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Socio-economic footprint of the energy transition

JAPAN

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About IRENA

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Disclaimer

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Abbreviations

°C degrees Celsius

1.5-S IRENA's 1.5°C Scenario

BECCS bioenergy with carbon capture and storage

CCUS carbon capture, utilisation and storage

CO_2 carbon dioxide

DACCS direct air capture with carbon storage

EUR euro

FIT feed-in tariff

GDP gross domestic product

GHG greenhouse gas

GW gigawatt

IRENA International Renewable Energy Agency

JPY Japanese yen

kWh kilowatt-hour

METI Ministry of Economy, Trade and Industry

MW megawatt

NEDO New Energy and Industrial Technology Development Organisation

NFC Non-Fossil Certificate

OECD Organisation for Economic Co-operation and Development

PES Planned Energy Scenario

PV photovoltaic

R&D research and development

TFEC total final energy consumption

TPES total primary energy supply

TWh terawatt hour

USD United States dollar

Scenarios and perspectives in this report

This outlook report presents two scenarios and their socio-economic outcomes:

The **Planned Energy Scenario (PES)** is the reference case for this study, providing a perspective on energy system developments based on governments' energy plans, as well as other planned targets and policies as of 2019, including Nationally Determined Contributions (NDC) under the Paris Agreement. This report considers policy targets and developments until April 2019. Policy changes and targets announced since then are not considered in the modelling exercise but are mentioned in the analysis to provide insights on latest developments.

The **1.5°C Scenario (1.5-S)** describes an energy transition pathway aligned with the 1.5 degree Celsius (°C) climate ambition – that is, to limit the global average temperature increase by the end of the present century to 1.5°C, relative to pre-industrial levels. It prioritises readily available technology solutions including all sources of renewable energy, electrification measures and energy efficiency, which can be scaled up at the necessary pace for the 1.5°C goal.

The time frame of the analysis covers the period to 2050.

The socio-economic analysis of these scenarios is carried out using a global macro-econometric model, E3ME[1], which links the energy system and the world's economies within a single quantitative framework. E3ME analyses the impact of the energy transition on variables such as gross domestic product (GDP), employment and welfare to inform energy system planning and policy making to ensure a just and inclusive energy transition at the global, regional and national levels. Energy mixes and the related investment based on the REmap Model[2] of the International Renewable Energy Agency (IRENA) are used as exogenous inputs for each scenario, as well as climate and transition-related policies. Annex II lists some of the key policy assumptions underlying each scenario and considers how indicators vary (or not) across both scenarios.

The outcome of implementing energy transition planning is closely linked to its socio-economic impacts. This socio-economic footprint of energy transition roadmaps results from the many interactions and feedbacks between the energy system and the wider economy and social systems. Understanding the socio-economic footprint of energy transition roadmaps informs policy making for a successful transition.

IRENA has been exploring the socio-economic footprint of energy transition roadmaps since 2016 (IRENA, 2016a, 2017, 2018, 2019a 2019b, 2020a, 2020b, 2021a, 2022a), analysing key drivers and impacts, providing insights to support energy transition planning and implementation at the global, regional and national levels. Throughout its reports, IRENA has emphasised that a holistic global policy framework is needed for the energy transition to be successful and broadly beneficial. Different policy elements complement and reinforce each other, covering a broad spectrum of technical, social and economic issues to accelerate the transition and ensure that its benefits are broadly shared, and its burdens minimised.

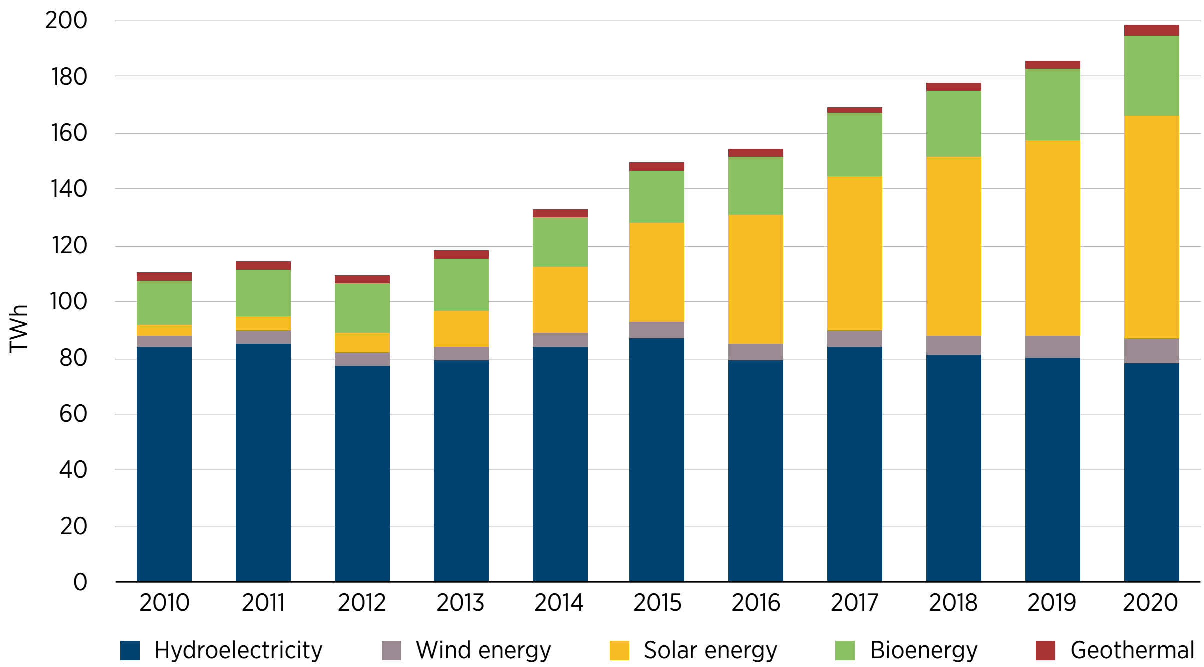
[1] *More information can be found at www.e3me.com*

[2] *More information can be found at irena.org/remap*

Executive summary

Japan is one of the world's most economically and industrially advanced nations. It is also one of the world's largest consumers and importers of energy. The country is still heavily dependent on fossil fuel imports; however, renewables play a small but growing role in the energy mix, and deployment is increasing every year (Figure S1).

Figure S1 Renewable energy generation in Japan, 2010 to 2020



Source: METI, 2021

In 2020, in terms of its renewable energy power capacity, Japan has one of the highest installed capacities. The country ranked third in the world for solar power and pumped storage, seventh for biomass, and tenth for geothermal and hydropower. The deployment of renewables in the power sector has been hampered by difficulties in connecting projects to the grid and in harmonising regional grids, as well as by low land availability and the occurrence of natural disasters.

Japan has put in place a diverse set of policies to support renewable energy deployment. In the power sector, policies have included liberalisation of the sector as well as instruments such as renewable portfolio standards (RPS), feed-in tariffs and auctions. Policies in the transport sector include measures related to biofuels as well as the promotion of e-fuels and electric vehicles. Some policies have also been enacted to strengthen research and development (although with limited budgets) as well as innovation and industrial development, for example in hydrogen. Carbon pricing policies are found in Japan, mostly at the local level.

Japan pledged to achieve carbon neutrality by 2050 in October 2020. In April 2021, the country reviewed its 2030 target for reducing greenhouse gas emissions and increased it from 26% reductions to 46% reductions from 2013 levels (Figure S2). The country's new, more ambitious emission reduction pathway is closer to the energy transition roadmap outlined by the International Renewable Energy Agency in its 1.5 degree Celsius scenario (1.5-S). Japan's new strategy for carbon neutrality has made the analysis provided in this report even more relevant, as the present discussion portrays the potential impacts (benefits and costs) of such a roadmap in comparison to the less ambitious targets of the past.

The transition's capital-intensive projects can boost investment while lowering dependence on fossil fuel imports, hence improving the trade balance and increasing gross domestic product (GDP). But in Japan and around the world, citizens care about more than just GDP; the sustainability and equity of economic activity is becoming increasingly important.

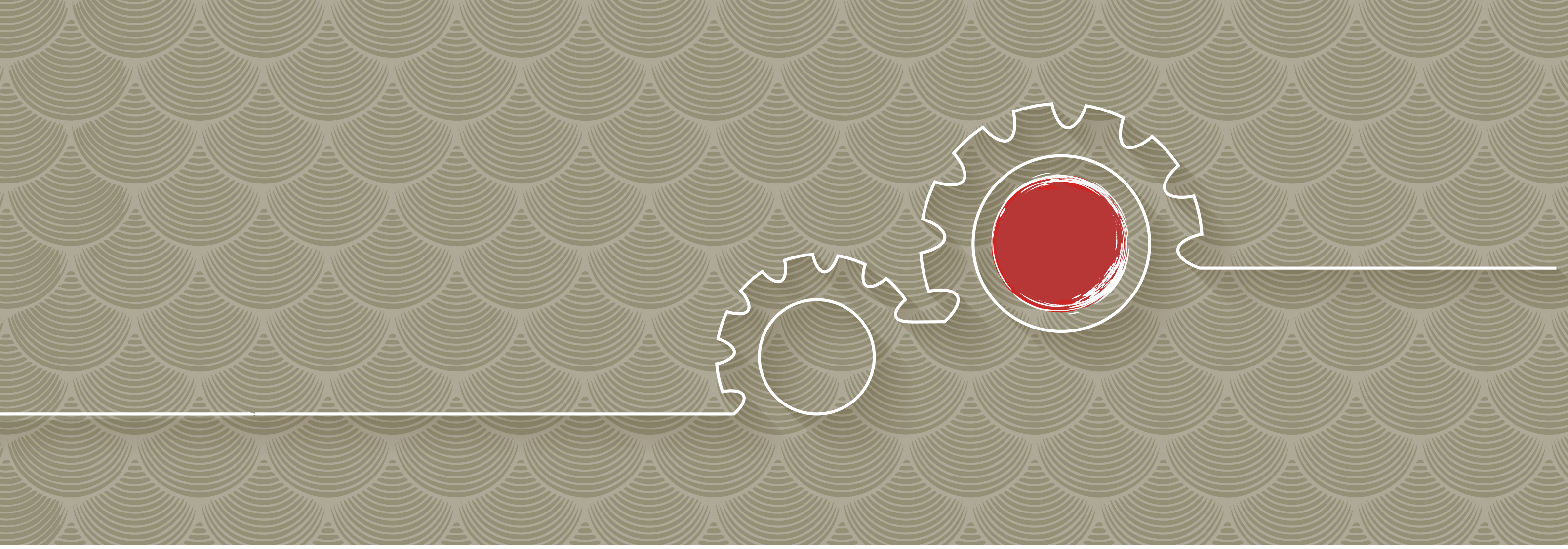
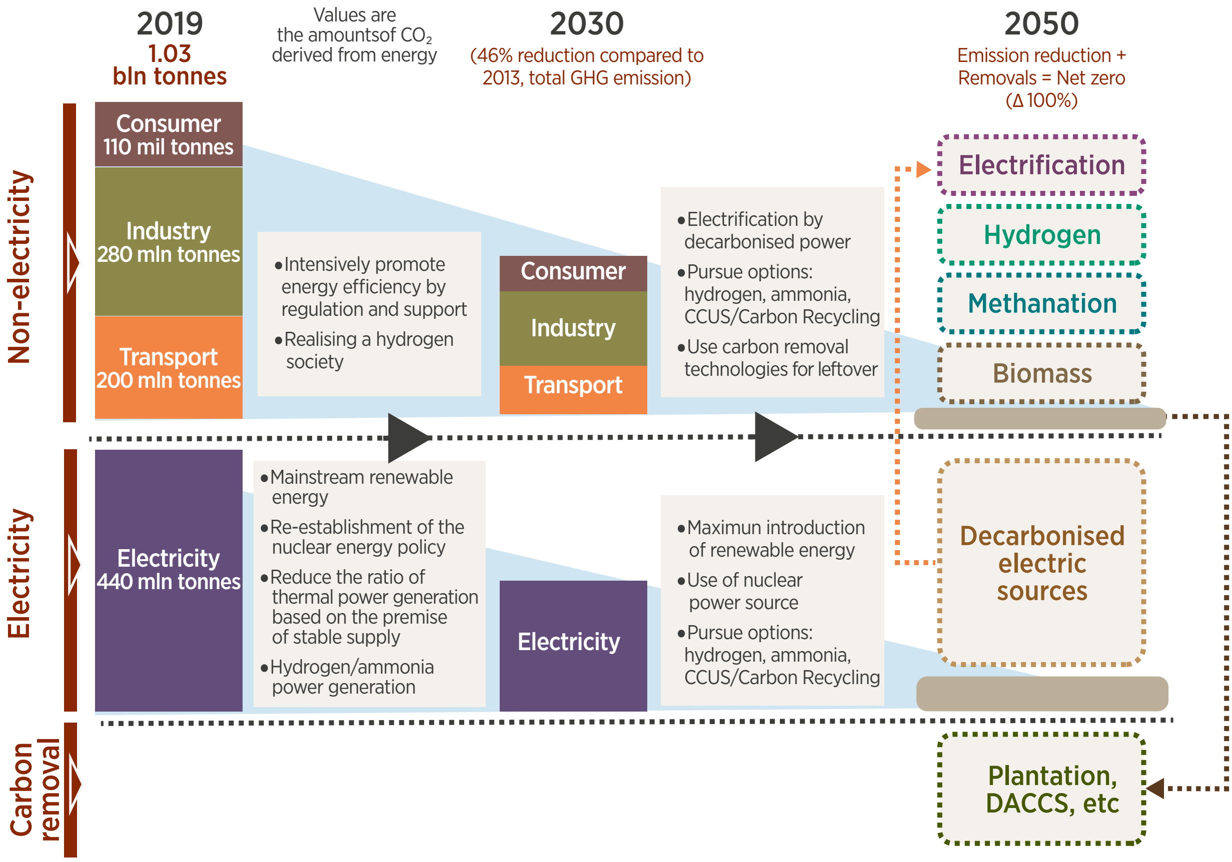


Figure S2 Japan's strategy for carbon neutrality by 2050



Note: CCUS = carbon capture, utilisation and storage; DACCS = direct air capture with carbon storage.

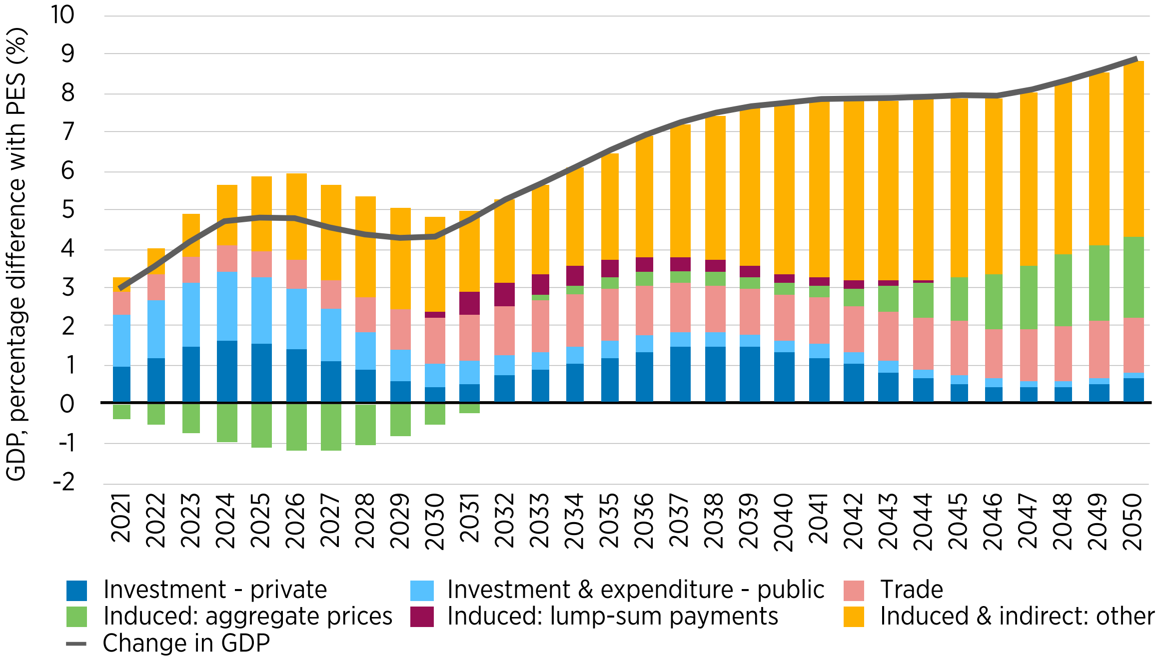
Source: METI, 2022.

The energy transition presents great potential to improve Japan's performance on broader socio-economic indicators and help Japan alleviate some of the existing challenges. Income and wealth inequalities have been long-standing issues, as well as relative poverty and low female participation in the labour force. Japan is the world's fifth largest emitter of carbon dioxide (CO_2) from fuel combustion, which, in addition to its impact on climate change, also causes significant deterioration in local air quality. Employment is high, but challenges and pressures imposed by the ageing and shrinking workforce have resulted in a labour shortage. While the nation and its economy are recovering from the impacts of the COVID-19 pandemic, these issues will continue to play an important role in the years ahead.

The energy transition can support in a multitude of ways. This is shown by this analysis that compares an ambitious 1.5 degree compatible pathway (1.5-S) and a reference Planned Energy Scenario (PES). Through higher shares of renewables, the energy transition will bring larger CO_2 emission reductions and lower local air pollution. The transition can also result in improved welfare, more jobs and higher GDP.

Under the 1.5-S, the country's economy is estimated to perform much better than under the PES: the average GDP difference compared with the PES is 6.3% over the period 2021-2050. In the PES, Japan is already expected to experience GDP growth of 1.1% per year from 2021 to 2050 (Figure S3) – therefore, the economic gains from the energy transition are significant. In cumulative terms, the country will add USD_{2019} 13.1 trillion to the growth already anticipated in the PES. This is the result of interplay between several drivers (defined in Box 3.1 in the main chapter) of the economy.

Figure S3 Japan's GDP percentage difference between the 1.5-S and the PES, by driver, 2021 to 2050

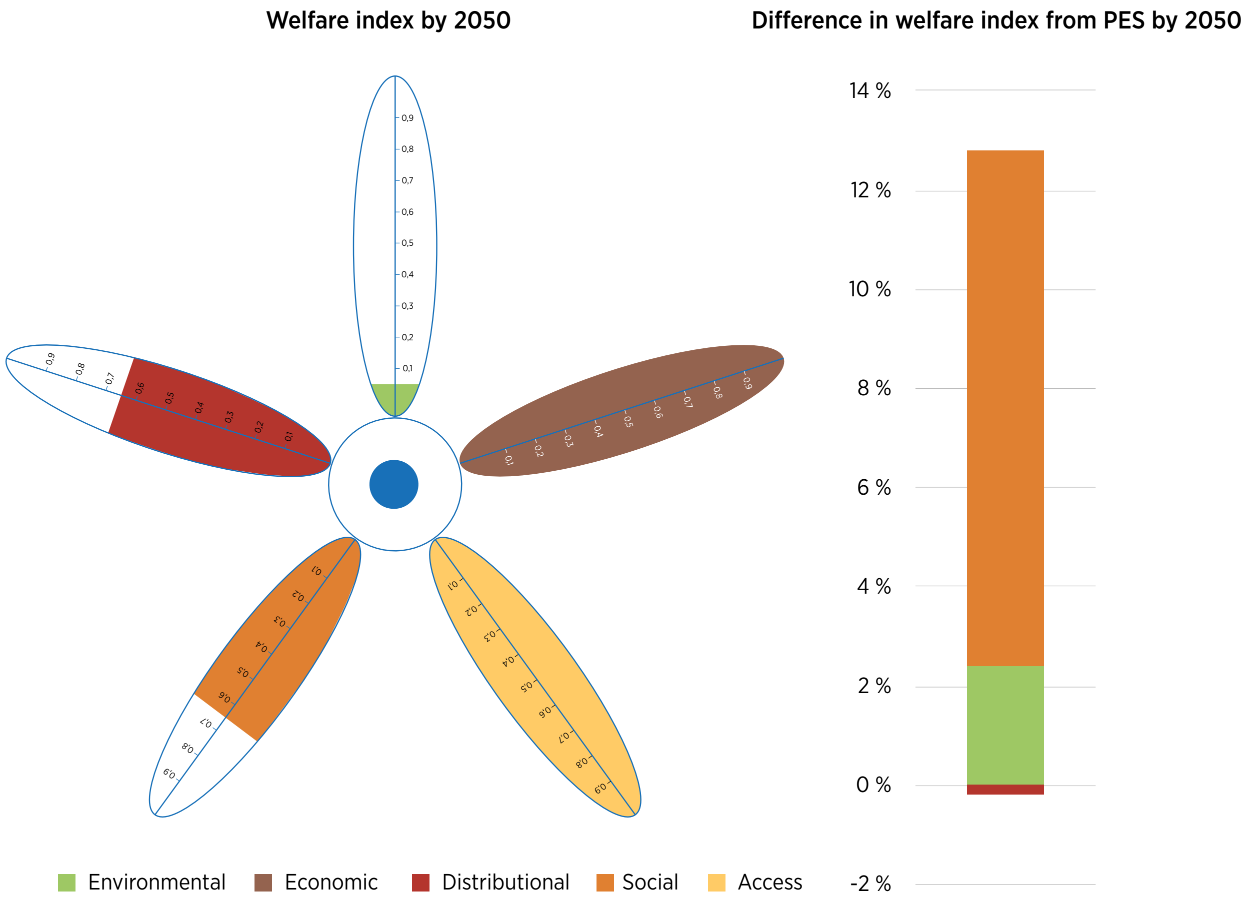


Some of the key drivers of growth are consumption, trade and investment. Household consumption has historically accounted for the largest share of GDP, and this trend continues in the 1.5-S, with the "induced and indirect effects (other)" driver holding the largest share in the additional GDP gain. Trade is also a positive and steady driver of the GDP differences during the transition. As Japan relies heavily on imports of fossil fuels, the lower fuel imports in the transition period improve the cumulative trade balance by an estimated USD_{2019} 3 trillion, or on average 18% of the total economic gain observed. Government spending also increases and results in an increase in GDP when compared to the PES (0.1% or USD 567 billion in 2050). It leads to increased spending on social services predominantly provided by the government including public administration, health care, and education, therefore mainly benefiting the public and personal services sector. This results in wider improvements in welfare.

Under the 1.5-S – and driven by the social and environmental dimensions – welfare in Japan improves compared with the PES (right side of Figure S4). The welfare improvement for Japan under the 1.5-S over the PES reaches 12.6% by 2050. This is a result of the reduced negative health effects from local air pollution, paired with reduced cumulative CO_2 emissions. The economic and energy access dimensions play less of a role in differentiating the 1.5-S and the PES, given that Japan already performs well in economic indicators and has achieved universal energy access. The distributional dimension performs slightly worse (-0.9%) under the 1.5-S, reflecting a balance between improvements in international distribution and a worsening of domestic distribution, the latter due in part to low carbon pricing limiting the fiscal space for domestic redistributive policies.

The analysis suggests that additional policy actions would be needed to further improve the human welfare indicators in Japan (as shown in the welfare index - left side of Figure S4). The environmental dimension offers the highest room for improvement, with a focus on limiting the consumption of materials. The social and distributional dimensions also offer room for improvement. Policies to increase social spending and further reductions in pollution would improve the social dimension index. Supportive policies would be crucial to close inequality gaps in Japan. To improve the distributional index, policy action to improve wealth distribution and to provide additional fiscal space (*e.g.,* higher carbon taxes) to increase lump-sum payments (addressing income distribution) would help.

