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Potential technology and business fields of mutual interest for German and Japanese companies

Analytical Paper

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Content

1. Introduction

The German-Japanese Energy Transition Council (GJETC) was established in 2016 by individuals from research institutions, energy policy think tanks, and practitioners in Germany and Japan. Chaired by Prof. Peter Hennicke (former President of the Wuppertal Institute) and Prof. Masakazu Toyoda (Chairman and CEO of IEEJ until 30 June 2021[1]), this expert council serves as a bilateral model of continued, independent, science-based and system oriented exchange on the energy transition. The GJETC publishes joint studies, policy papers and reports with policy recommendations. Its secretariat is provided by the Institute of Energy Economics (IEEJ), Wuppertal Institute for Climate, Environment, Energy, and ECOS Consult.

In the current phase, Innovation Partnerships (IPs) are a new format of the GJETC's work: The expert council will develop ideas, concepts and research inputs for joint pre-commercial innovation projects between selected complementary German and Japanese industries. The research-based impulses for the development, scientific support for processes, and evaluation of joint demonstration projects, which function as show cases, aim to support industrial partners and the relevant national industrial development institutions (e.g. NEDO and BMWi) with background information and analyses for their decisions on whether and how to implement joint projects.

The next chapter outlines the process suggested to establish Innovation Partnerships, the five technology fields considered and the function of this paper. The following chapters 3 to 7 are each dedicated to one of the five technology fields. Chapter 8 presents conclusions.

2. Establishment of Innovation partnerships

The following steps are suggested to establish the Innovation Partnerships.

Analysis

1. Systematic screening of strategic technological solutions and transformative innovations for the energy transition and decarbonization, and of the respective technological strengths and competences in both countries.
2. Identification of possible business fields of mutual interest for joint demonstration projects on a pre-competitive and complementary level while taking further supportive research topics into account.
3. Selection of one or two priority topics with potential for cooperation to be discussed at the first Innovation Roundtable, along the criteria mentioned below.

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[1] On 1 July 2021, Prof. Tatsuya Terazawa was appointed as the new CEO of IEEJ and as successor of Prof. Toyoda.

Round Tables

4. Suggestions for addressing suitable German and Japanese companies and institutes for promising cooperation topics.
5. Preliminary identification of possible barriers or counterproductive framework conditions
6. Conduction of first Innovation Roundtable in autum 2021 with like-minded companies and public observers (e.g. NEDO and BMWi) in order to get feedback on research projects, prompt Innovation Partnerships and suggestions to overcome barriers.

Innovation Partnerships

7. Invite private companies and governmental bodies to contribute to Innovation Partnerships.
8. Make research-based suggestions on projects and supporting policies and measures and share information with NEDO, BMWi etc. for possible demonstration projects and private company consortia.

This analytical paper presents results of the preparatory steps 1 and 2.

2.1. Selection of technologies

Many technology fields have to be further developed to speed up the energy transition. Joint demonstration projects between high-tech countries like Germany and Japan can make an important contribution by combining their complementary knowledge and strengths.
Based on the knowledge gained in the past five years of council work, five technology fields have been selected that are considered especially relevant for the energy transition in both countries and for their cooperation.

- Hydrogen
- Decarbonizing industry processes/Carbon recycling
- Energy-efficient and climate-neutral buildings
- Energy efficiency and renewable energies in industry
- Decentral, resilient and sustainable energy supply

The main basis for the screening of concrete innovations in these five fields was a report coordinated by the Wuppertal Institute (2018), which analyzed 31 technologies for the energy transition. These are coming from the fields of renewable energies, conventional powerplants, infrastructure, technologies for sector coupling/P2X, energy and resource efficient buildings, energy and resource efficiency in the industry, and finally integrative aspects. Their status, perspectives, innovation and market potentials were examined and compared. The GJETC council members and IEEJ have also contributed to these analyses with their expertise.

For each of the five technology fields, the following chapters will identify key issues/bottlenecks and technology needs of the selected technologies and derive possible research and business fields as well as first ideas for cooperation between German and Japanese companies.

2.2. Relevance for German-Japanese cooperation

Out of these topics, one or two ideas will be selected for the first Innovation Round Table along the following criteria:

- Are the current technological challenges of the energy transition that have been identified by the GJETC addressed?
- Does a potential cooperation project bring meaningful added value for the further development of key energy transition technologies in Germany and Japan?
- Does the potential project bring the respective competences in Germany and Japan together in an ideal and complementary way (avoiding direct competition)?

3. Hydrogen

Clean and ultimately green hydrogen with low or no greenhouse gas emissions across the whole chain from production to use will be an energy carrier that plays an important role in decarbonizing our economies and societies. A study co-funded by the ministries of economic affairs in Germany (BMWi) and Japan (METI) in 2019 analyzed the current status of hydrogen deployment and policies as well as the role of hydrogen in future energy systems in both countries, and hydrogen supply chains (Jensterle et al 2019). Based on this study, some key issues/bottlenecks and technology/know-how needed will be derived in the following subchapter.

