Technical Report

IGES 1.5°C Roadmap: An action plan for Japan

more ambitious emissions reduction and a prosperous, vibrant society

This report examines the feasibility of rapid and deep reductions in greenhouse gas (GHG) emissions in Japan, in order to contribute to the global goal of limiting the average temperature increase to below 1.5°C compared to pre-industrial levels. The scope covers not only how to achieve carbon neutrality by 2050, but also how to make its cumulative emissions as small as possible. The report examines pathways for Japan and proposes an action plan to realise them.

Key Messages

- **It is important to promote rapid socio-economic transformation associated with digitalisation and other drivers, in addition to the deployment of technologies that contribute to decarbonisation in energy demand and supply.** We consider scenarios that incorporate socio-economic changes such as creation of higher added value through investment in intangible assets, transformation of manufacturing industries into service industries, promotion of more efficient transportation and logistics using big data as well as automated technologies, and efficient and circular use of energy and materials. In such scenarios, the final energy consumption will decline early on, and by 2035 GHG emissions could be reduced by more than 60% compared to 2019 levels.

- **A shift to an electric power system based on renewable energy (RE) combined with promotion of energy saving and electrification of energy demand at an early stage could significantly increase energy self-sufficiency as high as about 90% while achieving significant emission reduction.** Energy saving, electrification and the expansion of RE all require strategic actions to overcome current challenges. Electrification often leads to reductions in energy costs and works in synergy with digitalisation and productivity improvement in various industries. To accelerate electrification, however, it is necessary to take measures such as providing expert knowledge and information, as well as enabling long-term capital investment so that the physical constraints of buildings, such as equipment installation space and plumbing, do not prevent these strategic actions.

- **The shift to a RE-based power system requires various efforts to ensure a balance between supply and demand, as well as efficient system operation.** Specifically, in a RE-based power system, power output can fluctuate according to natural conditions. Therefore, flexibility must be enhanced to cope with both short-term and long-term variabilities, from second-by-second and hour-by-hour fluctuations to seasonal and annual fluctuations. For this purpose, the rules for power system operation should be revised, and the entire system should be improved to enable the use of flexibility on the demand side. This could include V2G using EV batteries and various demand response systems, including water electrolysis equipment to produce domestic green hydrogen.

- **It is possible to foresee a significant expansion in the amount of RE deployment while limiting the negative impacts on the natural**

environment and local communities. RE expansion could also bring economic benefits such as job creation for local communities. A significant expansion in photovoltaic (PV) power generation is expected mainly on building rooftops, which has less impact on the landscape and ecosystems. This PV expansion will require rapid implementation of policy measures such as making it a requirement to install PV on new buildings, providing financial support to promote rooftop solar power, establishing a system that allows surplus power to be shared with other consumers, securing businesses that can select and install appropriate equipment, and promoting communication on the benefit and risks of utilising PV in local communities. In the long-term, tandem-type systems combining perovskite and silicon solar cells will contribute to generating more power output with the same space. Expansion of wind power generation can be expected mainly offshore, where the potential is large and higher capacity factor can be expected. To realise this, it will be important to quickly promote social consensus on the capacity targets and on a plan for sea area use, including coordination with users of the sea area. It is also important to expand offshore wind power as a domestic industry by developing facilities and ports for manufacturing and assembling floating structures, wind turbines and maintenance parts.

- **We found that energy supply costs could be almost equal to or lower than the current level, depending on the progressive decrease of initial investment costs for future RE, as well as on fossil fuel prices, and the costs of energy storage and hydrogen production.** Although it would depend on the allocation of costs shared with sectors other than electricity, such as mobility and hydrogen production, it is likely that, in the case of rapid and deep emission reductions, the range of future electricity cost increases will be smaller than the range of recent increases resulting from fossil fuel price hikes. The scale of investment in electric power generation and hydrogen supply facilities will average JPY 3.9 trillion/year to JPY 4.6 trillion/year from 2021 to 2050, which is much lower than the current annual fossil fuel imports (JPY 20 trillion/year to JPY 30 trillion/year).