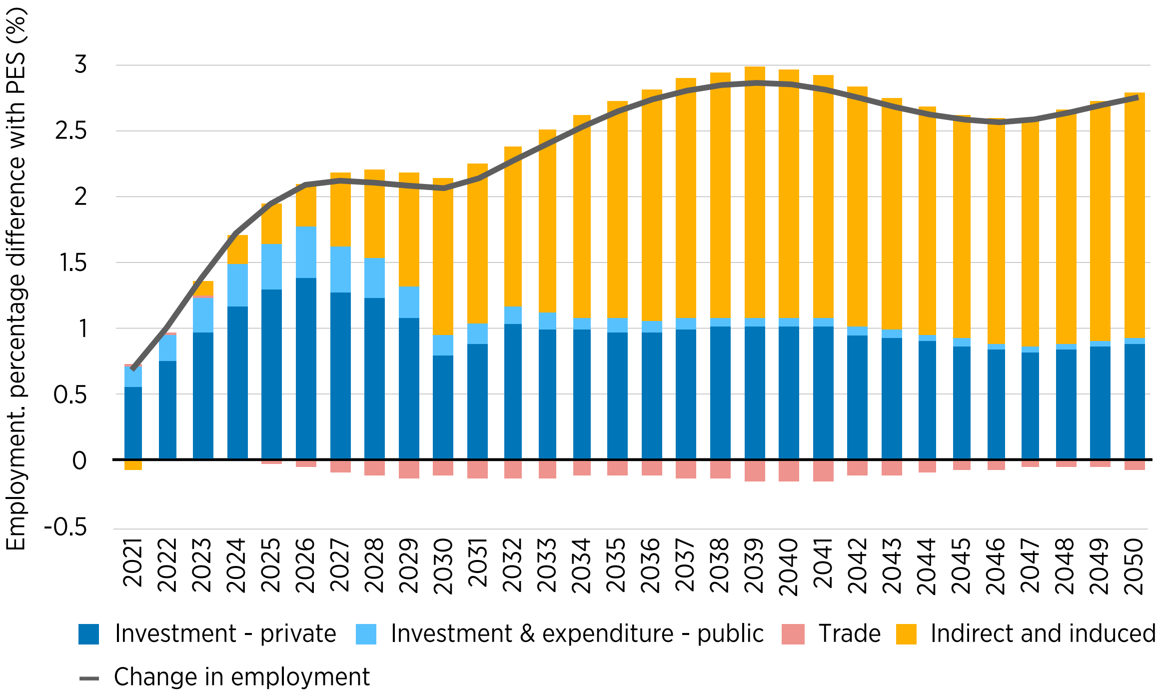
Figure S4 Welfare index for the 1.5-S and difference in welfare between the 1.5-S and the PES, 2050



Under the 1.5-S, employment is higher than the PES by an average of 2.3% over the 2021-2050 period, while population declines at a compound annual growth rate of -0.50% over the same period. Given the low unemployment rate in Japan today, there is little leeway for additional employment in both scenarios. By 2050, the 1.5-S results in 1.6 million additional jobs compared with the PES, corresponding to a 2.7% difference.

Similar to GDP, this trend is underpinned by drivers related to investment, trade, and indirect and induced effects (Figure S5). Front-loaded investment in capital-intensive transition technologies (renewables and other transition-related technologies) – both public and private – is the first driver of the additional jobs in the initial years to 2030. This effect is reduced and stabilises over the following decades with the decline in the relative weight of investment in GDP. After the first decade, the indirect and induced effects of consumer expenditures become the main driver of the increase in economy-wide employment.

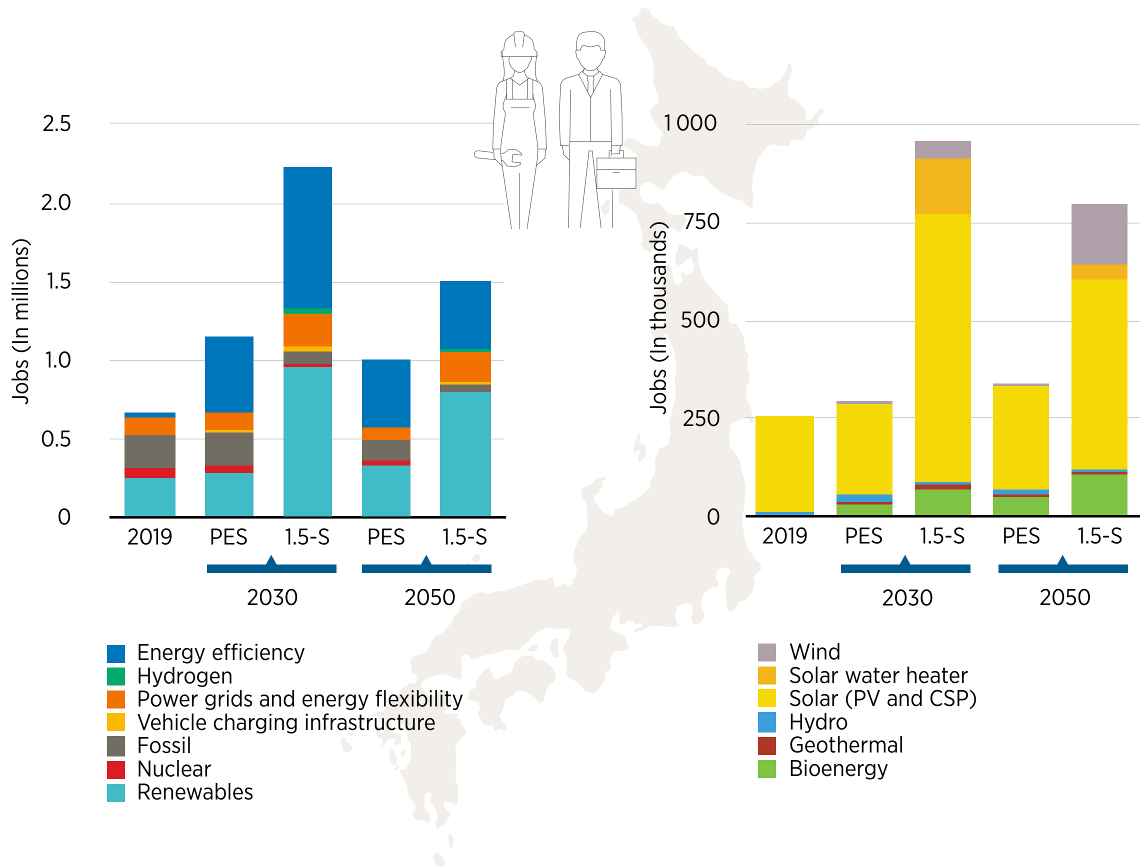
Figure S5 Employment in Japan, percentage difference between the 1.5-S and the PES by driver, 2021 to 2050



The number of energy sector jobs is estimated to be higher in the 1.5-S than the PES as the sector would have a total of 1.5 million jobs in the 1.5-S compared to 1 million in the PES (left side of Figure S6). A decline in jobs in 2050 compared with 2030 is a result of the front-loaded construction of new plants and infrastructure (including energy efficiency), the planned reduction of energy demand and an increase in productivity. Renewables contribute more than 50% (0.8 million) of the total energy sector jobs in the 1.5-S in 2050, followed by jobs in energy efficiency with a share of almost 30% (0.5 million jobs). Power grids and flexibility create 0.17 million jobs (11%). Nuclear, vehicle infrastructure and hydrogen each contribute 1%.

More specifically in jobs related to renewables, solar technologies (mainly PV) dominate the share of renewables (right side of Figure S6): under the 1.5-S, they account for 71% of renewable energy jobs by 2030 and 61% by 2050. Wind and bio-energy account for 19% and 13%, respectively, of renewable energy jobs by 2050. Comparing the PES and the 1.5-S, the highest relative differences in employment are seen in wind energy.

Figure S6 Energy sector (left) and renewable energy (right) jobs in the PES and the 1.5-S, 2019, 2030 and 2050



The additional jobs are more likely to be created in rural areas where renewable resources are more available, helping the country achieve its objective of improving rural demographics. The energy transition will also bring growth in jobs related to energy efficiency and energy flexibility. Simultaneously, jobs in fossil fuels will decline but are more than compensated by the growth in energy transition-related jobs.

The energy transition (1.5-S) can enable the country to meet its climate pledges, while supporting aggregated economic activity. Renewables can help to address concerns about declining rural populations and economies. A shift in technologies will create jobs across the value chain. There will be opportunities to create or revitalise the domestic manufacturing base across all transition-related technologies.

Self-reliance will increase significantly with local resource supply, reducing Japan's vulnerability to external geopolitical shocks and enhancing its energy security. Similar to many countries in transition, Japan faces challenges in the energy sector and beyond. With the global climate challenge, solutions are needed to swiftly advance the transition.

In short, a comprehensive and more ambitious energy transformation will lead to improved social well-being in Japan. But technological deployment alone will not necessarily deliver these socio-economic gains. The transition towards clean energy involves far-reaching changes across different dimensions of the economy, society and the surrounding natural ecosystems. To maximise the benefits of the energy transition, a wider policy framework is needed – one in which a set of structural and just transition policies are in place to manage potential misalignments. Ultimately, achieving Japan's goals will require fine-tuning the country's existing support policies and addressing the remaining policy gaps (as discussed in the report) in a holistic and comprehensive way.

01 Introduction

Japan is one of the world's most economically and industrially advanced nations. The country's economy, however, faces challenges related to an ageing population – currently 126.5 million (UN, 2019) – and a shrinking workforce. Japan is also one of the world's largest consumers and importers of energy. Lacking its own fossil fuel resources, it relies on imports for nearly all of its supply. This dependence on imports makes the country vulnerable to external forces, such as volatile fossil fuel prices and geopolitical shocks.

Since the oil crisis of the 1970s, Japan has placed energy security at the centre of its energy policy. The country's efforts to improve energy security and self-reliance were disrupted in 2011 by the Great East Japan Earthquake and related accidents at the Fukushima Daiichi nuclear plant. The resultant shuttering of the country's nuclear power plants created a 30% gap in electricity supply (METI, 2020a). This gap was partially covered by energy efficiency and conservation measures, such as the use of energy-efficient machinery, cutbacks in air conditioning use and power rationing.

To fill the rest of the gap, Japan increased its imports of liquefied natural gas (LNG) and coal, and boosted its efforts to adopt renewables. While the increase in renewable energy was initially small, it has been a testament to how rapidly energy transition technologies (such as energy efficiency and renewables) can replace conventional technologies (such as fossil fuel and nuclear) in energy-importing countries. In total, efficiency and renewables directly replaced 70% of Japan's 2010 (fiscal year) nuclear production in just five years (Zissler, Kåberger and Lovins, 2017).

The country's initial aim to reduce its greenhouse gas emissions, set in 2015, was revised, reiterated and strengthened in April 2021 at the Leaders' Summit on Climate. This resulted in a higher, more ambitious emission reduction target of 46% by fiscal year 2030, compared to 2013 levels – up from the previous target of only 26% (Reuters *et al.*, 2021).

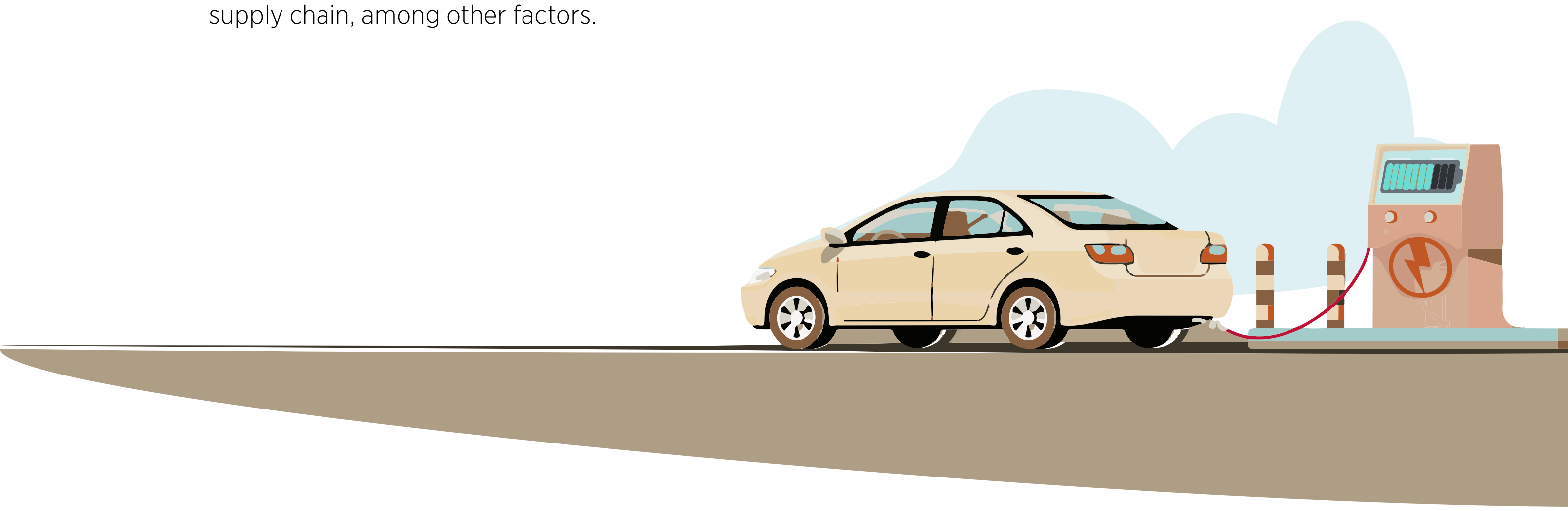
To reflect these latest commitments, in October 2021 the Ministry of Economy, Trade and Industry (METI) published the 6th Strategic Energy Plan, outlining Japan's further ambitions on decarbonisation. Under the plan, renewable sources will account for around 36-38% of the power supply by fiscal year 2030, more than double the current mix. Japan also expects 1% hydrogen/ammonia and 20%-22% nuclear power in the country's power generation mix in fiscal year 2030 – totalling around 60% of the non-fossil fuel power supply (renewables, hydrogen/ammonia and nuclear). However, this nuclear target is considered too high and unattainable given the current state of the country's nuclear plants.

Moreover, reducing dependence on nuclear power as much as possible is a fundamental premise of Japan's energy policy following the Fukushima accident (REI, 2021a). According to the 6th Strategic Energy Plan, "maximum efforts will be made to introduce renewable energy based on the principle of top priority". Some of the businesses, local governments, renewable energy industries and think tanks have called for setting a higher renewable energy target (of 40-50%) in power generation, as they deem it feasible to scale up the adoption of renewables (REI, 2021a).

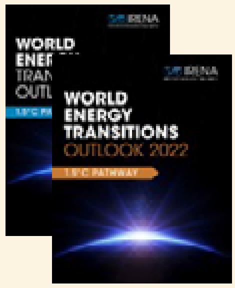
Achieving such targets will require additional efforts, however. The energy transition is not simply a matter of technology – i.e., shifting to renewable energy sources – but even more so about societal and institutional changes. A key question is: How will this complex transformation affect the well-being and overall welfare of the Japanese people?

The International Renewable Energy Agency (IRENA) has answered these questions at the global level – for the world economy – in its flagship report *World Energy Transitions Outlook: 1.5°C Pathway* (Box 1.1) (IRENA, 2021a, 2022a). The report provides an analysis of two energy roadmaps: 1) an ambitious energy transition scenario (1.5-S) that aims to reach the goal of keeping the global temperature rise below 1.5 degrees Celsius (°C); and 2) a scenario based on current plans, the Planned Energy Scenario (PES).

The results show that transforming the energy sector globally can yield widespread benefits, including additional growth in gross domestic product (GDP) averaging 0.5% through 2030, and energy sector employment reaching 139 million (33 million more than in the less-ambitious PES). Of those 139 million jobs, 38 million would be in renewable energy. Global welfare would be around 20% higher than in the PES. However, these impacts will be unevenly distributed across countries and regions, depending on local socio-economic structures, the degree of reliance on fossil fuels, and the depth of the renewables supply chain, among other factors.



BOX 1.1 WORLD ENERGY TRANSITIONS OUTLOOK: 1.5°C PATHWAY

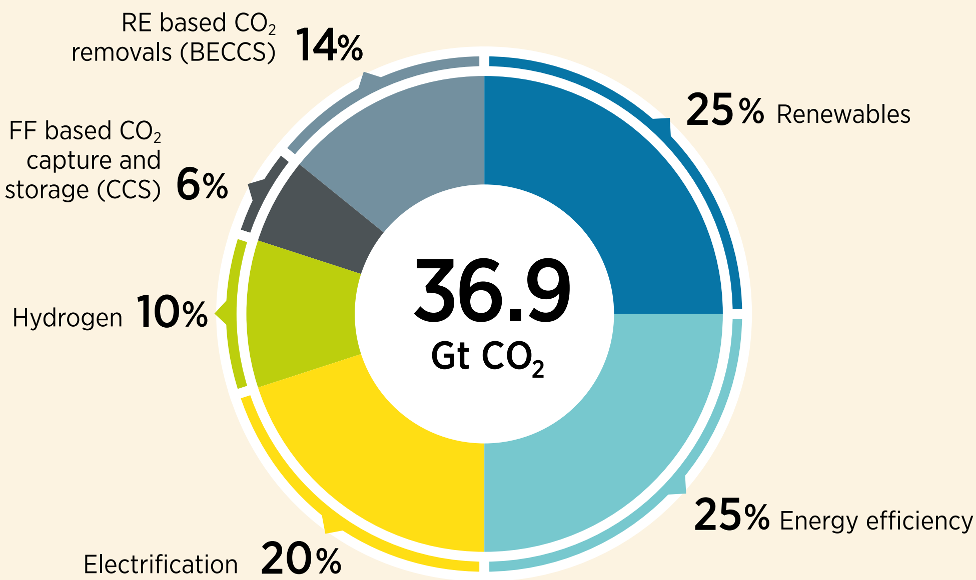


IRENA's World Energy Transitions Outlook, 2021 and 2022 editions, outline a pathway for the world to achieve the goals of the Paris Agreement and halt the pace of climate change by transforming the global energy landscape. The reports present options to limit global temperature rise to 1.5°C and to bring CO_2 emissions closer to net zero by mid-century. They offer high-level insights on technology choices, investment needs, accompanying policy needs, and the socio-economic implications to achieve a sustainable, resilient and inclusive energy future.

IRENA's 1.5°C scenario (1.5-S) considers today's proven technologies, as well as innovative technologies that are still under development but that could play a significant role by 2050. Figure 1.1 shows the six main components of the CO_2 emission abatement. Renewable energy plays a key role in the decarbonisation effort. More than 90% of the solutions in 2050 involve renewable energy through direct supply, electrification, energy efficiency, green hydrogen, and bioenergy with carbon capture and storage. Fossil-based carbon capture and storage has a limited role to play, and the nuclear contribution remains similar to today.

The report presents analysis at a globally aggregated level.

Figure 1.1 Reducing emissions by 2050 through six technological avenues



Note: RE = renewable energy; FF = fossil fuel; CCS = carbon capture and storage; BECCS = bioenergy with carbon capture and storage.

Source: IRENA, 2022a.

To offer a more granular insight at the country level, the present report focuses on Japan and provides an overview of IRENA's latest modelling results showing how the energy transition impacts Japan's economy and people – beyond emission reductions – to 2050.

Section 2 presents Japan's energy sector and macroeconomic trends, key policies and initiatives. Section 3 presents the results of the macroeconometric modelling to evaluate the socio-economic impacts of the energy transition in Japan, showing the extent to which the transformation would affect economic growth, welfare and employment. The fact that the country's revised pathway is now closer to IRENA's roadmap makes the analysis even more relevant, as it portrays the potential impacts (benefits and costs) against the less-ambitious targets of the past. Section 4 summarises the findings and provides policy recommendations to achieve the energy transition in a just and inclusive manner.

02 Japan’s key indicators: Energy, economic growth, welfare and jobs

With a view to assessing and providing background on the potential socio-economic impacts of the energy transition, this section discusses the latest trends and performance in key energy, economic and social indicators in Japan. These same socio-economic indicators – namely GDP, welfare and jobs – are used to report the results from the scenario analysis in section 3.

The COVID-19 pandemic has continued to affect most economies worldwide. Japan's economy shrank 4.5% in 2020 then bounced back in 2021 (1.6% growth) and is expected to continue growing (2.4% in 2022 and 2.3% in 2023); however, projections beyond 2023 remain below 1% (IMF, 2022). In any case, it is essential that the path to recovery is sustainable and inclusive (IRENA, 2020b). In late 2020, Japan announced a target of achieving net zero emissions by 2050. The transition towards that target should remain an urgent policy goal during the recovery period and beyond. Renewable energy will play the most significant role in this transition.

The following sub-sections describe the current status of Japan's energy system (section 2.1) as well the status of socio-economic indicators such as GDP (section 2.2), welfare (section 2.3), employment (section 2.4) and finally the socio-economic challenges linked to the energy sector and its transition (section 2.5).

2.1 THE CURRENT ENERGY MIX

Japan is the fifth largest energy consumer in the world (UNSD, 2020). Until the early 2000s, energy consumption grew along with GDP. By 2020, however, Japan's total primary energy supply (TPES) of 17 964 petajoules (METI, 2022) had dropped 8.7% below the 1990 level (Figure 2.1). Overall, the national primary energy supply fell 6.1% on a year-on-year basis. Importantly, the TPES started to decrease after the Fukushima accident in 2011. While improvements in energy efficiency have played a role in this decline, a statistical effect also stems from replacing nuclear energy with fuels that have lower conversion losses.

Although Japan's fossil fuel supply has decreased for seven consecutive years, the country still relies heavily on these fuels, comprising around 84.8% of the TPES in 2020 (METI, 2021). Oil has continued to dominate the TPES, but its overall share in the mix has dropped 20 percentage points since 1990, from 56.0% to 36.4% in 2020. As of 2020, the shares of coal and natural gas were 24.6% and 23.8%, respectively – an increase of 33.2% for coal and 107.8% for natural gas over 1990 levels. This is largely ascribable to the shutdown of Japan's nuclear power plants following the Fukushima accident.

Renewable energy sources represent around 10% of the total energy supply. Although at fairly modest levels, renewables have increased steadily over the past decade, from around 5.4% in 2012 to more than 10.4% of TPES in 2020.

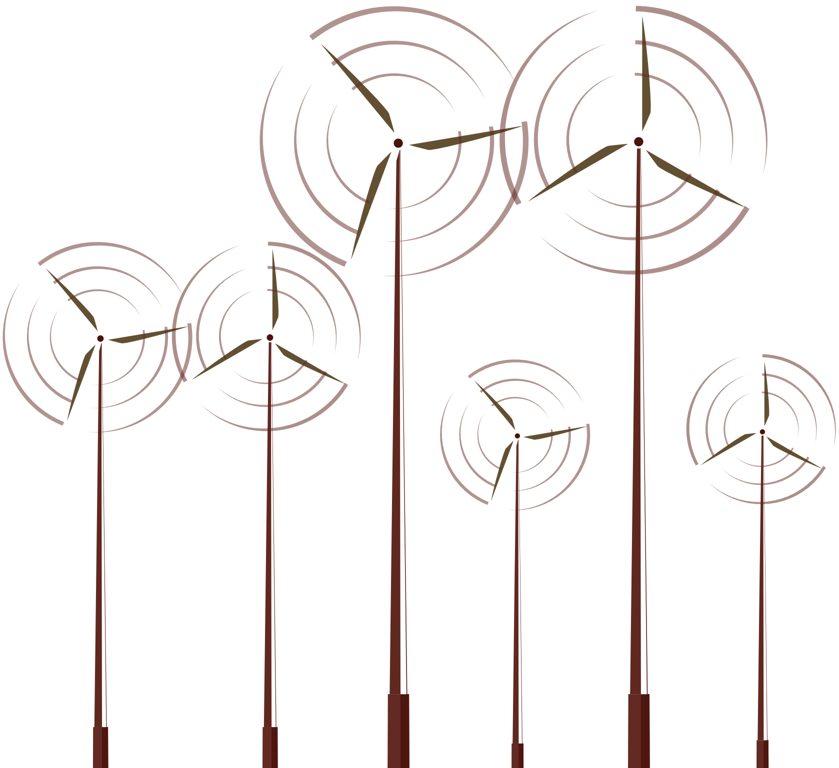
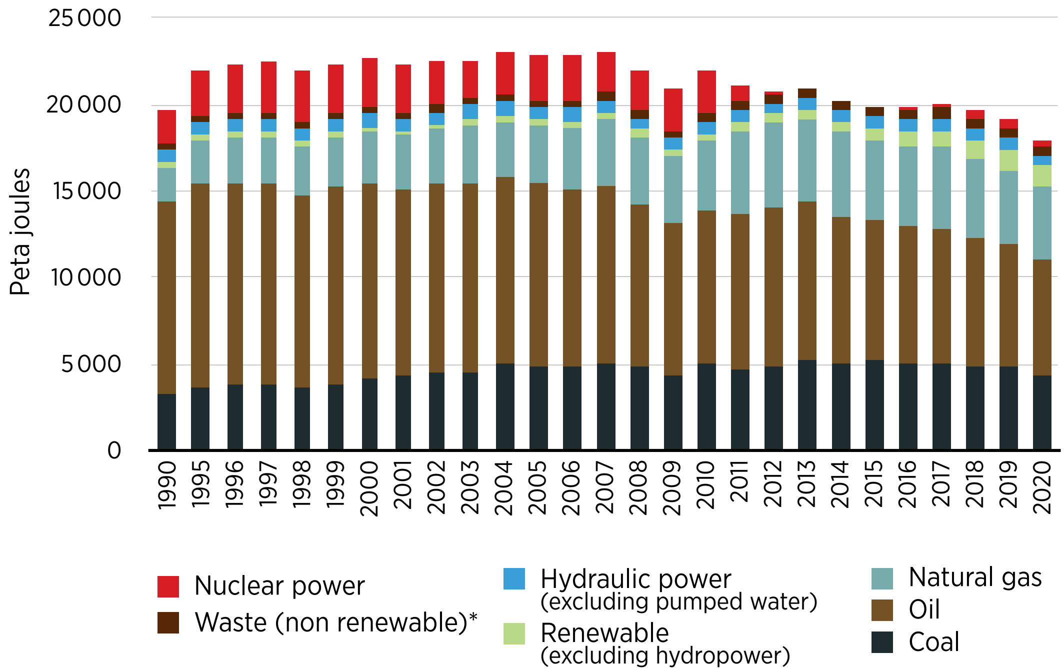


Figure 2.1 Japan's total primary energy supply, 1990 to 2020



* METI statistics use the term "Unutilised energy", which includes the utilisation and direct use of waste energy for heat generation or industrial steam recovery.

