自然エネルギー財団

Agora Energiewende

Request for proposal by 18th of September 2019

A 2050 renewable-based decarbonization pathway for Japan

Study on the role of renewable-based electrification in supplying power, transport, heating and cooling demands in Japan.

1. Background and objective

Background

As part of its commitments under the United Nations Paris Climate Agreement, in June 2019 the Japanese government adopted a Long-term Strategy on Climate Change that seeks to cut greenhouse gas emissions 80% by 2050 and to achieve net zero emissions "at the earliest possible time in the second half of the century". In the power sector, this long-term decarbonization strategy relies on renewable energy as a major power generation source and calls for a reduction of CO2 emissions from coal and gas power plants. The strategy is not prescriptive about the way to reach this goal but emphasizes the need for new technologies and "disruptive innovation", such as Carbon Capture and Storage (CCS), Carbon Capture and Utilization (CCU), hydrogen production, next-generation batteries, next-generation renewables and advanced nuclear power.

While this strategy is an important first step towards the definition of a long-term decarbonization vision for Japan, it has been considered by observers to be insufficiently concrete and insufficiently ambitious. Notwithstanding, despite keeping technology options open, the strategy recognizes the important role of electrification for reaching long-term decarbonization: either through direct electrification or the production of e-fuels. This, in our view, therefore calls for the decarbonization of power generation to be a top priority.

The next Japanese Strategic Energy Plan[1] will provide a good opportunity to develop this strategy in more concrete terms, by defining a baseline, sectoral targets and roadmaps. It is also potentially an opportunity to raising the mid- to long-term level of ambition.

Objective

The Renewable Energy Institute in partnership with Agora Energiewende wants to develop a range of detailed energy transition pathways/scenarios for Japan to 2050, in order to better inform ongoing and upcoming policy and expert discussions on this topic. The pathways that we will ask the consultant to produce should demonstrate how very large shares of renewables can be integrated into the power system, and also how renewables-based electrification can contribute to the decarbonization of power, heat and transport systems. The total system costs of the pathways must be analyzed in detail, based on an in-depth economic and technical assessment.

[1] The Strategic Energy Plan is revised every 3 to 4 years. Then next one could therefore be adopted mid-2021 or 2022.

Particular attention should be given to the mid-term 2030 horizon, so as to understand how long-term decarbonization commitments (2050) translate into short and mid-term priorities (2030). In particular, it will be important to understand which mid-term priorities are 'no regrets' for all technology options, and which technologies are essential to demonstrate for feasibility and cost discovery in the 2020s in order that investors have lead times to develop the supply chains and future demand loads – e.g. for hydrogen production and use – that will need to be ready to scale up after 2030.

These results will require a detailed modelling of the Japanese energy system with high spatial and temporal resolution. The modelling should be developed by the consultant (or a consortium of consultancies) in close exchange with a group of Japanese experts and with our teams at REI and Agora Energiewende. The modelling of the power system and its interaction with the heating and transport systems will be important. The study should also model flexibility provision (and requirements) in the power sector in light of renewable-based integration between the three sectors.

From an institutional perspective, this project (1) aims at leveraging independent technical expertise on mid-term and long-term energy strategies for Japan, and (2) focusing on identifying relevant knowledge gaps and implementing consistent scenario designs around which to base a sustainable dialogue with a group of key Japanese stakeholders. The results of the analysis shall be intended to support the work of the public authorities in their mid-to-long term planning for a resilient transformation of the Japanese energy system, in particular by better assessing the contribution of renewable-based electrification to the long-term decarbonization of the country.

2. Scope and work packages

Led by the Renewable Energy Institute in partnership with Agora Energiewende, this project aims to evaluate in detail the technical and economic evolution of the Japanese power system up to 2050 that is required to meet, at lowest cost, ambitious decarbonization targets in the Japanese power, heating and transport systems.

Two main scenarios should be analysed: a 'current policy scenario' and a 'best policy scenario'. This should include several sensitivity analyses on key parameters: the role of nuclear power, the impact of an electric grid interconnection between Japan and North-East-Asia, and the import of synthetic fuels (e-fuels and biofuels).

The following questions are at the core of the required analysis:

(1) How much renewable electricity can and must be integrated into the Japanese power system by 2050 in order to comply (at lower costs than by means of CCS and nuclear) with ambitious decarbonization targets set for power, heat and transport. What are the implications of this long-term transformation for the 2030-time horizon? What is the impact of those high shares of renewable electricity on (1) total system costs and investments needs (in generation technology and infrastructures), (2) the balancing of supply and demand at hourly time steps?

(2) What is the role of renewable-based electrification in supplying heating/cooling demand (household, tertiary, industry) and transport? In particular,

- Which end-use subsectors should rather be supplied by direct electrification rather than by synthetic gas/liquid or bioenergy and to which corresponding level?
- What are the implications of the results regarding renewables-based electrification for long-term power demand growth?