3.1. Key issues/bottlenecks and technologies/know-how needed

The following key issues and bottlenecks have been identified in the analysis. They are dependent on technology and cost developments, and the know-how needed in order to further promote the energy transition. From these findings, respective technological strengths and development competences for Germany and Japan are derived.

1) The first key issue is the ultimate goal of **cost-efficient green hydrogen production**. The study pointed out that for green hydrogen production to be cost-efficient, there is the need to further bring down costs of both renewable electricity and electrolyzers, and to improve technologies and efficiency regarding industrial scale and more decentralized electrolysis. Concerning technological strengths and development competences, the analysis showed that both countries have companies among the world leaders in electrolyzer technology and have already established large demonstration projects on green hydrogen

production, for example Westküste100 (Westküste100 2021) and the Fukushima Hydrogen Energy Research Field (FH2R) (Fuel Cells Bulletin 2020). Among other further projects, in Hamm (Germany), the establishment of a regional hydrogen cluster is being planned (Trianel 2020).

2) The second key issue is **hydrogen infrastructure**. For this key issue, overall concepts for regional/inter-regional hydrogen production, transport, distribution, and use are needed. For example, Jensterle et al. (2019) recommended to bring down costs and improve technologies regarding long-distance hydrogen transport and transformation of natural gas distribution infrastructures into hydrogen-ready infrastructures. Again, the technological strengths in Germany and Japan are quite well developed. Both countries have successfully set up demonstration projects on hydrogen infrastructure, for example H2 Region Emsland (H2 Region Emsland 2021) and in Woven City (Toyota 2021). In Germany, the government funded research project Trans4ReaL accompanies real laboratories, compiles the findings of the individual projects on hydrogen technologies and translates them into generally valid statements (Federal Ministry for Economic Affairs and Energy 2021).

3.2. Suitable research and business fields of mutual interest and potentially relevant actors

In this step of the analysis, we compared potential complementary know-how and solutions for the two key issues identified in chapter 3.1 to derive potential tasks for joint demonstration projects and to identify suitable research and business fields of mutual interest.

1) For improving the cost-effectiveness of green hydrogen production, an approach could be to harness and combine different technological approaches for electrolysis or its process steps existing in Germany and Japan for joint projects. The comparison, demonstration and upscaling of various electrolysis technologies and the further comparison from a cost and CO_2-emissions point of view would therefore be an important task.
2) Concerning the issue of hydrogen infrastructure, combining know-how from existing demonstration projects with different focus to establish new joint projects might foster joint transformative innovation. For example, the efficient and economically viable connection of central or distributed green hydrogen production with applications on the demand side (mobility, industry) could be demonstrated.

Involved actors

Plenty of actors participate in the hydrogen business in Germany and Japan. For example, various medium- and large-scale enterprises are involved in the development and production of electrolyzers. The production of fuel cells, fueling stations and storage tanks is brought forward by different companies especially in Japan. On the German side, the investment of established energy suppliers in the field of hydrogen it is worth noting: Some of them are involved in all stages on the green hydrogen value chain, while others run field tests on small scale hydrogen economies (EWE 2021). The natural gas supply industry in Germany has a focus on pipeline transport of hydrogen. The development of new hydrogen technologies is also supported by various research institutes both in Germany and Japan.

Framework conditions
For the realisation of joint demonstration projects on hydrogen, public support is crucial. Examples could be investment grants, possibly Carbon Contracts for Difference to ensure the continued operation of demonstration plants, and designing suitable EU, national and regional framework conditions. For example, Germany has recently exempt green hydrogen production from the levy that is imposed to fund the incremental costs of the renewable power plants under the FiT and auction schemes according to the EEG law.
In the research project Trans4ReaL that is supported by the German Federal Ministry for Economic Affairs and Energy (2021), comparative policy, discourse and acceptance analysis is conducted on sector coupling and hydrogen technologies. Beyond the analysis of demand-relevant factors, this work is analysing the socio-technical configuration that influences the diffusion process of the technology. For example, expectations, ideals of technology and reservations, but also learning processes and motives of different actors play a role - from the manufacturer, installer and maintenance engineer and the licensing authority to (inter-)national politics and societal reactions to the consequences of climate change, which can lead to a change in political priorities.

3.3. Existing joint German-Japanese demonstration projects

Inspiration for new joint innovation projects to be developed here may be found in existing cooperation projects. Therefore, in each of the five potential areas of cooperation, examples of such projects are briefly discussed.

Demonstration project for the production of green hydrogen in Herten, Germany
In April 2018, Asahi Kasei Europe, the operational European headquarters of Asahi Kasei, launched a demonstration project with an alkaline water electrolyzer in the hydrogen city of Herten, Germany. The plant simulates the production of hydrogen from electric power generated by wind energy. The joint demonstration project with the hydrogen competence center h2herten contributed to the development of a system for large-scale production of green hydrogen. Unlike h2herten's previous hydrogen energy system, the new demonstration plant from Japan is not designed for the intermediate storage of electricity, but exclusively for hydrogen production. The project has been continuously and intensively supported from the outset by the state economic

development agency NRW.INVEST and its Japanese subsidiary, NRW Japan K.K., and the NRW Energy Agency (Wasserstoffstadt Herten 2018).