Source: METI, 2021.

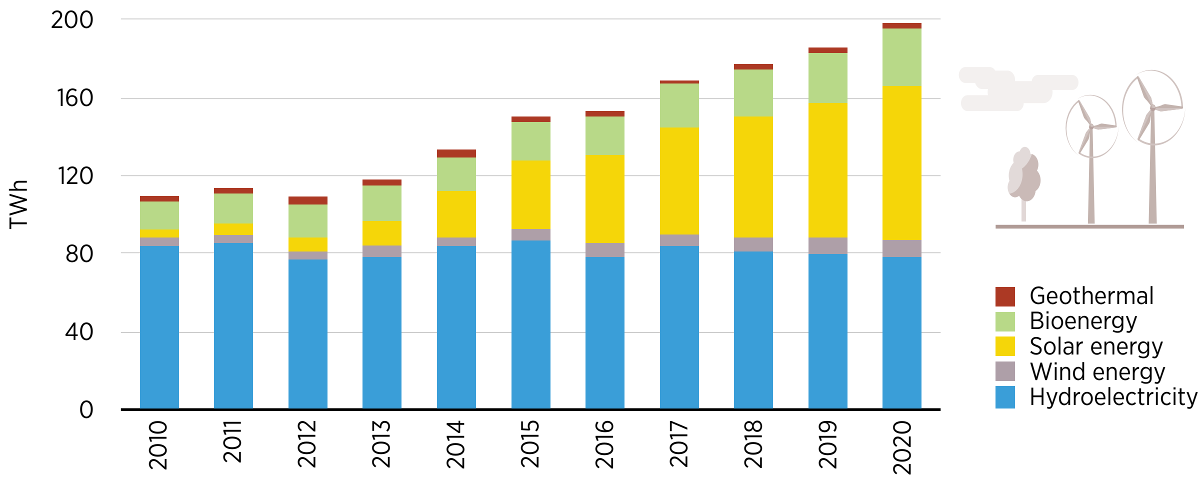
Meanwhile, Japan's total final energy consumption (TFEC) was 12 089 petajoules in 2020, down 10.8% compared to 1990 (METI, 2022). In 2020, renewable energy accounts for more than 8% of TFEC. The largest energy-consuming sectors in Japan in 2020 were manufacturing (42.1%), transport (22.3%), public and commercial services (16.6%), and residential (15.8%), with the primary sectors contributing a smaller share (3.2%) (METI, 2021). Electricity accounted for more than a quarter (27.0%) of the country's TFEC in 2020 (METI, 2021), well above the global average of around 21% in 2019 (IRENA, 2022a), indicating an increasing electrification of the energy system.

In response to the oil crisis in the 1970s, Japan turned to nuclear power to generate electricity. Since the 2011 Fukushima accident, however, most of the country's nuclear reactors have been temporarily suspended or shut down. To compensate for the loss of nuclear energy, Japan re-intensified its dependence on fossil fuel imports (together with renewables and energy efficiency measures). In the process, its energy self-sufficiency rate dropped from around 20% in the 2000s to just 6.6% in 2012, before increasing again to 11.2% by 2020 (METI, 2021). The resurgence of nuclear power plants has led to these improvements, with their share in TPES rising from 0.4% of the energy mix in 2015 to around 2% in 2020 (METI, 2021).

In the post-Fukushima period, when nuclear plants were still shut and Japan was experiencing power shortages, energy efficiency and conservation efforts were able to reduce power demand by almost 30%. This initiative was supported by a popular household-led movement known as *setsuden* ("saving electricity") together with the adoption of energy-efficient appliances by businesses and industries. People used simple methods such as setting thermostats higher in warm weather and turning off lights when not needed. With only minor discomfort, the collective effort helped Japan stop rolling blackouts (Myllyvirta and Guay, 2014).

Japan is a global leader in the deployment of renewable power capacity, and renewables play a growing role in the country's electricity generation. The share of renewables in power generation increased from around 10.0% in 2012 to 19.8% in 2020 (METI, 2021). In 2020, the share of renewables in Japan's electricity generation grew 9.2% (year on year), above the global average of 5.5% (IRENA, 2021b, 2020c). In absolute terms, generation from renewables rose from 107.4 terawatt-hours (TWh) in 2012 to 198.3 TWh in 2020, an increase of 84.6%. Most of this total represents hydropower and solar (79.4%), and the increase in renewable generation is attributed mainly to considerable growth in solar PV (Figure 2.2).

Figure 2.2 Renewable energy generation, 2010 to 2020



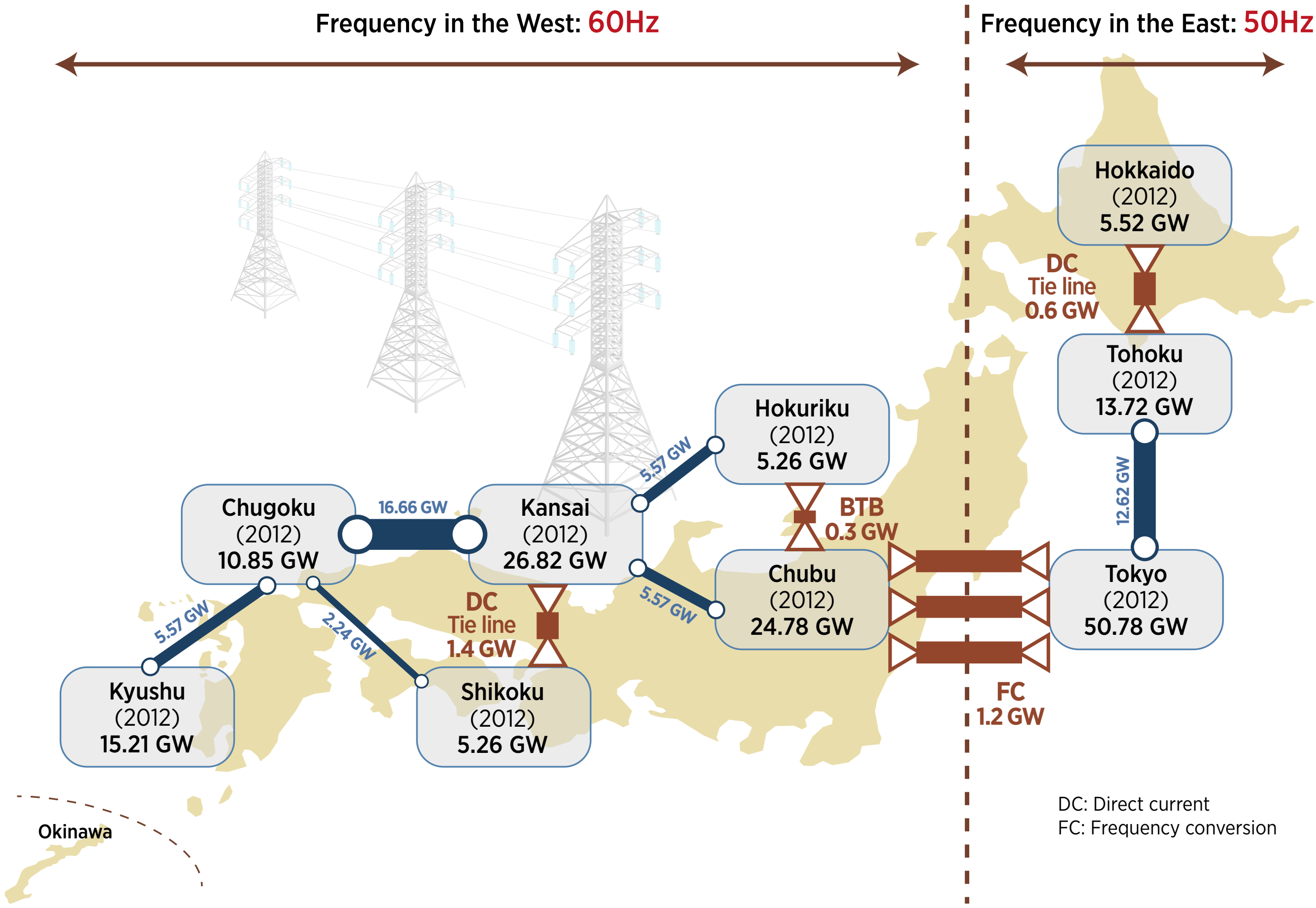
Source: METI, 2021.

While the potential of renewables in the electricity sector is considerable, further development is hampered by difficulties in ensuring grid connection and by limited land availability, given Japan's mountainous topography, natural disasters and high population density (IRENA, 2021c). This makes solar and onshore wind farms costlier to build than in places that have plenty of flat, empty land.

Being an island does limit the potential for cross-border grid integration, although this does not mean that integration is technically and economically unfeasible (Zissler, Kåberger and Lovins, 2017). Difficulties also have arisen from the fact that regional monopolies of Japan's 10 vertically integrated power utilities (Figure 2.3) have technical differences (with two synchronised grids, the East region operates at 50 Hertz and the West at 60 Hertz). For example, after the Fukushima accident, Tokyo's electricity needs could not be adequately met by the western regions due to transmission constraints (Fairley, 2011).

The current high-voltage direct current (HVDC) interconnection system was recently upgraded from 1.2 gigawatts (GW) to 2.1 GW capacity (Toshiba, 2021). However, after Fukushima, the system was estimated to be around 8-9 GW less in terms of interconnection than what the country might need to avoid bottlenecks in inter-regional transmission (Fairley, 2011). Since April 2016, the 10 utilities have been supervised by the Organisation for Cross-regional Coordination of Transmission Operators (OCCTO). Inter-regional data are publicly available at an hourly scale, making the system less fragmented than in previous years. The Renewable Energy Institute publishes inter-regional interconnection flow charts that ease analysis of real-time transfers (REI, 2021b).

Figure 2.3 Japan's electricity transmission lines



Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA.

Source: UNESCAP, 2017.

IRENA's report *Adapting market design to higher shares of variable renewable energy* (also available in Japanese) highlights the importance of the transmission system for greater integration of renewables, among other policies and regulatory aspects. The value and challenges of a cross-national transmission system are further discussed in the report Renewable energy and electricity interconnections for a sustainable Northeast Asia (IRENA, 2021d).

2.2 ECONOMY AS MEASURED BY GDP

Despite its widely discussed limitations, GDP remains the most generally adopted measure of economic performance. It measures the total monetary value added from the production of goods and services over a given period. However, GDP fails to account for non-monetary economic added value, such as household production and environmental services.

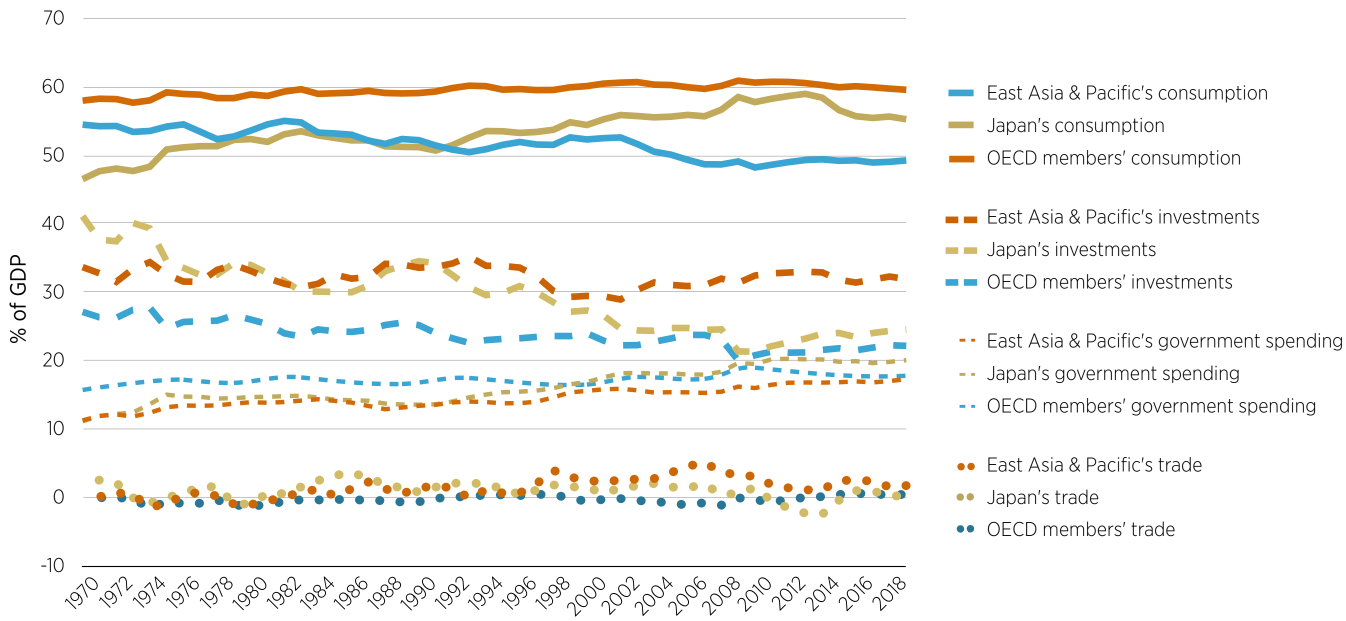
Measured by GDP, Japan is the world's fourth largest economy (World Bank, n.d.). In the 1960s, the GDP grew 10% annually, fuelled by high private investment, a shift from primary to secondary industries, an abundant labour force (high population growth) and productivity increases. The automotive sector propelled Japan's industrial economy in the post-war period (Amsden, 1992). Since then, the economy has developed sophisticated technologies, expanding into other manufacturing activities and the services sector[3]. The economy has faced challenges at various times – for instance, in the 1990s, when stock prices plummeted, marking the start of a major economic recession.

[3] *The sectoral contributions to GDP have changed between 1970, when the primary, secondary and tertiary sectors accounted for 5.9%, 43.1% and 50.9%, respectively, and 2018 (1.2%, 26.5% and 72.3%) (Statistics Bureau of Japan, 2020a).*

Since the Asian financial crisis in the late 1990s, GDP growth has been relatively slow, peaking at 2.2% in 2017. In 2019, Japan's GDP grew only 0.3%, well below the average rates in the East Asia and Pacific region (3.6%) and in the countries in the Organisation for Economic Co-operation and Development (OECD) (1.6%) (World Bank, n.d.). Following the onset of the COVID-19 pandemic, GDP fell 4.5% in 2020 and rebounded to 1.6% in 2021. GDP growth projections for 2022 and 2023 are 2.4% and 2.3% respectively, but beyond 2023 they fall to 0.8% and below (IMF, 2022). Besides the impacts of the pandemic, slow GDP growth in Japan can be explained by the fact that the country has the highest economic complexity[4] among 133 countries analysed; thus, substantial gains in GDP growth can come only by developing new products (CID, 2020).

Household consumption accounts for the largest share of GDP, and Japanese households greatly increased their consumption over time. Households have consumed increasingly more than their peers in the East Asia and Pacific region since 1992, but less than their OECD peers since the 1970s. Overall, Japanese consumption has stabilised, and its GDP shares started to fall in 2013 (Figure 2.4).

Figure 2.4 Household consumption, capital investments, government spending and trade balance, Japan, OECD, and East Asia and Pacific countries, 1970 to 2019



Note: OECD = Organisation for Economic Co-operation and Development. Household consumption = final consumption expenditure of households and non-profit institutions serving households; 2) government spending = final consumption expenditure of the general government; 3) capital investments = gross capital formation; and 4) trade balance (exports less imports) = external balance on goods and services.

Source: World Bank, n.d.

Capital investment accounts for the second largest share of GDP. While that share sank to a record low in 2010 – in the aftermath of the global financial crisis – it has since recovered. Japan's capital investment as a share of GDP has exceeded that of the OECD countries as a group since the 1970s. However, since 1992 it has been below that of the East Asia and Pacific region – with the gap widening in 2002 (Figure 2.4). Japanese industries have been moving overseas since the 1990s to get closer to fast-emerging markets and because the rising value of the yen was making them uncompetitive in the international market (Hirata, 1993).

[4] *The economic complexity of a country is determined by the diversity of exports it produces and their ubiquity, or the number of countries capable of producing them (as well as the complexity of those countries); see CID (2020) for more information.*

Government spending commands the third largest share of Japan's GDP. The share is higher than that of the East Asia and the Pacific region and the OECD as a whole. Around one-third (34.9%) of government spending goes to social security and 5.4% to education and science (Ministry of Finance, 2020). In 2018, Japan spent less on education than its OECD peers (4% of GDP compared with 4.9%) but more than in the East Asia and Pacific region on average (3.4%) (OECD, n.d.a; World Bank, n.d.). In April 2020, amid the COVID-19 pandemic, Japan released an emergency spending package of JPY 117 trillion (USD 1.1 trillion), equivalent to 22% of GDP. Three-quarters of the package focused on employment and business support, with the rest split among the healthcare system, public investment, and campaigns to promote consumption, among others. An additional stimulus package in May 2020, for the same amount, expanded work subsidies and provided subordinated loans and subsidies to affected firms (KPMG, 2020; IMF, 2020).

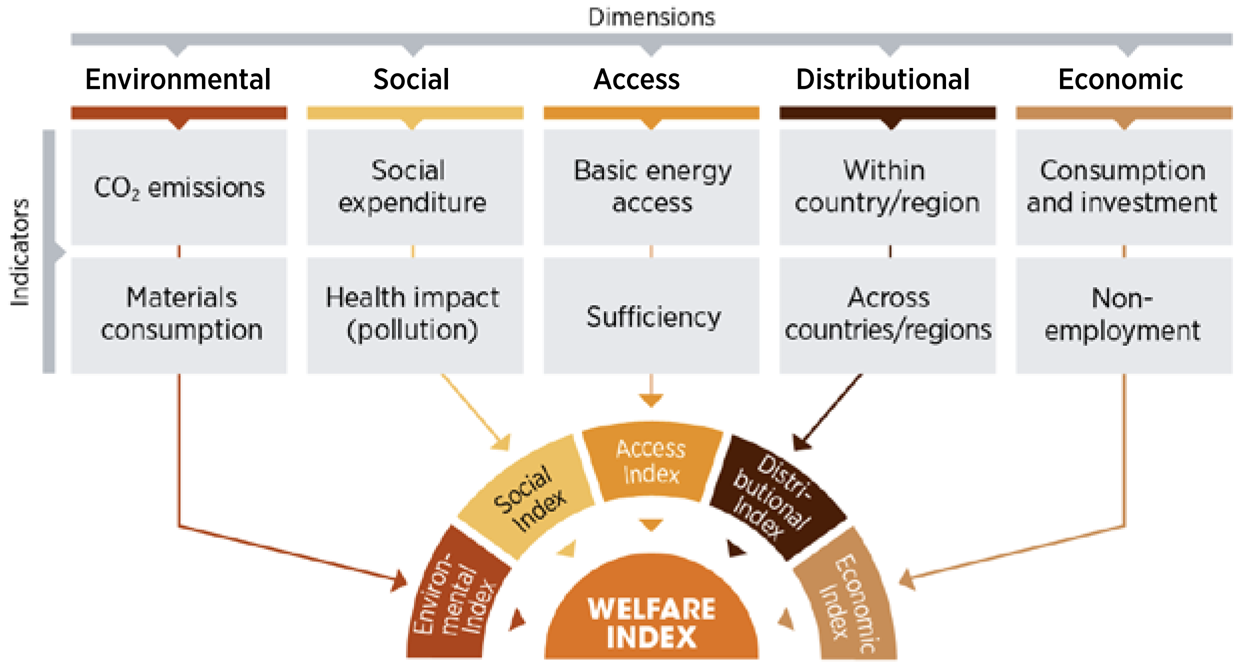
The trade balance accounts for just 0.17% of Japan's GDP. The gains of international trade, however, are normally small for a large and diverse economy like Japan's, which can produce most of what it consumes. Services, mainly in information and communications technology, travel and tourism, transport, and insurance and finance, drove export growth from 2015 to 2020 (CID, 2020).

2.3 THE DIMENSIONS OF IRENA'S WELFARE INDICATOR

GDP is the standard measure of economic output, but the well-being of citizens goes beyond GDP, which ignores factors that are not priced in the market, such as environmental quality. GDP also fails to consider other aspects that are of significant importance to communities/societies, such as housing conditions, opportunities for children, pollution, noise, sense of security, social connections, political voice and the quality of jobs (Stiglitz, Fitoussi and Durand, 2018). Communities that have strong social trust and connections are more resilient than others to economic crises and natural disasters (Aldrich and Meyer, 2015), and they cope better with illness, unemployment, low income, discrimination, family breakdown and insecurity (Helliwell *et al.*, 2020). Therefore, more indicators are needed to capture social costs (or benefits) that communities value highly.

To incorporate some of these aspects of social well-being, IRENA developed a welfare index in 2016 (IRENA, 2016a) that provides wider analyses on potential impacts. The index has since been upgraded (IRENA, 2021a) and currently covers five dimensions: economic, distributional, social, environmental and access (Figure 2.5).

Figure 2.5. Structure of IRENA's Energy Transition Welfare Index



Source: IRENA, 2021a.

The economic dimension has two indicators. The first measures consumption (a measure of present welfare) and investment (the benefits from a more efficient and sustainable future economy) per capita. The second tracks non-employment: those unemployed and those of working age outside of the labour force. In per capita terms, Japan's household consumption has increased significantly since the 1970s. And even though it was lower in 2020 than in the average of OECD countries, investment per capita has historically been above OECD averages (World Bank, n.d.). Ultimately, at USD 37 069 in 2019, the indicator on consumption and investment per capita was more than four times larger than the global average (Cambridge Econometrics, n.d.). Japan's unemployment rate is low and its population is ageing. As a result, non-employment is among the lowest in the world (Cambridge Econometrics, n.d.). These topics are discussed in more detail in section 2.4.

The distributional dimension: The Gini index is the most common measure of income inequality. It takes a value of 0 for complete equality and 100 for complete inequality. With values ranging around 33 since 2009, Japan's Gini coefficient is the 11th highest among OECD countries (OECD, 2020a). This dimension, however, uses quintile ratios to analyse income and wealth inequalities. Income inequality in Japan has improved in the context of financial/economic crises. This was the case in both the "Lost Decade's" economic stagnation and the global financial crisis in 2009, in which the impacts were felt first by the rich, who quickly recovered and managed to thrive to leave the bottom 20% behind.

Since 2010, income inequality has not improved: the bottom quintile has taken 2.3% of the income, while the top quintile has taken around 59%. Wealth inequality has been steady and wide. Since 1995, the bottom quintile has had a negative share of -0.7% of net personal wealth, while the top quintile has had a share of around 73% (WID, n.d.). At 10.6 in 2019, the income quintile ratio was significantly lower – and thus more equal – than the global average of 77.5, but also far from Iceland's 3.7. The wealth quartile ratio was 46.1 (Cambridge Econometrics, n.d.). In Japan, as in the rest of the world, wealth inequalities are larger than income ones (Piketty, 2014). That said, distributive justice can go beyond income and wealth. Energy poverty, for example, is a violation of distributive justice (Sovacool *et al.*, 2016).

BOX 2.1 MEASURING POVERTY IN JAPAN

Less than 0.7% of the Japanese population lives in extreme poverty (World Bank, n.d.). However, the (relative) poverty rate in Japan is gloomier if measured by the number of people whose income is less than half the median household income. Among OECD countries, the Japanese poverty rate is the 10th highest: 15.7% compared with Iceland's 5.9% or the United States' 17.8% (OECD, 2020b).

Poverty is also linked with energy poverty, especially if measured by the share of household expenditure on energy. A household is energy poor if it spends more than 10% of its income on energy, according to the first definition from the United Kingdom in 1991, which is still unofficially used by many countries. By this measure, the proportion of households in Japan experiencing energy poverty in the lowest income decile steadily increased from 34.6% in 2004 to 47.5% in 2013 (Oshikuwa, 2016).

The social dimension has two indicators: social spending and health effects from air pollution. Air quality affects human health substantially, and, depending on how the adverse health effects are monetised, they can exceed GDP growth estimates (Ackerman and Daniel, 2014).

At the same time, better environmental conditions (see environmental dimension below) and the lack of air pollution contribute to subjective well-being (Stiglitz, Fitoussi and Durand, 2018). Exposure to particulate matter has negative effects on citizens' life evaluations (Krekel and MacKerron, 2020), whereas exposure to green and natural environments improves perceptions of well-being (Guite, Clark and Ackrill, 2006; O'Campo, Salmon and Burke, 2009; Annerstedt *et al.*, 2012).

Education, too, contributes greatly to people's well-being. Besides its effects on income, citizens with more education enjoy better health, have more social connections, show greater engagement in political and civil life, and have lower rates of unemployment (Sen, Fitoussi and Stiglitz, 2010). Overall, the expansion of public funding for health care and education drove the rapid growth of social spending globally in the second half of the 20th century (Ortiz-Ospina and Roser, 2016).

