Is It Possible to Achieve Global-Scale Net-Zero Emissions by 2050?

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1. Possibility of Achieving Net-Zero Emissions by 2050 is Largely Dependent on CCS and BECCS

After the IPCC released its 1.5°C special report (SR1.5) in 2018 and, based on this report, in June 2019 the United Kingdom set net-zero emissions of greenhouse gases (GHG) by 2050 as legally binding target, net-zero emissions suddenly came into the spotlight. In September this year, China followed in the footsteps of the EU and announced that it will achieve net-zero emissions by 2060 (though not 2050), and in October, Japan declared the goal of net-zero by 2050. Many other countries are considering similar actions, but to date, the UK is the only country that has published sector roadmaps and technologies for achieving the goal of net-zero, the cost as a ratio of GDP, and the average cost of measures for each sector in detail. The UK's plan is to reduce most of its emissions using electrification, hydrogen, and large amounts of CCS (a technology which reduces emissions to zero by capturing CO_2 from fossil fuel combustion and storing it underground), and deal with the remaining hard-to-avoid emissions using negative emission technologies, specifically BECCS[1] (bioenergy with CCS) and small amounts of forestation and DACS (capturing atmospheric CO_2 directly and trapping it in geological formations semi-permanently) (the negative emissions from these technologies are hereafter collectively called "NEs"). In 2050, the amounts of CCS and BECCS will be equivalent to 35% of the total emissions in 2017, with BECCS alone accounting for some 10% (Fig. 1).

Other than the UK outlined above, what is the global situation? The key feature of the IPCC's 1.5°C scenario is that it depends on large amounts of NEs, mainly from BECCS. An analysis by the International Energy Agency (IEA) shows that 88 of the IPCC's 90 scenarios depend on BECCS, with a median of 4.7 Gt[2] as of 2050. While the central scenario of the IEA is the Sustainable Development (SD) scenario, which sets 2070, not 2050, as the target year for achieving net-zero emissions of CO_2, it has also published a scenario in which net-zero is achieved by 2050 by further progress in innovation. The latter estimates CCS at approx. 8 Gt in 2050, including around 3.3 Gt of NEs (of which about 3 Gt is BECCS). Here, CCS and BECCS together comprise a significant portion or one-fourth of energy-related CO_2 emissions in 2019, while the amount of BECCS is smaller than

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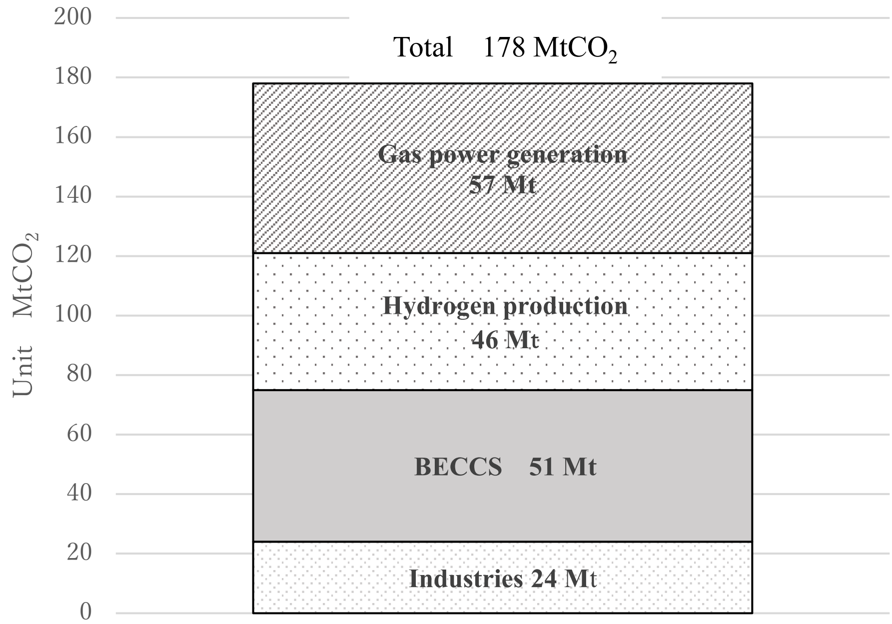
[1] BECCS (Bio-Energy with Carbon Capture and Storage): The CO_2 emissions generated from burning biomass as an energy source are counted as zero since plants absorb CO_2 as they grow. The emissions are counted as negative when captured and stored in the ground, which is why BECCS is counted as a negative emission.