Construction of a scalable electrolyzer/Green Energy Hub in Hamburg, Germany
The companies Shell, Mitsubishi Heavy Industries (MHI), Vattenfall and the Municipal Utility Wärme Hamburg are planning to jointly produce hydrogen from wind and solar power at the Hamburg-Moorburg power plant site and utilize it in its vicinity. To this end, the four companies have signed a letter of intent in January 2021. In addition to the construction of a scalable electrolyzer with an initial output of 100 megawatts, the further development of the site into a so-called "Green Energy Hub" is planned. This includes the exploration of the extent to which the existing infrastructure of the Moorburg location can be used for the production of energy from renewable sources. In this context, concepts for the necessary logistics chains and storage options for hydrogen will also be considered. The production of green hydrogen is anticipated in the course of 2025, making the electrolyzer one of the largest plants in Europe (City of Hamburg 2021).

4. Decarbonizing industry processes/ Carbon Recycling

In Germany and Japan, industry is not only relevant as a key economic player, but it also contributes almost 37% and 39% to total national GHG emissions[2], respectively. The potential role of carbon capture, utilization and storage (CCUS) technologies for decarbonization of industry is generally acknowledged in both countries. In addition, our analysis suggested that conversion of plastic waste to raw material, mass-production technology for paraxylene and Power-to-Liquid (PTL) technologies could be priority areas of German-Japanese cooperation for the energy transition and the decarbonization of industry.

4.1. Key issues/bottlenecks and technologies/know-how needed

The following key issues and bottlenecks have been identified in the analysis. They are accompanied by the technologies and the know-how needed in order to further promote the energy transition. From these findings, respective technological strengths and development competences are derived.

1) **Decarbonization of cement and concrete: carbonation process; CO_2 transport and (offshore storage) costs**. It is especially crucial to further develop the process of carbonation, in which CO_2 can be made use of in building materials, as an alternative to CCS. Both countries have research competences in this field, for example through the evaluation of various technologies, raw materials and products under ecological aspects (RWTH Aachen 2020) or R&D on use of CO_2 in

[2] Including indirect emissions from public electricity and heat supply.

concrete (Mitsubishi Corp. 2020a). In Japan, the process of concrete curing is of special interest. To gain further know-how on the issue of CO_2 transport and storage and their costs, the analysis of existing research approaches worldwide could be of interest.

2) **Conversion of plastic waste to raw material, with the components pyrolysis and gasification**: Efficiency improvement (higher product yield) and application to other plastics are key issues. To address them, improvement of selectivity and the application to mixed plastic waste and composite materials are needed. The analysis showed that the German automobile industry has already experiences with the processing of waste from engineering plastics into pyrolysis oil that can be used for new components (KIT 2020).
3) **Mass-production technology for para-xylene using innovative catalysts**. To this end, the innovative catalyst has to be improved and a method to mass-produce the catalyst has to be developed, as well as the para-xylene production process using this catalyst. Afterwards, demonstration of these processes should take place. In Japan, a project on the technology development of a catalyst for para-xylene production using CO_2 was already launched in summer 2020 (Mitsubishi Corp. 2020b).
4) **Power-to-Liquid (PTL) and increasing the efficiency of CO_2 utilization and conversion into synthetic fuels**. Concerning this topic, the production of sustainable aviation fuel (SAF) is of special interest. Both Germany and Japan have competences in this field. For example: In 2020, the Japanese New Energy and Industrial Technology Development Organization (NEDO) announced to support the development of a biofuel supply chain and plans for a biofuel manufacturing commercial plant by 2025 (Euglenia 2020). In Germany, the Federal Ministry of Transport and Digital Infrastructure (BMVI) commissioned DLR to plan a pilot plant for industrial-scale production of electricity-based kerosene for aviation (Green Car Congress 2021).

4.2. Suitable research and business fields of mutual interest and potentially relevant actors

Again, potential complementary know-how and solutions were compared to derive potential tasks for joint demonstration projects and identify suitable research and business fields of mutual interest.

1) In the case of decarbonization of cement and concrete, the exploration of industry clusters with cross-industrial business models (cement and building materials) should be fostered. For example, testing the possibilities to produce and/or use the CO_2-negative concrete SUICOM that was developed in Japan in building materials in Germany could be one option.

2) Concerning the raw material use of plastic waste with the components pyrolysis and gasification, potential complementary know-how between Japan and Germany still has to be identified.[3]
3) Mass-production technology for para-xylene could be further advanced by a joint demonstration project on the catalyst and para-xylene production process. Of special interest might be testing the above mentioned catalyst under German conditions.
4) In case of Power-to-Liquid and Sustainable Aviation Fuel, potential complementary know-how could be SAF production in both Germany and Japan, and its supply to scheduled flights between the countries. [4]

Involved actors

German and Japan companies are already involved in different application fields of decarbonizing industry processes and carbon recycling.