While Japan's social spending per capita has increased more than four-fold since 1980 and was above the OECD average in 2017, it was only the 14th highest among OECD countries and far behind Luxembourg's (OECD, n.d.b). Nevertheless, in 2020, at USD (2019) 7 418.6 per capita, Japan's social spending was almost six times larger than the global average (Cambridge Econometrics, n.d.).

Japan is aware of the need to increase spending on education and health. The elaborate Japanese health-care system provides wide coverage for all citizens. However, while Japan spent USD 3 937 per capita (in purchasing power parity) on government compulsory health care in 2019, this was only the 15th highest level among OECD countries (OECD, 2021a).

Regarding education and in the context of the energy transition, in 2000 Japan introduced "Integrated Studies" into the curriculum from the primary to upper secondary school levels. Integrated studies cover topics such as international understanding, data, the environment, health, and welfare, among other topics.

In addition, the country has acknowledged in its Long-Term Strategy for the Paris Agreement (Government of Japan, 2019) the need to offer vocational training to the fossil fuel workforce, to provide support for diversification and shifts in business operations, to support placement of the labour force, and to attract new business. The Strategic Energy Plan includes a commitment to energy education and public engagement on energy-related issues (METI, 2018a). However, there is little evidence of concrete efforts for training and re-skilling human resources towards clean energy. The lack of appropriate skills and training might bring difficulties in executing the energy transition swiftly.

In terms of health status, Japan's life expectancy is the third highest in the world, at 84 years, behind only Hong Kong and San Marino (both 85 years). In 2019, life expectancy at birth was 87.5 years for women and 81.4 years for men. Japan's infant mortality rate was 1.8 per 1 000 births that same year (World Bank, n.d.).

However, as nuclear energy has been replaced with fossil fuel energy, air pollution can become a problem. Pollution from burning fossil fuels kills more than 4 million people a year globally (The Economist, 2020a). This number can more than double when measured by a broader definition of air pollution. In the Asia-Pacific region alone, 4 billion people are exposed to the risk of air pollution (CCAC and UNEP, 2019), while in Japan estimates of premature deaths associated with ambient particulate matter range between 30 000 and 60 000 (Goto *et al.*, 2016; Sandoval, 2019; Statista, 2020). The per capita health costs linked to pollution in Japan are estimated at USD (2019) 596.4, slightly below the global average of USD 655.1 (Cambridge Econometrics, n.d.).

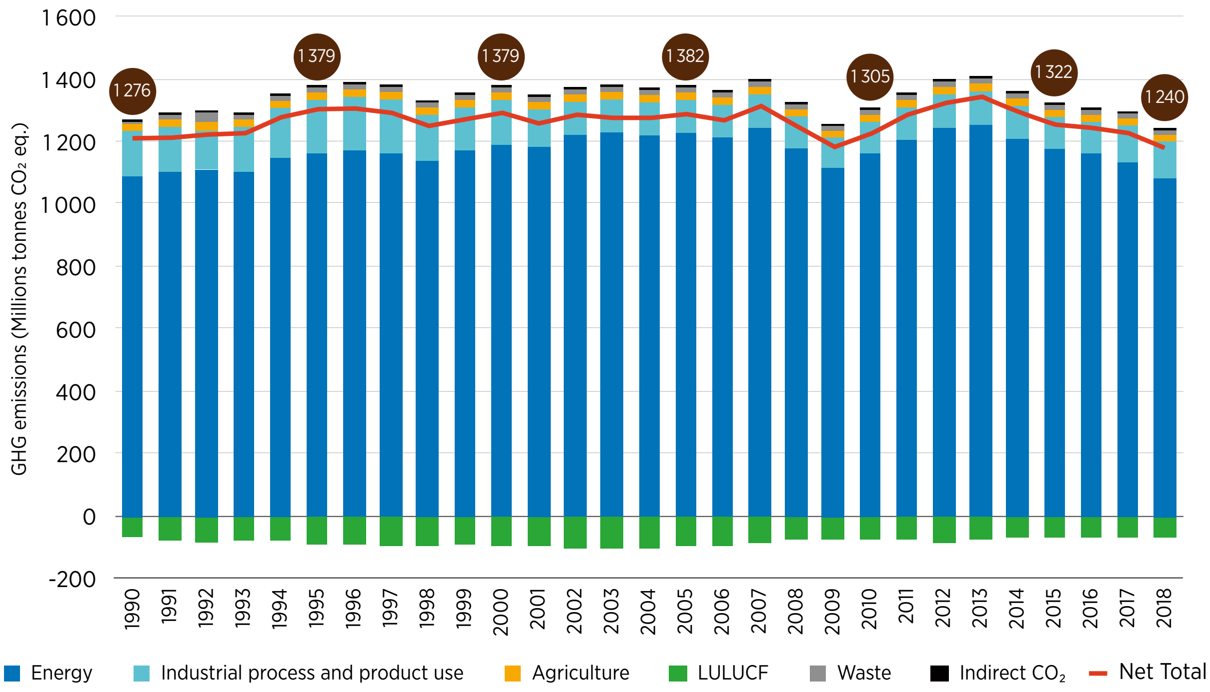
The environmental dimension: IRENA's welfare indicator also considers greenhouse gas emissions along with vulnerability to climate change, as well as the depletion of natural resources through consumption of materials (measured in domestic material consumption of metal ores, non-metallic minerals and biomass for food and feed).

Japan is among the world's top 10 emitters of greenhouse gases. In 2018, it was the fifth largest emitter of CO_2 from fuel combustion (1.1 gigatonnes), behind China (9.5 gigatonnes), the United States (4.9 gigatonnes), India (2.3 gigatonnes) and the Russian Federation (1.6 gigatonnes). That brought Japan's global share of CO_2 emissions to 3.28% (IEA, 2020a).[5]

In 2018, the energy sector (excluding indirect emissions of CO_2) accounted for 87.5% of Japan's total greenhouse gas emissions (Ministry of Environment, 2020). The next-highest emitting sectors were industrial processes and product use (excluding indirect CO_2) (8.1%), agriculture (2.7%), and waste (1.6%), followed by indirect CO_2 emissions (0.2%). Removals of greenhouse gases through land use, land-use change and forestry in fiscal year 2018 were equivalent to 4.6% of total emission s (Figure 2.6). In 2020, as a consequence of the COVID-19 pandemic, Japan's emissions dropped 4.8% from their 2019 level (Liu *et al.*, 2020; Carbon Monitor, 2021). The main drivers were the reductions in domestic aviation (around 28%), industry (around 10%) and road transport (around 6%). However, the pandemic-related emission reduction was short term and did not involve fundamental decarbonisation of the energy sector.

[5] *In per capita terms, however, Japan is in 23rd place (8.6 tonnes of CO_2 per capita), compared with Qatar, the largest CO_2 emitter per capita, at 31.3 tonnes.*

Figure 2.6 Trends in greenhouse gas emissions and greenhouse gas removals by sector, 1990 to 2018



Note: LULUCF = land use, land-use change and forestry.

Source: Ministry of Environment, 2020.

Japan's responsibility in the collaborative fight against climate change is significant. Historically, Japan is among the 10 largest contributors to CO_2 cumulative emissions, with estimates ranging from 3.9% in 2020 (Our World in Data, n.d.) to 2.7% in 2021 (Carbon Brief, 2021). Although Japan's climate vulnerability may be lower than in other countries (WWF, 2008; Rich, Inoue and Ueno, 2020; Margolis, 2021) and its adaptation capability is higher (University of Notre Dame, n.d.), further increases in global temperature would greatly disrupt its socio-economic system (IPCC, 2022). Success in tackling climate change depends on triggering the necessary global collaborative effort, which in turn depends on fulfilling responsibilities.

Domestic material consumption per capita in Japan is the sixth lowest among OECD countries (OECD, 2020c). Nevertheless, at 16.9 tonnes per capita in 2019, it was more than three times higher than the global average (Cambridge Econometrics, n.d.) and higher than what has been proposed as a sustainable limit for materials consumption (Bringezu, 2015; Hickel, 2020). On paper, Japan has decoupled its domestic material consumption from economic growth, meaning that domestic material use has decreased despite the increase in GDP. However, Japan's overall material footprint has increased significantly, mainly because of the country's dependence on imports for final consumption (Wiedmann *et al.*, 2013; Söedersten, Wood and Wiedmann, 2020).

This is an important aspect to consider for the energy transition (as described in the scenario analysis that follows). Importing energy technologies can increase the trade deficit on the material balance. Recycling or repurposing solar PV panels globally could unlock around 78 million tonnes of raw materials and other components by 2050. If this recovered material is injected back into the economy, its value could exceed USD 15 billion by 2050 (IRENA, 2016b).

The access dimension is measured by two sub-indicators. One indicator measures the share of the population without access to basic energy services, including electricity but also clean cooking and heating and cooling technologies. The second indicator is evolution along the "energy ladder", which assesses the progression of energy use to cover energy services and provide energy sufficiency.

Before the 1990s, Japan had achieved universal energy access (World Bank, n.d.). In 2019, Japan had a daily TFEC per capita of 72.5 kilowatt-hours (kWh), almost twice as high as the global average (Cambridge Econometrics, n.d.) and more than five times above the sufficiency level[6] estimated across all 119 countries covered in the Global Trade Analysis Project (GTAP, n.d.; Millward-Hopkins *et al.*, 2020).

2.4 JOB CREATION

Jobs have social and economic dimensions. People's livelihoods usually hinge on income obtained from a satisfactory job in a safe and unabusive environment. When applied to the energy transition, the transition should not leave out particular regions or social groups and, ideally, should help to mitigate existing distributional effects. This is relevant in the context of a just and inclusive transition.

Employment in Japan is high. The country's unemployment rate in 2020 was only 2.8%, well below those of the East Asia and Pacific region (4.3%) and OECD countries (7.1%). Unemployment had declined sharply after 2010 (5.1%) but increased starting in 2019 (2.4%) – as did the averages in the East Asia and Pacific region and OECD countries (World Bank, n.d.). Japan's system of lifetime employment essentially serves as a long-term employment contract for regular workers, as employees tend to stay with one firm their entire working life. Employees with seniority receive higher wages.

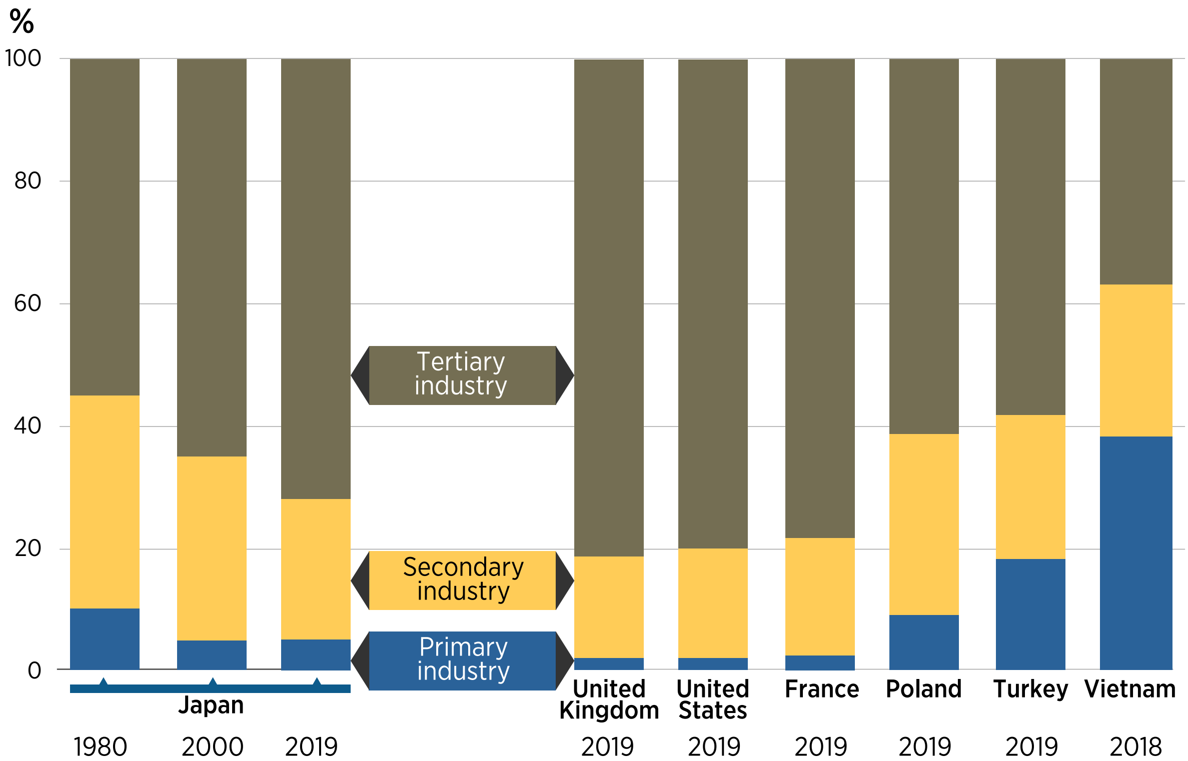
The unemployment increase can be explained by flexible forms of employment, such as *haken* workers, which have been introduced since 1986 in the Japanese labour market (OECD, 2019). Unlike fixed contract workers, *haken* workers are dispatched through a third party. The contract is limited in time and has led to large lay-offs during times of economic crises – for example, the 2009 financial crisis and the COVID-19 crisis. On the other hand, wages increased 2.3% in 2018, according to the government, with pay based on seniority accounting for around 1.8 percentage points (OECD, 2019).

Globally and in Japan, digitalisation is playing an increasing role. A recent OECD report on skills in Japan (OECD, 2021b) notes that automation takes place earlier in Japan than across OECD countries on average and also in high-skill occupations, sales and service jobs. The report finds that "Japanese adults also have above-average digital problem-solving skills, but inequalities in the distribution of this type of skills are large, thereby leading to further polarisation if proper adult training is not provided as technology advances".

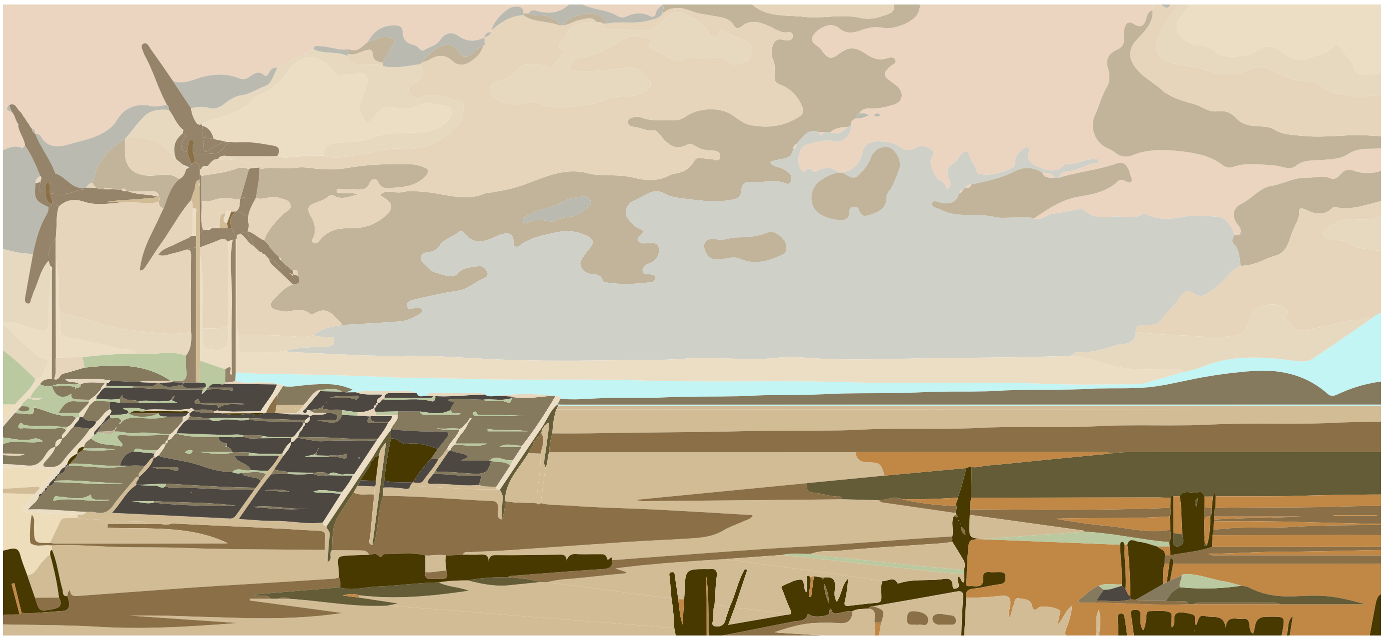
As with GDP, employment in Japan has gradually shifted from the primary to the tertiary sector. In 2019, the primary sector accounted for 3.4% of total employed persons, the secondary sector for 23.8% and the tertiary sector for 72.8%. Within the tertiary sector, the number of people employed in "medical, health care and welfare" has been increasing (Figure 2.7). In 2019, the percentage of male employment was highest in "mining and quarrying of stone and gravel" followed by "electricity, gas, heat supply and water" and "construction". The percentage of female employment (Box 2.2) was highest in "medical, health care and welfare" followed by "accommodations, eating and drinking services" and "living-related and personal services and amusement services".

[6] *This indicator has been defined as the required level of energy consumption for decent living, but no more.*

Figure 2.7 Employment by sector of the economy



Adapted from Statistics Bureau of Japan, 2020a



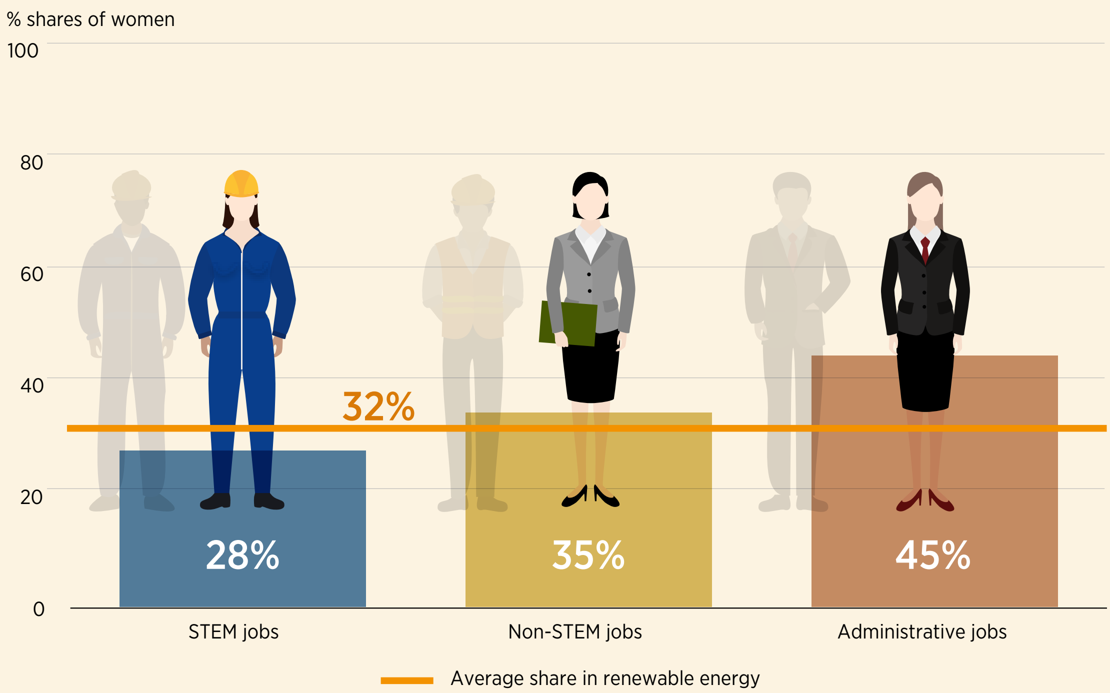
BOX 2.2 WOMEN IN THE WORKFORCE AND IN THE RENEWABLE ENERGY SECTOR

In 2019, women represented 44.5% of the overall Japanese workforce. Almost half (44.2%) of employed women were in part-time or temporary positions (Statistics Bureau of Japan, 2020b). Thus, they were more vulnerable than men to economic shocks wrought by crises such as the COVID-19 pandemic (IRENA, 2020b). This is one of the reasons behind Japan's underperformance in gender parity as reflected in the World Economic Forum's Global Gender Gap Report 2020 (WEF, 2020).

Despite government efforts in recent years to encourage women's participation in the workforce, the gender gap in the country has widened. Back in 2013, the prime minister pledged that by 2020, 30% of leadership positions across the Japanese economy would be filled by women (Abe, 2013). Only two years later, in 2015, this target for women in leadership roles was drastically lowered to 7% among national public servants and 15% among local government officials and in private companies. Given that in 2019 only 5.2% of board directors in Japanese companies were women (Gender Equality Bureau, 2020), the government has postponed for a decade the target of seeing women in 30% of leadership positions (Mainichi Shimbun, 2020).

IRENA's 2019 report *Renewable energy: A gender perspective* shows that worldwide, women represent 32% of the renewable energy workforce. IRENA's survey also finds that women account for 28% of science, technology, engineering and mathematics (STEM) positions and 35% of non-technical professionals – a much lower share than the 45% in administrative jobs (Figure 2.8) (IRENA, 2019c; the analysis contains no specific data for Japan).

Figure 2.8 Women's global participation in the renewable energy sector workforce



Note: Brown line indicates the average women workforce participation in the fossil fuel sector.
STEM = science, technology, engineering and mathematics.

Source: IRENA, 2019c.

Labour market challenges and pressures imposed by the shrinking workforce in Japan have resulted in a labour shortage in the country (Box 2.4). The government has tried to address this challenge through policies to increase productivity. The New Economic Policy Package, launched in December 2017, aimed to double the growth in labour productivity from 0.9% annually to 2.0% annually by 2020. The package includes fiscal and regulatory measures aimed at boosting the labour force, raising productivity in areas such as education, and spurring small and medium enterprises to adopt information and communication technologies. It also includes various tax measures for investment and retirement (OECD, 2018). While labour productivity is not particularly high among OECD countries, it has grown since 2009 and reached an all-time high in 2020, measured by GDP per hour worked (OECD, n.d.c). Japan has bigger productivity gaps between industries, within industries, and between company size groups than other OECD countries. Productivity disparities result in significant wage disparities (OECD, 2020d).

BOX 2.4 JAPAN'S AGEING POPULATION

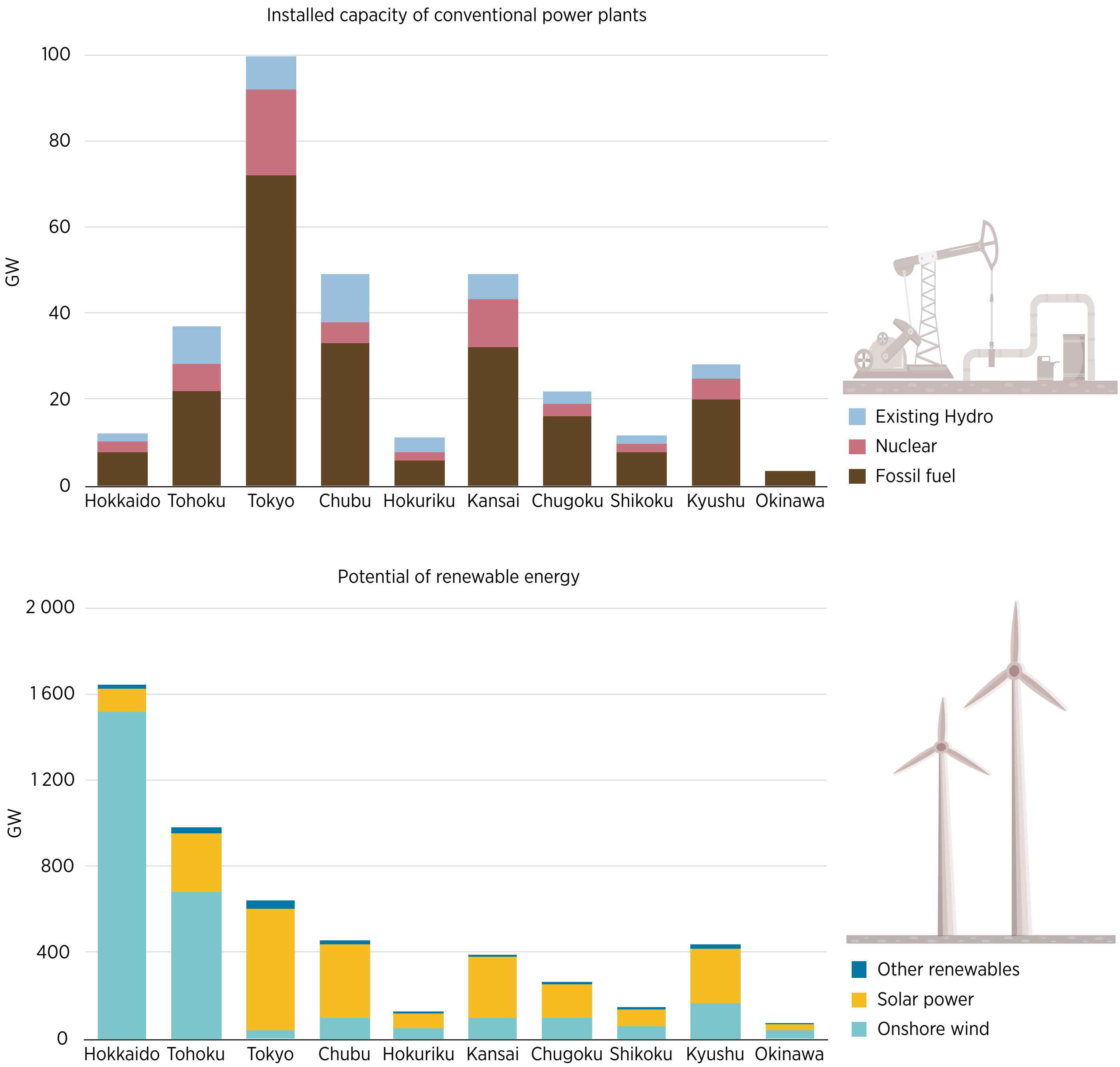
Japan has the 11th largest population in the world, at 126.3 million people, and the country's labour force totals 68 680 759. Population growth has been negative since 2011 (World Bank, n.d.). Japan's economic prosperity and well-being will depend to a large extent on how demographic challenges are managed. Between 2015 and 2050, the country's total population is projected to shrink almost 25%, to below 100 million (OECD, 2018).

