LONG-TERM SCENARIOS FOR DECARBONIZING JAPAN

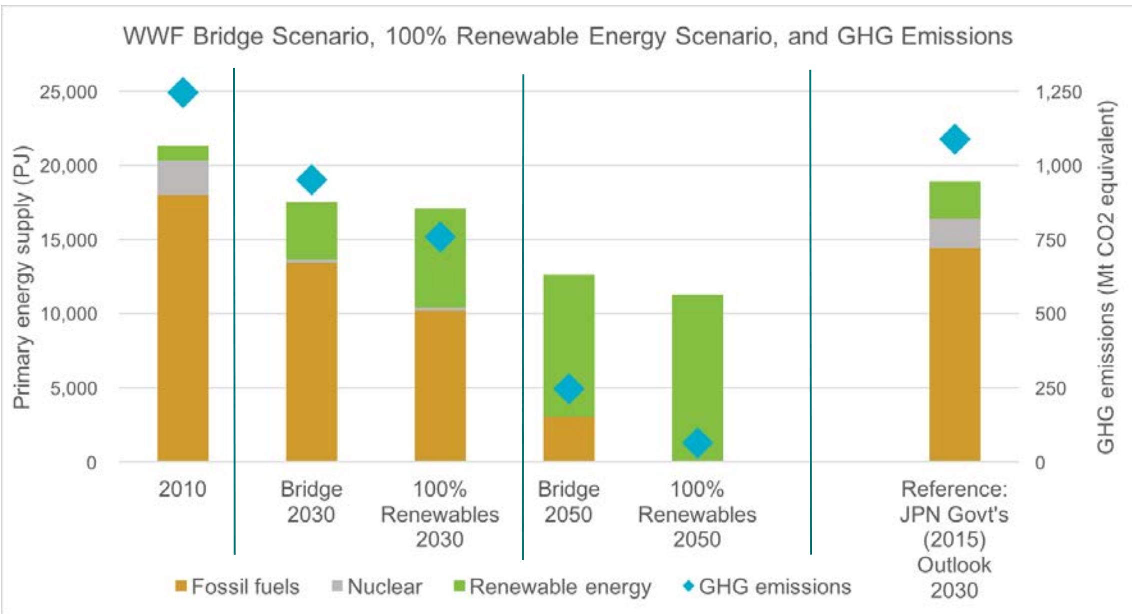
Executive Summary

WWF Japan (Feb 2017)

KEY POINTS

WWF Japan analyzed long-term scenarios for energy and the potential for greenhouse gas emission reductions, based on an assumption that Japan would be a forerunner among countries to achieve decarbonization as called for under the Paris Agreement. Specifically, the following two WWF scenarios were considered.

- **100% Renewable Energy Scenario:** This scenario assumes that in 2050, all of Japan's energy is supplied by renewable energy sources.
- **Bridge Scenario:** This scenario assumes that the government's official target of an 80% reduction in greenhouse gas emissions by the year 2050 is achieved. This is called the "Bridge Scenario" to reflect its role as a bridge to the 100% renewable energy scenario.



	2030		2050		2030
	Bridge	100% renewables	Bridge	100% renewables	Govt's 2015 long-term supply-demand outlook
Energy efficiency (reduction of FEC, compared to 2010)	16%	21%	39%	47%	14%
Renewable energy (share of primary energy)	22%	39%	74%	100%	13–14%
GHG emission reduction (compared to 2010) [compared to 2013]	26% [32%]	42% [46%]	81% [82%]	95% [95%]	20% [26%]

Results of the analysis for the **100% Renewable Energy Scenario** can be summarized as follows.

