Dynamic Transition Analysis with TIMES

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Outline

Motivation

- Dynamic transition analysis to minimize CO_2 emissions in Japan.
- Focus on optimizing **electricity supply**.
- **I^2CNER goal:** Reduce emissions by 80% from 1990 levels by 2050.
- After 2050: emissions held constant until 2100 if possible.
- Energy supply includes conventional and some I^2CNER technology.
- Using The Integrated MARKAL-EFOM System (TIMES) [1].

Outline

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3. Results
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Basics

- Constrained linear/mixed-linear optimization problem [2].
- Objective function - System Cost.
- Constraints - CO_2 emissions, demand.
- Novel tech - H_2 (steam reforming, photocatalytic conversion), absorption type carbon capture and sequestration (CCS)[3].

Assumptions

- New Nuclear = Advanced Boiling Water Reactors [4].
- Simplistic, conservative assumption about demand growth = +1.7% per year[5].
- Nuclear, wind, solar annual growth rate **limits** based on trends in USA, China, Japan [5, 6, 7, 8, 9].
- CCS: Available for deployment in 2030, costs reduce by 2050 [3].
- Offshore and onshore wind capacity limited to theoretical potential (about 450 GW and 200 GW respectively).
- H_2: Steam reforming available in 2030, photocatalytic conversion in 2050 (assumed cost-competitive with other generation methods) [3] [10].
- Hydropower, geothermal capacity held constant [6].

Levelized cost projections for solar and wind

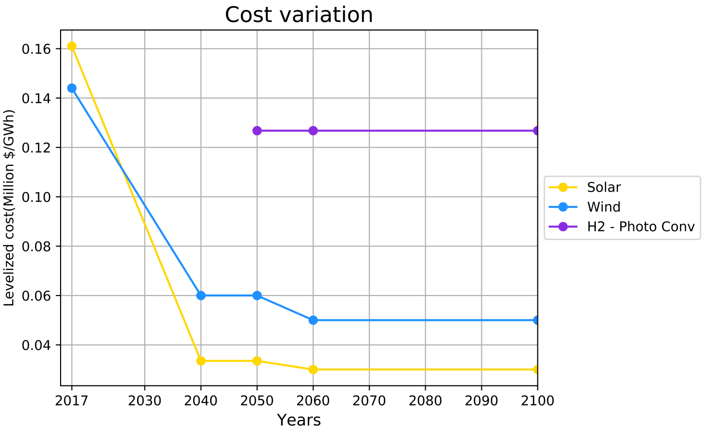

Figure 1: Levelized cost projections from Lazard [11] and Acar & Dincer [10]

Contribution to peak factor (C2P factor)

This is a TIMES parameter that defines what fraction of a energy source's capacity is guaranteed to be available during peak demand [2].

Energy source	**C2P factor**
Fossil fuels	1
Nuclear power	1
Solar power	0.42 [3]
Wind	0.20 [12]

This factor is reduced for solar and wind with increasing penetration [12].

Limitations

- Focus entirely on **electricity supply sector**.
- Cost of fossil fuels, geothermal, hydropower, steam reforming and nuclear is constant.
- Area cost not taken into account.
- Emissions tied to energy production, not capacity installation.
- Annual time-step cannot capture seasonal/daily variation in wind, solar (however annually averaged availability factors are incorporated).

Scenarios

Scenario	Figures	Conventional technology	I^2CNER technology	New nuclear reactors
1	Fig. 2&3	✓	✗	✓
2	Fig. 4&5	✓	✗	✗
3	Fig. 6&7	✓	✓	✓
4	Fig. 8&9	✓	✓	✗