As a result, Japan's dependency ratio – the ratio of pensioners to working population – is on track to become the highest in the world. A shortage of labour is reflected in the fact that there are now more available jobs per applicant than in the past 45 years and that unemployment rates before the pandemic were the lowest in nearly three decades.

Since renewable energy is more labour intensive than fossil fuels, a shortage of labour can be a real issue if not addressed appropriately by policies. Per gigawatt, the number of direct and indirect full-time jobs required for a conventional power plant is only 90; this is less than a quarter of the jobs required for geothermal power and one-third of the jobs required for solar, particularly for small-scale installations. In 2019, Japan's solar industry alone employed around 220 000 people along the value chain. Because additions to solar PV capacity in 2020 declined compared to the year before, the sector saw a reduction of 20 000 jobs from 2019 (IRENA, 2021e, 2021f). Labour shortage can become even more prominent during an energy transition as additional misalignments (educational, spatial, temporal) come into play.

Currently, Japan's conventional fuel plants are housed in regions such as Tokyo, Osaka and Nagoya. In contrast, solar and wind resources and their potentials are located in regions such as Hokkaido and Tohuku (Figure 2.9). In addition, geothermal energy, for which the country has the third highest potential in the world, has sites located in rural and mountainous regions (Tachev, 2021). As in many countries globally, younger Japanese are tending to move to cities, while rural areas face ageing societies, depopulation and generally fewer job opportunities. Reversing this trend will depend on a sustained programme of policies and incentives.

Figure 2.9 Regional siting of current power plants and available renewable energy resources



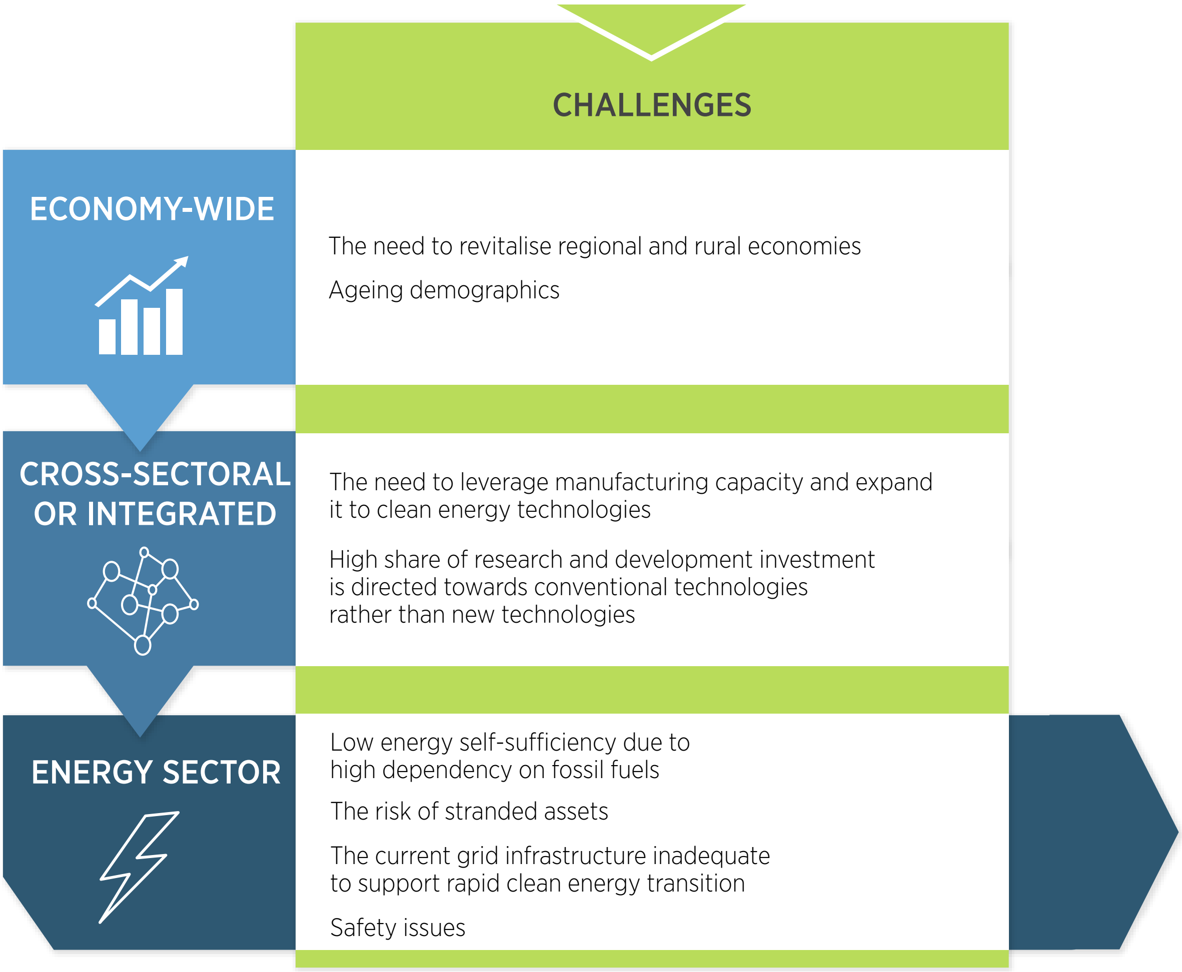
Source: Kuriyama and Abe, 2021.

Similarly, the 10 Japanese regions differ in their potential to accommodate renewable energy technologies that have different skill requirements. The operational skills required for managing and operating biomass and geothermal plants are similar to those needed for conventional power plants, since all have similar core equipment (boilers, turbines and electrical facilities). In contrast, the skills needed to operate and maintain solar and wind turbines are quite different. Higher future deployments of renewable energy technologies will need to shift skills from cities to the rural areas where they are needed. Making such skills available where needed may require active government intervention beyond the energy sector – *i.e.,* interventions that are economy-wide and cross-sectoral in nature.

2.5 JAPAN'S ENERGY TRANSITION CHALLENGES AND INITIATIVES

As discussed earlier, Japan is at a crossroads of structural change and faces several socio-economic challenges linked to the energy sector and its transition (Figure 2.10). The challenges have been further aggravated by the COVID-19 pandemic, as exemplified by the 4.6% drop in economic output in 2020 (IMF, 2022).

Figure 2.10 Challenges for the energy transition in Japan



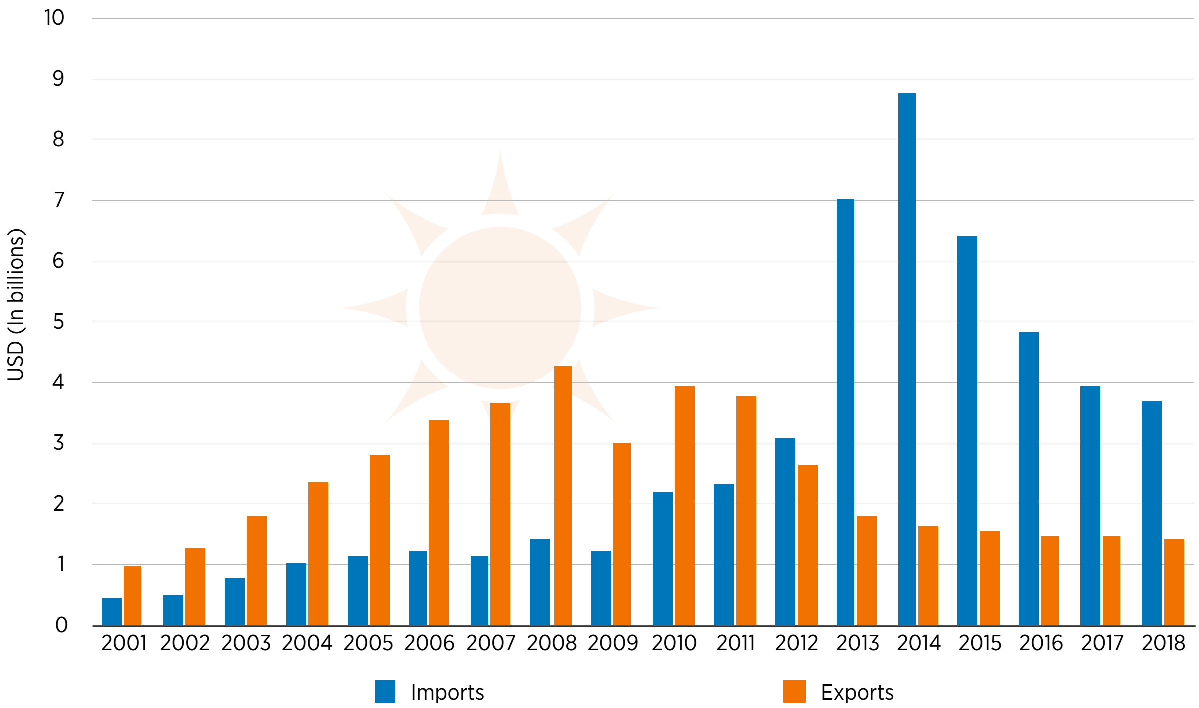
As Japan's recovery continues across **the economy**, issues that pre-date the pandemic will continue to play a significant role in the years ahead – for example, shrinking population and migration from rural areas. Rural areas face worsening social and economic challenges, including fewer local leaders, shrinking consumer markets and declining local economies. If this situation continues, it threatens to become a downward spiral in which a shrinking population will lead to a shrinking local economy, and a shrinking local economy will further accelerate the decline in population.

With such contractions, it will be difficult to maintain and secure essential services for rural residents, such as daily shopping and medical care. In 2019, 146 000 people moved into the Tokyo area, most of them young and seeking to take advantage of job or educational opportunities. However, due to COVID, which subsequently led to remote working, the pandemic has slowed the migration to Tokyo and other nearby cities (Japan Times, 2021). Regardless, between 2015 and 2045, the population of Tokyo is projected to increase 5%; meanwhile, the population of other cities will decrease 14%; and that of rural municipalities 47% (Cabinet Office of Japan, 2021).

Combined with slow economic growth (as measured by GDP) and an ageing population – issues that Japan has long been grappling with – shifts in the technologies that are a major component of the country's infrastructure constitute a significant challenge. Meanwhile, rising inequality and subsequent energy poverty are evident. Additionally, continued reliance on fossil fuels could result in health problems related to bad air quality.[7] The transformation of the energy sector may bring shifts in the labour market, with resulting misalignments between the supply of and demand for skills.

At the **cross-sectoral level**, the manufacturing sector is struggling to maintain bases at home. Japanese industries have been moving overseas since the 1990s to get closer to fast-emerging markets and because the rising value of the yen was making some of them uncompetitive in the international market (Hirata, 1993). The energy sector is no exception to this trend. While Japanese solar panel manufacturers were once the pioneers, other Asian countries now dominate the PV market and set the benchmark for falling costs and economies of scale (Figure 2.11). Japan recently updated its policies to support industries and their development, and the energy sector has been given a key role to achieve such objectives (Renewable Energy World, 2014; Colville, 2019; Nikkei, 2019).

Figure 2.11 Japan's export and import of solar PV panels (in billion USD), 2001 to 2018



Source: International Trade Centre, n.d.

Japan's aim to maintain its status as a technological frontrunner developing first-of-its-kind technologies is evident through its recent support for hydrogen development. The Japanese government provides robust funding for research, development, demonstration and deployment. Government funding for hydrogen for fiscal year 2020 includes USD 247 million for clean energy vehicles (among them hydrogen and fuel cell), USD 40 million for residential fuel cells and fuel cell innovation, USD 52.5 million for innovative fuel cell research and development (R&D), USD 30 million for hydrogen supply infrastructure R&D, USD 120 million for fuel cell vehicle refuelling stations, USD 141 million for the development of hydrogen supply chains using new sources abroad, and USD 15 million for hydrogen production, storage and usage technology development (Nakano, 2021). However, pursuing this aim may be compromised by the current allocation of R&D budgets, as a very high share is still allotted to fossil fuels and nuclear energy. In 2019, emerging technologies such as hydrogen and fuel cells were allotted less than 5% of the R&D budget (see Annex I).

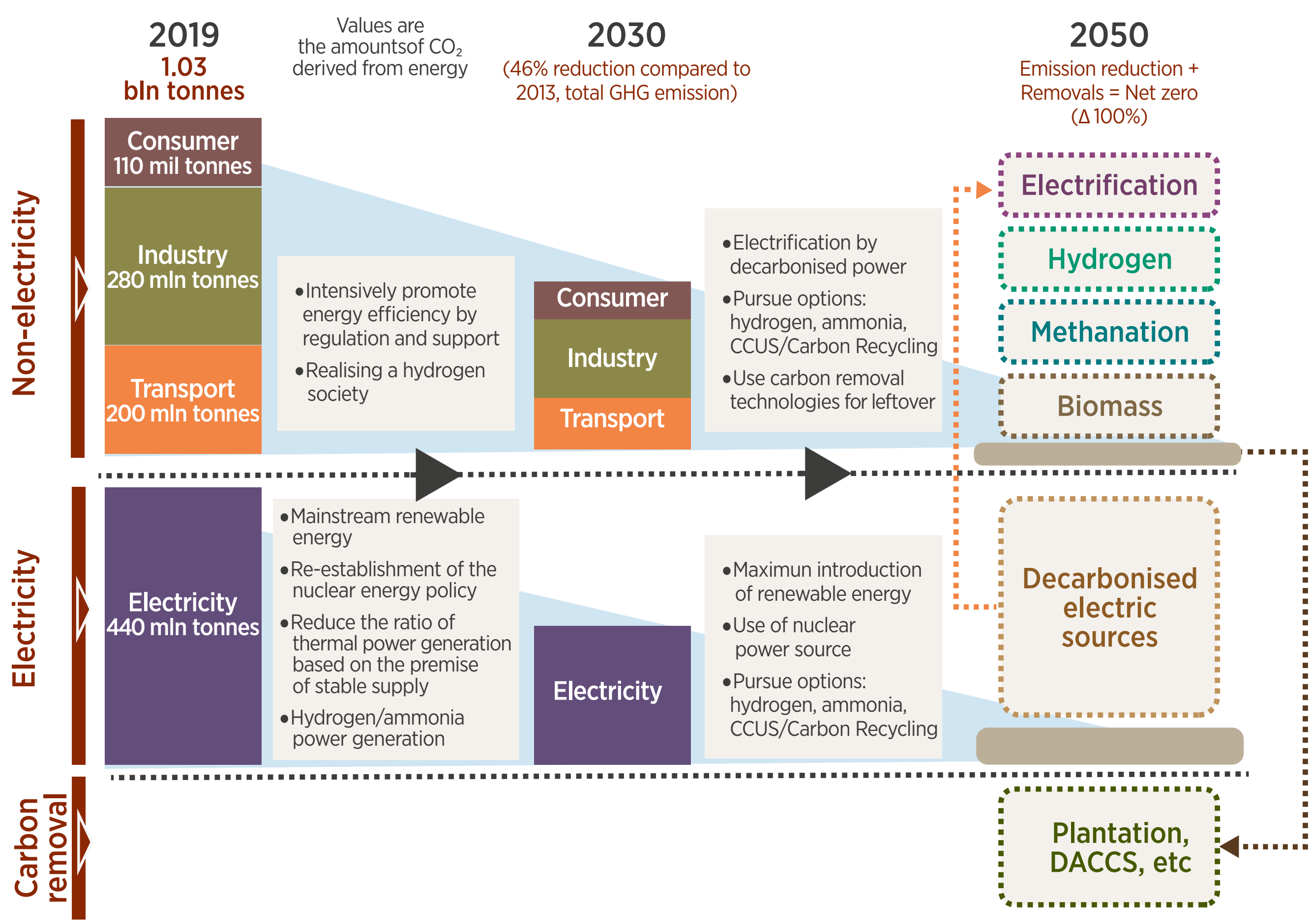
[7] *Air pollution could also be transboundary.*

At **the energy sector level**, high fossil fuel dependence remains a key hurdle. Studies have shown that the energy transition could lead to USD 71 billion in stranded assets in Japan (Carbon Tracker, 2019). Grid integration challenges such as different frequency levels and difficulty in entering the market pose threats to the accelerated and timely deployment of renewables.

Recognising the challenges, the government has introduced reforms. Japan ratified the 2015 Paris Agreement on climate change four days after the global pact officially entered into force. Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050, unveiled in December 2020, goes beyond energy planning and encompasses wider industrial and technological strategies. Key targets are promoting electrification in all sectors, strengthening digital infrastructure and making greater use of renewable energy and clean storage.

The energy outlook for 2050 is shown in Figure 2.12. The share of emerging technologies, such as hydrogen, in Japan's long-term planning is parallel to the share of hydrogen proposed in IRENA's roadmap. In 2021, Japan renewed and increased its pledge to cut total CO_2 emissions 46% from 2013 levels by 2030, up from the initial target of 26% (Ministry of Foreign Affairs, 2021).

Figure 2.12 Japan's strategy for carbon neutrality by 2050



Note: CCUS = carbon capture, utilisation and storage; DACCS = direct air capture with carbon storage.

Source: METI, 2022.

Although grid connection limitations have hindered the potential of renewables, efforts are being made to alleviate this constraint. The Long-term Cross-regional Network Development Policy was established in 2017 and is to be updated every five years. Discussion to update the master plan started in August 2020, following a framework that entails periodic assessments, cost-benefit analysis, and congestion and asset management. The updated version is expected to be published in 2022 (REN21, 2020).

Beyond discovering competitive prices, renewable energy auctions can also be designed to ease the integration of renewables into the grid (IRENA, 2019d). In 2017, Japan introduced renewable energy auctions for large-scale solar PV and biomass to keep up with the global trends in decreasing costs. The IRENA report Renewable energy auctions in Japan: Context, design, and results (IRENA, 2021b) analyses in detail the design elements and outcomes of five solar PV auctions (Box 2.5). Other auctions have awarded projects since. The awards of an offshore wind auction in late 2021, for example, are not included in the report. Aggressive bidding in the auction, which resulted in low prices, has raised concerns about the sustainability of the industry.

Future auctions will likely be adjusted to address these concerns and to pursue a 60% local content goal by 2040 (Wood Mackenzie, 2022). Other improvements could include the disclosure of more information during different stages of the auction, establishing a systematic auction scheme for 10-20 years to develop strong project pipelines, and increasing the budget for the auctions system, among other points (Eguchi, 2022). In March 2022, Japan awarded 268.7 megawatts (MW) in its 11th solar PV auction at an average price of JPY 9.99 per kWh (USD 77 per megawatt-hour). This was the last auction awarding fixed tariffs; future auctions will award feed-in premium tariffs (Bellini, 2022).

BOX 2.5 RENEWABLE ENERGY AUCTIONS IN JAPAN

As of October 2020, Japan had conducted five renewable energy auctions for solar PV and two for biomass and had launched a zone-specific offshore wind auction (in June 2020). Out of a total of 1 663 MW auctioned, the five solar PV auctions awarded 574 MW. The average awarded prices at these solar PV auctions fell more than 35% between the first and fifth rounds. For biomass, no project has yet been contracted.

In Japan, solar PV prices remain higher than the global average and above those in other countries that have similar macroeconomic conditions and levels of solar PV development. However, relatively high auction prices do not necessarily diminish an auction's success. The average awarded prices were close to the cost of solar PV power in Japan, underscoring the value of auctions in enabling price discovery. Solar power generation is costly in Japan due mostly to high installation and building costs, as well as the cost of modules and inverters.

Looking forward, the use of auction designs that look beyond price reduction should make it possible to tackle many of the challenges that Japanese auctions have faced. Such design can focus on smoother grid integration of renewables, ensuring timely project completion and supporting a just and fair energy transition.

Source: IRENA, 2021c.

These efforts demonstrate Japan's understanding that energy system reform is a significant potential driver of sustainable economic activity. As the energy transition advances, the world is beginning to see the benefits of basing future energy supplies on renewables and cutting energy demand through greater efficiency. A country like Japan – economically advanced but dependent on fuel imports – stands to benefit immensely from the opportunities created by the energy transition. By moving the supply of energy to domestic sources, which renewable energy makes possible, Japan can bolster its energy security and self-sufficiency. The next section explores the socio-economic footprint of Japan's energy transition, analysing key drivers to provide insights that inform policy making for maximising the transition's benefits.

03 Socio-economic impact of the energy transition

To support transition planning and informed policy making, IRENA analyses the socio-economic footprint of the energy transition using a macro-econometric model to measure impacts on GDP, employment and human welfare. This process provides insights into how the transition can be planned to attain the highest possible benefits.[8]

This section presents the key findings of IRENA's socio-economic analysis for Japan, outlining potential impacts on economic growth (GDP), employment and welfare, including a discussion of the underlying drivers (Box 3.1) that lead to the results. These findings delineate the difference between the 1.5°C Scenario (1.5-S) and the Planned Energy Scenario (PES).

BOX 3.1 DRIVERS OF GDP AND EMPLOYMENT DURING THE ENERGY TRANSITION*

The analysis presented in this report considers the specific impact of each driver of the energy transition, and the extent to which this impact shifts over time. The drivers included in the analysis are as follows:

- **Public investment and expenditure**, comprising public investment in renewable energy, energy efficiency, power grids and flexibility, green hydrogen, electrification, and other transition-related investments, subsidies, and finance, as well as additional social spending and investment.
- **Private investment**, including investment in the energy transition across all technologies and investment in fossil fuel-related industries (such as exploration and production, refining, logistics and crowding-out effects in the private sector).
- **Net trade,** primarily through reductions in hydrocarbon imports and exports, although trade differences in other sectors are also included.
- **Induced lump-sum payments,** specifically government recycling of fiscal surpluses in the form of lump-sum payments for lower-income groups to improve living standards.
- **Aggregated prices,** which reflect the effects of the energy transition on the price level. Prices can be higher or lower than under a less ambitious scenario because of the effect of factors such as carbon prices, the evolution of wages and the transition to less expensive fuels.

*In the case of employment, the "consumer expenditure" driver combines the impacts of taxes, indirect and induced effects, and aggregated consumer price effects, while capturing other labour-related dynamic effects.

Source: IRENA and AfDB, 2022.

[8] *See IRENA (2016a, 2020a, 2021a and 2022a) for the methodology analysis.*

3.1 THE PLANNED ENERGY SCENARIO (PES)

Under Japan's current plans and policies, which represent the basic characteristics of the PES, the country is expected to experience modest economic growth, as envisioned in the baseline assumption of the E3ME model.[9] Despite its demographic challenges (due to an ageing and shrinking population), Japan's real GDP is expected to increase by an average of 1.27% per year between 2021 and 2030 and by 1.01-1.02% per year between 2030 and 2050 (Table 3.1). The population is expected to decline over the 2021-2050 period, at a compound annual growth rate of -0.50%. Economy-wide employment is also likely to decrease.

Table 3.1 GDP, economy-wide employment and population growth projections under the PES

Variable	2021-2030 (CAGR %)	2031-2040 (CAGR %)	2041-2050 (CAGR %)
Real GDP	1.27%	1.01%	1.02%
Economy-wide employment	-0.24%	-0.67%	-0.55%
Total population	-0.37%	-0.56%	-0.56%

Note: CAGR = compound annual growth rate.

Source: E3ME analysis.

3.2 POLICY INPUTS AND ASSUMPTIONS IN THE 1.5°C SCENARIO (1.5-S)

Using the same inputs and assumptions as the 2022 edition of IRENA's annual flagship publication, the World Energy Transitions Outlook (WETO), this chapter analyses the socio-economic differences between the Planned Energy Scenario (PES) and the 1.5°C Scenario (1.5-S) in Japan.

