.6 Demand decline in response to high prices, selected countries, 2021**



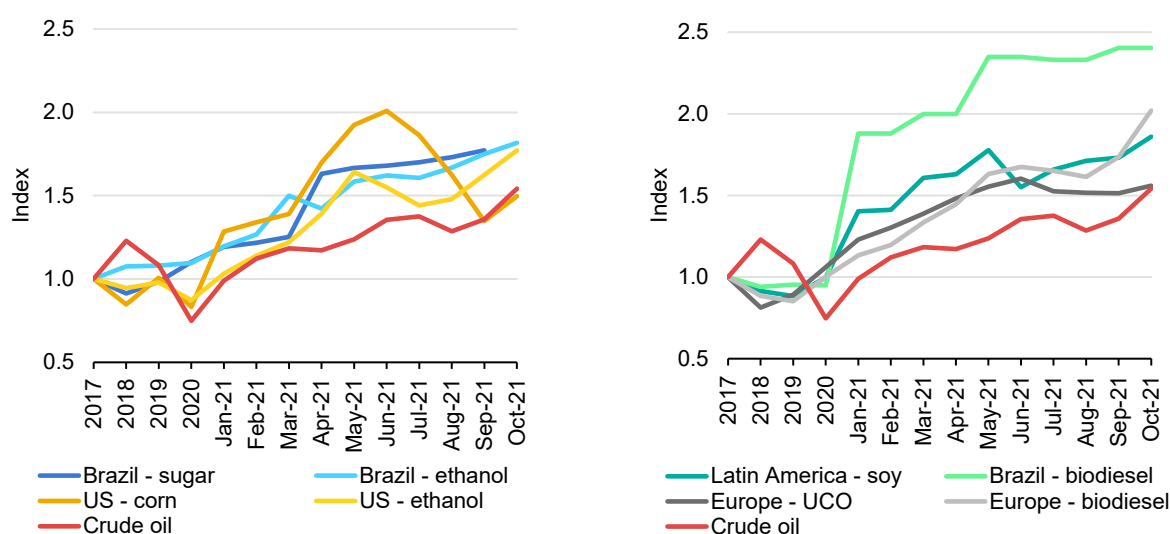
IEA. All rights reserved.

In the **United States** high feedstock prices are contributing to climbing Renewable Identification Number (RIN) trade prices. The US Environmental Protection Agency (EPA) uses RINs to track the production and use of qualifying renewable fuels under the Renewable Fuel Standard (RFS). RINs are tradeable and fuel providers with a deficit can purchase credits from those with a surplus. RIN prices are at an all-time high, having nearly tripled since 2019 for biodiesel and reaching seven times higher for ethanol as of October 2021, according to IHS Markit data. These increases are primarily a result of higher feedstock prices according to the US Environmental Information Administration. However, uncertainty around renewable fuel obligations, ongoing discussions on waivers for small refineries and lower ethanol production following Covid-19 impacts on fuel demand are also contributing. The impact these prices will have on biofuel production and demand is unclear. If the RIN market acts as intended, then higher RIN prices should create an incentive to produce more biofuels since biofuel producers will receive higher prices for their products. However, since biofuels are blended with gasoline and diesel, higher biofuel prices can also increase consumer fuel prices, which can reduce overall fuel demand. The EPA has also yet to set renewable fuel obligations for 2020/21 and will be starting the process for RFS obligations post 2022 later this year. Fuel costs will no doubt feature prominently in those discussions.

### What is driving price increases?

Weather impacts on biofuel crops, growing corn and soybean demand in China and certain other markets, and higher shipping costs are all contributing to higher biofuel prices. They have increased by between 70% and 150% from the 2019 average, and more than prices for crude oil in most cases, increasing the spread between biofuel and fossil fuel costs.

**Figure 4.7 Biofuel prices and feedstock costs in selected markets, ethanol (left) and biodiesel (right), 2017-2021**



IEA. All rights reserved.

Source: IEA analysis based on IHS Markits (2021b), indexed to 2017.

Chinese demand for soybeans and corn to help rebuild its pig herd after swine fever decimated its pig populations, combined with tight supplies, is one of the main drivers of cost increases for these feedstocks according to the US Department of Agriculture. Biofuel producers use soybeans to make biodiesel and renewable diesel, and corn to produce ethanol. To help keep costs in check, China has increased imports of both soybeans and corn. China’s corn imports more than tripled in 2021 relative to 2020, for example, to satisfy this demand (USDA, 2021). In the United States increased renewable diesel demand for soybeans has also contributed to cost increases by limiting the soybean harvest available for export.

In the case of sugar, used to produce ethanol, high costs are in part driven by a poor harvest in Brazil; sugar production in 2021 is down by 7% compared to 2020. In Europe, high shipping costs – up nearly 700% from 2019 levels for a shipment from China – have contributed to higher used cooking oil costs. Nearly 70% of used cooking oil for biodiesel production in Europe is imported according to IHS Markit estimates.

### *The impact of cost increases on the prospects for renewable diesel and biojet*

Production of renewable diesel and biojet is set to expand by 9 billion litres over the next two years in the main case, at a time of high feedstock costs. Despite the combination of high feedstock costs and growing demand for those feedstocks, renewable diesel and biojet facilities in the advanced stages of development remain on track. To date only one advanced project, CVR's Wynnewood facility, has delayed start-up, citing high feedstock costs. To mitigate cost increases, producers are building facilities that can process multiple feedstocks, buying agricultural supply chains and investing in non-crop feedstocks.

Refiners can produce renewable diesel from plant oils, used cooking oil and animal fats. One way to mitigate costs is to build renewable diesel facilities that can use a variety of feedstocks. This flexibility allows producers to purchase whichever feedstocks are the least costly at the time.

Owning feedstock supply chains also helps ensure supplies and keep costs in check. Some renewable diesel and biojet producers are pursuing this strategy by purchasing seed oil production and used cooking oil collection companies. For instance, Neste, a renewable diesel producer, purchased used cooking oil collection and refining companies in the United States and the Netherlands to improve the used cooking oil supplies it uses to produce renewable diesel.

Some investment continues as well in technologies to process wastes and residues that would avoid competition with food demand or for limited supplies of used cooking oil. Wood and agricultural wastes, for instance, can be processed into biofuels and have other benefits such as meeting sustainability requirements in regulations such as Europe's Renewable Energy Directive. These investments remain limited, however, with most new plants planning to use oil crops and used cooking oil.

### *What are the long-term implications?*

The long-term implications depend primarily on whether feedstock and biofuel prices stay high or not. Feedstock demand and weather impacts, mostly unrelated to biofuel demand, are driving high prices. There is little indication of changes in project plans for renewable diesel and biojet production, and governments seem willing to reinstate mandates should prices decline.

High prices are nevertheless a clear reminder of the links between feedstocks, biofuel costs and government and consumer exposure to them. This comes at a time when the United States, Europe, India, China and Indonesia are all

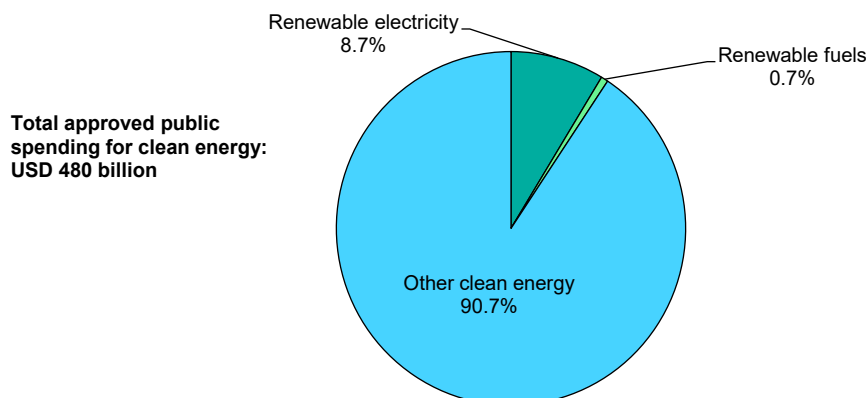
discussing new policies or working to implement existing plans that could increase global biofuel demand by 30% by 2026. The greatest risk of high costs may therefore be how they affect these policy discussions. Current high prices draw attention to important questions. Where will the feedstocks come from? How sustainable are they from an economic, environmental and social perspective? Will costs drive investment into new feedstocks? And what will be the cost impacts not just on fuels, but on agricultural products?

## How much will renewable energy benefit from global stimulus packages?

As of October 2021, governments around the world have mobilised almost USD 17 trillion in the form of rebates, grants, loans and tax incentives/exemptions to mitigate the effects of the Covid-19 crisis (IMF, 2021a). The majority of these measures are aimed primarily at providing relief to businesses, the public sector and consumers affected by the economic downturn arising from the Covid-19 pandemic and to channel public money towards rebuilding economies around the world.

Approved government spending on clean energy reached USD 480 billion. The USD 45 billion allocated to renewables – including electricity, heat and fuels (biofuels, advanced biofuels and biogas) – accounted for about 9% of announced public spending on clean energy. The majority of global clean energy stimulus is expected to be spent over 2021-2023.

**Figure 4.8** Global government clean energy stimulus in response to Covid-19, allocated up to October 2021



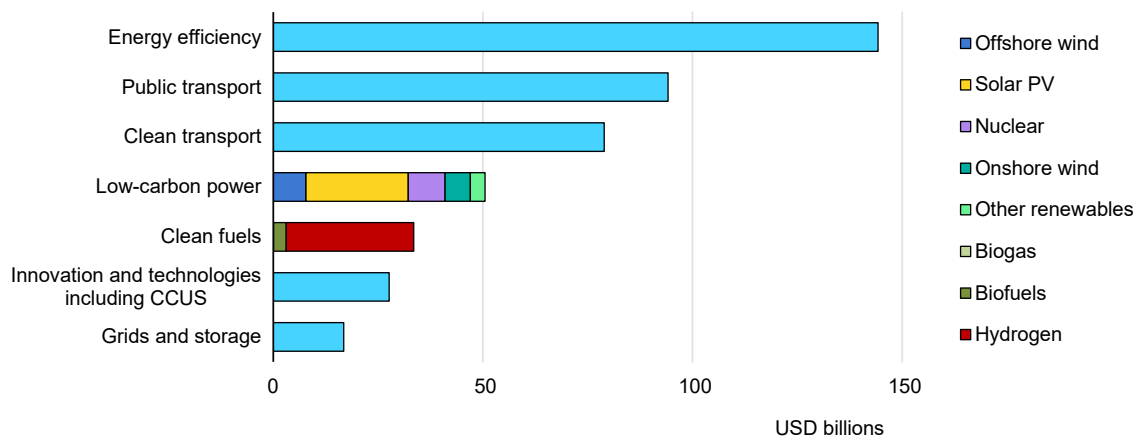
IEA. All rights reserved.

Note: Includes only approved government spending on clean energy.

Source: Based on IEA (2021h), [Sustainable Recovery Tracker](#).

Encouraged by its job creation potential and low cost as a CO<sub>2</sub> abatement technique, energy efficiency sector has received USD 144 billion, the greatest clean energy spending globally. The renovation of public and private buildings and energy efficiency investment in the industrial sector are the largest beneficiaries of the allocated spending. Depending on country-level regulations, renewable heat technologies can also benefit from spending allocated to energy efficiency. The second most supported sector is public transport (USD 94 billion), followed by low-emission vehicles and charging infrastructure (USD 79 billion). Investment in railways, mass/urban transit and walking/cycling infrastructure have so far received the largest portion of this funding, followed by EVs and alternative-fuel vehicles and their charging infrastructure.