[2] IEA World Energy Outlook 2019, p. 124

in the IPCC 1.5℃ scenario[3]. Thus, it is not possible to achieve net-zero by 2050 without large amounts of CCS and BECCS.

Fig. 1 UK's Dependence on CCS and BECCS (2050)



Source: 2019 material by The Committee on Climate Change
As GHG emissions in 2017 in the UK were 503 Mt, the total of CCS and BECCS, 178 Mt, accounts for 35%.

2. Other Measures towards Achieving Net-Zero Emissions by 2050

The reason for having to resort to large amounts of BECCS, as described earlier, is because CO_2 and other GHG emissions cannot be completely eliminated by any means. Why not? Consider the UK as an example, focusing on the power generation, transportation, industrial, and building sectors. The generation sector will boost the share of wind power and solar PV to 57% while dealing with the soaring demand caused by electrification, reduce emissions to near-zero using nuclear and gas with CCS, and use BECCS to achieve negative emissions. The transport sector will reduce emissions from 120 Mt in 2017 to 2 Mt in 2050 by making passenger vehicles and light trucks 100% electrified and large trucks electrified and hydrogen-fueled. To achieve this, only EVs will be sold as new cars from 2035, and about 25,000 chargers will be set up for them. Next, the aviation sector will have 31 Mt of residual emissions due to a lack of options other than replacing a part of fuels with biofuels. The shipping sector can slash its emissions significantly by using hydrogen (ammonia), while industry can cut its emissions to 10 Mt by using hydrogen, electrification, biofuels, and CCS. The building sector will reduce the direct emissions for heating buildings from 85 Mt to 4 Mt by installing

[3] Chapter 6, IEA Energy Technology Perspective 2020. Note that the scope of the IEA's analysis includes only energy-related CO_2. CO_2 absorption and emissions due to forestation and deforestation are not included.

heat pumps and shifting from gas to hydrogen energy. The measures above will be combined with lifestyle changes, such as eating less meat and avoiding air travel, and the last remaining emissions that are difficult to eliminate will be offset by NEs, mainly BECCS, to achieve net-zero emissions. The cost of this scenario in 2050 is estimated at 1– 2% of GDP (see Fig. 1 for the UK's dependence on CCS and BECCS).

Next, the IEA has conducted a detailed analysis of 800 technologies in the context of global CO_2 reduction based on the SD scenario. The analysis concluded that electrification, CCUS (carbon capture, utilization, and storage), hydrogen, and bioenergy will be the keys, in addition to energy conservation and renewable energy which are basic requirements. The analysis then grouped the 800 technologies into six stages, namely conceptual (lithium air batteries, etc.), initial prototype (battery-powered aircraft, etc.), prototype (ammonia-powered ships, DAC, etc.), demonstration (ammonia from electrolysis with decarbonized electricity, etc.), initial marketing (off-shore wind power, heat pumps, etc.), and mature (hydropower, railways, etc.), and applied them to the key sectors described above to estimate the residual emissions of each sector in 2070. The industrial (steel, cement), transportation (shipping, air transport, large trucks), and building sectors would have about 3 Gt of residual emissions, which would be offset by using BECCS and small amounts of DACS in the generation and energy conversion sectors to achieve overall net-zero emissions as a result. The IEA has also released a 2050 net-zero scenario for reference purposes; major additional requirements for achieving net-zero emissions 20 years earlier than the SD scenario are described in Table 1.

