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Electricity/Gas Market Retail Competition

The Spread of COVID-19 and Suggestions for Future Smart City Plans

Germany's National Hydrogen Strategy toward Acceleration of the Energy Transition

The Institute of Energy Economics, Japan

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Contents

Covid-19 and the Supply-Demand Outlook for Oil up to 2021

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Introduction

The number of people infected with Covid-19 has surpassed 5 million globally, and many countries continue to impose, to varying degrees, lockdowns and restrictions on the movement and outings of people. While around 70,000 to 100,000 new cases are still being recorded each day since April, the lockdown was lifted in Wuhan City in China, where Covid-19 started, on April 8, and has begun to be eased in many other countries. The restarting of economic activity will cause oil demand to recover but could also trigger another outbreak. It is widely assumed that the lockdowns have caused such a large amount of oil demand to evaporate that production cuts by OPEC+ and other oil-producing countries will not be enough to recover the supply-demand balance. This report presents an outlook for the supply-demand balance of oil up to 2021 based on the demand outlook previously released by the IEEJ.

1. Demand outlook

The IEEJ has forecasted the demand for oil up to 2021 using three scenarios based on the World Economic Outlook[1] of the International Monetary Fund (IMF): the Reference Scenario (RS), in which the Covid-19 pandemic will end within 2020; the Longer Pandemic Scenario (LPS), in which the virus continues to spread for longer and has a more serious impact on economic activity; and the Pandemic Second Outbreak Scenario (PSOS), in which the pandemic is prolonged and a second outbreak hits in 2021.[2] According to the forecast, the global oil demand will decrease from 100 mb/d in 2019 to 87.2–90.7 mb/d in 2020, and then increase to 89.0–100.7 mb/d in 2021, both annual averages. Under the RS, demand will bottom out in Q2 of 2020 with 83.3 mb/d and rise to 102.9 mb/d in 2021Q4. Oil demand will bottom out in Q2 of 2020 under the LPS and PSOS as well, but the demand for Q2 will be lower than under the RS, at 82.1 mb/d. Demand will recover to 102.0 mb/d in 2021Q4, but under the PSOS, which anticipates a second outbreak in 2021Q2, demand will be 92.9 mb/d in 2021Q4, falling short of the demand level in 2019Q4.

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[1] IMF, World Economic Outlook April 2020: The Great Lockdown, https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo-april-2020

[2] The Institute of Energy Economics, Japan, "Demand for Oil, Natural Gas, and LNG Facing the Worst Global Economic Conditions since the Great Depression," April 17, 2020; https://eneken.ieej.or.jp/data/8912.pdf, "Covid-19 and the Outlook for Oil, Natural Gas, and LNG Demand in 2021," May 1, 2020, https://eneken.ieej.or.jp/data/8928.pdf

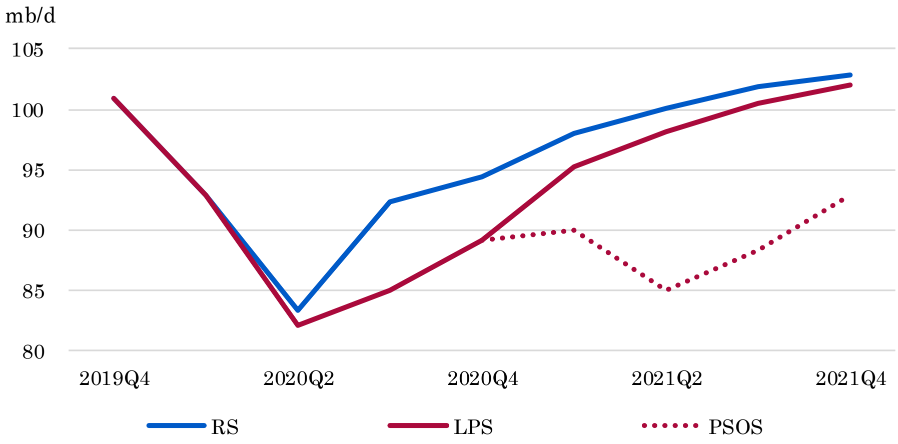

Fig. 1 Outlook for oil demand

Source: Institute of Energy Economics, Japan

2. Supply-demand adjustment scheme for responding to oversupply

Witnessing the oil price crash that occurred after the OPEC+ meetings on March 5 and 6, OPEC+ agreed to curb production by 9.7 mb/d at the meetings on April 9 and 12[3], following the intermediation efforts of President Trump. On April 10, the G20 Energy Ministerial Meeting was held, presided by Saudi Arabia, and the G20 reaffirmed that they will work closer together to stabilize the market and strengthen energy security.[4] However, despite the request by OPEC+, no numerical targets were indicated for production cuts by non-OPEC+ countries, including the United States.[5] Media reports emerged citing sources in OPEC+ that the effective supply-demand adjustment from May (production cut plus absorption of surplus) will exceed 20 mb/d when summing up production reductions by OPEC+ exceeding the agreed level and production curtailment by non-members, as well as additional strategic stockpiling to absorb excess supply from the market.[6] Furthermore, media reports on additional production cuts by Saudi Arabia, the UAE, and Kuwait in June[7] appeared on May 11. The additional cuts will consist of 1.0 mb/d by Saudi Arabia, 0.1 mb/d by the UAE, and 0.08 mb/d by Kuwait. It must be noted that the International Energy Agency (IEA) has played a vital role in building the additional production cut scheme which transcends the conventional framework, by releasing a joint statement with OPEC[8] and proposing that Saudi Arabia host a G20 Energy Ministerial Meeting.[9]

Non-OPEC+ countries including the United States are not under any obligation to cut production, and most of the reduction comes from "natural" decreases as producers suspend or scale back production amid a decline in profitability due to low oil prices. However, the scale of such reduction is not small, with the IEA expecting a possible decrease of approx. 3.5 mb/d in the US and Canada in the coming months.[10] Meanwhile, the government of Alberta, Canada's major oil-producing province, has required that producers within the province cut production by 325,000 b/d in January 2019. The requirement has since been eased, but the reduction is

[3] OPEC, April 12, 2020, https://www.opec.org/opec_web/en/press_room/5891.htm
[4] Ministry of Economy, Trade and Industry, April 11, 2020, https://www.meti.go.jp/press/2020/04/20200411001/20200411001.html
[5] The Nihon Keizai Shimbun, April 11, 2020, https://www.nikkei.com/article/DGXMZO57959490R10C20A4EA5000/?n_cid=SPTMG002
[6] Bloomberg, April 13, 2020, https://jp.reuters.com/article/global-oil-opec-idJPKCN21U0WS?utm_source=34553&utm_medium=partner
[7] Bloomberg, May 11, 2020, https://jp.reuters.com/article/global-oil-saudi-idJPKBN22N1WS
[8] IEA, March 16, 2020, https://www.iea.org/news/iea-executive-director-and-opec-secretary-general-discussed-the-current-situation-in-global-oil-markets
[9] IEA, April 10, 2020, https://www.iea.org/news/executive-director-s-speech-to-extraordinary-g20-energy-ministerial
[10] IEA, Oil Market Report, April 2020, p4

planned to continue until the end of 2020.[11] The Norwegian government will also cut production by 250,000 b/d in June and by 134,000 b/d in July through December 2020.[12] Aside from production cuts, regarding boosting stockpiles to absorb the surplus in the market mentioned earlier, the IEA estimates that China, India, South Korea, and the US can collectively take in 2.0 mb/d in 2020Q2.[13] As such, a scheme transcending the conventional framework, which could be called "OPEC++," has been established to combat the supply glut caused by this unprecedented decline in oil demand.

Table 1 OPEC++ market stabilization scheme

mb/d

	Baseline Production	Production	Production Target			
		Apr 2020	May 2020	Jun 2020	Jul-Dec 2020	Jan 2021-Apr 2022
OPEC						
Saudi Arabia	11.00	11.90	8.49	7.49	8.99	9.50
Iraq	4.65	4.50	3.59		3.80	4.02
UAE	3.17	3.85	2.45	2.35	2.59	2.74
Kuwait	2.81	3.05	2.17	2.09	2.30	2.43
Nigeria	1.83	1.76	1.41		1.50	1.58
Angola	1.53	1.32	1.18		1.25	1.32
Algeria	1.06	1.00	0.82		0.86	0.91
Congo	0.33	0.33	0.25		0.27	0.28
Gabon	0.19	0.20	0.14		0.15	0.16
Equatorial Guinea	0.13	0.12	0.10		0.10	0.11
Iran		1.99				
Venezuela		0.63				
Libya		0.08				
Total OPEC	26.68	30.73	20.60	19.42	21.82	23.03
Non-OPEC						
Azerbaijan	0.72	0.68	0.55		0.59	0.62
Kazakhstan	1.71	1.58	1.32		1.40	1.48
Mexico	1.75	1.75	1.65		1.65	1.65
Oman	0.88	0.96	0.68		0.72	0.76
Russia	11.00	10.44	8.49		8.99	9.50
Malaysia Bahrain Brunei Sudan South Sudan	1.11	1.04	0.85		0.90	0.96
Total Non-OPEC	17.17	16.25	13.55	13.55	14.26	14.96
Total OPEC+	43.85	44.28	34.15	32.97	36.07	37.99

	Baseline Production	Production	Production Target		
		Mar 2020	Apr-Jun 2020	Jun 2020	Jul-Dec 2020
Alberta, Canada	N.A.	3.47	3.81		N.A.
Norway	1.86	2.10		1.61	1.73
			Stock Fill		
China, India, Korea,			2.00		

Sources: OPEC, IEA, the government of Alberta, the government of Norway, Bloomberg

Needless to say, whether this new scheme can achieve its goal depends crucially on whether the pandemic will be contained soon. Also important is whether supply and demand will even out in the United States, the world's largest producer and consumer of oil. Prior to the OPEC+ meeting on April 9, Saudi Arabia and Russia had named the US' participation in the production cut as a condition for a larger production cut by OPEC+.[14] On the US side, the energy regulators of Texas, the key oil-producing state, considered cutting the state's output

[11] Government of Alberta, https://www.alberta.ca/oil-production-limit.aspx
[12] Government.no, April 29, 2020, https://www.regjeringen.no/en/aktuelt/reducing-oil-production-on-the-norwegian-continental-shelf/id2700542/
[13] Platts Oilgram News, April 16, 2020
[14] Bloomberg, April 7, 2020, https://jp.reuters.com/article/oil-opec-usa-idJPKBN21O2X8

by 1.0 mb/d (20%)[15], but the idea of setting a mandatory reduction target was abandoned due to staunch opposition by those who believed that output adjustment should be left to market forces.[16] With no moves toward mandatory reductions in other states, the direction of policy is toward further stockpiling[17], financial assistance for producers[18], and consideration of suspending oil imports from Saudi Arabia[19] by the federal government.

In the US, crude production finally peaked and began to decrease in the second week of March with 13.1 mb/d. Between then and the second week of May, production decreased by 1.5 mb/d.[20] The EIA predicts that annual average US oil production will decrease by 0.55 mb/d from the previous year's average to 11.69 mb/d in 2020, and by 0.79 mb/d to 109.0 mb/d in 2021.[21] These figures by the EIA are used as the production volume of the US in our supply scenario described later. Meanwhile, the IEA had forecasted an increase of approx. 1.0 mb/d for US crude production in 2020 in its monthly Oil Market Report released in March this year, but drastically revised the forecast to a year-on-year decrease of 400,000 b/d in its April report. Some consider that this difference of 1.4 mb/d caused by plummeting oil prices could arguably be regarded as the US' contribution to supply-demand stability in the form of reduction of production.

3. Storage capacity constraints

In forecasting the size of production reduction, we must consider not only price levels but also constraints on storage capacity. On April 20, the US WTI oil futures fell into negative territory as ETFs and other non-commercial players, who do not have real demand or means to trade oil, are forced to sold more as the May contract approached expiry, but there were no buyers due to a lack of tanks to store the crude.[22] The EIA forecasts that US demand will begin to recover in May and industry stocks will start to decrease in July, but any delay in the pace of decrease in output or recovery of demand would immediately put pressure on storage capacity and force deeper production cuts. There is even a possibility that the US may stop importing oil from Saudi Arabia to alleviate the oversupply. Were this situation to occur, it would worsen US-Saudi relations and could cause Saudi Arabia to walk out of the production cut agreement and the OPEC++ scheme to collapse.

Storage capacity constraints are not only a US problem. According to the IEA, the working global crude storage capacity, factoring in tank operation constraints[23], is 5.0–5.7 billion barrels.[24] The IEA estimates there are 4.6 billion barrels in stock as of the end of April 2020, and the number will rise to around 5.3 billion barrels in June before starting to decline.[25] Floating storage on tankers is also being employed to deal with the storage capacity crunch, and the IEA estimates that floating storage of 130–155 million barrels is possible considering unoccupied space caused by recent demand loss.[26] However, as the IEA themselves point out, there is insufficient data on storage capacity and these assumptions should be considered with a considerable margin.

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[15] Platts, April 14, 2020, https://www.spglobal.com/platts/en/market-insights/latest-news/oil/041420-texas-oil-regulator-weighs-20-production-cuts-against-free-market-opposition
[16] Platts, May 4, 2020, https://www.spglobal.com/platts/en/market-insights/latest-news/natural-gas/050420-texas-railroad-commissioner-declares-idea-to-limit-oil-production-dead
[17] Department of Energy, April 14, 2020, https://www.energy.gov/articles/doe-announces-crude-oil-storage-contracts-help-alleviate-us-oil-industry-storage-crunch
[18] Reuters, April 24, 2020, https://jp.reuters.com/article/usa-oil-mnuchin-idJPKCN22605Q
[19] The Nihon Keizai Shimbun, April 20, 2020, https://www.nikkei.com/article/DGXMZO58292270R20C20A4000000/
[20] EIA, Weekly Petroleum Status Report, May 13, 2020, https://www.eia.gov/petroleum/supply/weekly/
[21] EIA, Short-Term Energy Outlook, May 12, 2020, https://www.eia.gov/outlooks/steo/report/
[22] The Nihon Keizai Shimbun, April 27, 2020, https://www.nikkei.com/article/DGXMZO58525420X20C20A4QM8000/
[23] The IEA estimates the physical capacity to be 6.7 billion barrels but that the capacity that can actually be used is around 75–85% (i.e. 5.0–5.7 billion barrels) considering operational constraints such as the change in volume with changes in temperature and oil blending constraints.
[24] IEA, Oil Market Report, May 2020, p39
[25] Same as above.
[26] IEA, Oil Market Report, May 2020, p40

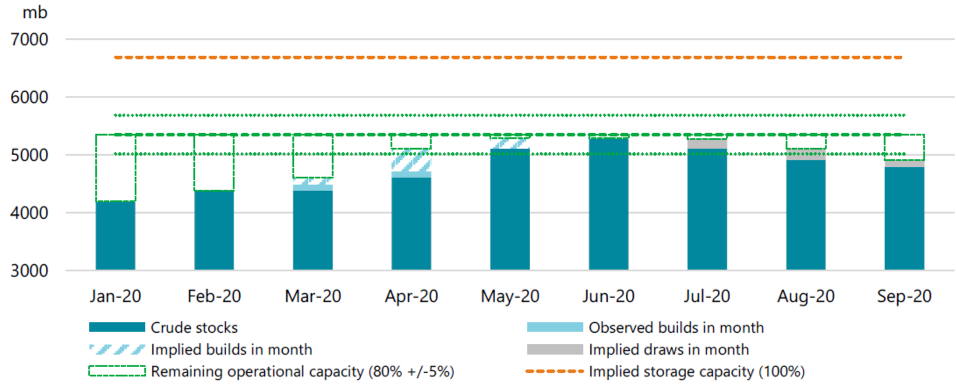

Fig. 2 World implied crude storage capacity

Source: IEA Oil Market Report

Storage capacity constraints will start to ease from 2020Q3 under the RS in which demand bottoms out in Q2. However, under the LPS in which recovery will be slower and the PSOS with a second outbreak, production cuts will need to be more persistently due to storage capacity constraints. If the constraints become tight, storage capacity will have to be increased even by sacrificing tank operation efficiency. However, even assuming an effective storage capacity of 6.155 billion barrels[27], to avoid a storage capacity crunch, production will have to be cut by an additional 1.5 mb/d on average from RS levels from 2020Q3 to 2021Q1, 2021 under the LPS, and by 7.6 mb/d on average from 2020Q3 to 2021Q4 under the PSOS. Note that the storage capacity discussed here is on a global basis, but in reality, storage capacity constraints differ by region. Therefore, even if stocks are still below the global storage capacity, some regions could already be facing insufficient capacity.

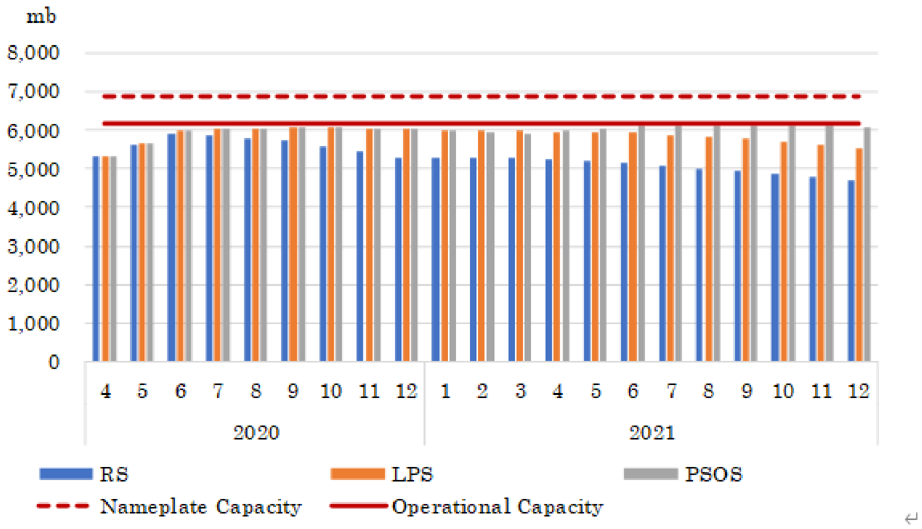

Fig. 3 Crude stocks and storage capacity

Note: Production is cut additionally by 1.5 mb/d on average from 2020Q3 to 2021Q1 for the LPS and by 7.6 mb/d on average from 2020Q3 to 2021Q4 for the PSOS, both from the supply levels under the RS. Construction of new storage capacity is not considered.

Sources: Created by the IEEJ based on IEA Oil Market Report, EIA Short-Term Energy Outlook, and “Demand for Oil, Natural Gas, and LNG under the Worst Global Economic Conditions since the Great Depression” and “Covid-19 and the Demand Outlook for Oil, Natural Gas, and LNG in 2021” by the IEEJ.

[27] 90% of the physical capacity of land-based facilities (6.0 billion barrels) plus the maximum floating storage capacity (0.155 billion barrels).

4. Supply-demand balance outlook

The chart below shows the supply-demand balance factoring in the demand outlook described above, the OPEC++ scheme for restoring supply-demand stability, production forecasts in countries without production cut obligations including the US, and storage capacity constraints. Here, the rate of compliance with the OPEC++ supply-demand stabilization scheme is assumed to be 100%. In the RS in which Covid-19 will end in 2020Q2, demand will exceed supply in 2020Q3 and remain so into 2021Q4. There will be no need for additional production cuts so long as the OPEC++ scheme is observed. However, for the LPS with a slower recovery and the PSOS with a second outbreak, additional production cuts from the RS' supply levels will be necessary, as described earlier.

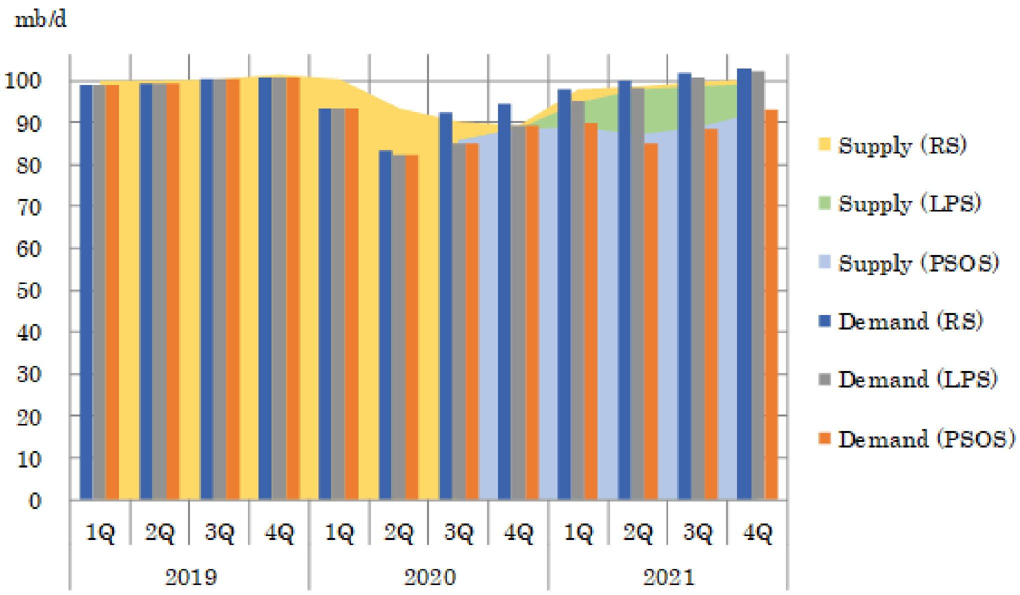

Fig. 4 Outlook for oil balance

Note: Production is cut by an additional 1.5 mb/d on average from 2020Q3 to 2021Q1 for the LPS and by 7.6 mb/d on average from 2020Q3 to 2021Q4 for the PSOS, both from the supply levels under the RS.

Sources: Created by the IEEJ based on IEA Oil Market Report, EIA Short-Term Energy Outlook, and "Demand for Oil, Natural Gas, and LNG under the Worst Global Economic Conditions since the Great Depression" and "Covid-19 and the Demand Outlook for Oil, Natural Gas, and LNG in 2021" by the IEEJ.

5. Conclusion

The number of new cases of Covid-19 infection remains high but the pace of increase has slowed significantly from March, and many countries are easing their lockdowns and restrictions on movement and outings. If the current trend continues, demand will start to recover from Q3, and if the OPEC++ scheme functions properly, the constraints on storage capacity will indeed ease. This is consistent with the RS. However, it is not at all clear how the pandemic will develop. Some fear that easing restrictions on movement and outings and the restarting of economic activity would lead to a second outbreak and a third, which may have a serious impact. Even if the world proceeds along the future path anticipated under the RS, the oil price crash has already dealt a devastating blow to oil-producing economies: the IEA estimates that even Saudi Arabia and other Gulf oil-producers with relatively large financial buffers will suffer a fiscal deficit of 10–12% and a funding shortage of $150–170 billion in 2020.[28] Regardless of how large or small the probability, actually implementing the extreme production cut that would be necessary under the PSOS for a sustained period of time would not only spell economic disaster for most oil-producing economies countries but could even shake each nation's system.

