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German Japanese Energy Transition Council

GJETC Report 2020

German-Japanese Cooperation in Energy Research

Supporting the closure of implementation gaps

Key Results and Policy Recommendations

Wuppertal Institut

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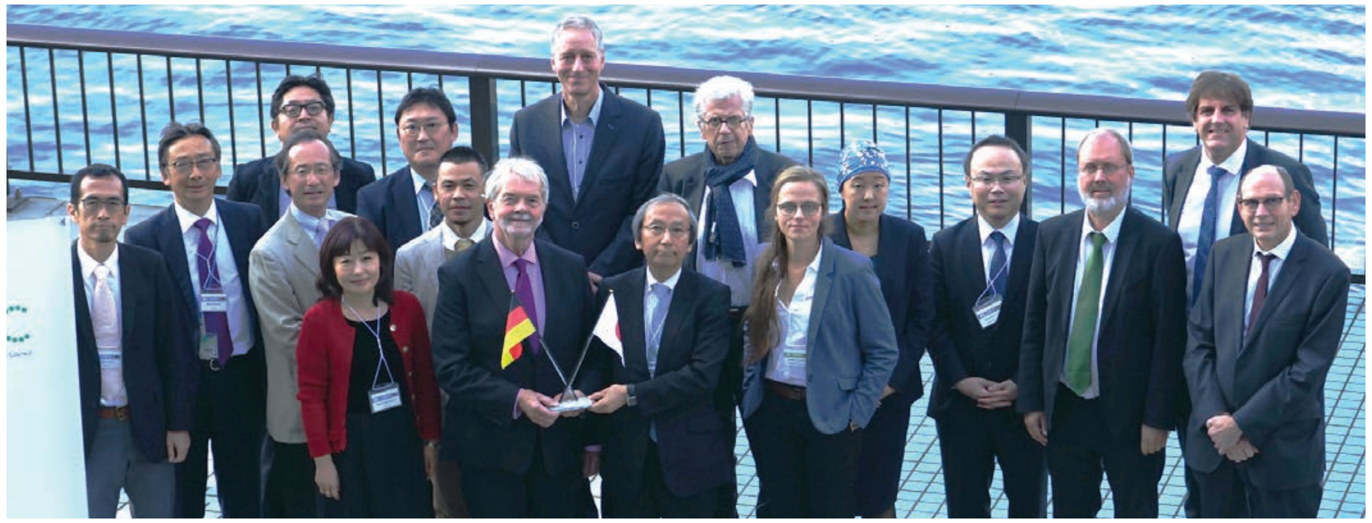
Preface

After four years of constructive cooperation, this report by the GJETC was discussed and approved by the members of the GJETC in March 2020 from their home offices via electronic communication channels. In this respect, it has been thoroughly effected by the coronavirus pandemic.



The pandemic has shone a spotlight on the vulnerability and connectivity of our "One World" like no other event for decades. Influenced by *immediate concern for and acute health risks* to millions of people, the world community was late in coming to a decision, but then most countries responsibly implemented comprehensive countermeasures that had previously not been considered possible. These measures and programs were all the more effective, the faster they were implemented, the better they were coordinated with neighboring countries, and the more they took the globalized exchange of goods, services, and people into account following the precautionary principle. Political and economic willingness to act, the ability to coordinate, and social solidarity in and between countries were practiced – despite conflicting self-interests – to an extent previously thought impossible. In both Germany and Japan for example, extensive "rescue packages" for the economy (e.g. budget allowances to compensate for reduced working hours, freelancers, and small businesses) that were ready for implementation were swiftly adopted.

Our condolences go to the victims of this catastrophic health and economic crisis all over the world. What we can learn from this global tragedy is how resolute, profound, and swift global action is possible, if the understanding of a common threat is communicated in a science-based and responsible manner.

We can therefore learn some fundamental lessons for joint action on the energy transition and climate protection: Many of the dramatic consequences of climate change are currently presented in the form of probability statements and future scenarios. In this respect, more ambitious energy and climate policy can only be based on an understanding of the *anticipated dismay* of all of us. We would all like to block out the image of living in a „hothouse earth"[1], as this is perceived as still being in the distant future, even the consequences of this may far surpass those of the coronavirus pandemic. In order to *transfer anticipated dismay to current willingness to act,* responsible science must simultaneously demonstrate the consequences of non-action as well as opportunities for action using the best possible scientific tools.

With all of its activities (e.g. a large study program, many individual studies and impulse papers, outreach events, and stakeholder dialogues), the GJETC has concentrated on opportunities for joint action to foster a just and economically feasible, if not attractive, energy transition in both countries. After four years of common intensive scientific policy advice, while certain cultural, geographical and energy policy differences remain, the similarities prevail and there is a resolute will to solve problems faster through cooperation than by advocating nationalist strategies.

The coronavirus pandemic took humanity by surprise, like a massive natural event; the causes are still unclear and the damage inflicted is devastating. Not so with climate change: We can predict many of the catastrophic consequences of inaction regarding climate mitigation with a high degree of certainty; on the other hand, much of these damaging impacts can still be prevented and the potential economic and social results of taking rapid action now are positive. This is one of the most important recent commonalities of German and Japanese energy policy. By presenting the "Long Term Strategy under the Paris Agreement"[2] Minister Abe said: "Responding to climate change is no longer a cost for the economy, but a growth strategy for the future. By firmly creating a virtuous cycle between the environment and growth, Japan will take the lead in making a paradigm shift in global environmental policy. The most important key to achieving the ultimate goal of a carbon free society is innovation" (Prime Minister Shinzo Abe, ibid.). "Virtuous cycle" in this context means that protecting the environment and new patterns of (decarbonized) economic growth can mutually and positively reinforce each other. This understanding follows a paradigm shift that is gaining more and more official acceptance in other parts of the world too, especially in Germany.[3]

In the same vein, when aiming to limit the economic effects of the coronavirus crisis, we recommend that stimulus packages to reduce the damage should focus on clean energy technologies, including both further development of traditional zero-carbon energy and new development of decarbonizing hydrocarbon, to avoid rebound effects in terms of CO_2 emissions after the economy recovers.[4]

Identifying technological and social innovations, cooperating to find the best common solutions, encouraging public acceptance of a just transition to a fully decarbonized economy, and building trust through evidence-based research and solidarity are the pillars of the work of the GJETC. We look forward to building a new phase of cooperation on these pillars in support of the German-Japanese Energy Partnership, and recommend that the public see the GJETC as a potential "role model" for international cooperation.

Prof. Dr. Peter Hennicke,
Prof. Masakazu Toyoda,
Co-Chairs of the GJETC, June 2020

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[1] https://www.pnas.org/content/115/33/8252

[2] See Prime Minister and his Cabinet (2019): Press release, online available under https://japan.kantei.go.jp/98_abe/actions/201906/_00031.html

[3] See e.g. the study of The Boston Consulting Group and Prognos (2018): Climate Paths for Germany, on behalf of of the Association of the German Industry (BDI), online available under http://image-src.bcg.com/Images/Climate-paths-for-Germany-english_tcm9-183770.pdf

[4] https://www.iea.org/commentaries/put-clean-energy-at-the-heart-of-stimulus-plans-to-counter-the-coronavirus-crisis

1

Introduction

1

Introduction

The German-Japanese Energy Transition Council (GJETC) was established in 2016 by experts from research institutions, energy policy think tanks, and practitioners in Germany and Japan.

The objectives and main activities of the Council and the supporting secretariats are to identify and analyze current and future issues regarding policy frameworks, markets, infrastructure, and technological developments in the energy transition, and to hold Council meetings to exchange ideas and propose better policies and strategies. In its second project phase (2018-2020), the GJETC had six members from academia on the Japanese side, and eight members on the German side, with one Co-Chair from each country.

From October 2018 to March 2020, the GJETC worked on and debated six topics:

- Digitalization and the energy transition (study)
- Hydrogen society (study)
- Review of German and Japanese long-term energy scenarios and their evaluation mechanism (working group)
- Buildings, energy efficiency, heating/cooling (working group)
- Integration costs of renewable energies (working group)
- Transport and sector coupling (working group)

The outputs and the recommendations of the second phase of the GJETC are summarized in this "GJETC Report 2020". This material is also published on the website www.gjetc.org.

Japanese-German Center
Berlin, February 2019

Figure 1: Structure and members of the GJETC 2018-2020

Japan		Germany
METI Ministry of Economy, Trade and Industry	**Financing**	The German Federal Environmental Foundation (DBU) Stiftung Mercator Foundation Federal Foreign Office
Chairman: Prof. Masakazu TOYODA (IEEJ)	**Management**	Chairman: Prof. Peter HENNICKE (hennicke.consult)
Scientific & Organisational Secretariat: Institute of Energy Economics Japan (IEEJ)		Scientific Secretariat: Wuppertal Institute
		Organization & Consulting: ECOS Consult

Japan		Council Members	Germany	
Prof. Jun ARIMA (University of Tokyo)	Prof. Dr. Yasumasa FUJII (University of Tokyo)		Dr. Harry LEHMANN (German Federal Environment Agency)	Prof. Dr. Andreas LÖSCHEL (University of Muenster)
Prof. Dr. Toshiharu IKAGA (Keio University)	Prof. Dr. Koji NOMURA (Keio Economic Observatory)		Dr. Felix C. MATTHES (Oeko-Institute)	Manfred RAUSCHEN (Eco-Center NRW)
Junichi OGASAWARA (Institute of Energy Economics, Japan)	Prof. Kazuhiko TAKEUCHI (Institute of Global Environmental Strategies)		Dr. Carsten ROLLE (Fed. of German Industries, BDI)	Franzjosef SCHAFHAUSEN (frm. BMU)
			Prof. Dr. Miranda SCHREURS (TU Munich)	Dr. Stefan THOMAS (Wuppertal Institute)

2

Policy recommendations by the GJETC

2

Policy recommendations by the GJETC

Since the first report by the GJETC was published in 2018, the IPCC's special report on 1.5 °C and the rise in worldwide movements by young people (e.g. 'Fridays for Future') as well as scientists and business (e.g. World Economic Forum Davos 2020) have provided new urgency and momentum for action and policy to mitigate climate change.

At the same time, the political narrative has changed to the economic opportunities of climate mitigation strategies and, e.g. in the EU, towards a strategy to steer the economy toward more sustainable development by concluding an ambitious European Green Deal.[5]

In Japan, the key message of its Long Term Strategy as Growth Strategy based on the Paris Agreement (June 2019) is a virtuous cycle of environment and growth.[6] The underlying technological trends are the huge potential still offered by cost-effective energy efficiency in all sectors and the continued improvement of the cost effectiveness of renewable energies and other relevant technologies (e.g. batteries, electrolysis, fuel cells, materials, ICT) and concepts (e.g. circular economy) needed for the energy transition.

We consider the key recommendations and other results presented in the GJETC 2018 Report still timely and appropriate. In light of the new developments mentioned above and the research and debate we have conducted over the last two years, we wish to add the following key recommendations.

(1) Improving energy and climate targets and policies

Policymakers in both Germany and Japan should reexamine their 2030 and 2050 energy and climate targets/goals in order to achieve nationwide GHG neutrality, no later than 2050 for Germany – which is now Germany´s target – and as early as possible in the second half of this century for Japan. It is important to implement policies with new innovative thinking such as carbon recycling and energy efficient sector integration. Furthermore, the level of commitment to targets/goals (e.g. making them legally binding as is the case with climate targets in the EU and Germany) and government accountability for how reliable targets/goals are and whether or not they are achieved should be increased to secure investment stability, enable long-term infrastructure decisions and targeted innovation policies as well as to avoid fossil fuel lock-in effects. In light of new technical and social developments, it is possible to increase targets and goals towards a faster reduction of GHG emissions, especially in the many areas and sectors that provide economic opportunities and high social co-benefits.

(2) Putting energy efficiency first

Energy efficiency continues to be the largest, fastest, and cheapest contributor to a sustainable energy system and climate change mitigation, and harnessing it should be given utmost priority. This has been demonstrated by research. Many scenarios by the IEA and the installation of a global high-level commission for urgent action on energy efficiency reiterate the importance of efficiency improvements.[7]

However, there are multiple barriers to energy efficiency, which require a policy mix that includes carbon pricing/energy taxation, information, direct financial incentives, standards, regulation, professional training, and research

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[5] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

[6] Government of Japan (2019): The Long-term Strategy under the Paris Agreement. The strategy also points out that "It could well be said that climate change mitigation measures are no longer a cost, but a source of competitiveness among companies".

[7] The Japanese Co-Chair of the GJETC, Prof. Toyoda, is a member of the Commission; see https://www.iea.org/news/iea-unveils-global-high-level-commission-for-urgent-action-on-energy-efficiency

and the development and demonstration of advanced energy efficiency solutions including digitalization.

Apparently, the policy mix in both countries must be further developed to reap all the benefits of energy efficiency and energy conservation.

(3) Improving the governance of energy efficiency policies

Against the background of what are still large implementation gaps regarding energy efficiency and energy conservation improvements, there is urgent need for strong governance of transformative energy efficiency policies, including the institutional arrangements for monitoring and evaluation. The high complexity of energy end-use efficiency technologies and energy service markets in particular raises the question of how to secure the process and steer responsibility for reaching the agreed energy conservation targets. Therefore, this report confirms the recommendations of the GJETC 2018 report[8]: "For example, if applicable, a country might consider establishing a strong National Energy Efficiency Agency and Energy Savings Fund that is integrated into the institutional setting and policy-making process, with a clear mandate for such policy and process responsibility to achieve energy saving targets."

(4) Advancing renewable energies, system integration, and sector coupling

In 2019, Germany reached a 40% share of renewables in total production and 42% in gross electricity consumption[9], and the government decided on a target of 65% renewable energy in gross electricity consumption by 2030. But the dynamics of market introduction, especially wind power, have slowed down and must be accelerated again to reach the 2030 target. The current share of electricity from renewable energy sources in Japan is about 18% (2018). The government has decided to increase this share to 22-24% by 2030. How this share can be increased beyond 2030 and how the relatively high costs of electricity from PV and wind in Japan can be decreased should be reconsidered taking weather and/or topographical conditions into account. Appropriate policies may include advanced FIT (feed-in tariff) and auctioning schemes that ensure accelerated expansion of electricity generation from renewable energies at minimized cost and carbon pricing, as well as enabling or supporting power purchasing agreements, peer-to-peer electricity trading, renewable energy cooperatives, and municipal utilities (Stadtwerke). Moreover, both countries should optimize grid integration, flexibility, and sector integration technologies, including batteries, and their mix, as well as energy efficiency, in order to minimize specific and overall power system costs with growing shares of variable renewable energy.

(5) Developing a "hydrogen society"[10]

Germany and Japan should work together and with other interested parties to

(a) bring down costs and improve technologies regarding (1) renewable power generation (for so-called green hydrogen), (2) electrolysis (for green hydrogen), (3) CO_2 capture, transport, and storage (for so-called blue hydrogen produced from fossil fuels), (4) long-distance hydrogen transport, (5) transformation of natural gas distribution infrastructures into hydrogen-ready infrastructures and (6) hydrogen-ready application technologies.

(b) explore an international governance scheme that safeguards GHG standards and broader sustainability for H_2 supplies in order to advance and take points (1) to (4) above into account. These joint efforts should also aim to safeguard investment security for overseas investments in green or blue hydrogen and safeguard a competitive H_2 market, especially in the ramp-up phase.

In particular, the GJETC recommends exploring technical, safety, and environmental/sustainability standards and certification for green and blue hydrogen as soon as possible to define ‚clean' hydrogen in a transparent and comparable way. This includes,

> [i] as a first step, exploring a data transparency initiative for embedded GHG emissions for internationally traded hydrogen. Such data disclosure could encourage international hydrogen trade with a lower GHG footprint.
>
> [ii] in addition to this, exploring whether the environmental standards and potential certification should include an appropriate maximum universal threshold level of specific GHG emissions for internationally traded hydrogen until the border gate.[11] The certification should provide incentives to go below this level.

Further sustainability criteria e.g. for water and soil, as well as social aspects, should be examined and included in the disclosure scheme and a potential certification scheme.

(c) take the initiative to build up an international production and supply infrastructure for clean hydrogen with a number of like-minded supplier and importer countries meeting the certification criteria together.

(d) cooperate in building the infrastructure for the distribution and use of clean hydrogen in Germany and Japan to advance points (e) and (f) above.

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[8] http://www.gjetc.org/wp-content/uploads/2018/04/GJETC-Report-2018.pdf

[9] https://www.bdew.de/media/documents/20200211_BRD_Stromerzeugung1991-2019.pdf

[10] We use the metaphor "hydrogen society", which is quite popular in Japan, but less so in Germany because – according to representative scenarios – hydrogen will contribute an important, but not a dominant share of total energy production in both countries by 2050 (see below). Hydrogen will, however, play a key role in the climate neutrality of industrial sectors with high shares of process emissions (e.g. iron & steel or chemical industries).

[11] A GHG emissions reduction of least 50% compared to natural gas – the fossil fuel with the lowest GHG emissions – in a ‚well-to-tank' analysis would be desirable as a credible contribution by clean hydrogen to climate change mitigation, in order to enhance its acceptance by the public. Analysis in the GJETC's study on hydrogen suggests that such a 50% reduction, which would require specific well-to-tank emissions of below approx. 33 gCO_{2eq} / MJ_{H2}, could be achievable using blue hydrogen in the cases analyzed. This may allow a maximum universal threshold level of specific GHG emissions for internationally traded hydrogen until the border gate of 30 gCO_{2eq} / MJ_{H2}, for example, allowing for approx. 3 gCO_{2eq} / MJ_{H2} for national hydrogen distribution from border gate to tank. While this level of 30 gCO_{2eq} / MJ_{H2} could be used to set a minimum GHG reduction standard or a maximum threshold level for specific GHG emissions for internationally traded hydrogen until the border gate, it would not be sufficient for hydrogen to be imported to the EU. It should be noted that the recently revised EU Directive on renewable energies requires a 70% reduction in GHG emissions in a well-to-tank analysis compared to natural gas as the benchmark. This may go further than is feasible with blue hydrogen and its transportation to many potential importer countries.

(6) Harnessing sustainable digitalization for the energy transition[12]

Digital technologies, solutions, and business models can be an important enabler for the energy transition, provided their own energy and resource use is considered and minimized. The GJETC recommends analyzing the balance of opportunities and possible counterproductive increases in energy and resource consumption by the ICT infrastructure and devices. The GJETC sees potential for German-Japanese cooperation, e.g., in 1) energy management systems for buildings, factories, city districts, and whole cities; 2) integrating variable renewable energies and other low-carbon generation technologies as well as flexibility options in the electricity markets and grids by enabling shorter trading intervals, peer-to-peer electricity trading, and other solutions such as “connect and manage”; 3) digital solutions for optimizing the use of technologies that can provide both flexibility and sector coupling in order to maximize the use of variable renewable energies in the system; this includes the system integration of stationary batteries and battery electric vehicles, hydrogen-fueled CHP plants, heat pumps and heat storage, as well as other technologies.