- Japan's final energy consumption (i.e., demand) can be reduced to about half by 2050 (47% reduction below 2010 level), based on currently-foreseeable penetration and advances in energy efficiency technologies and measures. This is certainly not an unrealistic scenario. For example, for energy efficiency in major industries in the industrial sector, the scenario assumes efficiency improvements of 20% to 30% over approximately the next 40 years to 2050. All housing and at least 40% of buildings are assumed to at least meet today's latest energy efficiency standards. And it is assumed that all vehicles will shift to electric and fuel-cell vehicles (EVs and FCVs), which are already starting to become more popular.
- The above-mentioned energy demand in 2050 is within the realm of Japan's potential supply of renewable energy. If the share of renewable energy is assumed to follow a straight-line increase to 100% of the energy mix in 2050, then in 2030, renewable energy must supply 37% of electricity (share of "pure" electricity demand; details below), and 39% of the primary energy supply.
- Renewable energy supplies (especially wind power and photovoltaic) are sometimes said to be difficult to match with electricity demand, due to power output fluctuations. However, the simulation conducted in this scenario study indicates that 100% of demand in 2050 could be continuously met with renewable energy sources, 365 days a year. To do so, however, a unified national electricity grid would be essential, and a two-to-one ratio of photovoltaic to wind power generation would be desirable.
- Considering the big picture for energy, the supply of renewable energy to meet electricity demand is theoretically not a major issue. Rather, the challenge is finding how to meet demand for heat energy and fuels. For this challenge, the keys will be to significantly expand the use of biomass, to use surplus electricity to produce hydrogen, and to utilize that hydrogen.
- Achieving this scenario will require capital expenditures (CapEx) of 365 trillion JPY (3.3 trillion USD) over approximately 40 years (2010 to 2050), but this would be offset by a reduction (i.e., savings) in operating expenditures (OpEx) amounting to 449 trillion JPY (4.1 trillion USD), which means a net savings (Net) of 84 trillion JPY (0.8 trillion USD).
- In 2050, CO_2 emissions from energy will ultimately become zero, and greenhouse gas emissions will have decreased by 95%.

The **Bridge Scenario** envisions a somewhat delayed achievement of the 100% Renewable Energy Scenario. Energy efficiency goals are achieved with a delay of about five years, and the renewable energy supply goals with a delay of about ten years. The basic features of this scenario can be summarized as follows.

- The penetration of energy efficiency technologies and measures results approximately in a 40% reduction in energy consumption in 2050 compared to 2010.
- In 2050, renewable energy provides approximately 74% of the primary energy supply, and about 90% of electricity ("pure" electricity basis; details below). In 2030, it provides about 22% of the primary energy supply and about 37% of electricity.
- In 2050, of the "remaining 20%" of emissions from fossil fuels, coal is used for blast furnace steel production and oil is used for heat demand in various industries including chemical production, and for aviation fuel, while gas supplies heat demand in the household and commercial sectors.
- Achieving this scenario will require capital expenditures (CapEx) of 296 trillion JPY (2.7 trillion USD) over approximately 40 years (2010 to 2050), but this would be offset by a reduction (i.e., savings) in operating expenditures (OpEx) amounting to 392 trillion JPY (3.6 trillion USD), which means a net savings (Net) of 96 trillion JPY (0.9 trillion USD).

Assumptions and methodology

The list below summarizes the assumptions and analytical steps used in both WWF scenarios.

1. Assume significant reductions in energy demand through energy efficiency, based on assumptions about currently-foreseeable advances in technologies and measures.
2. Assume the gradual phase-out of nuclear power.
3. Consider how demand can be met, based on consideration of the potential available for each type of renewable energy sources.
4. Separately, use Dynamic Simulation based on meteorological and other data to see whether renewable energy and other sources can supply fluctuating power demands 24 hours a day, 365 days a year, in 2050.
5. Assume the gradual phase-out of fossil fuels based on the progress described above.

One major difference between the WWF scenario and other similar energy scenarios is the approach to using renewable energy. The WWF scenario envisions not only supplying all electricity with renewable energy sources in the future, but besides electricity, also meeting demand for heat and fuels by using hydrogen produced with surplus electricity (it also assumes to meet demand for heat and fuels with biomass, solar heat, and other sources). This approach also makes it possible to resolve the issue of surplus electricity from fluctuating renewable sources, and at the same time to meet demand for heat and fuels.

Energy demand: How much can energy efficiency reduce?

Steps to consider the potential for energy efficiency

The WWF scenarios consider the potential for improvements in energy efficiency, based on the following steps.

1. Determine typical energy efficiency measures and technologies in each sector (i.e., industrial, households, commercial, transport), and consider the pace of energy efficiency improvements (e.g., improved performance and large-scale deployment of LED lighting).
2. Calculate energy demand based on the contribution of each technology and measure to energy consumption reduction, by sector and by use (e.g., by sector—household; by use—lighting, hot water supply). (For activity levels, individual assumptions are specified separately; e.g., using ratio of population to calculate number of vehicles). The following equation is used:

   Final energy demand (by use) in year T

   = 2010 final energy demand (by sector and by use) x
   Change in activity level from 2010 (by sector) in year T x
   Pace of improvement in energy efficiency in year T