Oil prices have been relatively stable since the start of May, albeit at low levels. The main factor behind this is the mounting expectations for a recovery in demand as restrictions are eased and economic activity restarts. Under the RS, which predicts that demand will steadily recover from Q3, oil prices are expected to rise as the supply-demand nears balanced. However, prices would once again face downward pressure under LPS and PSOS.

Since a severe scenario like the PSOS cannot be ruled out, the highest priority is for the entire world to continue to focus to end the pandemic. The US did not commit to mandatory production cuts in April, but under the PSOS, the country may be forced to reconsider its policy. Meanwhile, the absence of reliable global data on storage capacity is a serious problem, particularly if the LPS or PSOS becomes a reality. To prevent storage capacity constraints and panic in the market, governments will need to assess the precise capacities of their storage facilities quickly and share the information with the rest of the world.

[28] IEA, Oil Market Report, April 2020, p17

COVID-19: Impact of Lower Oil Export Revenues on the Finances of Gulf Oil-producing Countries◆

Ryohei Ikarii*

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic causes a tremendous amount of infections and deaths in the world and forces numerous cities and borders to be closed. Stagnation in overall energy consumption, due to lockdowns, results in a substantial decline in global oil demand. Even after the Organization of the Petroleum Exporting Countries (OPEC) and other oil-producing countries agreed to reduce production by a total of 9.7 million barrels per day (bpd), the West Texas Intermediate crude futures contract temporarily plunged last April into negative territory for the first time in history. Weak oil prices are hitting hard the finances of oil-exporting countries and among them are Persian Gulf oil-producing countries that are key suppliers to many countries in the world. Destabilization of their financial, economic, political and social structures should be avoided. This paper analyses the impact of weak oil prices and lower oil exports on the revenues and finances of each Gulf oil-producing country.

2. Overview of Gulf oil-producing countries

The economic size of the eight Gulf oil-producing countries (six Gulf Cooperation Council members, Iran and Iraq) is $2.3 trillion, of which Saudi Arabia accounts for one-third (Fig. 1). Their population totals 180 million, of which Iran commands nearly 50 percent (%).

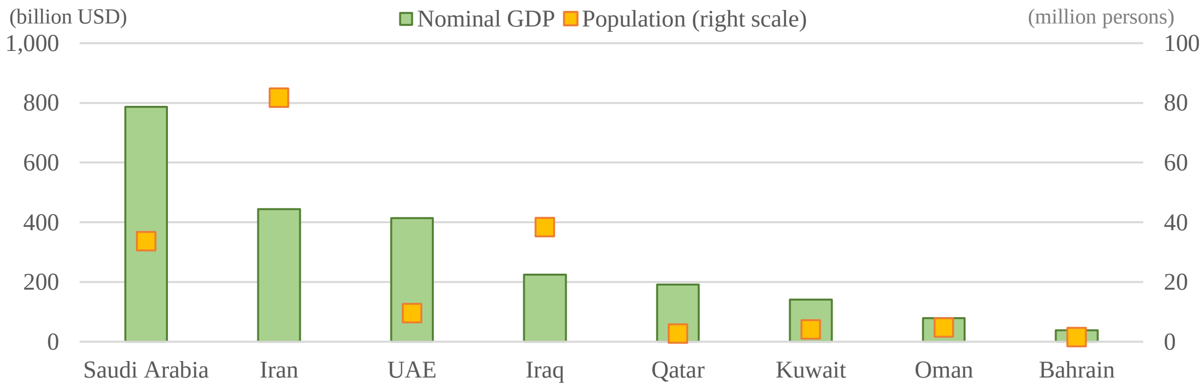

Fig. 1 Nominal GDP and population (2018)

(Sources) IMF REO; World Bank (2020) "Population (Open Data)"

3. Methodology

Crude oil export revenues are computed by multiplying each country's daily export volume (as reported in the IMF IMF REO[1]) by the international oil prices of $52.8/bbl for 2017, $68.3/bbl for 2018 and $61.4/bbl for 2019 (as reported in the IMF WEO[2]). The oil production and export volume for the eight Gulf oil-producing

◆ This paper covers the six GCC countries, Iran and Iraq as eight Gulf oil-producing countries.

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[1] International Monetary Fund, "Regional Economic Outlook Middle East and Central Asia" (April 2020)

[2] International Monetary Fund, "World Economic Outlook" (April 2020)

countries in 2020, relative to 2019, is assumed to be lower by 5.23 million bpd and by 4.61 million bpd, respectively. The 2020 crude oil export revenues are projected by multiplying each country's projected export volume (as estimated by the IMF REO, the IEA OMR[3] and the IEA GER[4]) by an estimated international oil price of $35.6/bbl (IMF WEO).

In the factor analysis of the year-on-year changes, the price impact of the COVID-19 pandemic on oil export revenues is based on each country's export volume for 2019 multiplied by the change in oil prices of $25.8/bbl (the gap between the actual oil price in 2019 and the projected price in 2020). The export volume impact is estimated by multiplying the projected drop in each country's export volume between 2019 and 2020 by the projected oil price of $35.6/bbl for 2020. The price and export volume impacts are combined to compute the impact on each country's revenue.

The price impact on government finance is estimated by multiplying each country's export volume, assumed unchanged from 2019, by the gap between the oil price for a balanced budget for 2020 in the IMF REO and the projected price for 2020. The export volume impact on government finance is estimated by multiplying the gap between each country's planned oil export volume for a balanced budget for 2020 and its estimated volume for 2020 by the projected oil price for 2020 of $35.6/bbl. Both impacts are combined to compute the impact on each government finance.

This impact of the oil export revenue decline on government finance is divided by total budgeted expenditure to compare the impacts among countries. The oil and gas revenue in a budget is divided by overall budgeted revenue to see how each government finance depends on oil and gas revenue. Comparison between the above two percentages would imply how vulnerable the government finance of each country, who is dependent on oil export revenue, is in case that each takes balanced budget.

4. Impacts on crude oil export revenues in 2020

Given the global oil demand decline and resulting oil price drops, oil export revenues in 2020 for the eight Gulf oil-producing countries are estimated to decline by $220 billion from 2019. Since the export revenue is a component of GDP, the export revenue decline of $220 billion amounts to a weakening of 9.3% from 2019 in nominal GDP terms. Considering the economic interdependence between countries, the decline is far from negligible for the whole of the Gulf oil-producing countries (Fig. 2).

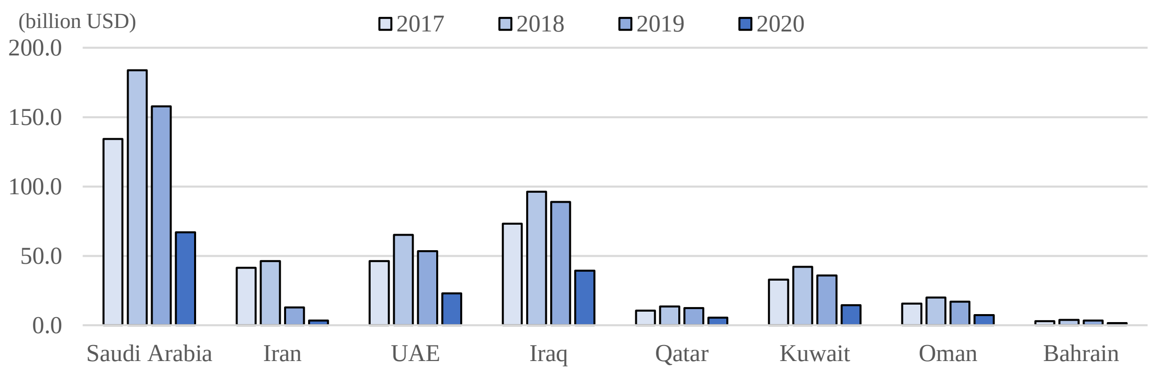

Fig. 2 Oil export revenue (results for 2017-2019 and estimates for 2020)

(Sources) IMF WEO; IMF REO; IEA OMR; IEA GER

3 International Energy Agency, "Oil Market Report" (April 2020)
4 International Energy Agency, "Global Energy Review 2020" (April 2020)

A breakdown of the decline in export revenue into its price and volume components indicates that the impact of lower prices is far more substantial than that of the lower export volume, caused by the global oil demand plunge through lockdowns (Fig. 3). Of particular interest, the loss of export revenues for Saudi Arabia is $90.8 billion, the largest among the Gulf oil-producing countries. It is comprised of an oil price impact of $66.2 billion (73% of the total) and of a volume impact of $24.6 billion (27%).

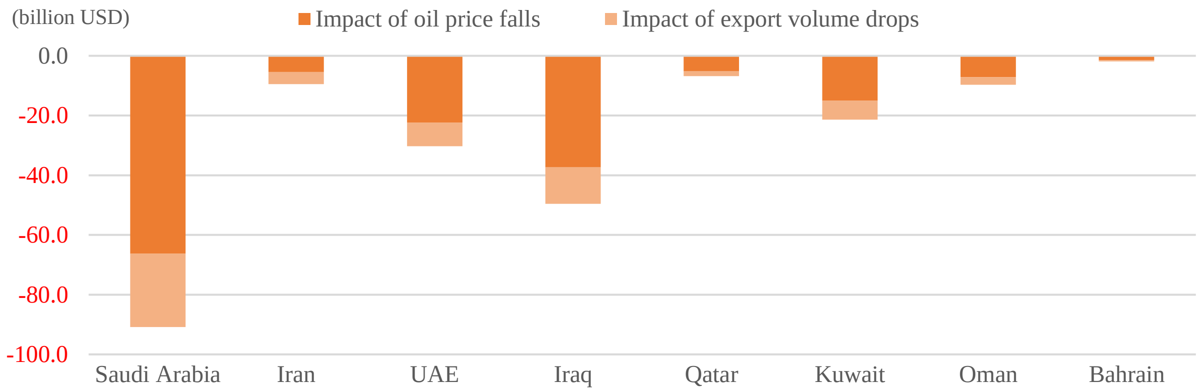

Fig. 3 Oil export revenue declines and their factor analysis (estimates for 2020)

(Sources) IMF WEO; IMF REO; IEA OMR; IEA GER

5. Impacts on 2020 government finance

The Gulf oil-producing countries depend heavily on oil exports for their government revenue; therefore, the impact of lower revenues from oil exports for each country's government finance is quite relevant. If the government revenue includes all of the oil export revenues, Saudi Arabia's revenue would be $128.6 billion short of the initially anticipated level in its 2020 budget. Revenue shortages would total $48.2 billion for Iraq, $37.0 billion for the United Arab Emirates, $21.3 billion for Kuwait, $16.7 billion for Oman and $3.8 billion for Bahrain.

Situations in Iran and Qatar differ somewhat from those in other Gulf oil-producing countries. The oil price for a balanced budget for Iran is as high as $389.4/bbl, indicating the enhancement of U.S. economic sanctions and an assumed budget deficit. In contrast, the oil price for a balanced budget in Qatar is as low as $39.9/bbl, the lowest among the Gulf oil-producing countries, with the impact on government finance limited to $2.5 billion. However, it should be noted that natural gas accounts for half the Qatari export revenue, indicating that natural gas exports have a greater impact than oil exports.

A factor analysis of the impact of lower export revenues on government finance in the Gulf oil-producing countries shows that the price impact is also larger than the volume impact. On an average basis for the Gulf oil-producing countries, other than Iran, the price impact in 2020 is 3.6 times greater than the volume impact. The large gap between the price and volume impacts may be attributable to a deeper-than-expected plunge in crude oil prices and an optimistic pricing for formulating budgets (Fig. 4). If the Gulf oil-producing countries wish to enhance their resilience to shocks, such as the COVID-19 tragedy, they should estimate crude oil prices more conservatively for the purposes of formulating budgets.

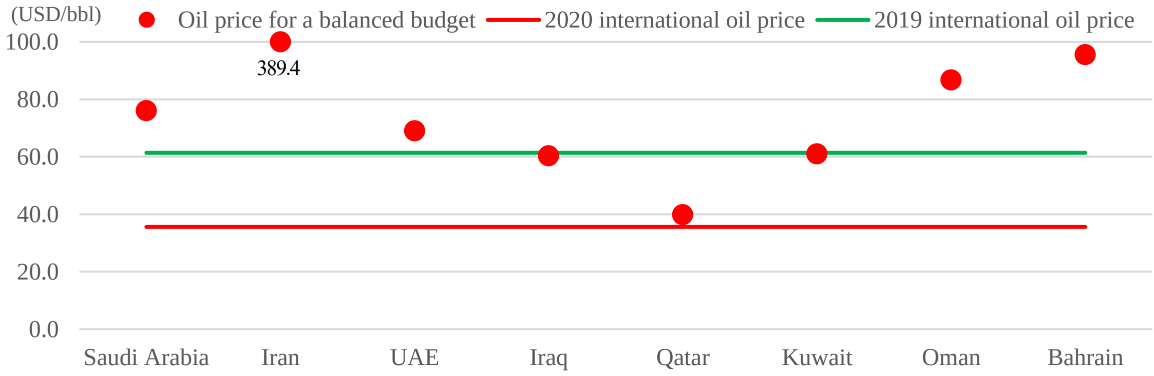

Fig. 4 Balanced budget oil prices and international oil prices

(Sources) IMF WEO; IMF REO

The percentage of the impacts on Gulf oil-producing countries government finance shows also a severe situation (Fig. 5). If the government revenue includes all of the oil export revenue, as in the above case, government revenue would decline by two-thirds in Iraq, by 50% in Oman, by 42% in Saudi Arabia, by 31% in Kuwait, by 30% in Bahrain and by 28% in the UAE. Qatar's revenue decline is estimated to be as low as 4%, but the impact of lower natural gas exports on its government finance could be large. The combined impact of $258.1 billion for seven Gulf oil-producing countries, other than Iran, is equivalent to nearly 30% of their budget revenue.

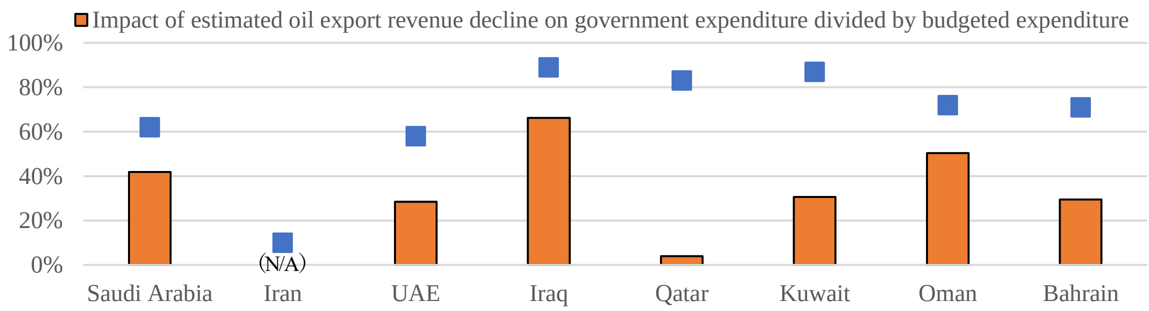

Fig. 5 The impact of estimated oil export revenue decline on government expenditure and the share of budgeted oil and gas revenue in government revenue (estimates for 2020)

(Sources) IMF WEO; IMF REO; IEA OMR; IEA GER; World Bank Group (2019) "Gulf Economic Update"; IEEJ

(Note) As Iran is suspected to have formulated a budget assuming a deficit, the impact of the oil export revenue decline on government expenditure is given as N/A (not available).

Gulf oil-producing country governments recognize their overdependence on oil exports and hope to tighten their budgets. Under the current pressure from COVID-19, they are trapped into massive withdrawals from foreign exchange reserves to meet government expenditure expansion and investments in priority areas[5].

[5] Saudi Arabia announced to cut expenditure by $26.6 billion, raise the value added tax from 5% to 15% and cut citizen allowances, while Oman announced a budget cut. A few budget-tightening measures have thus been taken among Gulf oil-producing countries.

6. Conclusion

Lower oil prices and reduced demand, under the COVID-19 pandemic, have remarkably diminished the oil export revenues and the budget balances of the Gulf oil-producing countries. Of particular interest, weak oil prices have had a huge impact that is in part attributable to optimistic oil price projections and in part attributable to much greater-than-assumed drops in prices. To ease similar impacts in the future, the Gulf oil-producing countries should project more conservative oil prices when formulating budgets and reduce their heavy dependence on oil revenue. Given that the international crude oil price may remain weak in 2021 (around $37.87/bbl, as anticipated in the April 2020 IMF World Economic Outlook), Gulf oil-producing countries could be plagued with budget deficits, making it difficult to address increases in COVID-19 patients and unemployment. This could lead to financial and economic deterioration as well as political and social destabilization.

This is a matter of grave concern not only to Gulf oil-producing countries but to all oil-importing countries, including Japan. To avoid destabilization, Gulf oil-producing countries should learn lessons from the COVID-19 disaster and accelerate their self-help efforts to diversify their economies and cut government spending. On the other hand, Japan and other oil-importing developed countries should enhance their bilateral cooperation with them to reduce their dependence on oil with investment in activities such as the production and export of blue and green hydrogen.

Estimation of Changes in the Electricity Demand Curve under the State of Emergency
Estimation Using an Artificial Neural Network (ANN)

Yu Nagatomi[*1] Natsumi Aizawa[*2], Hideaki Okabayashi[*3], Yuji Matsuo[*4]

Abstract

Governments around the world have taken powerful measures to counter the spread of the new coronavirus (Covid-19), such as requesting voluntary restraint of economic activity and imposing city-wide lockdowns, causing enormous economic damage and a major decline in energy demand as a result. The Japanese government declared a state of emergency following a stay-at-home advisory as Covid-19 spread. This report analyzes the impact of Covid-19 and the state-of-emergency declaration on Japan's energy demand, focusing on the impact on hourly electricity demand. In the analysis, we use the artificial neural network developed by the IEEJ to obtain estimates that take into account the air temperature and other meteorological conditions, and compare these estimates with the actual values to determine the change in the electricity demand curve.

The analysis shows that the electricity demand declined by an estimated 3.8% in April and 9.5% in May in the Tokyo area. The impact of the declaration on the decline in demand varied by region but tended to be greater in metropolitan areas where the number of cases was high. The impact also varied by hour of day, presumably reflecting regional industrial structures.

1. Introduction

Governments around the world have taken powerful measures to counter the spread of the new coronavirus (Covid-19), such as requesting voluntary restraint of economic activity and imposing city-wide lockdowns, causing enormous economic damage. Accordingly, energy demand declined sharply in a wide range of sectors as economic activity declined and more people stayed home due to city-wide lockdowns. Japan declared a state of emergency on April 7 for seven prefectures, namely Tokyo, Saitama, Chiba, Kanagawa, Osaka, Hyogo, and Fukuoka as Covid-19 spread, placing self-imposed restrictions on a wide range of activities. As the declaration was subsequently expanded to include all prefectures on April 16, the spread of Covid-19 and the resulting decline in economic activity significantly affected the demand for energy in Japan.

As examples of the reported impact of Covid-19 on electricity demand, Abiko (2020)[1] found that demand declined by just under 10% compared with other years in the TEPCO power grid area as of late April. Further, the Agency of Natural Resources and Energy (ANRE) (2020)[2] reported that the demand for April 2020 declined by 1.1–9.2% year-on-year (by 4.2% for the Tokyo area) and by 1.1–5.0% year-on-year (4.0% for the Tokyo area), with and without adjustment for meteorological conditions, respectively. Moreover, in the Electric

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1 Naoto Abiko (2020). The impact of Covid-19 on electricity demand. https://www.mri.co.jp/knowledge/mreview/202006-1.html

2 Agency for Natural Resources and Energy (2020), Matters related to electricity demand. https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/pdf/025_07_00.pdf

Daily News[3] newspaper dated June 11, 2020, the Japan Weather Association noted that weekday demand was around 10% lower than the past few years even when considering temperature differences, and attributed the decline to the slump in and voluntary restraints on corporate activity. When analyzing the impact of Covid-19 and the resulting state-of-emergency declaration on electricity demand, it is essential to adjust for temperature and other meteorological conditions. Abiko based his estimate on the daily average temperatures during the past three years and the daily electricity demand for the same period, while the Japan Weather Association plotted an approximate curve based on the relationship between the daily average temperature and demand using the data for the past five years, and used it for analysis. It is not known how the ANRE adjusted their data based on meteorological conditions.

This report analyzes the impact of the spread of Covid-19 and the state-of-emergency declaration on Japan's energy demand, focusing on the impact on hourly electricity demand. In the analysis, we use the artificial neural network developed by the IEEJ to obtain estimates that take into account the air temperature and other meteorological conditions, and compare these estimates with the actual values to determine the change in the electricity demand curve caused by the declaration.

2. Estimation method and data used

2-1. Estimation method: Electricity demand curve estimation model using artificial neural network (ANN)

We used an electricity load estimation model that uses an artificial neural network (ANN) in order to project the impact of the state-of-emergency declaration by plotting the electricity demand curves without the impact of Covid-19 or the declaration, and comparing it with the actual electricity demand values. ANN is one of the most frequently used means of machine learning in recent years and has been used in many published studies for forecasting electricity demand. The ANN creates a forecast model by "learning" numerous pairs of past input data and output data; by entering a new input data into the model, a corresponding output data is generated. We used the following data for our model (see Appendix 1 for details).

Input data: Calendar data (year, month, day, day of week, and whether the day is a holiday) and meteorological data (air temperature, rainfall, and 24-hour solar radiation)
Output data: electricity demand (24-hour value)

We estimated the change in electricity demand associated with the state-of-emergency declaration by first making the model learn the situation before Covid-19 using the input and output data from January 1, 2012 to March 1, 2020, then entering the input data after the spread of Covid-19 into the model to generate output data for up to May 31, 2020, and comparing the output data with the actual data. We used the same model as in past reports[4],[5], but with modifications (see Appendix 2 for details).