**Figure 4.9 Global government clean energy spending by sector and technology, allocated up to October 2021**



IEA. All rights reserved.

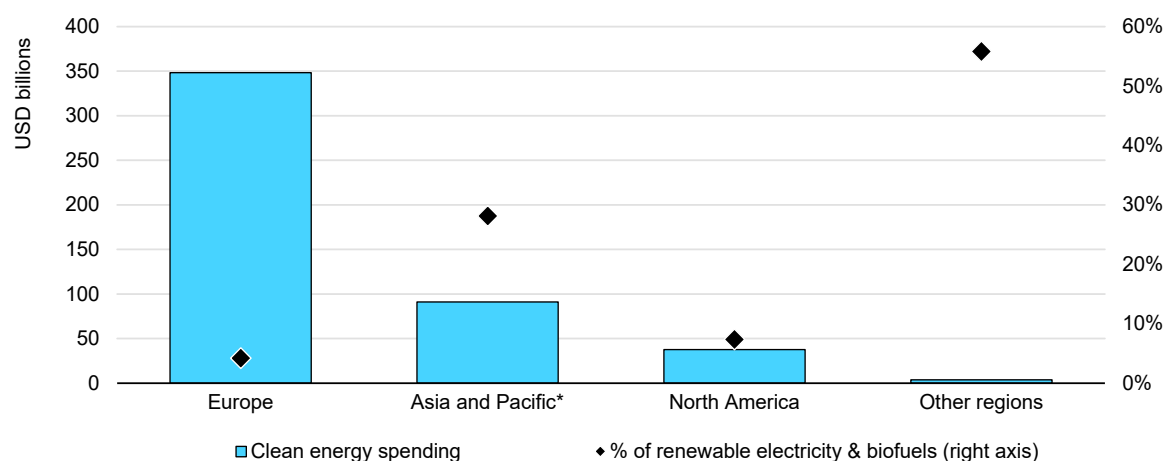
Source: Based on IEA (2021h), [Sustainable Recovery Tracker](#).

Of the spending on low carbon power, we expect solar PV to receive the largest amount, accounting for almost half of low-carbon electricity spending (USD 24 billion) and split between utility-scale and distributed PV. This stimulus money will mostly support already developed markets in China, Korea and the European Union to further accelerate investments. Nuclear power has received around USD 9 billion in public spending, followed by offshore wind and onshore wind. Despite increasingly needed flexibility capabilities, dispatchable renewables including hydropower, geothermal and bioenergy received only USD 3.5 billion. Similarly, biogas and biofuels only received around USD 3 billion, despite their major contribution to decarbonisation of the hard-to-abate sectors such as aviation and heavy industry. Many governments consider low-carbon hydrogen to be the main fuel for decarbonising the hard-to-abate sectors. This is reflected in large

public spending of about USD 30 billion allocated to hydrogen. However, uncertainty remains about whether this allocated spending will be for hydrogen produced from renewables or non-renewables.

As of October 2021, almost three quarters of public spending on clean energy was allocated in Europe, followed by the Asia Pacific region and North America. The share of renewables, including biofuels and renewable electricity, in overall clean energy spending ranged from 4% to almost 56% depending on the region. In Europe and North America, transport infrastructure and energy efficiency spending took priority over renewables. In Asia Pacific, focusing on reaching ambitious renewables targets have led to a higher renewable share in overall clean energy spending, especially in China and Korea.

**Figure 4.10 Government clean energy approved spending by region and share of renewables, allocated up to October 2021**



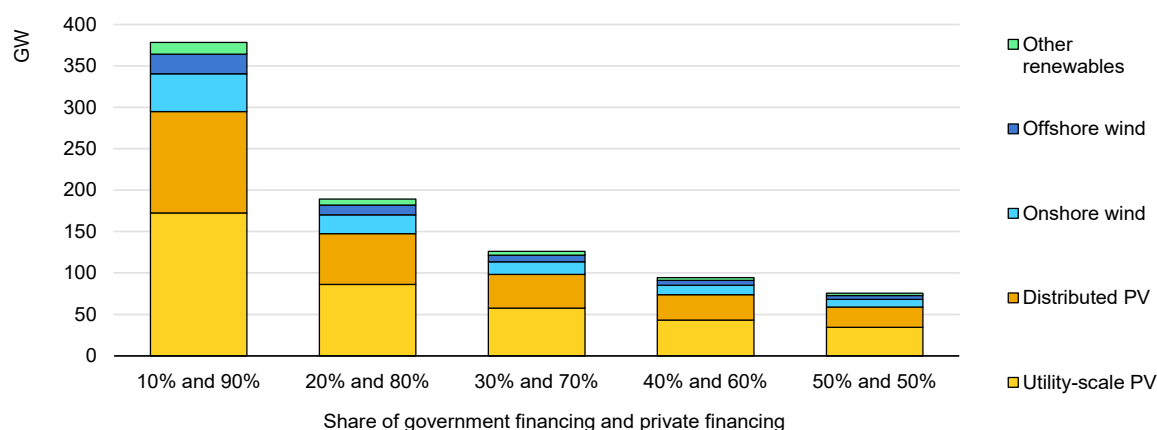
IEA. All rights reserved.

\* Includes China

Source: IEA analysis based on IEA (2021h), [Sustainable Recovery Tracker](#).

About USD 42 billion of approved public spending on renewable electricity could mobilise USD 380 billion of additional private investment if this spending attracts nine times more capital. However, the contribution of the private sector will highly depend on the effectiveness of policies and implementation measures to attract investment. This would result in the development of an additional 380 GW of renewable projects in the coming years, with solar PV providing over 90% of this upside potential. However, the IEA's Sustainable Recovery Plan suggests an additional USD 800 billion investment in renewables is needed over 2021-2023. This requires not only increasing public spending but also mobilising additional private capital.

**Figure 4.11 Estimated renewable capacity additions resulting from approved government spending, depending on private financing leverage, to be commissioned over 2021-2026**



IEA. All rights reserved.

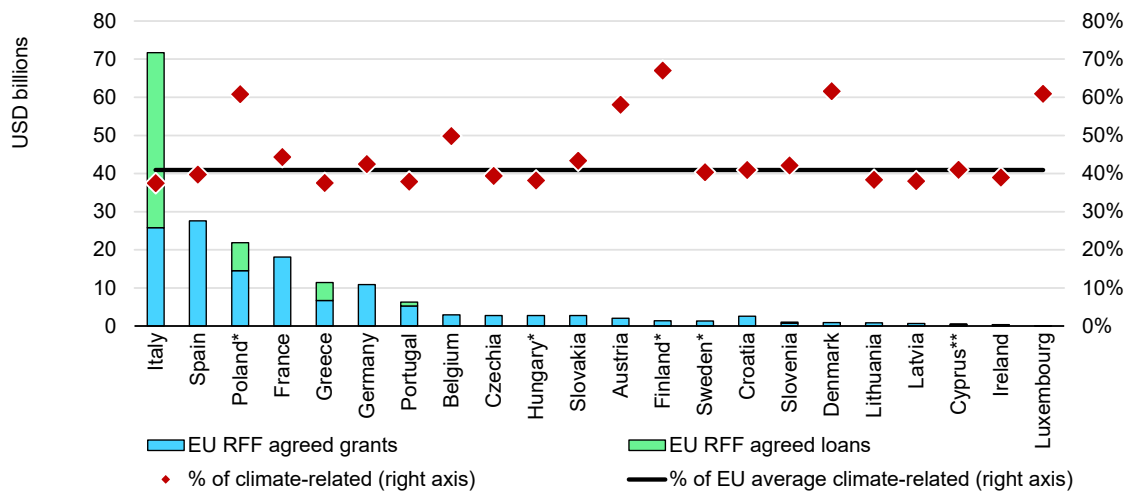
Source: IEA analysis based on IEA (2021h), [Sustainable Recovery Tracker](#), Bloomberg LP, IRENA (2020).

## Focus on the EU Recovery and Resilience Facility

In addition to its long-term budget of EUR 1.2 trillion, the European Union announced in 2020 the Next Generation EU stimulus programme worth EUR 800 billion to support recovery in member countries in the form of grants and loans to be allocated over 2021-23. The Recovery and Resilience Facility (RRF) accounts for about EUR 724 billion of the total spending allocation in the Next Generation EU programme. Climate-related spending must account for at least 37% of RRF funding used in member states. From March to September 2021, 22 member countries proposed their spending plans, with 18 of them receiving approved from the European Union.

Overall, EU member countries requested over EUR 460 billion, with two-thirds in the form of grants. The climate-related part of their proposals was 41%, or USD 191 billion, higher than initial minimum target of 37%. While the majority of country plans include a climate-related spending share ranging around the average, Finland, Denmark, Austria and Luxembourg proposed to spend higher shares of 60% to 70%. Italy has requested the largest absolute amount of spending for clean energy at over EUR 70 billion, followed by Spain, Poland, France and Greece. These five countries account for almost 80% of all climate-related spending under the RRF facility.

**Figure 4.12 EU RFF funding allocation by country and share of clean energy**



IEA. All rights reserved.

\* Member country spending plan proposed but not yet approved by the European Union.

\*\* Note by Turkey: The information in this document with reference to “Cyprus” relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the “Cyprus issue”.

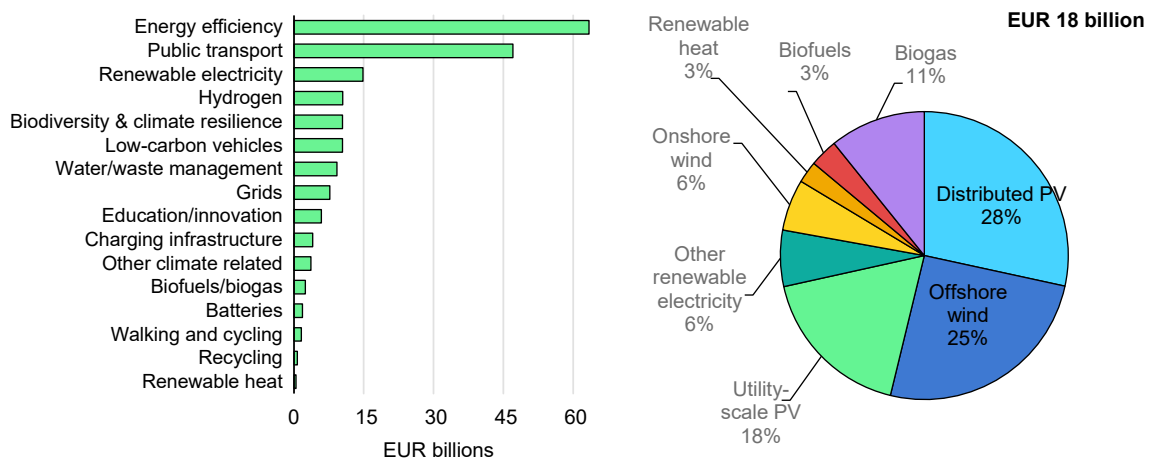
Note by all the European Union member states of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Source: [European Commission](#) (2021f).