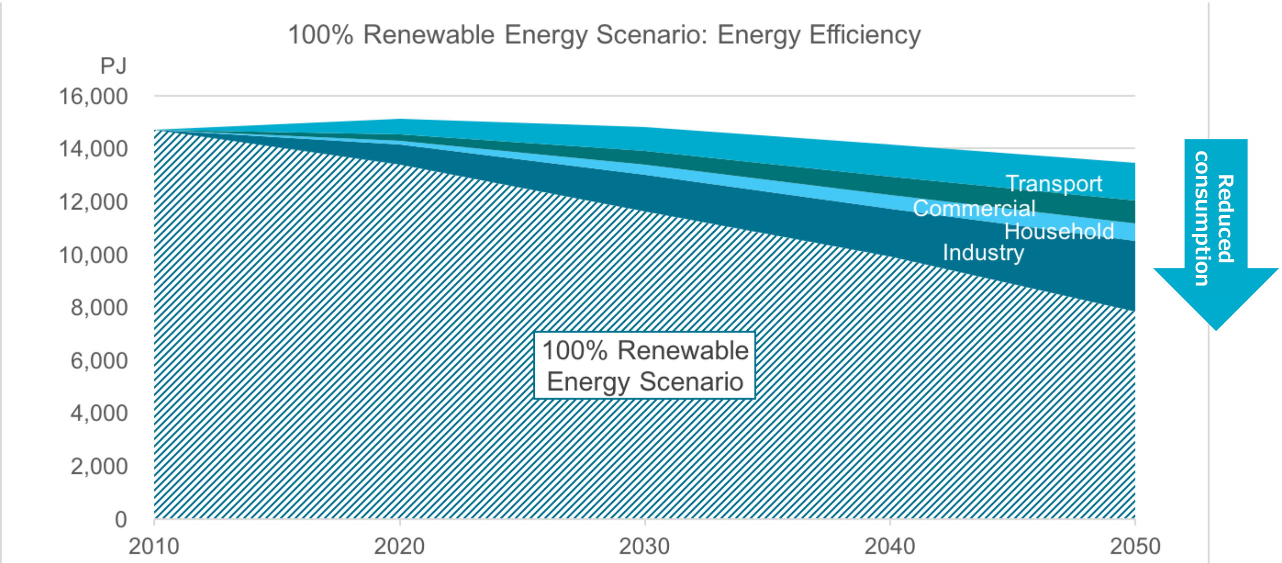
3. Add up energy consumption in all sectors and categories to produce the total energy consumption.

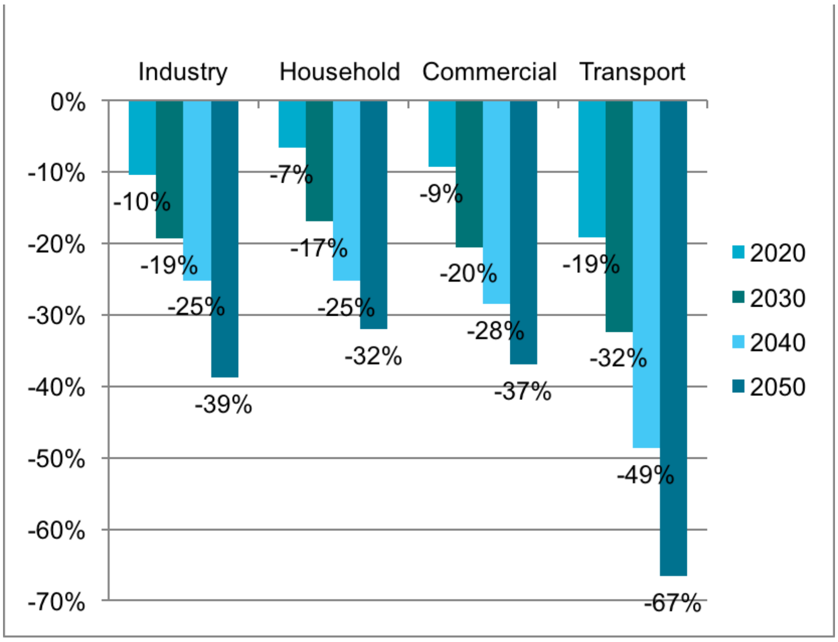
Results: The potential for energy efficiency

For the society-wide activity levels, the scenarios make assumptions that trends, such as a population decline to 76% of the 2010 level and a shift toward sustainable society, lead to a 20% reduction in activity level for resource consumption compared to 2010. Accordingly, as in many other energy scenarios, the energy consumption decreases even in the business as usual (BAU) case to 2050.