- **It is necessary to establish rules that provide sufficient incentives to encourage major socio-economic changes and to promote the energy transition as soon as possible.** It is essential to introduce a sufficiently high level of carbon pricing to encourage changes in investment flows and consumer behaviour. In addition, the key to increasing the social acceptability of pro-decarbonisation policies is to promote a just transition of workers to business sectors with higher labour and carbon productivity. This can be done through active labour market policies and increased investment in human capital, such as vocational skills development, education and training.

- **To realise these changes, it is important to formulate policies from an integrated perspective as well as to build proactive strategies by businesses which view the transition to net zero as an opportunity for growth.** The socio-economic changes envisioned in this report encompass changes in cities, buildings, road space and land use, as well as changes in the activities of local communities, businesses and consumers. It is essential to involve a wide range of stakeholders in the policymaking process, not just those related to the energy sector. Moreover, the socio-economic changes examined in this report are rooted in a major trend toward higher productivity and a safer, more convenient and more comfortable society. Efforts to pursue the 1.5°C goal must be developed as an integrated strategy that also contributes to solving various issues faced by industry, society and infrastructure, as well as improving well-being. This report can be used as a reference for businesses to build their own strategies in light of the global trend toward decarbonisation, and as a guide to foresee when and how changes will occur in order to take advantage of the opportunities for growth during the course of further acceleration of drastic changes in the future.

Executive Summary

At the Group of Seven (G7) Ministers' Meeting on Climate, Energy and Environment held in the UK in 2021, each country confirmed its commitment to pursue the 1.5°C goal. In addition, at COP26 (the 26th Conference of the Parties to the United Nations Framework Convention on Climate Change) held in the same year, a decision was made to "resolve to pursue" the 1.5°C goal (Glasgow Climate Accord). Since then, the international community has shifted the focus of the Paris Agreement from the 2°C goal to the 1.5°C goal. In 2023, the G7 Hiroshima Leaders' Communique reaffirmed the commitment of the G7 countries including Japan to this goal. However, according to the latest report of the Intergovernmental Panel on Climate Change (IPCC), even if all currently submitted NDCs (Nationally Determined Contributions) were realised by 2030, the world would not reach the level of greenhouse gas (GHG) emission reductions necessary to achieve the 1.5°C goal. It is noted that countries need to raise their emissions reduction targets in order to achieve a 60% reduction in global GHG emissions from 2019 levels. The Paris Agreement incorporates a "ratchet-up mechanism" that allows countries to raise the level of ambition of their targets over time, and assessing progress and continuing to aim for more ambitious emission reductions is critical to achieving the long-term goals of the Paris Agreement.

This report examines the potential for rapid and deep reductions in Japan's GHG emissions. It not only considers technologies that contribute to decarbonisation in energy demand and supply, but also conducts a multifaceted examination of socio-economic changes associated with digitalisation and other drivers.

First, we developed multiple scenarios with different assumptions on the amount of countermeasure technology introduced and the range of socio-economic change. We then estimated cumulative GHG emissions from 2020 to 2050 and compared these scenarios (Chapters 2-5). The scenarios developed are: (1) "Technology-Driven Transformation Scenario," in which the maximum amount of technology (such as renewable energy (RE) and imported hydrogen) is introduced; (2) "Social Transformation Scenario," in which significant socio-economic changes occur in a way that contributes to decarbonisation, and technology introduction is more gradual; and (3) "Balanced Scenario," in which both socio-economic changes and technology introduction are moderate. In addition, based on information disclosed by the Japanese government in sector-specific roadmaps for the promotion of transition finance and other documents, we developed (4) "Government Target Scenario". Energy and electricity demand were estimated based on socio-economic assumptions and the amount of countermeasure technology introduced in each scenario (Chapter 3). Following this, we examined power source composition, electric power system, and the amount of imported hydrogen, and conducted simulations for electric power networks and domestic hydrogen production (Chapter 4). Based on the results, key indicators such as GHG emissions, energy self-sufficiency and electricity costs were estimated (Chapter 5).