(7) Achieving sustainable mobility and the energy transition in the transport sector

Decarbonizing the transport sector is still a major challenge for both countries, especially Germany. The GJETC was only able to take a preliminary look at contributing to solutions e.g. in light of several demonstration projects. According to a hearing with experts and a broad review of existing literature, it can be stated that about half of the way to a more sustainable and decarbonized transportation system can be reached using three key mobility policies, i.e., 1) avoiding unnecessary transport, 2) shifting transport from road and air to ships, trains, local public transport, bicycles, and walking, and 3) improving the energy efficiency and emissions balance of vehicles. For the other half of the way, an energy transition to electric vehicles, hydrogen, and clean fuels is needed. Germany and Japan should create the policy framework needed to achieve this double transition and work together to further develop the necessary technologies and solutions.

(8) Making buildings GHG neutral

In addition to the transport sector, decarbonizing the building sector, especially by retrofitting the existing buildings stock, is still an unsolved problem for both countries. The task for energy and building policy is 1) to reduce the energy needs of both existing and new buildings to a minimum through efficient design, thermal insulation, shading, and heat/cold recovery ventilation, so that 2) the remaining energy need can be covered more easily by renewable energies and making it possible for buildings to even become net energy producers over the year (“Plus energy houses/buildings”). Connecting German knowledge of and technology for building shell energy efficiency and Japanese knowledge of and technology for BEMS/HEMS and Smart Cities could provide better energy performance in both countries, and opportunities for implementation in other countries too.

(9) Establishing appropriate monitoring and governance schemes

Both countries still face significant gaps that need to be closed to be fully compliant with even existing CO_2 reduction targets by 2030 and beyond. Against this background, comprehensive, objective and scientific assessment mechanisms for monitoring, evaluation, target revision and further development of target structures as well as the policies which enable target achievement are increasingly important elements of climate and energy policies. The exchange of experiences on these as well as on policy design and the government institutions and capacities needed to sustain a polycentric governance capable of achieving the targets could be an interesting field of cooperation too. For example, the German Climate Protection Act (12/18/2019) established legally binding sector targets for 2030 and the corresponding monitoring and enforcement mechanisms.
If continuing gaps between targets and implementation occur, strengthening of policies particularly in sectors that show implementation gaps will be appropriate, but a flexible adaptation of ambition levels of sectoral targets while respecting the overall national target might be justified too. In this respect, the new and legally binding sector-specific enforcement mechanism[13] of the German Climate Protection Act will provide interesting experiences.

(10) Enabling system integration of high shares of variable renewable energies

The GJETC therefore recommends (1) further analysis and simulation to better understand the opportunities of different technologies and their combination, as well as the differences in costs between Germany and Japan (cf. chapter 4.6), taking experiences in other countries on board, such as US federal states or Denmark; (2) implementing joint German-Japanese demonstration and pilot projects to test advanced technologies and business models for flexibility, similar to the SINTEG program in Germany, for example; and (3) developing a priority list for market readiness and implementation of different flexibility options, with the timing of implementation related to the share of VRE in the system. Obviously, such a priority list would also be adapted to the situation in each country, Germany and Japan.

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[12] The GJETC of course recognizes the profound impacts of digitalization, which go far beyond the energy system. However, in view of the significant implications for the energy transition (e.g. super-efficient production systems, changes in lifestyle, all of which can reduce energy and material use), the focus here is on the energy-related issues of digitalization.

[13] The law has defined annual sectoral maximal emissions per sector for each year until 2030. As for monitoring, the Federal Environmental Agency will compile sectoral emissions data for a calendar year until 15 March of the following year and send them to the expert council on climate issues (§5 (1) of the law). The council assesses the data. If the sectoral emissions according to the data are higher than the allowed sectoral emissions for the year, the ministry in charge of the sector has to prepare an urgency program within 3 months from the assessment by the expert council; the urgency program has to ensure that the annual targets for the sector will be met for all future years until 2030 (§8 (1) of the law). Available at: https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Gesetze/ksg_final_en_bf.pdf

3

Studies and Working Group results and specific recommendations

3

Studies and Working Group results and specific recommendations

Based on the in-depth studies on digitalization and hydrogen and the output papers of the four GJETC working groups, as well as the joint outreach events, the following chapter presents the key results and specific recommendations.

3.1

Digitalization and the energy transition

The GJETC Study on Digitalization

Digitalization in the energy system is progressing rapidly with the spread of artificial intelligence (AI), such as software tools to optimize demand and weather forecasts, and internet of things (IoT) technologies, including smart meters and secure data communication systems such as blockchain. As a result of the development, virtual power plants (VPP) are being put into operation in some countries, and peer-to-peer (P2P) energy trading utilizing blockchain technology is starting to be demonstrated, for example. These new business models, as well as power purchasing agreements (PPAs), may advance both the expansion of electricity generation using renewable energies, and their integration into power markets and grids.

This was the motivation for the IEEJ and the Wuppertal Institute to perform a study on ‚Digitalization and the energy transition', with financial support from DBU and METI, as part of the GJETC's work in its second two-year phase from 2018 to 2020. The study was performed in two parts, one in 2018/19 (Japanese FY2018), and one in 2019/20 (Japanese FY2019).

The first part of the study (Ninomiya et al. 2019) focused on VPP and, to a lesser extent, on the use of blockchain technologies in the energy sector. The second part of the study (Ninomiya et al. 2020) focused primarily on P2P energy trading and also analyzed PPAs.

This chapter of the GJETC 2020 report summarizes the results of the study and the comments of the GJETC's Facilitating Working Group on digitalization and the energy transition.

Key findings

A) Virtual Power Plants

VPPs can serve various purposes in liberalized power markets with a growing share of renewable energy and other distributed energy resources. 1) VPP can pool small to medium-sized renewable energy sources (RES) generators and offer to sell their power on the wholesale market (day-ahead market). In Germany, this is a service to fulfil a legal requirement for medium to large RES generators. 2) Particularly for biomass and hydro power plants, their flexibility allows the VPP pool to both maximize revenues by selling when power is more expensive on the day-ahead market, and to operate in the control reserve power market (required by the energy market legislation in Germany since around 2010 and currently under development in Japan), as well as in the intraday market for short-term trade that supports balancing energy supply and demand for the individual balancing groups. 3) Therefore, in addition to RES generators, VPP can also include gas-fired CHP, battery storage, emergency gensets, and demand response.

The case studies analyzed in Germany, Japan, and the USA, and their comparison have shown that the VPP business model will largely depend on the regulatory framework for renewable energy resources (RES) and electricity supply as well as the electricity market system. These are the main factors that have significant impacts on the status and purpose of the VPP examined in the case studies.

An existing, generous RES support scheme such as a fixed FIT or net metering for RES clearly prevents RES producers from connecting to a VPP, and this is currently being observed in Japan and the US. Germany's experience shows that mandatory direct marketing of RES required by the law has a strong impact on the RES producers, which has created the market for the VPP aggregators and a basis for the VPP business model in the country. The VPPs now also include gas-fired CHP plants, demand response, and other resources such as gensets. In addition to this, in Germany, transmission system operators (TSOs) are legally required to purchase control reserve though the market so that VPP aggregators can offer their aggregated distributed energy resources (DERs) to this market. In this context, biomass/biogas power plants are considered to be indispensable resources for the large VPP such as Next Kraftwerke, since they are as flexible as gas-fired power plants. The gradual expiry of the FIT entitlement in Japan after 2019, which requires RES producers to sell the power on the market by any means, would bring about a favorable situation for VPP as occurred in Germany, although the majority of RES will continue to qualify for the FIT entitlement over the next decade.

The organization of the electricity supply system is also an important factor for the development of VPP. An unbundling of the traditional, vertically integrated power supply system establishes a fundamentally positive environment for market entry by new suppliers as seen in Germany. Similarly, an electricity market system can also have an impact on VPP development. The balancing group model adopted in Germany and Japan can be highly favorable for VPP in comparison to the power pool model adopted in the USA[14]. These findings imply that a positive environment for VPP can be expected in Japan, particularly after 2020 as the unbundling of the vertically integrated supply system is scheduled for that year.

Such positive prospects for VPP in Japan would even be enhanced by the fact that the share of VRE will increase, as the Japanese government has set a clear policy target for renewables to be major power resources by 2030 and beyond. The higher share of VRE will obviously require an

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[14] Two aspects should, however, be mentioned:
1.) VPP could have a positive impact on minimizing infrastructure needs; however, whether VPPs would also increase the system costs due to their focus on micro-optimization is still a source of significant controversy.
2.) On the one hand, centralized liberalization models (as are found in the USA, for example) certainly have some problems with decentralized trading activities, but, on the other hand, they offer options for dealing with locational price signals, which is a blind spot of the decentralized balancing group model.

increase in grid flexibility, suggesting that VPPs would be one type of favorable flexible resource for the grid in the future. The capacities of each individual RES developed in Japan are currently much smaller than in Germany and the USA, reflecting less availability of suitable land for ground mounted PV/RES production in areas with high population densities. Thus, an aggregation of the small DERs via a VPP aggregator rather than an individual DER could create more valuable resources for grid flexibility in Japan, particularly if the share of VRE increases significantly in the future. The share of VRE also seems to be an important element in providing a business opportunity for VPP to participate in flexibly matching supply to demand, as seen in Germany.

Compared to the factors explained above, including the existence of an unbundled electricity market, the *structure* of the electricity market (regulation, rules, procedures and requirements for participation, excluding incentive mechanisms for RES) does not seem to be one of the main causes of the difference between the VPP models, as the markets *currently* developed in the three countries are relatively similar (with the exception of the balancing group model in Germany and Japan vs. the power pool model in a number of states in the USA). However, details of the minimum size of bids or conditions for prequalification to a market, for example, may be decisive for the prospects of VPPs or types of DERs to participate in the markets. Likewise, IT systems employed in VPP also seem to be an insignificant factor in explaining the diversity between them. In fact, in Germany there are several providers of software systems for VPP operators.

However, it should be noted that the outcomes of the case studies explained above may change considerably *in the future*. This is because full commercialization of VPP has only been seen in Germany so far, implying that there is still substantial room for further development of VPP in other countries that may have very different consequences. For instance, *at a mature stage*, different market structures and IT systems could make a substantial distinction between VPP models. There is further need for VPP development in Germany. This includes making better use of demand response, batteries – including in electric vehicles, and other flexibility options such as power-to-gas, power-to-heat, or power-to-fuel; improving consideration of regional or local network constraints in the scheduling of DERs for the day-ahead and intraday markets as well as in their use as control reserve; prequalification of wind and PV plants for control reserve; and in general, further improving the market conditions for DERs and VPPs. Nevertheless, at this stage, it can be said that the regulatory framework for RES, the unbundling of the electricity supply system, and the existence of an electricity market system are the main factors in explaining differences between VPP models in the three countries examined in this comparative study.

Regarding the use of blockchain technologies, the main conclusion of the analysis is that what their potential main use for the energy system in the near or further future is still unclear. Will they be used to simplify transactions between actors already active in today's energy markets and reduce the cost of these? Or will they increasingly be used for P2P energy trading?

B) P2P energy trading and PPAs

The second year study examined a series of questions on P2P energy trading and PPAs. For this analysis, the authors of the study defined P2P energy trading as "a contractual model that will enable short-term electricity exchange on a regional or national scale between multiple peers such as 'prosumers' or/and small to medium power generators and/or electricity appliances located at the end of distribution networks, i.e. distributed energy resources". Meanwhile, the following definition has been used for PPAs: "A PPA is a medium-to-long-term electricity supply agreement concluded between a seller (plant operator) and a buyer, e.g. an energy supplier or final electricity consumers, such as large industrial consumers, data centres, and large buildings". Both were chosen since they may be promising market models for integrating renewable energies into the electricity market. P2P trading is clearly more innovative in its business models and use of digitalization, so it was the main focus. PPAs for variable renewable energies will also involve greater digitalization requirements than a traditional base load PPA, e.g. to forecast market prices, but were a minor focus of the study. The questions concern purposes/objectives of P2P trading and PPAs, models of P2P trading and PPAs, preconditions for the implementation of the models, the current status of development in Germany and Japan, incentives/opportunities and barriers/threats for market actors, potential positive/negative impacts for markets and energy systems, and opportunities/threats for market actors and consumers/prosumers, in order to make recommendations on P2P trading and PPAs as well as policies needed for their successful implementation.

a) Purposes/objectives of P2P trading and PPAs

The purposes/objectives of P2P trading have been identified as;

(1) enabling the continued economic operation of the post-FIT renewable plants, for which their FIT support period has ended; their numbers and capacity will be increasing, particularly for wind and solar plants from 2021 in Germany, and a large number of residential roof-top solar plants as early as 2019 in Japan;

(2) financing new renewable power plants in a post-FIT era without payments of a FIT or FIP/MP[15] type, as it may be useful and possible in the long run to have a market design that integrates renewable assets without a FIT or FIP/MP scheme;

(3) meeting corporate green electricity purchase or decarbonization goals;

(4) matching supply and demand of the participating generators and customers in total and in regional decentralized markets especially as long as regional and real time market prices for smaller customers have not been developed yet;

(5) grid stabilization via targeted P2P trading.

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[15] Under the German Renewable Energy Law, grid access and payments for new medium to large renewable energy generators are granted only by succeeding in an auction. The generators will receive the Feed-in Price (FIP) they bid or the wholesale market price at the time of feed-in, whatever is higher. If the wholesale market price for the same type of generator (e.g. Solar PV, onshore wind), averaged over the month, is lower than the FIP, the generator will receive the Market Premium (MP) covering the difference to the accepted FIP of the generator. Japan currently considers to newly introduce the FIP/MP scheme similar to German in place of the existing FIT scheme for large scale solar PV and onshore/offsore wind.

Similarly, the purpose/objectives of PPAs are:

(1) the promotion of newly-built renewable power plants over the longer period in a post-FIT era, providing security of price and green electricity supply for both generator and buyer;

(2) supporting continuous operation of "FIT-expired" renewable energy plants without explicit financial support from the public sector or energy consumers;

(3) meeting corporate green electricity purchase or decarbonization goals.

However, several distinct differences between P2P trading and PPAs are highlighted, which are the capacity size of power plants (typically those in PPAs are much larger than in P2P), the type of consumer (the consumer/buyer side of PPAs is likely to be a large energy consuming company, which is typically larger than P2P customers, or a green electricity supplier, whereas it is often smaller consumers for P2P trading), and the duration of contracts (duration of PPAs is normally much longer, for instance between 3 and 20 years, which is longer than P2P trading contracts, which usually have the same duration as normal supply contracts). All of these differences imply that an amount of electricity traded under a P2P trading contract can be far smaller than in PPAs.

b) Models for P2P trading and PPAs

A number of models for P2P trading have already been both proposed in theory and tested in practice in Germany and Japan. In this paper, they are re-categorized according to the centrality of whole system of operation, focusing on who has operational responsibility for the network, between a centralized model (controlled P2P network model, with an energy supplier or other central operator controlling the P2P trading and supporting it, for example by providing balancing services and contracts for network use) and a decentralized model (decentralized autonomous P2P network model, where each producer or prosumer acts as its own balancing group). The controlled P2P network model is further divided into three sub-category models with respect to the object of each model, which are the wholesale market model, the regional/local electricity procurement model and the P2P trade serving grid stabilization model. In the same way, the decentralized autonomous P2P network model is further divided into two sub-category models, namely on-grid trading and off-grid trading (local physical microgrid model). As a result, in total, five categories of P2P trading models are identified for Germany and Japan, which are summarized in the following table.[16]

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[16] The GJETC study report on digitalization includes graphs presenting the models. They are not repeated here for lack of space.

Table 1: P2P trading models

Centralized or Decentralized	Sub-category	German model name	Japanese model name
Controlled P2P network model	Wholesale market model	Model G1	Model J4: Existing electricity retailer acts as P2P platformer J5: P2P platformer is independent of the electricity retailer J6: P2P transaction b/w factories/buildings owned by the same company J7: P2P transaction b/w prosumers/consumers forming a partnership
	Regional/local electricity procurement model	Model G2	
	P2P trade serving grid stabilization model	Model G3	
Decentralized autonomous P2P network model	on-grid trading	Model G4	
	local microgrid trading (off-grid)	Model G5	Model J1: P2P transaction within a limited building/flat/apartment J2: P2P transaction using charged electricity in EV J3: P2P transaction via private line within a limited community

Note: model numbers were defined by the study team from the IEEJ and the Wuppertal Institute

The models discussed in Germany fit all five categories (called Model G1 to G5 for each category), while the models proposed in Japan are divided into two models (Model J1-3 in the off-grid model within the decentralized autonomous P2P network model and Model J4-J7 in the wholesale market model within the controlled P2P network model).

PPAs can simply be distinguished as on-site and on-grid PPAs.

c) Preconditions of P2P trading and PPAs

With regard to the preconditions of P2P trading, a large-scale deployment of smart meters, also known as 'intelligent metering systems' in Germany, is identified as the primary precondition for implementing P2P trading with its full potential to support flexible markets and grids[17]. The current status of and plan for smart meter roll-out in Germany and Japan highlights a clear difference between the two countries, whereby the installation of smart meters is expected to be completed in Japan by 2024 and in Germany by 2032. This implies that Japan is, at least on the basis of technological infrastructure, in a more advanced position for nationwide implementation of P2P trading than Germany. In Germany, P2P trading models are now working with standard load profiles instead of loads measured and transferred by smart meters.

The second key precondition is a digital system for data transmission and handling with an economic transaction system, which often employs blockchain technology, though other systems using central database and data processing technologies and software would be feasible too.

d) Current status of development of P2P trading and PPAs

The current status of development of P2P trading in Germany is quite promising. There may currently be a total of more than 15 schemes. Most of them are on-grid P2P trading controlled by a utility company or a new, specialized platform provider (models G1 and G2). While most of these are pilot projects, full commercial products for P2P trading of renewable electricity are available from at least two providers. In Japan, only a few projects have been developed on a pilot basis, coming under models J3 and J4.

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[17] There may still be a need to add specific devices to the smart meters in order to execute the trading and remote control functions, and potentially other functions that are necessary but not included in the smart meters themselves. But smart meters are required as the basis and for the full flexibility potential.

None of them are commercialized yet or have publicly released tangible results. The development of P2P trading is still at a very early stage, at least in Japan.