Under the WWF scenarios, with energy efficiency increased by additional 20–30%, a reduction in energy demand as outlined below is possible (Assumptions for technologies and measures in specific sectors are described further below).

Under the **100% Renewable Energy Scenario**, it is possible to reduce energy consumption in 2050 by 47% compared to 2010, and by 42% compared to the business as usual case (based on final energy consumption). In terms of amount, the industrial sector will have the largest reduction, but in terms of percentage, the transport sector will be the largest. The following two graphs show the reduction amount and percent from the BAU scenario.





Under the **Bridge Scenario**, improvements in energy efficiency reduces energy consumption in 2050 by 39% compared to 2010, and by 34% compared to the BAU scenario (based on final energy consumption). As in the 100% Renewable Energy Scenario, the largest reduction is in the industrial sector, but in terms of percentage, the reduction in the transport sector is the largest. Compared to the 100% renewable scenario, the annual rate of improvement in energy intensity (final energy consumption per unit of real GDP) is slightly lower (2.6% for the 100% Renewable Energy Scenario versus 2.3% for the Bridge Scenario). This is about the same level as Japan's actual rate of improvement in the past (1970 to 1990) at 2.3%. In addition, with population decline and other factors, even in the BAU scenario during the same period, the average annual rate of improvement in energy intensity is 1.3%, so if we take Japan's energy efficiency potential into account, the Bridge Scenario would be quite achievable.

Key energy efficiency measures and technologies

The WWF scenarios envision energy efficiency technologies and measures like the ones indicated below. The scenarios are based on factors such as the currently-foreseeable penetration of technologies, and can be fully achieved even without excessive reliance on innovative technologies.

Sector	Examples of technologies and measures
Industry	Inverter controls on pumps, inverter controls on fans, iron/steel recycling
Household	Promotion of zero energy houses (ZEH), heat pumps, and LED lighting, more efficient electric refrigerators, reduced standby energy consumption
Commercial	Promotion of zero energy buildings (ZEB), replacement of hard-disk storage in data centers with flash memory
Transport	Promotion of eco-friendly driving, car sharing, electric vehicles (EV), and fuel cell vehicles (FCV)

ENERGY SUPPLY: MOVING TOWARD 100% RENEWABLE ENERGY

For renewable energies, based on a study by Japan’s Ministry of the Environment regarding their potentials, certain constraints are applied for the actual amount of renewable energies utilized, with consideration given to their sustainability.

For this scenario, "renewable energy" is defined to include, among other types, hydroelectric (of which only small and medium hydro is expected to increase), photovoltaic, wind power, geothermal, biomass (heat and electricity), wave power, and solar heat.

Electricity supply

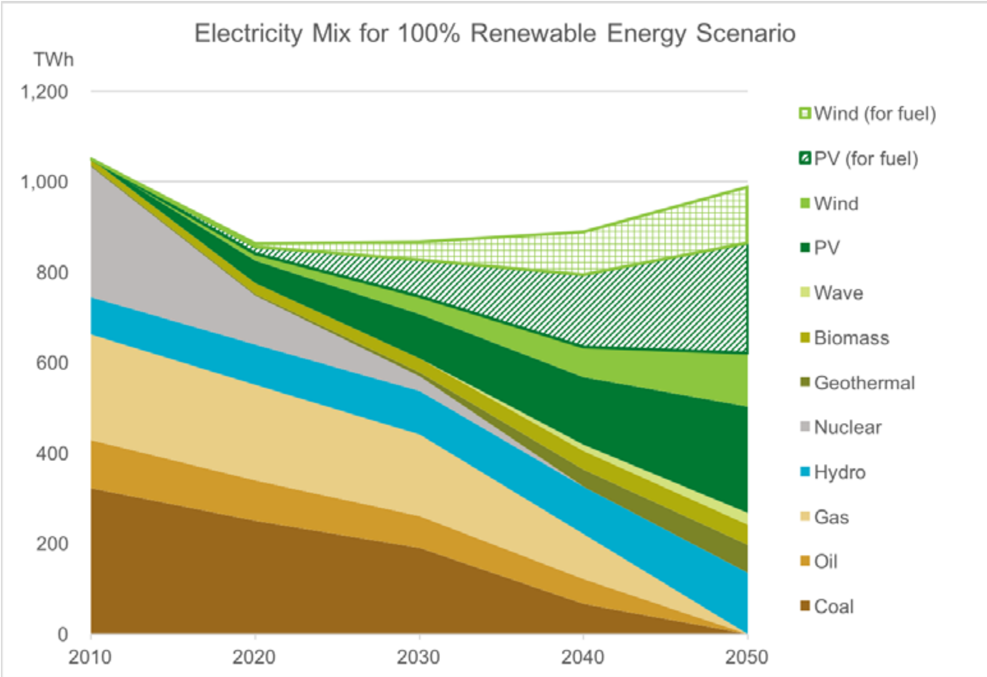
For electricity, since photovoltaic and wind power have large future potential, their shares are assumed to increase. In order to supply electricity continuously 365 days a year, the simulation shows that a desirable proportion of photovoltaic to wind power would be approximately two to one. Thus, the WWF scenarios assume that same proportion in the supply in 2050.