For socio-economic changes, we assumed multifaceted changes such as the shift to high value-added through increased investment in intangible assets, the transformation of manufacturing industries into service industries, the rationalisation of labour flow and logistics through the use of big data and automated driving technology, and efficient and circular energy and material use. By projecting these assumptions onto an Input-Output table and other tools, we created a picture of the future social economy in a way that was as consistent and quantitative as possible. Regarding the simulation of electric power networks, we also considered measures to ensure a stable supply by examining an hourly supply-demand balance at 450 points nationwide, taking into account the constraints of transmission lines and other factors.

Next, we formulated key milestones that indicate what assumptions need to be realised and when, in order to attain the Balanced Scenario. We then summarised the action plans of specific policies and the behavioural changes necessary to achieve those milestones (Chapter 6). We presented the results of these analyses to stakeholders in the business community, as they are the ones expected to take actions in the real world. We then revised the scenarios based on their feedback. This iterative process was taken to ensure that the scenarios and action plans were based on views and practical knowledge from diverse perspectives, and also to make them transparent and more acceptable to stakeholders.

As a result of the scenario analysis, it became clear that socio-economic changes, such as digitalisation, could have a non-negligible impact on the decrease in final energy consumption. Figure ES-1 shows the difference in final energy consumption between the current level (2015-2019 average) and the 2050 level under the Balanced Scenario, broken down by factors. Even though socio-economic changes in the Balanced Scenario are set at a moderate level between the Social Transformation Scenario and the Technology-driven Transformation Scenario, about 16% of the 47% reduction in final energy consumption is the result of initiatives such as digitalisation and changes in material use by stakeholders.

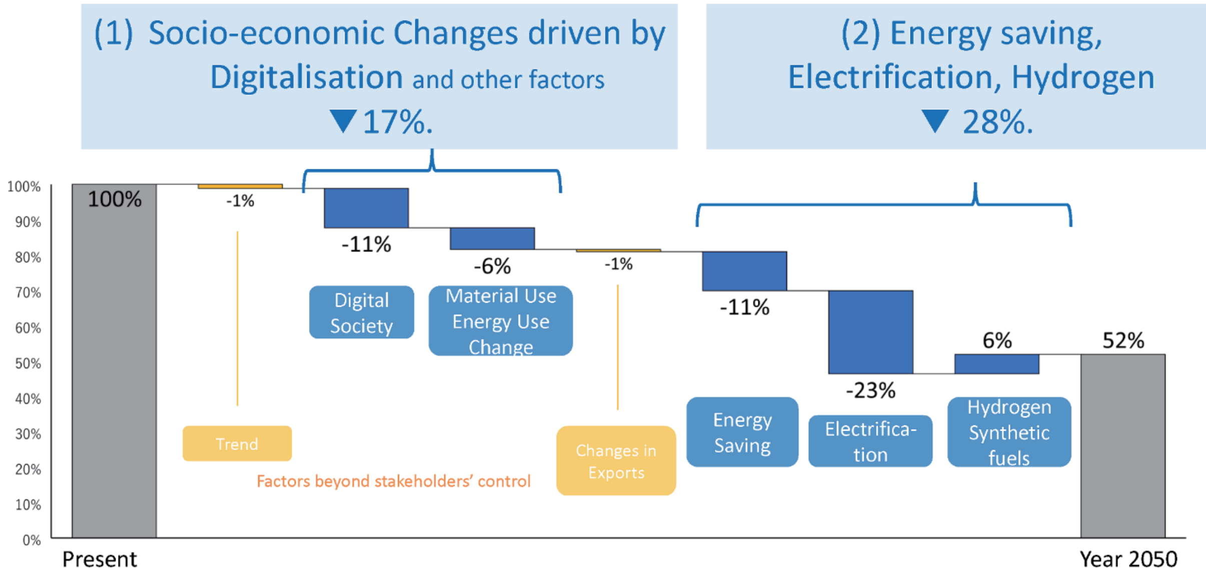

Figure ES-1. Breakdown of Final Energy Consumption reduction in the Balanced Scenario in 2050.