Regarding PPAs, the examples in Germany indicate that PPAs have been developed in the country, though not as much as in the Netherlands and the UK, for example. This is expected to increase, especially for FIT-expired plants, but also for new PV plants that wish to avoid the cumbersome auctioning process and the risk of not winning the bid. In Japan, the development of PPAs is behind Germany but likely to grow in the near future.

e) Incentives for and barriers to P2P trading and PPAs for market actors

In terms of incentives for and barriers to P2P trading for market actors, the most heavily impacted area would be the business opportunities of traditional electricity retailers. There is a significant risk of losing their business margin as their customers move to P2P trading. Wholesale trade companies, including VPP operators, would also be affected since the direct P2P trading will reduce their business opportunities. Therefore, there will be a strong incentive for traditional electricity retailers and wholesale trade companies to become P2P platformers themselves in order to avoid losing their business margin; this has actually been observed in Germany and Japan. In contrast, small to medium renewable generators, prosumers and consumers would have substantial positive opportunities to enter P2P trading. They can avoid the margin of traditional electricity supply and share these savings between them, if the costs and the risks associated with implementing P2P trading are effectively addressed. Risks include privacy and data security as well as other potential risks posed by blockchain technologies. In addition, P2P platformers and P2P platform technology providers would see enormous business opportunities in the field of P2P trading.

The impacts on TSO and distribution system operators (DSO) would be a mixture of positive opportunities and threats. This is because it has been found that on-grid P2P trading per se is unlikely to change anything in regard to the physical flows of electricity compared to the traditional electricity market model unless P2P trading either explicitly includes or induces additional demand/supply changes through demand-side management (DSM), flexible generation, system-driven use of batteries/ battery electric vehicles (BEV), or they are otherwise induced by grid operators or government policies. Therefore, it would not provide any additional benefits per se for the alleviation of grid bottlenecks and grid integration of renewable energy without additional measures to induce changes in demand/supply. Therefore, the impact on TSO and DSO is depending on whether or not additional demand/supply change can be induced by supplemental measures associated with P2P trading.

The incentives for and barriers to on-grid PPAs are quite similar, but their impacts are far less significant for all of the market actors, implying that PPAs are generally quite compatible even in the existing market.

On-site PPAs and off-grid P2P trading are particularly attractive for the parties involved, since they will (partly) avoid retail electricity prices (incl. grid fees, taxes, and the FIT surcharge in Japan, but not including the FIT surcharge for PV plants larger than 10 kW in Germany) for the parties.

f) Impacts of P2P trading and PPAs for markets and the energy system overall

The existing P2P trading business models and PPA contracts in both countries indicate that both could contribute to the continued use of post-FIT renewable energies and new investments in renewable energy plants without a FIT payment. This will increase the amount of renewable energy in the system and therefore benefit society. If both models reduce the margins of traditional electricity supply, as some P2P trading schemes in Germany seem to indicate, this will benefit society too.

However, as stated above, neither on-grid P2P trading nor on-grid PPA models will contribute per se to market or grid stabilization by supporting the use of flexibility options in their operation. Incentives for generators and consumers in this direction will need to be added as in any other market and supply model. To the extent that P2P trading accelerates the installation of smart meters in Germany, it will also enhance the options for supporting flexibility options through its smart contracts and blockchain transaction infrastructure. If off-grid P2P trading and on-site PPAs involve storage and an energy management system between P2P trading participants or within the PPA site, this is likely to lead to some grid stabilization effects at the local (at least substation) level.

To the extent that customers in on-site PPAs and off-grid P2P trading save grid fees, taxes, and FIT surcharges, this would cause a distributional effect, since the other connected consumers would have to pay a correspondingly higher share of total grid costs and the FIT surcharge, and the community of taxpayers would lose a certain amount.

Conclusions and policy recommendations

a) Conclusions and policy recommendations regarding VPPs

VPPs are a useful model for integrating renewable energies and other distributed energy resources (DERs), such as gas-fired CHP, battery storage, and demand response, into the liberalized energy markets organized according to the balancing group model, which are established both in Germany and Japan. VPPs can market power from these DERs in the day-ahead, intraday, and balancing power markets flexibly to optimize revenues by balancing high and low price periods. Policy should (continue to) legally allow and enable the operation of VPPs and support this by rolling out smart meters and safe communication gateways, which can be used by VPP operators to add their control devices. Flexible power prices, including time-dependent grid tariffs, would improve the economic conditions for integrating further flexibility options, such as battery electric vehicles or heat pumps.

b) Conclusions on useful P2P trading and PPA models

Insofar as they contribute to the objectives listed above, P2P trading and PPA models will be useful.

For on-grid P2P trading, we found that, in the short run, only those models will be possible in practice, which are offered by an existing electricity supplier operating a P2P trading platform or a new P2P platform provider that can either take balancing group responsibility for the participating generators, prosumers, and consumers or cooperates with a company that organizes balancing group responsibility (Models G1 to G3 in Germany, Model J4 and, if legal preconditions are created, Model J5 in Japan).

Self-organized, decentralized autonomous models without the support of an external retailer or balancing group responsible are unlikely to flourish in on-grid P2P trading (Model G4) without major changes in legislation and regulation, but might be useful in off-grid P2P trading (Model G5 and Model J1 to J3) within a certain site or building behind the grid connection and metering point.

Both on-site and on-grid PPA models may also be useful for sustaining post-FIT operation of PV or wind power plants and to accelerate the expansion of new RES-E capacities.
However, the open questions, potential risks and distributional effects mentioned above should be considered when assessing the usefulness of these models.

c) Policy recommendations regarding P2P trading and PPAs

The GJETC study found that P2P energy trading and PPAs can offer promising solutions to support the expansion of renewable energies in the electricity system and market. However, the question remains as to whether there are better alternatives. Whether concrete policy support for the renewable energy P2P trading business itself may be needed and wanted will depend on whether there are other options 1) to secure the operation of post-FIT plants, such as a kind of “macro-PPA” or “2nd FIT period” regulation[18], and 2) to stimulate the ambitious construction of new RES-E plants (e.g. a 65% share for Germany in 2030), e.g. via a sufficient capacity awarded through auctions for FIP/MP for the latter. These are ultimately political decisions on the preferred policy framework for the expansion of renewable energy sources:

- Should the target be to end fixed FIT schemes and auctions for FIP/MP for new renewable power plants, and to support market solutions such as P2P trading and PPAs for certified green electricity instead?
- Or is it wiser to secure politically defined paths for expansion of the various types of renewable energies through auctions for FIP/MP and continued fixed FIT schemes for prosumer-scale to medium-sized PV, including support for post-FIT generators?

This will depend on such general political decisions and paradigms, to which extent policy will need to and should support the wide-scale implementation of the useful models previously identified. Even if a general decision in favor of FIT schemes and auctions for FIP/MP is taken, the extent to which P2P trading and PPAs will be useful in further boosting renewable energy development remains to be seen.

Since a number of open questions and risks have yet to be clarified or resolved, we recommend that policy allows and enables the use of P2P trading models G1 to G3 and J4 and J5, but closely monitors their development to learn about their potential and any possible positive or negative impacts. Further support for appropriate P2P trading models may be useful, among other policy options, if monitoring reveals that other available options are not sufficiently able to ensure the operation of post-FIT plants and stimulate the construction of new RES-E plants, e.g., if auctions for FIP/MP for the latter have problems in securing the capacity needed to achieve RES-E expansion targets from new plants.

Furthermore, in order to support the use of flexibility potentials of RES-E generators and particularly of demand and storage, policy should accelerate and support the roll-out of smart meters, especially in Germany which is lagging behind, and other required IT, as well as their use to stimulate flexibility options. This will be particularly useful for participants in existing or new P2P trading, as the blockchain transaction infrastructure built up for P2P trading also makes it easier to integrate the transactions for flexibility. In addition, we see a need to support investments in creating flexibility options that can be controlled using the smart meters.

The required specific policies to enable the use of P2P trading models J4 and J5 in Japan have been identified, including those related to the existing measurement law, privacy risk, grid fees, imbalance responsibility of P2P platformers and the existing regulation on partial electricity supply to small consumers by multiple suppliers.

For Germany, as the growing number of pilot or fully commercial schemes shows, on-grid P2P trading is already possible. Policy should promote coupling them with flexibility options, i.e. by accelerating smart meter roll-out. Moreover, the government could develop standard rules/templates for smart contracts that specifically meet data and consumer protection requirements.

For PPAs, we also recommend that policymakers continue to legally allow and enable the use of PPAs but closely monitor their development and impacts, as well as potential alternatives.

Please find recommendations on further research needs in Chapter 4.

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[18] “Macro-PPA” would mean that the government would introduce regulations requiring that TSOs or DSOs, or a public single buyer as in Austria, buy the power from all post-FIT generators in their area at a negotiated or fixed price and sell it as a certain share of electricity supplied at the average price achieved in the grid area to all suppliers serving customers in the area, or averaged across the country. A “2nd FIT period” regulation would mean a new but much lower FIT is set or a feed-in price determined by auctions for these generators. Note: if the price in the “macro-PPA” model is fixed and the average price is determined across the whole country, this will be the same as a “2nd FIT period” scheme.

3.2

Hydrogen society

The GJETC Study on a Hydrogen society

Clean hydrogen with low greenhouse gas emissions from production to use could be an energy carrier that plays an important role in decarbonising our economies and societies. Clean hydrogen can be green hydrogen, produced from green electricity through electrolysis, or blue hydrogen, produced from fossil fuels with carbon capture and storage.

The study for the GJETC on a hydrogen society had two parts. During the Japanese fiscal year 2018, a study co-funded by the ministries of economic affairs in Germany (BMWi) and Japan (METI) analyzed the current status of hydrogen deplyoment and policies as well as the role of hydrogen in future energy systems in both countries, and hydrogen supply chains (Jensterle et al., 2019). The second part of the GJETC study on the "hydrogen society" mainly aimed to deepen the analysis on potential criteria for clean hydrogen that is sustainable and low-carbon as well as other aspects of a possible international certification scheme (Ninomiya et al. 2020).

Key findings

Status quo, opportunities and challenges, and potential solutions

a) Hydrogen uses, supply, and policy strategies in Japan and Germany

JAPAN
Japan has more experience in fuel cell demand-side applications than Germany, especially in stationary applications for residential use and in the transport sector (2018: 270,000 residential CHPs, 2,800 FCEV). Hydrogen gas turbine and co-firing of ammonia in coal power plants are possible technologies for future practical use in the power sector. Great efforts are being made in R&D and demonstration projects for energy carriers such as liquefied hydrogen, liquid organic hydrogen carriers and ammonia, aiming at establishing a large-scale hydrogen supply chain.

In Japanese scenarios, the total hydrogen demand by 2050 appears high at 600 to 1,800 PJ (approx. 9% to 22% of the total final energy demand).[19] Japan envisions most of hydrogen being consumed in power generation, followed by the transport sector at a limited volume. By comparison, the direct share of renewable energies in primary energy supply is projected to reach only 13% to 14% in Japan by 2030.

Japan is pursuing a strategy where hydrogen (at least in the near to medium future) would principally be sourced from abroad (blue hydrogen produced from fossil fuels with CCS until about 2040; green hydrogen will then be added). Domestic renewable energy sources are considered too limited for the meaningful supply of green hydrogen.

The government has taken an active approach in market deployment strategies, including the formulation of a "Strategic Roadmap for Hydrogen and Fuel Cells" and "Basic Hydrogen Strategy", with concrete development targets for 2030. With its Basic Hydrogen Strategy, Japan was the first country in the world to have laid out a comprehensive hydrogen and fuel cell technology development plan.

GERMANY
Germany is a worldwide leader in Power-to-X testing, carrying out more than 30 projects, and plans to drastically increase total electrolyzer capacity in the coming years with an eye on realizing 'sector coupling'. It also provides notable support for hydrogen technologies in the transport sector and in stationary applications such as fuel cell CHP plants and uninterruptible power supply units. A rapidly growing field of interest is the use the hydrogen to decarbonize industrial sectors with high process emissions (e.g. iron & steel and chemical industries). Regarding demand, Germany sees both the industry and transport sectors as the first large consumers, followed at later stage by the replacement of natural gas in CHP and backup power plants. Depending on the scenario, by 2050 the demand for hydrogen is projected to be between 300 and 600 PJ per year in most scenarios, or up to 15% of final energy demand. Hydrogen-based synthetic fuels are typically expected to gain higher demand shares than hydrogen itself, reaching up to 39% of final energy demand.

Germany has ambitious and clearly quantified GHG emissions reduction targets, e.g. reducing GHG emissions by up to 95% by 2050. These targets are one of the primary drivers of penetration by hydrogen and other synthetic fuels. The share of renewables in primary energy supply is generally projected to reach between 26% and 32% by 2030. Nuclear power generation will be phased out by 2022, and the decision has been taken to phase out coal by 2038 at the latest.

The German scenarios focus on green hydrogen, due also to the lack of public acceptance for the implementation of CCS. Most of the green hydrogen and derived synthetic gases and fuels

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[19] Jensterle et al. (2019): The role of clean hydrogen in the future energy systems of Japan and Germany.

are expected to be imported in most scenarios. Furthermore, some smaller PtX-volumes are likely to be produced domestically from renewable electricity as a flexibility and seasonal storage option according to the scenarios analyzed. This scenario-based analysis is, however, contrasted by the range of recent pilot projects in Germany that also include the production of blue hydrogen (steam reforming of imported natural gas in coastal areas with CO_2 capture and shipping to offshore storage sites) or turquoise hydrogen (city-gate pyrolysis of imported natural gas and landfilling the solid carbon byproduct).

Both the sectoral distribution of hydrogen use and the relationship between hydrogen and other synthetic fuels will depend on future development of technologies and policies.

The government has only been focusing more strongly on market deployment strategies since the start of the second National Innovation Programme Hydrogen and Fuel Cell Technology (NIP) in 2017; Germany has now developed a National Hydrogen Strategy which has been published in June 2020.

b) Sustainable global and national supply chains

Potential criteria for defining clean hydrogen, frameworks enabling hydrogen certification, GHG intensities of hydrogen supply chains and countries with an interest in participating in global clean hydrogen trade can be regarded as aspects of hydrogen supply chains.

Important criteria for hydrogen certification are a minimum level of GHG emission reductions compared to fossil fuels – which implies, inter alia, efficient and reliable carbon capture and storage for blue hydrogen and the additionality of renewable energy sources for green hydrogen[20] –, land and water use, as well as social and economic impacts. The EU Guarantees of Origin (GoOs) scheme developed by CertifHy during an initial pilot project could be used as a starting point for an international certification scheme. But neither this nor any other current certification schemes include these additional criteria and only count the emissions resulting from hydrogen production. Some of the existing certification schemes could be used for both green and blue hydrogen, while others are only intended for green hydrogen.

Regarding the *GHG intensities*, the production stage is by far the most significant in the life-cycle. In general, green hydrogen generates fewer emissions by an order of magnitude than blue hydrogen, even if CCS is applied for the latter.

Some of the countries with good wind and solar power potential as required for low-cost green hydrogen production are also producers of the fossil fuels necessary for blue hydrogen production. On the other hand, many countries with potential interest and the means to start importing clean hydrogen are already heavily dependent on energy imports.

This means that the potential is great for developing an international cooperation between potential hydrogen producing and importing countries. The transportation and application infrastructures could initially be built using blue and green hydrogen in parallel. This would also allow producers of fossil fuels to complete the conversion to producers of low-carbon fuels. Path dependencies on fossil fuels must be avoided by embedding the transformation period in a clear scenario-based roadmap for decarbonizing the economy.

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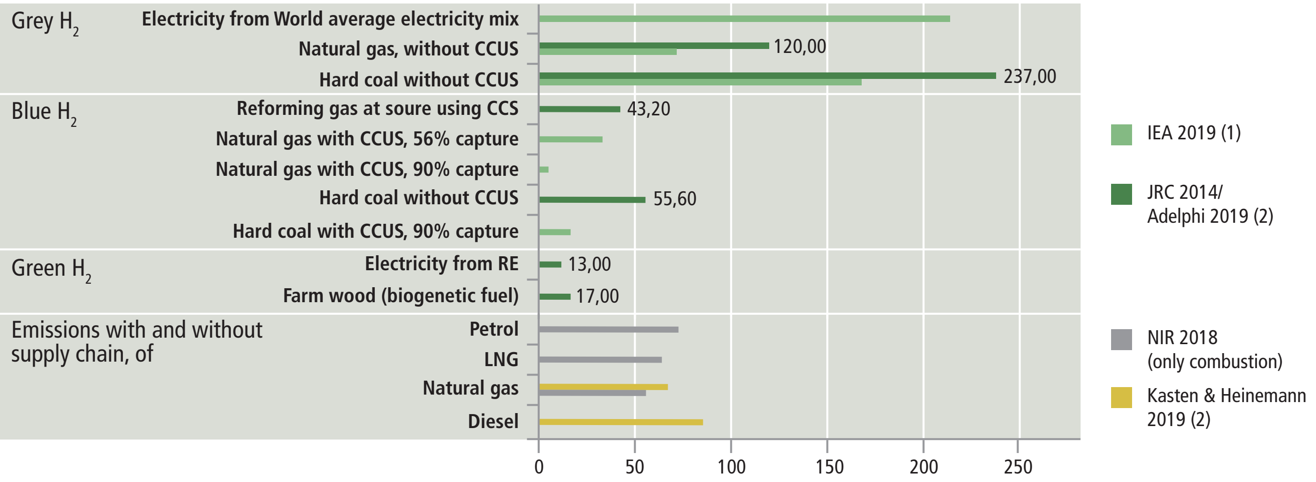
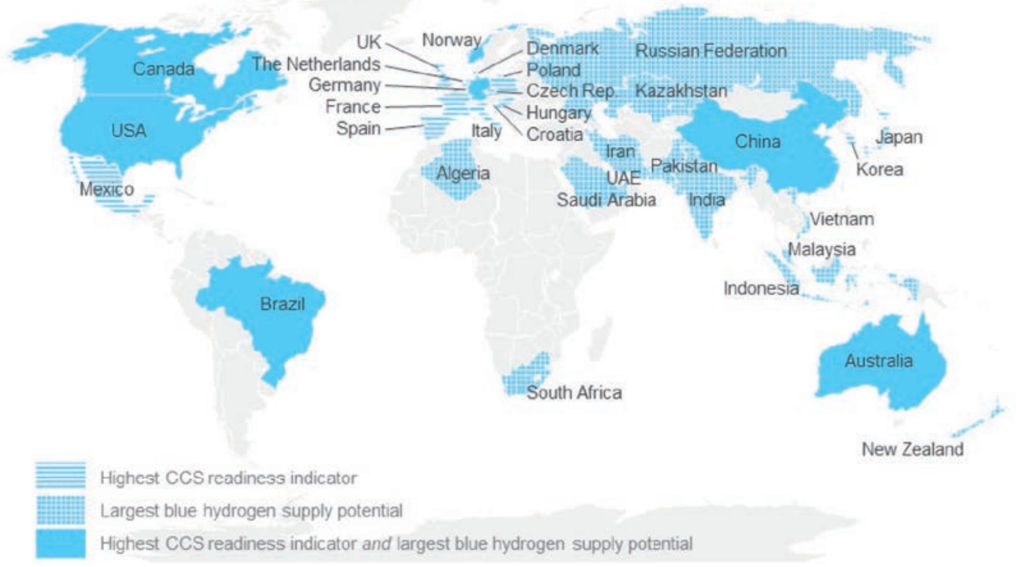
[20] In addition, some experts are of the opinion that nuclear power could also be an option for producing hydrogen.