IRENA's analysis explores the socio-economic footprint outcomes resulting from the implementation of different combinations of energy transition roadmaps and accompanying climate policy baskets. The climate policy baskets include a range of tools to support a just and inclusive transition, among them carbon pricing, international collaboration, subsidies, progressive fiscal regimes to address distributional aspects, investments in public infrastructure and spending on social initiatives. The baskets also contain policies that deploy, integrate and promote energy transition technologies.[10]

Carbon pricing under the 1.5-S is higher than under the PES. However, because of the regressive implications of carbon pricing, levels have been reduced by half compared to previous reports (IRENA, 2021a, 2020a). Under the 1.5-S, carbon prices are higher for high-income countries than for less wealthy ones. For example, Japan's carbon price for 2030 under the 1.5-S is set at USD (2019), 150 per tonne of CO_2, while this carbon price in low-income countries is USD 30 per tonne of CO_2.

The macroeconomic modelling for most cases assumes revenue neutrality in governments' fiscal balances. The policies used to implement revenue neutrality depend on the progressiveness of the applied policy basket. In the PES, when government revenues increase (for instance through carbon prices), income taxes are reduced, whereas income taxes are increased when government revenues decrease. This approach has regressive implications, however, as the wealthiest households generally pay the lion's share of income taxes and benefit accordingly from the tax cuts. By contrast, in the policy basket used for the 1.5-S, revenues are recycled through lump-sum payments that target lower-income households

[9] *Baseline forecasts are constructed using a comprehensive set of international data sources. The main source for population data is the United Nations (World Population Prospects), and for GDP forecasts is the International Energy Agency (World Energy Outlook). These are supplemented with data from the International Labour Organization, OECD (STAN), World Bank, Asian Development Bank, and European Commission (AMECO, Eurostat, EC Annual Ageing Report, EU Reference Scenario reports). E3ME is a global, macroeconometric model owned and maintained by Cambridge Econometrics: www.e3me.com.*

[10] *See Section 3.2 and Box 3.2 of the World Energy Transition Outlook (2022 edition) for more details.*

progressively: 60% of the payments go to the lowest-income quintile, 30% to the second quintile and 10% to the third quintile.[11] Distributional policies help to mitigate regressive effects of the energy transition and climate change itself.

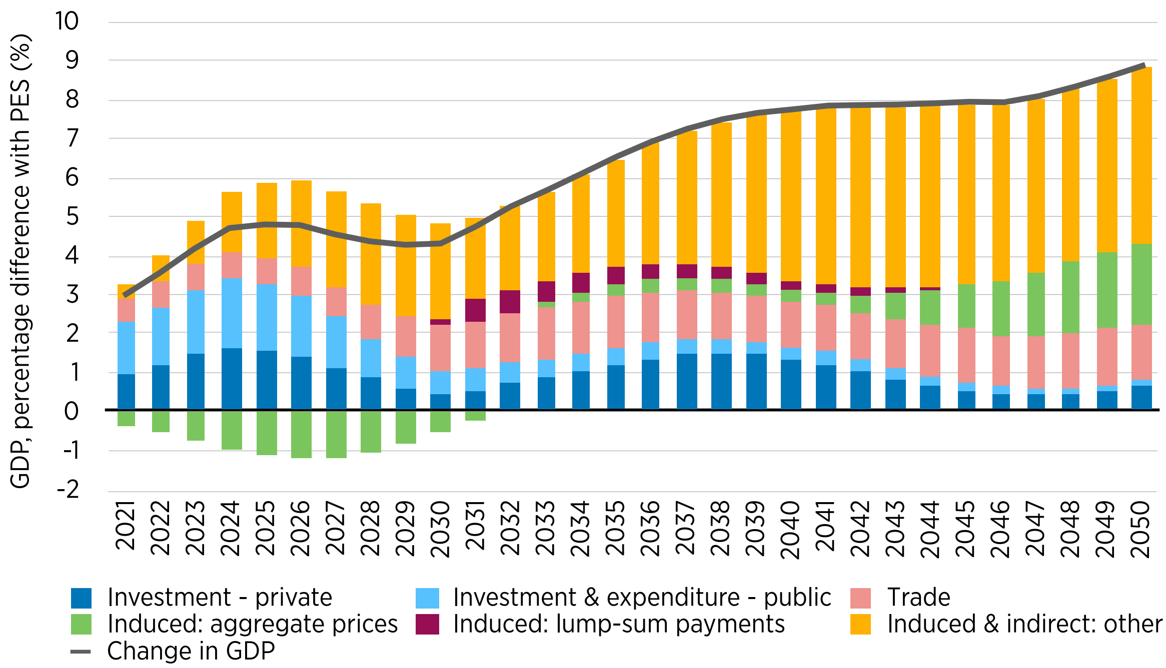
Another key component of the climate policy baskets is the level of international collaboration. In the PES, no additional international collaboration is assumed. The 1.5-S policy basket includes enhanced levels of international collaboration to address the climate change challenge and the structural aspects underpinning an unequal distribution of burdens and responsibilities. Within this framework, all countries contribute to a joint effort according to their respective capability and responsibility in terms of climate equity[12]. International collaboration under the 1.5-S is 0.7% of the global GDP between 2021 and 2050. In contrast, and given that current commitments and climate finance pledges have not been met, the PES does not consider international climate co-operation flows. Other policies are mentioned in Annex II.

3.3 ECONOMIC GAINS, AS MEASURED BY GDP, UNDER THE 1.5°C SCENARIO (1.5-S)

As discussed earlier, Japan is expected to experience GDP growth of 1.1% per year in the PES from 2021 to 2050. Under the 1.5-S, however, the country's economy is estimated to perform much better: the average GDP difference with the PES is 6.3% over the period 2021-2050. In cumulative terms, the country will be adding USD (2019) 13.1 trillion to the growth already anticipated in the PES. Specifically, in 2050, GDP is 8.8% higher in the 1.5-S than in the PES. These differences in GDP have various drivers, such as trade, investment, and energy prices, as discussed below.

To gain a better understanding of the structural elements underlying the socio-economic footprint, IRENA's macroeconomic analysis disaggregates the outcomes by drivers and sectors. The main macroeconomic drivers that have key impacts on GDP are indirect and induced effects, investment and trade (Figure 3.1).

Figure 3.1 Japan's GDP, percentage difference between the 1.5-S and the PES, by driver, 2021 to 2050



[11] A quintile refers to any of five equal groups into which a population can be divided according to the distribution of values of a particular variable. Thus, the lowest-income quintile refers to the poorest 20% of a given population, the second quintile encompasses the next 20% moving up the income ladder, and so on.

[12] Based on the Climate Equity Reference Calculator, https://calculator.climateequityreference.org.

Induced and indirect effects play the strongest role in the GDP difference. Results in Figure 3.1 present three groups of induced and indirect effects: aggregate prices, lump-sum payments and other.

Household consumption has historically accounted for the largest GDP share, and **the induced and indirect effect (other)** holds the largest share in the additional GDP gain as well. A diversified economy allows Japan to multiply the economic benefits from investment stimulus and more favourable trade balance through indirect effects and induced effects such as those arising from increases in labour income (leading to additional real income and thus spending).

Changes in income tax rates, which is a part of the driver, have a modest negative impact in the overall induced effects. Income taxes are driven by general economic activity and by the requirement of revenue neutrality in government fiscal balances. The transition introduces significant modifications on both the revenue and spending sides of government fiscal balances. On the revenue side, carbon pricing and revenue from public energy-related investment greatly increase revenues in the 1.5-S compared to the PES. On the spending side, subsidies to support the transition, public transition-related investment and contributions to the global collaborative effort all increase the public expenditure in the 1.5-S as compared to the PES. Differences in revenue and spending between the 1.5-S and the PES are fairly balanced throughout the transition period, requiring small increases of income taxes in the 1.5-S during the first decade and allowing for higher lump-sum payments in the 1.5-S from 2030 to 2045 to maintain government revenue neutrality.

Induced effect (aggregate prices) play a positive role. While the impact in the initial years is negative, it turns positive in the later years. In the early years of the transition, energy prices increase in the 1.5-S compared to the PES, following the imposition of a higher carbon price and the faster deployment of transition-related technologies. Reacting to the higher energy prices, households and industries deploy energy efficiency measures post-2030, enabling a further reduction in fossil fuel demand (as well as lower fossil fuel prices). This would result in lower aggregate price levels than in the PES, exerting a positive influence on real consumption and GDP levels.

With the projected changes in energy sources, electricity prices are estimated to decrease compared to the PES in the long term (-12.5% in 2050). In the short- to mid-term, however, electricity prices are higher than under the PES (8% in 2030 and 0.1% in 2040). Firstly, coal is relatively inexpensive in the PES. However, with a carbon tax under the 1.5-S, the cost of coal and other fossil fuels rises, translating into higher electricity prices.

In the long run, the cost of renewables is expected to continue to fall (due to learning-by-doing effects), bringing down the cost of electricity. As deployment of renewables increases at a faster rate in the 1.5-S, the effect of falling renewable energy costs translates into lower electricity costs in the 1.5-S. Additionally, consumer investment in more energy-efficient technologies and measures will lead to reduced electricity use; the resulting higher disposable incomes permit more spending elsewhere in the economy. The additional revenues from carbon pricing are playing a central role by enabling Japan to boost spending on clean energy technologies and hard-to-abate sectors and support a just transition.

Induced effect (lump-sum payments) plays a positive but marginal role in the difference of GDP with the PES. Lump-sum payments are introduced in the 1.5-S to address domestic distributional issues. The driver is supported by the resulting government fiscal balances and the requirement of revenue neutrality. As discussed earlier, significant increases in both the revenue and spending side of government fiscal balances occur under the 1.5-S. Since the increases in revenue and spending are rather equilibrated, there is limited room for lump-sum payments. Implementing higher carbon taxes in the 1.5-S, such as those considered in IRENA (2020a, 2021a) would increase the fiscal space for lump-sum payments and its socio-economic benefits.

Trade is a positive and steady driver of the GDP differences during the transition. As described in section 2, trade balance plays a small role in Japan's GDP, but at the same time, the country relies heavily on imports of fossil fuels. Import dependence ratios in 2019 were 99.7% for oil, 97.7% for LNG and 99.6% for coal (Agency for Natural Resources and Energy, 2021). Crude petroleum and petroleum gas are the two largest single commodities imported, comprising 15% of total imports. Coal and refined petroleum contribute around 5% of total imports.

The trade balance, which currently accounts only for 0.17% of GDP, is estimated to improve as Japan greatly lowers imports of fossil fuels – the reduction in energy import bills reaches USD 130 billion by 2050. The country is then able to shift resources to other purposes and reduce the burden of import dependence. In cumulative terms from 2021 to 2050, lower import of fuels is estimated to improve the trade balance by around USD (2019) 3 trillion, or on average 18% of the total economic gain observed. The impact of reduced imports is two-fold. First, the full value of reduced consumption is reflected as a positive GDP effect. Second, there are minimal negative multiplier effects domestically, given that the supply chain is outside Japan.

The impact of **private investment** comes in waves but is positive throughout the transition. This is consistent with the analyses in section 2, which suggest that a high share of investment in GDP is the result of attractive returns to investment in Japan. The driver is strong in the first five years of the transition and later towards the 2035-2040 period, while it is lower in the mid-evaluation period and end stages. The higher initial impacts are partly because of the front-loaded nature of transition-related investment.

Other sectors in the wider economy, such as basic manufacturing, engineering and transport equipment, and construction, experience positive impacts due to transition-related investments. If additional measures were introduced, more domestic value could be captured for Japanese industry. Currently, importing PV modules and wind turbines means that parts of the investment impact leave the country again, which is reflected in the trade balance. Also, it is assumed that increased transition-related investment crowds out investment in other parts of the economy. Additionally, private investment in fossil fuel sectors is 66% lower than in the PES by 2050. Yet the magnitude of this impact is not substantial since investment in the coal, oil and gas sectors is relatively small in Japan (USD 9.6 billion – 0.002% of the GDP).

The public investment and expenditure driver plays a dominant role in the first decade of the transition. This is primarily due to the front-loaded investment needs of the energy transition.

Government spending also increases and results in an increase in GDP when compared to the PES (0.1% or USD 567 billion in 2050). It leads to increased spending on social services predominantly provided by the government including public administration, health care, and education, therefore mainly benefiting the public and personal services sector.

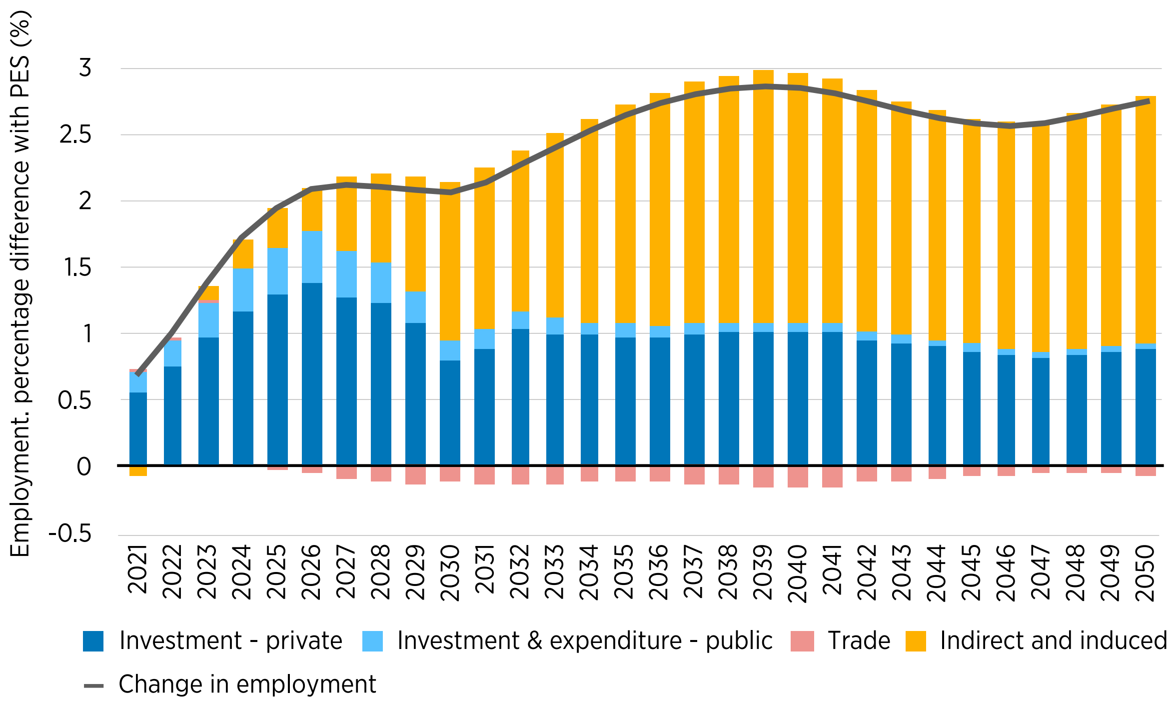
3.4 EMPLOYMENT

Economy-wide employment

Reflecting a decrease in population, the number of jobs across the economy is estimated to be lower in both scenarios. Given the low unemployment rate in Japan today, and in both scenarios, there is little leeway for additional employment. Despite the increase in demand (which as per various literatures creates jobs), increases in productivity require fewer workers.

Under the 1.5-S, employment is higher than in the PES by an average of 2.3% over the 2021-2050 period,[13] rising to a 2.7% difference (1.6 million in absolute numbers) in 2050. Similar to GDP, this trend is underpinned by drivers related to investment, trade, and indirect and induced effects.

Figure 3.2 Employment in Japan, percentage difference between the 1.5-S and the PES, by driver, 2021 to 2050



Compared with the PES, the 1.5-S experiences an increase in economy-wide employment mainly driven by the indirect and induced effects of consumer expenditures (Figure 3.2). The effect is at its peak in 2040 at 1.9% (1.2 million additional jobs), then declines progressively by 2050. A more detailed description of the role of drivers and the impacts on different sectors is provided below.

Indirect and induced effects. These effects become the main driver after the first decade, mainly the ripple effects from front-loaded transition-related investment in the form of more consumer spending. The consumer expenditure response in the 1.5-S plays an important role in creating more jobs in sectors meeting consumer demand. Basic manufacturing is the key sector in this trend. Other dynamic and indirect effects also play a positive role through sectors such as manufacturing and business services.

[13] Note that along the same period population decreases at a compound annual growth rate of -0.50%.

Front-loaded investment, both public and private in capital-intensive transition technologies (renewables and other transition-related technologies), are the first driver of the additional jobs in the first years through to 2030. This effect is reduced and stabilises over the following decades with the decline in the relative weight of investment in GDP.

Private investment leads to increased employment in the 1.5-S, contributing up to almost 1% additional employment on average between 2021 and 2050. The majority of jobs are created in the electricity sector.

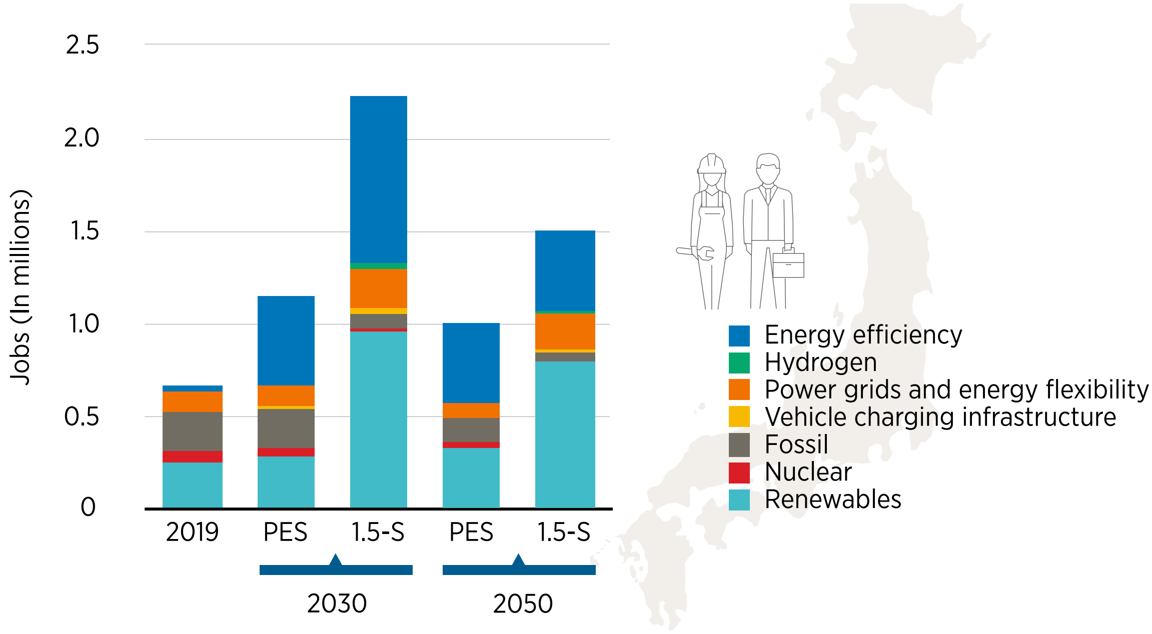
Public investment and expenditure also lead to more jobs. The effects are higher in the short run, which suggests that the government contributes more to investments that are more employment intensive (such as energy efficiency) in the short term. The number of jobs created is lower than from private investment because in aggregate the amount of public investment is lower than private investment.

Trade. The employment impacts from trade are negative throughout the analysis period, although trade's impact is small in relative terms (Figure 3.2). Non-energy trade is lower in the 1.5-S as a result of competitiveness changes in international markets and a shift towards higher goods imports driven by increased consumer expenditure. Trade in fossil fuels is also reduced under the 1.5-S.

Energy sector jobs

The number of energy sector jobs is estimated to be higher in the 1.5-S than in the PES. In 2030, there would be a total of 2.2 million jobs in the 1.5-S compared to 1.2 million in the PES. In 2050, the energy sector would have a total of 1.5 million jobs in the 1.5-S compared to 1 million in the PES. A decline in jobs in 2050 compared to 2030 is a result of the front-loaded construction of new plants and infrastructure (including energy efficiency), the projected reduction of energy demand, and an increase in productivity.

Figure 3.3 Overview of energy sector jobs in Japan under the 1.5-S and the PES, by sector, 2019 to 2050



Source: IRENA analysis.

In 2050, renewables contribute to over 50% of the total energy sector jobs in the 1.5-S. This is followed by jobs in energy efficiency with a share of almost 30% (0.5 million jobs). Power grids and flexibility create 0.17 million jobs with an 11% share. Nuclear, vehicle infrastructure and hydrogen each contribute 1% (Figure 3.3).

Renewables jobs

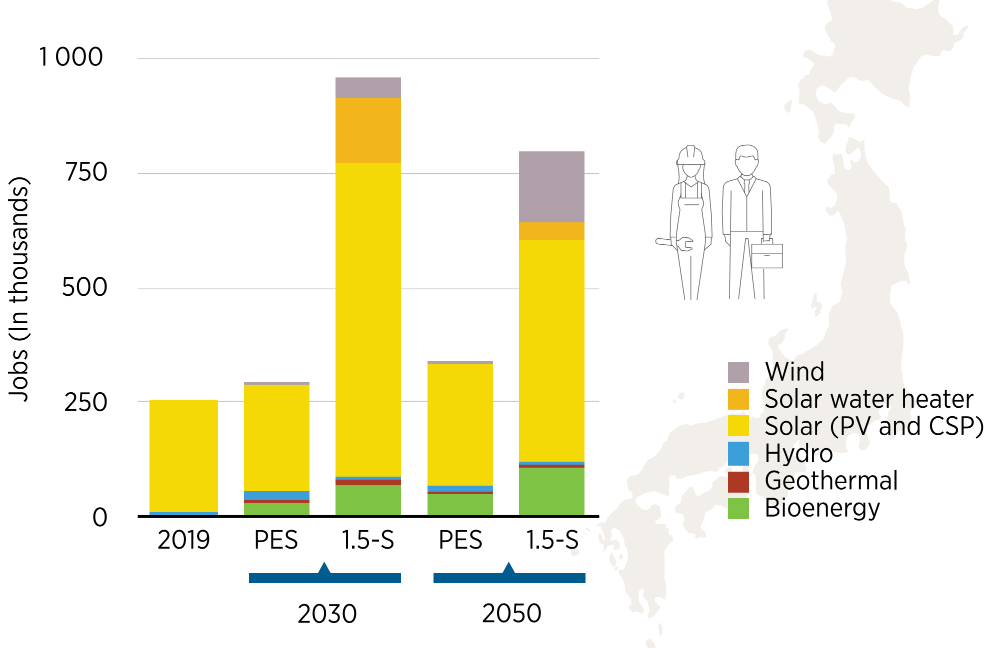
Renewable energy jobs in Japan have declined in recent years (Box 3.2). Nonetheless, the energy transition is expected to revive the jobs in the sector as the country adopts the pathway for the 1.5-S. Jobs growth in the PES is modest, reaching 0.29 million in 2030 and 0.34 million in 2050. The 1.5-S sees a significant increase in renewable energy jobs over the PES (more than three-fold in 2030 and two-fold in 2050), reaching 0.8 million jobs by 2050.

BOX 3.2 SOLAR PV JOBS IN JAPAN

Japan's PV sector is the third largest in the world in installed capacity (IRENA, 2021e). Nonetheless, it is one of the few markets that has charted a decline in new installs. Challenges implementing feed-in tariff projects, land shortages and limited grid access for new projects are some of the underlying causes for the recent decline (see section 2). As per Tokyo Shoko Research, a private credit analysis firm in Japan, 88 bankruptcies were filed in Japan's solar industry during 2017, over 35% more than in 2016. Poor sales were mentioned as the primary reason for bankruptcy among 42 of the 88 companies (EnergyTrend, 2018). New installations of solar PV also declined in 2020. IRENA estimates that consequently, jobs fell from 241 000 in 2019 to 220 000 in 2020 (IRENA, 2021f).

Solar technologies (mainly PV) strongly dominate the share of renewables: under the 1.5-S, solar technologies account for 71% of renewable energy jobs by 2030 and 61% by 2050. Wind and bio-energy account for 19% and 13%, respectively, of renewable energy jobs under the 1.5-S by 2050. Comparing the PES and the 1.5-S, the highest employment relative differences are seen in wind energy (Figure 3.4).

Figure 3.4 Renewable energy jobs in Japan, 2019, 2030 and 2050 in the PES and the 1.5-S



Note: CSP = concentrating solar power.