In Germany, large enterprises with expertise in chemistry like BASF, Lanxess and Convestro do research and development on low-carbon concrete and chemical recycling e.g. of plastics. Smaller companies also participate in the market by working on climate-neutral concrete and CO_2-reduced cement as well as new recycling options, for example through the recovering of raw materials from metal-bearing secondary materials and intermediate products. The use of alternative, sustainable fuels has not been broadly covered so far. Only some airlines and engine manufacturers have activities in this field, and synthetic fuel production from hydrogen will be tested in the Westküste 100 project, whereas the production of hydrogen will soon be tested in several projects such as Westküste 100 and Hamburg-Moorburg, see chapter 3.

Various medium to large sized Japanese companies are involved in the development of sustainable concrete, the use of carbon capture technology in cement production and CO_2 transport and storage as well as raw material use of plastic waste with the components pyrolysis and gasification. In 2020, five Japanese companies, amongst others Nippon Steel and Mitsubishi, announced a cooperation on technology development for industrial para-xylene production from CO_2 (Nippon Steel Engineering 2020). As mentioned above, the production of renewable jet fuel is publicly funded and is conducted by the Japanese company Euglena together with other international companies (ARA 2021). Furthermore, six companies including Toshiba Energy System, Idemitsu, and ANA annouced that they start develop a supply chain and a business model of SAF produced from the new electro-chemical process (Toshiba 2020).

Decarbonizing industry processes and carbon recycling is also within the scope of specialized research institutes and departments as well as universities in both Germany

[3] For example, BASF is engaged in developing various new concepts for a circular economy using pyrolysis under the headline ChemCycling® (BASF 2021).

[4] The newly founded PtX Lab Lausitz will focus on the development of PtX especially for shipping and aviation; compare Federal Ministry for the Environment, Nature Conservation and Nuclear Savety (2021).

and Japan. In Germany, the Competence Center ZUG supports the development of decarbonisation options for energy intensive industry, see ZUG (2019).

Framework conditions
In general, for the further decarbonization of industry processes and the development of Carbon Recycling, strong public support to conduct R & D projects is required. It has to be further analysed how by German-Japanese cooperation these activities can be speeded up. Broader experience in this field can only be gained when creating suitable national framework conditions by transformative industrial policy in both countries and thereby laying the foundations for upscaling. The mutual exchange of knowledge can support this processes.

4.3. Existing joint German-Japanese demonstration projects

The respective competences in both countries seem to be well developed, cooperations less so. Thus, it may be particularly interesting to initiate joint projects through the GJETC and the Innovation Partnerships by contributing enabling information and analysis.

5. Energy-efficient and climate-neutral buildings

Buildings take a significant share in energy consumption and greenhouse gas emissions in both Germany and Japan. For example in 2015, buildings consumed 42 % of the final energy in Germany and 32 % in Japan. In addition, despite significant improvements in energy efficiency in the past, the potential for further energy savings still is very large. Consequently, energy efficiency in buildings plays a key role in most energy and climate scenarios and targets. In this chapter, different aspects of energy-efficient and climate neutral buildings will be analyzed, including the use of renewable energies in heating and cooling technologies, the respective strengths of both countries, and options for possible joint German-Japanese demonstration projects.

5.1. Key issues/bottlenecks and technologies/know-how needed

The following key issues and bottlenecks have been identified in the analysis. They are accompanied by the technologies and the know-how needed in order to further promote the energy transition. From these findings, respective technological strengths and development competences are derived.

1) **Integrated net zero energy building concepts**. For this issue, technologies and standards of design concepts such as nearly zero emission houses, passive houses and plus energy houses have to be developed and adjusted to different climate zones. To achieve this, building design, building shell technologies, HVAC technologies, and energy management systems have to be advanced in an

integrated manner, both in terms of performance and cost. Germany has strong experiences with building design and shell technologies, while Japan has relative strengths in energy management systems.

2) **Improving cost-effectiveness of energy-efficient building renovation and new build**: For this key issue, industrial construction, digital design tools, and process optimization are needed. In Germany, the government supports the gradual market development of serial refurbishment solutions. The know-how for prefabricated buildings for cost-effective energetic renovation of appartment houses is developed in cooperation with the Dutch company Energiesprong. A first residential building under the pilot project "Energiesprong" was completed in the spring of 2021 (Energiesprong 2021). Concerning prefabricated housing, strong competences can be found in Japan, due to the high share of this type of construction in new build (Rauschen et al. 2020).
3) **Improved building envelope and construction technology**. In addition to overall concepts discussed above, specific technologies needed include marketable high-performance but cost-effective thermal insulations and adapted thermal radiation properties of surfaces. Know-how about cost reduction, long-term stability, reduction of grey energy and the combination of technologies in multi-functional systems should be achieved. The respective technological strengths and development competences of Germany and Japan still have to be identified.
4) **Improved building system technology using renewable energies**. To this end, the following steps have to be taken: increasing efficiency, reducing costs, advancing towards the smart grid (e.g., network efficiency), enabling sector coupling and increasing storage capacity. Currently, there is a lack of economic offers e.g. for heat recovery ventilation systems, geothermal heat pumps, biomass boilers, and solar thermal systems as well as experience in planning and installation (market breakthrough) in both countries.
5) **Climate neutral buildings (life-cycle approach/grey energy)**. In addition to energy efficiency in building operation, it is also important for the construction sector to reduce the embedded 'grey' energy and CO_2 emissions from building construction. The use of renewable materials, i.e. wood, is a key factor to optimize the construction in this respect. Therefore, it is crucial to further develop timber buildings and apply research results to Germany/Japan (Churkina 2020). In Germany, optimized planning processes for buildings in prefabricated timber construction are being researched (Holzbauwelt 2021). A ten-story wooden building presents a prototype for innovation in the construction industry (Nachhaltigkeitspreis 2021). In Japan, competences in alternative building materials are similarly well established: The highest wooden skyscraper of the world with 70 floors is already being planned (The Guardian 2018).