Figure 2: GHG emission intensities of hydrogen production or supply in gCO_{2eq} / MJ H_2, using different technologies, in comparison to fossil fuels for transport and power plants.



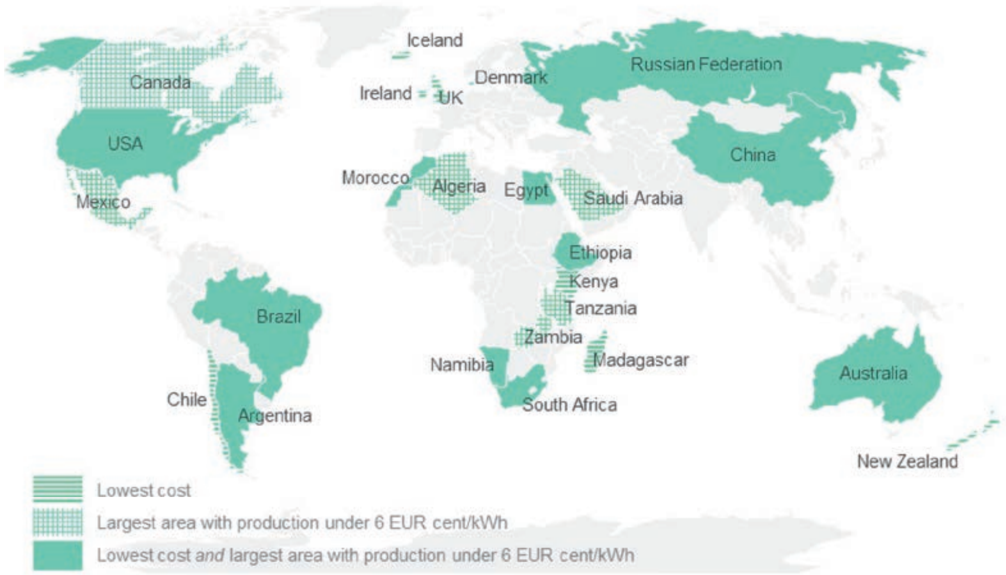
Source: Wuppertal Institute, based on the sources cited
(1) Production and CO_2 only; (2) whole supply chain and all GHG in CO_{2eq}

Figure 3: Countries with high blue hydrogen supply potential



Source: Jensterle, Miha, et al. (2019)

Figure 4: Countries with high green hydrogen supply potential



Source: Jensterle, Miha, et al. (2019)

c) Challenges and obstacles

The role of hydrogen in the energy mix has been the subject of international debate for decades with waves of hypes and slowdowns. Many challenges remain. Costs need to be brought down and technologies improved in the fields of renewable power generation, electrolysis, CO_2 capture transport and storage, long-distance hydrogen transport, transformation of natural gas distribution infrastructures into hydrogen-ready infrastructures and hydrogen-ready application technologies.

Fragmented energy policies and the impact of different hydrogen/PtX policies on market liquidity

The key driver of wider use of hydrogen and related Power-to-X products is ambitious climate policy targets. However, hydrogen is still in the initial market development stage, with the associated need to advance technologies and bring down costs, and will require a long-term perspective. Reliable political commitments and targets are extremely important in order to translate these into a clear roadmap with significant market signals.

Technological and economical challenges across the value chain

· *Technologies for producing and using hydrogen or other PtX products and cost reduction*

The production of hydrogen from low-carbon sources today is costly. Over 60% of the cost of hydrogen production using electrolyzers is the cost of the electricity. Thus, continued deployment of lower cost renewable generation and the reduction of power prices are important for the production of hydrogen. Technology companies from Germany (19%) and Japan (17%) hold the strongest global position[21] in terms of market share of electrolyzers, which may also be relevant for industrial strategies and forms of cooperation and standardization.

· *Technologies for transporting hydrogen and other PtX products*

How should hydrogen be transported over long distances? Pipelines and shipping as well go along with large infrastructure investments by governments or as public-private partnerships, some of which would also require additional cross-border coordination and commitment. Again, different competing ways exist, such as LH_2, LOHC, NH_3 and synthetic liquid fuels. Japan with its international cooperation in hydrogen production seems to be quite advanced in developing technologies for maritime long-distance transport.

· *Capability of different consumers to cope with blended hydrogen in the public gas infrastructure*

There are several ways of distributing hydrogen to the end user: Mixing hydrogen with natural gas in the public gas grid, transforming it into synthetic methane and blending it, or providing it as pure hydrogen through a newly-built hydrogen-specific grid or by partly using converted natural gas pipelines. The extent to which the different appliances are technically ready for blending hydrogen is still subject to analysis.

Which way to choose? Hydrogen in comparison to synthetic fuels and direct/battery use of electricity

All competing energy carriers offer advantages and disadvantages. Efficient *direct use of electricity/battery use,* e.g. in heat pumps and battery electric vehicles, is the most efficient mode in terms of losses across the entire conversion chain and batteries will establish themselves as daily energy storage. However, they require new distribution, storage, charging, and fueling infrastructure. Hydrogen is somewhat less energy efficient but better suited for seasonal energy storage, larger vehicles, and longer distances. But it also requires new distribution, storage, charging, and fueling, as well as transport infrastructure. *Synthetic fuels* can be used in existing transport, distribution, and application infrastructure. Similar to hydrogen, they are currently best suited for seasonal energy storage, larger vehicles and longer distances. But they are much less energy efficient (cf. Figure 5) and hence costlier to produce. Still, since they do not need new infrastructure after production, they are expected to be the second best option for transport in economic terms, after battery electric vehicles (UBA 2019). Their potential for enhancing CCU technology and deployment could also be seen as an advantage.

However, considering only conversion efficiencies and economics would fall short of describing the complex interrelations adequately; aspects such as providing energy storage, demand-side flexibility and the necessary infrastructure need to be taken into account.

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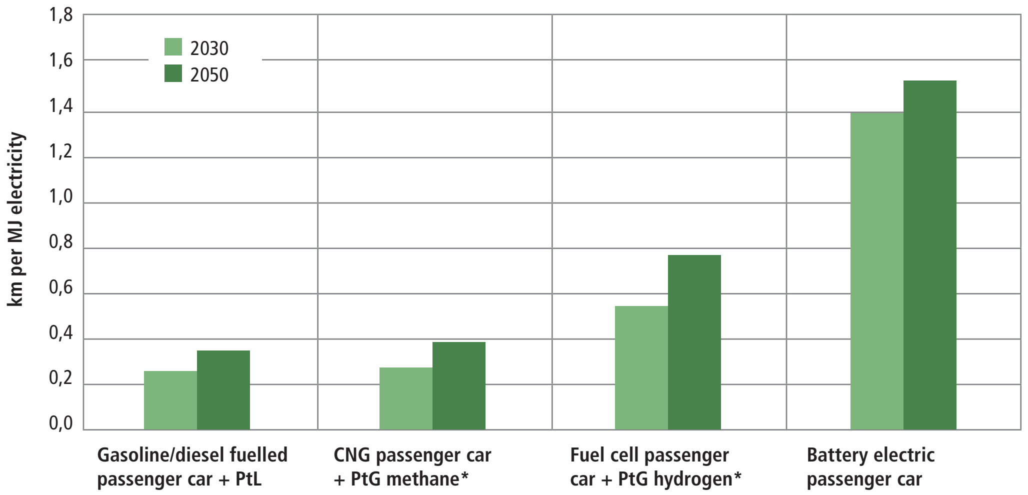
[21] However, according to Bloomberg New Energy Finance, Chinese producers already offer electrolyzers domestically for 200 USD/kWel and may therefore gain higher market shares in the future. https://www.bloomberg.com/news/articles/2019-08-21/cost-of-hydrogen-from-renewables-to-plummet-next-decade-bnef

Figure 5: Transport efficiency of different routes for using green electricity



Source: INFRAS/Quantis 2015 ; * compressed

Regulatory challenges

More widespread use of hydrogen is confronted with a broad variety of regulatory barriers that have to be overcome. These include:

- A certification system that allows for clear measurement of the emission reductions relating to blue and green hydrogen
- Making hydrogen economically competitive, inter alia, through carbon pricing and targeted support schemes in the ramp-up phase to bridge the current cost gap to fossil fuel technologies
- Development of a regulatory system for hydrogen infrastructure, similar to and on a level playing field with electricity and gas infrastructure
- Security standards for hydrogen transport and usage.

Public acceptance

In Japan, the use of blue hydrogen is part of the national strategy, including international cooperation with Australia and Brunei. In Germany, however, acceptance may well be linked to the fact that it is definitively and credibly produced from additional renewable energies (green hydrogen), at least in the longer run. This is important to consider when roadmaps for hydrogen are being formulated, as blue hydrogen technologies may help to bring down the costs in an initial phase that has to be clearly defined.

Conclusions and policy recommendations

a) The potential role of blue and green hydrogen

The use of blue and green hydrogen is likely to be accepted by the public if it brings significant and trusted GHG emission reductions and if this is the most cost-effective way to decarbonization by 2050. On the other hand, there is already a need to develop hydrogen supply and use technologies and infrastructures in the short to medium term. Therefore, a compromise has to be found between immediate GHG emission reductions and infrastructure development.

Based on the analysis provided above and in the GJETC study, blue hydrogen could work as a preceding measure that enables CO_2 reduction on a large scale until green hydrogen becomes more available and affordable. A merit of blue hydrogen is that it allows fossil fuels to be utilized in a more environmental manner and to enhance energy security. To make blue hydrogen acceptable, CCS technology needs to be advanced in order to improve safety, prevent CO_2 leakage also in the long term, reduce costs, and gain public support.

In contrast to blue hydrogen, green hydrogen can be zero-carbon in production if the electricity used is from additional green, i.e. renewable energy-based generation. Proving this as full additionality in physical terms requires 100% of the electricity demand in a power system before electrolysis being covered by green electricity whenever the hydrogen electrolysis process is used. This may only be possible in the longer term in many countries, because periods of the year showing such situations will increasingly occur at above approx. 60% to 70% of total annual share of green electricity in the system. In regional systems with high potentials for low-cost renewable energy and constraints on the grid connection to the rest of the country, such as in North Germany and North Japan, this may happen much earlier. A solution could be to require that hydrogen from electricity is not completely zero-carbon, but only meets clean hydrogen thresholds such as those discussed below. This would enable *partial additionality* with blending in 10% to 15% of electricity from gas or coal power plants. However, it still may not deliver high amounts of green hydrogen soon enough to enable early deployment of electrolysis-based hydrogen and its consideration as 'green'. Therefore, it may be necessary to also allow an economic or political link[22] for the definition of green hydrogen: This would allow renewable energy-based power plants to be purpose-built for electrolysis for an interim period of between five and ten years until enough green hydrogen with physical additionality is available from Western Australia or Patagonia for example, or grid-constrained areas in Germany or Japan. As with blue hydrogen, reducing costs is an important goal for green hydrogen development.

b) Public acceptance

As previously mentioned, a crucial requirement for the development of hydrogen will be that it is able to demonstrate significant and credible potential to reduce carbon emissions. This is crucial for both its environmental effectiveness and public acceptance. A credible certification scheme will therefore be paramount for public acceptance of blue hydrogen and for international joint efforts to supply sustainable hydrogen.

c) Political framework needed, particularly certification criteria for green and blue hydrogen

In order to establish an international supply infrastructure and market for clean hydrogen, an international governance and certification scheme that safeguards GHG as well as broader sustainability standards for H_2 supplies would appear to be essential requirements. Therefore, the GJETC has assessed the following important aspects for such an international certification scheme:

- Criteria for sustainable and low-carbon hydrogen
- With regard to blue hydrogen, the long-term sustainable potential and possible standardization of CCUS and dealing with concerns about it
- Options for ensuring the additionality of electricity from renewable energy used in the production of green hydrogen.

In addition to the GHG emissions balance of clean hydrogen, the certification should cover further sustainability requirements, for example with regard to water or land use and the balance with the climate protection strategies of the exporting countries.

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[22] The **political link** could be made in a RES support system with auctions for a maximum amount of capacity defined by the government, for example as in Germany. If the capacity politically defined and then auctioned is increased by a certain amount for the purpose of providing electricity for electrolysis, this amount of capacity and the subsequent amount of electricity generation could be seen as **additional to the baseline policy.** However, it could be argued that this capacity and generation is anyway urgently needed to accelerate decarbonization of the electricity system itself, and RES-E targets should therefore be increased. Here, we therefore see the need for international political agreement on whether this option of political linkage would be allowed under an international certification system.

An **economic link** could also be made by a company building RES power plants **outside of the public support scheme** for electricity or hydrogen (such as a FIT scheme) to produce hydrogen for its own purposes, e.g. in production or transport of goods. This could be seen as **fully** additional if the power plant and electrolyzer unit are not connected to the grid. If there is a grid connection, the part of the hydrogen generated from electricity equivalent to the annual production of the RES power plants could still be seen as **fully** additional in economic terms. Hydrogen should **not** be granted a 'green' certificate simply by buying proof of origin for the electricity required.

Such comprehensive sustainability criteria should obviously cover both blue and green hydrogen in an integrated and non-discriminatory manner, and should do so regardless of whether it is domestically produced or internationally traded.

In order to analyze the GHG reduction potential, it is necessary to compare the whole value chain from clean hydrogen production and supply to its use in different applications with traditional energy sources and use technologies. Firstly, the result of such comparisons makes the GHG reduction criterion dependent on the hydrogen application, and secondly on the conditions for hydrogen distribution and dispensing in different countries as well.

In regard to these differences in hydrogen applications and national distribution and use conditions, we may conclude that a comprehensive international hydrogen certification system could have two separate parts:

> [i] The first step could explore a data transparency initiative for embedded GHG emissions for internationally traded hydrogen. Such data disclosure could encourage international hydrogen trade with a lower GHG footprint.
>
> [ii] Furthermore, whether the environmental standards and potential certification should include an appropriate maximum universal threshold level of specific GHG emissions for internationally traded hydrogen until the border gate[23] could be explored. The certification should provide incentives to go below this level.

Both parts together should certainly achieve significant GHG reductions for each application case or sector in the *well-to-wheel* assessment. A level of *60% or more compared to the relevant benchmarks would be desirable.* However, it seems appropriate to allow *some flexibility* for nationally determined benchmark or threshold levels for GHG reductions, given the differences in sectoral priorities for achieving the biggest GHG emission reductions or in the availability of low-carbon energy resources both for hydrogen and its alternatives. However, the assessment principles and methods, as well as the publication requirements of the international certification system would need to be followed.

Based on the available estimates of achievable emissions values for blue and green hydrogen production and transport, a potential total maximum universal absolute threshold level of specific GHG emissions until an appropriate level at the border gate could be explored. Such absolute thresholds could be further reduced, ultimately aiming at zero, in accordance with technology development. This could provide incentives for further technology development.

The GJETC study on a hydrogen society also discusses potential overall threshold values of 'well-to-use' GHG emissions for a number of applications, reducing emissions by 60 or 70% compared to application-specific benchmarks.

d) International cooperation for the supply of sustainable hydrogen

Given the potential shown above as well as the challenges of supplying and applying clean hydrogen, we see important potential for closer cooperation in developing clean hydrogen and its infrastructure on a larger scale.

Costs need to be brought down and technologies improved (especially in the fields of renewable power generation, electrolysis, CO_2 capture, transport and storage, long-distance hydrogen transport, transformation of natural gas distribution infrastructures into hydrogen-ready infrastructures and hydrogen-ready application technologies.)

This calls for joint efforts by international organizations such as the G20/G7, the WTO, and sectoral organizations like the ICAO for aviation, the IMO for shipping, and others.

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[23] A GHG emissions reduction of least 50% compared to natural gas – the fossil fuel with the lowest GHG emissions – in a 'well-to-tank' analysis would be desirable as a credible contribution by clean hydrogen to climate change mitigation, in order to enhance its acceptance by the public. Analysis in the GJETC's study on hydrogen suggests that such a 50% reduction, which would require specific well-to-tank emissions of below approx. 33 gCO_{2eq} / MJ_{H2}, could be achievable using blue hydrogen in the cases analyzed. This may allow a maximum universal threshold level of specific GHG emissions for internationally traded hydrogen until the border gate of 30 gCO_{2EQ} / MJ_{H2}, for example, allowing for approx. 3 gCO_{2eq} / MJ_{H2} for national hydrogen distribution from border gate to tank. While this level of 30 gCO_{2eq} / MJ_{H2} could be used to set a minimum GHG reduction standard or a maximum threshold level for specific GHG emissions for internationally traded hydrogen until the border gate, it would not be sufficient for hydrogen to be imported to the EU. It should be noted that the recently revised EU Directive on renewable energies requires a 70% reduction in GHG emissions in a well-to-tank analysis compared to natural gas as the benchmark. This may go further than is feasible with blue hydrogen and its transportation to many potential importer countries.

But there is also room for closer bilateral German-Japanese cooperation in R&D, formulating standards and shared financing of the learning curve. Germany and Japan, which are leading the world in hydrogen technology and manufacturing, can help build the international clean hydrogen supply chain as technology providers – and as hydrogen importers creating early and significant demand.

The rapid development of production and transportation technologies on a larger scale, of upstream investments and applications in different sectors cannot be achieved in isolation. They require a more coordinated policy approach in order to establish trust in the timing of the next steps necessary and to avoid stranded assets. Thus, joint efforts need to be made to safeguard investment security for overseas investments in green or blue hydrogen and for a competitive hydrogen market, especially in the ramp-up phase.

A starting point for such a common perspective on the future role of hydrogen and the necessary steps to be addressed might be a joint roadmap for Germany, Japan, and other interested countries that helps to reduce (political) uncertainty and identifies an aligned and coordinated approach. An urgent matter in regard to such a roadmap would be a trusted international transparency and certification scheme for clean hydrogen as discussed above in order to provide investment security. Along with this, the roadmap would include areas and goals for technology collaboration in the areas mentioned above.

Further international institutional arrangements that might foster deeper technological cooperation and a sharing of the learning costs could include a joint initiative by Germany and Japan with two or three supplier countries and possibly further importing countries to build further hydrogen production facilities and means of transport. Japan is already cooperating with Australia and Brunei Darussalam in pilot projects for blue hydrogen production and shipping to Japan. A private consortium including Siemens aims to build a green hydrogen production facility in Western Australia. In Europe, Norway is a potential supplier of both blue and green hydrogen at low cost, including to Germany. Morocco, Algeria, Egypt, Turkey, and Russia are other potential suppliers of green hydrogen that could be connected to Germany via hydrogen pipeline infrastructures (Jensterle et al. 2019b).