Energy efficiency and public transport together account for more than half of the overall climate budget under the RFF, followed by renewable electricity and “green” hydrogen. Overall renewables including the electricity sector, biofuels, biogas and renewable heat are to receive about EUR 18 billion, less than 10% of overall climate-related EU public spending. Based on country proposals, we estimate that the majority of the renewables spending will be used for distributed PV applications followed by offshore wind, utility-scale solar PV and onshore wind. Outside the electricity sector, spending on biogas remains a policy priority in some countries to decarbonise existing gas infrastructure. The spending allocation for biofuels (including both conventional and advanced biofuels) remains despite the European Union’s Net Zero by 2050 goal, where biofuels play a key role in decarbonising hard-to-abate sectors. Renewable heat received the lowest spending allocation among all climate-related technologies, although part of the energy efficiency stimulus may be spent towards renewable heat in buildings and industry.



**Figure 4.13 EU RFF fund allocation by sector and between renewables**

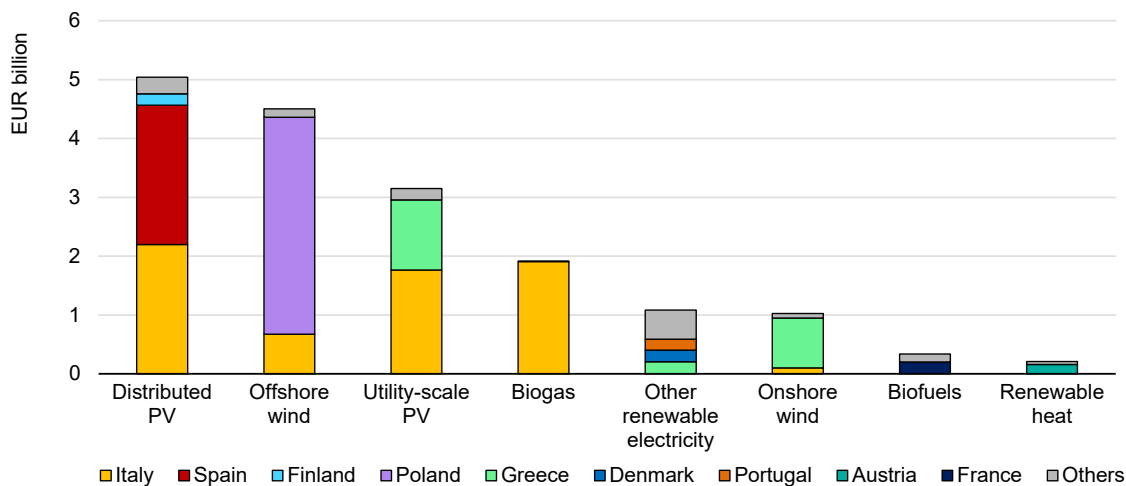


IEA. All rights reserved.

Source: [European Commission](#) (2021f).

Spending proposals for specific renewable technologies are geographically concentrated among two to three countries. For distributed PV, self-consumption programmes in Italy and Spain are expected to dominate, while Poland has requested funding for development of its first-ever offshore wind projects and associated infrastructure. For utility-scale PV and onshore wind, Greece’s policy on island electrification and Italy’s agrovoltaics programme will receive the majority of the EU spending. For renewable heat and biofuels, Austria and France respectively support national programmes on the exchange of oil and gas heating systems with renewable heat options and the production of advanced biofuels.

**Figure 4.14 EU RFF fund allocation by renewable technology or fuel**



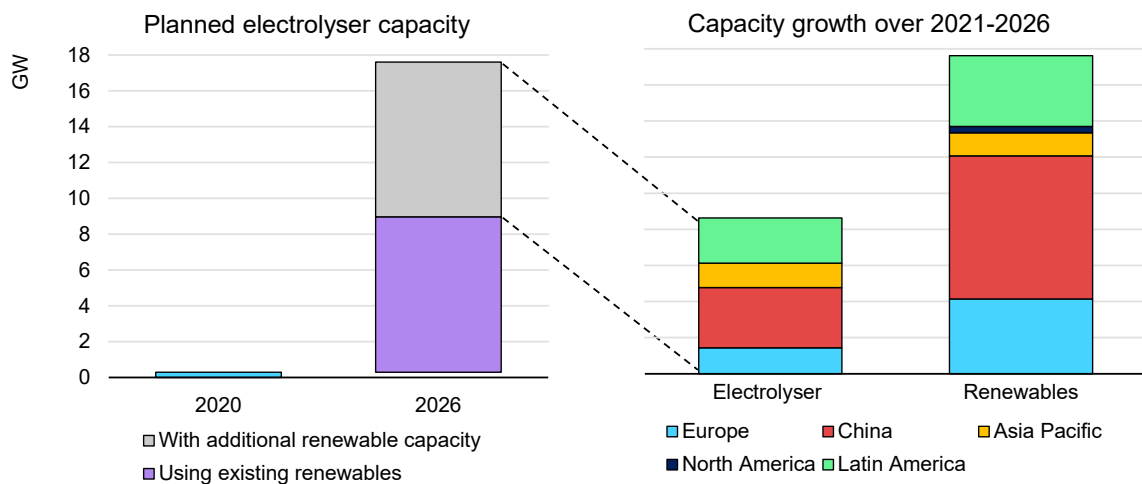
IEA. All rights reserved.

Source: [European Commission](#) (2021f).

## Could the green hydrogen boom lead to additional renewable capacity by 2026?

In 2020 global electrolyser capacity stood at 0.3 GW, mostly using grid electricity to produce hydrogen. Planned project pipelines in almost 30 countries indicate that global electrolyser capacity could reach almost 17 GW by 2026. Based on project announcements, we estimate that almost half of the planned expansion to use existing renewable capacity. Most announced projects range from 1 MW to 10 MW in size and are close to industrial sites and ports. The additional renewable capacity installed for these small projects is expected to be limited, as they will mostly use renewable electricity from the grid through bilateral agreements with developers and utilities.

**Figure 4.15** Global installed electrolyser capacity in 2020 and projects planned for commissioning, 2021-2026 (left) and additional renewable capacity for electrolysis, 2021-2026



IEA. All rights reserved

Notes: The figure is not a forecast of global electrolyser capacity by 2026. It is based on project announcements and their announced commissioning deadlines. Additional renewable capacity is also based on project announcements by developers. For missing data, an average electrolyser to renewable capacity ratio was used at country or regional level based on data already available from developers.

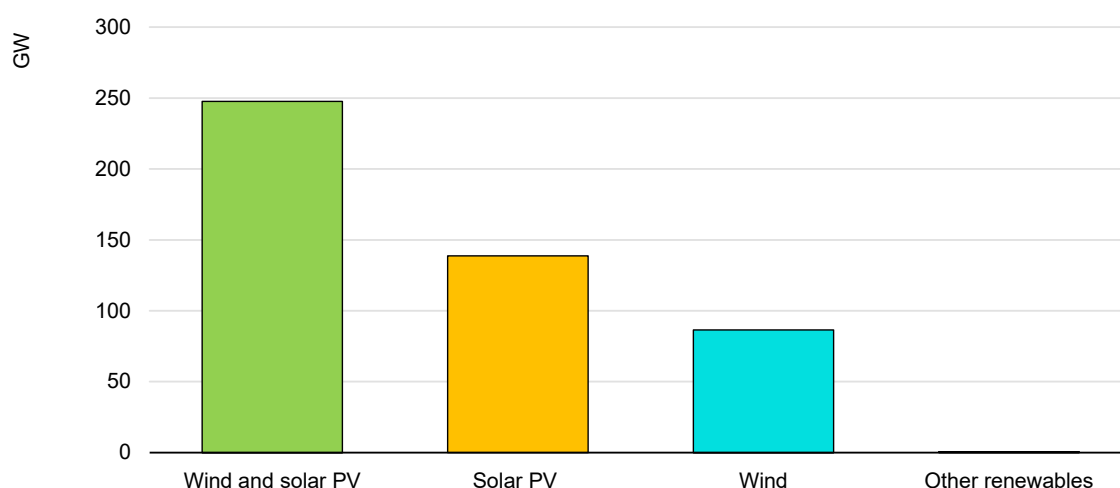
Source: IEA analysis based on IEA (2021g), [Hydrogen Projects Database](#).

Larger projects (10-100 MW) are expected to bring almost 18 GW of additional renewable capacity during 2021-2026 dedicated to the production of hydrogen or ammonia from renewables, accounting for only 1% of our main case forecast growth in renewables. This includes some developers using a combination of renewable electricity from the grid and new capacity in the initial phases of project development. If planned projects are commissioned by 2026, China, Chile, Spain and Australia could together bring 85% of the additional 18 GW of renewable

capacity dedicated to green hydrogen production. The combination of targets and financial support, coupled with solar and wind resource availability, make these countries lead the short-term large-scale expansion of hydrogen produced by dedicated renewable capacity.

By October 2021 the announced electrolyser project pipeline had reached over 260 GW globally. We estimate that this could bring an additional 475 GW of wind and solar PV capacity, one-third of total installed variable renewables today, dedicated mostly to green hydrogen production. The majority of planned projects consider hybrid wind, solar PV and battery storage plants for hydrogen production.

**Figure 4.16 Additional renewable capacity according to planned and announced green hydrogen projects**



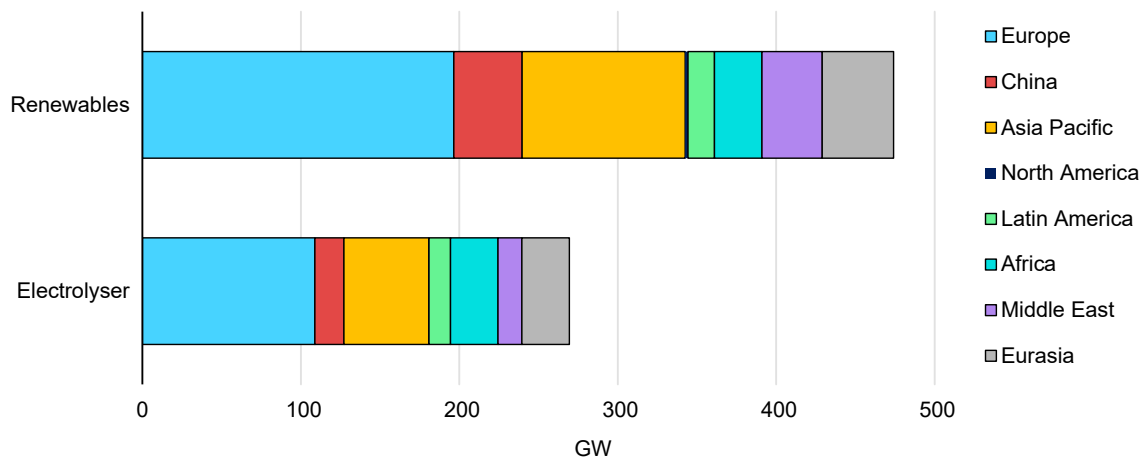
IEA. All rights reserved.

Notes: The allocation of the capacity is based on project announcements from developers. For missing data, an average electrolyser to renewable capacity ratio was used at country or regional level based on data already available from developers.

Source: IEA analysis based on IEA (2021g), [Hydrogen Projects Database](#).