Also, the WWF scenarios assume that a portion of heat and fuel demand is supplied by electricity from renewable energy sources. There are two approaches for this. One is to use electricity to replace heat and fuel demand, which until now has largely been supplied by sources such as gasoline and gas. Examples include electric vehicles and air conditioning by heat pumps.

Another approach is to use electricity to produce hydrogen, and then meet demand for heat and fuel (including fuel cell vehicles) using that hydrogen. It is assumed that all surplus electricity is used to produce and store hydrogen, so that the fluctuating electricity supply from renewable sources can be utilized effectively, even during time slots when the amount of electricity generated exceeds demand. This strategy has enormous merits in terms of electricity grid operations.

The following graph shows the electricity supply under the **100% Renewable Energy Scenario**. It includes electricity for the production of hydrogen for fuel use, as described above. Toward 2050, "pure" electricity demand declines by about 40% from 2010 due to factors such as population decline and improved energy efficiency, but electricity generation itself is maintained at about the same level as today if the proportion of electricity used to provide heat and fuel is included. At the midpoint in 2030, the renewable energy share is approximately 37% of "pure" electricity, and approximately 45% of electricity supply if we include generation for heat and fuel uses. Photovoltaic and wind power are major sources in that mix.

The **Bridge Scenario** assumes some gas use remaining even in 2050. Specifically, gas is assumed to supply 8% of electricity including for heat and fuel uses, and 10% of "pure" electricity. The reason to use gas (as opposed to oil and coal) in this scenario is that it emits less CO_2 to obtain the same amount of electricity, and can also respond flexibly to fluctuations in renewable energy supply. However, conversely, even in the Bridge Scenario, there is a need to decarbonize approximately 90% of the electricity supply in 2050. At the midpoint in 2030, the renewable energy share is approximately 37% of "pure" electricity, and approximately 43% of electricity supply if generation for heat and fuel uses is included.