(3) What are the implications of these results for projections about the size and operation of the Japanese power system: how would the alternatives impact requirements for generation capacity and for the provision of additional flexibility to the power system using demand-side management, e.g. smart charging of electric vehicles, flexible heat-pumps, DSR technologies, storage, Power-to-X…? What are the implications of those long-term transformations for the 2030-time horizon.

Proposed work packages:

WP 1: Model set-up and Data collection

WP 1.1. Model set-up

The consultant should use an adequate techno-economic energy model for Japan (including power, heat and transport) for the transition period from today until 2050, including high geo-spatial and temporal resolution. An important criterion for the selection of the consultant will be their ability to develop such a model, by accessing and working with existing data on the Japanese energy system, both in the public domain and potentially beyond it. The Renewable Energy Institute will – to the limit of its ability - support the consultant in this task, in dialogue with a consulting committee of key stakeholders. We expect that this consulting committee can help to facilitate data access and validation.

The model should be able to integrate the different energy sectors (power, heat and transport) and end-use demands (household, services, industry). We would like to do this as comprehensively as possible, but will require at least some capability for sector coupling in a simplified way. The analysis must focus on the impact of deep-decarbonization strategies for Japan on the implications regarding the size and operational characteristics (at hourly time step) of the Japan power system. As such, the power system (and its interaction with the heat and transport systems) should be modelled with a higher level of granularity and technical details. It should in particular integrate flexibility potential and constraints for all modelled technologies.

It is however not required to model power grid infrastructure in detail (no load-flow modelling). A simplified multi-region approach (ideally one node for each of the 9 EPCOs) with Net Transfer Capacities between the regions would be a sufficient first approximation. This multi-region description of the power system should ideally also be reflected (to some extent) in the modelling of the heat and transport systems. In addition, the model should integrate a simplified description of the balancing reserve requirement to ensure system stability.

The level of granularity of the model (higher geo-spatial and temporal resolution) as well as the level of integration between the different energy sectors (power, heat and transport) will be a key parameter in evaluating consultant's proposals. Given the relevance of the model set-up and data

access for this project, the consultant must address following points in its proposal (see also below the section on data preparation):

- Describe in detail which model they intend to use and why such a model is appropriate for performing the required analysis;
- Provide an overview description of the technical and economic input and output parameters of the model
- Outline which data are needed to perform the analysis, including
    - A description of the data that will be brought by the consultant to set-up the model;
    - A description of the additional data (detail will be helpful) that are needed to perform a satisfying analysis but cannot be provided by the consultant.
- Explain the methodology applied for defining renewable energy technology potentials and time-series.

The consultant is expected to make a balanced and well justified proposal which will be discussed in an initial workshop and then refined with the client, also taking into account stakeholder feedback from the consulting committee. The proposal must also explain which input and output data will be delivered after completion of the project and how far the rights to use and share the model developed for this project can be transferred to the Renewable Energy Institute after project closure, as we wish to enable further work and additional development.

WP 1.2. Data collection and preparation

REI, in close dialogue with a stakeholder group of Japanese experts, will support the collection and validation of the required input data. As data availability is rather limited in the Japanese context, the consultant should specify as precisely as possible for all of the most relevant input parameters of the model if

a) Japan-specific data can be provided by the consultant from its own database (data validation for key parameters (such as technology costs) would ultimately be performed – where agreed with the consultant – through consultation with the Japanese experts) or if those data should be provided by the project client.
b) The consultant should also describe briefly how those data could be approximated, in case neither the consultant nor the Japanese partner project can provide Japan-specific data.

In order to best document this point, the consultant must develop and populate a table similar to that given in the Annex (indicative). Offers that provide significant Japan-specific data (or makes propositions/ assumptions in case the consultant does not hold such data) will have an advantage. The consultant must adjust its core offer accordingly in case (labour-intensive) collection of some input data need to be performed by REI and the expert stakeholders. The offer will be further negotiated on this basis, taking into account additional missing data that the consultant/client may effectively be able to provide. As specified above, data validation for key dimensioning parameters (such as technology costs) would be performed through consultation with the Japanese experts.

WP 2: Scenario Definition

Two main scenarios should be defined up to 2050, preferably in 5-year intervals. The scenarios definition and underlying energy-related $CO2_{eq}$ trajectories will be based on discussion with the client.

The energy-related $CO2_{eq}$ trajectories (policy targets) will be defined from a top-down analysis of the overall greenhouse gas emissions trajectories for Japan (including non-energy related emissions) and allocated to the different sectors. These target trajectories will operate as the main constraint for the energy system optimization. The two following energy transition pathways will be investigated:

- A **current policy scenario**, based on the current long-term commitment of Japan (-80% greenhouse gas scenario by 2050)
- A **best policy scenario**, with a more ambitious decarbonization target, for example carbon neutrality in 2050.

In addition, we would like to include a sensitivity analysis on key dimensioning parameters, for example: variations in technology cost assumptions, stricter constraints posed on the technical potential of renewable deployment, the level of nuclear power maintained in the electricity mix, a ratio of synthetic fuel import, and/or an electric interconnection between Japan and North-East-Asia. The consultant should provide a price tag for each potential sensitivity analysis.