Europe has the greatest planned electrolyser and associated renewable capacity globally, mostly from offshore wind and solar PV. This is driven by the European Union’s green hydrogen targets and associated funding to scale up production to decarbonise hard-to-abate sectors in line with the bloc’s long-term Net Zero by 2050 target. With excellent wind and solar resource availability, Australia has the second-largest pipeline following Europe, the country aiming to export green hydrogen and ammonia. Similar drivers make the business case for electrolyser expansion in the Middle East and Eurasia. In China and Latin America, projects announced for the long term remain limited, but the upside potential remains, especially to reduce curtailment and to abate CO<sub>2</sub> emissions in the industrial sector.

**Figure 4.17 Global planned electrolyser capacity and estimation of additional renewable capacity by country/region**



IEA. All rights reserved.

Notes: The allocation of the capacity is based on project announcements from developers. For missing data, an average electrolyser to renewable capacity ratio was used at country or regional level based on data already available from developers.

Source: IEA analysis based on IEA (2021g), [Hydrogen Projects Database](#).

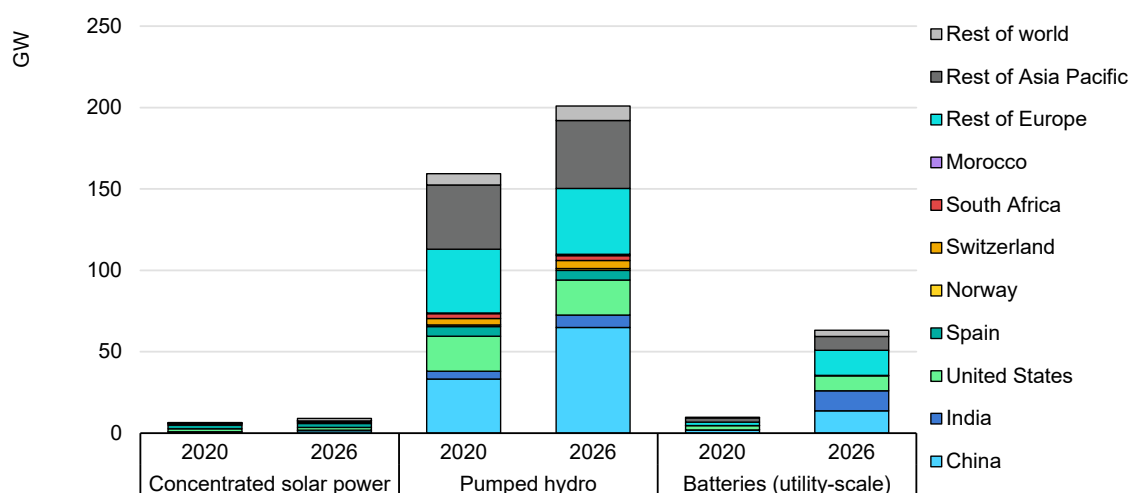
While large companies and countries have announced ambitious green hydrogen expansion plans for the next two decades, it remains uncertain how many of these projects will actually be commissioned on time and on budget. Globally, almost USD 30 billion of government subsidies for green hydrogen have already been announced as part of stimulus packages. Despite this, financing challenges concerning the profitability of green hydrogen projects remain; in many parts of the world the cost of producing hydrogen from renewable electricity remains higher than fossil fuel alternatives. The pace of electrolyser capacity expansion is key to achieving the cost reductions necessary to make hydrogen production from renewable electricity comparable or lower than fossil fuel alternatives.

In addition, the mismatch between currently planned projects and the demand for green hydrogen output remains a key uncertainty for future electrolyser expansion. Government policies are currently more focused on decarbonising hydrogen production than developing demand for new applications, and current country ambitions to stimulate hydrogen use in new applications are not sufficient to meet their net zero pledges (IEA, 2021a).

## How rapidly will the global electricity storage market grow by 2026?

Global installed storage capacity is forecast to expand by 56% in the next five years to reach over 270 GW by 2026. The main driver is the increasing need for system flexibility and storage around the world to fully utilise and integrate larger shares of variable renewable energy (VRE) into power systems.

**Figure 4.18 Concentrated solar power, pumped hydro and batteries, installed storage capacity in 2020 and 2026**



IEA. All rights reserved.

Notes: Rest of Asia Pacific excludes China and India; Rest of Europe excludes Norway, Spain and Switzerland.

Source: For battery storage: IEA (2021b), [World Energy Outlook 2021](#).

Utility-scale batteries are expected to account for the majority of storage growth worldwide. Their installed capacity increase sixfold over the forecast period, driven by incentives and an increasing need for system flexibility, especially where the share of VRE covers almost all demand in certain hours of the day. Hybrid auctions combining wind or solar PV with storage have emerged in India and Germany, with contracts in the range of USD 40-60/MWh over the last year. In the United States federal tax incentives, combined with high peak prices in several markets, are driving expansion, while long-term government targets in China see battery storage increasing fivefold over 2021-2026.

Pumped storage hydropower (PSH) provides 42% of global expansion of electricity storage capacity. With over 40 GW of expansion in the next five years, PSH remains the largest source of installed storage capacity, achieving 200 GW cumulatively installed by 2026, three times larger than batteries. China alone

accounts for three-quarters of global PSH capacity growth thanks to the government's long-term targets and new remuneration scheme aimed at reducing VRE curtailment.

Concentrated solar power (CSP) storage expands by only 2.6 GW during the forecast period. China leads the expansion thanks to a generous FIT scheme, which is set to continue until the end of this year. Beyond China, the United Arab Emirates is expected to bring online the second-largest volume of new capacity globally, thanks to phase four of the Dubai Electricity and Water Authority's Mohammed bin Rashid Al Maktoum Solar Park, which brings an additional 700 MW and aims to help the country achieve its target of 75% clean energy by 2050.

Installed capacity does not provide a full picture of each storage technology's capabilities.<sup>2</sup> PSH and CSP can provide medium-term storage capabilities cost effectively. In the case of CSP, storage is usually in the range of 5-15 hours. In contrast, the most widely used lithium-ion battery technology can usually store electricity for less than 4 hours. For PSH, the storage duration ranges from 5 to 175 hours, but some installations, such as PSH units installed in cascading systems that link two or more large reservoirs, offer even greater storage capacity (IEA, 2021f).

Addressing global electricity storage capabilities, our forecast expects them to increase by 40% to reach almost 12 TWh in 2026, with PSH accounting for almost all of it. India dominates storage capability expansion by commissioning over 2.5 TWh (80% of the expansion) thanks to projects using existing large reservoirs. CSP storage capabilities almost double partly thanks to the longer storage hours (10 hours on average) of projects under construction in China, the United Arab Emirates, Morocco, South Africa, Chile and Greece. Similarly, global battery storage capabilities also increase eightfold by 2026.

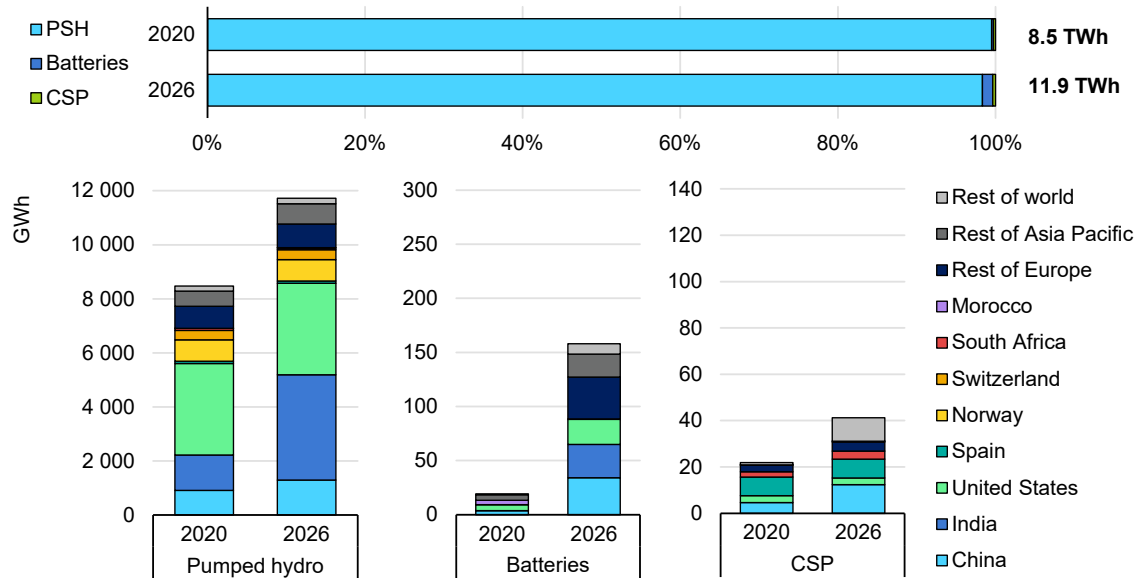
In addition to PSH, CSP storage and batteries, the IEA Special Hydropower Market Report estimated the energy storage capabilities of hydropower (IEA,

---

<sup>2</sup> Our estimates of storage capabilities, or stored electrical energy, for PSH are based on the International Commission on Large Dams' database of existing dams and reservoirs (ICOLD, 2021), country-level storage data and IEA research. Energy storage capability calculations depend on the potential energy of water that can be used for power generation stored behind each dam. Factors include the average head of the dam, energy conversion efficiency (assumed at 90%) and estimates of the live part of a reservoir's volume. In some cases, we also applied a standard assumption of 10 hours' storage capability. We based storage capabilities of CSP on the SolarPaces NREL database and project level research (NREL, 2021). For batteries, we used information from the WEO 2021 report (IEA, 2021d). All capability calculations are for one charge cycle, and these technologies operate under different charging cycling patterns.

2021f). Accordingly, existing conventional reservoir hydropower plants can store up to 1 500 TWh of electricity, significantly more than all other storage technologies combined.

**Figure 4.19 CSP, PSH and battery storage capability in 2020 and 2026**

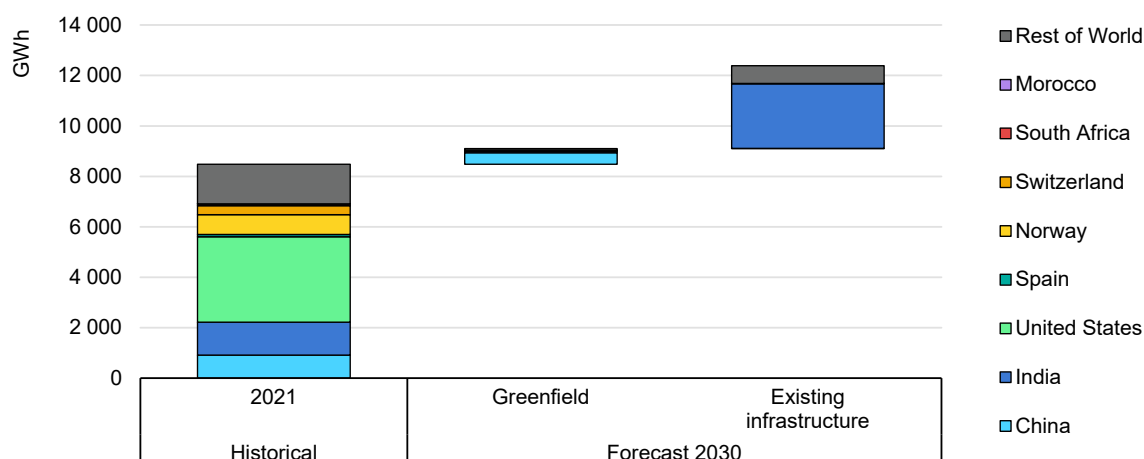


EA. All rights reserved.