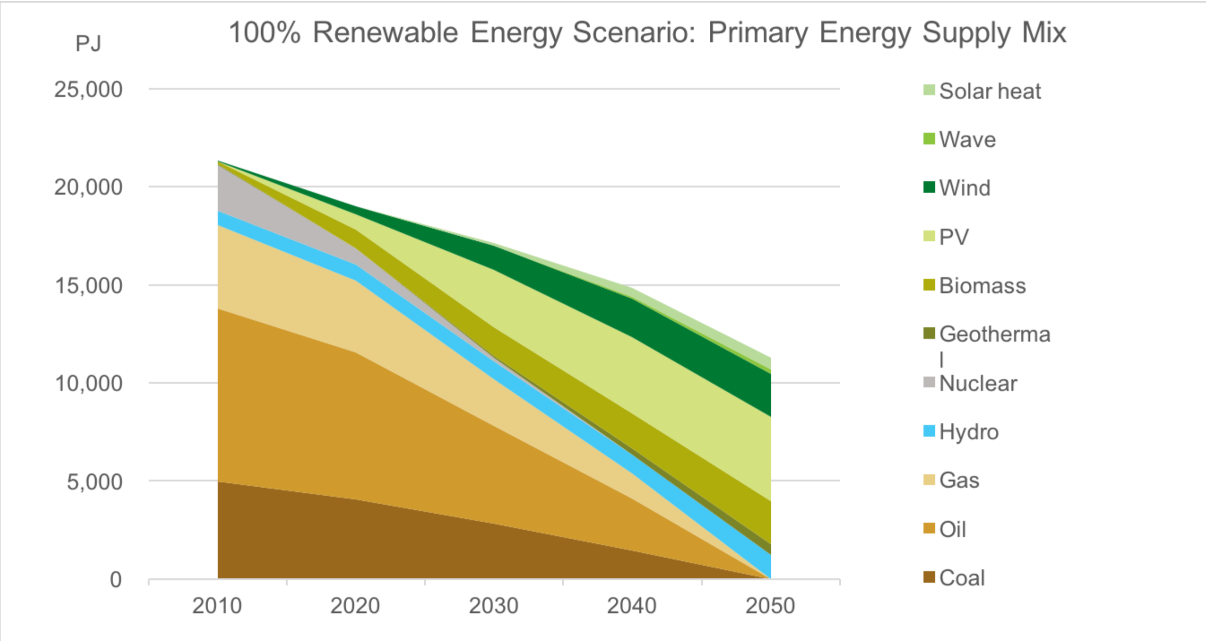


	Electricity generation (TWh)					Share ("pure" electricity)		Share (incl. heat & fuel uses)	
	2010	2020	2030	2040	2050	2030	2050	2030	2050
Coal	322	250	190	66	0	25%	0%	22%	0%
Oil	107	90	70	55	0	9%	0%	8%	0%
Gas	233	210	180	100	0	24%	0%	21%	0%
Hydro	83	90	97	105	135	13%	22%	11%	14%
Nuclear	288	108	33	0	0	4%	0%	4%	0%
Geothermal	3	4	7	37	61	1%	10%	1%	6%
Biomass	15	23	32	42	45	4%	7%	4%	5%
PV	0	50	98	150	235	13%	38%	11%	24%
Wind	0	16	40	66	118	5%	19%	5%	12%
Wave	0	0	0	13	26	0%	4%	0%	3%
"Pure" electricity total	1,051	840	747	635	621	100%	100%	86%	63%
PV for heat & fuel	0	15	80	160	245			9%	25%
Wind for heat & fuel	0	8	40	95	122			5%	12%
Total electricity, incl. heat & fuel uses	1,051	863	867	889	988			100%	100%
Renewable energy total ("pure" electricity)	101	182	274	414	621	37%	100%		
Renewable energy total (incl. heat & fuel uses)	101	205	394	668	988			45%	100%

Primary energy supply

In the **100% Renewable Energy Scenario**, just as in the case in which only electricity is considered, the proportion of wind power and photovoltaic generation increases, but to respond to heat and fuel demand, the role of biomass increases (to approximately 20% of total energy in 2050). In addition to biomass and solar heat, it is also assumed that hydrogen produced by photovoltaic and wind power is utilized. At the midpoint in 2030, renewable energy has a 39% share of the total.

For the **Bridge Scenario**, coal is used for blast furnace steel production, oil for thermal heat demand in various industries including chemical production and for aviation fuel, while gas supplies heat demand in the household and commercial sectors. As a result, in 2050, renewable energy has a 74% share, while, coal, oil, and gas still have a 6%, 8%, and 12% share, respectively. At the midpoint in 2030, renewable energy has a 22% share of the total energy supply.



	Primary energy supply (PJ)					Share	
	2010	2020	2030	2040	2050	2030	2050
Coal	4,981	4,076	2,814	1,443	0	16%	0%
Oil	8,819	7,474	5,009	2,657	0	29%	0%
Gas	4,243	3,682	2,380	1,278	0	14%	0%
Hydro	747	810	873	949	1,215	5%	11%
Nuclear	2,322	801	207	0	0	1%	0%
Geothermal	28	33	66	331	552	0%	5%
Biomass	153	938	1,500	1,778	2,200	9%	19%
PV	20	794	2,890	3,900	4,316	17%	38%
Wind	29	397	1,260	1,946	2,167	7%	19%
Wave	0	0	2	118	237	0%	2%
Solar heat	0	20	120	444	600	1%	5%
Total	22,157	19,025	17,122	14,844	11,287		
Total renewables	976	2,992	6,711	9,466	11,287	39%	100%

Costs

In the **100% Renewable Energy Scenario**, total capital expenditures over the 40 years from 2010 to 2050 come to 191 trillion JPY [1.7 trillion USD when 1USD=110JPY] for energy efficiency and 174 trillion JPY [1.6 trillion USD] for renewable energy, totaling 365 trillion JPY [3.3 trillion USD]. However, the promotion of energy efficiency and expansion of renewable energy end up limiting fossil fuel consumptions, resulting in a significant decline in facility operating costs, which, in turn, generates savings. The amount of savings comes to 281 trillion JPY [-2.6 trillion USD] for energy efficiency and 168 trillion JPY [-1.5 trillion USD] for renewable energy, totaling 449 trillion JPY [-4.1 trillion USD]. Thus, the net cost over 40 years comes to a total of minus 84 trillion JPY [-0.8 trillion USD]. In other words, this is a net benefit of 84 trillion JPY [-0.8 trillion USD].