We also found that early GHG emission reductions can be achieved by assuming socio-economic changes. Benchmarks for cumulative GHG and CO_2 emissions in Japan from 2020 to 2050 were set based on the global emission pathway for limiting temperature increase to within 1.5°C, a they were compared with the cumulative GHG emission estimates of each scenario (Figure ES-2). As a result, only the Social Transformation Scenario and the Balanced Scenario remained below the cumulative emissions set as benchmarks while limiting the risk of reliance on negative emission technologies and CCS (Carbon Capture and Storage). Both scenarios assume socio-economic changes, although to different degrees. The changes in production processes, industrial structures and lifestyles, originating from digital technology, will reduce final energy consumption from an early stage and, as a result, fossil fuel use in the 2030s can also be reduced, thus achieving early GHG emission reductions.

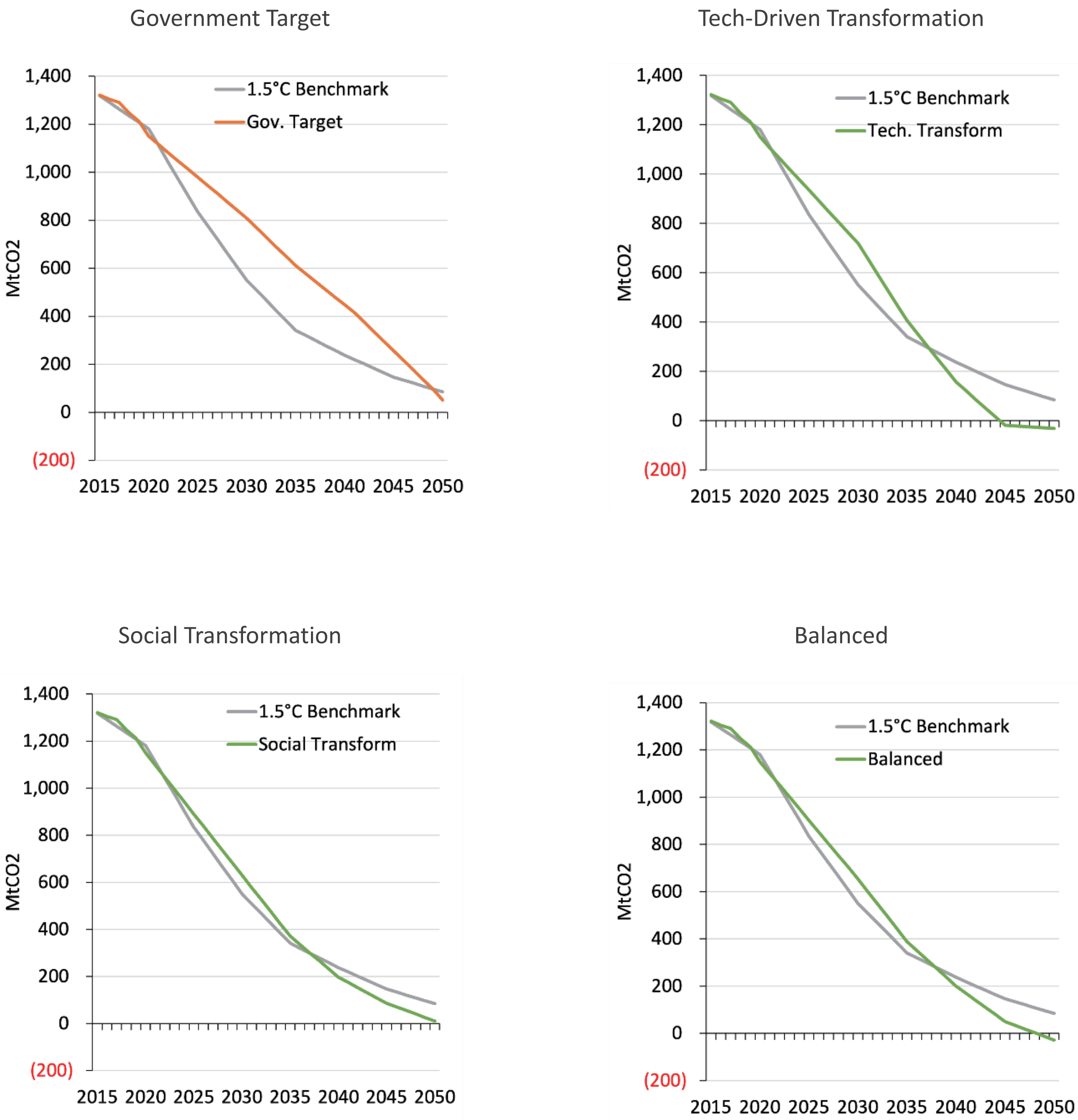

Figure ES-2. A comparison between GHG emission changes in four scenarios and a benchmark.

Furthermore, if the expansion of RE (mainly rooftop solar power and offshore wind power) is started as early as possible, and at the same time, if the electricity system and demand-side facilities are improved so that electricity from RE can be used effectively and the variability of RE can be addressed, we found that energy self-sufficiency of 40% by 2040 and nearly 90% by around 2050 can be achieved.

As a countermeasure to the variability of RE, we examined the development of a system that utilises various flexibilities, including hydrogen-fired thermal power plants that refurbish gas-fired power plants, a hydrogen production facility using RE, V2G using EV storage batteries, and grid-forming technology. As a result, electric power network simulations showed that a supply-demand balance could be established at each point and at each hour. In addition, the cost of electricity was examined. We found that even if variable RE becomes the main source of power, as long as there is investment in facilities to increase flexibility, energy prices could be at a lower level than at present (Figure ES-3). In this case, the average investment amount for the period 2021-2050 would be JPY 3.9 trillion/year to JPY 4.6 trillion/year, which is much lower than the current annual fossil fuel imports (JPY 20 to 30 trillion/year). The key to achieving the energy system envisioned in the Balanced Scenario is working out how to direct the funds and overseas investments that Japan currently spends on fossil fuel imports toward domestic investments in RE development, and how to develop the market environment for this purpose.