2-2. Data used

We conducted the analysis for each area of the 10 Japanese power transmission and generation utilities as with past reports. The calendar data (year, month, day, day of week, and whether the day is a holiday) of that day and the meteorological data (air temperature, rainfall, and 24-hour solar radiation) were used as input data,

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[3] Electric Daily News, Demand falls 10% due to Covid-19, June 11, 2020
[4] Yuji Matsuo, Kimiya Otani, Tomofumi Shibata, Yasuo Yorita, Yasuaki Kawakami, Yu Nagatomi (2018). Short-term electricity demand forecasting using artificial neural network ―Study on 10 cities in Japan―. http://eneken.ieej.or.jp/data/8106.pdf
[5] Tomofumi Shibata, Kimiya Otani, Yasuo Yorita, Yasuaki Kawakami, Yu Nagatomi, Yuji Matsuo (2019). Evaluation of Factors Influencing the Accuracy of Electric Demand Forecasting by Artificial Neural Networks: Effect of Changes in Model Configuration, Journal of Japan Society of Energy and Resources, 40(5), pp. 144–153.

and the electricity demand (24-hour) was analyzed as output data. This allowed us to incorporate the calendar data and meteorological data into the electricity demand analysis. By comparing estimates that reflect the temperature and other meteorological conditions with the actual data, we were able to analyze the impact of the expansion of Covid-19 and the state-of-emergency declaration more accurately.

The outline and sources of data used are described in Appendix 1.

3. Evaluation results

3-1. Comparison by area

The evaluation results for each region are described below. The results for the Tokyo area, as a representative region, and the Chubu area, which saw the greatest fall in electricity demand, are described in detail. Then, the results for all areas are compared horizontally in the next section.

3-1-1. Tokyo area

The Tokyo area has had the highest number of Covid-19 cases in Japan and residents had been advised to stay home since before the state of emergency was declared. This area also has the highest electricity demand in the country, with particularly high demand in the business sector for offices and commercial facilities, and is thus expected to be affected strongly by a stay-at-home advisory.

The evaluation showed that the change in Tokyo's electricity demand for April (trend of actual and estimated values) was not large before the declaration (Fig. 1). However, the gap between the values began to widen from April 7 when a state of emergency was declared, widening further toward the latter half of April (Fig. 2). This suggests that the impact on electricity demand grew from this point due to close compliance with the stay-at-home advisory, closure of retailers and restaurants, and temporary suspension of manufacturing following the declaration.

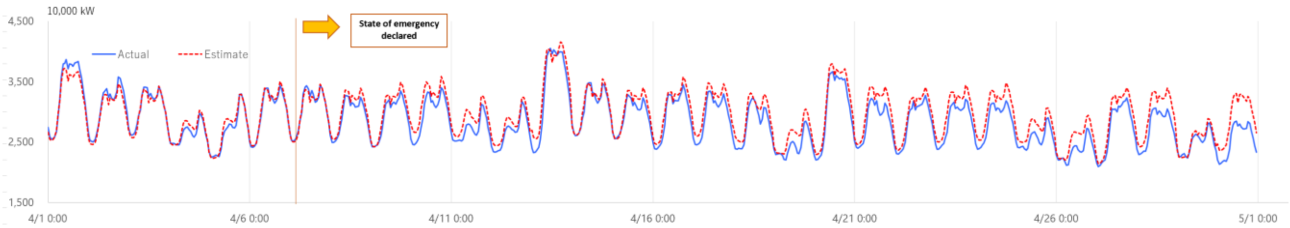


Fig.1 Electricity demand of Tokyo area (trend of actual and estimated values) (April)

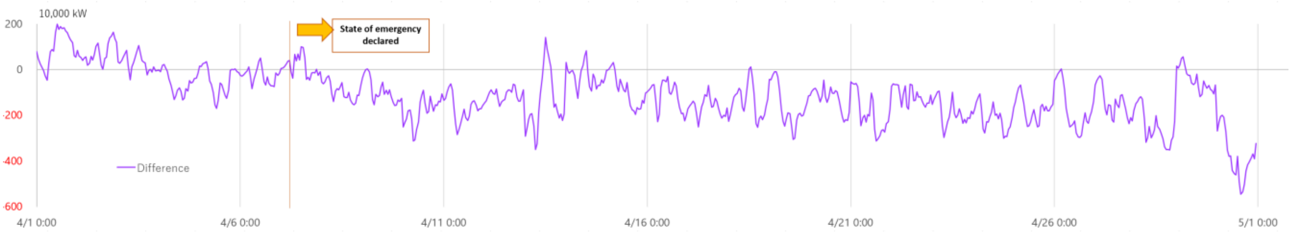


Fig. 2 Electricity demand of Tokyo area (difference between actual and estimated values) (April)

The gap between estimated and actual values grew further from the start of May, and electricity demand was greatly reduced during the "Golden Week" holidays (Fig. 3, Fig. 4). It is considered that people voluntarily refrained from leisure activities due to the stay-at-home advisory and that the cancellation of events during the holidays significantly limited people's activities in the Tokyo area, reducing electricity demand. The electricity demand remained low after the holidays ended, as the voluntary restraint on activities continued after the holidays due to the extension of the declaration till May 31, which was announced on May 4. Then, after it was announced that the declaration would be lifted on May 25 for the Tokyo area, the chart shows that the decline in electricity demand shrank around late May as people expected that the declaration would be lifted before it actually was.

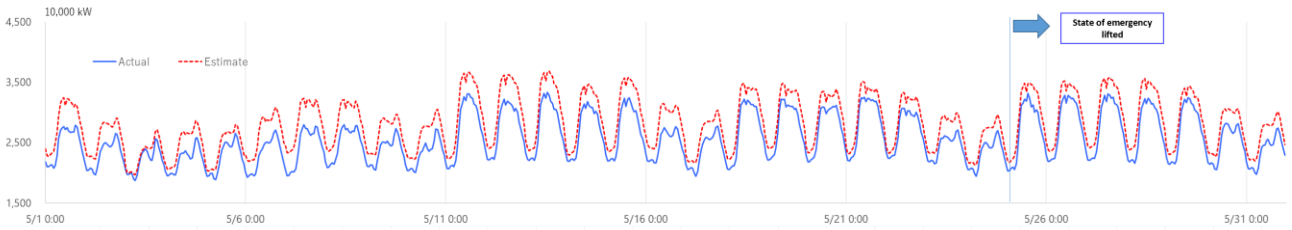


Fig. 3 Electricity demand of Tokyo area (trend of actual and estimated values) (May)

Fig. 4 Electricity demand of Tokyo area (difference between actual and estimated values) (May)

As described above, Tokyo's electricity demand began to fall particularly after the state of emergency was declared, and the decline grew till the end of the Golden Week holidays that started at the end of April. The decline then gradually decreased toward the lifting of the declaration. The decline in Tokyo's electricity demand was estimated to be approx. 3.8% versus the estimated value for April and approx. 9.5% for May (Tables 2 and 3).

3-1-2. Chubu area

In the Chubu area, the number of cases soared in the initial stage of the spread of Covid-19 in Japan. Aichi prefecture, the area's largest, declared a state of emergency on its own on April 10. The area is home to the auto industry and aircraft-related manufacturing, and therefore industry accounts for a large portion of electricity demand.

The evaluation showed that for Chubu's electricity demand for April (trend of actual and estimated values), the gap between the actual and estimated values began to grow gradually before the state of emergency was declared (Fig. 5). The gap widened further with the expansion of areas covered by the state of emergency on April 16 to include the Chubu area, widening even more toward the latter half of April (Fig. 6). Accordingly, Chubu's electricity demand declined throughout April since before the declaration due to Aichi prefecture's unique initiatives and the decline in industrial activity as a whole, including that of domestic and international manufacturing supply chains. The impact on electricity demand then increased toward the Golden Week holidays as more retailers and restaurants closed, in addition to the manufacturing sector.

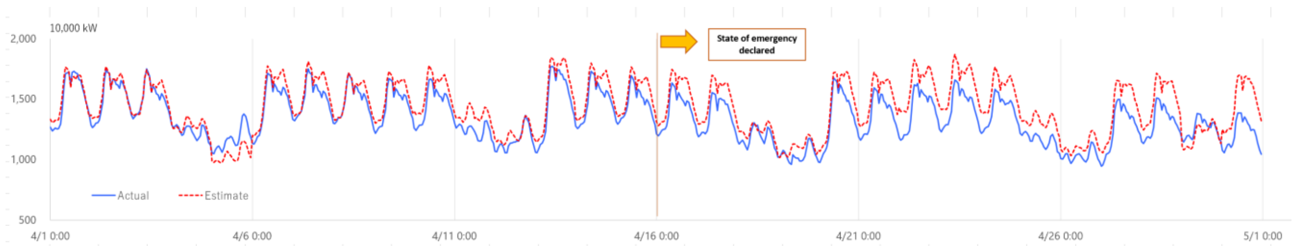


Fig. 5 Electricity demand of Chubu area (trend of actual and estimated values) (April)

Fig. 6 Electricity demand of Chubu area (difference between actual and estimated values) (April)

In May, the gap between estimated and actual values grew wider than in April, indicating that electricity demand dropped significantly during the Golden Week holidays (Figs. 7 and 8). It is considered that people voluntarily refrained from leisure activities due to the stay-at-home advisory, and that the cancellation of events during the holidays significantly limited people's activities in the Chubu area and reduced electricity demand, as happened in the Tokyo area. Although an extension of the declaration till May 31 was announced on May 4 during the holidays, the pace of decline of the Chubu area's electricity demand slowed gradually from the end of the holidays due to speculation that the declaration would be lifted earlier. Then, when the declaration was lifted on May 14, the fall in electricity demand shrank toward late May.

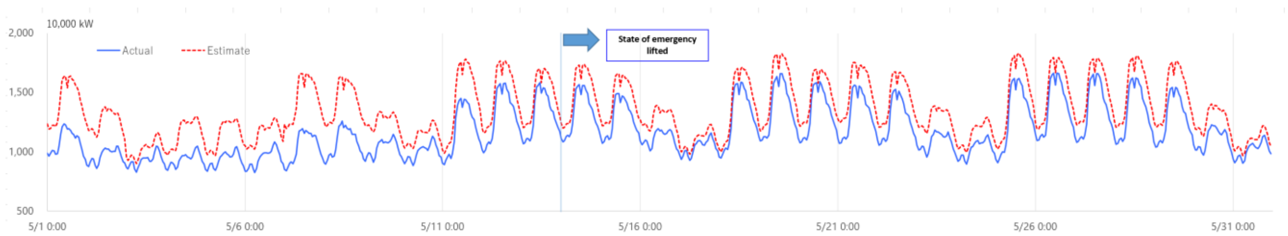


Fig. 7 Electricity demand of Chubu area (trend of actual and estimated values) (May)

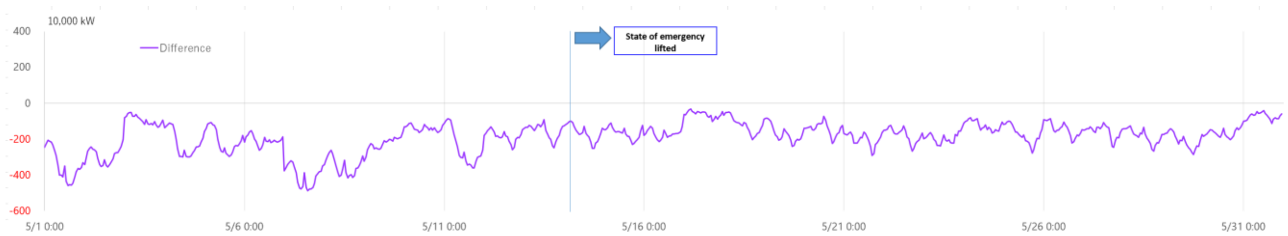


Fig. 8 Electricity demand of Chubu area (difference between actual and estimated values) (May)

As described above, Chubu's electricity demand began to fall before the state of emergency was declared, and the decline grew till the end of the Golden Week holidays that started at the end of April. The decline then gradually narrowed toward the lifting of the declaration immediately after the holidays. The decline in Chubu's electricity demand was estimated to be approx. 6.4% versus the estimated value for April and approx. 14.0% for May (Tables 2 and 3).

3-1-3. Comparison of full-day demand curves of the Tokyo and Chubu areas

The analysis showed that electricity demand declined in both the Tokyo and Chubu areas mainly due to the impact of the state-of-emergency declaration. The Chubu area saw a larger drop in electricity demand compared to other areas and therefore is considered to have been hit hard by the stay-at-home advisory and impact on industry associated with Covid-19.

Regarding changes in the electricity demand curves, we compared the hourly electricity demand during the state of emergency against estimated values assuming there was no declaration. The result showed that the impact on electricity demand varied by hour of day, with Tokyo having a relatively flat curve with a 5–10% decrease while Chubu slumped by over 15% at around 17:00 (Fig. 9). Since this analysis was conducted using macro electricity demand data for the entire area, it is difficult to analyze the hourly change in electricity demand by sector or by region within an area. One theory for the differences by sector is that the Chubu area's overall hourly demand may be affected to a greater extent by changes in demand in the industrial sector than in other areas due to the higher ratio of demand from manufacturing in electricity demand, in addition to the impact of the closure of retailers and restaurants which may occur in other areas as well.

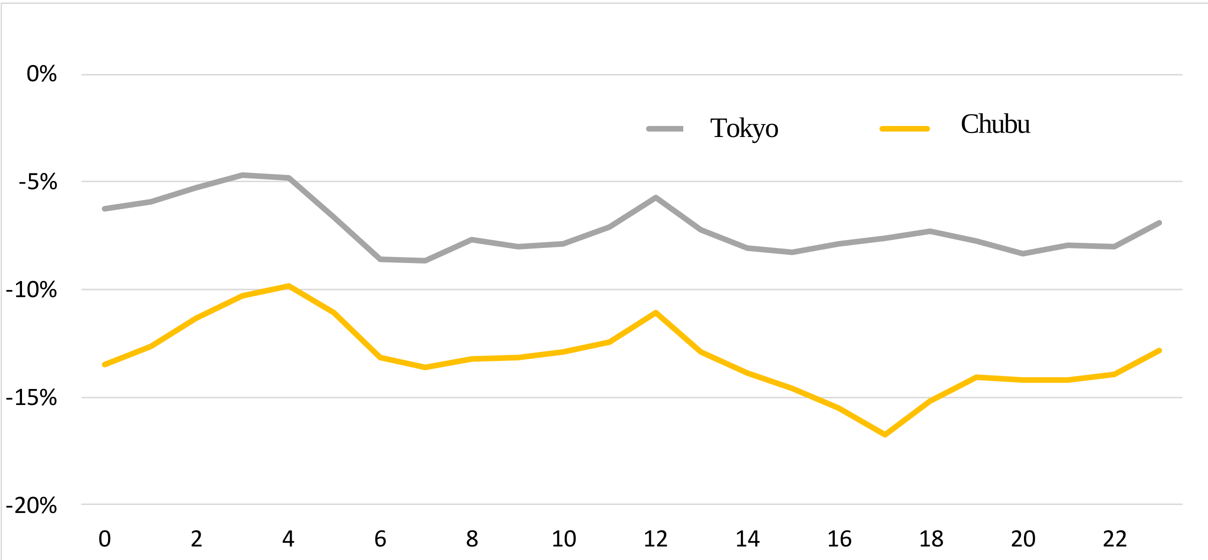


Fig. 9 Hourly difference in actual and estimated electricity demand during the state of emergency (Tokyo and Chubu areas)

3-2. Comparison among areas

This section compares the monthly analysis results among the areas to clarify the differences between regions and the changes in impact with the progress of Covid-19 countermeasures, including the state-of-emergency declaration.

3-2-1. Electricity demand in March

A state of emergency had yet to be declared in March although the number of Covid-19 cases was increasing in major cities and Hokkaido. The impacts on economic activity and electricity demand were caused mainly by each municipality's initiatives and advisories to stay home and close businesses during this period. The impact on electricity demand was relatively minor but was somewhat greater in the Tokyo and Kansai areas compared to other areas.

Table 1 Average electricity demand for March (in 10,000 kilowatts)

	Actual value	Estimated value	Difference ratio	(Reference) Result for 2019
Hokkaido	367	367	0.0%	370
Tohoku	950	962	−1.2%	977
Tokyo	3,167	3,209	−1.3%	3,195
Chubu	1,507	1,521	−0.9%	1,556
Hokuriku	341	341	0.0%	351
Kansai	1,588	1,620	−2.0%	1,662
Shikoku	304	302	0.7%	308
Chugoku	674	681	−1.0%	690
Kyushu	931	940	−0.9%	949
Okinawa	77	78	−0.9%	76

Source: All actual values for 2019 in this article have undergone day-of-week adjustments relative to 2020.

3-2-2. Electricity demand in April

A state of emergency was declared on April 7 in seven prefectures and was expanded to all prefectures on April 16, requiring the nationwide implementation of countermeasures and extensive staying at home. As a result, the gap in impact on demand between regions grew compared to March, with Chubu, Kansai, and Okinawa showing greater falls.

Table 2 Average electricity demand for April (in 10,000 kilowatts)

	Actual value	Estimated value	Difference ratio	(Reference) Result for 2019
Hokkaido	325	330	−1.6%	323
Tohoku	876	879	−0.3%	873
Tokyo	2,853	2,966	−3.8%	2,910
Chubu	1,346	1,439	−6.4%	1,386
Hokuriku	314	319	−1.6%	312
Kansai	1,453	1,528	−4.9%	1,493
Shikoku	282	281	0.2%	275
Chugoku	615	603	2.0%	616
Kyushu	860	879	−2.2%	862
Okinawa	74	78	−5.2%	82

3-2-3. Electricity demand in May

In May, electricity demand fell significantly in all areas during the Golden Week holidays as leisure-related economic activity shrank due to stay-at-home advisories during the holidays. The state-of-emergency declaration began to be lifted in phases starting on May 14 and was lifted completely on May 25, including in the four remaining prefectures of Tokyo, Kanagawa, Chiba, and Saitama. Nationwide, electricity demand plummeted during the holidays but the fall gradually shrank after the holidays due to widespread expectation that the state of emergency would be lifted. Of the regions, Chubu, Kansai, and Chugoku experienced relatively large declines.

Table 3 Average electricity demand for May (in 10,000 kilowatts)

	Actual value	Estimated value	Difference ratio	(Reference) Result for 2019
Hokkaido	285	297	4.3%	295
Tohoku	757	826	−8.4%	815
Tokyo	2,553	2,822	−9.5%	2,848
Chubu	1,162	1,352	−14.0%	1,355
Hokuriku	258	286	−9.9%	288
Kansai	1,296	1,462	−11.4%	1,456
Shikoku	256	267	−4.3%	265
Chugoku	529	593	−10.8%	585
Kyushu	790	848	−6.8%	855
Okinawa	84	91	−7.5%	87

Based on these results, a time-based observation of changes in regional electricity demand shows that electricity demand declined significantly in the metropolitan areas of Tokyo, Chubu, and Kansai due to the impact of the state of emergency and others (Fig. 10). Covid-19 countermeasures including the impact of the state of emergency on electricity demand varied among regions depending on their industrial structure and meteorological conditions. Going forward, in restarting economic activity while containing the spread of Covid-19, a shift to "new lifestyles" is being recommended. The impact of this shift on electricity demand deserves attention.

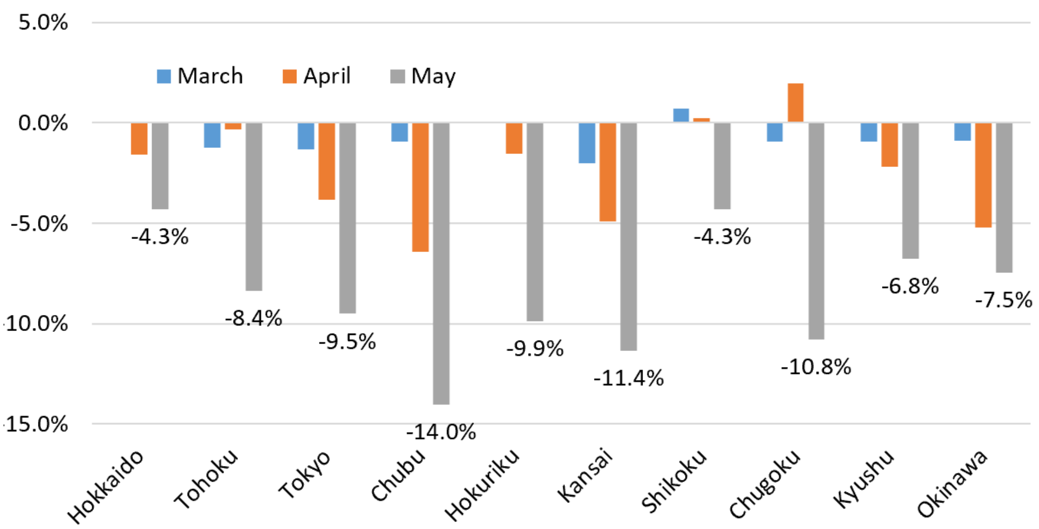


Fig. 10 Difference between estimated and actual values (average of each month)

3-2-4. Comparison of full-day demand curves of the 10 areas

Based on the analysis in Section 3-1-3, the difference between the full-day demand curve from the full-day average is illustrated in Fig. 11. The figure shows that the curve tends to be positive in the early morning as the fall in demand is smaller than the full-day average, but becomes larger toward the evening and falls below average, resulting in a greater fall in demand. This indicates that the fall in demand is greater during times of the day with more human activity. Further, Section 3-1-3 noted that the Chubu area saw a particularly large fall in demand around 17:00, but a comparison of the 10 areas shows that Chugoku and Shikoku also saw large falls at the same time of day.

By analyzing changes in electricity demand due to the state-of-emergency declaration in more detail on an hourly basis as in this study, in addition to on a monthly basis, the impacts of the state-of-emergency declaration, voluntary quarantines, and new lifestyles including teleworking can be analyzed in more detail.