5.2. Suitable research and business fields of mutual interest and potentially relevant actors

For the five key technology needs identified in chapter 5.1, potential complementary know-how and solutions were compared to derive potential tasks for joint demonstration projects and identify suitable research and business fields of mutual interest.

1) In case of integrated net zero energy building concepts, complementary know-how/solutions can be found in the combination of German building design and shell technologies with Japanese energy management systems. Both countries have efficient HVAC systems adapted to their climates, whereas strengths regarding heat recovery ventilation will need further analysis. The demonstration of cost-effective net zero energy design combining technologies might be of interest for both countries.
2) Regarding cost-effectiveness of energy-efficiency in renovation and new build and
3) improved building envelope and construction technology, demonstration of industrial design, digital design tools and process optimization could be interesting for cooperation. Japanese prefabricated housing companies might collaborate with stakeholders of the German “Energiesprong” project on prefabricated construction although potential complementary know-how between Japan and Germany still has to be identified in detail.
4) When it comes to improved building system technology using renewable energies, Germany has strong experiences in the heating sector, while Japan is leading in the cooling sector. Research projects have been carried out or are ongoing in both countries. Tasks for joint demonstration projects might be: 1. development of combined heat pumps, heat/cold storage, and heat recovery ventilation technologies, 2. comparing heat pumps (Germany) and fuel cells (Japan), 3. trigeneration as pilots of Energy Service Companies (ESCOs), 4. evidence of technical and economic feasibility and 5. disclosure of market barriers for the development of information strategies and qualification programs.
5) Concerning climate neutral buildings (life-cycle approach/grey energy), the analysis showed that Japan has a long tradition of timber buildings. A cooperation with the German/Austrian (Thoma 2021) prefabricated timber buildings industry for private houses and commercial buildings/hotels might be of interest for both countries. Possible tasks for demonstrations projects could be: 1. hybrid constructions (concrete and wood), wood only, prefabrication, 2. optimized workflow of cooperative planning and implementation processes in timber construction, 3. innovative lean processes and cooperation models for planning and production of urban timber buildings, 4. improving recyclability of timber buildings.

Involved actors

German and Japanese companies are involved in all areas contributing to energy-efficient and climate neutral buildings. Both countries have companies in wood construction, thermal insulation technologies, as well as heating and air conditioning technology. In Japan, the industry for prefabricated houses seems to be especially well established with many providers of those houses. Building designers in Germany probably have more advanced knowledge with respect to integrated net zero energy building concepts. In addition, we found two specialised research institutes with focus on energy-efficient and climate neutral buildings: The Eco-Center North Rhine-Westphalia in Germany and the Building Research Institute in Japan.

Framework conditions

Although many cost-effective technologies and options to save energy or to offer energy-efficient technologies and services exist, the manifold barriers (e.g. low market transparency, split incentives, short pay-back expectations) against the implementation of energy efficiency investments are often stronger. If only one actor in the market chain for buildings decides against the energy-efficient solution, it will not happen. Therefore, energy efficiency policies must support all market actors in overcoming these barriers.

In Germany, there are push and pull measures for energy efficiency in buildings, i.e. regulations (push) and support programs and informational measures (pull). The programs support building efficiency levels and renewable energy technology applications going beyond the regulations. Germany has a long history of building regulations, dating back to the seventies, which have continuously been updated.

In Japan, in contrast to the large number of specific instruments in Germany, one comprehensive regulatory instrument, namely the Building Energy Conservation Act, was introduced. Incentive measures defined by the act became effective from April 2016 and regulatory measures from April 2017.

Particularly for research and demonstration projects, financial support, active matchmaking of potential partners, and project aggregation (which is the second innovative element in the Energiesprong concept) or public procurement can provide guidance and financial security for companies willing to invest in advancing their technologies and solutions.

5.3. Existing joint German-Japanese demonstration projects

There is an already existing exchange between the German and Japanese prefabricated housing industry on energy-efficient buildings[5], as well as scientific exchange. These can be explored further, if this technology field is chosen as the subject for an innovation roundtable.

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[5] Personal communication from GJETC member Manfred Rauschen.

