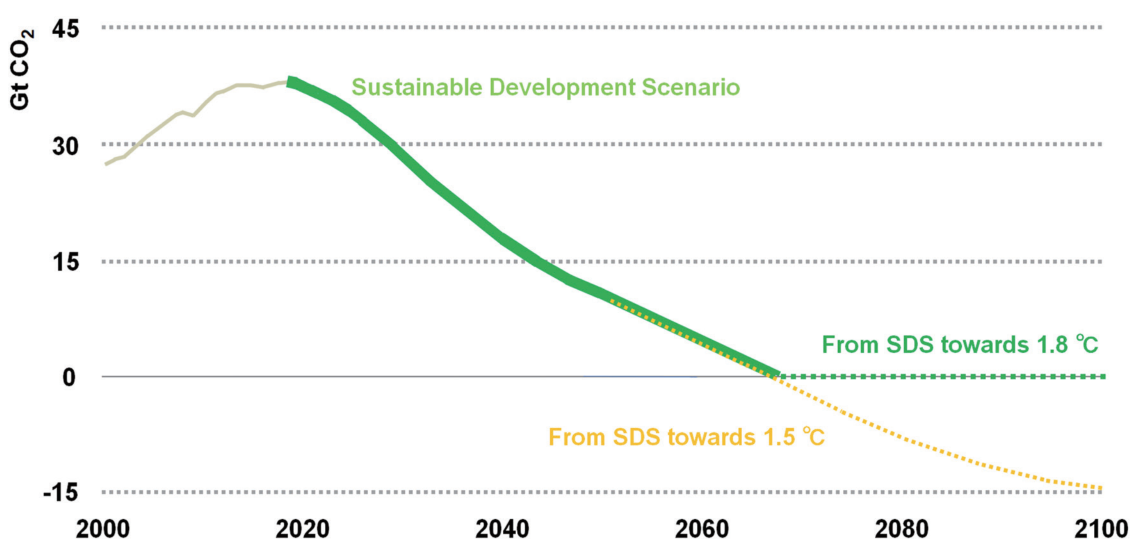
Carbon Capture and Storage, the Key to Achieving Net Zero Emissions

The Government of Japan has announced its intention to cut emissions of greenhouse gases to net zero by 2050. **Yamaguchi Mitsutsune**, Special Advisor to the Research Institute of Innovative Technology for the Earth (RITE), investigates how this target might be achieved.

In September 2020, Prime Minister Suga Yoshihide announced in a speech to the Diet that Japan would cut greenhouse-gas (GHG) emissions to net zero (carbon neutral) by 2050, which was welcomed by the United Nations and European countries. Yet the question is how this target is to be achieved. The speech did not suggest any roadmap to achieving the target but simply made abstract references to the creation of a virtuous circle of environment and economy that will revolutionize the industrial structure and economic system through innovation.

In May 2016, the year after the adoption of the Paris Agreement, Japan made a cabinet decision to cut GHG 80% by 2050. According to the "Long-term Strategy under the Paris Agreement," also adopted by the Cabinet in June 2019, the aim is to realize a decarbonized society (net zero emissions), as the ultimate goal, at the earliest possible time in the second half of this century. It also clarified that cutting emissions by 80% by 2050 is a checkpoint. A strategy for promoting innovative climate change technologies was announced in January 2020. It identifies concrete actions and scenarios with thirty-nine themes where Japan can contribute, with regard to sixteen technological challenges that are important in five areas of energy supply and demand. However, this strategy applies to the global level, so the citizens of Japan have not been given an overall picture of how the 80% reduction target will be achieved or told what measures will be in place by field. Since the net zero announcement by the prime minister, the government has established the Growth Strategy Council in October 2020 and has started a discussion toward achieving the net-zero

Figure: Relationship between the SDS scenario and 1.5°C



Note: The green thick line represents the SDS (sustainable development scenario), with CO_2 emissions at 10 Gt in 2050. According to the SDS, keeping net zero emissions after 2070 (green dotted line from 2070) is in agreement with the Paris Agreement since it has a 66% chance of limiting the temperature increase in 2100 to 1.8°C (50% chance for 1.65°C). If net minus emissions continues after 2070, then it might be possible to limit the increase at 1.5°C (orange line).