In addition to cooperation on international hydrogen supply chains, German-Japanese joint research, development, demonstration, commercialization, and standardization efforts by Germany and Japan would be useful, particularly in the following areas:

- Replacing grey hydrogen (fossil fuel-based hydrogen without CCS) in existing industrial uses and using clean hydrogen in new production processes to replace fossil fuels;
- Fuel cell technologies in transport, including trains, buses, trucks, ships, and cars;
- Hydrogen-based advanced power plant technologies.

Please find recommendations on further research needs in Chapter 4.

3.3

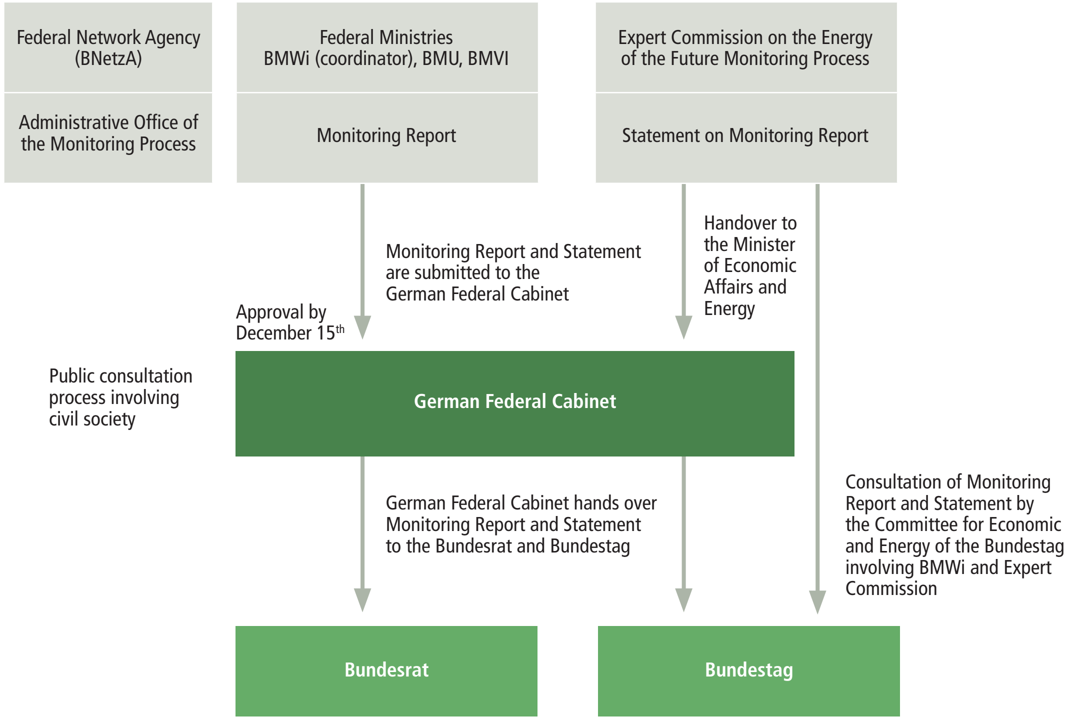
WG1: Climate & energy policy; targets, plans and strategies. The role of monitoring and evaluation mechanisms

Key findings

Germany and Japan are pursuing ambitious energy and climate policies. Both countries have set themselves quantified targets for the medium-term time horizon, i.e. with a view to 2030. These targets relate primarily to the reduction of national greenhouse gas emissions, but also to other areas where energy and climate policy is geared toward comprehensive target architectures. However, the structure of these target architectures and their direct links to international targets differ considerably in some cases.

The target architecture in Germany and its development for the 2030 time horizon is characterized by comparatively high complexity, a relatively high dynamic and a high frequency of updates as well as linkages to both, European and international climate or energy commitments and an increasing legally binding nature. This concerns, the European Union Emissions Trading System (EU ETS), the European Effort Sharing Regulation (ESR), the EU targets on energy efficiency and renewable energies combined with the EU Regulation on the Governance of the Energy Union and Climate Action, and the German Federal Climate Protection Act (Bundes-Klimaschutzgesetz – KSG), which has established legally binding sector targets for 2030 (EU ETS, ESR, KSG) and legally binding emission trajectories up to 2030 (ESR, KSG), for example. On the other hand, Japan's target is linked to the international climate regime while reflecting its complex energy challenges after the Fukushima Daiichi nuclear accident and achieving it is not legally binding based on domestic legislation. The reasons for these differences can be found in different traditions, different economic and technical core beliefs or perceptions in a few areas (nuclear, renewables, costs, etc.). Some but not all of them can be linked to the significant differences in terms of geography, infrastructure, political and cultural traditions between both countries.

Figure 6: The German monitoring cycle for the energy transition

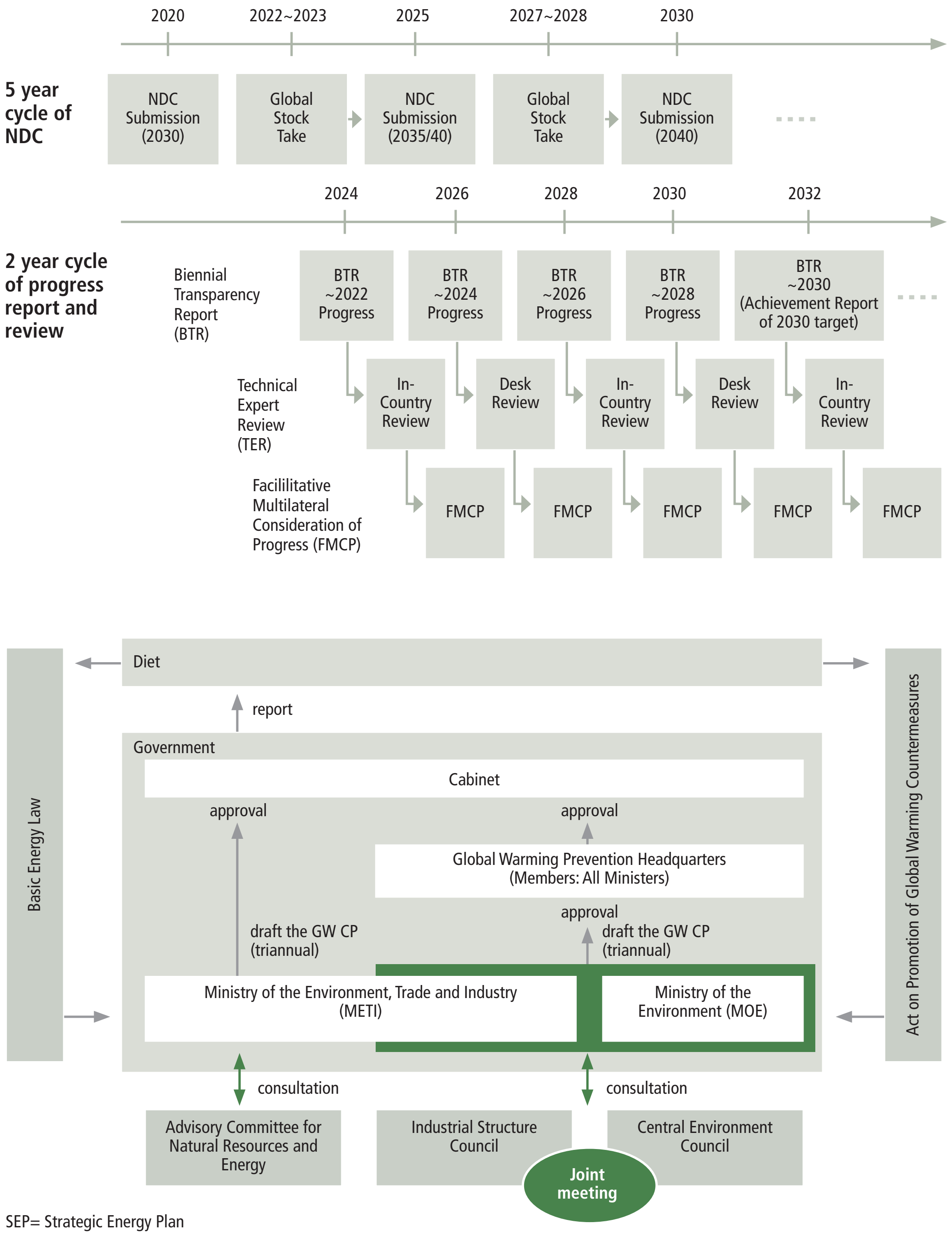


Source: own illustration

Both countries still face significant gaps that need to be closed to be fully compliant with the targets by 2030. Against this background, comprehensive monitoring, evaluation and revision approaches are becoming increasingly important elements of climate and energy policies. The comparison of the wide range of experiences from ex-ante and ex-post evaluations and revision mechanisms in Germany, Japan and other countries underlines the fact that the process, procedures and institutional arrangements for monitoring, evaluation and policy revision need to be advanced and streamlined. If gaps between targets and implementation continue to occur, strengthening of policies would be appropriate, particularly in sectors that show implementation gaps, though flexible adaptation of the ambition levels of sectoral targets while respecting the overall national target might be justified too. In this respect, the new and legally binding sector-specific enforcement and revision mechanisms created by the German Climate Protection Act and the EU's Governance Regulation will provide interesting experience.

Figures 6 and 7 provide examples of monitoring processes in Germany and Japan. The output paper by the Working Group (Matthes et al. 2020) provides more detailed information on these and other existing monitoring processes.

Figure 7: Monitoring process in Japan (upper: NDC, lower: the strategic energy plan and the basic environment plan)



SEP= Strategic Energy Plan
GW CP= Global Warming Countermeasures Plan

Source: upper; Takahiro Ueno, lower; GJETC

Ex-ante evaluation is becoming increasingly important, also with a view to long-term goals, e.g. for 2050. The nature of targets or goals for 2050 differs more between Germany (more binding and policy-guiding targets) and Japan (more indicative goals) than for the medium-term 2030 time horizon. The approaches for dealing with technology and cost uncertainties differ in part but using long-term targets/goals at least for consistency checks for long-term decisions, e.g. for infrastructures and innovation efforts, will be of growing relevance. An interesting field of further research cooperation will be to analyze different approaches and methodologies for setting and meeting long-term targets or goals in the face of uncertainties (e.g. regarding global trends, technology developments) as well as with a view to investment security, innovation dynamics, avoiding lock-in effects, and reflecting path dependencies.

However, the approaches to preparing medium and long-term decisions differ much less than expected. In both countries, the long-term horizon (2050) is primarily addressed by techno-economic analysis of technical and economic feasibility, whereas the medium-term horizon (2030) is addressed more from the perspective of policy implementation and political feasibility.

Conclusions and policy recommendations

With the increasing evidence from monitoring and evaluation processes and the improvement of ex-ante evaluation, it might be worth making additional efforts to at least gain a better understanding of the factual basis of the different core beliefs in the energy transitions. The exchange of experiences on policy design, monitoring, evaluation, and revision cycles could be an interesting field of cooperation.

The study concluded with the following recommendations for the respective countries in order to make the evaluation mechanisms more effective and thereby help achieve their energy and environment targets.

GERMANY

a) Diversity, consistency and focus of monitoring and evaluation processes

Germany’s experience shows that a relatively broad diversity of monitoring and evaluation processes has developed over time. While this has provided significant value, significant overlaps also emerged at the same time. A clearer structure and possibly a defined hierarchy of monitoring and evaluation efforts including for EU targets could streamline the monitoring and evaluation processes.

In addition to this, greater attention should be paid to ex-ante evaluation of policy mechanisms, including learning from enhanced ex-post evaluation.

b) Institutional arrangements for monitoring and evaluation

The institutional arrangements of the Energiewende monitoring process in Germany are increasingly being used as a blueprint for other monitoring or review processes. This approach should be used more widely at least for monitoring and evaluation processes that focus on the aggregated trends.

c) Target hierarchy

Initially, all targets were seen as equally important. But given the large number of targets, conflicts between targets were unavoidable. Prioritization has been achieved. The non-superior targets and the individual policies can and should be flexibly adaptable, if the superior targets are to be met. Some further revisions are proposed in the WG1 output paper.

d) Indicators

While the large number of indicators offers a lot of information, it is too complex and incomprehensible to guide decisions. The German Energiewende expert commission proposes using core indicators, which significantly compress information and present it in a comprehensible and understandable way.

Qualitative indicators are also important.[24] Otherwise, the risk of failing to address relevant dimensions of the energy transition may arise.

e) Presentation design

A visual and easy to understand presentation such as the energy transition traffic light, is recommended.

f) Policy evaluation

It is also highly important to evaluate the implementation and impacts of policies. Indicators cannot reflect the risks of positive or undesirable side effects of policies, or can only do so with a very long delay. It is only with the help of policy evaluation that risks and co-benefits can be identified at an early stage, and policy learning can be enabled.

JAPAN

a) NDC compatible with 3E+S

It should be kept in mind that the 26% GHG emission reduction target and underlining energy mix was formulated with the aim of simultaneously achieving 3E+S, more specifically, a) restoring energy self-sufficiency to pre-earthquake level, b) reducing electricity costs compared to today, c) presenting a GHG emissions target comparable with other developed countries. Monitoring and evaluation should explore whether the 26% target is still achievable while maintaining the balance between 3E+S. However, it is not pragmatic to stick to 26% under all circumstances, even if it is found that it the balance between 3E+S would fail to be achieved.

b) Evaluation of policy impact

Cost effectiveness of policies and measures should be thoroughly evaluated from the perspective of 3E+S. It is not justifiable to introduce unduly expensive policies just to achieve the 26% target. On the other hand, if the assessment shows improved cost effectiveness, a more ambitious approach should be considered.

c) Scientific review focusing on innovation

The “scientific review” process, which is expected to support long-term decarbonization up to 2050, is still under development and has not yet been fleshed out. Deep decarbonization will only be possible in the 3E+S framework when technologies to achieve this become cheap enough to be disseminated. Therefore, the review process should focus on examining the maturity of various technologies and the effectiveness of policies in making this happen rather than setting arbitrary percentage figures for GHG emission reductions.

Please find recommendations on further research needs in Chapter 4.

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[24] Please refer to chapter 4.1.4 of the output paper by the GJETC Working Group1 for details: „Climate & Energy Policy: Targets, Plans and Strategies. The Role of Monitoring and Evaluation Mechanisms“. Available at: http://www.gjetc.org/publications/

3.4

WG2: Energy efficiency in buildings

Buildings account for a significant share of energy consumption and greenhouse gas emissions in both countries. For example, in 2015, buildings consumed 42% of the final energy in German and 32% in Japan. This represented 45 GJ/capita in Germany and 34 GJ/capita in Japan (Ecofys and IAE 2017). In addition, despite significant improvements in energy efficiency in the past, there is still great potential for further energy savings. Consequently, energy efficiency in buildings plays a key role in most energy and climate scenarios and targets.

However, it is still important to understand in detail the potential of building concepts and technologies as well as non-technical solutions and actions, the barriers to be tackled, and the effectiveness of policies. In addition to analyzing this for each country, further conclusions and lessons can also be drawn by examining the differences and similarities between the two countries, Germany and Japan.

Against this background, the GJETC Working Group concentrated on three main topics:

1 I Energy performance of typical German and Japanese new buildings as well as advanced building concepts in various climate zones

2 I Potential overall energy saving targets for the building stock in 2030 and 2050

3 I Policy packages that can mainstream energy-efficient building concepts and technologies, including in existing building stock.

Key findings

a) Energy performance of typical and advanced buildings in Germany and Japan

Germany has had mandatory energy requirements (MEPS) for all heated buildings for many decades. These also apply for major renovations to existing buildings. They save approx. 60% to 70% of heating energy compared to uninsulated homes and buildings built before 1980. Japan introduced MEPS for new buildings with gross floor areas larger than or equal to 2,000 m^2 in 2015, and has extended their application to new non-residential buildings with gross floor areas larger than or equal to 300 m^2 since 2019 in order to comply with the Paris Agreement. Furthermore, from 2021, architects designing new residential or non-residential buildings with a total floor area of less than 300 m^2 are required to explain the MEPS compliance status to building owners.

In addition, both countries have been working on advanced building concepts that save even more energy and meet the remaining energy demand using renewable energies. In Germany, these include the Passive House concept (since 1991) and the more recent KfW 40+ standard, which can even produce homes that are net energy producers, while Japan has focused on Zero Energy Houses and Buildings (ZEH/ZEB).

The building concepts mentioned above for both countries yield the following energy performances for new single or multi-family buildings in various climates:

Table 2: Energy performance of new single family homes in Germany and Japan

	Germany			Japan
Building standard	useful energy heating/cooling kWh/(m^2*yr)	solar PV generation kWh(m^2*yr)	(fossil fuel) primary energy kWh/(m^2*yr)	primary energy (heating, cooling, ventilation, lighting and hot water supply primary energy consumption amount minus primary energy supply by PV) for all rooms 24 hours operation (values in brackets: for partial intermittent operation) kWh/(m2*yr)
MEPS	typically: **70**	**0**	typically: **45**	typically: 305 (-) in Area 1 (4,500 to 5,500 HDD) typically: 270 (-) in Area 2 (3,500 to 4,500 HDD) typically: 242 (156) in Area 3 (3,000 to 3,500 HDD) typically: 253 (153) in Area 4 (2,500 to 3,000 HDD) typically: 233 (143) in Area 5 (2,000 to 2,500 HDD) typically: 228 (136) in Area 6 (1,500 to 2,000 HDD) typically: 192 (117) in Area 7 (500 to 1,500 HDD) typically: 189 (103) in Area 8 (0 to 500 HDD)
KfW 40+	typically: **40**	**14**	typically: **18**	-
Passive House	maximum: **30 (15 for heating plus 15 for cooling)**	**0**	maximum: **120** (incl. hot water, ventilation, and user's electricity for lighting, any elevators, and plug loads)	
ZEH	-	-	-	**0 for Net Zero Energy House**

Climate characteristics:
Germany: 3,500 to 4,000 HDD, 10 to 50 CDD incl. zero dehumidification requirement
Japan: 10 to 5,500 HDD, 0 to 600 CDD incl. zero dehumidification requirement

Building concepts and energy performance values for multi-family buildings and non-residential buildings are similar.

For refurbishment, MEPS requirements in Germany are a little less stringent than for new build and only valid in the case of major renovations. Nevertheless, they also save approx. 60% to 70% of heating energy compared to uninsulated homes and buildings. Some projects have shown that savings of up to 80 or 90% are technically possible.

b) Energy efficiency policy targets for buildings

Given the high energy saving potentials in the building sector, which are mostly cost-effective when harnessed during normal (re)investment in buildings, it is advisable to set *sector-specific energy efficiency or consumption targets* for the building sector in order to contribute to the overall energy transition and climate change mitigation targets. Since 2010/11, Germany has had the following policy targets for the buildings sector:

- Reduce total heating energy consumption in buildings by 20% from 2008 to 2020;
- Reduce non-renewable primary energy consumption in buildings by 80% by 2050;
- Increase the rate of comprehensive building renovation from 1%/year to at least 2%/year as an operational target.