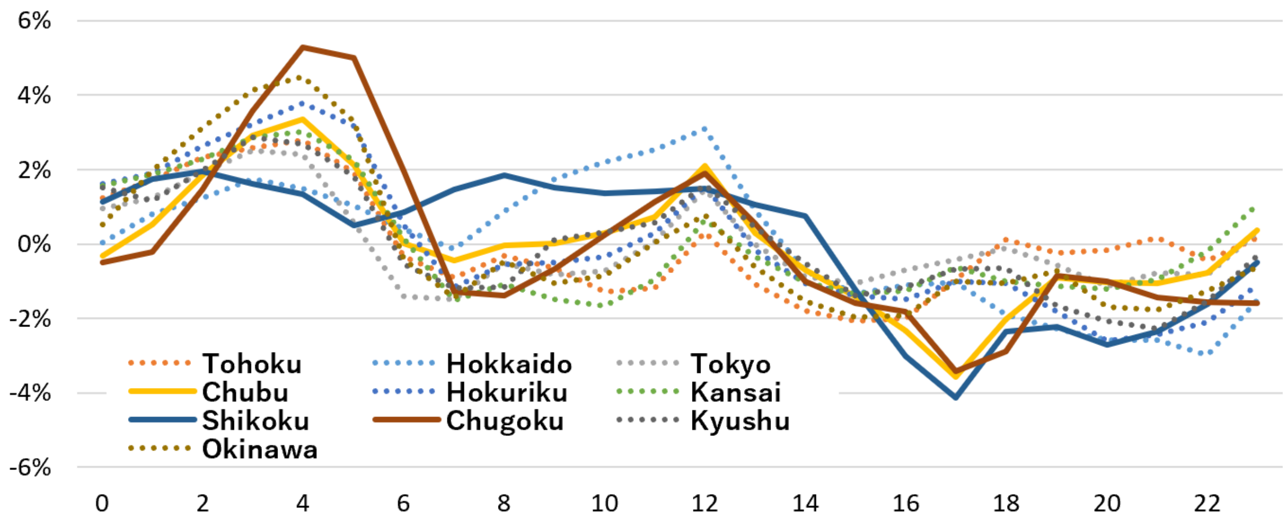


Fig. 11 Difference between the hourly demand curve from the full-day average during the state of emergency

4. Conclusion

This report analyzed the impact of the spread of Covid-19 and the state-of-emergency declaration on Japan's energy demand, focusing on the impact on hourly electricity demand. We used the artificial neural network developed by the IEEJ to obtain estimates that took into account the air temperature and other meteorological conditions, and compared these estimates with the actual values to determine the change in the electricity demand curve caused by the declaration.

The analysis showed that the impact of the state of emergency on electricity demand varied by region but tended to be greater in metropolitan areas with larger numbers of cases. Further, the impact also varied by hour of day, presumably reflecting regional industrial structures. The recovery of decline in demand showed signs of easing with the lifting of the declaration, but the hourly electricity demand is expected to follow a new pattern as quarantines associated with the state of emergency and the resulting “new lifestyles” take root, along with awareness of the possibility of second and third waves of Covid-19.

Appendix 1 Details of the data used

The following data was used.

- Calendar data (year, month, day, day of week, whether the day is a holiday)
- Meteorological data (air temperature, rainfall, and 24-hour solar radiation): created based on the Japan Meteorological Agency website
- Electricity demand (24-hour values): Created from disclosed data of general power transmission and distribution companies

Appendix Table 1 Electricity demand analysis data

Area	Data acquisition period	Data Number of days	Data Days without data
Hokkaido	2012/1/1 – 2020/5/31	3,038	36
Tohoku	2012/1/1 – 2020/5/31	2,610	464
Tokyo	2012/1/1 – 2020/5/31	3,045	29
Chubu	2012/1/1 – 2020/5/31	3,035	39
Hokuriku	2012/1/1 – 2020/5/31	3,067	7
Kansai	2012/1/1 – 2020/5/31	3,066	8
Shikoku	2012/1/1 – 2020/5/31	3,065	9
Chugoku	2012/1/1 – 2020/5/31	3,067	7
Kyushu	2012/1/1 – 2020/5/31	3,069	5
Okinawa	2012/1/1 – 2020/5/31	1,978	1,096

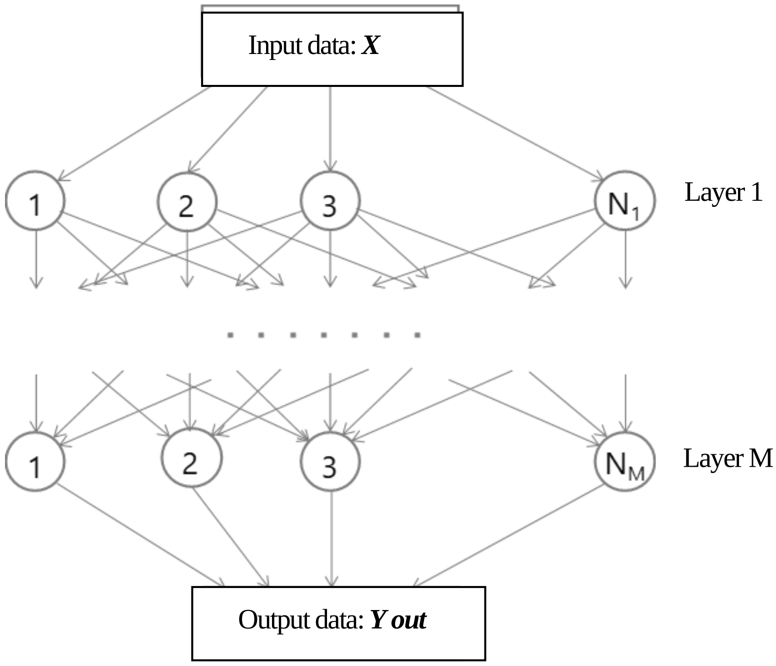
Source: Created based on websites and disclosed data of utilities. Missing data is due to errors in the data recording stage.

Appendix Table 2 Cities whose meteorological data was used

Area	City	Area	City
Hokkaido	Sapporo	Kansai	Osaka
Tohoku	Sendai	Chugoku	Hiroshima
Tokyo	Tokyo	Shikoku	Takamatsu
Chubu	Nagoya	Kyushu	Fukuoka
Hokuriku	Toyama	Okinawa	Naha

Appendix 2 Electricity demand curve estimation model using artificial neural network (ANN)

We used the same ANN-based forecast model that we developed for predicting electricity demand, with some modifications. The ANN is a method for teaching a computer large volumes of data on the non-linear relationship between the input vector and the target value (a scalar or a vector). The concept is illustrated below.



Appendix Fig. 1 Conceptual diagram of a multi-layer artificial neural network

In this model, M number of middle layers (hidden layers) are set between the input and output layers, and the n-th layer consists of N_n nodes (called neurons). That is, the size (complexity) of the model is determined by the size of M and N_n. If the input data is expressed by a N_0 dimensional vector $\boldsymbol{y_0} = \boldsymbol{X}$, and if the n-th middle layer is expressed by a N_0 dimensional vector $\boldsymbol{y_n}$, output data $\boldsymbol{y_{out}} = \boldsymbol{y_{M+1}}$ can be obtained successively from input data $\boldsymbol{X}$ by postulating the following relative equation:

$$\boldsymbol{y_{n+1}} = \phi(\boldsymbol{w_n}\boldsymbol{y_n} + \boldsymbol{b_n}) \qquad n \in \{0, 1, \ldots, M\} \qquad \text{(Appendix 2.1)}$$

where, φ is a nonlinear function called an activation function, and matrix $\boldsymbol{w_n}$ and vector $\boldsymbol{b_n}$ are parameters called weight and bias, respectively. The nonlinearity of the activation function allows complex events to be modeled and enables highly accurate forecasts.

For teaching the neural network, large quantities of pairs of input data $\boldsymbol{X}$ and output data (teacher data) $\boldsymbol{Y}$ are prepared as learning data. The input data is fed into the network, and $\boldsymbol{w_n}$ and $\boldsymbol{b_n}$ are optimized to minimize the difference between the output data obtained and the teacher data (in many cases, the square of the Euclidean distance between $\boldsymbol{y_{out}}$ and $\boldsymbol{Y}$ is used). Here, this optimization problem is typically solved by using the method for gradient descent. First, the initial values for $\boldsymbol{w_n}$ and $\boldsymbol{b_n}$ are determined, and the descent down the gradient begins from there to an optimal $\boldsymbol{w_n}$ and $\boldsymbol{b_n}$. Thus, the result may differ to a certain extent depending on how the initial values are set. In the model we used, φ is a softplus function $\varphi(x) = \log(1 + e^x)$, the number of layers M is set to 3, and the number of neurons on each layer N_i is 30. Further, Adam was used as the method for gradient descent.

Here, the calendar data (year, month, day, day of week, and whether the day is a holiday) and meteorological data (air temperature, rainfall, and 24-hour solar radiation) for a certain day (day *d*) was used as ***X***, and the 24-hour electricity demand of day *d* as ***Y***. For calendar data, natural numbers were used for the year, month, and day, and for day of week, Sunday was expressed as 0, Monday as 1 … and Saturday as 7. For holidays, 1 is set if the day is a national holiday or falls between December 29–January 3 or August 13–16, and 0 if it does not. Further, all values of the calendar data, meteorological data, and electricity demand data were standardized using the following equation to be used as input and output data for the model:

$$x_t = \frac{X_t - \bar{X}}{X_{max} - X_{min}} \qquad \text{(Appendix 2.2)}$$

where, X_t is the original value, $\bar{X}$, X_{max}, and X_{min} the average, maximum value, and minimum value of X_t, respectively, and x_t the value of input and output data for the model.

Note that the model used in this report used selective ensemble averaging (20 tries). For details on this method, refer to the cited sources.

Competitive Landscape After Three Years Of Japan's City-Gas Market Full Retail Competition

Daisuke Masago*

1. Introduction

More than three years have passed since Japan's city-gas retail market for all the market segments was opened for competition on 1 April 2017. In the city-gas retail market, competition for gas customers has intensified as new entrants, led by electric power companies, have set new pricing menus, improving services, and implemented business alliances between companies. This paper studies supplier-switching[1] trends, regional topics, and future trends in the Japan's city-gas market full retail competition, with reference to the electric power market, which is also an energy business utilizing infrastructure network, where retail competition was introduced one year ahead of the city-gas market. When the third set of recommendations by Advisory Board on Regulatory Reforms under the Cabinet Office was concluded in June 2018, it was widely recognized that the liberalization of the electric power market had progressed rather smoothly with the gas market left behind. In that sense, it is important to observe the latest developments in the two markets closely.

2. Numbers of Customer Switching

About 3.43 million retail customers have applied to switch their city-gas providers as of the end of March 2020, increasing by 63.3% or 1.33 million customers in one year.[2] More than four years have passed since Japan's electric-power retail market for all the market segments was opened for competition on 1 April 2016, one year ahead of the country's city-gas market full retail competition. Retail customers of 15.75 million have applied to switch their electric-power providers as of the end of March 2020, increasing by 39.5% or 4.46 million customers in one year.[3]

Fig. 1 shows numbers of residential retail customers that new entrants have acquired, in each region. Osaka Gas acquired more than 300,000 electric power customers from Kansai Electric Power, during the first year of the electric retail liberalization. Kansai Electric Power acquired a little less than 400,000 city-gas customers from Osaka Gas in one year, in the city-gas retail liberalization that started the following year. Since then, the two companies have competed fiercely for customers in the Kinki region. Meanwhile, as CD Energy Direct Company - established by Osaka Gas and Chubu Electric Power - and TEPCO Energy Partner entered the city-gas retail business in the Kanto region. As a result, the number of city-gas switching customers in the region increased and exceeded that in the Kinki region in June 2019.

Fig. 2 shows numbers of retail customer switchings in the city-gas and electric power markets by geographic region. While customer switchings in the city-gas retail markets have happened only in the Kanto. Chubu/Hokuriku, Kinki and Kyusyu/Okinawa regions, customer switchings in the electric power markets have been observed in all regions in the country. It is difficult for new players to enter those market where city-gas distribution pipeline networks have not been well established and densely connected, alternative gas supply sources are not easily found, or retail customers have been tightly captured by incumbent suppliers recently through improved service programs - including reduced prices of combined provisions of electric-power and city-gas supply and better customer loyalty award programs.

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[1] Numbers of customers who have changed their retail gas suppliers in different regions in the country
[2] The Agency for Natural Resources
[3] the Organization for Cross-Regional Coordination of Transmission

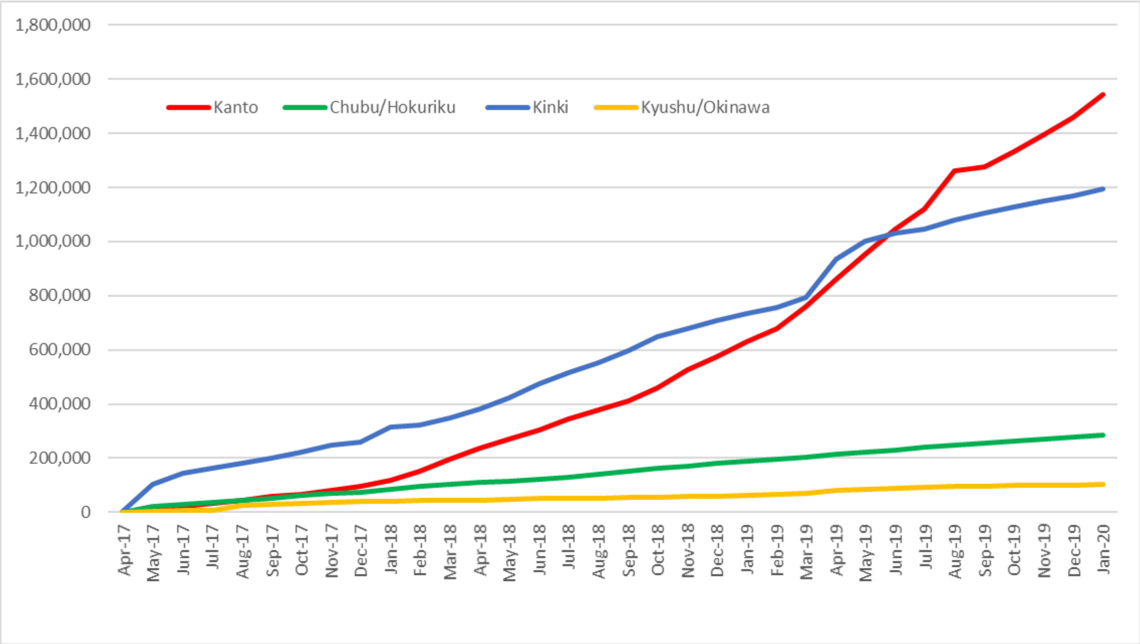

Fig. 1 Numbers of City-Gas Residential Customers Secured by New Entrants

(Source) Compiled by the authors based on materials provided by the Electricity and Gas Market Surveillance Commission

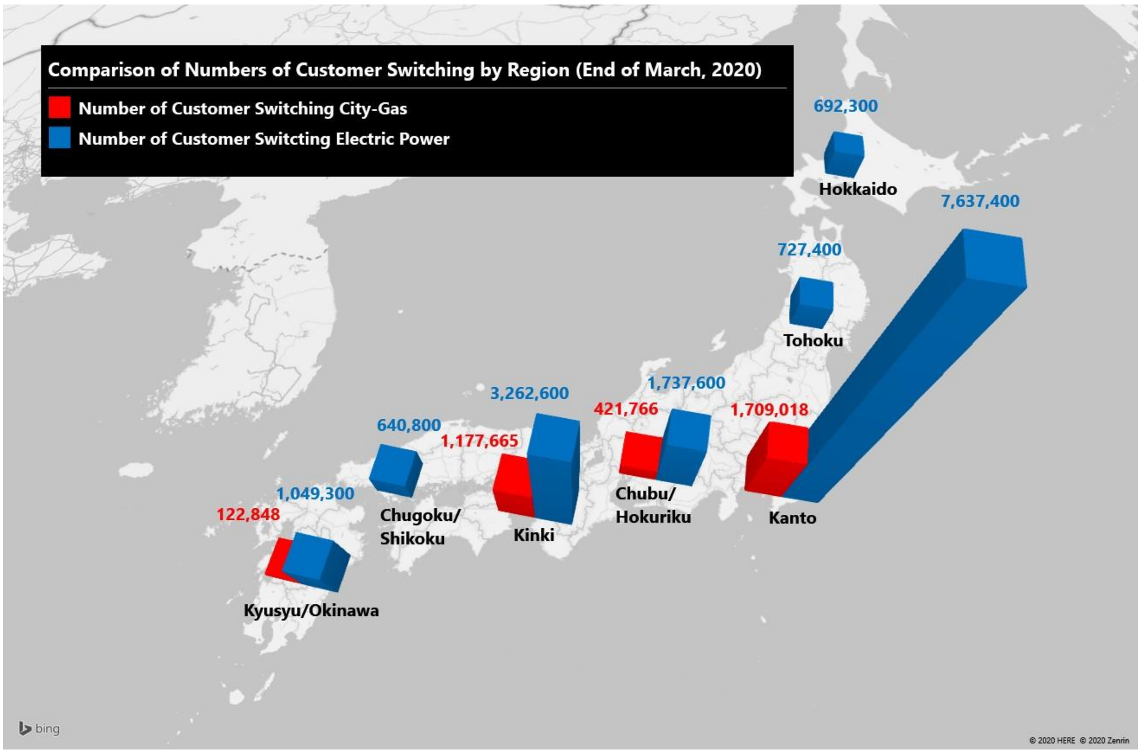

Fig. 2 Trends in Customer Switching

(Source) Compiled by the authors based on materials provided by the Agency for Natural Resources and the Organization for Cross-Regional Coordination of Transmission

3. Customer Switching Rates

When observing trends in the full retail market liberalization, it is useful to consider not only the cumulative number of switchings, but also the switching rate, which shows the rate of switching to the size of each market ,as well as the differences in the period when the full liberalization of retailing was implemented. In addition to the different timings of the full retail liberalization of city-gas and electricity, there are differences in market sizes between regions and between city-gas and electric power.

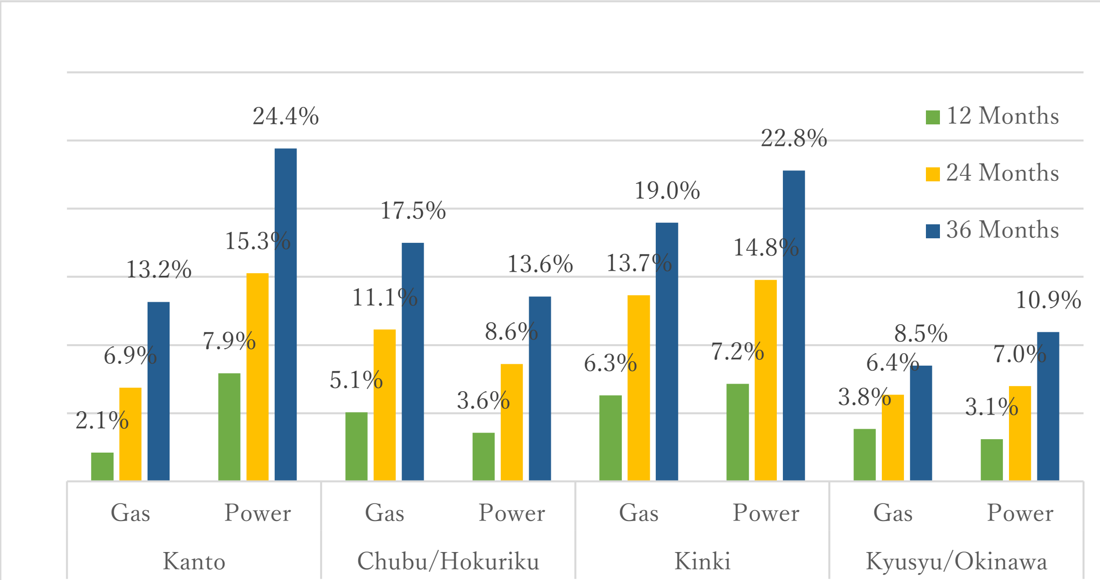

Fig. 3 Customer Switching (Losing) Rates After 12, 24 and 36 months of City-Gas and Electric Power Retail Liberalization

(Source) Compiled by the authors based on publicly available information

Fig. 3 shows the city-gas and electric-power switching rates - in the four regions where customers have switched providers in both city-gas and electric-power markets - by year until three years after the start of respective retail liberalization[4]. After three years, the electric-power switching rates in the Kanto and Kinki regions were more than 20%. City-gas and electric-power switching rates were all more than 10%, except for the Kyusyu/Okinawa region. Except for the Chubu/Hokuriku region, the city-gas switching rates have been lower than electric-power switching rates for respective regions.

4. Topics by Region

<Hokkaido>

Hokkaido Electric Power has lost about 690,000 residential electric-power customers, due to entry by Hokkaido Gas and other new entrants. In April 2020, Ichitaka Gas One, an LPG provider of the Saisan Group, started city-gas retail services for residential customers within the Hokkaido Gas service area, except for certain municipalities. Ichitaka Gas One makes use of the 'start-up wholesale' service[5] provided by Hokkaido Gas to supply retail customers. As Ichitaka Gas One's city-gas pricing menu may not look very attractive as it is the same as that of Hokkaido Gas, the company tries to attract customers by offering bundled services of city-gas,

[4] Figures are from April 2016 to March 2019 for electric power and from April 2017 to March 2020 for city-gas

[5] The 'start-up wholesale' service is defined as a voluntary arrangement by the incumbent city-gas utility company to promote wholesale activities to make city-gas supply sources available to new entrants at prices competitive enough against the incumbent retail services at specific market locations.

kerosene and electric power with discount pricing. Meanwhile, Hokkaido Electric Power also announced at its FY 2019 financial presentation its plan to start city-gas retail services taking advantage of the 'start-up wholesale' service.

<Tohoku>

Tohoku Electric Power has lost about 730,000 residential electric-power customers. Tohoku Electric Power has already registered as a retail city-gas provider, although the company has not entered the retail city-gas market yet. In April 2020, the municipal city-gas business in Nikaho City, Akita Prefecture, was acquired by TOKAI Group, which is an LPG service company, and relaunched its city-gas business as Nikaho Gas. In addition, Tohoku Electric Power and Nikaho Gas started offering a bundled discount service of electric power and city-gas.

<Kanto>

Kanto is the region where the largest number of customers have switched their city-gas and electric-power retail providers. The consortium of TEPCO Energy Partner, Nippon Gas (Nicigas) and Tokyo Energy Alliance (TEA) announced that the total number of city-gas customers of city-gas operators in the country using the TEA platform had amounted to more than 2 million in March 2020. The platform has been adopted by about 30 companies in the Kanto, Kinki and Chubu regions. In addition, Nicigas alone has acquired 100,000 electric-power customers, making it one of the most notable companies in the Kanto area. In April 2020, CD Energy Direct, established by Chubu Electric Power and Osaka Gas, announced that it had received 200,000 applications for electric power and city-gas, including contracts with service providers. Meanwhile, Tokyo gas announced that it had acquired 2 million retail electric-power customers as of August 2019.

<Chubu/Hokuriku>

In the urban areas of the Chubu region, Toho Gas and Chubu Electric Power Miraiz are intensifying competition to acquire retail customers in the city-gas and electric-power markets. Toho Gas announced during its FY 2019 result presentation that it had acquired 330,000 electric-power customers by the end of March 2020. Meanwhile, Chubu Electric Power Miraiz has acquired more than 300,000 city-gas customers. Although Hokuriku Electric Power has not entered the city-gas business, the company has tried to solidify its customer base by forming business alliances with several city-gas companies to provide combined offers of city-gas and electric power, and other service programs.