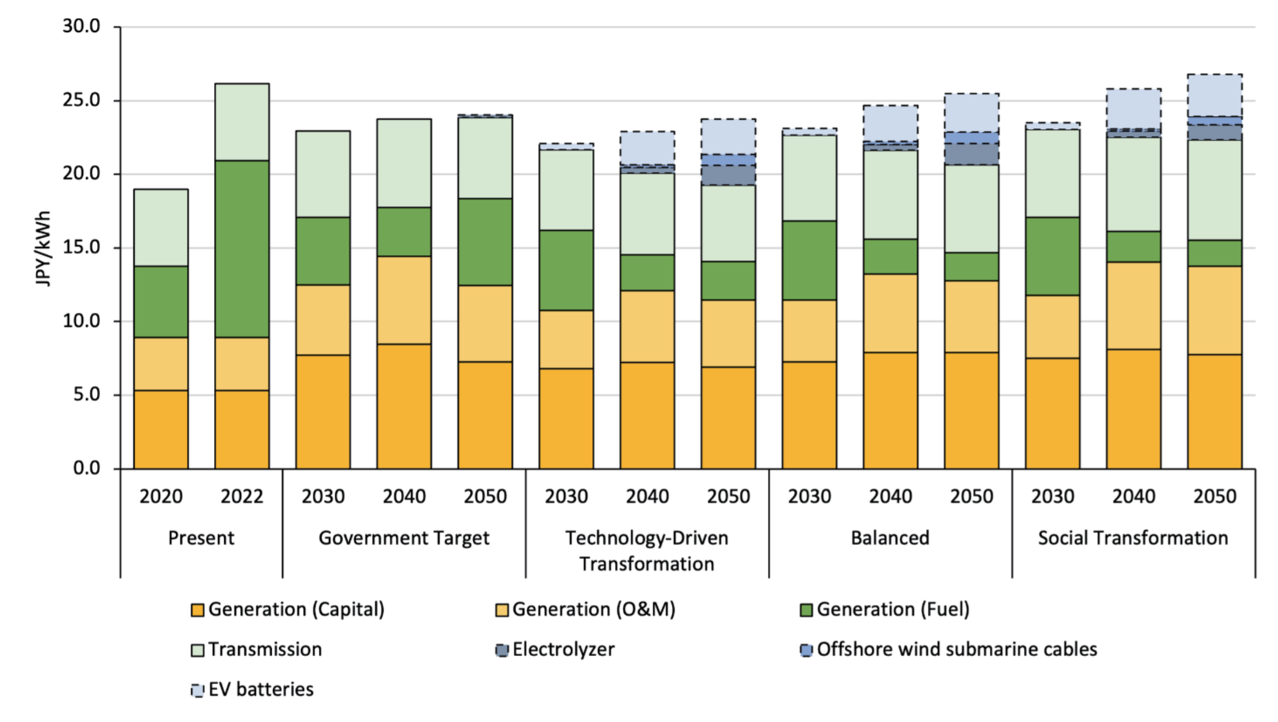

Figure ES-3. Electric power cost estimates in 2030, 40, 50 for the four scenarios considered, compared with those in 2020 and 2022.

Note: shaded areas are shared costs between electricity and other sectors, a part of which may be included in electricity cost

Milestones and action plans have been summarised (Chapter 6, Figure ES-4) to achieve the path outlined in the Balanced Scenario. An overview is provided below.