However, in recent years, Germany has not been on track to meet these targets. This is due to a number of factors, including a higher rate of new builds, which increased overall energy consumption of buildings, combined with a capacity-constrained construction sector, which leaves little capacity for renovations, insufficient financial incentives, and insufficient intensity of other policies, even though the combination of policies is well developed. In addition, the 2050 target would need to be revised to a 100% reduction in the use of non-renewable energy sources, in light of Germany's new ambition to achieve total climate neutrality by 2050.

In 2016, Japan set the following policy targets for the buildings sector for 2030 in order to comply with the Paris Agreement. However, Japan has not yet set a policy target for the building sector for 2050.

- Reduce total primary energy consumption in non-residential buildings by 14% from 2013 to 2030;
- Reduce total primary energy consumption in residential buildings by 27% from 2013 to 2030.

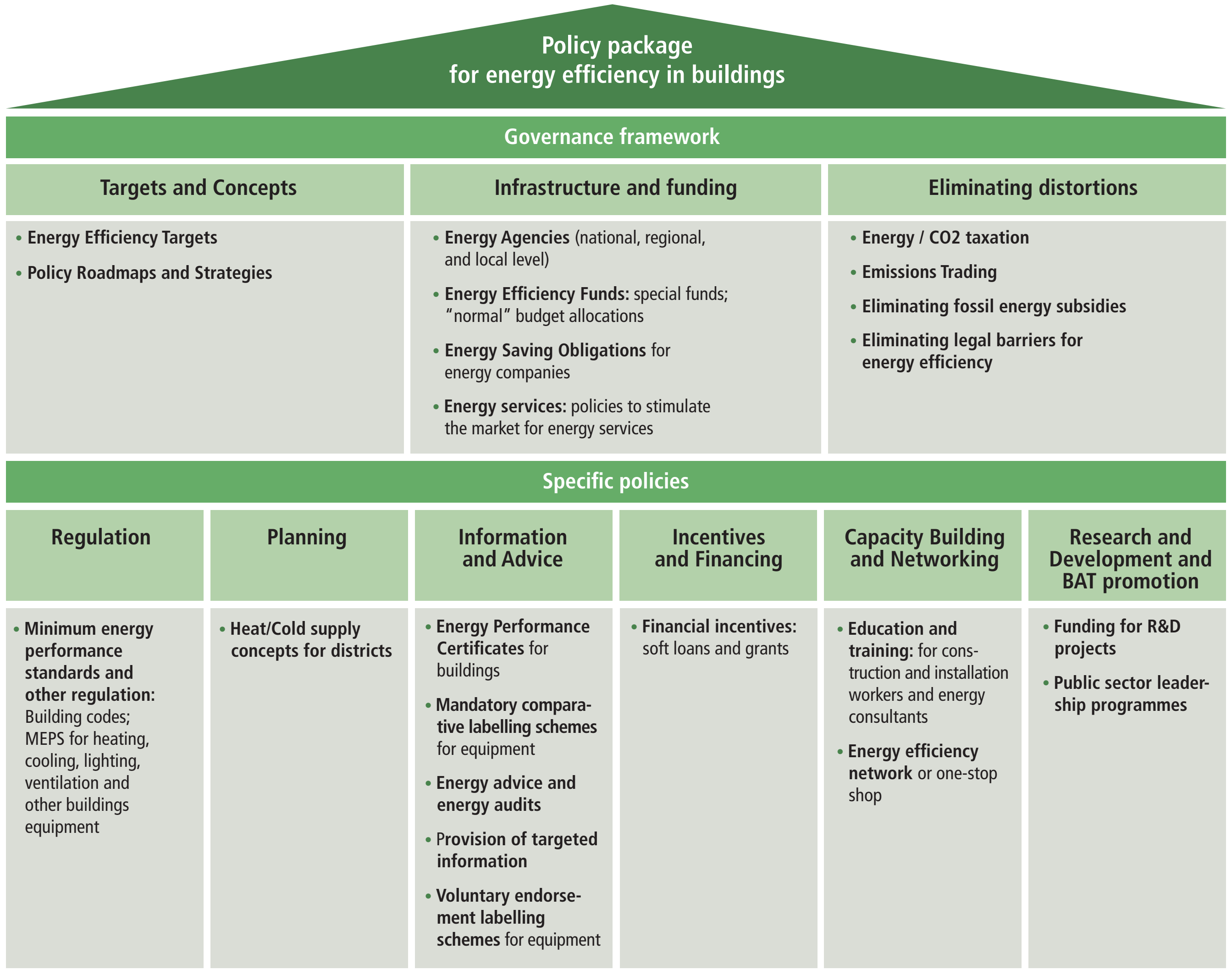
c) Effective energy efficiency policies for buildings

In order to harness the energy efficiency potential and achieve policy targets as discussed in the previous section, governments need to engage building owners and all building market actors and help them overcome the many barriers with a well-combined package of policies and measures. In particular, financial and informational barriers often prevent owners from implementing energy efficiency actions. If just one actor in the market chain for buildings decides against the energy efficient solution, it will not happen.

Figure 8 shows the prototypical energy efficiency policy package for buildings that emerged from research in recent years. The upper part contains the typical instruments of the governance framework overarching the sectors and enabling the implementation of sectoral policies. It should be noted that Energy Saving Obligations for energy companies are an alternative to the combination of government's Energy Agencies and Energy Efficiency Funds. The lower part shows the typical sector-specific policies for buildings and installed equipment.

Both countries have already implemented a broad set of policies from this package, but both are still facing gaps and weaknesses. The working group therefore analyzed needs and potential options for improving the policies.

Figure 8: Prototypical energy efficiency policy package for buildings



Policy package
for energy efficiency in buildings

Governance framework

Targets and Concepts	Infrastructure and funding	Eliminating distortions
• **Energy Efficiency Targets** • **Policy Roadmaps and Strategies**	• **Energy Agencies** (national, regional, and local level) • **Energy Efficiency Funds:** special funds; "normal" budget allocations • **Energy Saving Obligations** for energy companies • **Energy services:** policies to stimulate the market for energy services	• **Energy / CO2 taxation** • **Emissions Trading** • **Eliminating fossil energy subsidies** • **Eliminating legal barriers for energy efficiency**

Specific policies

Regulation	Planning	Information and Advice	Incentives and Financing	Capacity Building and Networking	Research and Development and BAT promotion
• **Minimum energy performance standards and other regulation:** Building codes; MEPS for heating, cooling, lighting, ventilation and other buildings equipment	• **Heat/Cold supply concepts for districts**	• **Energy Performance Certificates** for buildings • **Mandatory comparative labelling schemes** for equipment • **Energy advice and energy audits** • **Provision of targeted information** • **Voluntary endorsement labelling schemes** for equipment	• **Financial incentives:** soft loans and grants	• **Education and training:** for construction and installation workers and energy consultants • **Energy efficiency network** or one-stop shop	• **Funding for R&D projects** • **Public sector leadership programmes**

Source: based on Thomas et al. (2015)

Conclusions and policy recommendations

a) What could be improved in building energy efficiency policies in Germany?

In order to reach the target of *80% of non-renewable primary energy savings by 2050*, renovation rates, which are currently at about 1%, need to at least double. The German building stock is quite old, and 50% must be renovated in the next 20 years.

For years, the government has followed the three-pronged policy approach of 'Inform, Support, Regulate', and is likely to continue this approach in the future.

Regulation is the basis for most of the other policies. However, a revision of the building codes for new builds to include very energy efficient nearly zero energy building (nZEB) requirements, as required by EU legislation to enter into force on 1 January 2021, is still pending. The new buildings energy performance level that we consider adequate for this next generation building code is equivalent to the KfW40+ standard. Standards for renovation should also be further enhanced.

However, increasing the renovation rate and the energy saving levels of each renovation at the same time will require more than legal standards. Firstly, targeted training of a larger number of building experts and workers is key both to providing detailed advice on actions and mentoring building owners through the renovation process and, in particular, the renovation work itself. All of this can be better organized and coordinated at local level through local or regional energy agencies acting as a one-stop shop on energy efficient renovation and renewable energies for building owners. A financial support program for such agencies will therefore also be needed.

Financial incentives to invest in comprehensive renovations were recently enhanced. However, KfW program funding and tax deductions need to be increased to around €5 bn/yr. Grant rates for single actions (e.g. insulating the roof or walls) should be increased, if the actions are in line with an individual building renovation roadmap towards nearly zero energy building standards.

Regulation on refurbishing old and inefficient building stock should also be taken into consideration at this stage. Along with improved financial incentives, this may overcome the split incentive barrier.

Furthermore, there is a need to bring down renovation costs through industrial construction, digital design tools, and process optimization in the area of renovation too. Examples show potential savings on renovation costs and time of up to 40%. Financial support could also be provided for agencies that bundle renovation. Finally, policies should also target so-called grey energy. This becomes more and more important, the lower the direct energy consumption of a building during its use phase is.

Last but not least, we see a need to improve the governance framework through a stronger coordination agency in polycentric energy efficiency governance. Institutionalized steering responsibility needs to be created with sufficient capacities to coordinate and bundle the overall energy efficiency packages in order to meet official energy savings targets (Wuppertal Institute 2013). Whether it would be a new institution or whether the duties and resources of the existing BAFA/BfEE and dena agencies would be enhanced is open to policy debate.

b) What could be improved in building energy efficiency policies in Japan?

The building energy performance requirements under the Building Energy Conservation Act are applied to new buildings/extensions/renovations with a floor space area over certain thresholds. Additional supporting measures should be provided for buildings with small floor spaces and old, vintage housing stocks. However, these are based on the design phase evaluation before completion of the building. Policies on energy monitoring with advice during the utilization phase are recommended as building performance decreases compared to the initial condition in the long run.

In certain cases, energy performance certificates should be required in order to raise awareness of the energy consumption of the building. As in Germany, this obligation can be fulfilled when selling, renting or leasing property, as well as for buildings with a publicly accessible area of a size that needs to be defined for Japanese conditions.

In addition to this, mandatory energy consultancy could be provided, especially for people who are willing to buy or build a house. This targeted advice could show the potential to reduce the building's energy consumption.

Outlook on the cooperation between Germany and Japan

Since the Meiji Restoration, Germany and Japan have been cooperating in many subject areas, and this has been developing quite strongly in the environmental field in recent years.

Because Germany introduced some types of policies on energy efficiency in buildings earlier on, Japan has been able to gain inspiration for its own energy and environmental policies, inter alia, from Germany's set of policies in the past. This applies to the Energy Saving Ordinance, the Renewable Energy Sources Act and the DIN 18599 balancing system for non-residential buildings, which have largely been copied for the Japanese regulation.

A Memorandum of Cooperation has existed between the construction ministries of the two countries since 2013 and has also been extended to the research level between the BBSR in Bonn and Berlin and the Institute for Building Research in Tsukuba. Within the framework of this cooperation, a basis of trust and a state of knowledge on the respective standards and developments has emerged, which seems to present a very fruitful basis for further exchange.

A further approach to the exchange may build on German experience with the work of energy and climate protection agencies. In Germany, the work of such agencies for the efficient implementation of political goals is important at the federal, state and local levels. The agencies manage to build up competences and implement projects professionally over longer periods under public or partly public sponsorship.

The principle of 'Inform, Support, Regulate based on Research' has established itself in German building energy policy. A similar approach seems to apply in Japan as well, so that an exchange on the respective political measures is possible along these lines and based on the prototypical policy package outlined above. In all policy areas, parallels can already be seen in the work, even if the levels are still different.

The German side in particular can benefit from the Japanese experience of Smart City projects. In addition to fuel cells, which are much more highly developed in Japan, their use combined with photovoltaics in such settlements is a model for Germany, where urban neighborhoods are still very heat-oriented.

Therefore, connecting German knowledge of and technology for building shell energy efficiency and Japanese knowledge of and technology for BEMS/HEMS and Smart Cities could provide even better energy performance in both countries, and opportunities for implementation in other countries too.

Please find recommendations on further research needs in Chapter 4.

3.5

WG3: Transport and sector coupling

Decarbonizing the transport sector will be a challenge for both Japan and Germany, but it also offers opportunities on future markets. In addition to transport sector measures, sector coupling, i.e. the use of green electricity, clean hydrogen, and derived fuels, will be required. In both countries, there is great interest in sector coupling and e-mobility. In September 2019, the Council invited two renowned experts in the field of transport, Martin Schmied (Germany Federal Environment Agency) and Prof. Yoshitsugu Hayashi (Chubu University), to discuss new approaches to transport and sector coupling. Afterwards, the GJETC secretariat summarized the conclusions in a short policy paper and compiled a factsheet of corresponding facts and figures. The following chapter provides a summary of the knowledge gained and the GJETC's recommendations in the field.

Key findings

GERMANY

In Germany, energy consumption per capita in the transport sector is 31.7 Petajoule (PJ). The main reason for this comparatively high consumption rate is the modal split in passenger and freight transport. In passenger transport, almost 80 percent of passenger kilometers are provided by cars, while railway and other public transport accounts for only 14.6%. In freight transport, the consumption rate is 657 billion metric ton-kilometers per year. The freight transport volume has risen by a total of around 76% since the mid-1990s and freight transport by road has even doubled. One of the reasons for this is Germany's role as a transit area for European freight transport. Freight transport is mainly conducted by road (approx. 65%) or by rail (24%), while shipping plays a minor role (11%). Regarding the types of drive, research shows that only 0.3% are hybrid vehicles, while fully electric vehicles account for less than 0.1% of Germany's passenger transport.

Germany's binding sectoral target set out in the German Climate Act (KSG) is 95 Mt CO_{2e} for the transport sector, which is 68 Mt CO_{2e} (-41.7%) below the 2018 level and 69 Mt CO_{2e} (-42.2%) below the 1990 level. Many measures are technology-oriented, and the measures supporting alternative fuel systems and digitalization are expected to achieve more than half of the required GHG emission reductions. Avoiding road mobility does not seem to be a priority goal: There are no speed limits on highways, and since many years no measures to change taxation of vehicles and fuel, or road tolls have been taken.

JAPAN

In Japan, energy consumption per capita in the transport sector was 24.2 PJ. Only 60 % of passenger transport is conducted by car, while rail and other public transport account for 34.2%. Freight transport accounts for 400 billion metric ton-kilometers. The volume declined between 1990 and 2010 and has stagnated since 2010. Shipping plays a major role in freight transport. Almost half of the goods are transported by ship, while road transport accounts for the other half. Hardly any freight is transported by train. Regarding the types of drive, more than 13% of vehicles in Japan are hybrid vehicles, while full electric vehicles account for approx. 0.1%.

Japan's sectoral target set out in the "Long-term energy supply-demand outlook" of April 2015, corresponding to the 4th and 5th Strategic Energy Plan, is to reduce the annual energy consumption attributed to the transport sector by 26% compared to the 2013 fiscal year, which can be translated as a reduction of 62 million metric tons of CO_{2eq} by 2030. In order to achieve this energy efficiency target for the transport sector, the Japanese Ministry of Trade, Economy, and Industry (METI) has identified a set of measures and their effect on reducing energy consumption. These address various fields of action in passenger transport and freight transport, for example the promotion of high efficiency vehicles, the optimization of freight transport, and automated driving. The list indicates that Japan needs to pursue both improvement of vehicles and their transition to low-carbon electricity and fuels, as well as various other transport measures to meet the energy and climate target.

Conclusions and policy recommendations

Both in Germany and in Japan, policy measures should focus on the strategy of "avoiding, shifting and improving". Firstly, the mobility system should be restructured so that traffic is avoided. Secondly, transport should be shifted to more eco-friendly modes, e.g. rail, bus, cycling, and walking instead of car. Thirdly, vehicles have to become more energy efficient, and sector coupling needs to be advanced in the mobility sector through battery electric and hydrogen fuel cell vehicles along with the expansion of electricity generation from renewable energies.

GERMANY

The Council recommends establishing measures in line with the German Federal Environment Agency's recommendations (see Figure 9 and German Federal Environment Agency 2019). Compared to the measures planed by the Federal Ministry of Transport, the Agency's recommendations focus more heavily on economic measures such as a significant increase in energy taxes or an increase in road tolls for trucks.

JAPAN

In addition to the set of measures identified by METI, different measures are recommended by Hayashi (2019) to implement the strategy of "avoiding, shifting and improving" in Japan. Land use planning, which avoids the use or development of peripheral areas outside of cities or in other regions with limited access to alternatives to the car, will avoid unnecessary car traffic. In middle-sized cities, where cars play a major role in the mobility of citizens, the conditions for shifting to alternative modes of transport, e.g. public transport or cycling, need to be improved.

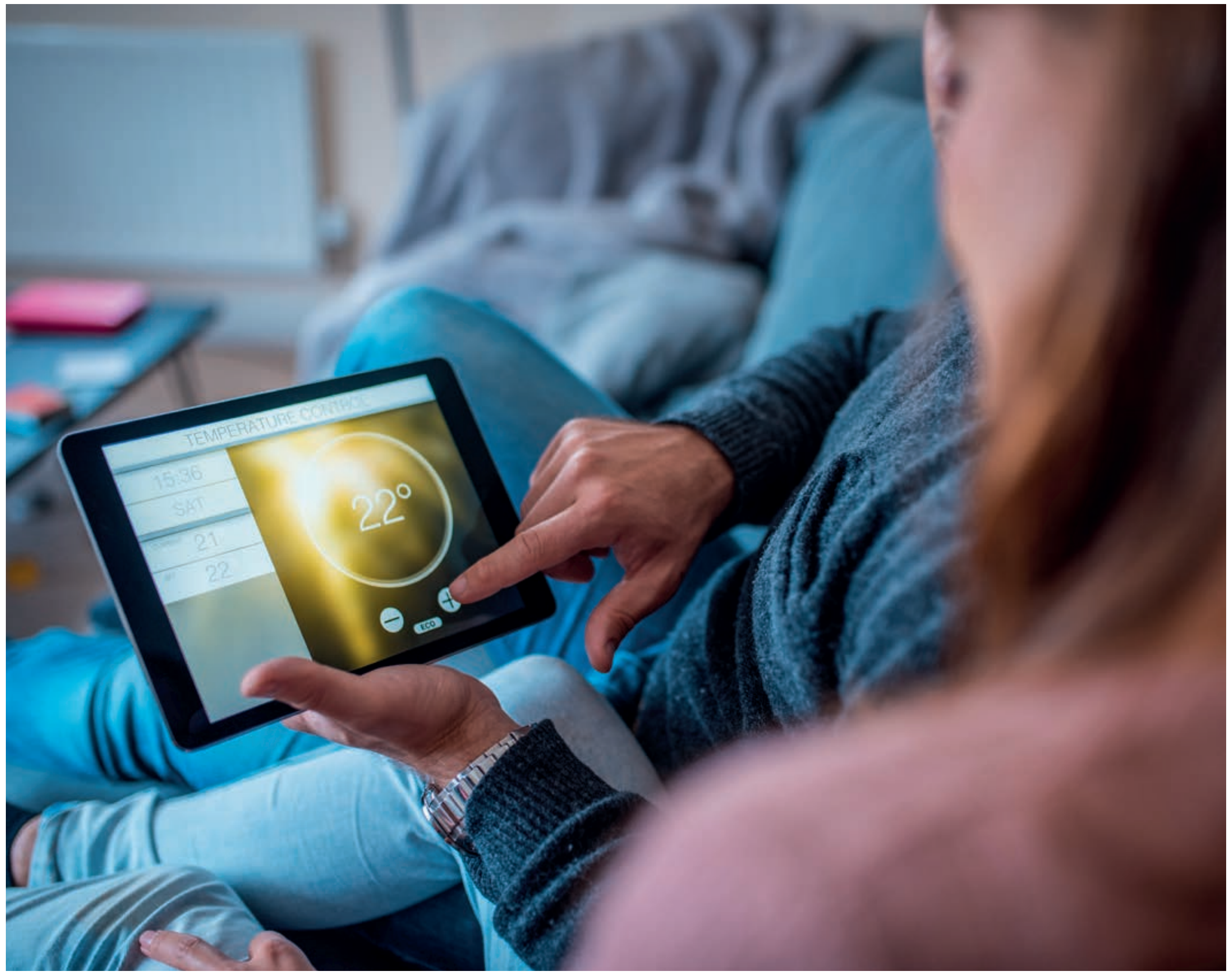
Similar to the recommendations in Germany, economic measures should be implemented. These could include high taxes on large cars in cities combined with a large tax reduction for newly developed small vehicles with state-of-the-art technology. Promotion of sector coupling will need to go hand in hand with the expansion of electricity generation from renewable energies.