6. Energy efficiency and renewable energies in industry

The industrial sector is responsible for about one-third of the global total final energy consumption and CO_2-equivalent emissions today. Economically viable energy efficiency actions, based on the existing technology solutions, have the potential to already deliver up to 30% of energy consumption reductions globally across the industry sector. This potential then increases up to 60% when taking into account future technological innovation (United Nations Economic and Social Council 2020). In this chapter, different aspects of energy efficiency and renewable energies in the industry and the respective strengths of both countries will be analyzed and options for possible for joint German-Japanese demonstration projects will be explored.

6.1. Key issues/bottlenecks and technologies/know-how needed

The following key issues and bottlenecks have been identified in the analysis. They are accompanied by the technologies and the know-how needed in order to further promote the energy transition. From these findings, respective technological strengths and development competences are derived.

1) **Electric motors: efficiency improvement (IE 5+), improved small motors, system integration**. It can be specified that firstly, the components have to be improved with regard to, e.g., high temperature superconductivity (conductors, cooling), cheap high-density magnetic materials (limited use of rare earths), component design (with regard to bearings, cooling), advanced switched reluctance motors. Secondly, the system integration has to be optimized in regard to downstream applications, needs-based motor control and "intelligent" integration into the overall system. The respective strengths and development competences of Germany and Japan still have to be identified.
2) **Heat pumps: Temperature up to 200 °C at high temperature spread**. It can be specified that firstly, components have to improve with new refrigerants, improved compressors and optimized design (cooling techniques, heat exchangers, design). Secondly, system integration needs optimization with control concepts and integration into load management systems as well as automated integration into systems (link of heat source, heat sink). The respective strengths and development competences of Germany and Japan still have to be identified.
3) **Waste Heat Usage**: For this key issue, increased efficiency and cost reduction of thermoelectric generators (for using waste heat), Organic Rankine Cycle (ORC) plants, industrial heat pumps (also see previous priority), and heat storage with phase-change materials (PCM) are of interest. NEDO promotes projects on the development and commercialization of technologies that effectively use unutilized heat (NEDO 2021) and on high-speed, high-density heat storage devices (Nippon Shokubai 2021). BMWi promotes activities to save energy by

using waste heat as well (Federal Ministry for Economic Affairs and Energy 2021b).

6.2. Suitable research and business fields of mutual interest and potentially relevant actors

For the three key issues identified in chapter 6.1, potential complementary know-how and solutions were compared to derive potential tasks for joint demonstration projects and to identify suitable research and business fields of mutual interest.

1) To deliver energy services at least costs for customers, it is often more cost-effective to save energy instead of producing and buying it. With this background, a target for energy savings combined with an incentive regulation for energy utilities can enable these energy suppliers to build “energy conservation power plants” focussing on efficient use of electricity at the site of their customers instead of building new supply facilities[6]. The concept of a “conservation power plant” includes the support for the application of all cross-cutting efficiency technologies (also for households and SMEs), through personal advice, financial incentives/rebates and energy performance contracting arrangements. For example, within the framework of the EU’s Energy Efficiency Directive (EED) (European Commission 2021) it is possible to involve energy utilities more actively in energy efficiency activities helping their customers to save energy. Additionally to experiences in many European countries (IEA 2017, Fawcett et al 2019), the USA and several emerging countries wordwide are using binding targets and incentive regulation to encourage utility-lead efficiency programs for their customers. Neither Japan nor Germany have implemented such schemes to date. Therefore, it might be a fruitful field of cooperation between German and Japanese utilities to exploit the wordwide experiences and adapt it to the framework conditions in Germany and Japan.
   When it comes to the components and system integration of electric motors, joint demonstration projects on materials, design and application-specific solutions would also be of interest.
2) Regarding heat pumps, tasks for joint demonstration projects could be RD&D on new refrigerants, improved compressors and optimized design. In case of system integration, pilot projects on industrial application would be of interest.
3) For the improvement of waste heat usage, the following complemantary know how could be identified: Japans knowledge on Thermoelectric generators could be used to advance joining technology. Material development in the temperature range 200 - 400 °C, mass production suitable production concepts, substitution of critical raw materials and an increase of service life would be of

[6] Compare for an example in a metallurgical works (Kazarinov and Barbasova 2015); see the Japanese edition of Hennicke and Seifried (1996).

interest. Concerning Organic Rankine Cycle (ORC)-plants, heat exchangers specially designed for ORC and the development of new climate-neutral refrigerants could be tasks for joint projects. The technology on industrial heat pumps could be enhanced by increasing the coefficient of performance (COP) of heat pumps and demonstration for use of industrial heat pumps e.g. in the food industry (cooling/heating/drying by waste heat). Lastly, Japans knowledge on high-temperature latent heat storage through micro-encapsulated PCM and Germanys knowledge on Carnot batteries could be combined in an demonstration project on PCM with Carnot batteries.

Involved actors

In both Japan and Germany there are plenty of medium- to large-scale producers of energy-efficient drive technologies to be found. The inclusion of those technologies into the overall system is facilitated by companies in both countries as well. Different research institutes in Germany and Japan support the technological development of drive technologies and heat pumps, for example the Institute for Power Electronics and Electrical Drives of the RWTH Aachen and the Heat pump center Japan.

Framework conditions

The framework conditions on energy efficiency and renewable energies in the industry are similar to those for CCUS projects (in case of larger and disruptive technology advances) or to buildings (in case of improvements for components and integrated application concepts of energy-efficient technologies).

