**Project Report**

**Dynamic Transition Analysis With TIMES**

**September 2018**

We initiated a project in January 2018 to simulate dynamic transition scenarios for the energy industry in Japan to suggest pathways for minimizing carbon emissions. This report is a summary of the progress we have made so far, the challenges we currently face, and the future direction of this research.

**Project Progress, Results and Post Hoc Assessment**

***Progress***

The tasks that we performed can be divided into two categories: technical tasks associated with implementation of details and features in our model, and data collection and organization. Our accomplishments have been:

* January – March 2018: **Installation of and familiarization with VEDA**: To model Japan’s energy industry, we chose VEDA, a TIMES (The Integrated MARKAL-EFOM System) <cite something> model generator. We found the format of the developer-prescribed model files restrictive and unsuitable for our purposes. Therefore, we took the time to develop our own model files, which we have progressively refined since then. Major impediments to this process were the quality of documentation and customer-support provided by VEDA developers, which delayed the process.

At the same time, we collected data pertaining to electricity generation from sources such as EDMC (cite handbook, databank), MoE JPN, Fed Pow Comp.

* April – May 2018: **Incorporation of fossil fuel-related data**. We incorporated data for electricity generation from fossil fuels from The Energy Data and Modelling Center (EDMC) databank of the The Institute of Energy Economics, Japan (IEEJ), along with creating a simplified demand process reflecting the recent trends in electricity demand in Japan.

While collecting this data, we noticed that the EDMC databank that we have been relying on has no data for the amount of electricity generated from individual fossil fuels for the years 2011-12. Instead, the amount of electricity generated from coal, oil, and natural gas is lumped together in one category titled “thermal”. Further, the 2016 data seems slightly inconsistent across different data tables in the EDMC databank. The source of variation in these numbers is likely to be the changes in the electricity distribution system of Japan since 2016.

* June – August 2018: **Incorporation of nuclear, hydropower and renewables into the model**. The process of incorporating these into the model was similar to the previous energy sources, but simpler, since the data obtained for these energy sources from EDMC was consistent across EDMC data tables and secondary sources (EIA, IEA). We have also included processes for the projected growth of nuclear, solar and wind based on data from the Federation of <bleh>, JWPA, and <some solar body.>
* August – September 2018: Refining CO2 emission processes. While we had been modelling CO2 emission processes in parallel with the electricity processes, it was only after incorporating all conventional energy sources that we could move on to fine-tuning CO2 emission values to ensure they match the actual emissions from Japan. The major obstacle we faced was the absence of data pertaining to electricity generation from individual fossil fuels, with each fossil fuel’s energy cycle having different emission coefficients. We estimated the missing figures based on previous years’ trends (cite EDMC 2012 handbook) and arrived at reasonable estimates of electricity generation, which result in CO2 emission values that differ from actual values by about 5% at most.

***Results***

Our model focuses on the electricity generation sector. The following assumptions and limitations are present in our model:

* **All the energy generated by a given process is transferred to the grid without losses to satisfy the demand process.** Since the EDMC data has values in terms of units of electrical energy produced (GWh), we have had no need for incorporating data about raw fossil fuel consumption, plant efficiency, and utilization factors.
* The coal and natural gas capacities are held constant throughout the simulation.
* Oil-based electricity has been gradually retired due to the emphasis of the Japanese government on energy self-sufficiency and minimizing costs, and due to a general trend in the EDMC data indicating declining use of oil.
* Nuclear capacity is increased in chunks equivalent to the capacity of GE-Hitachi’s ABWRs, which are under consideration for construction <cite elec review>, with efficiency values based on existing ABWRs in operation. It has been assumed that there can be as many as 22 ABWRs constructed in between 2020-2100, with the number of reactors constructed during the earlier years based on the number of projects currently under consideration for construction, and the pace of construction based on similar reactors constructed in Japan. All nuclear technology, current or future, has a finite lifetime based realistic values <cite hitachi>.
* Solar – Any new solar capacity created by the model has been assumed to be non-tracking. The maximum capacity implemented is based on <>
* Wind –The offshore and onshore wind capacity potential for Japan is based on the report by <>.
* Hydropower – held constant at current levels.
* Geothermal – expanded to maximum potential <cite>.
* The values of electricity generated from coal, oil and natural gas in 2011 and 2012 have been estimated using previous years’ values and CO2 emissions.
* The CO2 emission constraints implemented are very lax and not representative of any constraints that the Japanese government or i2cner wish to implement. This feature of the model is still under-development, since we do not have accurate data for electricity generated from fossil fuels for the years 2011, 2012, and 2016.

Based on these assumptions, the preliminary transition scenario gives the following distribution of electric utilities to meet the supplied demand process:

<include elc plot, const hyd>

The emitted CO2 values for the period 2011-16 are as follows. The error is at most 5.7% (see fig), which is due to the aforementioned absence of accurate data for 2011, 2012 and 2016.

<include co2 plot>

**Post Hoc Analysis and Challenges**

The project was significantly delayed due to the quality of the documentation and customer support provided by the VEDA developers. The primitive, black-box like nature of the software often produces inexplicable, illogical results and inhibits efficient debugging. Therefore, while data acquisition and organization proceeded at the originally suggested pace, the incorporation of this data into the model has been behind schedule, by about three months.

In addition to having incomplete/inaccurate data for 2011, 2012 and 2016, EDMC has been eliminating data related to electricity generation from individual fossil fuels and lumping power from coal, oil, and natural gas into a category called “thermal” in its databank. This complicates the process of estimating CO2 emissions from these energy sources, since each fossil fuel has a different emission coefficient. Losing the primary data that we have been relying on has affected our pace and the reproducibility of our research significantly. The EDMC databank figures in GWh, instead of in tons of coal or oil, have influenced our model’s simplistic design, as discussed previously. Our efforts to find similar data have been unsuccessful. Switching to data in terms of the quantity of raw fossil fuels consumed instead of GWh of electricity produced may require a substantial revision of our model.

**Future direction**

Considering these challenges, any future efforts on this project will be concentrated in the following areas, in this order of precedence:

* Acquisition of accurate data for electricity generation from fossil fuels. The most promising source now seems to be the EDMC 2017 handbook.
* Refining fossil fuel-based electricity generation values and hence CO2 emission values
* Implementation of realistic CO2 constraints based on Kyoto protocols and i2cner targets.
* Refining the demand process and aligning it more closely with realistic projections.
* Incorporation of i2cner technologies in the model.
* Incorporating capacity constraints on technologies such as nuclear power, geothermal power, carbon sequestration etc to model different scenarios.
* Sensitivity analysis of model parameters to analyze the relative impact of incorporated technologies on the decarbonization goal.

In case we must switch to more accurate data that is different from the EDMC figures, we may have to modify the model accordingly. For instance, if the data is in terms of units of fossil fuels consumed, we must model the appropriate fossil fuel conversion processes with the relevant conversion factors and efficiencies. This will further delay the project by another one to two months.