Please find recommendations on further research needs in Chapter 4.

Figure 9: Policy measures recommended by the German Federal Environment Agency

Passanger Transport (PT)		Goods Transport (GT)	
2030 EU CO$_2$ standards for passenger cars and light commercial vehicles	4,5	2030 EU CO$_2$ standards of heavy duty vehicles	5,5
Quota for new electric cars of 70 % in 2030	8		
CO$_2$-based Bonus-Malus-system for new passenger cars	3,5		
Equal taxation for gasoline and diesel; fuel taxation increase by introducing carbon pricing	14	Fuel tax lorries	1
Abolition of tax advantages for the private use of company cars	4	Lorry toll increase	4
Abolition of commuting allowance	4		
Speed limit on motorways	3	OH-Lorry	1,5
Public transport, cycling and walking	2		

Source: German Federal Environment Agency (2019)



3.6

WG4: Integration costs of variable renewable energy sources

The costs of variable renewable energies (VRE), such as wind and solar PV, have been falling rapidly, and they are expected to fall further in the future. However, a major barrier to the use of both wind and solar PV is their recognized variability, or intermittency, with fluctuating power outputs depending on weather and climate conditions. Therefore, a massive introduction of VRE would require additional costs for flexibility technologies to support their system integration, affecting the economics of the power sector considerably. The GJETC investigated the feasibility of (almost) complete decarbonization of the power sector, comparing related studies for Japan and Germany, fully taking into account the economic aspects related to high penetration of VRE.

Key findings

The GJETC has found many similarities and differences between the Japanese and German studies. Generally speaking, the results of the Japanese studies imply significantly higher costs for achieving very high (>80-90%) shares of variable renewables than those of the German studies. This may be due to differences in multiple conditions, assumptions, and integration into modelling for the studies, such as future costs and the availability of renewable resources in comparison to clean hydrogen and nuclear power, power grid interconnection with neighboring countries, and further flexibility options including demand-side management, batteries including BEV, heat storage and heat pumps, smart grids and grid restructuring, and the existing pumped storage hydro, as well as electrolysis and gas-fired back-up power using green hydrogen or methane. More detailed analysis would be required to elucidate the background of these discrepancies.

Thus, it is highly important to investigate further the differences in the methods, assumptions, and results of these studies in order to obtain more general and robust policy recommendations.

At the same time, the GJETC also finds common conclusions; both countries will face challenges in achieving very high shares of VRE. Firstly, in both counties, large wind power potentials exist in areas remote from large energy consumers, resulting in massive investment needs for grid transmission lines. Secondly, the so-called "cannibalization" effect, which refers to the decline in the market values of power generating facilities under high shares of VRE, may also be a major challenge in the mid to long-term. Thirdly, safely managing the duration of "dark doldrums", or "windless and sunless" periods, when VRE outputs are extremely low, may prove to be the greatest challenge associated with very high penetration of VRE, because it is likely to require gas or hydrogen-fired backup power plants and means of seasonal storage.

Despite all these challenges, the calculations imply that high penetration of VRE may not result in a very large economic burden depending on the country and region and on the development of flexibility options, which also has to be evaluated in regard to possible innovation and climate change mitigation effects.

Under German conditions and the Paris Agreement, even reference scenarios have a high share of VRE by 2050 (60% to 70%). The difference between scenarios analyzing pathways to minus 95% of GHG emissions by 2050 and the reference scenarios is only 10% to 20% of total electricity system costs, which can be interpreted as the integration costs of very high shares of VRE. For example, the increase in costs for the 95% scenario in the BDI's 2018 study is 1.3 cents/kWh versus the reference scenario and 2.1 cents/kWh versus the base year 2015, and almost zero versus 2020.

Even in the case of Japan, with the use of a reasonable amount of nuclear power and/or imported hydrogen, the cost hike associated with achieving an almost decarbonized power system can be reduced to less than 3 JPY/kWh (2.5 Euro-cents/kWh), although it should be noted that these calculations make optimistic assumptions regarding future technology improvements to overcome several foreseen challenges, such as those related to rotational inertia.[25]

Conclusions and policy recommendations

The GJETC concludes that 1) the potential of achieving a high share of variable renewable energies in power generation will be highly dependent on the future development of their generation costs in relation to hydrogen and – according to current policy priorities in Japan – in relation to nuclear power plants, and 2) it will be necessary to optimize grid integration, flexibility, and sector integration technologies and their mix, as well as energy efficiency, in order to minimize specific and overall power system costs with growing shares of VRE. The studies reviewed here indicate that it will be possible to limit additional power system costs to reasonable levels even with high shares of VRE, if we can address several anticipated challenges properly and optimize our efforts to achieve ambitious GHG reduction targets.

The GJETC therefore recommends (1) further analysis and simulation to better understand the opportunities of different technologies and their combination, as well as the differences in costs found between Germany and Japan (cf. chapter 4.6), taking experiences in other countries on board, such as in federal states in the USA or in Denmark; (2) to implement joint German-Japanese demonstration and pilot projects to test advanced technologies and business models for flexibility, similar e.g. to the SINTEG program in Germany; and (3) to develop a priority list for market readiness and implementation of different flexibility options, with the timing of implementation related to the share of VRE in the system. Obviously, such a priority list would also be adapted to the situation in each of both countries, Germany and Japan.

Please find recommendations on further research needs in Chapter 4.

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[25] Rotation inertia of large generators is a function to stabilize the frequancy of electricty. If the number of such generators, typically equiped with thermal power plants, is reduced due to increasing use of solar PV or wind turbine, power grids will need to install different mechanisms to stabilize the frequency.

4

Further research needs

4

Further research needs

The second phase of GJETC succeeded in delivering valuable results through research on and discussion of topics of mutual interest. However, as the discussion progressed and deepened, the GJETC identified new challenges as well. In addition, both countries are called upon to address new issues and to adjust the energy transition pathway to reflect continuously changing external conditions including social, economic, and technological development.

This section discusses the further research needs that emerged through the second phase of activity by the GJETC. They are not a matter only for Germany and Japan. Although the surrounding conditions differ, it can be said that most issues will become common challenges for the countries pursuing long-term energy transition. This indicates that the activity of the GJETC and resulting insights addressing integral questions of energy transition can also contribute to other economies. Germany and Japan are asked to confront such energy transition challenges and present their successful results to the world.

4.1

Digitalization and the energy transition

The GJETC study has focused on a range of aspects of digitalization for the energy transition, namely VPPs, P2P trading, and PPAs. However, it should be noted that these are merely a part of the broad opportunity of digitalization for the energy transition. Due to the very wide application potential and rapid development of digital technology, it is not easy to grasp the perspective links between digitalization and the energy transition. On the other hand, this calls for strong efforts by academia including the GJETC. We shall seek to apply the full benefits of digitalization to the energy transition in both countries though further research.

- What other applications as well as benefits and challenges of digital technology are anticipated for the energy transition?
- In particular, the application of digital technology is currently almost entirely focused on the supply side of the energy market (including load management via DSM). The challenge remains to integrate this perspective with energy efficiency and energy conservation activities on the supply side (e.g. co- and trigeneration) and especially on the demand side.
- For example, Home Energy Management Systems (HEMS) in Japan/Smart Home Systems in the EU, Building EMS (BEMS) in Japan/BACS – Building automation and control systems in the EU, and other optimization systems for individual premises, city districts, or even smart cities are just a few example.
- Which applications would bring greater benefits and should therefore be prioritized?
- One aspect we were not able to address is the energy and resource use caused by digitalization, and how this might be reduced.

In which of these fields are Germany and Japan already cooperating, and where are there further promising areas of cooperation?

4.2

Hydrogen society

The study shared the importance of hydrogen as a source of heat, fuel for vehicles, and a means of energy storage. The study also identified the challenges that remain for hydrogen to become viable energy source. The need for further research and innovation is great when it comes to transport modes for hydrogen, challenges regarding energy security and conversion technologies, even more so than in hydrogen production technologies where scale is the dominant issue. However, CCUS technologies for blue hydrogen production and their sustainability are also in significant need of further research and innovation. Further study should also address the carbon recycling concept comprising both hydrogen and CCUS, which is expected to contribute to decarbonizing the energy system.

Policy and regulation framework for hydrogen

- How and to what extent can hydrogen technical and safety regulation, standards, and environmental certification be harmonized? How can the potential principles for an international certification system outlined in this study be made more operational and cost-effective, i.e. through pragmatic standardization approaches and default values that are not harmful to its environmental integrity?

- Are the common features of and differences between Japanese and German/European legislation regarding hydrogen/PtX a barrier to joint development, and what else other than certification should be made consistent?

- To which extent do both electricity and gas (including hydrogen) network planning and electricity and gas/hydrogen market functioning need to be taken into consideration together in the future, so that sector coupling will not lead to market distortions or contradictions, but to more efficient infrastructure use, net GHG reductions, and better allocation of resources?

Blended hydrogen

- What are the technical limits of blending hydrogen in the gas infrastructure and what maximum quota would be generally feasible (30%?)? To what extent and at what cost could new membrane technologies filter hydrogen for sensitive users and help stabilize the composition of the gas mix?

- Is “blending” or “hydrogen island solutions” the way to go? The answer may vary from country to country and should be based on a well-founded impact assessment.

Energy security

- What are the energy security risks of hydrogen supply, particularly imported hydrogen, and what policy and actions are needed?

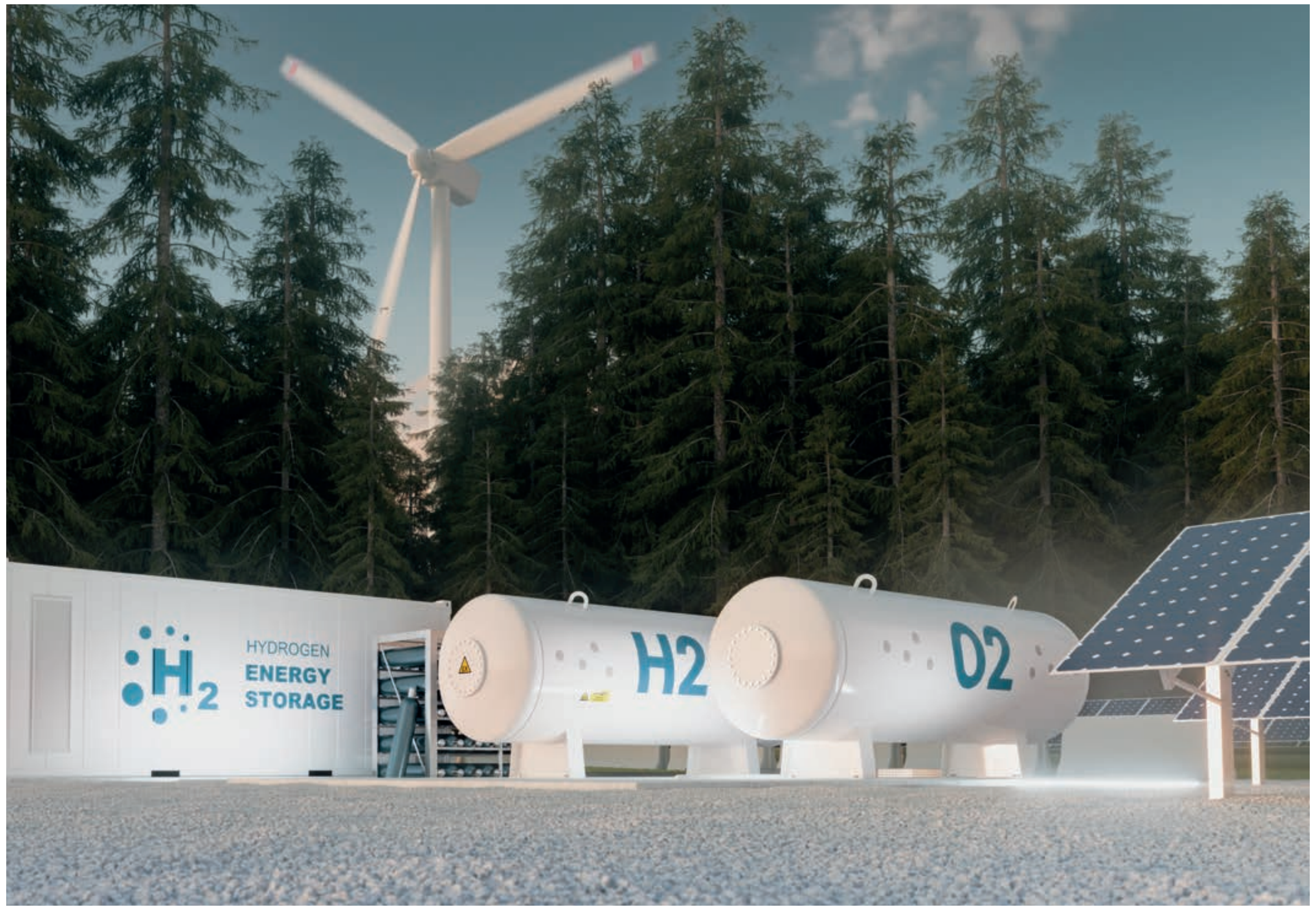
Public acceptance

- The extent to which public acceptance of hydrogen is influenced by its carbon footprint, not only nationally but also internationally, and how this might be changed by binding political strategies are open questions that require further research.

4.3

Climate & energy policy; targets, plans and strategies - The role of monitoring and evaluation mechanisms

The study identified the importance of both ex-post evaluation and ex-ante assessment of strategies or policies and measures. At the same time, the study also identified room to improve such mechanisms to make them more effective.



- What evaluation and ex-ante assessment mechanisms work better?

- What can both countries learn from each other in terms of experience in policy design, target/goal setting procedures, monitoring, evaluation, revision cycles, and the link between monitoring & evaluation and the revision of policies in order to close gaps in order to achieve targets?

The study identified that, in both Germany and Japan, the long-term horizon (2050) is addressed in technical and economic feasibility studies, which means the energy transition strategy will be more reliant on innovation in every aspect including technical, economic, and business model issues.

- What policies or mechanisms can promote such innovations?

- Can we learn from past or present experiences?

- Can we reach at least a better understanding of the facts regarding the different core beliefs in the energy transitions, and how they shape the research approaches and results in technical and economic feasibility studies?

- Are binding and sector-specific targets for 2030 (e.g. Germany`s current policy) succeeding in speeding up, scaling up and tightening up decarbonization processes? What about suitable procedures to close implementation gaps and gain public acceptance?

4.4

Energy efficiency in buildings

The output paper on energy efficiency in buildings has provided some insights into the similarities and differences in energy use in homes and buildings, building energy performance, design, and technologies, as well as policy targets and packages of instruments implemented. However, there is still considerable need for further in-depth comparable research to better understand what both countries could learn from each other, and what they could jointly offer to other countries to advance the energy transition in cities and buildings.

- Could connecting German knowledge of and technology for building shell energy efficiency and Japanese knowledge of and technology for BEMS/HEMS and Smart Cities provide even better energy performance in both countries, and opportunities for implementation in other countries too?
- Which other benefits can be achieved, e.g. for health and productivity?
- What can be mutually learned to make energy efficiency (and sufficiency) policies for new build and energy efficient renovation more effective in both countries?

4.5

Transport and sector coupling

The study identified policies necessary to make the transport sector sustainable, reflecting conditions in the respective countries. Although the resulting recommendations are viable options, there is a need for further research both on action in the transport sector only (avoid – shift – improve measures) and in sector coupling. The latter is a broader concept that includes integrated management of battery electric vehicles, solar PV, and power supply for households and businesses, for example. It also potentially includes hydrogen energy with fuel cells and derived fuels through carbon recycling, which can be used in vehicles driven by internal combustion engines; and obviously the use of digital technology is inevitable too. Due to this complexity, research questions include the following:

- What priority technology and fuel paths are to be followed, and what priority modes of transport and means of transport are to be addressed?
- What alignment is needed in market/regulatory design, e.g. interlinking with power market reform or power pricing?
- What impact can various policies or measures have on primary energy savings and GHG emission reduction?
- The role of also establishing legally binding sectoral targets (2030; 2050) for the transportation sector as a guideline for rational decisions on a decarbonized future of mobility.
- What policies and measures are effective in preventing traffic and shifting transportation needs to more environmentally benign modes? What might present a consistent package of measures to achieve ambitious climate protection goals and the potential of integrating mobility into sector coupling in Germany and Japan?

4.6

Integration cost of renewable energy sources

The study identified several differences in the approaches taken or conditions of the reviewed studies in Germany and Japan. For example, Japan's analysis does not consider demand-side management including heat storage and vehicle-to-grid (V2G) technology as a means of flexibility to the same extent that the German studies did. As the cost of both solar and wind power, and flexibility technology will obviously have a considerable effect on the economic viability of a high penetration of VREs, it would be worth extending the analysis by applying it to a wider range of flexibility technology or demand response mechanisms.

- What flexibility technology will become available and what will it cost?
- Which combination of flexibility technology might be more economically efficient and what conditions will define this?