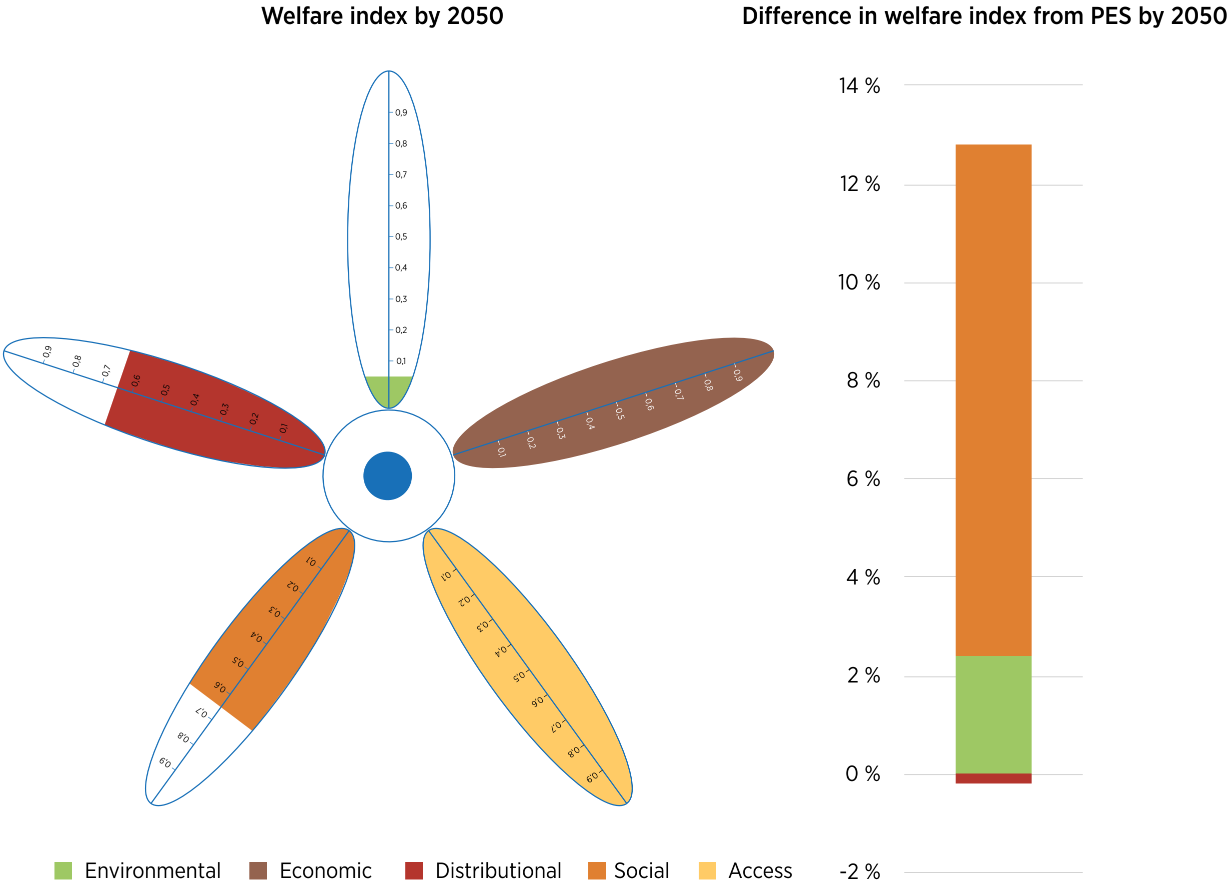
Source: IRENA analysis.

3.5 WELFARE

On top of the specific economic benefits discussed above, the main potential of the energy transition is to improve overall welfare in Japan. IRENA quantifies the impact of the energy transition through its Welfare Index (IRENA, 2021a). The index captures five welfare dimensions: economic, social, environmental, distributional and energy access (see section 2.3).

Figure 3.5 presents the welfare index and its dimensional indexes for the 1.5-S by 2050 for Japan, and the relative difference in welfare indices, broken down by dimensional contributions, between the PES and the 1.5-S, by 2050 for Japan. The welfare improvement for Japan under the 1.5-S compared to the PES reaches 12.6% by 2050.

Figure 3.5 Welfare index for the 1.5-S and difference in welfare between the 1.5-S and the PES, 2050



Source: IRENA analysis.

The welfare improvements of the 1.5-S over the PES are led by **the social dimension**. This dimension is informed by two indicators: health impact and social expenditure. Japan performs rather well under both these indicators in the 1.5-S, with the health impact indicator experiencing a significant improvement over the PES (whereas the social expenditure indicator remains similar to the PES). Under the PES, the reliance on fossil fuels is expected to worsen health impacts in Japan drastically. Thus, by ameliorating indoor and outdoor air pollution, the 1.5-S improves welfare significantly by 2050 compared with the PES. The absolute social index reaches 0.65 under the 1.5-S by 2050 (left side of Figure 3.5), with rather equilibrated contributions from its two indicators (indexes of 0.70 and 0.61 for social expenditure and health impact respectively), indicating room for improvement of overall welfare by further improving these two indicators.

The environmental dimension is the second largest driver in improving welfare in the 1.5-S over the PES. This dimension is informed by two indicators: CO_2 emissions and materials consumption. The CO_2 emission indicator is entirely responsible for the improvements in this dimension over the PES. As with air pollution (see above), the 1.5-S markedly reduces global cumulative CO_2 emissions compared to the PES, therefore helping to reduce the impacts from climate change. The material consumption indicator in Japan is above the threshold for bad performance under both the PES and the 1.5-S, and hence the resulting index for this indicator is zero for both scenarios, dragging down the absolute environmental index (left side of Figure 3.5), and not contributing to the improvement of the 1.5-S over the PES. More must be done to reduce material consumption in Japan in the future, with significant room to improve the absolute welfare index.

The **economic** and **access dimensions** see no improvement under the 1.5-S over the PES, since both of them reach the maximum index values by 2050 for both scenarios (left side of Figure 3.5), indicating that further emphasis in improving these dimensions will not produce additional welfare benefits in Japan.

The economic dimension is informed by two indicators: consumption and investment, and non-employment. As explained in section 2.3, consumption and investment per capita in Japan are high when compared to other parts of the world. The 1.5-S, by boosting disposable incomes, increases the levels even further. But ultimately both consumption and investment have decreasing marginal returns and do not improve welfare after a certain point. Under both the 1.5-S and the PES the consumption and investment indicator exceeds the sufficiency limit, and hence its index is 1 for both scenarios, with no improvement in the 1.5-S over the PES. Similarly, by 2050 Japan does not have non-employment under either the PES or the 1.5-S, and hence its index is 1 for both scenarios.

The energy access dimension is informed by two indicators: basic energy access and energy sufficiency. As Japan has already reached universal energy access, the basic energy access indicator is the same for both the 1.5-S and the PES reaching its maximum index value of 1. Energy consumption in Japan, in turn, exceeds the sufficiency level under both the PES and the 1.5-S, providing the maximum index value of 1. Therefore, the 1.5-S does not provide any improvement over the PES in this dimension.

For the **distributional dimension**, by 2050, a negative but almost negligible difference is observed between the 1.5-S and the PES in Japan (right side of Figure 3.5), hence it does not make a significant contribution to the difference in welfare between the 1.5-S and the PES. The absolute distributional index reaches 0.65 under the 1.5-S by 2050 in Japan (left side of Figure 3.5), a similar value to that under the PES, and a good value (the global index is 0.36), although it indicates significant room for improvement. The distributional dimension is informed by two sub-dimensions, intra (within country) and inter (between countries) distribution, and each sub-dimension is in turn informed by two indicators: income and wealth distributions.

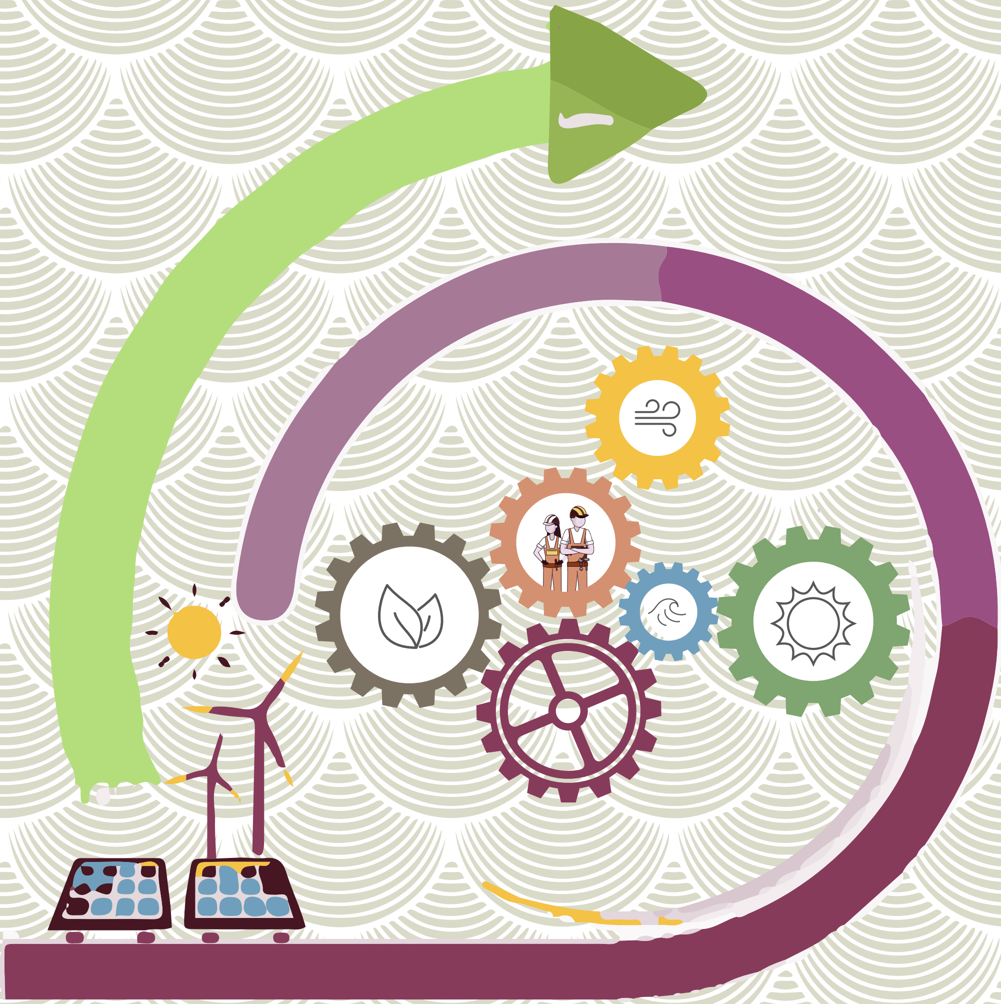
The climate policy basket accompanying the 1.5-S includes policies directly targeting the improvement of income distributions (both intra and inter). These policies are successful in improving the inter-distributional index. In Japan, due to the limited available fiscal space with the implemented carbon pricing level, the income distribution experiences only a small improvement over the PES, with the wealth distribution dragging the intra distributional index down. Additional policies allowing higher improvements in income distribution and directly addressing wealth distribution would be needed for Japan to advance in the distributional dimension of the welfare index.

The welfare index and its dimensional indexes (left side of Figure 3.5) provide a clear indication of where to focus policy action to improve welfare in Japan. Under the 1.5-S an overall welfare index of 0.49 by 2050 is achieved, indicating significant room for improvements in welfare. The economic and access dimensions have reached the maximum index value (1), and hence no additional policy efforts are needed in these dimensions.

The environmental dimension offers the highest room for improvement, with a focus on limiting the consumption of materials being the most effective at improving this dimension's index. The social and distributional dimensions also offer room for improvement. Policies addressing increases in social spending and further reductions in pollution would produce improvements in the social dimension index. To improve the distributional index, policy action focused on improving the wealth distribution and at providing additional fiscal space[14] to increase lump-sum payments (addressing income distribution) would help to improve the distributional index.

[14] *Higher carbon taxes would contribute to this goal.*

04 Conclusion

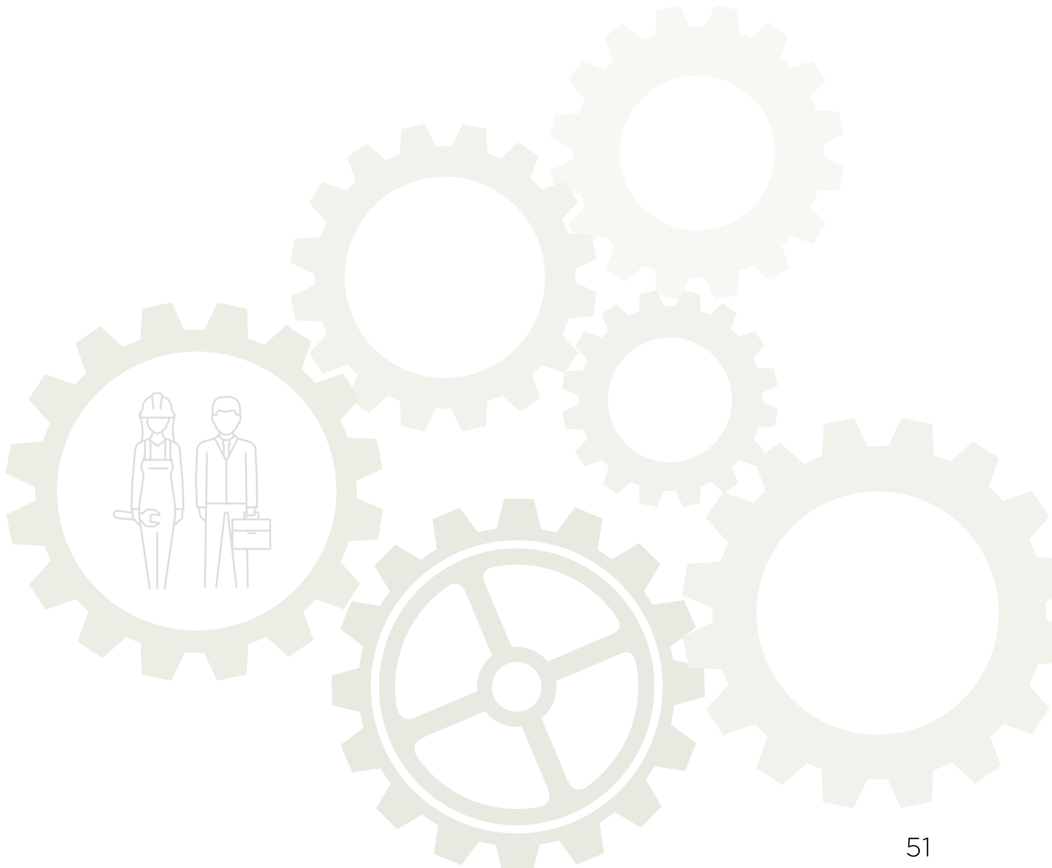


Japan's energy sector is highly dependent on fossil fuels. However, the government has taken steps to change this. The country recently pledged to achieve net zero emissions by 2050 and has developed a plan to reduce emissions 46% by 2030 compared to 2013 levels. Renewables will be a pillar of these plans. A key question is how Japan's current energy policies and wider economic plans will impact its socio-economic development. Globally, the sustainability and equity of economic activity is acquiring increasing relevance. In developed countries such as Japan, sustainable development has increasing marginal returns in terms of well-being (De Neve and Sachs, 2020).

The analysis has shown that a scenario involving larger amounts of renewable energy and more efficient energy demand management – in short, a comprehensive and more ambitious energy transition – will lead to improved socio-economic outcomes. Under the 1.5-S, Japan's GDP is estimated to be, on average, 6.3% higher than in the PES over the 2021-2050 period and is 8.8% higher in 2050. Greater household consumption and lower fossil fuel imports, as well as higher transition-related investment, are the main drivers of this GDP difference. Economy-wide employment will be 2.7% higher under the 1.5-S than under the PES by 2050 (1.6 million additional jobs), while the energy sector adds 0.5 million jobs under the 1.5-S compared to the PES.

Human welfare under the 1.5-S improves by 12.6% in 2050 compared to the PES, led by the social and environmental dimensions. From the five dimensions of the welfare index, the economic and energy access dimensions reach the maximum index value under both scenarios, and hence do not provide additional room to improve the welfare index. Policy action aiming to improve welfare should therefore focus on the environmental, social and distributional dimensions.

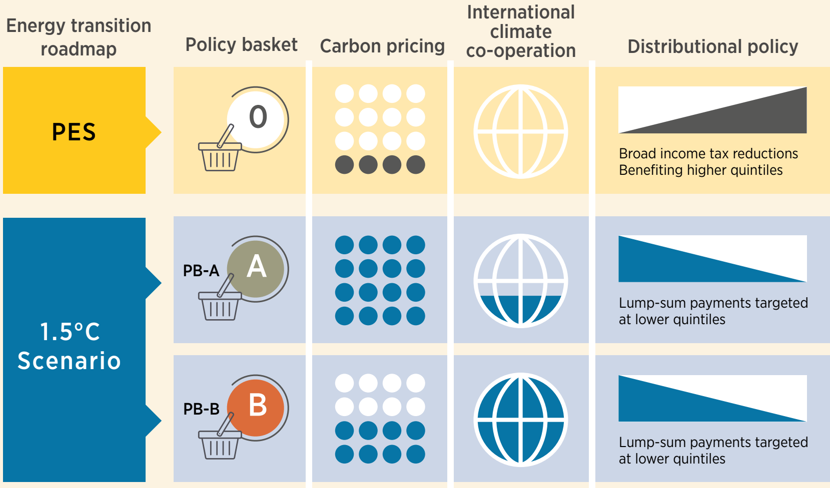
A successful energy transition capable of limiting climate change impacts and damages requires an unprecedented global collaborative effort. Triggering this collaborative effort, in turn, hinges on bringing all on board by successfully addressing the equity and justice dimensions of the transition. Policy action is a cornerstone to achieve these goals. Thus, IRENA has studied the impact of different policy baskets to facilitate this effort of co-operation (Box 4.1).



BOX 4.1 THE VALUE OF COLLABORATION FOR A SUCCESSFUL TRANSITION

IRENA has explored the impact of policy baskets aiming to facilitate the global collaborative effort required for a successful energy transition. Results from this analysis are presented in IRENA and AfDB (2022) and IRENA (2022a). The analysis explores the socio-economic footprint of the 1.5-S energy transition roadmap with two different climate policy baskets (Figure 4.1), which differ in the level of carbon pricing and international collaboration, and unlike the PES policy basket include policy instruments to address improvements in the intra income distribution. In the present report, the socio-economic footprint results for Japan presented in section 3 correspond to the more progressive policy basket (high international collaboration and low carbon taxes, *i.e.* policy basket B [1.5-S PB-B]).

Figure 4.1 Energy transition roadmaps and climate policy baskets

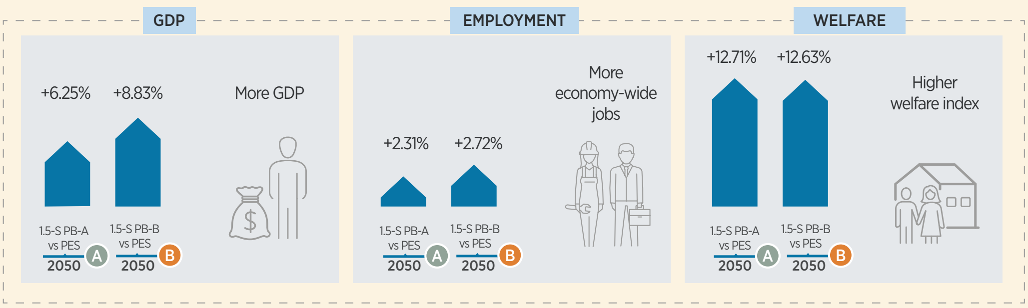


Source: IRENA, 2022a.

The analysis showcases the important role of international collaboration, providing very important improvements in the transition's socio-economic footprint in most of the world (referring to developing countries), while not imposing significant negative effects in the socio-economic footprint of developed economies.

In the case of Japan, in average terms over the 2021-2050 period, the two policy baskets produce almost the same results in terms of GDP, employment and welfare, while by 2050 better GDP and employment results are obtained with the more progressive policy basket (Figure 4.2).

Figure 4.2 GDP, economy-wide employment and welfare difference in Japan in the two 1.5°C Scenario variants compared with the PES, 2050



Nevertheless, beyond the impact of policy baskets in the socio-economic footprint for a given energy transition roadmap (such as the 1.5-S), the highest value of progressive policy baskets addressing the equity and justice dimensions of the transition is that they ultimately enable high mitigation roadmaps – that is, they allow such mitigation pathways to become a reality by triggering the required collaborative effort, hence effectively limiting global warming and containing the impacts of climate change for all.

In addition to these quantitative benefits, the energy transformation will help address many of the country's other concerns including the revival of regional economies, digitalisation and industrial development. That said, technological deployment alone will not necessarily deliver economic and social gains. To maximise the benefits of the energy transition, a wider policy framework is needed. Indeed, a just policy framework is essential to a successful energy transition (IRENA, 2019a).

A holistic transition policy framework rests on three transformative pillars: cross-cutting policies (such as R&D), policies to support the technological avenues of the energy transition, and policies for structural change of a just transition. While all stakeholders need to come together for co-ordinated action, governments in particular have an important role in driving the energy transition and in putting in place appropriate mechanisms to ensure that countries are on the path to achieving climate targets.

Policy measures set by governments play a crucial role as they are best positioned to ensure that the full spectrum of the energy transition is covered, and that short-term actions are aligned with longer-term climate and socio-economic development objectives. Achieving a structural transformation spans beyond one sector and often engages several cross-cutting policies. Stakeholders and institutions of multiple sectors need to come together to create a conducive environment for the energy transition. Such multi-sector and multi-stakeholder engagements are essential and should aim to:

- reduce the dependence on fossil fuel assets;
- eliminate distortions and incentivise energy transition solutions; and
- raise awareness among consumers and citizens.

Japan has already embarked on several of these policy objectives. The long-term energy transition plan has been released with raised ambition to meet the net zero target. Other challenges remain to be overcome. Japan has liberalised its electricity market, but small market players still face difficulty due to grid constraints and market information (Reuters *et al.*, 2021) and will need more attention (IEA, 2021). Organisational structures for the power sector need to be aligned with the requirements of renewable-based power systems to prevent additional transition barriers (IRENA, 2020d; 2022b). Another measure could be a stronger nationwide carbon tax mechanism, which has to be designed carefully to not have a regressive impact and to contribute to improving the distributional dimension of the welfare index.

Supported by the fact that renewables are abundantly available in Japan's countryside, the energy transition provides a unique opportunity to revitalise the rural economy, increase regional autonomy, and create jobs, addressing spatial[15] re-alignment of the energy transition. Increasing digitalisation efforts in Japan will have an impact on the wider economy and in the energy sector. The energy transition has a two-way relationship with digitalisation. On the one hand, renewable energy deployment adds jobs to the economy. With appropriate skills training programmes, these jobs could be made available to those who have lost jobs due to digitalisation. On the other hand, the energy transition can be accelerated when taking advantage of the existing and emerging digital infrastructure. Artificial intelligence can be instrumental in devising high-efficiency materials for solar PV, and drones are already supporting the installation and maintenance of several renewable technologies.

In any case, pro-active and supportive government policies will be needed in the energy transition, just as they were needed to support economic growth since World War II and the development of leading industries and technologies. Currently, Japan is promoting hydrogen and several other innovations to support the energy transition and economy. Both the technology and the infrastructure remain heavily subsidised, illustrating the government's faith in the future of hydrogen and innovations, and its efforts to lead the world in the race to commercialise it (Okutsu and Shibata, 2020).

[15] *Spatial misalignments refer to new jobs that may be created in different communities, regions or countries than those where the principal job losses occur. Other misalignments include temporal (when job are losses and gains play out over diverging time scales rather than in parallel), educational (when skills associated with vanishing jobs do not necessarily match the profiles and occupational patterns of emerging industries), and sectoral (when jobs created in new industries that are quite different from existing jobs).*

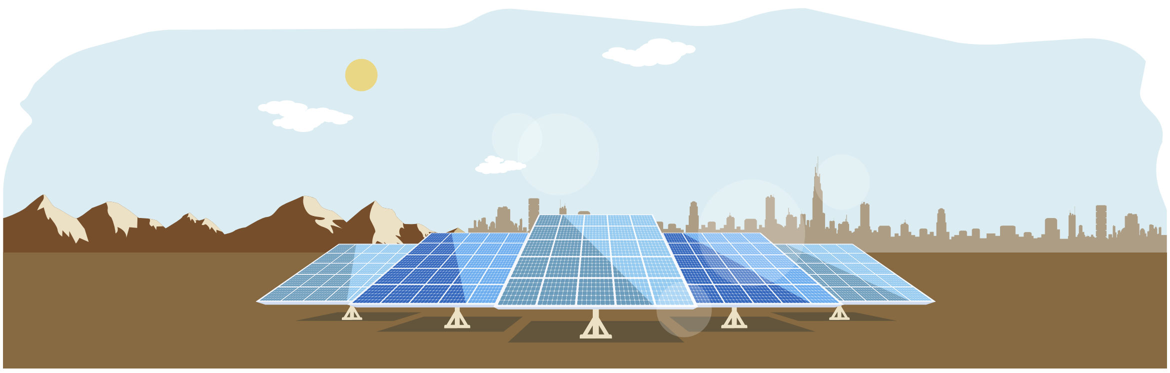
Despite having successfully deployed solar energy, Japan has not been able to extend to a diverse set of technologies such as bio-energy and wind. What is needed to deploy these technologies will have to be determined via consultations with stakeholders, including government, industry and citizens. Collaboration and co-operation among system operators, regulators, government and citizens is needed to integrate demand management and energy efficiency and to make the electricity system smarter with technology (smart grids) and economic interactions (smart prices).