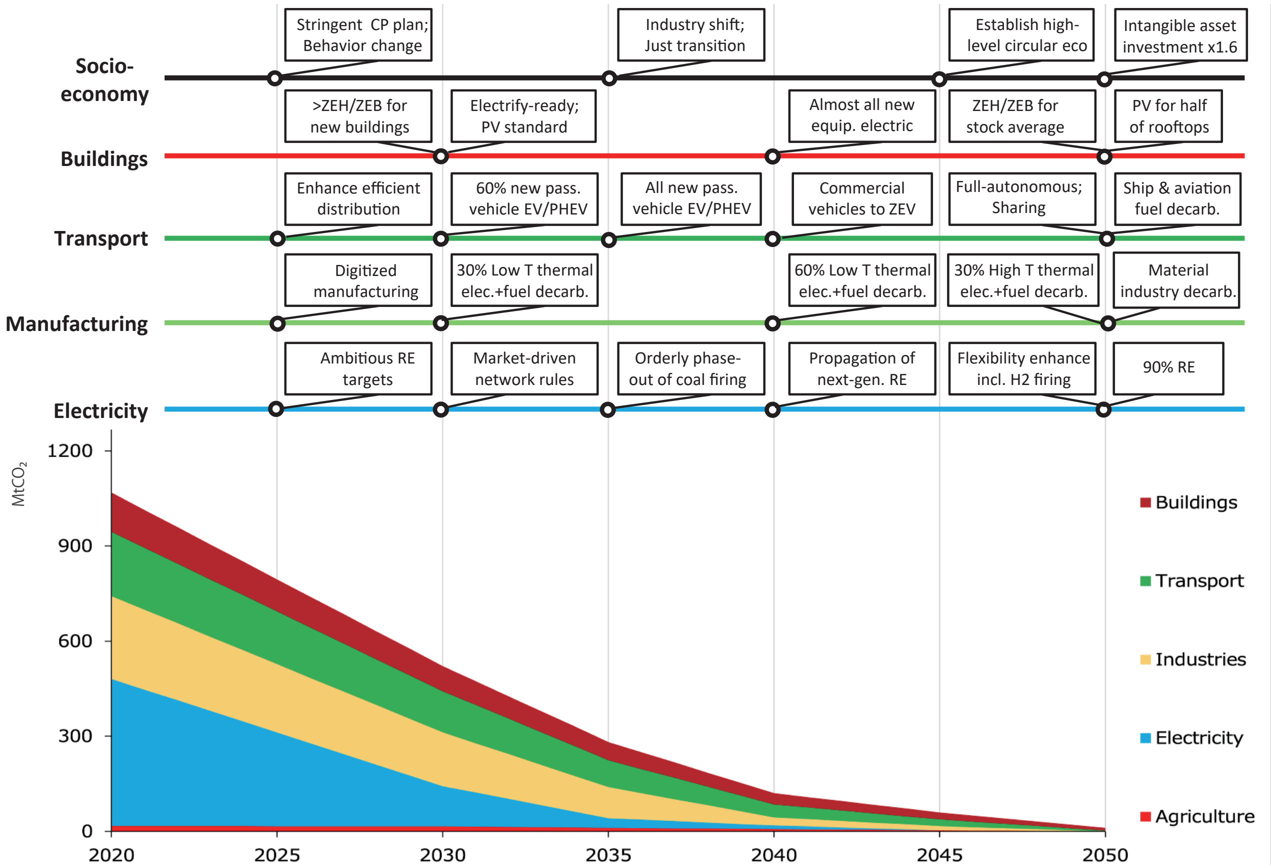

Figure ES-4. Changes of energy-originated CO_2 emissions from sectors until 2050 in the 1.5°C roadmap (the Balanced Scenario) and major milestones

- **Socio-economic changes**: Strategies must be developed and implemented to promote productivity and value-added growth while accelerating decarbonisation, including digitalisation and changes in materials use. Carbon pricing that induces sufficient incentives needs to be introduced around 2025, thereby effectively promoting behavioural changes and industrial restructuring over society as a whole. At the same time, active labour market policies such as increased investment in human capital and unemployment benefits should be enhanced while socio-economic changes take place to prevent further inequality and disparity as the economy changes. It would be desirable to promote a shift to industries with high labour productivity and carbon productivity in a socially acceptable manner by creating an environment in which everyone can actively take risks.

- **Development of buildings, infrastructure and facilities**: It is reasonable to implement a transition to ZEB/ZEH and EV charging infrastructure development when buildings and facilities are renewed. In cases when immediate, full-scale installation of relevant facilities is difficult, it is important to proceed with ZEB/ZEH-ready, electrification-ready, and IoT-ready facilities. Similarly, the industrial sector will need a medium- to long-term plan so that decarbonisation technologies can be sequentially and smoothly incorporated when investment is made for equipment renewal. The transportation sector faces challenges such as solving labour shortages and mobility issues for the elderly, but there are also expected changes in mobility demand due to advances in automated driving technology and the development of online and virtual space technology. Efficient measures should be considered with a medium- to long-term outlook for human flow and logistics based on these changes.