More fundamentally, the study sees challenges in comparing the studies in Germany and Japan due to the application of different analysis models and conditions. Therefore, it is thought that a comparative analysis based on the same methodology would deliver a clearer view of similarities and differences, and hence implications for the integration cost of VREs in both countries.

- Why are the modelling estimates for the full economic impact of VREs different for the two countries?
- How can barriers be removed for better economic efficiency?

5

The GJETC as a role model of bilateral cooperation

5

The GJETC as a role model of bilateral cooperation

The GJETC was established as a non-governmental initiative by a small number of experts from research institutions, energy policy think tanks, and practitioners in Germany and Japan. Facing the challenges of transforming the energy demand and supply system towards being climate-neutral, reliable, affordable and low in risk and resource use, while maintaining or strengthening international competitiveness, and recognizing the complexities of the ecological, social, and economic system changes, the aim was to demonstrate how two high-tech countries like Germany and Japan – despite different preconditions – can overcome such challenges much more successfully and effectively by working together as partners.

Learning from each other's approaches and experiences in a trustful and well organized manner is assumed to promote a more socially and economically sound transition, advancing technology innovation and its rapid market deployment, thus creating synergies and accelerating successes. The knowledge and advice generated should be made available for everybody to use, from policymakers to businesses and other stakeholders, to civil society.

With this setup, the following question was raised: Can the GJETC act as a role model of international cooperation that can be transferred to other countries and other fields of sustainable development? Certain analytical, reflexive, and administrative resources seem to be crucial. Choosing topics in a consensus-oriented manner, conducting bilateral research, having rules for the mutual exchange, achieving trust-building and mutual understanding, initiating open research-based debates on controversial issues, and having structured proceedings ensured by clear agendas and preparation by supporting organizations and offices all play an important role.

Based on the experience of four years, the GJETC reflected on the concept in order to make it available as a blue print for other countries. This reflection is based on a Master Thesis at the University of Maastricht comparing the GJETC with other international cooperation formats.[26]

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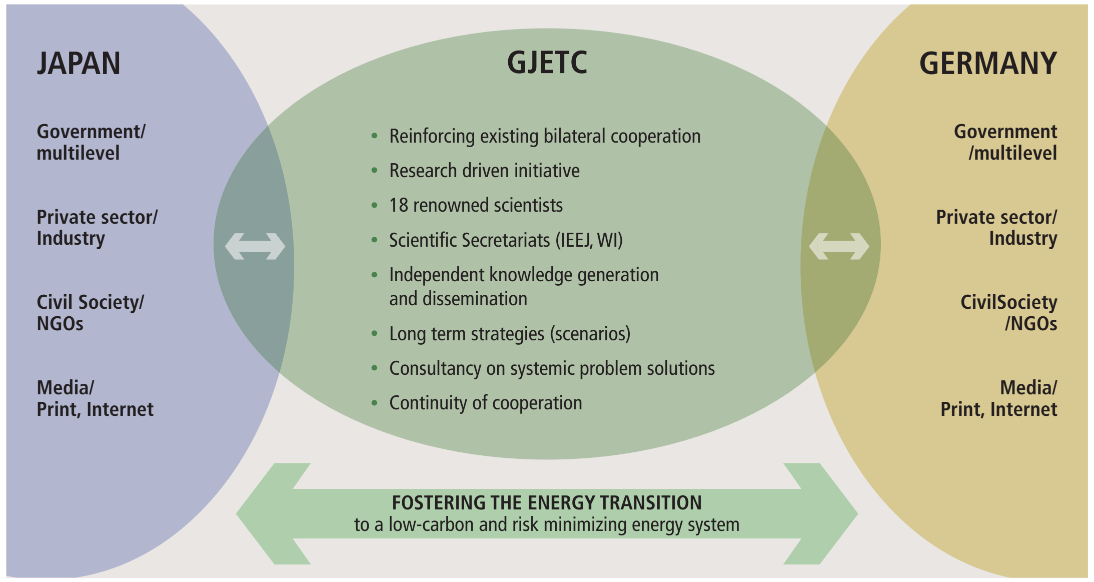
[26] Trautmann, H.O. (2019): Policy Learning and Transfer within Sustainable Development Governance: Evidence from Bilateral Sustainability Dialogues, University of Maastricht, Sept. 2019

Table 3: Enabling international knowledge exchange and mutual learning



Binational expert commission from academia and civil society

High-level representatives of scientific discourse on the energy transition were invited to the Council. In order to cover the manifold aspects of the topic, great importance was placed on the fact that a range of topics and expertise, as well as different institutional backgrounds were represented. The GJETC had six to eight members from academia or civil society and one Co-Chair from each country (see figure 1, Chapter 1). Further members in 2016-2018 have been Dr. P. Graichen (Agora Energiewende), Prof. Dr. U. Leprich (German Federal Environment Agency), Prof. Dr. Claudia Kemfert (German Institute for Economic Research), Prof. E. Weber (Fml. Fraunhofer Institute ISE), Prof. T. Taniguchi (Tokyo Intitute of Technology), Mami Ito (Nihon Dento Kougyo Co., Ltd.), Dr. H. Okamoto (TEPCO Research Institute) and S. Sasayama (Tokyo Gas). The Council worked independently of interference from politics and business. Its main activities were to identify and analyze current and future issues regarding policy frameworks, markets, infrastructure, and technological developments in the energy transition. The GJETC held semiannual meetings either in Tokyo or Berlin to exchange research findings and new ideas, proposed innovative policies and strategies, and publish policy papers on strategic topics of mutual interest.

Strategic topics and in-depth research by bilateral study groups

Every two years, the Council members identified strategic topics to be analyzed in comprehensive German-Japanese studies on the energy transition. In the first phase of the project, there was a comprehensive study program with four studies and a call for tender aimed at German-Japanese research consortia from outside the GJETC (see GJETC Report 2018 and http://www.gjetc.org/publications/scientific-contributions/). In the second phase, the identified key topics were analyzed by binational working groups within the Council. External experts were invited to the Council meetings to share their research expertise and comments on selected topics, e.g. from the Agency for Natural Resources and Energy, Agora Energiewende, Chubu University, the European Commission, the European Energy Exchange, the Federal Institute for Research on Building, Urban Affairs and Spatial Development, 50Hertz, the Building Research Institute, the National Organisation Hydrogen and Fuel Cell Technology, NEXT Kraftwerke, Siemens AG, European Energy Exchange and DENEFF.

Table 4: List of stakeholder dialogues in chronological order 2016 – 2018

Topical field	Stakeholders
Politics	German-Japanese Parliamentarian group
Business and industry	Toyota, JX Nippon Oil & Energy, Daikin, NTT Data, Global CCS, Tepco, Sumitomo, Euras Energy, Hitachi, EWE, BayWa R.E., Daimler, Enercon, AHK, TÜV Rheinland
Decentral actors in the energy system	Ohisama Shinpo Energy, Miyama Smart Energy, NTT Data IMC, Aizu Electric Power, Heilberger Energiegenossenschaft eG, Lichtblick, IdE Kassel, Solarcomplex, SW-Union Nordhessen, Elektrizitätswerke Schönau, EnergieAgentur NRW
Energy efficiency	Mitsubishi UFJ Financial Group, Taisei Corporation, Japanese Electric Manufacturers Association, Yazaki Energy Systems Corporation, Lawson Inc. Azbil Corporation, VDMA, Knauf Internationl, TÜV Süd Japan Co. Ltd., Evonik Japan Co. Ltd., AHK, DENEFF

Both approaches called for strong and close co-operation by all involved parties. Council members, secretariats and research consortia had to coordinate and organize their proceedings despite cultural, language and long-distance differences, completing the binational research work, or reviewing and commenting on the reports. Thanks to a stepwise approach to a structured format and ICT-based communication (e.g. video conferences), a promising exchange of knowledge and mutual learning was ensured.

Multi-perspectives and participation: Stakeholder dialogues with practitioners and politicians

The German-Japanese Energy Transition Council seeks to develop scientific impulses and alternative long-term overall strategy options for stakeholders in politics, science, NGOs and the economy in both countries. The expertise of this broad range of stakeholders also provided valuable input to the work of the Council and to making the policy recommendations more relevant. Accordingly, the GJETC initiated periodical stakeholder dialogues and invited high level representatives of companies, politics and NGOs to participate on selected topics. Thematic questionnaires for the stakeholders were developed and the answers submitted served as preparation for several discussions in tandem with the Council meetings. In total, four stakeholder dialogues enriched the discussion by maximizing the available information, ensured that the working results were cohesive and turned out to be among the highlights in the Council work.

Enabling controversial debates based on a trustful relationship

Geographical and socio-cultural conditions as well as political power structures differ in general between countries, so that a direct transfer of experiences is rarely possible. Instead of concentrating on positional disagreements and efforts to convince the counterpart of one's own opinions, analyzing the causes of divergent analyses often helps to better achieve a common understanding and find solutions. But such mutual understanding and learning, especially of each other's strengths and weaknesses, needs an open, unbiased, confidential and respectful environment, as was gradually developed within the GJETC. A certain phase of mutual learning and trust-building – maybe one to two years – seems to have been indispensable. It is the basis for what was then a much smoother and effective working phase. Rules of procedure and a common understanding including the agreement on Chatham House rules supported this. The continuity of the partnership, direct cooperation and a high level of commitment by all Council members contributed further to a growing basis of trust.

During the first phase from 2016 to 2018, the Co-Chairs invited individual input papers to be written by the Council members in order to promote debates even on controversial issues e.g. the role of nuclear energy or the costs of renewables and their system integration: When one Council member presented his or her standpoint, another Council member replied on the arguments raised by writing an equally research-based commentary. In the GJETC Report 2018, the German and Japanese Council members reflected on past discussions and stated their opinions on and critiques of their perceptions of their own and the partner country's development. Here, they were able to express what had been considered and what still appeared to be problematic and should therefore constitute a topic of future discussion and research (see Chapter 4 of the GJETC Report 2018). It is evident that such a fruitful socio-cultural exercise is not possible through occasional conferences or workshops and would never have happened within the polite constraints of official diplomatic events. Although the GJETC was thus very successful in building mutual trust and understanding, future projects may benefit from providing intercultural sensitivity training to participants early on in order to improve reflexive understanding and communication.

Council reports, key recommendations and outreach events

As a working result, the GJETC regularly publishes reports based on the Council work, including findings from the bilateral study program, the stakeholder dialogues, the input papers and the working groups. The reports include joint key recommendations on strategic issues for policymakers in both countries as a top-level key guide towards a successful energy transition, which may also serve as a model for other countries. Further specific recommendations for policy implementation (e.g. for the industry and transport sectors) and further research needs based on the study program[27] completed the reports. Various outreach events were organized to distribute the working results to policymakers, businesses and other stakeholders, and to civil society.

Administrative support: Organizational and scientific secretariats

Efficient work needs a thematic focus, structured processes, a clear agenda, and preparatory work. In a Council with almost 20 members, research partner institutes and representatives from business, politics and NGOs in two different countries at great geographical and cultural distance, a lot of coordination and communication work is also required. Results of the work also have to be published.

Therefore, scientific and organizational secretariats were set up in both countries, represented by the Wuppertal Institute and ECOS Consult in Germany, and the Institute of Energy Economics, Japan (IEEJ). Before the Council work, they conducted a preliminary study, analyzing the feasibility and developing the concept of the Energy Transition Council. Later, both institutions became the secretariats and assisted the Co-Chairs, organized the Council meetings, stakeholder dialogues and outreach events, coordinated the study program, and supported the completion of reports, publications and press work. They also launched a website where the working results of the GJETC could be distributed to a broader public. It should be noted that due to limited resources some tasks and post-processing were impossible to carry out.

Co-financing

Sufficient financial resources from both sides are important. In the four years, the work of the GJETC was financed by the German Federal Environmental Foundation (DBU), the Stiftung Mercator Foundation, the German Federal Foreign Office, the Japanese Ministry of Economy, Trade and Industry (METI), Elektrizitätswerke Schönau eG, the Alfred Ritter Foundation, Knauf Insulation, and WS Wärmeprozesstechnik GmbH. Furthermore, it was supported by the German Federal Ministry for Economic Affairs and Energy (BMWi), the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), the Japanese-German Center Berlin (JDZB), the German Chamber of Commerce and Industry in Japan (AHK), and Medienbüro am Reichstag (MaR) (media partner). Both the IEEJ and the Wuppertal Institute also provided significant resources and funding themselves.

Summary: Why the GJETC might serve as a role model

When comparing the format and working methods of the GJETC with the variety of successful dialogues, conferences and workshops that already exist between Germany and Japan, the GJETC offers the following unique characteristics that make it a potential role model for bi-national cooperation.

- The approach in terms of format, knowledge generation and energy policy discussion is comparable to a scientific advisory panel (e.g. in Germany: Enquete Commissions), but does not have a political mandate and is therefore more *scientifically independent.*
- The *bilateral cooperation between countries within an Energy Partnership,* both in the official political arena and in a research-based format like the GJETC, is close to, but not dependent on the current government policy. Thinking "outside the box" thus reinforces mutual learning processes.
- The *continuity and research depth* of the work (study program, input papers, the analysis of special key topics of common interest) clearly go beyond ad-hoc events of both policy dialogues and economic contacts.
- The enabling of dialogical and (self-) critical handling of *controversial topics* goes beyond the scope of the usual diplomatic search for consensus.
- The provision of indirect support to policymakers, NGOs, and civil society with reference material and science-based arguments through the publication and *broad communication* of all research results.
- The development and deepening of personal networks within the *energy research landscape* in both countries (e.g. the consortia of German and Japanese research institutes within the study program).
- The inclusion of relevant stakeholders through their responses to the GJETC questionnaire and the discussions at the *stakeholder dialogues.*

There is much evidence that the GJETC is – in terms of format, working methods and objectives – an institutional innovation in international mutual knowledge exchange previously unheard of in this form. Its research-based, continuous policy advice concept can effectively support the diversity of governmental, societal and business activities. Against this background, it contributes to advancing the implementation of the energy transition in both countries through mutual learning on technologies, business concepts, and governance, as well as through joint development of techno-socio-economic innovation. The members of the GJETC and the secretariats would therefore be proud if its format, results and impacts were to be seen as a role model for cooperation on energy and low-carbon transitions in other countries, and possibly for other fields of sustainable development too. The creation of an enhanced scientific advisory board format to support the current German-Japanese Energy Partnership is planned in the years to come. Speeding up implementation processes with the partnership of pioneering companies and conducting pilot and flagship projects could be decisive new elements of fruitful bilateral cooperation by the two countries.

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[27] The GJETC Report 2018 was entitled 'Intensifying German-Japanese Cooperation in Energy Research, and Policy Recommendations' (Wuppertal Institut and IEEJ 2018) Available at: http://www.gjetc.org/publications/

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Concluding remarks

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The GJETC Report 2020 concludes a phase of fruitful cooperation between Japanese and German energy and climate experts.

It has shown that continuity over several years is necessary and helpful in order to build a basis of trust across geographical, cultural and energy policy differences in order to generate new insights and problem solutions for politics and society in both countries using scientific methods and analysis.

Not only did the GJETC publish a wealth of scientific results on the website (see www.gjetc.org), efforts were also made within the limited budget to communicate the core results more broadly through stakeholder dialogues, outreach events and press conferences.

The Council members of both countries therefore assume that the work of the Council has contributed to effectively and significantly supporting German-Japanese governmental cooperation activities and strengthening synergies.
The Council is convinced that through its work it has demonstrated that international cooperation, particularly in the urgent field of climate and energy policy, leads to better and more effective strategies than policies that are nationally limited or even exclude other countries.

To strengthen German-Japanese cooperation, METI and BMWi signed a declaration on cooperation for a joint Energy Partnership between Japan and Germany in June 2019.

- The energy partnership should ensure that bilateral cooperation in the area of the energy transition is further strengthened.
- In order to coordinate this cooperation even more, two working groups have been set up: one for hydrogen and one for the energy transition in general, which will deal with renewable energies and energy efficiency.
- German-Japanese cooperation within the framework of the energy partnership is seen as a great opportunity for the development of a safe, affordable and climate-friendly energy system in both countries.
- As technologically leading countries, Germany and Japan can push ahead with the development of required technologies for the global energy transition. Both countries have a lot of know-how in different areas, so that both countries can learn a lot from each other.

Against this background, BMWi and METI expressed their thanks for the intensive and productive German-Japanese research cooperation carried out within the context of the GJETC over the past few years and the links it has provided for the energy partnership. In this respect, the BMWi and METI agree that the work of the GJETC can be associated with the Energy Partnership in the future in the sense of a scientific advisory board. The GJETC looks forward with great expectations to this in-depth cooperation in a new format and with new scientific challenges.

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List of abbreviations

AHK	German Chambers of Commerce (Deutsche Außenhandelskammern)
AI	Artificial Intelligence
APEC	Asia-Pacific Economic Cooperation
App.	Approximately
BCG	Boston Consulting Group
BDI	Federation of German Industries (Bundesverband der deutschen Industrie e.V.)
BEMS	Building Energy management System
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit)
BMWi	Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie)
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization, and Storage
CDU	Christian Democratic Union of Germany (Christlich Demokratische Union Deutschlands)
CSU	Christian Social Union in Bavaria (Christlich-Soziale Union in Bayern e. V.)
DBU	German Federal Environmental Foundation (Deutsche Bundesstiftung Umwelt)
DG Clima	Directorate-General for Climate Action
DIHK	German Chamber of Commerce (Deutsche Industrie-und Handelskammer)
DICE	Düsseldorf Institute for Competition Economics
EEG	German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
e.g.	exempli gratia
EU	European Union
EU-ETS	European Union Emission Trading Scheme
ESCO	Energy Service Company
FDP	Free Democratic Party (Freie Demokratische Partei)
FIT	Feed-in Tariff
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJETC	German-Japanese Energy Transition Council
GW	Gigawatt
HEMS	Home Energy Management System
IEA	International Energy Agency
IEEJ	The Institute of Energy Economics, Japan
i.e.	id est
IMF	International Monetary Fund
IoT	Internet of Things
IT	Information Technology
JDZB	Japanese-German Center Berlin (Japanisch-Deutsches Zentrum Berlin)
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
MaR	Medienbüro am Reichstag
METI	Ministry of Economy, Trade and Industry, Japan
MW	megawatt
NGO	Non-Governmental Organization
PV	Photovoltaics
R&D	Research & Development
RD&D	Research, Development & Demonstration
RE	Renewable Energy
RES-E	Electricity from Renewable Energy Sources
SAIDI	System Average Interruption Duration Index
SDGs	Sustainable Development Goals
SMEs	Small and Medium-sized Enterprises
ST	Study Topic
Three E	The principles of economic efficiency, energy security and environmental sustainability
Three E+S	A nation's energy policy, emphasizing energy security, economic efficiency, and environmental protection without compromising safety
Three R	Key mechanisms of a circular economy include Reduce, Reuse, Recycle
TWh	Terawatt-hour
VRE	Variable (output) Renewable Energy
Yr	year

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