<Kinki>

Osaka Gas announced at the time of its FY 2019 reporting that it had acquired 1.32 million electric-power customers by the end of March 2020. Meanwhile, Kansai Electric Power announced at the time of its FY 2019 financial reporting that it had acquired 1.22 million city-gas customers by the end of March 2020. The two companies are still in fierce competition for customers, with new pricing menus and active campaigns.

<Chugoku/Shikoku>

Chugoku Electric Power has lost about 380,000 and Shikoku Electric Power has lost about 260,000 residential electric-power customers, respectively. However, the two companies have not entered the city-gas business. Also, city-gas companies in various areas have not entered the electric-power business. Hiroshima Gas is partnering with Chugoku Electric Power and Shikoku Gas is partnering with Shikoku Electric Power for customer-loyalty-reward programs, respectively, in an effort to secure customers by expanding services.

<Kyusyu/Okinawa>

Kyusyu Electric Power has lost about 1.01 million and Okinawa Electric Power has lost about 30,000 residential electric-power customers, respectively. Kyusyu Electric Power announced that it had acquired 110,000 residential city-gas customers as of September 2019. Meanwhile, Saibu Gas announced that it had acquired 100,000 residential electric-power customers as of July 2019. In Kagoshima Prefecture, Koa Gas, an LPG service company, started city-gas retail business in April 2020 for residential use within the Nihon Gas' service area. Koa Gas makes use of the 'start-up wholesale' service provided by Nihon Gas to supply retail customers. Koa Gas' website does not provide information on its pricing and service area.

5. Future Trends

More than three years have passed since Japan’s city-gas retail market for all the market, and the new entrants are appearing one after another in urban areas such as Kanto and Kinki, and competition for customer is getting fiercer by setting different pricing menus and improving services. In fact, as the number of switching cases and switching rate are increasing year by year and existing suppliers are also taking measures to improve services to secure customers, so that many customers in these areas have benefited from the retail liberalization.

On the other hand, the number of switching cases is still zero in the Hokkaido, Tohoku and Chugoku/Shikoku regions as of the end of March 2020. However, new entrants are emerging in the city-gas retail services in Hokkaido and Kagoshima, taking advantage of the 'start-up wholesale' arrangement, which should be watched carefully. The 'start-up wholesale' service is defined as a voluntary arrangement by the incumbent city-gas utility company to promote wholesale activities to make city-gas supply sources available to new entrants at prices competitive enough against the incumbent retail services at specific market locations. But the arrangement is closely in line with the policy direction of the gas industry restructuring - securing stable city-gas supply services, keeping prices paid by consumers at the lowest possible level, providing diversified service programs and business opportunities, and expanding utilization of natural gas - especially helping new entrants into the city-gas retail business. The next question is whether other areas will see more cases of new entry with effective use of the 'start-up wholesale' arrangement, leading to fruits of the liberalization to be enjoyed by more and more customers in all regions.

Analysis of low-voltage power market competition four years after electricity retail deregulation◆

Hideaki Okabayashi*

1. Review of sales by new PPS companies

Four years have passed since new power producers and supplier companies began to sell electricity to low-voltage users such as residential and commercial users upon the full electricity retail deregulation in April 2016. I would like to review electricity sales by those new PPS companies and analyze reasons for relevant developments, based on monthly Electricity Trading Reports by the Electricity and Gas Market Surveillance Commission.

1-1. New PPS companies' share of low-voltage power sales sharply rose to 16.8%

New PPS companies' share of low-voltage electricity sales soared rapidly to 16.8% (17.3% for low-voltage lighting services and 12.6% for low-voltage power services). In an apparent synergy effect, their share of high-voltage electricity sales that were deregulated 15 years ago almost doubled in the four years.

1-2. New PPS companies won 1.1 trillion yen per year in low-voltage electricity sales

Sales volume, the number of contracts and sales value for traditional electric power utilities and new PPS companies in the year to February 2020 have been tabulated (Table 1).

Although traditional power utilities had occupied low-voltage electricity sales until March 2016, new PPS companies won 45,921 GWh per year in such sales volume, 10.85 million contracts per month (a total of 130 million contracts per year) and 1.1 trillion yen per year in sales value from traditional utilities.

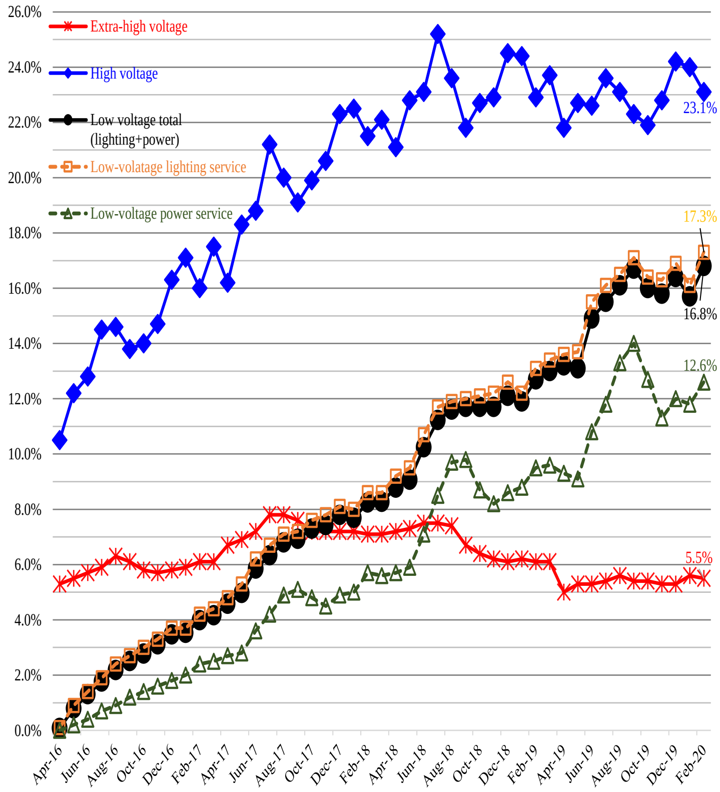

Fig. 1 New PPS companies' share of nationwide electricity sales

Prepared from Electricity Trading Reports by the Electricity and Gas Market Surveillance Commission

Monthly average low-voltage sales per contract came to 353 kWh or 8,432 yen for new PPS companies, some 30% higher than 278 kWh or 6,281 yen for traditional power utilities, indicating new PPS companies' cream-

◆ This paper adds "reasons for customers' switching to new PPS companies" to a report in the June 2020 issue of *EDMC Energy Trend*.

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skimming practice of attracting high-value customers with lower unit prices for higher consumption. Many new PPS companies discount unit prices for highest or third bracket users (more than 300 kWh per month) in the lighting service market featuring progressive unit prices (Table 2) and those for larger-lot customers (paying higher basic charges) in the low-voltage market (Table 3), resulting in PPS companies' gap with traditional utilities in sales per contract.

Table 1 Annual nationwide electricity sales volume, contracts and value

		New PPS companies						Traditional power utiities (deemed retailers)				
		Extra-high volatage	High voltage	Low voltage total	Low-voltage market share	Lighting	Electric power	Extra-high voltage	High voltage	Low voltage total	Lighting	Electric power
Annual electrcity sales volume (GWh)	①	12,519	69,322	**45,921**	**15.3%**	41,922	3,999	217,265	232,248	254,264	223,935	30,328
Total number of contracts (1,000 contracts per year)	②	18	2,698	**130,209**	**12.5%**	123,339	6,870	114	7,393	915,326	845,754	69,572
Annual sales value (million yen)	③	167,348	1,137,569	**1,097,979**	**16.0%**	985,834	112,145	2,615,354	3,646,308	5,749,074	4,968,261	780,814
Electricity sales volume per contract (kWh/contract, month)	①÷② ×1,000	706,625	25,694	**353**	**122.8%**	340	582	1,904,179	31,416	**278**	265	436
Electricity sales value per kWh (yen/kWh)	③÷①	13.4	16.4	**23.9**	**104.8%**	23.5	28.0	12.0	15.7	**22.6**	22.2	25.7
Sales value per contract (yen/contract, month)	③÷② ×1,000	9,445,618	421,648	**8,432**	**128.8%**	7,993	16,324	22,921,798	493,239	**6,281**	5,874	11,223

		Nationwide total				
		Extra-high voltage	High volatage	Low voltage total	Lighting	Electric power
Annual electrcity sales volume (GWh)	①	229,784	301,570	300,185	265,857	34,327
Total number of contracts (1,000 contracts per year))	②	132	10,090	1,045,535	969,093	76,442
Annual sales value (million yen)	③	2,782,702	4,783,877	6,847,053	5,954,094	892,959
Electricity sales volume per contract (kWh/contract, month)	①÷② ×1,000	1,743,219	29,887	287	274	449
Electricity sales value per kWh (yen/kWh)	③÷①	12.1	15.9	22.8	22.4	26.0
Sales value per contract (yen/contract, month)	③÷② ×1,000	21,110,504	474,097	6,549	6,144	11,682

Prepared from annual data into which monthly data in the EGC Electricity Trading Reports from March 2019 to February 2020 were totaled.

Table 2 Low-voltage lighting service prices for a traditional utility and a new PPS company

		Example: Traditional utility A (Transitional lighting service price)	Example: New PPS company B (Deregulated lighting service price)	B-A gap
Basic price	per 10A	286.00 yen/contract, month	286.00 yen/contract, month	±0.00 yen/contract, month
Power price	[1st stage] 1-120 kWh	19.88 yen/kWh	19.85 yen/kWh	△0.03 yen/kWh
	[2nd stage] 121-300 kWh	**26.48 yen/kWh**	25.35 yen/kWh	△1.13 yen/kWh
	[3rd stage] 301 kWh or more	30.57 yen/kWh	**27.48 yen/kWh**	△3.09 yen/kWh

Prepared from electricity price tables on websites of Companies A and B

Table 3 Low-voltage power service prices for a traditional utility and a new PPS company

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	[3rd stage] 301 kWh or more	30.57 yen/kWh	**27.48 yen/kWh**	△3.09 yen/kWh

Prepared from electricity price tables on websites of Companies A and B

1-3. New PPS companies' higher average unit sales price, impacts of gaps between regional regulated prices

It is generally known that new PPS companies have taken advantage of lower prices to expand their share of electricity sales. Strangely, however, the average sales value per kWh in Table 1 stands at 23.9 yen for new PPS companies, higher than 22.6 yen for traditional power utilities. One reason for the gap may be new PPS companies' practice of attracting high-value customers with lower unit prices for higher consumption. Another apparent reason is that large gaps between regional regulated electricity prices lead new PPS companies to be more competitive (with higher market shares) in regions where regulated prices are higher and less competitive than in those where such prices are lower, resulting in new PPS companies' higher unit price as the weighted average.

Table 4 New PPS companies' share of electricity sales by region and regulated unit rates

	New PPS companies			Nationwide total	Comparison target (regulated price for traditional utilities)	
	Low-volatage electricity sales (GWh)	Sales share (%)	Order	Low-voltage electricity sales volume (GWh)	(yen/353kWh, month)	Order
Hokkaido	1,680	13.1%	3	12,817	12,063	10
Tohoku	2,239	8.3%	6	26,867	10,376	9
Tokyo	22,429	22.6%	1	99,451	10,188	7
Chubu	4,340	11.3%	4	38,498	9,603	3
Hokuriku	349	3.8%	9	9,087	9,335	1
Kansai	9,807	20.0%	2	48,925	9,684	4
Chugoku	1,037	5.3%	8	19,552	9,836	5
Shikoku	789	7.7%	7	10,204	9,920	6
Kyushu	3,161	10.0%	5	31,668	9,567	2
Okinawa	90	2.9%	10	3,116	10,374	8
Nationwide total	45,921	15.3%	—	300,185	10,006	—

Prepared from annual data into which monthly data in the EGC Electricity Trading Reports from March 2019 to February 2020 were totaled and from data on websites of traditional power utilities.

* Traditional power utilities' regulated prices are compared by new PPS companies with the prices for the PPC average electricity consumption of 353 kWh per month.
Those prices are for the meter rate lighting B plan (contract current at 40 amperes) for Hokkaido, Tohoku, Tokyo, Chubu, Hokuriku and Kyushu, for the meter rate lighting A plan (unrelated to contract current) for Kansai, Chugoku and Shikoku, and for the meter rate lighting plan (unrelated to contract current) for Okinawa in February 2020.
The prices include the 10% consumption tax, fuel cost adjustments and the renewable energy promotion surcharge, without reflecting discounts for account transfer payments.

2. Analyzing reasons for switching to new PPS companies

2-1. Reasons for users to switch new PPS companies: Prices

Lower electricity prices are a reason that can be immediately assumed for the shift of 1 trillion yen in annual low-voltage electricity sales to new PPS companies. In fact, most new PPS companies have lower price plans than traditional power utilities. There are many electricity price comparison sites on the internet, and consumers receive phone calls and direct mails from new PPS companies publicizing lower electricity prices. Lower electricity prices may thus be leading users to switch to new PPS companies. One of the objectives for deregulating electricity retail is to hold down electricity prices as much as possible[1]. Users' selection of power suppliers is undoubtedly designed to hold down electricity prices.

How much lower are PPS prices? Each household can use power price comparison websites, leading us to assume that overall PPS prices would be lower. As discussed in 1-3, however, the average unit price for new PPS companies is higher, while it is difficult to get adjustment information such as each new PPS company's breakdown of electricity consumption by volume bracket, and the number of contracts and sales by region. Therefore, I would like to leave the question of how much lower PPS prices are to be answered in the future.

[1] "Integrated Energy System Reform," Agency for Natural Resources and Energy website
https://www.enecho.meti.go.jp/category/electricity_and_gas/energy_system_reform/

2-2. Reasons for users to select new PPS companies: Non-price reasons

In fact, prices alone cannot easily lead consumers to switch to new PPS companies. How does each new PPS company attract customers with non-price incentives? I collected and grouped information about sales promotion by the top 100 new PPS companies in the low-voltage electricity market for households and shops in a bid to verify non-price reasons for customers to switch to new PPS companies. Many new PPS companies refused to publish prices and proposals for sales promotion to corporate customers, making it difficult for us to understand the relevant realities. Therefore, their sales to corporate customers are exempted from the verification.

<Method for verifying non-price reasons for new PPS companies to be selected>

○ Annual sales from March 2019 to February 2020 were computed for 619 new PPS companies covered by the Electricity Survey Statistics ((3)-1 electricity demand) published by the Ministry of Economy, Trade and Industry on May 29, 2020. Then, 399 companies reporting sales in the low-voltage electricity market in February 2020 were selected.

○ Among those in the low-voltage market, the top 100 companies in sales were selected as those selling electricity to individuals according to information on their websites. In this process, 21 companies having no record of sales to individuals were excluded. In this way, the top 100 companies were sampled from 378 companies excluding the 21 firms. Although the number 100 looks far smaller than indicated by the total number of 378, the 100 companies account for more than 97% of annual PPS sales in the low-voltage market, indicating the number as significant for explaining changes in PPS companies' share of total sales in the market.

○ From the websites of the top 100 companies, information on sales areas, mainstay businesses for contacts with customers, the presence or absence of contract cancellation penalties, contract terms and values, new price plans and services, etc. was collected for cross tabulation.

① Satisfaction and me-tooism (selection from numerous options, nearby people are switching, companies seen frequently on commercials and banners)

Generally, people feel satisfaction when selecting from numerous options, although such selection is accompanied by confusion. There is me-tooism when people see others selecting some companies or see these companies frequently on commercials. I checked the distribution of the top 100 new PPS companies' sales areas to find how far they participated in the market (Table 5).

In regions other than Okinawa served by Okinawa Electric Power Co., there are numerous options, as shown by the distribution. There are more new PPS companies in regions having greater economic sizes. Correlation is seen between the number of new PPS companies in a region and their share of regional sales (new PPS companies' large share in Hokkaido may be attributable to higher regulated prices).

Among the top 100 PPS companies, those offering services in Okinawa are two mobile carriers, a travel company and a new specialized PPS company.

Table 5 Sales areas of top 100 new PPS companies

	Sales areas for top 100 companies	Share of sales in Electricity Trading Reports (same as in Table 1-4)
Tokyo	65	22.6%
Kansai	55	20.0%
Chubu	51	11.3%
Kyushu	51	10.0%
Tohoku	47	8.3%
Chugoku	43	5.3%
Shikoku	38	7.7%
Hokkaido	36	13.1%
Hokuriku	31	3.8%
Okinawa	4	2.9%

② Security, confidence (familiar, credible)

Given that dealing with familiar or credible companies can enhance security or confidence and become a reason for selecting a new PPS company, I put in order the relationship between the top 100 new PPS companies' mainstay businesses and their sales shares (Table 6).

Those having continuous contacts with consumers through their respective mainstay businesses boast higher sales shares, including nine city gas companies, three mobile carriers, four telecommunications (optical communications and cable TV) companies, 27 liquefied petroleum gas companies, and three oil companies.

Table 6 Mainstay businesses of top 100 new PPS companies

	Low-voltage market sales volume (GWh)	Share (%)	Number of companies	Cancellation penalty Present	Cancellation penalty Absent
City gas companies	14,885	36.7%	9	-	9
Mobile carriers	7,869	19.4%	3	1	2
Specialized PPS firms	4,459	11.0%	37	14	23
Telecom (optical/CATV)	3,809	9.4%	4	1	3
LPG firms	3,100	7.6%	27	10	17
Oil firms	2,878	7.1%	3	-	3
Cross-border sales by traditional utilities	1,269	3.1%	4	1	3
Cooperatives (regular delivery)	870	2.1%	10	-	10
Travel firms	599	1.5%	1	1	-
Railway firms	588	1.4%	1	-	1
Mass retailers	281	0.7%	1	-	1
Total	**40,609**	100.0%	**100**	**28**	**72**

Specialized PPS companies are struggling due to their small sales shares as they lack continuous contacts with consumers and have difficulty taking advantage of any other businesses for selling electricity. (The presence or absence of a contract cancellation penalty is discussed later).

③ Fitness (suitable for equipment, favorite)

A sense of fitness about equipment in possession (such as electric and other heat sources and telecommunications) and values (such as consciousness of environmental and regional contributions, and risk tolerance) can be a reason for switching to a new PPS company.

Electricity retail deregulation was intended to lead to new price plans and services [2]. In fact, numerous price plans and services that fit various equipment and values and can be customized have been offered (Table 7).

Table 7 Conditional price plans of 64 among top 100 new PPS companies (including overlaps)

	Plan overview	Number of firms
Plans meeting equipment or values	Prices for all-electric houses	11
	Renewable energy (higher)	8
	Regional contributions (higher)	3
	Linked to JEPX market trends	2
	Discounts for introducing other customers	2
	Pedometer-linked discounts	1
Combined discounts	City gas	21
	LPG	19
	Delivery system	9
	Telecom (optical/CATV)	8
	Water delivery	4

	Plan overview	Number of firms
Combined discounts	Equipment in possession or under leasing	4
	Mobile phones/cheap SIM cards	3
	Proprietary credit cards	3
	Kerosene	3
	Fueling	1
	Vehicle leasing	1
	EV purchase	1
	Water services	1
	Website registration	1
	Relatives' subscriptions	1

* No company pursuing local consumption of locally generated electricity (as cited by the Agency for Natural Resources and Energy) was discovered.

Price plans for all-electric houses have increased, while plans that had not been expected have appeared, including plans contributing to renewable energy diffusion and regional communities, those reflecting price changes on the Japan Electric Power Exchange, and network business plans that offer greater discounts in exchange for the introduction of other customers.

There are also discount price plans combined with mainstay or new businesses of new PPS companies. Simple discount price plans for electricity sales alone were offered by only 36 of the top 100 new PPS companies.

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[2] "What Changes Would Come from the Full Electricity Retail Deregulation?" Agency for Natural Resources and Energy website https://www.enecho.meti.go.jp/category/electricity_and_gas/electric/electricity_liberalization/merit/

④ Easiness (If a new PPS is not satisfactory, a customer may be allowed to switch back to a traditional utility)

The absence of a contract cancellation penalty leads to easiness of switching, lowering hurdles to switching to new PPS companies. As indicated in Table 6, 72 of the top 100 new PPS companies take advantage of the absence of a contract cancellation penalty for attracting new customers. The remaining 28 companies require contract cancellation penalty payments. Lower ranked companies feature higher cancellation penalty fees, longer cancellation penalty periods and automatic contract renewal (Table 8). This means that it is difficult for consumers to select companies requiring contract cancellation penalty payments.

Table 8 Distribution of 28 companies requiring contract cancellation penalty payments by sales, cancellation penalty fee and cancellation penalty period brackets

Sales volume ranking \ Cancellation penalty	500 yen	2,000 yen	3,000 yen	3,000 yen	Basic price× 1.5	3,500 yen	3,500 yen	3,850 yen	5,000 yen	5,400 yen	9,800 yen	15,000 yen	N/A	Number of firms
Cancellation penalty period	1 year	1 year	1 year	2 years	1 year	1 year	2 years	Renewal in 2 years	1 year	Renewal in 3 years	2 years	3 years		
1st-20th	1	1	2											4
21st-40th		1	1				1							3
41st-60th		2	5											7
61st-80th		1	2	1	1			1				1		7
81st-100th					1	1			1	1	1		2	7
Total number of firms	1	5	10	1	2	1	1	1	1	1	1	1	2	28

(Note) A cancellation penalty period is a period within which a party cancelling a contract must pay a penalty fee. “Renewal” means automatic contract renewal. Contract termination in months other than designated expiration months amounts to cancellation. (Some companies do not designate contract expiration months.)

3. Evolving and deepening electricity deregulation and prospect

The full electricity deregulation is evolving and deepening while providing customers with various options.

Not only the top 100 new PPS companies on which this paper focused, traditional power utilities are also enhancing their customer services by offering new electricity price plans, various combined discounts, visualization services and cross-border sales in Japan. Therefore, irrespective of whether customers have switched to new PPS companies, all people have variously benefitted from the full electricity deregulation. Among the 278 lower-ranked new PPS companies are regional firms that fail to grow due to their policy of selling locally generated power to local customers.

However, there are matters of concern for the future, including heavy incentives for high-consumption (high-value) customers that make it difficult to analyze unit prices, as well as potentially illegal practices regarding contract cancellation penalty. I would like to identify up-to-date information and track changes.

In the future, traditional power utilities are expected to change their electricity price plans through the restart of nuclear power plants. I would like to continuously analyze how new PPS companies would follow traditional power utilities regarding electricity procurement and price plans and what their financial profiles are.