Note: Rest of Asia Pacific excludes China and India; Rest of Europe excludes Norway, Spain and Switzerland.

PSH and CSP storage can use already-installed plant infrastructure instead of greenfield projects, providing cost-effective opportunities to accelerate storage capabilities locally. Currently around half of CSP installations worldwide do not have any storage capability, especially in Spain and United States (HELIO CSP, 2020). Accordingly, we estimate the potential for retrofitting CSP projects by adding storage could be significantly higher compared with our forecast for greenfield plants. For instance in Spain, solar PV developers face grid constraints to connect new projects. CSP retrofits adding storage could help alleviate some of these grid constraints. For CSP retrofits to make economic sense, remuneration for existing projects would need to be extended and adjusted to reward flexibility and storage capabilities. For PSH, existing reservoir plants and dams can offer opportunities to achieve long-term storage cost effectively. In the IEA Special Hydropower Market Report (IEA, 2021f), the outlook to 2030 indicated that adding PSH capabilities to existing reservoirs would add more storage capability than new projects.

**Figure 4.20 PSH storage capability, 2021-2030**



IEA. All rights reserved.

Source: PSH forecast from IEA (IEA,2021f), [Hydropower Special Market Report](#).

Technologies like CSP and PSH not only generate electricity and serve as daily or weekly balancing, but also provide additional services to the grid, such as system inertia, frequency response and grid regulation by means of their rotating mass. They are difficult to finance because of their high investment costs and, in many countries, the lack of remuneration schemes valuing grid services and therefore long-term revenue visibility. Some markets, such as the United Kingdom, Ireland and some Nordic countries, provide market-based remuneration for grid services. However, energy sales continue to be the primary source of revenue for both CSP and PSH, given that revenues from ancillary services range from 1% to 5% of total revenue in many markets (IEA,2021f). More income streams are therefore required for storage technologies to become bankable. Auctions that support hybrid plants can provide a good solution to scale up PSH and CSP. In India, for instance, a PSH and PV system won a hybrid auction last year at USD 57/MWh (PV Magazine, 2020).

## Are conditions right for biojet to take flight over the next five years?

Five conditions will help dictate whether biojet takes flight over the next five years:

- Aviation fuels must be proven safe and technically sound, and the airline industry must have confidence in them.
- Costs need to be acceptable to consumers and airlines.



- Governments need to implement clear regulatory and supportive policies, such as low-carbon fuel standards, mandates, R&D funding, standards development and incentives.
- Biojet producers need to finance, permit and build planned facilities.
- Fuel feedstocks need to be sustainable.

With these conditions in mind, we expect biojet demand to range from 2 to 6 billion litres by 2026 in our main and accelerated cases respectively. Biojet production is around 0.1 billion litres today. Existing biojet pathways are safe and commercial, costs seem acceptable at proposed blend rates, and the biofuels industry can satisfy demand even in an accelerated case. While biojet is ready, policies are not, or at least not yet. How high biofuel demand increases most depends on a handful of policy discussions in the United States, Europe and potentially China. Given the low absolute volumes proposed, even in our accelerated case, feedstock sustainability is unlikely to prove a constraint over the next five years. However, production plans depend heavily on edible oils and certain wastes and residues for which there is limited supply and considerable competition. Commercialising new feedstock supplies and production pathways is critical to medium- and long-term expansion of biojet.

## Condition 1 – Confidence in biojet

Biojet already meets the condition that fuels be safe and technically sound. There are seven certified biojet fuels for use in commercial flights, with blending ratios up to 50% depending on the technology in question and compatibility with existing fuelling infrastructure (IEA Bioenergy, 2021). Hydroprocessed esters and fatty acids (HEFA), the most produced biojet, is approved for up to 50% blending with kerosene. Major airlines and aircraft and engine manufacturers, as well as many airports, have experience with biojet and are publicly committed to commercialising sustainable aviation fuels (SAFs) more broadly via the Clean Skies for Tomorrow Coalition.

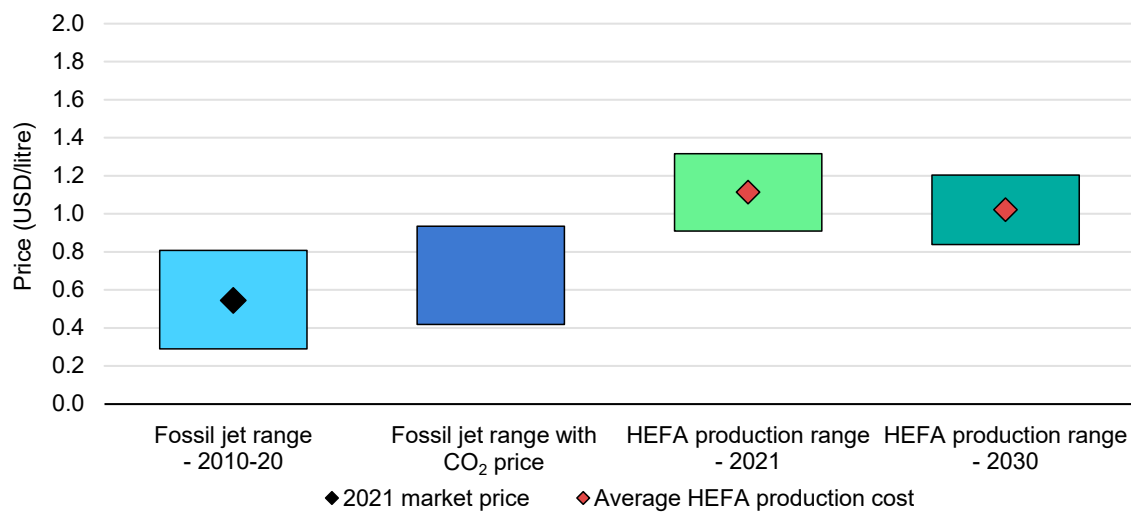
The work of international organisations such as ICAO and IATA, as well as industry groups bringing together engine manufacturers, airlines, fuel providers and airports, has been critical to understanding the role of SAFs in reducing emissions and solving challenges related to standards, logistics, investment, policy design and building public confidence. SAFs include fuels made from biological sources, such as biojet, and renewable non-biological sources, such as power-to-liquids. Industry and governments need to evaluate and certify new fuels and share learnings across the industry, but successes to date are sufficient to support significant SAF expansion, as considered in this forecast.

## Condition 2 – Costs

While biojet is considerably more expensive than fossil jet fuel, additional costs at 2% blending rates are unlikely to pose a major challenge to biojet expansion in our forecast. For instance, a Paris to New York one-way flight using 2% blended biojet would cost 0.4% more, or only USD 1.80.<sup>3</sup> The European Commission’s ReFuelEU proposal targets a 2% blend in 2025. This cost difference drops further to USD 1.40 if fossil jet fuel is exposed to a USD 50/tonne CO<sub>2</sub> price. As production expands, the biofuels industry also expects biojet costs to decline nearly 10% over the next decade via learning by doing and through economies of scale according to the Clean Skies for Tomorrow Coalition. For instance, large dedicated SAF production facilities or the repurposing of existing refineries offer opportunities for cost reductions.

HEFA producers will need to keep costs in check, however. Biojet market prices have soared to an average of USD 1.80/litre over the past year because of commodity price increases. On the path to net zero, blending will also need to climb to the double digits by 2030 according to the IEA Net Zero by 2050 Scenario.

**Figure 4.21 Fossil jet and biojet fuel production cost ranges**



IEA. All rights reserved.

Note: Carbon price = USD 50/tonne.

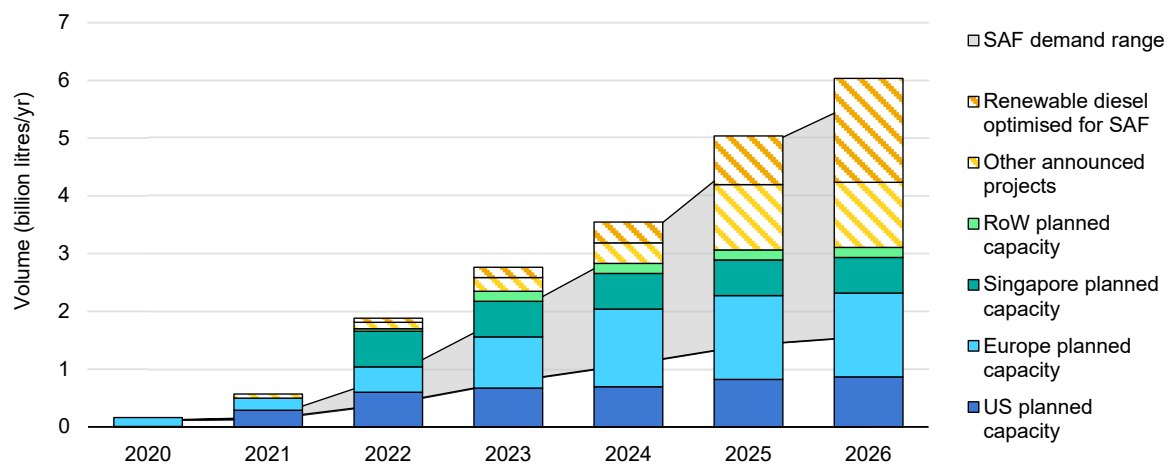
Sources: IEA analysis based on EIA (2021c), ICAO (2021b), Argus Direct (2021a), (IATA, 2021) and World Economic Forum (2021) data.

<sup>3</sup> Biojet prices for the above calculation are based on average production costs not accounting for the recent increase in commodity prices.

## Condition 3 – Policies

Policies under discussion in the United States and Europe would expand biofuel demand by a factor of five in 2026 compared with existing policies. Current mandates, financial support and airline offtake agreements for SAFs are likely to drive biojet demand to 2 billion litres by 2026, up from 0.1 billion litres in 2021. This growth includes SAF mandates in countries such as Norway and Sweden, and existing policies in the United States. Airlines are also directly contracting for the purchase of SAFs via offtake agreements for 16 billion litres over the next 20 years (ICAO 2021b). Averaged over 20 years, offtake agreements are equivalent to 0.8 billion litres of demand per year, eight times 2021 demand. Policies and offtake agreements are not necessarily additive, however. An airline that has already committed to purchase SAFs in a country that then adopts a SAF mandate can use its commitments to satisfy the policy, for example. Nevertheless existing policies are helpful and necessary to demonstrate commercial production and streamline policy design. However, growth could be five times higher if all the measures currently under consideration were to come to fruition.

**Figure 4.22 Annual SAF demand range over the main and accelerated cases compared with capacity potential**



IEA. All rights reserved.