The **Bridge Scenario** is similar. Total capital expenditures over the 40 years from 2010 to 2050 come to 156 trillion JPY [1.4 trillion USD] for energy efficiency and 143 trillion JPY [1.3 trillion USD] for renewable energy, totaling 299 trillion JPY [2.7 trillion USD]. Cost savings from the promotion of energy efficiency and expansion of renewable energy come to 242 trillion JPY [-2.2 trillion USD] for energy efficiency and 146 trillion JPY [-1.3 trillion USD] for renewable energy, totaling 388 trillion JPY [-3.6 trillion USD]. The net cost over 40 years comes to a total of minus 90 trillion JPY [-0.8 trillion USD]. In other words, this is a net benefit of 90 trillion JPY [-0.8 trillion USD].

These calculations were based on a period of 40 years to estimate investment and returns, but in the real world of capital investment, it is rare to see investments planned over such a long time period. Thus, it will be important to introduce policies that offer incentives to encourage investment and produce these kinds of benefits in the long term.

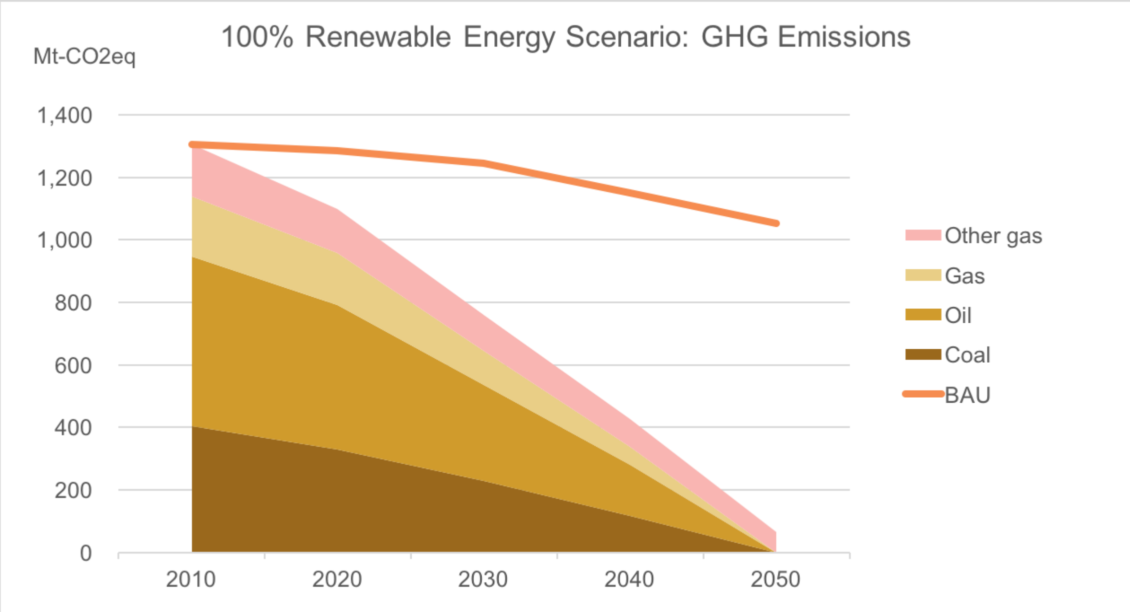
Expenditures (trillion JPY) [trillion USD; 1USD=110JPY]	100% Renewable Energy Scenario			Bridge Scenario		
	Capital	Operating	Net	Capital	Operating	Net
Energy efficiency	191 [1.7]	-281 [-2.6]	-90 [-0.8]	156 [1.4]	-242 [-2.2]	-86 [-0.8]
Renewable energy	174 [1.6]	-168 [-1.5]	+5.9 [+0.05]	143 [1.3]	-146 [-1.3	-3.5 [-0.03]
Total	365 [3.3]	-449 [-4.1]	-84 [-0.8]	299 [2.7]	-388 [-3.5]	-90 [-0.8]

* Some numbers don't add up due to rounding.”