Source: Created by the author based on "World Energy Outlook 2019," p.122, International Energy Agency target without sacrificing economic growth in collaboration with the technological research of the Green Innovation Strategy Promotion Council. Looking at the material of the Growth Strategy Council, it appears that hydrogen, batteries, carbon recycling, and offshore wind power are priority areas.

The International Energy Agency is conducting detailed analysis of global net zero from a technological standpoint. The IEA's core scenario, the sustainable development scenario (SDS), aims to achieve net zero by 2070 (not 2050) (**Figure**). According to the IEA's Energy Technology Perspective 2020 (ETP 2020), the key to the SDS is energy conservation and renewables such as wind and solar power, as well as the four other technologies; namely, electrification (including decarbonization of the relevant power generation sector), CCUS (carbon capture, utilization, and storage), hydrogen (including hydrogen-derived fuels), and bioenergy. This is something that both Japan and the UK, which we will discuss later, have in common and it pretty much is the whole world's consensus. With regard to electrification, decarbonization of the power sector is assumed to be achieved before 2060 thanks to the rapid growth of renewables. With regard to CCUS, about 10 $GtCO_2$ will be captured in 2070, of which 90% will be stored underground, 1/3 of which are negative emissions (NEs) centering on BECCS (bioenergy with carbon capture and storage), and 10% will be CCU (CO_2 recycling). The ETP 2020 classified technologies into six stages: (1) concept, (2) small prototype, (3) large prototype, (4) demonstration, (5) early adoption, and (6) mature. This way of thinking is applied to technologies in each sector such as industry and transportation. Of those, the SD scenario does not cover technologies in stages 1 and 2. Only 25% of the cumulative reduction to be made by 2070 comes from mature technologies in stage 6. That is, 3/4 of the reduction will come from technologies currently not on the market. If we are to achieve net zero by 2050, it is necessary that the reduction is sped up.

Based on past experience, the IEA thinks the commercialization of new technologies takes twenty to seventy years, but also considers it somewhat possible to shorten the time if there is strong government support. However, there is only thirty years left if net zero is to be achieved by 2050. In that case, it will be necessary to ready some of the technologies in stage 2, which are not covered by the SDS, within the next decade. They say that hydrogen-based steel production and ammonia fuel, from hydrogen manufactured through water electrolysis, have to appear on the market within six years at the latest.

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The UK's Transparent Plan and the Situation in Japan

In June 2019, the UK became the first country to enshrine net zero GHG emissions by 2050 in law. Not only that, but it is an extremely transparent plan that specifies the means to reach the target by sector along with reduction volumes and costs (**Table**). Decarbonization of the power sector, electrification, hydrogen, and bioenergy make up the core in the UK as well, but even then, 86 Mt of emissions, mainly from aviation and agriculture, remain unabated. Of that, 54 Mt will be offset by NEs, mainly through BECCS, while the remaining 32 Mt will be reduced through lifestyle changes, further afforestation, DACS (Direct Air Capture and Storage), and a variety of other means. What stands out in particular in the UK is that CCS, including BECCS, in 2050, will account for 176 Mt, corresponding to almost 35% (of which 10% make up BECCS) of the UK's 2017 total emissions.[1] CCS make up about 9 Gt corresponding to 25% of 2019 emissions globally in the IEA's SDS, but the UK goes above and beyond that, so much so that the government considers CCS not an option but a necessity.

How is Japan in comparison? As I already mentioned, we are innovating through public and private initiatives and are world-leading especially in the fields of hydrogen and CCU.

1 Shortly after this article was finalized, the UK's Committee on Climate Change (CCC) released "The Sixth Carbon Budget, The UK's path to Net Zero" in December 2020. In this report, the CCC proposed slightly different emissions pathways through 2050 and average abatement cost by sector than the previous one, including less reliance on CCS. But these changes do not affect the essence of this article.