When accounting for proposed policies, demand swells to near 6 billion litres per year, similar to renewable diesels growth over the last five years. The EU and US policy proposals will have a significant influence on biojet demand prospects. The ReFuelEU proposal would see a 2% blending target for SAF across the bloc by 2025 for any flight leaving an EU airport (European Commission, 2020). The United States is proposing a tax credit for SAFs and plans to start rulemaking for post-2022 targets in its RFS in December 2021. These measures may help the

United States achieve its Sustainable Aviation Challenge, which sets a goal for the aviation industry to use 11 billion litres of SAF 2030. Both EU and US policy proposals incentivise GHG intensity reductions.

There are some important uncertainties too. The Chinese government is aiming for peak CO<sub>2</sub> emissions before 2030 and, as in other countries, SAF is one of the few options to reduce airline emissions in the near term. A 1% blending target by 2025 in China alone would increase demand by four times global production in 2021. Indonesia also has a 5% SAF mandate on the books, although it is not enforced. Brazil, a biofuels powerhouse, could also turn its sights on biojet, although there are no proposals beyond existing policies. Some governments are also requiring a specific role for non-biojet SAFs such as electrofuels. The ReFuelEU proposal includes a 0.7% target for synthetic fuels by 2030 and Germany is exploring a SAF mandate specifically for renewable fuels from non-biogenic origins with a 1% target by 2028. Renewable non-biogenic fuels are not included in this analysis given the likely small values by 2026.

## Condition 4 – Production

Planned projects are more than sufficient to meet existing policy commitments, but significant additional capacity must be added if proposed policies are implemented. Projects in advanced stages of development account for just over 3 billion litres of biojet capacity. Nearly half of this proposed capacity is in Europe, with the remaining split nearly equally between the United States and Singapore. This capacity is well beyond the 2 billion litres likely to be needed under existing policies.

If governments implement all proposed policies, then planned projects would supply 60% of demand. Other projects that have been proposed, at the early proposal stages or lacking financial commitment, could add a further billion litres per year of capacity. However, this still leaves a near 2 billion litre gap. Biojet to fill that gap could come from new plants or optimising existing and planned renewable diesel plants to produce biojet. This would require optimising around 15% of 2026 renewable diesel capacity for biojet production, well within the realm of possibility. There are other options too, such as new dedicated SAF production beyond what is currently on the books, from existing technology pathways or new. Production is therefore not a constraint for the level of deployment considered in this analysis.

## Condition 5 – Feedstock sustainability

Planned biofuel policies in the United States and Europe include sustainability requirements, but new fuel pathways and feedstock treatment technologies must be commercialised to sustain future growth. Biojet must be produced using sustainable feedstocks to avoid the risk of negative impacts on biodiversity, freshwater systems, and food prices and availability. The IEA Net Zero Scenario found that to sustain growth, new biofuel production, including SAFs, can and must increasingly be from wastes, residues and woody energy crops grown on marginal land and cropland not suitable for food production. The Clean Skies Coalition sees a limited role for used cooking oil and residue fats, which it estimates could supply only a maximum of 5% of aviation fuel demand in 2030, and excludes edible oil seeds as an acceptable feedstock. The ReFuelEU proposal also recommends excluding feed and food crop-based fuels. Edible oil crops, and wastes and residues (primarily from used cooking oil and animal wastes) are the main feedstocks for proposed biojet facilities.

Since forecast volumes to 2026 remain relatively small and biojet plants could accept oils from other feedstocks in the future, feedstocks and sustainability constraints do not yet pose a major constraint. However, feedstock constraints for used cooking oil, animal fats and edible oil crops are likely to apply at some point if biojet is to expand at the scale envisaged in the IEA Net Zero Scenario, either as a cost issue or unacceptable impacts on sustainability measures. In the medium and long term, biojet will need to be produced overwhelmingly from wastes, residues (beyond used cooking oil and animal wastes) and crops that do not compete with arable land.

Governments will also need to include GHG performance criteria as part of SAF support. This is already the case in proposed and existing policies in Europe and the United States, examples that other countries considering SAF support could learn from.

Biojet is ready to take off if governments are willing to establish the right policy environment. Long-term growth, however, depends on commercialising technologies and new feedstocks that do not compete with edible crops and use wastes and residues beyond animal fats and used cooking oil.

## Are renewable heating options cost-competitive with fossil fuels in the residential sector?

While fossil fuels met more than 60% of heat demand in the buildings sector globally in 2020, the recent rebound in oil and gas prices revives the question of the cost-competitiveness of renewable space and water heating technologies.<sup>4</sup> The cost-competitiveness of heating technologies depends on a combination of parameters, including initial investment costs, variable operating costs, fixed operating and maintenance costs, and the presence of financial and economic incentives or disincentives.

### Upfront costs

The purchase cost of residential heating units varies greatly, not only from one technology and sub-technology to another – depending on the system's functionality, quality and degree of automation – but also between regions, depending on the scale of the market. Although economies of scale and market competition can still yield significant cost reductions in various regions, the purchase cost of most renewable heating technologies, for example heat pumps and automated biomass boilers, is anticipated to remain higher than for fossil fuel options, such as oil and gas boilers, in the medium term. Ground-source heat pumps have among the highest upfront costs; however, this is partly due to the drilling for and installation of the underground heat exchanger, whose lifetime can reach 40 to 100 years, and which should thus be considered as a long-term investment. The relatively high cost of reversible heat pumps should also be put in the context of the additional possibility of operating them as air-conditioning systems.

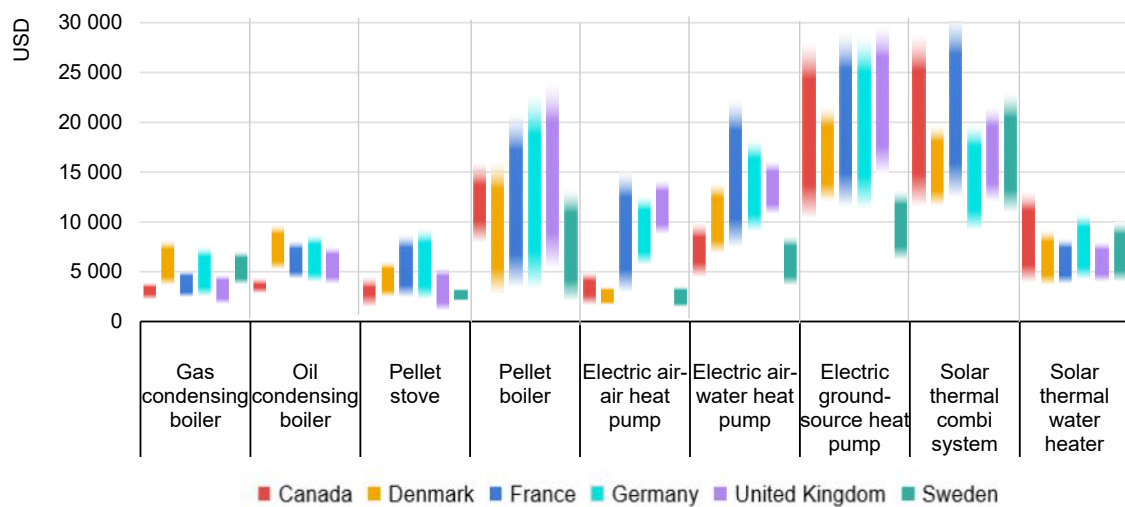
In addition to the cost of the heating unit per se, upfront costs also include installation costs (e.g. transport, piping work) as well as ancillary costs (e.g. fuel storage tank, buffer storage tank). Whether the new heating configuration combines space and water heating or requires two separate systems (e.g. a biomass stove for space heating in combination with a heat pump or solar thermal water heater) also influences total investment costs. Importantly, in some cases, switching to renewable-based technologies for space heating may also require replacing or adapting the heat distribution system. For instance, heat emitters

---

<sup>4</sup> Renewable space and water heating options comprise all technologies using renewable energy sources, including biomass, geothermal heat, solar thermal heat and ambient heat harnessed by heat pumps.

designed for use with fossil fuel boilers typically operate in the range of 60-80°C, while heat pumps are more efficient with output temperatures below 55-60°C.<sup>5</sup> In the United Kingdom, about half of all dwellings may require either modification of the heat distribution system or reducing heat demand through building retrofits in order to operate with a 55°C flow temperature on an average winter day. This share increases to more than 85% of dwellings on a cold winter day (BEIS, 2020). The cost of installing larger hydronic radiators, underfloor heating or forced-air heating systems can be significant – as much as half the cost of the heating unit. Such investments are not necessary with solar thermal systems, which can be combined with existing installations. This flexibility may, for instance, partly explain the high interest for solar thermal systems under the United Kingdom’s recent Green Home Grant scheme, in which it represented 60% of all low-carbon heat installations (Solar Energy UK, 2021). For most other countries, however, limited data are available on the characteristics of installed heat distribution systems in buildings. Consequently, the financial cost and the levels of disruption implied by a wide-scale transition to renewable heating are difficult to estimate.

**Figure 4.23 Investment cost range for selected residential space and water heating technologies and regions**



IEA. All rights reserved.

Notes: Investment costs shown in this figure include unit purchase and installation costs, including value added tax (VAT), for an average single-family house. They exclude ancillary costs (e.g. distribution system) and do not account for policy support.

In addition to affecting overall cost-competitiveness, the high upfront cost of renewable technologies can also create financing obstacles for households.

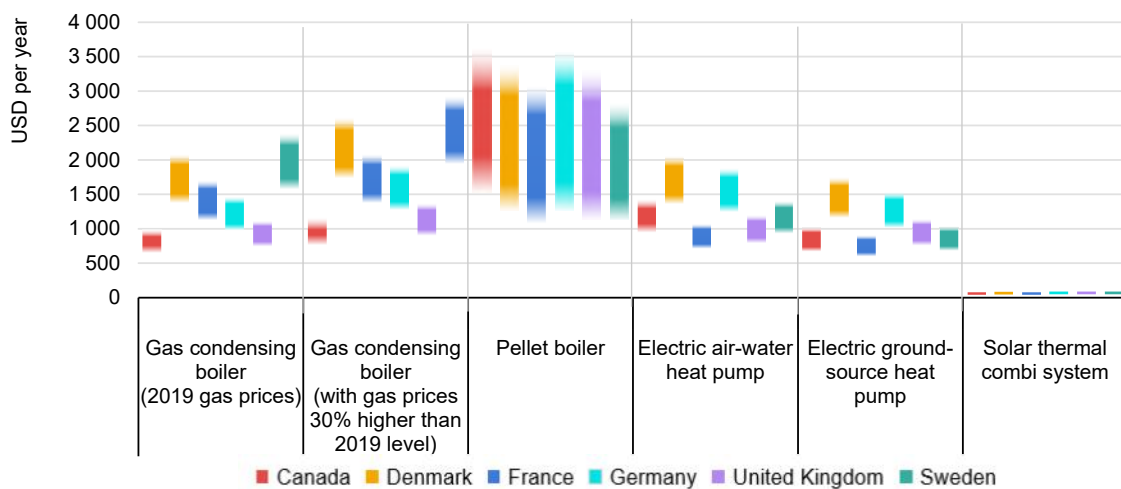
<sup>5</sup> Similarly, integrating renewable heat technologies like solar thermal, geothermal and heat pumps into district heating systems is easier in high-efficiency networks that operate at low temperature.

Policies can play a key role in overcoming these challenges, for instance through investment grants, rebates, fiscal incentives and loan schemes. Policies supporting energy efficiency investment in buildings can also assist the transition to lower-temperature distribution systems.