The Spread of COVID-19 and Suggestions for Future Smart City Plans

Yu Nagatomi*

Countermeasures to the global spread of infectious diseases are being considered as a result of the spread of COVID-19 (the novel coronavirus disease). In our daily lives, we are now being called upon to adopt new lifestyles whereby we avoid crowds and crowding and ensure social distancing, and it has been pointed out that the spread of COVID-19 has the potential to bring about changes to our way of thinking, with this including how public health ought to be structured moving forward. Cities formed along with the development of industry in order to improve the convenience and efficiency of everyday life by having people cluster together. Yet the spread of COVID-19 has the potential to alter our sense of values with respect to cities. As a result, it is conceivable that progress will continue to be made with redesigning existing smart city projects and reassessing urban development for a post-coronavirus world based on the use of digital technologies, changes in people's behavior, and the way infrastructure ought to be configured moving forward.

In light of the aforementioned awareness of the issues, this paper will perform a literature survey focused primarily on the most recent studies with the aim of sorting out the issues in question and offering proposals in order to find suggestions for future smart city plans from among the changes in people's awareness and behaviors brought about by the spread of COVID-19. This will be centered around the three axes below of: (1) the spread of COVID-19 and reviews of smart city projects, (2) the composition of cities and concentrations of people in the Society 5.0 era, and (3) legislation and smart cities in Japan.

1. The spread of COVID-19 and reviews of smart city projects

- **Advances in digital technologies and smart city projects**

The collection and analysis of a wide variety of data as a result of the recent advances in digital technologies has given rise to hopes regarding the pursuit of improved productivity and convenience. The adoption of data usage is moving forward in a wide variety of sectors, including manufacturing and retail. What is more, a new type of urban development project referred to as "smart cities" is being promoted in various countries as a type of initiative to harness digital technologies to achieve smarter urban design and social systems as a whole.

The **Cabinet Office (2020a)** has listed examples of smart cities in other countries that include the suburbs of Toronto in Canada, the United States, Buenos Aires in Argentina, Xiong'an New Area in China, Songdo City in South Korea, Singapore, Dubai in the UAE, Barcelona in Spain, Estonia, Helsinki in Finland, Amsterdam in the Netherlands, and more. Chief among these, Sidewalk Labs, a subsidiary of the major IT company Google, is promoting the case in Toronto, Canada, which had been garnering enormous attention.

- **The spread of COVID-19 and reappraisals of smart city-related projects:**

As reviews of smart city projects were moving forward in a number of countries, it was being pointed out that there was a possibility that the global spread of COVID-19 that began at the end of 2019 could give rise to changes in people’s behavior and to urban development. In particular, the potential for achieving measures to combat infectious diseases through the use of smart city technologies, primarily digital technologies, was identified.

Barcelona has pointed out the possibility that, amidst the environmental changes that have come about due to the spread of COVID-19, harnessing digital technologies offers the potential to be able to smoothly proceed ahead with calling off lockdown measures **(Barcelona (2020))**. In addition, Dubai has pointed to the fact that

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cities must ensure an even greater degree of resilience from the perspectives of employment, corporate management, and services with respect to the existence of cities that have been affected by the spread of COVID-19 and strategies that include resilience **(Smart Cities World News Team (2020))**. Ravi Seethapathy, who is an ambassador for the Global Smart Grid Federation, has stated with respect to the "new normal" that will follow COVID-19 that we must redefine our current way of thinking about smart cities, in which densely concentrating people together to boost the efficiency of public transportation and work convenience constitute important elements **(Ravi Seethapathy (2020))**. Specific examples he has raised for this include work spaces, virtual team work, residential spaces, schools, public areas, public transportation, and greetings. In response to these, he has pointed out that we must redefine our current plans for smart cities by considering issues like: (1) redesigning physical elements, (2) considering approaches to work through the use of digital technologies, and (3) personal protections against infection. As for the impact this will have on energy, it is conceivable that the expanded use of servers as a result of the use of digital technologies will increase energy consumption, while at the same time the energy consumption needed for commuting will decrease as a result of changing work styles due to people working remotely (working from home), and so forth. At this point in time it is difficult to predict which of these factors will have the greater impact. As we go about redefining smart city plans in the wake of the spread of COVID-19, this will conceivably give rise to shifts in the types of energy consumed and qualitative changes in our energy consumption.

In relation to public health issues related to preventing infectious diseases in particular, **Sugiyama (2020)** has pointed to a number of measures to reduce our environmental impact since before the spread of COVID-19. These include how many researchers of environmental problems and activists have been encouraging people to ride together in automobiles through ride-sharing and reducing energy consumption by improving the utilization rates of facilities, and other measures that had been expected to contribute to lessening the environmental impact. In this capacity, Sugiyama points to the possibility that due to the spread of COVID-19—the so-called coronavirus pandemic—emphasis is being placed on the upsurge in people's health preparedness which has historically persisted, which in turn may lead to expanding energy consumption by promoting private ownership of goods and spaces, such as by promoting increased use of privately-owned automobiles instead of vehicle ride-sharing, for example. He also indicates the importance that health preparedness has as a driver of future scenarios.

As part of a study concerning the spread of COVID-19 and cities in Japan, **Fujita and Hamaguchi (2020)** found that during the period when COVID-19 infections were spreading in Japan, the connection between the increase in people infected by prefecture and the proportion of the population of each prefecture to the national total indicated a trend whereby the number of people infected was rising the most in places where people are densely concentrated, mainly Tokyo. They pointed to the "effects of population size," based on which they posited that "Major cities that have grown as a result of the 'Three C's' (closed spaces, crowded places, and close-contact settings) are faced with the paradox that they must now avoid the Three C's to evolve in response to the risk of infectious diseases in the future. The key to overcoming this lies in ensuring that office work and remote work function in a complementary manner, rather than having one replace the other" **(Fujita and Hamaguchi (2020))**. In Japan as well, when it comes to modalities for cities the back and forth of people primarily centered around modalities for how workplaces are structured and the growth in data communications through the increased use of digital technologies could potentially result in the emergence of changes to both the places where energy is used and the amount consumed unlike those seen in past trends.

- **The Google subsidiary Sidewalk Labs has pulled out of a smart city project**

Canada's Sidewalk Toronto project is one of the projects which is expected to make greater use of data and which has garnered the greatest amount of attention from the smart city plans due to the involvement of a subsidiary of the major IT company Google. However, amidst discussions over reappraising its smart city plans in the wake of the spread of COVID-19, on May 7, 2020 Daniel Doctoroff, a representative of Sidewalk Labs, announced that the company's continued involvement in the project had become difficult due to the unforeseen decline in economic transparency in both global real estate markets and Toronto's own market.[1]

The Sidewalk Toronto project was launched in October 2017. Sidewalk Labs categorizes the composition of cities up into the physical areas of infrastructure, public areas, mobility, and buildings, as well as a digital layer. The project had been planning to undertake urban development as a platform for coordinating between these various different layers **(Iran Hayashi (2020))**. Issues with data privacy had been pointed out as one of the challenges with promoting the project. In April 2019 the Canadian Civil Liberties Association (CCLA) initiated legal proceedings to shut down the project **(Iran Hayashi (2020))**. Such incidents point to the concerns felt over privacy violations due to the sensors used to handle big data as well as the ownership of said data, and the project was plagued by repeated delays. Sidewalk Labs has stated that its reasons for discontinuing its involvement in developing smart cities was due to the financial challenges this entailed. Yet some have pointed to the possibility that this was directly caused by issues of data and privacy given the development of digital technologies related to this project, as well as the relationship of trust between Sidewalk Labs and the city of Toronto **(Gaku Funada (2020) and Masahiro Ogamino (2020))**. The claim could be made that the company's withdrawal from the project in the wake of the spread of COVID-19 has resulted in renewed recognition of the challenges for smart city projects.

Some have pointed to the possibility that the spread of COVID-19 will prompt people to change how they think about and behave in their everyday lives, and that the impact from this could even extend to changes in our sense of values for things like health preparedness. We must adopt the use of digital technologies and alter people's behavior in order to achieve a new lifestyle in which we avoid crowds and crowding as a countermeasure against infectious diseases. When it comes to urban development for a post-coronavirus world, consideration will continue to be given to the changes liable to newly arise in the wake of the spread of COVID-19, as well as to responses to challenges that have once again been thrown into sharp relief with respect to the previous plans, such as issues surrounding data and privacy. The thinking is that this will lead to discussions over redesigning the existing smart city projects.

2. The composition of cities and concentrations of people in the Society 5.0 era

As was mentioned in the previous section, the spread of COVID-19 has sparked discussions on reappraising the thinking behind smart cities. Based on these, this section will lay out issues like urban values and an outlook for cities in a post-coronavirus / Society 5.0[2] era based on the composition of cities in Japan by referring to a study by Associate Professor Soichiro Takagi of the University of Tokyo announced at COMEMO by NIKKEI on the composition and roles of cities.

- **The concentration of the population in cities in Japan**

Takagi (2020a) posits that the concentration of the population in cities in the post-war period continued as a result of increased labor productivity in the agricultural industry and the shift from agriculture to manufacturing in the period of rapid economic growth from the 1960s to the 1970s. Then the latter half of the 1970s through the first half of the 1990s saw the concentration of white-collar manufacturing industry jobs in major cities and the relocation of factories overseas. As for the heavy concentration in Tokyo seen from the 1990s onward, he

[1] Daniel L. Doctoroff (2020), Why we're no longer pursuing the Quayside project — and what's next for Sidewalk Labs, May 7, 2020, https://medium.com/sidewalk-talk/why-were-no-longer-pursuing-the-quayside-project-and-what-s-next-for-sidewalk-labs-9a61de3fee3a

[2] The Cabinet Office (2020) defines Society 5.0 as "A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space." It goes on to state that, "In Society 5.0, AI exceeding the capabilities of humans analyzes vast quantities of big data and the results obtained from this are fed back to humans through robots and the like. This process brings new value to industry and society in ways not previously possible."

states that the shift to a knowledge-based economy coupled with urban redevelopment led to an erasure of the geographical constraints placed on cities, which in turn promoted this heavy concentration. He points out that each time transitions in the composition of industry have proceeded from agriculture to manufacturing, and then on to the information industry, the conditions required of residential areas have changed dramatically in order to procure the resources required for this. He points out that this has resulted in a history in which each transition has continued to heighten the pressure on people to concentrate in cities. In other words, the areas in which people resided were situated in rural regions when agriculture formed the heart of the economy, but in an economy centered around manufacturing these came to be situated around factories, then in locations where knowledge was concentrated with the knowledge industry.

When it comes to considering how cities should be structured in the future based on the spread of COVID-19, Takagi similarly organizes this by dividing up those elements of urban life that can be replaced by technology from those that cannot by applying the concept of deframing.[3] Of these, he listed those elements that cannot be achieved in short order in a technical sense by digital and other technologies as including the act of holding carefree discussions, standing around engaged in conversation, and enjoying the atmosphere of wherever they are, as well as the appeal of the actual site where artistic performances are held. In light of this, he points out that, “The majority of these are not directly tied to work, but are those moments found in the margins of daily life. Yet the fact of the matter is that perhaps this in itself constitutes one of the major reasons that people will continue to live in cities in the future” **(Takagi (2020a))**. In other words, such elements can be thought of as one example of the value that is likely to remain in cities as we consider new movement patterns for people, such as remote work, in societies that must respond to the coronavirus pandemic. Moreover, with regards to the value of cities **Nakagawa (2020)** has pointed out the importance of productivity that harnesses the "*technology* of cities" in light of the fact that people have continued to concentrate in cities in Japan over the long-term amidst past infectious diseases, earthquakes, and other such shocks. He posits that, "Rather than intermixing aggregation with crowding and congestion, perhaps we ought to emphasize the continued formation of aggregation that avoids the latter two" **(Nakagawa (2020))**.

From the studies by Takagi and Nakagawa mentioned above, as well as that by Fujita and Hamaguchi from the previous section, the presumption is that when it comes to urban development for a post-coronavirus world, it will be important to continue examining the question of what sort of value cities possess as a result of their clustering functionality together that is more than mere crowding and congestion, with this including the use of digital technologies.

- **What will concentrations of people look like in the Society 5.0 era?**

What is more, when it comes to the question of how cities ought to be structured in the coming Society 5.0 era, for the four eras that have led up to Society 5.0 (hunting era, agricultural era, industrial era, information era) **Takagi (2020b)** posits that the resources that were important in each era have differed, and that the differences in these resources have significantly altered the mechanisms by which populations clustered together (Fig. 1). In this regard, he contends that one important resource in the Society 5.0 era will be the ability to perform analysis in cyberspace, or in other words, the ability to generate insights. He points out that another important resource will be the data generated from physical spaces. Having passed from the decentralization of the hunting and agricultural eras through the eras of concentration in the industrial and information eras, the thinking is that in the Society 5.0 era the data generated by concentrations of people and analytical capabilities

[3] This is a neologism coined by Takagi that signifies the collapse of a framework (or frame). Here, the consideration will be advanced via the notions of "decomposition and recomposition," which are the foremost concepts of deframing.

that can be demonstrated anywhere will respectively serve as resources. The question of what direction clustering will move in as a result—whether people will move towards decentralization, or towards concentration, or in another direction entirely—has not been clearly elucidated within the discussion.

Industrial structure	Important resources	Directionality of clustering
Hunting era	Game	Decentralization
Agricultural era	Agricultural land	Decentralization
Industrial era	Factory plots / logistical access	Decentralization around a central core
Information era (Improving efficiency through digitization)	Access to information / face-to-face access to other people	Concentration
Society 5.0 Integration of cyber / physical spaces	Analytical abilities / access to technology	???

Fig. 1 Industrial structure, resources, and the directionality of clustering

(Source) Soichiro Takagi (2020b), “What will urban clustering look like in the Society 5.0 era?”

- **Alternatives to a future of urban concentration**

In response to smart city-type ideas that are predicated on clustering in cities in the information era, Professor Kazuto Ataka of Keio University has proposed the "Valley of Wind" concept as an alternative to a future of urban concentration. Ataka has this to say about the Valley of Wind: "If we persist in this manner on our present course, then I feel that mankind will inevitably arrive at a 'future of urban concentration.' Yet as opposed to this, perhaps there are other alternatives apart from this whereby the power of technology can be harnessed to live lives of abundance together with nature? This is our idea, to create a Valley of Wind-type future" **(Ataka (2020))**. Thus, he proposes future cities and social systems that harness technology. In this sense, the "Valley of Wind" concept sets forth automation through the use of technology as an unsolvable problem, while also raising the issue of converting the enormous burden of infrastructure costs in local regions that Japan is facing over to an off-grid approach, and also the issue of generating a "centripetal force" pushing people towards local regions by reorganizing the relationship with cities.

Consideration of the "Valley of Wind" concept began in the fall of 2017, and was announced by **Ataka (2020)** on March 2, 2020. As COVID-19 happened to begin spreading in Japan after the start of 2020, there was growing interest in moving away from the densely-packed life in cities to more socially-distanced lifestyles. The author is of the opinion that, based on the connection between industry, resources, and the direction in which clustering is headed as indicated in Takagi's discussion, Ataka's concept could potentially produce a diverse array of directions in which clustering could head as a result of new resources being sought-after outside of cities. It is impossible to foresee how this will be integrated with the social systems, urban development, and smart city plans of the Society 5.0 era. But it is conceivable that as the situation continues to change in light of the spread of COVID-19, there will likely be a growing need to pursue the possibility of alternatives to urban concentration.

Based on the above, the discussion by Takagi and Ataka's "Valley of Wind" concept can be thought of as raising points of view regarding questions of what sort of value is to be found in cities in a Society 5.0 era and a post-coronavirus world, what sort of value is to be found in alternatives to cities, and how to go about altering these via advances in digital technologies and technology in a broader sense.

3. Legislation and smart cities in Japan

As indicated above, discussions have been raised surrounding reassessing the thinking behind smart cities and over what are the inherent values of cities amidst the coronavirus pandemic. As part of this, Japan enacted the Super Cities Act as a law that will have an impact on future urban development. In addition, it has also set forth new governmental policies on improving infrastructure, which is an important element of urban development and will also pose a challenge given the country's declining population. This section will show examples of recent revisions to laws, while also laying out the hopes and challenges for the related laws when it comes to smart city projects, urban development, and improving infrastructure in Japan.

- **The Super Cities Act and reviews by local governments**

Japan's Super City Initiative[4] is being considered as an initiative that aspires to achieve the cities of the future by having local regions, businesses, and the national government work together by applying Japanese technology[5] to regional challenges. On May 27, 2020, the Bill for the Partial Amendment of the National Strategic Special Zones Law, which incorporates the establishment of systems geared towards achieving the Super City Initiative, was enacted. Regarding the role of the Super Cities Act, the **Cabinet Office (2020a)** has stated, "First, it will establish procedures for the simultaneous and integrated promotion of regulatory reforms in multiple sectors in order to simultaneously establish multiple services. Second, it will add provisions that will enable businesses engaged in projects to improve data linkage infrastructure to request that national and local governments provide the data in their possession." In other words, the expectation is that under this law local governments will submit project plans rooted in the consensus of their residents to the prime minister, based upon which reviews by each ministry will proceed forward in an integrated manner, thereby ensuring that consistency is maintained with the contents of said projects. What is more, the expectation is that this will be used in an orderly fashion through the use of the linkage infrastructure. Local governments will continue to formulate plans to resolve challenges in their own particular regions, and projects will proceed based on the approval of the national government. The subjects under review by local governments span a wide range, and as of June 1, 2020 the Cabinet Office has received ideas submitted from 56 organizations **(Cabinet Office (2020a))**.

- **Improving energy infrastructure and revising related laws**

Concurrent with the enactment of the Super Cities Act, which serves to set in place the legal framework for urban development as a whole, discussions were also advanced over revising laws related to improving the energy infrastructure that underpins said urban development. The Act for Establishing Resilient Energy Supplies[6] was adopted and enacted at a plenary session of the House of Councillors on June 5, 2020. This law

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[4] An overview of the Super City Initiative has been organized by the Cabinet Office (2020a) as indicated below. (1) Initiatives must not be proof-of-concept initiatives limited to individual fields like those for self-driving and renewable energies carried out to date. Rather, the initiatives must extensively cover daily life as a whole, including making payments completely cashless, making it so that administrative procedures only have to be carried out once, distance education and remote medical care, and making full use of self-driving within certain areas, for example. (2) The experiments must not be for temporary proofs-of-concept, but rather must be initiatives actually implemented within people's lifestyles and society in order to take the lead in achieving the lifestyle from the "ideal future" that is achievable by around the year 2030. (3) In addition, efforts must be made to achieve a better life from the perspective of the citizens, rather than from the perspective of the suppliers and technical experts.

[5] World-class Japanese technologies that were "developed in Japan" are referred to as "J-Tech."

[6] This law was enacted as a bill incorporating revisions to the Electricity Business Act, the Act on Special Measures Concerning

incorporated revisions to laws like the Electricity Business Act and the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities in the aim of responding to recent natural disasters, promoting the dissemination of renewable energy, and improving upon the development of energy networks centered around electricity. Particular items related to smart cities found within the law include the revision of the feed-in tariff (FIT) scheme, the introduction of a revenue cap scheme for wheeling charge, the formulation of cooperation plans for when disasters occur, cross-region grid development plans to develop "push-type"[7] power distribution grids, the adoption of licenses for electricity distributors, and consistency with the provisions of the Measurement Act. With regard to the improvement of power distribution grids in particular, an expert committee of the Organization for Cross-regional Coordination of Transmission Operators (OCCTO) has proposed deepening discussions in the form of a master plan. This is designed to promote cross-regional grid improvements that take costs and benefits into consideration while ensuring consistency with the Strategic Energy Plan and other plans.[8] The expectation is that presenting these legal frameworks and policies will ensure that resilient social infrastructure is set in place in a more efficient manner.

- **Legal frameworks in Japan and challenges for urban development and smart city-related projects during the coronavirus pandemic**

The thinking is that the Super Cities Act and the Act for Establishing Resilient Energy Supplies, which had been under discussion since prior to the spread of COVID-19, have laid the groundwork for promoting distinctive urban development and smart city plans at the local government level. The following section will lay out future challenges for urban development and smart city plans, including challenges that have come to the forefront due to the coronavirus pandemic.

- **Data and privacy issues**

With the data and privacy issues from Sidewalk Labs in mind, **Takahashi (2020c)** indicates the unique features of cities where data is concerned with the word “accountability.” Specifically, he points to the fact that projects are increasing in complexity as a result of the sharing and linking of data via the public nature of cities, their involuntary participatory nature, individual interventionality, and urban OS, and posits that the extent to which any one person is accountable presents a challenge. He is concerned that as cities get smarter on the whole, the relationship between the beneficiaries and the providers of data will continue to grow more complicated. As one example of responding to this challenge, he indicates that during an initiative by Kakogawa City that aimed to achieve a city where people could raise their children with peace of mind through the installation of surveillance cameras, the city worked to promote understanding among the residents by enacting ordinances, receiving comments from the public, and carefully addressing data and privacy issues. This is a case example where attempts were made to deal with the issue of accountability pointed out by Takahashi and the issue of trusting relations that arose between the people implementing the Sidewalk Labs project and the local government. Most recently, there have been initiatives in places like China and South Korea that make

Procurement of Electricity from Renewable Energy Sources by Electricity Utilities, the Act on the Japan Oil, Gas and Metals National Corporation, Independent Administrative Agency, and others in order to respond to challenges such as the frequency of natural disasters, changing geopolitical risks, and the primary sources of renewable energies.

[7] With respect to push-type grids, the Agency for Natural Resources and Energy (2019) has stated, "In the interest of promoting the large-scale adoption of renewable energy sources while curbing the burden on the public, it will be important to move ahead with considerations for shifting away from creating 'pull-type' grids, which comply with each request for power from a power source, to 'push-type' grids that comply with said requests in a systematic manner by taking the power source potential into consideration."

[8] Secretariat of the Cross-regional Grid Development Committee (2020), “Modalities for Shaping Core Grid Facilities (Basic Thinking behind the Master Plan regarding Electricity Grids),” Document 2 from the 48th meeting of the Cross-regional Grid Development Committee,
http://www.occto.or.jp/iinkai/kouikikeitouseibi/2020/files/seibi_48_02_01.pdf

use of data on infected people as measures to combat the spread of COVID-19, and even in Japan the Ministry of Health, Labour and Welfare (MHLW) has released a contact-tracing app for the novel coronavirus. While initiatives that harness digital technologies from a public health perspective like this are promising, issues of data and privacy regarding information on infected persons remains a point at issue.