Both of these two fields are priority areas in the government's innovation action plan. Of these, things were progressing steadily with regard to hydrogen by sponsoring the Hydrogen Energy Ministerial Meeting, initiating publication of the IEA's special report on hydrogen, as well as the plans to produce hydrogen through water electrolysis using PV energy in Fukushima, and the plan to construct ships dedicated to transporting overseas-made hydrogen to Japan. The government started considering tax benefits for de-carbonization.

However, something we must not forget here is the necessity of NEs focusing on CCS and BECCS/DACS. It is technologically and economically impossible to create a society that uses no fossil fuels by 2050. A degree of fossil fuels are needed especially in the steel production industry and the transportation sector, including large trucks and aviation, as well as in power generation. As is clear from the cases of the IEA and the UK, net zero can only be realized by using CCS to get rid of the CO_2 that is hard to cut and then use BECCS and other NE technologies to offset the remaining CO_2. An academic article[2] discussing Japan's 80% reduction by 2050 estimates CCS to be 200 million tons in 2050. A research report[3] from the institution I am affiliated with also reports that 2050 CCS will be 100-200 million tons and that it will be difficult to achieve an 80% reduction without the use of CCS (not CCU). This is the situation with just an 80% reduction, with a net zero or 100% reduction requiring about twice the CCS including BECCS/DACS, meaning the same situation in the UK that CCS and NEs are not an option but a necessity. Part of the CCS can be implemented overseas and some of the BECCS biomass can be imported, but even then, key themes are the selection of storage locations, and associated geological surveys in Japan and legal frameworks, which require prompt action. Moreover, sufficient consideration needs to be given to consistency with the 2050 net zero target and the revised 2030 midterm target to be submitted this year.

To ensure effectiveness, it will be important to make a comprehensive judgment based on these points, provide the general public with information about roadmaps and technologies for 2050 net zero in every field, overall and sector specific costs, and the impact on international competitiveness, as well as secure agreement for their implementation.

Table: Average abatement costs by sector and measures (2050)

Average abatement costs by sector (2050)

Sector or measure	Abatement cost ($£/tCO_2e$)	Sector or measure	Abatement cost ($£/tCO_2e$)
Power	**20**	**Agriculture**	**-55**
Variable renewables	-5	Agricultural soils	-80
Firm low carbon power	50	**Land use**	**85**
CCS for mid-merit generation	80 - 120	Tree planting	10
Residential buildings	**155**	Forestry management	-50
New homes	70	Peatland restoration	See note
Heat in space constrained homes	310	**Waste**	**10**
Heating in homes off the gas grid	-20	**Transport**	**-35**
Non-residential buildings	**95**	Cars	-40
Industry	**120**	Buses	200
Iron and steel	100	HGVs	-35
Cement	95	**Aviation**	**-10**
Stationary combustion	120	Fuel efficiency	-50
Engineered removals	-	Biofuels	125
Bioenergy with CCS	125 – 300	**Shipping**	**200**
Direct air capture with CCS	300	**F-gases**	**-10**

Notes: Costs correspond to the Further Ambition scenario and are rounded to the nearest £5/tCO2e. Not all sectoral emissions sources are included. Costs of demand measures (aviation demand, diet shift and transport modal shift) are assumed to be zero. CCS cost range reflects different uses of CCS (lower bound is cost of CCS for firm power and upper bound for peak power). Peatland restoration costs vary significantly, between £75 -5,885/tCO2e (depending on e.g. type of peatland restored, ease of access to the location), but these estimates ignore significant co-benefits resulting from restoration. Lower bound BECCS costs correspond to costs using domestically produced bioenergy, while upper bound corresponds to imported bioenergy.

Source: Table 7.3 of "Net Zero, The UK's contribution to stopping global warming," Committee on Climate Change 2019, p. 225

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2 Fujimori et al., Energy transformation cost for the Japanese mid-century strategy, Nature Communications (2019) 10 47337 1–11. The article's figure did not include an explanation about CCS, so I confirmed 2050 CCS in communication with the author.

3 Research report on the costs of contract research (research projects to introduce CCS in Japan) contributing to global warming and resource recycling measures in 2019, March 2020, in Japanese, Research Institute of Innovative Technology for the Earth
https://www.meti.go.jp/meti_lib/report/2019FY/000145.pdf