WP 3: Analysis of energy transition pathways

The model results should evaluate the cost-optimal evolution of the Japanese power system up to 2050 that is required to meet, at lowest possible cost, the current and higher ambition decarbonization targets set for power, heat and transport.

The model should also evaluate the cost-optimal dimensioning of the various outputs (GW, number of appliances, costs) and provide information on the short-term operation of the system (hourly intervals) in order to inform an assessment of system dynamics and flexibility requirements.

The hourly model run should cover entire years for the different proposed scenarios at 5 year intervals up to 2050. The following output should be provided for every modelled year:

- Energy system costs and CO2 emissions.
- Primary energy demand (by sector) based on assumptions on the economic growth rate and efficiency gains;
- Power generation (TWh) and capacity (GW) by technology, including the new installed capacities required to decarbonize heat and transport, as well as curtailment levels of renewables;
- Electric transmission between the nodes of the model (allowing for a first-order quantification of grid reinforcement needs – and costs – through a simplified approach based on geographic distance between the nodes);
- Storage: Short-term electricity storage (batteries, pumped-hydro…) and heat storage; long-term energy storage, including power-to-gas, which allows the production of hydrogen and synthetic methane to be utilised by the system (in both the heat and transport sectors);

- Heating/cooling: demand and supply of the different technologies (in case the model provides a full representation of the heating/cooling sectors) or at least the power-to-heat generation/demand (direct electrical heaters/coolers and heat pumps);
- Transport: demand (road, rail, marine and aviation) and shares of the demand supplied by different fuel types (including hydrogen, synthetic hydrocarbons, direct electrification), or at a minimum results on electric vehicle deployment and EV power system integration (at least in a simplified fashion)

The analysis should be complemented by an estimation of the balancing reserve requirement with increasing shares of variable renewables as well as a qualitative description of the impact of those very high shares of renewables on system stability.

WP 4: Recommendations for incentivizing efficient decarbonization, system integration and system flexibility

Based on the analyses of WP 3, and taking into account the current situation in Japan, the consultant will be asked to report their preliminary key recommendations for amending current long-term energy plans for Japan. A particular focus should be on the implications that the 2050 deep-decarbonization objective imply for the 2030 horizon. However, REI reserves the right to publish the final report with their own conclusions and recommendations.

3. Deliverables and timeline

A representative group of key Japanese stakeholders will be involved in the project, both to facilitate the design of the study, as well to contribute to the understanding, appropriation and dissemination of project results. These will include experts from the electric power companies, the Ministry of Energy, regional authorities, and other stakeholders of the private sector (including renewables companies and developers, Electric-Vehicle companies, HVAC equipment companies, industry companies) and academia.

Weekly (or twice monthly) calls will be set-up between the consultant and the clients. Two expert roundtable meetings are planned, one during the model set-up (WP1) and scenario definition phase (WP2) and one during the analysis (WP3) and recommendation (WP4) phase. The expert group involvement is to be taken into account in budgeting the project and planning the timeline.

The consultant shall provide a final report at the end of the project that will include

- An executive summary of 3-5 pages;
- A detailed description and justification of the model, methodology and input parameters;
- The most relevant input and output parameters and output results from the energy transition pathways in .xls format, including hourly load and generation curves of the different scenarios;
- A description, quantification and adequate graphic representation of the results of the scenario analysis
- A discussion of the power system focused on flexibility options and barriers and making tangible recommendations for to Japan should adjust its operational and planning procedures and the regulatory framework.

Main results will also be displayed in a power point presentation.

The indicative timeline of the project is as follows:

- First half of October (ideally 07.10): Project kick-off and start of WP 1.1 (and WP2)
- Mid of November 2019: First expert and stakeholder group meeting in Tokyo
- End of December 2019: short interim report on WP 1.1., WP 1.2. and WP2.
- January 2020: start WP3
- February 2019: Presentation of first interim results on WP3
- April 2019: Second expert and stakeholder group meeting / discussion of interim results (WP3 and WP4)
- End of July: submission of final draft report and ppt presentation
- Beginning September: Presentation of final report in public event in Tokyo

The project proposal should discuss the proposed time frame and identify potential risks for not meeting it.

4. Contact person

For any considerations or questions regarding the project, please refer to

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Annex

Table 1. Input parameter and data availability (Exemplary – the number of entry (lines) must be provided by the consultant depending on its modelling approach)

Input parameter	Does the consultant provide Japan-specific data for that parameter?	In case, neither the consultant, nor the Japanese partner has access to the relevant data, how the consultant proposes to approximate those data
Resource potential for RES at high geographic resolution	Yes	X
Hourly heat/cooling demand curves for industry, tertiary sector, households	Partially (for household and tertiary sector). No data for industrial heat)	In order to approximate the heat demand curves in the industry sector, the consultant proposes to…
Power plant database in Japan (status quo)	…	…
Time-series for RES	Partially (for wind and solar), not for hydro	For approximating the hydro time series, the consultant proposes…
Financial and technical assumptions for relevant technologies	Yes	X
Other relevant parameters (1)		
Other relevant parameters (2)		
…		