With respect to data and privacy issues in considerations of smart cities, obtaining the consent of those involved, to include both residents of the city in question as well as the people who are not direct beneficiaries themselves, presents a challenge. In addition, the concern is that to the extent that data administrators are unable to clearly shoulder accountability, projects will not proceed ahead due to a lack of trust in the plans. Attention is being paid to how each local government is considering such questions under the Super Cities Act, including what sort of data each person is handling as well as the technical responses to this.

- **Installing core energy infrastructure and local infrastructure**

Under the Act for Establishing Resilient Energy Supplies, the thinking behind a master plan was presented that would provide predictability regarding the use of power distributor licenses and the improvement of electricity infrastructure at the national level. Conversely, under the Super Cities Act there are a diverse array of municipal projects and plans. In addition, uncertainties remain over how to promote the establishment of local infrastructure based on the smart city plans unique to each local government in harmony with the policy of establishing infrastructure in the form of core power grids based on the power potential as seen from Japan as a whole in a push-type approach. What is more, as consideration goes to ways of working with a certain degree of freedom, including ensuring social-distancing, and people examine urban development that makes it possible to avoid crowding that includes consideration for public health due to the spread of COVID-19, there will potentially come to be calls for the installation of sparse infrastructure in a manner that is spread out geographically. The expectation is that decentralized urban development covering a wide range whereby infrastructure is not excessively concentrated in urban areas will result in contributing to increasing the number of people bearing the cost of the infrastructure in rural regions.

For some time, discourse had been promoted on compact cities projects that were initiatives to reduce the cost burden and improve the efficiency of cities by promoting the concentration of infrastructure in rural areas. The compact cities concept was centered primarily around issues like the concentration of commercial districts and means of transportation. But under the Super Cities Act, considerations are being advanced on the efficient use of energy, with this including the local production of renewable energies for local consumption, together with the use of data, with the expectation being that comprehensive reviews will be carried out on the infrastructure underpinning people's lives. In light of the existing plans for smart cities and as we give consideration to post-coronavirus societies, attention will be paid to how the Super Cities Act and the Act for Establishing Resilient Energy Supplies will continue to contribute to new urban development and the formation of infrastructure.

4. Conclusion

This paper reassessed behavioral changes in people and the plans for smart cities in the wake of the spread of COVID-19. It also suggested and arranged various points at issue regarding what sorts of modalities for cities will be required in a post-coronavirus world through a literature survey. It also arranged trends with the relevant laws in Japan and their impact in relation to this. This literature survey did not try to organize and analyze a single direction on the whole. Rather, it was nothing more than an attempt to indicate the existence of a diverse array of viewpoints and to present outlooks that can prove useful for future considerations to the extent possible. The hope is that presenting these diverse viewpoints and outlooks can contribute to further analyses and considerations pertaining to this issue in the future.

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Germany's National Hydrogen Strategy toward Acceleration of the Energy Transition

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Summary

Germany is committed to an energy transition which facilitates a more efficient energy system and shifts from fossil fuels and nuclear power to renewable energy. Germany's long-awaited *National Hydrogen Strategy* was published on June 10, 2020. Hydrogen is expected as a crucial technology which will enable Germany to decarbonize the economy and accelerate the energy transition.

This was not a surprise beyond our expectations as some principles were reported by media before the official publication. Still, it is important to point out three issues as vital aspects of the strategy: first, blue hydrogen is allowed as a transitional technology although only green hydrogen is considered to be sustainable in the long-term; second, hydrogen import is expected to meet domestic demand in the future; and third, the State Secretaries' Committee on Hydrogen and the National Hydrogen Council are established for effective governance to implement the strategy.

The National Hydrogen Strategy is considered in two phases until 2030. In the first phase to 2023, the hydrogen market will be ratcheted up and a basis for domestic demand will be established. In parallel, fundamental measures such as research and development (R&D) will be undertaken. The second phase from 2024 to 2030 blueprints that the domestic hydrogen market will get on the right track, the European and international dimensions of hydrogen will be set, and the German industry will take this opportunity. There are 38 measures proposed in the strategy from the hydrogen supply chain to international cooperation for the first phase.

Germany's support for hydrogen deployment centers on R&D in the field of fuel cell and hydrogen technologies, even before hydrogen gains momentum, and has recently focused on more large-scale demonstration projects. There are also programs to develop the hydrogen refueling station network and introduce hydrogen fuel cell technology in municipalities and regions. Germany leads the world in the Power-to-Gas projects as they have increased in number and scale and are conducted in various sectors.

That the Federal Government showed approaches for hydrogen deployment and clarified the support for technology innovation will stimulate private investment in hydrogen technology. Taking the possibility of hydrogen imports into consideration, the Federal Government will establish and strengthen partnerships with countries which envisage hydrogen exports.

Introduction

Germany's long-awaited *National Hydrogen Strategy* went public on June 10, 2020.[1] It was not a surprise beyond our expectations as some principles were reported by media in early 2020 when a draft was circulated among ministries. Still, it is worthwhile to pay attention to the strategy to better understand how Germany approaches hydrogen energy in domestic and international markets.

Germany is committed to an energy transition which facilitates a more efficient energy system and shifts

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[1] The Federal Government (2020). *The National Hydrogen Strategy*. Berlin/ Federal Ministry for Economic Affairs and Energy (BMWi)

from fossil fuels and nuclear power to renewable energy. With the purpose of improving energy security, environmental sustainability, and economic efficiency, Germany has set out measures to increase renewable energy consumption and energy efficiency in order to achieve the energy transition target such as a reduction of greenhouse gas emissions of 55% by 2030 compared to the 1990 level and an expansion of the share of renewable sources in power generation to 65% by 2030. Renewable energy sources have steadily increased in power generation. However, the rapid growth of renewable energy has made it difficult to maintain the power grid because areas with abundant renewable energy sources are distant from the region where electricity demand is high, i.e., most wind power is installed in the north whereas the industry is more active in the south and west. In addition, the industry and transport sectors have struggled to make progress in decarbonization, which makes it seem difficult to achieve the 2030 target. Hence, hydrogen is expected as a crucial technology which will enable Germany to decarbonize the economy and facilitate the energy transition.

This report first sheds light on the important issues that require attention in the strategy and succinctly describes the goals and the action plans of the strategy. Then, some essential measures that Germany has implemented are presented to show the country's efforts to develop hydrogen industry/society. Several demonstration cases of Power-to-Gas (PtG) are also illustrated as Germany is the pioneer of PtG applications.

1. Germany's National Hydrogen Strategy

The *National Hydrogen Strategy*, whose publication was initially planned in 2019, came to light in June 2020. Disagreement among the ministries on targets of green hydrogen[2] production and the extent to which blue hydrogen should be used as a bridging technology seemed to delay the finalization of the strategy.[3] The strategy finally revealed how Germany encourages hydrogen development and explores international cooperation regarding hydrogen, as well as action plans in the hydrogen supply chain from production through transport to various applications. The strategy is a milestone that Germany pursues to lead the world in the field of hydrogen technology.

1-1. Key issues of the National Hydrogen Strategy

The media revealed some primary schemes of the National Hydrogen Strategy before it was officially approved. Nevertheless, it is important to grasp the fundamental policy direction of the strategy. This section presents the following three issues as vital aspects of the strategy: first, blue hydrogen is allowed as a transitional technology; second, hydrogen import is expected to meet domestic demand in the future; and third, the State Secretaries' Committee on Hydrogen and the National Hydrogen Council are established for effective governance to implement the strategy.

(1) Green hydrogen vs. blue hydrogen

The National Hydrogen Strategy clarifies Germany's position to prioritize green hydrogen. As only green hydrogen is regarded as sustainable in the long term, the Federal Government aims to accelerate its deployment and establish the necessary value chains. Carbon-free hydrogen including blue hydrogen and turquoise hydrogen is likely to be traded in global and European markets to be developed in the coming decade. Germany acknowledges that carbon-free hydrogen needs to be utilized as a transitional means until green hydrogen is supplied to meet demand at an affordable price. In Germany, opposition to the use of fossil fuels is intense due to the environmental impacts and it is difficult for CCS to receive public acceptance because concerns on the

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[2] There are different names for hydrogen by color which are customarily used, based on how it is produced. Green hydrogen is produced through electrolysis, a chemical process to extract hydrogen from water using renewable power. Grey hydrogen is extracted from fossil fuels such as natural gas and coal whereas blue hydrogen is the same as grey hydrogen but carbon capture and storage (CCS) technology is involved in the production process to reduce CO_2 emissions. Turquoise hydrogen is produced through methane pyrolysis.

[3] Amelang, S. (May 18, 2020) "Merkel's coalition partner pushes for ambitious green hydrogen production" *Clean Energy Wire*

possibility of CO_2 leakage are never be cleared. Such public resistance to CO_2 emissions stood in a way that blue hydrogen production was put on the table. However, Germany compromised and accepted carbon-free hydrogen in the strategy probably because hydrogen deployment needs to be prioritized to accelerate decarbonization against climate change. One condition attached is that blue hydrogen should not be produced domestically and only that imported will be allowed.

(2) Electrolysis capacity target and hydrogen import

It is necessary to develop a robust and sustainable domestic market in hydrogen production and application in the initial phase of market development with regard to hydrogen technologies. Demand for hydrogen is currently 55TWh (approximately 1.38 million tons) in Germany, of which green hydrogen accounts for merely 7% (3.85TWh, about 96,000 tons). The Federal Government has extensively supported research and development (R&D) on hydrogen technology. In addition, on June 3, 2020, the government coalition adopted a €130 billion stimulus package for 2020-2021 to recover from the COVID-19 pandemic and €7 billion out of the package is spared for accelerating hydrogen technology development.[4]

The target of electrolysis capacity, which was an issue that the relevant ministries found difficult to reach agreement on, is set at 5GW by 2030 and a further 5GW will be added by 2030 if possible and no later than 2040. The electrolysis capacity of 5GW provides hydrogen production of 14TWh (about 350,000 tons)[5]. While hydrogen demand is estimated to reach 90-110TWh (about 2.25 million tons to 2.75 million tons) by 2030, the domestic supply of green hydrogen is not likely to meet the demand sufficiently. Therefore, Germany anticipates that hydrogen will need to be imported. To this end, the country aims to strengthen international cooperation and partnerships. Since there are great potentials for green hydrogen production found in some EU member countries such as offshore wind power in the North and Baltic Sea and solar energy in southern Europe, Germany needs to foster cooperative relationships with the EU members. Germany will also plan green hydrogen production projects in partner countries as a part of development cooperation. €2 billion of the stimulus package is appropriated to support such hydrogen production projects in partner countries.

(3) A flexible and results-oriented governance framework

To implement the National Hydrogen Strategy effectively, a State Secretaries' Committee on Hydrogen with which relevant ministries are involved will be established. This Committee takes corrective measures in cooperation with the Federal Cabinet in case the actions required to carry out the strategy are delayed or it is foreseeable that the targets will be missed.

The National Hydrogen Council also plays a critical role to provide the Committee with the necessary support and advice in implementation of the strategy. This Council is composed of 26 high-level experts from business, science, and civil society who will be appointed by the Federal Government. Designated representatives at the Director-General level of the relevant ministries take part in the Council as guest, as do two delegates of Länder (the local government at state level in Germany) at the request of the Länder. The Council is held at least twice a year and has a joint meeting regularly with the Committee on Hydrogen to facilitate coordination.

In addition, the Hydrogen Coordination Office in association with the National Hydrogen Council will be organized to assist the relevant ministries in exercising necessary measures for the strategy and the Council in coordination and drafting recommendations. The Hydrogen Coordination Office is in charge of monitoring the implementation of the strategy and submitting an annual monitoring report to the Committee and the Council. Based on the annual monitoring reports, an extensive report will be made every three years, which will include evaluation of progress of the strategy and the action plans and make suggestions on necessary remedial

[4] Wehrmann, B. and Wettengel, J. (June 4, 2020). "German gives energy transition mild boost with economic stimulus program." *Clean Energy Wire*

[5] 4,000 full-load hours of electrolyzer operation is assumed.

measures. Accordingly, the strategy will be ensured to be consistent with market development and the targets to be achieved.

1-2. Goals and ambitions of the National Hydrogen Strategy

The National Hydrogen Strategy provides a crucial framework to build up the necessary hydrogen supply chain and encourages technology innovation and private investment. The strategy is also expected to help Germany to meet the climate targets, create new value chains for the economy, and to promote international cooperation in energy policy. The strategy raises the goals and ambitions as follows:

- To take responsibility for greenhouse gas emission reductions globally
- To reduce the cost of hydrogen technology and make it competitive
- To develop a domestic market for hydrogen technology, paving the way for hydrogen imports
- To ensure hydrogen as an enabling energy source for decarbonization
- To make hydrogen a sustainable input for the industry sector
- To develop hydrogen transport and distribution infrastructure in the regulatory framework and technical requirements to enhance safety of hydrogen use
- To facilitate appropriate capacity development and set up new research institutes
- To create the energy transition process to which hydrogen technology contributes
- To strengthen the German industry by means of the hydrogen technology and provide global market opportunities for German companies
- To develop international hydrogen markets and establish international cooperation on hydrogen with the prospect of turning into a hydrogen import country
- To promote international cooperation that benefits the partner countries for climate change mitigation and sustainable development, taking advantage of heightened momentum around hydrogen
- To secure quality assurance for hydrogen production, transport, storage and use, and build trust for the users
- To review the progress of the strategy on regular basis and consider the further development including necessary measures

1-3. Action plans to develop the hydrogen supply chain

The measures of the action plans listed in the National Hydrogen Strategy are considered in two phases until 2030. In the first phase to 2023, the hydrogen market will be ratcheted up and a basis for domestic demand will be established. In parallel, the fundamental measures such as R&D will be undertaken. The second phase from 2024 to 2030 blueprints that the domestic hydrogen market will get on the right track, the European and international dimensions of hydrogen will be set, and the German industry will take this opportunity. With expectations toward the strategy which will encourage private investment and stimulate the economy to recover from the COVID-19 pandemic, there are 38 measures proposed in the strategy from the hydrogen supply chain to international cooperation for the first phase. These action plans aim to develop a framework for the supply chain and expedite technology innovation and investments. The relevant ministries are responsible for implementing and financing the measures. Among others, some important measures are outlined below.

(1) Hydrogen production

It is critical to scale up the production capacity to bring down the hydrogen production costs. Preferential tax treatment for electricity used to produce green hydrogen (e.g., exemption of green hydrogen production from the EEG[6] surcharge) and funding for investments in electrolyzers are raised as measures to assist hydrogen production. Regarding offshore wind as a promising technology to produce green hydrogen, the strategy also

[6] Renewable Energy Source Act (Erneuerbare Energien Gesetz)

indicates the necessity to develop a framework that will encourage investment in offshore wind energy.

(2) Hydrogen application

To facilitate hydrogen use in practice, the strategy focuses on the applications that are to reach economic feasibility in the short- or medium-term, or that are difficult to find alternative options for decarbonization for the measures to be taken.

In the transport sector, the use of green hydrogen as an alternative to conventional fuels will be incorporated into a domestic law which reflects the EU Renewable Energy Directive (RED II). One of the schemes in discussion is that the aviation industry which heavily depends on petroleum products may be required to use electricity-based jet fuel at a minimum quota of 2% by 2030. Funding from the Energy and Climate Fund will also be available to increase investments in fuel cell vehicles until 2023.[7] Specifically, the fund prepares €3.6 billion for clean energy vehicles including fuel cell vehicles, €1.1 billion for installations for the production of synthetic fuels, and €3.4 billion for the construction of a refueling and charging infrastructure. Since the Federal Government promotes the use of green hydrogen in commercial vehicles such as heavy-duty road haulage, the network of refueling stations needs to be developed quickly.

Hydrogen rollout is expected to speed up in the industry sector. Grey hydrogen is possibly replaced by green hydrogen in the chemical industry or refineries while pilot projects testing hydrogen reduction of iron ore are already being attempted in the steel industry. The Federal Government will render a pilot program of Carbon Contract for Difference (CfD) in the steel and chemical industries. This program will compensate for the difference between the actual cost of avoided emissions based on a contractually agreed carbon price per amount of GHG emissions prevented and the prices of the Emissions Trading System (ETS). If the ETS price is above the carbon price agreed contractually, the difference exceeding the agreed price above needs to be paid back to the government. The strategy also will develop hydrogen-based long-term decarbonization strategies with stakeholders, which will start with energy intensive industries such as the chemical, steel, logistics and aviation sectors.

(3) Heat supply

Even after energy efficiency and electrification are utilized in the heat supply process or in buildings, there is room for hydrogen and synthetic fuels to contribute to decarbonization. The Energy Efficiency Incentive Programme which has been put in place since 2016 will be continuously used for funding to support highly efficient fuel cell heating systems.[8]

(4) Hydrogen supply infrastructure

Hydrogen supply systems that are secure, reliable, and demand-based will be important in the future hydrogen market. While it is an option to transport hydrogen using the existing gas infrastructure, development of transport infrastructure dedicated to hydrogen is necessary to be considered as swiftly as possible. When it comes to the transport of hydrogen in the international market, hydrogen needs to be liquefied, or transported as liquid organic hydrogen carriers, ammonia or methane. It is urgently important to take on developing the

[7] The Energy and Climate Fund was established in 2011 to implement the energy shift and funding is provided annually (€4.5 billion in 2019). The funding is available for measures such as investments in energy efficiency including building modernization, renewable energy, and energy storage.
(The Federal Government (March 12, 2019). “More money for the energy shift” https://www.bundesregierung.de/breg-en/service/more-money-for-the-energy-shift-1589036)

[8] The Energy Efficiency Incentive Programme provides support measures to modernize heating and ventilation systems to improve energy efficiency and the energy transition in the building sector.
(BMWi. “Energy Efficiency Incentive Programme - Targeted funding for more investment in comfort and efficient heating in the home”
https://www.bmwi.de/Redaktion/EN/Dossier/enhancing-energy-efficiency-in-buildings.html)

regulatory framework for construction and expansion of the hydrogen infrastructure. Sector coupling connecting electricity, heat, and gas also necessitates further facilitation for the energy transition. If a network of hydrogen refueling stations is newly planned, it requires deliberate coordination among road transport at suitable locations, the railway network, and the waterways.

(5) Research, education and innovation

Germany aims to lead the global market of green hydrogen technology. A roadmap for the German hydrogen industry will be developed as guidance to achieve the purpose. Demonstration projects regarding green hydrogen will be conducted in the short-term. Under the new initiative of "hydrogen technologies 2030," some research activities in the area of key hydrogen technologies are bundled for strategic implementation. In addition, from 2020 to 2024, a total of €25 million from the Aviation Research Programme and a portion of approximately €25 million of the Maritime Research Programme are allocated to work related to hydrogen technology in the aviation and marine industry, respectively.

(6) Necessary actions at European level

Germany sees the EU Council Presidency for the last half of 2020 as an opportunity to promote hydrogen in preparation for the legislative package on sector coupling and gas market design. Development of a robust market in which hydrogen can contribute to the energy transition and decarbonization and boosts export opportunities for German and European companies requires sustainability standards, high quality infrastructure, and proof of origin for electricity from renewable energy and for green hydrogen. Furthermore, setting up the international hydrogen market entails sustainability and quality standards at the European level with regard to hydrogen and Power to X, a concept of converting electricity through green hydrogen or synthetic methane to other energy carriers such as liquid fuels, power, and heat. At the EU level, approval as Important Project of Common European Interest (IPCEI)[9] may work to encourage investments in research, development and demonstration of green hydrogen technology. Hence, the Federal Government has proactively approached the European Commission and other member states to initiate a joint project that will qualify for the IPCEI.

(7) International hydrogen market and partnership

As a new prospect of international cooperation on hydrogen, Germany provides partner countries with German hydrogen technology, which will help them to produce hydrogen from renewable energies or fossil fuels and consequently export it to Germany as well as to reduce dependence on fossil fuels. With this type of partnerships established, Germany will be able to import hydrogen while fossil fuel exporting countries will turn to hydrogen producing and exporting countries and achieve decarbonization and economic growth with less use of fossil fuels. It is obvious that Germany will strengthen the existing international framework and partnership to see the global trend of hydrogen and obtain information to identify potential partner countries.

2. Germany's approach to support hydrogen applications

In Germany, renewable energy has been steadily expanding its share in the power sector, which helps to decarbonize the sector as intended, whereas the other industries, the transport sector, and buildings have struggled to improve energy efficiency and facilitate decarbonization, failing to fulfill the targets. A distinctive aspect of Germany's energy demand is that heating accounts for more than half of the final energy consumption. This fact implies that it is key to decarbonize the heating supply systems for the buildings and the industry

[9] State aid which is financial assistance given to companies or organizations with the potential to distort market competition is prohibited under EU rules. If a project is to be qualified for approval from the European Commission under the IPCEI framework, certain criteria set out in the IPCEI Communication need to be fulfilled, for instance, that the project is jointly supported by several member states and contributes to economic growth, job opportunities and competitiveness across Europe.

sector in order to succeed in the energy transition. Given the difficulty to reduce GHG emissions in these sectors, carbon-neutral hydrogen and synthetic fuels are expected to decarbonize the sectors in which there is no alternative technology available. The 2030 Climate Action Programme adopted in September 2019 points out a vital role of hydrogen in R&D.[10] This chapter seeks how Germany has supported hydrogen development.

2-1. Policy measures to encourage hydrogen deployment

2-1-1. Support for research, development, and demonstration

Germany is one of the countries that have recognized the potential of fuel cell and hydrogen technologies even before hydrogen gains momentum. Germany has provided support primarily for R&D in the field of fuel cell and hydrogen technologies through the Energy Research Programme since 1977. Under the 7th Energy Research Programme for 2018-2022, the Federal Government provides €6.4 billion for research, development and demonstration (RD&D), which is a 45% increase from the 6th program for 2013-2017.[11] The 7th Energy Research Programme broadens the scope of funding, covering not only individual technologies but also cross-cutting topics which are important in restructuring the energy system. In addition to digitalization and the energy transition, sector coupling is especially focused on as it will enable renewable energies to be used efficiently in transport and the heating/cooling systems of the industry and building sectors. Encouraging further utilization of green hydrogen and synthetic fuels in these sectors will be a challenging issue.

The 7th Energy Research Programme adds an important role to support large-scale field testing (a term of '*Reallabor*' in German is used to describe it and it means 'real-environment laboratory').[12] On July 2019, the Federal Ministry for Economic Affairs and Energy (BMWi) announced the winners of the competitive bidding of "Real Laboratories for the Energy Transition (*Reallabore der Energiewende*)" and awarded them €100 million annually.[13] The selected 20 projects plan to examine low-carbon hydrogen technologies regarding production, transport, or utilization at industry scale. These demonstration projects are expected to offer necessary data and information to utilize the new hydrogen technologies in practice and identify possible impacts on the energy system or the energy transition. They will also help to develop the necessary regulatory framework to make a competitive business model in the long-term.