GHG emissions

Under the 100% Renewable Energy Scenario, unsurprisingly, energy-related CO_2 emissions drop to zero. With other non-CO2 gases considered, greenhouse gas emissions ultimately decline by approximately 95% in 2050. At interim points in 2020 and 2030, for the **100% Renewable Energy Scenario**, the reductions compared to 2010 are approximately 16% and 42%, respectively (or approximately 14% and 40% compared to 1990, or 22% and 46 compared to 2013).

Under the **Bridge Scenario**, in 2020 and 2030, the reductions compared to 2010 are approximately 7% and 26%, respectively (or approximately 4% and 24% compared to 1990, or 14% and 32% compared to 2013).



Long-term strategy for a "decarbonized society" in Japan

To achieve the 100% Renewable Energy Scenario or the Bridge Scenario, certain assumptions are made for the calculations. Conversely, one could say that these assumptions must be achieved in order to realize the scenarios. Below is a selection of the most important assumptions.

In this report, the Bridge Scenario is presented as a scenario on the path to achieve the 100% Renewable Energy Scenario; thus, essentially, there are no major differences in the criteria to achieve either one. In fact, supplying 100% of electricity from renewable energy sources is an extension of technologies that already exist, so realization of this goal is entirely within the realm of possibility. However, some prospects are still not fully known, such as the potential to fully use renewable energy for heat and fuels, as well as certain industrial processes such as iron- and steelmaking. In this regard, the Bridge Scenario has shown that an 80% reduction in 2050 at the latest is entirely achievable, as it still includes the use of gas in the electricity sector, and permits gas, oil, and coal in sectors where it is currently difficult to find alternatives. Nevertheless, for the long-term planning to 2050, it is necessary to present an ambitious vision such as the 100% Renewable Energy Scenario to accelerate processes to achieve decarbonization.

Below is a set of some major conditions to be achieved, considering the assumptions used to create the scenarios.

Energy efficiency

- **Promotion of energy efficiency for housing and buildings (e.g., ZEH, ZEB):** By 2050, nearly all housing and about 40% of buildings other than housing meet today's latest energy efficiency standards.
- **More efficient industry and promotion of metal recycling:** Material manufacturing industries aim to increase efficiency by 20–30% over approximately 40 years from 2010 to 2050. Also, iron and steel industries, the largest emission sources in the industrial sector, aim to increase the proportion of electric furnaces being used with a target of approximately 70% and contribute to emission reductions.
- **Accelerated penetration of EVs and FCVs:** By 2050, nearly all vehicles are electric vehicles or fuel-cell vehicles. This requires more than half of vehicles operating in the 2030s to be EVs or FCVs.

Renewable energy

- **Reform of power grid operations:** Reform power grid operations with a real priority given to the use of renewable energy.
- **Development of hydrogen infrastructure based on renewable energy:** Install infrastructure to produce hydrogen using surplus electricity from renewable energy sources. Full-scale utilization comes around 2030 approximately.
- **Expanded use of heat from biomass:** Develop systems to enable sustainable biomass supply at the level of 60 million m^3 per year in total.

Phasing out fossil fuels

- **Carbon pricing of fossil fuels:** As part of the capital investment required by the scenarios, some items will take time to recover the investment. For the scenarios, a carbon price has not been explicitly provided, but in order to induce more capital investment for decarbonization, carbon pricing needs to be introduced, with emissions trading (cap and trade) in particular.
- **Decarbonization of electricity sector (in particular, phase out of coal-fired power plants):** It is necessary to decarbonize the electricity sector faster than other sectors. For example, coal-fired power generation decreases by more than 40% from 2010 to 2030. If power generation efficiency remains unchanged, generation capacity needs to decrease by about that amount, so new construction of coal-fired plants would be unlikely. On this point, there is no difference between the 100% Renewable Energy Scenario and the Bridge Scenario.

Gradual phase-out of nuclear power

- **Articulation of policies to gradually phase out nuclear power:** In principle, nuclear is phased out after they reach thirty-year lifetime. As for the existing plants, immediately phase out those that are not able to meet new safety standards, and those that do not have consent of the local community.

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The full report (only in Japanese) can be downloaded from the WWF Japan website:
http://www.wwf.or.jp/re100_2017/