- **Electricity**: In order to expand RE, it is imperative to develop rules for refining operations of the power grid which forms the foundation of the power system. Such rules, which should be developed by around 2030, should increase the stability and predictability of RE businesses and will greatly contribute to the promotion of RE investment by the private sector. The development of grid operation rules will also contribute to stabilising the grid system itself by ensuring flexibility through the use of various resources such as V2G and demand response. In addition, it is necessary to provide clear signals regarding RE that is eligible for investment. Studies in this report show that two electricity power sources will be at the centre of RE deployment, namely roof-mounted solar PV utilising new technologies such as perovskite solar cells, and floating offshore wind power. For floating offshore wind power generation, it will be important to develop manufacturing / assembly infrastructure including making use of shipyards and decommissioned facilities such as fossil-fuel power plants throughout 2030s. Therefore, the government should promptly develop and articulate a long-term strategy which would encourage the private sector to develop business in this area.

- **Hydrogen**: To achieve carbon neutrality, it is necessary to use hydrogen in areas where electrification is difficult. For example, the steel and chemical industries could use hydrogen to achieve decarbonisation, and thus hydrogen supply chains should be established around related plants by around 2040.

Many of these actions could be initiated by a single company, but in order to scale up the actions and develop enhanced synergy, it is vital that various sectors, companies and other entities should form collaborative projects to take advantage of each other’s strengths. Each entity should create medium- to long-term strategies from a cross-sectoral and integrated perspective, rather than sticking to a conventional, sector-optimised approach.

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