The transition towards clean energy involves far-reaching changes along different dimensions of the economy, society and the surrounding natural ecosystem. Section 3 has showed how the energy transition can help to address the challenges outlined in section 2. Figure 4.3 presents some of the key opportunities that arise from the energy transition and how they can be mapped with the key challenges facing Japan.

Economy-wide. The energy transition (1.5-S) can enable the country to meet its climate pledges, while supporting aggregated economic activity. Renewables create more jobs than conventional technologies, especially in rural areas, which means that the energy transition can help to address concerns about declining rural populations and economies if the appropriate policies are in place. Health can be improved with cleaner air. International collaboration will enable an effective global transition that mitigates global CO_2 emissions, hence reducing the direct climate damages[16] in Japanese aggregated economic activity, and preventing social and economic disruptions triggered by increasing climate events that would have further negative socio-economic impacts for Japan.

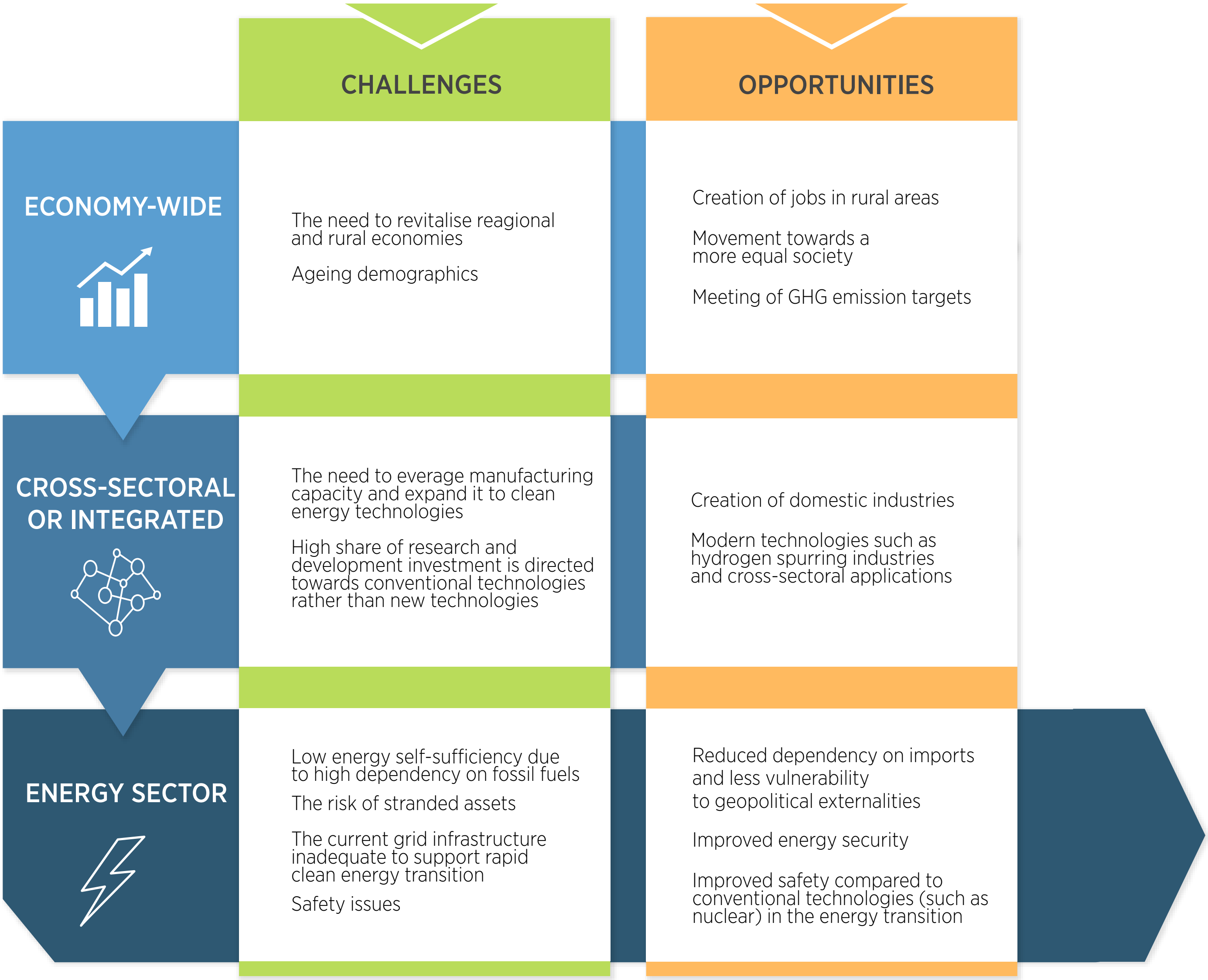
Cross-sectoral. A shift in technologies will create jobs across the value chain. There will be opportunities to create or revitalise the domestic manufacturing base across all transition-related technologies. Uptake of innovative technologies related to hydrogen or energy storage will present cross-sectoral opportunities. Likewise, the shift away from current technologies, both on the generation and demand sides, will introduce challenges for people with jobs that are bound to disappear and for communities that have grown economically dependent on current technologies. Focused policy action will be needed to address these misalignments (temporal, spatial and educational) to enable all citizens to benefit from the transition benefits.

Energy. Self-reliance will increase significantly with local resource supply, thus reducing Japan's vulnerability to external geopolitical shocks and enhancing its energy security. However, these opportunities, whether economy-wide or limited to the energy sector, do not automatically materialise – they require a wide range of policy and regulatory changes. Long-term integrated energy planning strategies can ensure sustained benefits. The energy transition is an intensive and deep process that must be unfolded quickly, and policy makers will need to ensure harmony between energy policy and other areas of national policy for the transition to flow smoothly.



[16] *Note that the results presented in this report do not include the effect of climate damages in the aggregated economic activity. However, these are significant, even for ambitious transition pathways such as the 1.5-S. For information on the impact of climate damages on GDP, see IRENA (2021a) and IRENA and AfDB (2022).*

Figure 4.3 Challenges and opportunities presented by the energy transition in Japan



Like many countries in transition, Japan faces challenges in the energy sector and beyond. With the global climate challenge, solutions are needed to swiftly advance the transition. As this report shows, a more ambitious energy transition offers many benefits. It will enhance sustainable economic activity, alleviate strains on the labour market and improve energy security by reducing import costs and exposure to geopolitical risks. Most of all, with the appropriate policy framework, such an ambitious energy transition offers the opportunity to provide huge improvements in welfare. Maximising these benefits will require further fine-tuning the existing support policies and addressing some of the policy gaps discussed in the report in a holistic and comprehensive way.

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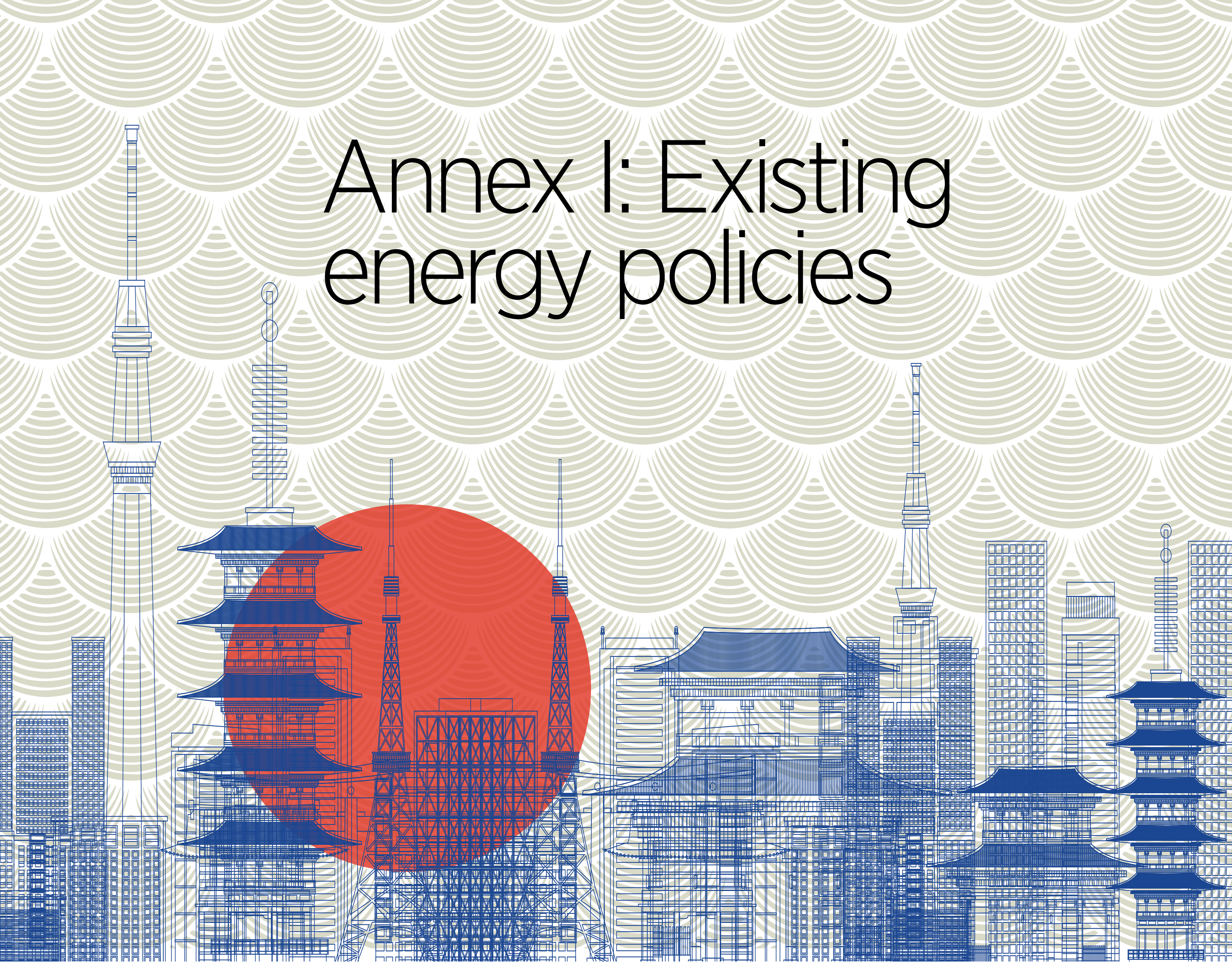
Annex I: Existing energy policies



Power sector

Renewable energy deployment in Japan is hampered by the structure of the power generation sector. The sector was partially liberalised in 1995, allowing steel, paper and gas companies to enter the market as independent power producers (IPPs) and to supply wholesale electricity to the incumbent and vertically integrated utilities. The legal framework for unbundling, however, was not completed until April 2020. Japan's power system has 10 regional utilities, successors to the 10 vertically integrated regional monopolies that existed before liberalisation. In theory, unbundling generation from transmission and distribution services opens the way for new entrants – notably renewable energy generators – to enter the market. So far, however, this has not been successful to the extent estimated as new entrants continue to find it difficult to enter the market (The Economist, 2020b).

In 2009, Japan introduced a feed-in tariff (FIT) for excess rooftop solar generation. The FIT was broadened and expanded in 2012 to cover all solar generation and any other sources recognised as renewable by the Japanese cabinet. The FIT scheme replaced a less-ambitious renewable portfolio standard (RPS) policy introduced in 2003, with very small portfolio shares such as 1.34%. The FIT proved to be more successful in deploying renewables than the RPS. However, the attractive FIT rates offered – which were not adjusted to falling technology costs – led to ever greater surcharges as deployment grew. In 2017, having reached substantial solar PV capacity additions, but with the FIT scheme having grown too expensive, Japan introduced renewable energy auctions for large-scale solar PV to keep up with the global trends in decreasing costs.

The IRENA report Renewable energy auctions in Japan: Context, design and results (IRENA, 2021c) analyses in detail the design elements and outcomes of five solar PV auctions (see Box 2.5). In November 2018, a bill promoting the commercial use of offshore wind in Japanese waters was passed by both houses of Japan's National Parliament. Pursuant to the bill, the Ministry of Economy, Trade and Industry (METI) and the Ministry of Land, Infrastructure, Transport and Tourism will identify potential offshore wind zones, after which developers will submit their bids. The successful candidates will be granted a 30-year lease to develop and operate wind farms at the designated areas. The government has conducted auctions in 5 promotion areas and is expected to designate more than 10 offshore wind development areas

Transport sector

In the transport sector, Japan began biofuels promotion programmes in 2005 as part of its commitment to the Kyoto Protocol. These programmes have focused largely on bioethanol over biodiesel. Different ministries are engaged in biofuels promotion: METI promotes them from an energy security perspective; the Ministry of Agriculture, Forestry and Fisheries from a rural development perspective; and the Ministry of Environment from an environmental perspective (Koizumi, 2011).

In 2007, the country established the Japan Biofuels Supply Limited Liability Partnership to accelerate the use of biofuels in transport. The first target was to blend 210 million litres (crude oil equivalent) of bio-ETBE (a derivative of bioethanol) into fossil fuels by 2010, a target that was successfully achieved. Pursuant to a 2011 law known as the Sophisticated Method of Energy Supply Structure, the Japanese oil industry gradually increased the volume of bio-ETBE to 500 million litres (crude oil equivalent) by 2017. In 2018, that target was extended to 2022 (JBSL, n.d.).

While biofuels promotion programmes have been in effect for years, biofuels do not feature as prominently in the long-term strategy of Japan's automotive industry, which envisions a major role for electric, fuel cell and clean diesel vehicles (sometimes referred to as next-generation vehicles). According to the strategy, between 58% and 83% of the new vehicles sold in 2030 are to be next-generation vehicles – including clean diesel (5% to 10%) and fuel cell electric (3%) (METI, 2018b; NeV, 2018).

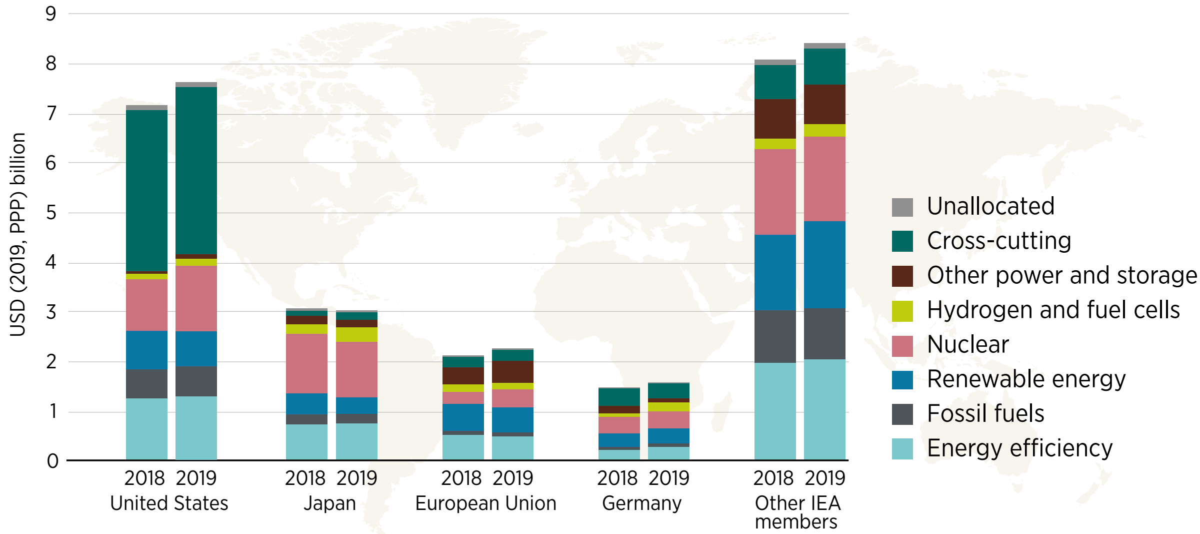
Japan aims to excel in environmental performance across the automotive sector. By 2050, every vehicle produced by Japanese automakers is to be electrified. Under a Well-to-Wheel Zero Emissions policy, emissions from the overall operation of a vehicle will be reduced to zero. By implementing these measures, the country is expecting an 80% reduction in emissions per vehicle and a 90% reduction for passenger vehicles (METI, 2018c).

Japan relies heavily on R&D, innovation and industrial development through public-private co-ordination. This largesse extends to policies for developing the renewable energy industry, although these are still at an early stage. After the first oil shock in the 1970s, METI initiated a 25-year R&D plan called the Sunshine Project to develop solar energy technologies. The plan was accompanied by a 200% increase in the solar energy research budget and the establishment of the New Energy and Industrial Technology Development Organisation (also known as NEDO).

Several other efforts are ongoing. The Japan Revitalization Strategy was first released in June 2013 to "put the economy back onto a full growth path" (Prime Minister of Japan and His Cabinet, 2014; Cabinet office of Japan, 2015). The strategy aimed to make Japan into a society where clean and economical energy is produced and distributed efficiently through market competition and consumed wisely.

In 2019, Japan spent the most on energy R&D of any country except the United States, followed by Germany, France, the United Kingdom, Canada, the Republic of Korea, Italy and Norway (IEA, 2020b). The public energy research, development and demonstration budget per unit of GDP was 0.57 in 2019 – only behind Norway (1.69) and Finland (0.81). Nonetheless, the budget for renewables dropped between 2018 and 2019 (Figure A1). Still, the share of clean energy increased between 2018 and 2019. and the country remains the largest funder of hydrogen and fuel cell research (USD 303 million). Despite the fact that Japan is one of the leading nations in renewables-related patents, there is still room for improvement. A shift of fossil fuel research and development (R&D) investment towards renewables could present the opportunity to make Japan a global leader in the energy transition.

Figure A1 R&D expenditure on various energy technologies in selected countries, 2018 and 2019



Note: IEA = International Energy Agency; PPP = purchasing power parity

Source: IEA, 2020b.

In May 2020, METI announced the Industrial Technology Vision (METI, 2020b), with the goal of helping Japan achieve the United Nations Sustainable Development Goals and resolve social issues. Supporting R&D is an integral part of the vision. In 2021, Japan also introduced a JPY 2 trillion (USD 19 2 billion) Green Innovation Fund to support ambitious green projects.

Japan is home to the world's largest hydrogen production facility (FCHEA, 2020; Government of Japan, 2020). The government has been working on international trade in hydrogen-based energy since the 1990s (Chiba, Arai and Fukuda, 1998). In 2017, Japan adopted its first national hydrogen action plan – the Basic Hydrogen Strategy (Makino, 2020) – which was later updated in 2019 as the Strategy for Developing Hydrogen and Fuel-Cell Technologies (METI, 2019; IRENA, 2020e). Japan has framed its hydrogen strategy around CO_2-free hydrogen, meaning that it covers both blue hydrogen (based on fossil fuels, but with carbon emissions captured and stored) and green hydrogen (produced with renewables-based electrolysis) (METI, 2017).

Because Japan's hydrogen strategy does not prioritise any technology, supplier or carrier, the country is pursuing agreements and demonstration projects for various pathways (Box A1). Australia, Brunei, New Zealand, Norway and Saudi Arabia all have agreements with the Japanese government to research possible pathways, which include both blue and green hydrogen. This would be shipped to Japan as liquid hydrogen or ammonia, or by using liquid organic hydrogen carriers (organic compounds, such as toluene, that can absorb and release hydrogen through chemical reactions).

Japan's hydrogen strategy focuses on the demand side (power, transport, industry and consumer sectors) as well as on reducing hydrogen costs. The country aims to implement hydrogen-fired power plants, fuel cell vehicles, hydrogen boilers in industries, etc. On the supply side, the country is looking to develop commercial-scale supply chains to procure 300 000 tonnes of hydrogen annually by 2030 to ensure that the cost of hydrogen decreases to no more than JPY 30 per normal cubic metre – equivalent to USD 3.2 per kilogram, down from today's USD 46 per kilogram (METI, 2017).

Japan's Global Warming Countermeasure Tax, enacted in April 2012, establishes a nationwide carbon price. At JPY 289 per tonne of CO_2 (around USD 2.6 per tonne of CO_2), it is low compared with other carbon pricing mechanisms in force today (World Bank, 2020). The average effective carbon rates for two large emitters – the industrial and the electricity sectors – are USD 3.92 per tonne of CO_2 and USD 12.3 per tonne of CO_2, respectively (Kojima and Asakawa, 2020).

BOX A1 FUKUSHIMA HYDROGEN ENERGY RESEARCH FIELD

After a construction phase of around two years, the Fukushima Hydrogen Energy Research Field (FH2R) in Japan became operational in March 2020. The objective of the facility is to serve as a research laboratory for hydrogen projects and to acquire data for practical application of power-to-gas technology.

The facility comprises a 10 MW hydrogen production unit with a maximum production capacity of around 2 000 normal cubic metres of hydrogen per hour. The power is generated by an on-site solar PV unit of 20 MW. The produced hydrogen serves as fuel for stationary fuel cells in fuel cell vehicles, for the Tokyo Olympic games and more. The public-private project is co-ordinated with NEDO, which provided around EUR 150 million (USD 176 million*) for the R&D of the facility. Several other stakeholders – such as Toshiba Energy Systems & Solutions Corporation (Toshiba ESS, Tohoku Electric Power Co., Inc)), Tohoku Electric Power Network Co., Inc, Iwatani Corporation and Asahi Kasei Corporation – also have individual roles and responsibilities.

*EUR 1 = USD 1.77 [as of 22 October 2021].

Source: IRENA Coalition for Action, 2021.

Japan has also introduced certificates for power generated by non-fossil fuels that do not fall under the FIT. The first auction of such Non-Fossil Certificates (NFCs) was conducted in 2018 on the Non-Fossil Value Trading Market, which facilitates the trading of the environmental value of electricity that does not emit CO_2. The prices are JPY 1.1-1.3 per kWh (Ishida, 2021), or around JPY 2 400 per tonne of CO_2 (USD 21.99 per tonne of CO_2). In the latest auction result, the prices are JPY 0.33 per kWh (FIT NFCs) and 0.6 per kWh (non-FIT NFCs). Japan has also conducted a series of auctions for FIT NFCs for renewable power generation under the FIT since 2018.

At the local level, two municipal emission trading systems are in operation in Tokyo (since 2010) and in Saitama (since 2011). Nevertheless, the burden of carbon pricing varies across regions and across households and is regressive, particularly in advanced economies (Dorband *et al.*, 2019).

Japan's sustainable investment landscape also includes a market for green bonds, which has received considerable public support in recent years. The Ministry of Environment began publishing green bond guidelines and model cases in March 2017. A year later, it launched an incentive scheme that enabled issuers to obtain a grant of up to USD 476 000 to help structure green bonds (Milburn, 2019). The successful scheme resulted in 33 issues in 2018. The Development Bank of Japan issued the country's first green bond in 2014. By the end of 2020, Japan's cumulative issuance of green bonds reached USD 10.6 billion, ranking the country seventh globally (CBI, 2021). In 2018, Japan issued USD 4.1 billion in green bonds, up 22% from 2017 and representing 42% of the total issuance to date.

IRENA's socio-economic footprint analysis includes in its modelling a very diverse set of policies to enable and support a sustainable energy transition. Holistic planning and synergistic implementation can address the multiple angles of the interactions between the energy, economy and social systems more successfully than an approach that relies on only a limited number of interventions.

Annex II: E3ME policies

The Integrated Assessment Models that have carbon pricing as the main (and often sole) policy to drive the transition are a case in point. The resulting needed carbon prices are too high to be socio-politically feasible. Since IRENA's analysis includes a diverse policy basket, the transition goals can be achieved with significantly lower carbon prices. It should be noted that with a diverse climate policy basket, the final level of carbon pricing needed to bring about an energy transition roadmap depends on the effective implementation of accompanying policies.

The IRENA socio-economic analysis assesses the following policies:

- International co-operation, supporting enabling social policies in all countries and addressing the international justice and equity dimensions.
- Domestic progressive redistributive policies.
- Carbon pricing, evolving over time with carbon prices differentiated by each country's income level and special treatment of sectors with high direct impacts on people (households and road transport).
- Fossil fuel phase-out mandates in all sectors.

- Phase-out of all fossil fuel subsidies.
- Regulations and mandates to deploy transition-related technologies and strategies, including renewables, electric vehicles, hydrogen and system integration through electrification and power-to-X.
- Mandates and programmes for energy efficiency deployment in all sectors.
- Policies to adapt organisational structures to the needs of renewable-based energy systems (such as in the power sector).
- Subsidies for transition-related technologies, including for households and road transport.
- Direct public investment and spending to support the transition, with participation in all transition-related investments, but with special focus on enabling infrastructure deployment (electric vehicle charging stations, hydrogen infrastructure, smart meters, etc.), energy efficiency deployment and policy expenditure.
- Policies to align international co-operation with transition requirements: earmarking of funds to transition-related investments, increasing social spending.
- Public involvement in addressing stranded assets challenges, both domestically and internationally.
- Policies to align government fiscal balances with transition requirements, addressing domestic distributional issues and aligning deficit spending with transition requirements.

IRENA

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