## Operating costs

Variable operating costs depend on annual heating demand, technology efficiency and consumer fuel prices. Electric heat pumps – especially ground-source systems – are by far the most efficient technology, with their coefficient of performance about three to five times higher than the efficiency of condensing gas and oil boilers. In contrast, biomass boilers are generally 10% to 20% less efficient than their gas equivalents on annual average (Energistyrelsen, 2021). As for fuel prices, solar thermal systems make use of a free energy source, while other renewable heating technologies benefit from better price visibility than fossil fuel options, since wood pellet and electricity end-user prices are generally less volatile than oil and gas prices.

**Figure 4.24 Average annual operating cost range for selected space and water heating technologies and regions**



IEA. All rights reserved.

Note: Operating costs shown in this figure are calculated based on national average dwelling heat demand, technology efficiency, fixed operation and maintenance costs and 2019 end-user fuel cost for each country.

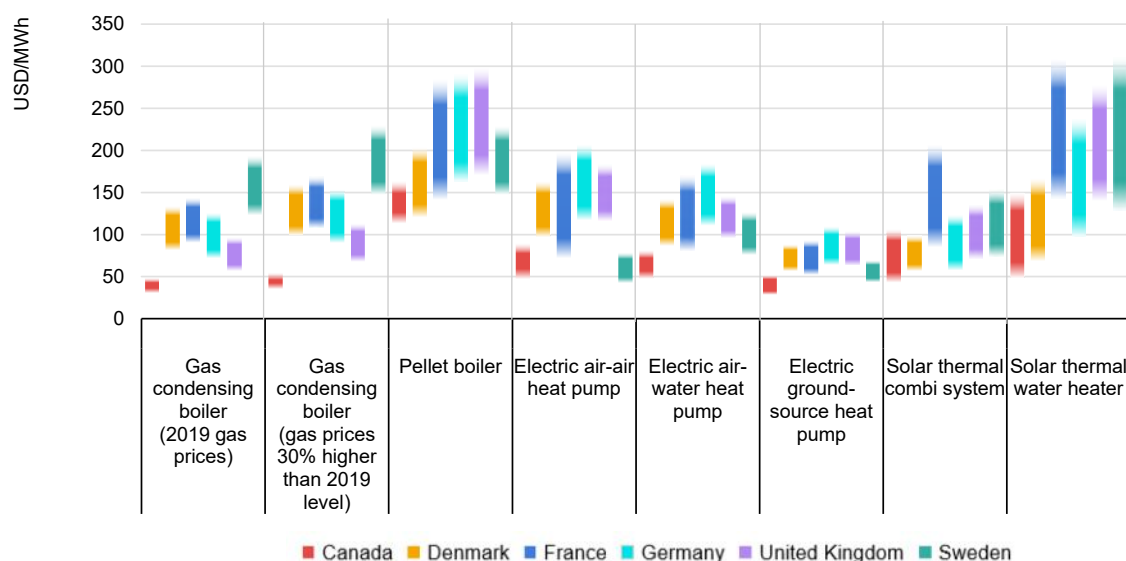
Importantly, the policy environment can considerably influence fuel costs, for instance through subsidies, fuel taxes or fuel tax reliefs (e.g. on renewable electricity used for heat), and carbon pricing. While incentives for renewable heating in buildings are increasingly prevalent, in many countries, policies subsidising the use of fossil fuels for heating continue to conflict with those that



support the uptake of renewables (REN21, 2021). For instance, for the year 2020 IEA estimates of global fossil fuel consumption subsidies exceed USD 180 billion (IEA, 2021i).

## Overall cost-competitiveness of heating technologies

**Figure 4.25 Levelised cost of heating for consumers, for selected space and water heating technologies and countries**



IEA. All Rights Reserved

Notes: The levelised cost of heating ranges shown here are simplified estimates provided for information. The calculation includes investment costs (including VAT., excluding ancillary costs and policy support), maintenance costs and fuel costs over the lifetime of the technology. It does not account for the cooling potentially supplied by reversible heat pumps. For ground-source heat pumps, we considered the lifetime of the borehole (assumed to last 60 years), with replacement of the compressor unit every 20 years. The calculation assumes constant average dwelling space and water heat demand for each country, constant average national end-user fuel prices at 2019 values (unless specified) and a 2% discount rate. In practice, parameters such as heat demand, total investment costs, technology lifetime and efficiency vary significantly across the building fleet, making each installation a specific case.

Overall, the cost-competitiveness of renewable heat technologies versus fossil fuel options varies significantly across regions. In Sweden, for instance, the combination of a carbon tax and relatively low equipment costs for heat pumps make the later more competitive than fossil fuel heating in most cases. In France, excluding investment support, the payback period of an electric air-to-water heat pump versus a condensing gas boiler for average heat demand can exceed 15 years at 2019 fuel prices. In the United Kingdom, Canada and Germany, renewable space heating technologies struggle to compete with gas without policy support. At 2019 fuel prices, the levelised cost of heating with air-to-water heat pumps for an average German dwelling is about 50% higher than with a condensing gas boiler, and about 55-70% higher in Canada. In Canada, the

levelised cost of pellet boiler heating can be over three times higher than for condensing gas boiler heating. Based on 2019 gas prices, assuming a USD 50/tonne carbon tax<sup>6</sup> would increase the levelized cost of heating with gas boilers in Canada by over 20%.

Capital costs account for a particularly high share of the cumulative discounted cash flow over the lifetime of heat pumps and solar thermal technologies: in France, Germany and the United Kingdom, capital costs represent between a third and half of the levelized cost of heat for heat pumps, and more than 85% for solar thermal technologies. Consequently, the cost competitiveness of these technologies is highly sensitive to their lifetime.

In 2021 the United Kingdom announced a target for the installation of 600 000 heat pumps a year by 2028, while Ireland announced a plan to install 600 000 heat pumps in total by 2030, two-thirds of them in existing buildings. Both targets imply a significant step up from current deployment levels: in 2020, heat pump sales amounted to 37 000 units in the United Kingdom and 8 000 units in Ireland (EHPA, 2021). Achieving Ireland's target requires heat pumps to account for approximately half of all heating system replacements in both residential and commercial buildings over the 2021-2030 period. In the United Kingdom, compensating for the current investment cost differential between gas boilers and heat pumps for 600 000 installations would represent a commitment of over £3 billion in loans or subsidies. However, such a boost in heat pump installations is expected to push average installation costs down through economies of scale and stronger market competition.

In addition to the technologies discussed in this section, other renewable heating solutions are emerging, such as solar PV-to-heat (PV2heat), which consists of PV modules directly (and solely) connected to an electric resistance water heater using DC power without inverters. This concept is, for instance, gaining ground in South Africa, with almost 12 000 systems installed in less than five years (IEA SHC, 2021b). While this progress is being driven in South Africa by a mandate limiting the share of fossil fuels in hot water supply, the simplicity of installation, the reliability and the cost-competitiveness of PV2heat systems offer perspectives for wider deployment.

In the longer term, renewable gases could also play a role in specific cases by taking advantage of existing gas infrastructure. In the case of renewables-based

---

<sup>6</sup> For comparison, carbon prices in the European trading system have been higher than EUR 50/tonne since May to the time of writing.

hydrogen, this would imply end-user appliances being hydrogen-ready, which entails limited extra cost compared with traditional gas appliances.

Beyond cost-competitiveness, multiple non-economic barriers still hinder the uptake of renewable heat in the residential sector. Some challenges are technical (e.g. building suitability), others concern the maturity of fuel and technology supply chains – including the availability of qualified installers – while others again relate to factors influencing consumer choices, such as confidence in the technology, awareness of potential benefits, split incentives, access to financing and “hassle costs” associated with the installation (IRENA, IEA and REN21, 2020). Scaling up the use of renewable heating in buildings therefore requires policy makers to address these challenges through comprehensive and multidimensional policy approaches. These can potentially include a combination of awareness-raising campaigns, regulatory measures and economic incentives, which – most importantly – should place social justice at the heart of the transition.

## References

- Argus Direct (2021a) Data services. <https://direct.argusmedia.com/> (accessed September 2021).
- Australian Government Department of Industry, Science, Energy and Resources (2020), Wind towers exported from the People’s Republic of China and the Republic of Korea. [https://www.industry.gov.au/sites/default/files/adrp/2019\\_100\\_wind\\_towers\\_-\\_attachment\\_f\\_public\\_notice.pdf](https://www.industry.gov.au/sites/default/files/adrp/2019_100_wind_towers_-_attachment_f_public_notice.pdf) (accessed November 2020).
- BEIS (2021) Domestic heat distribution systems : evidence gathering, Final Report, BEIS Research Paper Number: 2021/015 [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/976021/beis-dhds-final-report\\_1\\_.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/976021/beis-dhds-final-report_1_.pdf) (accessed September 2021).
- Bloomberg LP (2021), Bloomberg Terminal (accessed September 2021).
- BNEF (2021e), 1H 2021 Wind Turbine Price Index (WTPI) New Costs Stress (accessed September 2021).
- Canada Border Services Agency (CBSA) (2015), Concerning the final determinations with respect to the dumping and the subsidizing of certain photovoltaic modules and laminates originating in or exported from the People’s Republic of China
- EHPA (2021), Online stats tool <http://www.stats.ehpa.org/> (accessed November 2021)
- EIA (2021c) U.S. Gulf Coast Kerosene-Type Jet Fuel Spot Price FOB. [https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER\\_EPJK\\_PF4\\_RGC\\_DPG&f=A](https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EER_EPJK_PF4_RGC_DPG&f=A) (accessed September 2021)
- Energistyreslsen (2021), Technology catalogue for individual heating systems <https://ens.dk/service/fremskrivninger-analyser-modeller/teknologikataloger/teknologikatalog-individuelle> (accessed November 2021)

- European Commission (2021d) Sustainable aviation fuels – ReFuelEU Aviation. [https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12303-Sustainable-aviation-fuels-ReFuelEU-Aviation\\_en](https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12303-Sustainable-aviation-fuels-ReFuelEU-Aviation_en) (accessed September 2021).
- European Commission (2020), Commission Implementing Regulation (EU) 2020/1080. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R1080&from=EN> (accessed November 2021).
- European Commission (2021e), AD674 – Steel wind towers originating from the People's Republic of China. (accessed October 2021).
- European Commission (2021f), Recovery and resiliency facility, [https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility\\_en](https://ec.europa.eu/info/business-economy-euro/recovery-coronavirus/recovery-and-resilience-facility_en) (accessed September 2021).
- Fast Markets Media Bulletin (2021a), Chinese zinc, lead smelters told to cut power usage after energy shortage stretches to autumn. <https://www.metalbulletin.com/Article/4008958/Chinese-zinc-lead-smelters-told-to-cut-power-usage-after-energy-shortage-stretches-to-autumn.html> (accessed October 2021).
- Fast Markets Media Bulletin (2021b), European long steel producers cut output to manage skyrocketing energy costs <https://www.metalbulletin.com/Article/4011619/European-long-steel-producers-cut-output-to-manage-skyrocketing-energy-costs.html> (accessed November 2021)
- Federal Register (2012), Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled Into Modules From the People's Republic of China: Amended Final Determination of Sales at Less Than Fair Value, and Antidumping Duty Order <https://www.govinfo.gov/content/pkg/FR-2012-12-07/pdf/2012-29668.pdf> (Accessed November 2021).
- Federal Register (2013), Utility Scale Wind Towers from the People's Republic of China: Countervailing Duty Order. <https://www.federalregister.gov/documents/2013/02/15/2013-03728/utility-scale-wind-towers-from-the-peoples-republic-of-china-countervailing-duty-order> (accessed November 2021).
- Federal Register (2021), Utility Scale Wind Towers from India and Malaysia; Scheduling of the Final Phase of Countervailing and Antidumping Duty Investigations. <https://www.federalregister.gov/documents/2021/10/20/2021-22804/utility-scale-wind-towers-from-india-and-malaysia-scheduling-of-the-final-phase-of-countervailing> (accessed October 2021).
- Financial Times (2021), China's magnesium shortage threatens global car industry <https://www.ft.com/content/1611e936-08a5-4654-987e-664f50133a4b> (accessed October 2021).
- HELIOCSP (2020), Concentrated Solar Power New Builts to Revive in Spain, <https://helioscsp.com/concentrated-solar-power-new-builts-to-revive-in-spain/> (accessed September 2021).
- IATA (International Air Transport Association) (2021), Jet Fuel Price Monitor <https://www.iata.org/en/publications/economics/fuel-monitor>. (accessed September 2021).
- IEA (2021b), World Energy Outlook 2021, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2021> (accessed September 2021).