Table 1 Additional Requirements for Achieving Net-Zero by 2050 (main differences with the SD scenario)

- The technologies currently in the prototype stage must reach the market faster than prior successful cases, and the market is assumed to expand if there is just one case of commercial implementation.
- It is essential that innovation progresses at an unprecedented speed. Technologies currenty in the demonstration or prototype stage, such as steel production using hydrogen, ammonia fuel from electrolysis for shipping and CCS in cement production, must be available in the market in 6 years at most.
- Technologies in the lab or small prototype stage must become available within 10 years from now in average. The only technology that has achieved this is LED.
- The power generation sector needs 20000 TWh of additional output by 2050 compared to the SD scenario. This is equivalent to the output of China and India combined in 2050.
- Renewable capacities must grow by 770 GW each year up to 2050 (50% more than the SD scenario).

Source: Created by the author based on Chapter 6, IEA Energy Technology Perspective 2020

3. Is it Possible to Achieve Net-Zero Emissions by 2050?

This question needs to be approached from three standpoints: (1) speed of innovation, (2) emissions from existing facilities, and (3) the potential of NEs. Among them, Table 1 indicates that the issue of (1) speed of innovation would be extremely difficult to tackle.

The greatest problem in terms of (2) emissions from existing facilities is China. CO_2 stays in the air very long time, which makes the cumulative amount of CO_2 and temperature increase almost directly proportional to each other. Accordingly, it is possible to estimate the total cumulative emissions in order to keep the temperature increase to, for example, below 2°C or 1.5°C above pre-industrial levels. This amount minus the amount of emissions generated to date gives the maximum amount of emissions, or remaining carbon budget, permitted to keep the rise in temperature to 2°C or 1.5°C. The IPCC's SR1.5 estimates the remaining carbon budget for the 1.5°C scenario (equivalent to reaching carbon-neutrality in 2050) at 420–580 Gt, but a study[4] published in the academic journal Nature points to the growth in the number of coal-fired thermal power stations being constructed or planned in developing countries, particularly in China, and states that these facilities worldwide will generate 846 Gt of emissions if they operate until the end of their lives, exceeding the carbon budget. Therefore, the possibility of achieving net-zero by 2050 will depend on whether CCS can be installed in the thermal power stations of China and other countries, or whether these facilities can be scrapped before the end of their lives.

As for (3) the potential of NEs, the main issues with BECCS, the most important NE technology, include adverse effects on biodiversity, availability of land for growing biofuels, and competition with food production. The IEA's special report on CCUS has estimated the land area necessary for 1 Mt of BECCS[5]. This, when multiplied by 3 Gt, the IEA's estimate for the amount of BECCS in 2050, gives 300–5100 Mha, and when multiplied by the IPCC's median of 4.7 Gt, gives 470–8000 Mha. The former is roughly 0.33–5.5 times, and the latter 0.5–8.7 times, the area of the United States. The greater figures were presumably calculated for agriculture and forest residues and the smaller ones for energy crops, but are inconceivable all the same.

From these three standpoints, achieving net-zero emissions by 2050 appears to be extremely difficult, if not impossible.

Writer's Profile

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Mr. Yamaguchi's previous position include Visiting Professor/Project Professor, University of Tokyo (2006-2015) and Professor of Economics, Keio University (1996-2004). Prior to this, he was Senior General Manager at Tokio Marine & Fire Insurance Co., Ltd. He served in numerous positions on committees and councils related Climate Change and Environmental issues such as a Lead Author of IPCC Working Group III.

[4] Tong et al. Committed emissions from existing energy infrastructure jeopardize 1.5°C climate target, Nature **572**, 15, Aug. 2019, 373–377

[5] IEA Energy Technology Perspectives 2020, Special Report on Carbon Capture Utilization and Storage, CCUS in clean energy transitions, p. 87

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