Particularly for research and demonstration projects, financial support, active matchmaking of potential partners, and project aggregation or public procurement can provide guidance and financial security for companies willing to invest in advancing their technologies and solutions.

6.3. Existing joint German-Japanese demonstration projects

No joint demonstration projects on the technology fields mentioned above could be found. Thus, it may be particularly interesting to initiate joint projects via the GJETC and the Innovation Partnerships.

7. Decentral, resilient and sustainable energy supply

The topic of a decentral, resilient and sustainable energy supply relates to the energy system as a whole. In both Germany and Japan, the reduction of the integration costs of variable renewable sources of power production (e.g. PV, wind) is of special interest. For this goal to achieve, different flexibility options and complementary approaches need to be demonstrated and adopted. For example, the GJETC recently published a study on the use of smart grid technology and other digital technologies to harness Distributed

Energy Resources (DERs) to enable the integration of a higher proportion of variable Renewable Energy Resources (RES) into the distribution grid (Ninomiya et al. 2021). Further topics that will be explored in this chapter are metering and control/contracts and technologies for increasing network capacity and efficient network operations.

Additionally, the development of DERs in the country side (e.g. based on PV, wind, biomass and geothermal), their institutional and financial setting (e.g. cooperatives, energy citizens, Stadtwerke) and their grid integration would be interesting. For this field of cooperation advanced German experience could be combined with regional development and resilience needs ("revitalisation of the country side"). Also decentalized co- and trigeneration options for SMEs and commercial buildings in combination with local heat / cold distribution networks would be of interest.

7.1. Key issues/bottlenecks and technologies/know-how needed

The following key issues and bottlenecks have been identified in the analysis. They are accompanied by the technologies and the know-how needed in order to further promote the energy transition. From these findings, respective technological strengths and development competences are derived.

1) **Reducing power system integration costs with a high share of VRE**. For this key issue, grid integration and flexibility have to be optimized, as well as sector integration technologies and their mix. Technological strengths in this field can be found in both countries: The German SINTEG projects recently explored different sample solutions for a safe, economic and environmentally compatible energy supply with at times 100% electricity generation from renewable energies (SINTEG 2021). In Japan, the world's largest grid-connected battery energy storage system with 720 MWh storage capacity is being planned (Jensterle and Venjakob 2019).
2) **Further development of smart grids**. For this key issue, smart grid technology including Artificial Intelligence (AI) and Internet of Things (IoT) needs to be further advanced and the Distribution and Transmission System Operators (DTSO) level optimized. In Germany, this topic has also been explored by the SINTEG projects, for example within the enera showcase on intelligent and automated grid management (Enera 2021). In Japan, a demonstration project on management platform for Distributed Energy Resources (DERs) was launched in 2020 (Ninomiya et al. 2021).
3) **Technologies for a safe and efficient network operation**. This key issue includes methods and tools of operations management: Amongst others, cellular network operations management, operational management algorithms and process control automation for system services at all voltage levels, network state detection also in lower network levels, prediction of power flows, interplay between network levels, network recovery concepts as well as network interaction and market. Within the German Enera showcase, different solution

approaches for these topics have been demonstrated, for example a congestion resolution system for the ‘yellow traffic light phase’ on a grid with regional flexibilities (Enera 2020).

4) **Metering and control/contracts**: Here, standardization of metering and communication mechanisms for data connection and control of individual plants and prosumers via smart meters and contracts, e.g. V2G, is needed. In Germany, small-scale experiences with communication mechanisms for data connection have been made within the context of SINTEG, and smart meter roll-out is slow. Japan on the other hand has major compentences in this field. For example, TEPCO in cooperation with a Swiss-based company has implemented a project based on an IoT network, aiming to connect 30 million smart devices in TEPCO’s supply area (Jensterle and Venjakob 2019).
5) **Technologies for increasing network capacity**. Here, the offshore connection of wind turbines is one topic that could be further explored, including amongst others the improvement of components and equipment for the offshore sector and the improvement of maintenance concepts. Competences can be found in both countries: A German company recently developed and tested a prototype for an offshore floating wind turbine (German Energy Solutions 2020) while in Japan, NEDO supports different projects on offshore connection (NEDO 2019a and 2019b).

7.2. Suitable research and business fields of mutual interest and potentially relevant actors

In this step of the analysis, potential complementary know-how and solutions were compared to derive potential tasks for joint demonstration projects and identify suitable research and business fields of mutual interest.

1) Concerning the issue of additional power system costs with a high share of VRE, joint demonstration of optimized grid integration, flexibility, and sector integration technologies and their mix in a local area would be of interest.
2) For the further development of smart grids, technical solutions from either country and business models from Germany could possibly be combined.
3) In the case of technologies for a safe and efficient network operation, potential complementary know-how between Japan and Germany has still to be identified.
4) In case of metering and control/contracts, a demonstration project on metering and the connection of smart devises drawing on Japans major experiences in this field could be of interest.
5) Regarding technologies for increasing network capacity and offshore connection of wind turbines, a cooperation between experienced German companies and Mitsubishi Corporation and Chubu Electric might be of mutual interest.