- IEA (2021f), Hydropower Special Market Report, Paris.  
<https://www.iea.org/reports/hydropower-special-market-report> (accessed September 2021).
- IEA (2021g), Global Hydrogen Review 2021, IEA, Paris <https://www.iea.org/reports/global-hydrogen-review-2021> (accessed October 2021)
- IEA (2021h), Sustainable Recovery Tracker, IEA, Paris,  
<https://www.iea.org/reports/sustainable-recovery-tracker> (accessed September 2021)
- IEA (2021i) Energy subsidies, tracking the impact of fossil-fuel subsidies,  
<https://www.iea.org/topics/energy-subsidies> (accessed November 2021)
- IEA SHC (2021b), PV2heat in South Africa —Almost 12,000 Systems Installed  
<https://www.iea-shc.org/Data/Sites/1/publications/2021-07-PV2heat%20in%20South%20Africa.pdf> (accessed November 2021)
- ICAO (International Civil Aviation Organization) (2021b) Sustainable Aviation Fuel.  
<https://www.icao.int/environmental-protection/pages/SAF.aspx> (accessed September 2021).
- IEA Bioenergy (2021) Progress in the Commercialization of Biojet / Sustainable Aviation Fuels: Technologies, potential and challenges.  
<https://www.ieabioenergy.com/blog/publications/progress-in-the-commercialization-of-biojet-sustainable-aviation-fuels-technologies-potential-and-challenges/> (accessed September 2021).
- IHS Markits (2021b), Biofuels market (subscription service) (accessed September 2021).
- IRENA (2020), Renewable Power Generation Costs in 2020,  
<https://www.irena.org/publications/2021/Jun/Renewable-Power-Costs-in-2020> (accessed September 2021).
- IRENA, IEA and REN21 (2020), 'Renewable Energy Policies in a Time of Transition: Heating and Cooling'. IRENA, OECD/IEA and REN21  
<https://www.irena.org/publications/2020/Nov/Renewable-energy-policies-in-a-time-of-transition-Heating-and-cooling> (accessed September 2021).
- IMF (2021a) (International Monetary Fund)  
<https://www.imf.org/en/Publications/FM/Issues/2021/10/13/fiscal-monitor-october-2021> (accessed October 2021)
- IMF (2021b). World Economic Outlook: Recovery during a Pandemic—Health Concerns, Supply Disruptions, Price Pressures. Washington, DC, October. (accessed October 2021)
- International Commission on Large Dams (ICOLD) (2021) World Register of Dams,  
[https://www.icoldcigb.org/GB/world\\_register/world\\_register\\_of\\_dams.asp](https://www.icoldcigb.org/GB/world_register/world_register_of_dams.asp) (accessed May 2021).
- MNRE (2021). Imposition of Basic Customs Duty (BCD) on Solar PV Cells & Modules/Panels.  
[https://mnre.gov.in/img/documents/uploads/file\\_f-1615355045648.PDF](https://mnre.gov.in/img/documents/uploads/file_f-1615355045648.PDF) (accessed October 2021).
- NREL (2019). Crystalline Silicon Photovoltaic Module Manufacturing Costs and Sustainable Pricing: 1H 2018 Benchmark and Cost Reduction Roadmap.  
<https://www.nrel.gov/docs/fy19osti/72134.pdf> (accessed September 2021).
- NREL (2020), 2019 Cost of Wind Energy Review  
<https://www.nrel.gov/docs/fy21osti/78471.pdf> (accessed September 2021).

- NREL (2021), Concentrating Solar Power Projects, <https://solarpaces.nrel.gov/fr> (accessed September 2021).
- OECD (2021b), OECD Economic Outlook, Interim Report September 2021: Keeping the Recovery on Track, OECD Publishing, Paris, <https://doi.org/10.1787/490d4832-en>. (accessed October 2021).
- PV Magazine (2020), India's renewables-plus-storage tenders mark a new beginning with highly competitive tariffs: NSEFI, <https://www.pv-magazine-india.com/2020/05/12/indias-renewables-plus-storage-tenders-mark-a-new-beginning-with-highly-competitive-tariffs-nsefi/>, (accessed October 2021).
- PV Tech (2021), Polysilicon price jumps 9% in a week as energy crisis hits China <https://www.pv-tech.org/polysilicon-price-jumps-9-in-a-week-as-energy-crisis-hits-china/> (accessed November 2021)
- REN21 (2021), Global Status Report 2021, [https://www.ren21.net/wp-content/uploads/2019/05/GSR2021\\_Full\\_Report.pdf](https://www.ren21.net/wp-content/uploads/2019/05/GSR2021_Full_Report.pdf) (accessed October 2021).
- Reuters (2021a), China power curbs are challenge for steel mills – industry group <https://www.reuters.com/business/energy/china-power-curbs-are-challenge-steel-mills-industry-group-2021-10-25/> (accessed November 2021).
- Reuters (2021b), Power crunch hits Europe's silicon and zinc supplies for renewables <https://www.reuters.com/business/energy/1meweek-power-crunch-hits-europes-silicon-zinc-supplies-renewables-2021-10-15/> (accessed October 2021).
- Solar Energy UK (2021), Solar Thermal Progress, <https://solarenergyuk.org/the-solar-thermal-progress/> (accessed November 2021)
- TFI Global News (2021). China is shutting down Aluminium, Textile and many more industries <https://tfiglobalnews.com/2021/09/27/china-is-shutting-down-aluminum-textile-and-many-more-industries/> (accessed October 2021).
- USDA (2021), Grain: World Markets and Trade. <https://apps.fas.usda.gov/psdonline/circulars/grain.pdf> (accessed October 2021)
- United States Department of Commerce (2020), Crystalline Silicon Photovoltaic Products From the People's Republic of China and Taiwan: Continuation of Antidumping and Countervailing Duty Orders on China and the Antidumping Duty Order on Taiwan <https://www.govinfo.gov/content/pkg/FR-2020-09-11/html/2020-20076.htm> (accessed November 2021).
- United States International Trade Commission (2020), Utility scale wind towers from Canada, Indonesia, Korea and Vietnam injure U.S. Industry, says USITC [https://www.usitc.gov/press\\_room/news\\_release/2020/er073011614.htm](https://www.usitc.gov/press_room/news_release/2020/er073011614.htm) (accessed November 2021).
- United States Trade Representative (2018), Section 201 Cases: Imported Large Residential Washing Machines and Imported Solar Cells and Modules <https://ustr.gov/sites/default/files/files/Press/fs/201%20Cases%20Fact%20Sheet.pdf> (accessed November 2021).
- World Economic Forum (2021) Clean Skies for Tomorrow: Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation. <https://www.weforum.org/reports/a356c865-311e-45ca-845d-efe5f762a820> (accessed September 2021).

# General annex

## Abbreviations and acronyms

ACPA	American Clean Power Association
AEMO	Australian Energy Market Operator
ANEEL	Agencia Nacional de Energia Electrica
AWEA	American Wind Energy Association
BCD	Basic Customs Duty
CEEW	Council on Energy, Environment and Water
CfD	Contract for difference
CNMC	Comisión Nacional de los Mercados y La Competencia
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSP	Concentrated solar power
DISCOM	Distribution companies
DRHI	Domestic Renewable Heat Incentive
EBRD	European Bank for Reconstruction and Development
EHI	European heating industry
EHPA	European Heat Pump Association
EPA	Environmental Protection Agency
EREF	European Renewable Energy Foundation
ESTIF	European Solar Thermal Industry Federation
FIP	Feed-in premium
FIT	Feed-in tariff
GC	Green Certificate
GE	General Electric
GSE	Gestore dei Servizi Energetici
HEFA	Hydroprocessed esters and fatty acids
HVO	Hydrogenated vegetable oil
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IEEJ	Institute of Energy Economics Japan
IHA	International Hydropower Association
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
ITC	Investment tax credit
MENA	Middle East and North Africa
MODS	Monthly Oil Data Service
NECP	National Energy and Climate Plans
NREL	National Renewable Energy Laboratory
PPA	Power purchase agreements
PSH	Pumped storage hydropower
PTC	Production tax credit
REZ	Renewable Energy Zones
RFS	Renewable Fuel Standard
RIAB	Renewable Industry Advisory Board
RIN	Renewable Identification Number
RPS	Renewable portfolio standard
RRF	Recovery and Resilience Facility
SAF	Sustainable aviation fuel
SMP	System marginal price

TCP	Technology Collaboration Programme
TRNC	Turkish Republic of Northern Cyprus
VAT	Value added tax
VRE	Variable renewable energy
WTPI	Wind Turbine Price Index

## Units of measure

bbbl	barrel
bbbl/d	barrels per day
bcm	billion cubic metres
bcm/yr	billion cubic metres per year
cm/s	centimetres per second
gCO <sub>2</sub>	gramme of carbon dioxide
gCO <sub>2</sub> /kWh	grammes of carbon dioxide per kilowatt hour
GJ	gigajoule
Gt/yr	gigatonnes per year
GtCO <sub>2</sub>	gigatonne of carbon dioxide
GtCO <sub>2</sub> /yr	gigatonnes of carbon dioxide per year
GW	gigawatt
GWh	gigawatt hour
MWh	megawatt hour-



Revised version, December 2021.

Information notice found at:

<https://www.iea.org/corrections>

<http://www.oecd.org/about/publishing/corrigenda.htm>

This publication reflects the views of the IEA Secretariat but does not necessarily reflect those of individual IEA member countries. The IEA makes no representation or warranty, express or implied, in respect of the publication's contents (including its completeness or accuracy) and shall not be responsible for any use of, or reliance on, the publication. Unless otherwise indicated, all material presented in figures and tables is derived from IEA data and analysis.

This publication and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

IEA. All rights reserved.

IEA Publications

International Energy Agency

Website: [www.iea.org](http://www.iea.org)

Contact information: [www.iea.org/about/contact](http://www.iea.org/about/contact)

Typeset in France by IEA - November 2021

Cover design: IEA

Photo credits: © GraphicObsession