The actual outlays of the project funding for fuel cells and hydrogen technology provided by the Federal Government maintain an amount of around €20 million and it was €24.41 million in 2018 (Fig. 1). The funding was centered on fuel cell technologies early on, but it has been allocated more to the projects on hydrogen production or storage technologies lately.

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[10] The Federal Government (September 20, 2019). "Climate Action Programme 2030" (https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzprogramm-2030-1674080)

[11] BMWi (2018). *Innovations for the Energy Transition – 7th Energy Research Programme of the Federal Government.* Berlin/BMWi. p.8

[12] Jensterle, M. et al. (2019). *The role of clean hydrogen in the future energy systems of Japan and Germany*. Berlin/Adelphi. p.14

[13] BMWi (July 18, 2019). "Altmaier verkündet Gewinner im Ideenwettbewerb ‚Reallabore der Energiewende': „Wir wollen bei Wasserstofftechnologien die Nummer 1 in der Welt werden"." (https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2019/20190718-altmaier-verkuendet-gewinner-im-ideenwettbewerb-reallabore-der-energiewende.html)

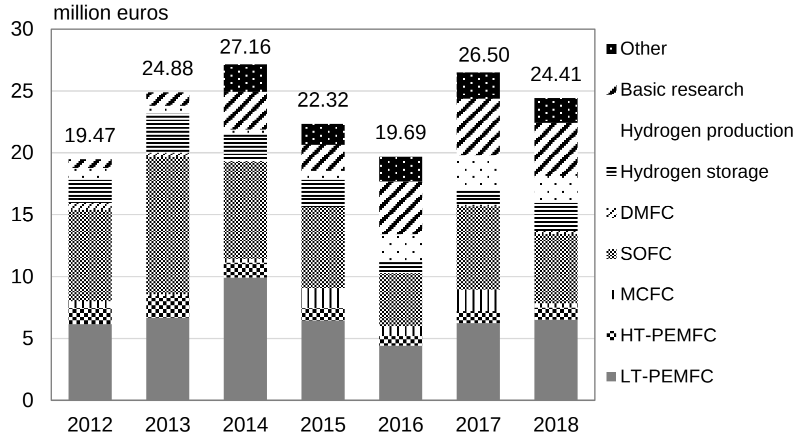

Fig. 1 Actual outlays of the project funding for fuel cells and hydrogen technology

Note: LT-PEMFC = low-temperature proton exchange membrane fuel cell, HT-PEMFC = high-temperature proton exchange membrane fuel cell, MCFC = molten-carbonate fuel cell, SOFC = solid oxide fuel cell, DMFC = direct methanol fuel cell

Source: BMWi (2019)[14]

2-1-2. NOW's assistance for hydrogen and fuel cell technology development

The National Organisation of Hydrogen and Fuel Cell Technology (NOW) plays the major role in hydrogen and fuel cell technology development in Germany. NOW facilitates collaboration among the government, industry and academia and coordinates activities in national and international frameworks.[15] As one of the major tasks, NOW oversees the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP), which aims to enable hydrogen and fuel cell technology to enter the market and make them competitive globally. To this end, NOW supports innovation of fuel cell technology and development of a hydrogen refueling station network. The Federal Government funded around €700 million between 2006 and 2016 and approved a total of €1.4 billion in funding between 2016 and 2026 under the NIP.[16] In the second phase, the Federal Government provides support to the products that are not competitive yet in the market for market entry.[17] There are two programmes, namely H2 MOBILITY and HyLand, supported by NOW under the NIP framework.

(1) H2 MOBILITY

NOW assists the development of a hydrogen refueling station network in Germany.[18] Within the term of NIP, NOW supports H2 MOBILITY, the joint venture H2 MOBILITY Deutschland GmbH & Co.KG. established by six companies - Air Liquide, Daimler, Linde, OMV, Shell, and Total – in 2015 and a partnership to establish a nationwide infrastructure for hydrogen mobility. H2 MOBILITY pursues building up to 10 stations each in six major regions – Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Stuttgart, and Munich along with the hydrogen corridor. This partnership is also supported by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) of the European Commission.

(2) HyLand - Hydrogen regions in Germany

NOW introduced a new funding program called 'HyLand - Hydrogen regions in Germany' to support

[14] BMWi (2019). 2019 *Federal Government Report on Energy Research – Funding research for the energy transition.* Berlin/ BMWi. Table 2 (pp.57-58).
[15] Jensterle, M. et al. (2019). *op.cit*. pp.14-15
[16] The Federal Government (2020). *op.cit.* p.3
[17] NOW. "NIP Funding Programme" (https://www.now-gmbh.de/en/national-innovation-programme/funding-programme)
[18] NOW. "Development of a hydrogen refuelling station network" (https://www.now-gmbh.de/en/national-innovation-programme/aufbau-wasserstoff-tankstellennetz)

municipalities and regions for green hydrogen deployment under the NIP in 2018. It is necessary to incorporate deployment of green hydrogen into regional development planning in order to achieve the nation's goal of CO_2 reductions. The program intends to assist the municipalities and regions to conceptualize initial ideas or make plans more concrete so that the plan would be carried out. Since each municipality and region has a different basis on green hydrogen deployment, this program is grouped into three categories; 'HyStarter' for awareness improvement or an initial phase organization, 'HyExperts' for developing integrated concepts and in-depth analysis, and 'HyPerformer' for taking steps to procure actual applications and implementing the concepts.[19]

The municipalities and regions to be qualified for this federal aid measure need to go through a competition process. For 'HyStarter,' nine regions in seven categories were chosen as winners out of 85 applications submitted in September 2019. Those nine regions receive advice for about two years on the joint development of initial concepts on subjects of hydrogen and fuel cells in the areas of transport, heat, electricity, and storage systems. Subsequently, thirteen regions of 'HyExpert' and three regions of 'HyPerformer' were selected in December 2019.[20] Funding of €300,000 is provided to each HyExpert to develop feasible project plans for hydrogen concepts and €20 million to each HyPerformer in the form of investment grants for the implementation of existing concepts.

2-2. Overview of hydrogen applications in Germany

2-2-1. Current situations of hydrogen deployment by sector

This part briefly reviews the current situations of hydrogen use in Germany. In practice, grey hydrogen produced from fossil fuels has been utilized mainly in the industrial process in Germany as it is in Japan. Yet, there are various PtG demonstration projects using renewable energy as described in the next subsection.

Industry sector: Approximately three-quarters of hydrogen is produced and used in refineries and chemical industry in Germany.[21] Hydrogen application is a critical technology to reduce CO_2 emissions in the industry sector facing difficulty for decarbonization. Hence, PtG demonstration projects are expected to prove this potential.

Transport sector: Deployment of fuel cell vehicles (FCV) has been encouraged in the transport sector. As of October 2019, there are 530 FCVs, 21 FC buses, 2 FC trucks, and 100 FC forklifts.[22] Infrastructure development required to promote FCV deployment has steadily made progress, as well. As of June 2020, 84 hydrogen refueling stations are in operation, and 21 more stations are underway.[23] Therefore, the target of developing 100 hydrogen refueling stations by 2020 is likely to be achieved. In September 2018, a breakthrough happened in the transport sector. That is, the trial operation of the world's first passenger train powered by a hydrogen fuel cell rolled out in Lower Saxony.[24] The two hydrogen trains were operated on the 100 km route between the cities of Cuxhaven and Buxtehude and this trial was successfully completed at the end of February 2020. Along with a hydrogen refueling station to be built near Bremervoerde station, 14 hydrogen powered trains will replace the existing diesel units in 2022.

Residential sector: Mini- and micro- cogeneration systems with a fuel cell are available in Germany as the ENE-FARMs are in Japan. There are 6,600 units of CHPs installed as of October 2019.[25] The apartment

[19] NOW. "HyLand- Hydrogen regions in Germany" (ttps://www.now-gmbh.de/en/national-innovation-programme/hydrogen-regions-in-germany)
[20] NOW (September 9, 2019). "HyStarter competition: nine regions win hydrogen region status" (https://www.now-gmbh.de/en/news/press/hystarter-competition-nine-regions-win-hydrogen-region-status)
NOW (December 11, 2019). "Germany on its way to becoming a hydrogen country: Another 16 regions receive support for H2 projects" (https://www.now-gmbh.de/en/news/press/germany-on-its-way-to-becoming-a-hydrogen-country)
[21] Jensterle, M. et al. (2019). *op.cit*. p.6
[22] International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE). "Germany" (https://www.iphe.net/germany)
[23] H2.LIVE. https://h2.live/en/
[24] Alstom (May 19, 2020). "Successful year and a half of trial operation of the world's first two hydrogen trains, next project phase begins" (https://www.alstom.com/press-releases-news/2020/5/successful-year-and-half-trial-operation-worlds-first-two-hydrogen)
[25] IPHE. *op.cit*.

complex-scale systems which produce hydrogen from extra renewable power, store and use it in a fuel cell-based CHP system or combust it in a boiler have already been introduced to improve energy efficiency and reduce CO_2 emissions in the building.[26] Hydrogen can be also stored in the form of synthesis gas.

Power sector: Fuel cell-based UPS (uninterruptible power supply) systems are utilized as back-up power supply in Germany although they are not very popular in Japan. Also, research on hydrogen combustion in a gas turbine has been in progress. Currently, a fuel mix with up to 60% hydrogen content is operable and the development of turbines allowing pure hydrogen is expected in the future.[27]

2-2-2. Demonstration projects in Power to Gas (PtG)

Germany is leading the world in PtG which converts renewable electricity through an electrolyzer to hydrogen or, by subsequent synthesis, to methane, which can be transported in the existing infrastructure and utilized in different sectors. The German Energy Agency (DENA) set up the PtG strategy platform (Strategieplattform Power to Gas) in 2011 to advance technology development and market uptake of PtG.[28] Approximately 30 companies participate in this platform to commercialize PtG and develop the market, which will lead to the establishment of business models and achievement of economy of scale. The PtG projects have steadily increased and, as of June 2020, 68 projects from planning to commercialization phases are identified in the platform. Some of them are also large-scale projects funded by the 7th Energy Research Programme.

The year of 2019 witnessed a robust increase in the PtG projects. At the beginning of the year, there were 50 plants with a total electrolysis capacity of approximately 50 MW in operation or planned. Then, further electrolysis capacity of the PtG projects announced by the end of 2019 reached almost 600 MW (Fig. 2).[29] The PtG systems substantially increased in size and a PtG system with an electrolyzer of 100 MW is expected to operate in the future.

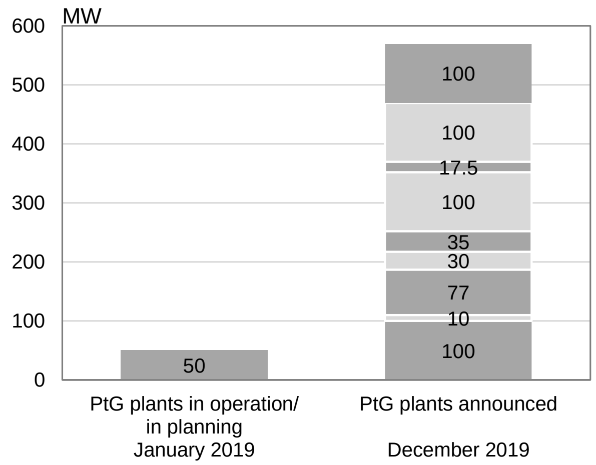

Fig. 2 Development of PtG plant capacity in Germany in 2019

Source: TÜV SÜD

Among the various PtG demonstration projects, the following part briefly illustrates some projects at large-scale and in the industry and residential sectors.

[26] Jensterle, M. et al. (2019). *op.cit*. p.5.
[27] *Ibid*. p.7
[28] Strategieplattform Power to Gas. https://www.powertogas.info/die-plattform/
[29] TÜV SÜD (January 28, 2020). “Power-to-Gas expansion on steep growth path” (https://www.tuvsud.com/en/press-and-media/2020/january/power-to-gas-expansion-on-steep-growth-path)

(1) Large-scale green hydrogen projects

ELEMENT EINS: The transmission system operator TenneT and the gas transmission operators Gasunie Deutschland and Thyssengas plan to build a 100 MW PtG pilot plant around the area of the TenneT substation Diele in Lower Saxony which collects and distributes offshore wind energy.[30] Using the existing gas infrastructure for the transport of hydrogen, the plant is expected to be gradually connected to the grid from 2022 and convert green electricity into gas which will facilitate decarbonizing the heat and industry sectors.

Hybridge: The transmission system operator Amprion and the gas transmission operator Open Grid Europe also plan a similar project called Hybridge.[31] With an investment of €150 million, a 100 MW PtG pilot plant will be installed near Amprion's substations in southern Emsland on the border between Lower Saxony and North Rhine-Westphalia. The pilot plant is to start conversion from electricity to hydrogen from 2023 and transport it via the existing gas network. The provision of hydrogen refilling stations in motor vehicles or trains and the hydrogen storage facilities are also included as a possibility in the further course of the project.

ReWest 100 (Reallabor Westküste 100): ReWest 100 plans to produce hydrogen from offshore wind energy on the west coast of Schleswig-Holstein, which then will be used to create climate-friendly fuels, fed into the gas network, and stored in a salt cavern.[32] In this five-year project, an electrolysis plant with a capacity of 30 MW will be installed initially to gain better understanding about the operation and maintenance, and grid serviceability of the plants, followed by the next phase of scaling up a plant to 700 MW. The project also aims to examine whether oxygen produced through electrolysis along with hydrogen can be fed into the combustion process of a cement plant to reduce CO_2 emissions.[33] Furthermore, CO_2 produced in the cement plant can be used as a raw material with hydrogen in the refinery to produce synthetic fuels such as aviation fuels or chemical raw materials. Consequently, this process will help the cement and aviation industries to be decarbonized.

(2) Industry sector

GrInHy/ GrInHy2.0: Between March 2016 and February 2019, GrInHy (Green Industrial Hydrogen via steam electrolysis) was conducted to evaluate the energy efficiency and performance of reversible high-temperature electrolysis based on a solid oxide electrolysis cell (SOEC) with a capacity of 150 kW in the process of iron and steel works. As a result of the operation for approximately 10,000 hours, since a significant share of energy input was provided from waste heat as well as renewable energy in the steelworks, the high-temperature electrolysis achieved high efficiency of 84 $\%_{LHV}$ although stack testing was stopped after 8,300 hours due to contaminations and failures of the test bench.[34] A successor project, GrInHy2.0, started in January 2019 with a scaled up high-temperature electrolyzer of 720 kW to test and prove the technology (Fig. 3).[35] By the end of 2022, this project will be in operation for at least 13,000 hours and produce 100 tons of high-purity (99.98%) green hydrogen at under €7/kg. Five partners - Salzgitter AG, Sunfire, Paul Wurth, Tenova, and CEA – work on the GrInHy2.0 project with a budget of €5.5 million.[36]

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[30] TenneT (January 20, 2020). "Power-to-Gas-Projekt ELEMENT EINS fasst Standort Diele ins Auge" (https://www.tennet.eu/de/news/news/power-to-gas-projekt-element-eins-fasst-standort-diele-ins-auge/)
[31] Hybridge. https://www.hybridge.net/index-2.html
[32] Westküste 100. https://www.westkueste100.de/en/
Westküste 100 is a cross-industry partnership which consists of EDF Germany, Holcim Germany, OGE, Ørsted, Raffinerie Heide, Stadtwerke Heide, thyssenkrupp Industrial Solutions, Thüga, Heide Region Development Agency, and the Fachhochschule Westküste University of Applied Science.
[33] Oxyfuel combustion is a technology to capture CO_2.
[34] GrInHy2.0. https://www.green-industrial-hydrogen.com/
[35] Salzgitter AG and Sunfire GmbH (March 14, 2019). "GrInHy2.0 – Hydrogen for low-CO_2 steelmaking." (https://www.green-industrial-hydrogen.com/fileadmin/user_upload/2019_March_GrInHy_2.0_press-release.pdf)
[36] GrInHy has eight partners from five different EU countries - Salzgitter Mannesmann Forschung GmbH, Salzgitter Flachstahl GmbH, Boeing Research and Technology Europe, Sunfire GmbH, VTT Technical Research Centre of Finland, EIFER - European Institute for Energy Research, Institute of Physics of Materials, Brno, and Politecnico di Torino.
Salzgitter AG has been proactive to reduce CO_2 emissions in steel production under the project SALCOS (Salzgitter Low CO_2 Steelmaking).

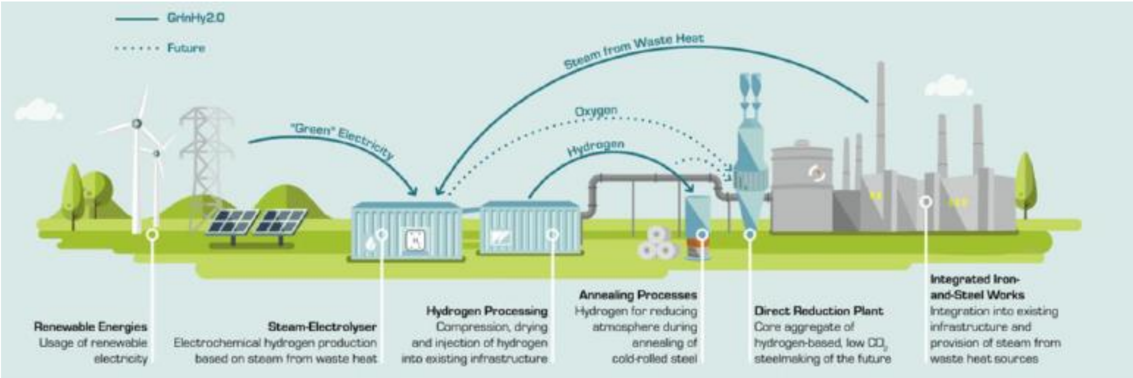

Fig. 1 Schematic of GrInHy2.0

Source: GrInHy2.0

CCU P2C Salzbergen: This project tests a CCU process which captures CO_2 and uses it for different applications. CO_2 emitted by a local waste incineration plant in Salzbergen is captured in a prototype on an industrial scale (64,000 t-CO_2/year) and then CO_2 and green hydrogen are converted into synthetic fuels.[37]

(3) Residential sector

Exytron climate-friendly living/ Exytron Zero-Emission residential park: Exytron provides an environmentally friendly energy system that produces hydrogen from renewable energy and coverts it into synthetic methane which can be stored in the building and burned in a CHP or boiler to meet demand for electricity, heat, or cold as necessary.38 The cyclical system in which CO_2 released from the CHP or boiler is used to produce methane lowers CO_2 emissions substantially. This PtG system is effective not only for new buildings (e.g., 37 residential units supplied with electricity and heat from the PtG system in Alzey) but also for renovation of old buildings (e.g., 70 units supplied electricity from a rooftop PV as well as heat and electricity from the PtG system of a renovated block of flats from 1974 in Augsburg). This decentralized PtG case demonstrated energy efficiency improvement and decarbonization of the buildings.

Conclusion

Germany's National Hydrogen Strategy is to accelerate the energy transition. That the Federal Government showed approaches for hydrogen deployment and clarified the support for technology innovation will stimulate private investment in the fields related to hydrogen with expectations for business opportunities. Taking hydrogen imports into consideration, the Federal Government will establish and strengthen a partnership with countries which envisage hydrogen exports. In fact, Germany and Morocco signed an agreement on the development of the green hydrogen production sector right after the National Hydrogen Strategy was announced.39

Germany's advantage is that hydrogen development can be accelerated across Europe as the momentum toward hydrogen uptake has been heightened in Europe as well as Germany. With the European Green Deal aiming for no net GHG emissions by 2050, the EU is committed to take effective measures which advance

[37] BMWi (2019). "Gewinner des Ideenwettbewerbs „Reallabore der Energiewende" – Steckbriefe –" p.1 (https://www.bmwi.de/Redaktion/DE/Downloads/P-R/reallabore-der-energiewende-gewinner-ideenwettbewerb-steckbriefe.pdf?__blob=publicationFile&v=9)

[38] Exytron. https://exytron.online/en/the-principle-of-smart-energy-technology-zero-emission-technologys/

[39] Guessous, H. (June 10, 2020). "Morocco First to Partner with Germany to Develop Green Hydrogen Sector" *Morocco World News*

decarbonization. In Europe, there are countries in which renewable energy accounts for the majority of power generation such as Norway and Spain. Norway actually released the hydrogen strategy in June 2020, as well. It is highly possible that green hydrogen development will speed up once a regulatory framework is established and agreed among European countries with regard to hydrogen utilization such as fuel cells and use of existing gas networks.

Japan launched the *Basic Hydrogen Strategy* in 2017. While the basic policy directions towards hydrogen society are common in the strategies of both Japan and Germany, there are some differences between the two countries. For instance, Japan's strategy explicitly presents the specific targets in hydrogen supply costs and applications. Japan will establish commercial-scale supply chains by 2030 to procure 300,000 tons of hydrogen annually and ensure that the hydrogen cost will be JPY30/Nm^3 (USD3.2/kg). Japan's strategy also includes hydrogen power generation as an application and aims to commercialize hydrogen power generation with the generation cost of JPY17/kWh (USD0.16/kWh) by around 2030. In the transport sector, Japan's strategy centers on fuel cell technology and sets a numerical target for FCVs, FC buses, and FC forklifts but does not touch on aviation fuels. In contrast, Germany intends to use electricity-based jet fuel which is produced from green hydrogen, given focuses on the use of synthetic fuels in the transport sector in general.

The Germany-Japan economic relationship has been strong. Friendly rivalry as well as collaboration may advance technology development and innovation of hydrogen further. The two countries have paid attention to green hydrogen in the bilateral cooperation so far. However, they have expanded the hydrogen schemes, indicating a new opportunity for both countries. Germany has accepted blue hydrogen although it is a transitional technology and imported only. Japan conducts demonstration projects to produce green hydrogen while seeking imports and utilization of blue hydrogen. The latest development is that the Fukushima Hydrogen Energy Research Field (FH2R) with a renewable energy-powered 10MW-class hydrogen production unit started operation in March 2020.[40] It is essential to reduce hydrogen production costs through technology development if a hydrogen society is expected. Both Germany and Japan will continuously improve hydrogen technology levels to gain competitive advantages, which will contribute to decarbonization globally.

[40] New Energy and Industrial Technology Development Organization (March 7, 2020). "The world's largest-class hydrogen production, Fukushima Hydrogen Energy Research Field (FH2R) now is completed at Namie town in Fukushima - This demonstration project will be operating to aim for low-cost Green hydrogen production technology -" (https://www.nedo.go.jp/english/news/AA5en_100422.html)

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