Involved actors

Companies of different areas of business are involved in building a decentral, resilient and sustainable energy supply. When it comes to these rather general topics of the energy transition, most activities come from larger, established companies like Siemens, Mitsubishi and Toshiba as well as from German and Japanese energy providers. In some cases, a market participation of smaller companies, for example, a start-up that provides scalable software platforms for the intelligent grid management (Envelio 2021), was also analyzed. Different research institutes in Germany and Japan support these developments. For example, the Fraunhofer Institute for Solar Energy Systems (FES) established a Digital Grid Lab for the modelling of distribution grids (Fraunhofer ISE 2021). FES, BayWa r.e. and others also developed interesting options for optimizing land use by the combined development of agriculture und PV (AgriPV) (BayWa r.e. 2021).
In Japan, the Offshore Renewable Energy Research Group of the National Maritime Research Institute is conducting technological development, safety evaluation, and actual sea measurement for floating offshore wind turbines (National Maritime Research Institute 2021).

Framework conditions
Within the German Ariadne research project (Federal Ministry of Education and Research 2021), the local negotiation arenas and interactions with national framework conditions for the expansion of renewable energies are examined and evaluated. The project focusses on the question of policy instruments with regard to the coordination and coherence of the expansion process and the associated distribution of benefits and burdens in society. The SINTEG projects also tested a number of innovative regulations under experimental allowance clauses. The GJETC also analyzed potential framework conditions for smart grids (Ninomiya et al. 2021).

7.3. Existing joint German-Japanese demonstration projects

In the case of decentral, resilient and sustainable energy supply, future projects can draw on quite a few good practice examples for German-Japanese cooperation.

Demonstration project on a large-scale hybrid battery system in Varel, Germany
In 2017, NEDO and the Ministry for Economics, Labour and Transport of Niedersachsen (Germany), EWE-Verband, an association managing the electric power supply of 17 districts and four cities in Niedersachsen, and EEW Holding have agreed to jointly implement a demonstration project on a large-scale hybrid battery system in the German city of Varel (NEDO 2017).

Intelligent energy management in Speyer, Germany
The efficient use of self-produced solar energy with an intelligent energy management was the focus of a three-year project in Speyer, whose results were further used for industrial purposes. Launched in September 2015, it has been financed with 20 million Euros by NEDO. ECOS Consult coordinated a part of the project. Other partners were the

city of Speyer, the municipalities SWS and the housing association GEWO GmbH (ECOS Consult 2015).

Solutions for energy management in Smart cities, Urasoe, Japan
The German company GreenPocket offers national and international customers intelligent and flexible solutions for energy management. It's software is also being used in the government-funded Urasoe Smart City Development Project in Japan. The project required energy management software to visualise and manage the consumption of public buildings and areas. GreenPocket provided a software for this task, which was translated into the Japanese language specifically for this purpose (Green Pocket 2017).

8. Conclusion

This analysis showed possible research and business fields of mutual interest for both Germany and Japan, which could be explored in joint cooperation.

- In the case of hydrogen, both countries have technological strengths and plenty of activities in this field. Different technological approaches for cost-effcient production of green hydrogen in Germany and Japan could be harnessed for joint projects. Also, combining know-how from existing demonstration projects with different focus to establish new joint projects might foster innovation. Due to existing comprehensive H2 roadmaps and financial support programs of both governments in Germany and Japan, it should be carefully analyzed where the activities of the GJETC and Innovation Partnerships can create added value, fill gaps, and contribute to synergies.
- Decarbonizing industry processes and the development of Carbon Recycling can be enhanced by joint demonstration projects as well. First ideas for business cooperations could be 1) to explore the production and/or use of the CO_2-negative concrete SUICOM in building materials in Germany and 2) a joint demonstration project on the catalyst and para-xylene production process.
- Know-how and technologies for energy-efficient and climate neutral buildings can be found both in Germany and Japan. In this field, joint demonstrations projects are especially obvious, due to complementary strengths. First ideas draw on 1) Germany's strong experiences in the heating sector and Japan leadership in the cooling sector, 2) the combination of German building design and shell technologies with Japanese energy management systems and 3) technologies for serial renovation, combining Germany's experience with the "Energiesprong" project and the strong Japanese prefabricated housing industry.
- Energy efficiency and renewable energies in the industry still have potential to be further explored in both countries. First ideas for cooperation could be very topic-specific. For example, when it comes to the components and system integration of electric motors, joint demonstration projects on materials, design and application-specific solutions might be of interest. On the other hand, a

business and policy innovation that could jointly be developed are utility-led energy efficiency programs for this sector and the deployment of its key technologies.

- The topic of a decentral, resilient and sustainable energy supply addresses the energy system as a whole. Both countries have competences in this field, and can draw on public funding. Suggestions for joint demonstrations projects could make use of technical solutions from either country and combine them with business models from Germany for market and grid integration of distributed energy resources. Furthermore, Japans experiences with smart metering and the connection of smart devices could be harnessed for cooperation.

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