Outline

Scenario 1: No I^{2}CNER technology, with new nuclear

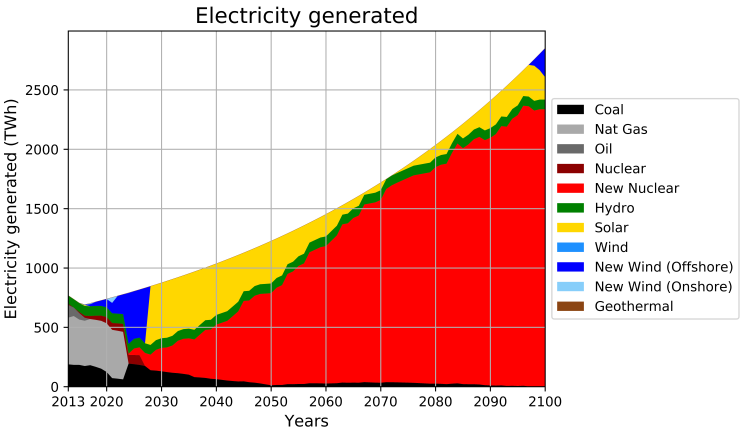

Figure 2: Scenario 1 Electricity Generation.

Scenario 1: No I^{2}CNER technology, with new nuclear

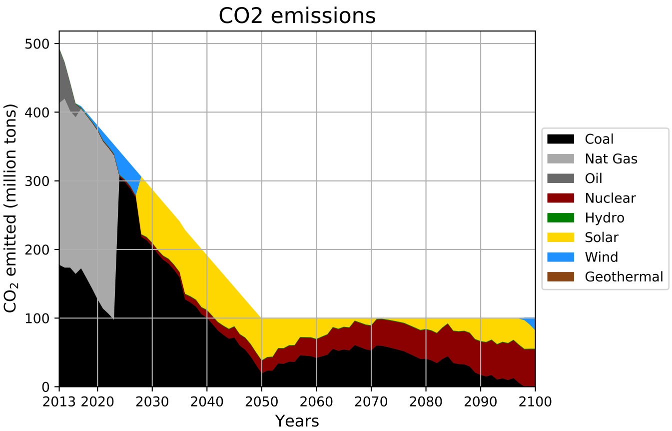

Figure 3: Scenario 1 CO_2 emissions.

Scenario 2: No I^{2}CNER technology, no new nuclear

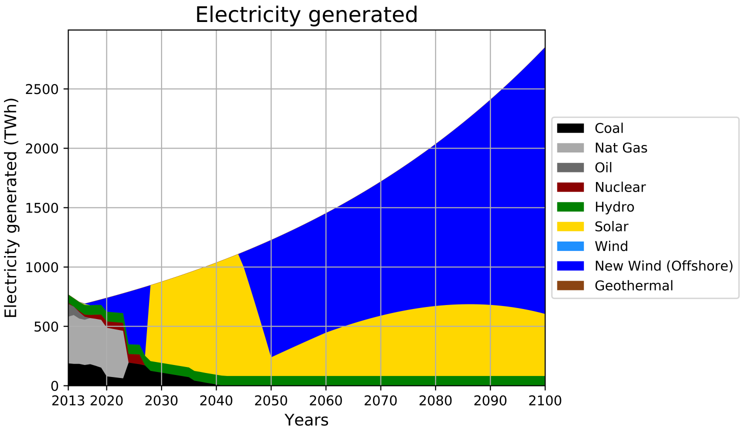

Figure 4: Scenario 2 Electricity Generation.

Scenario 2: No I^{2}CNER technology, no new nuclear

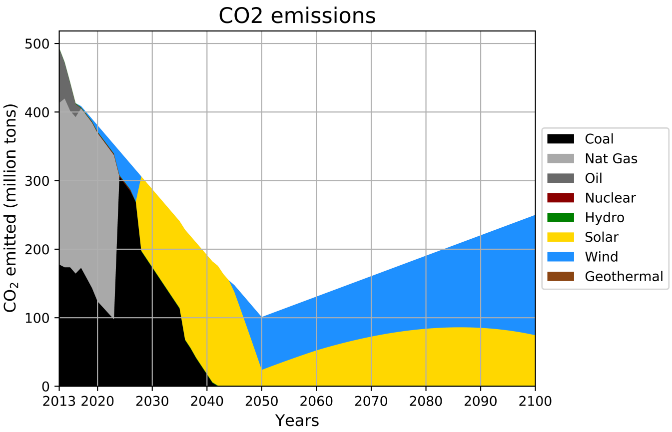

Figure 5: Scenario 2 CO_2 emissions.

Scenario 3: With I^{2}CNER technology and new nuclear

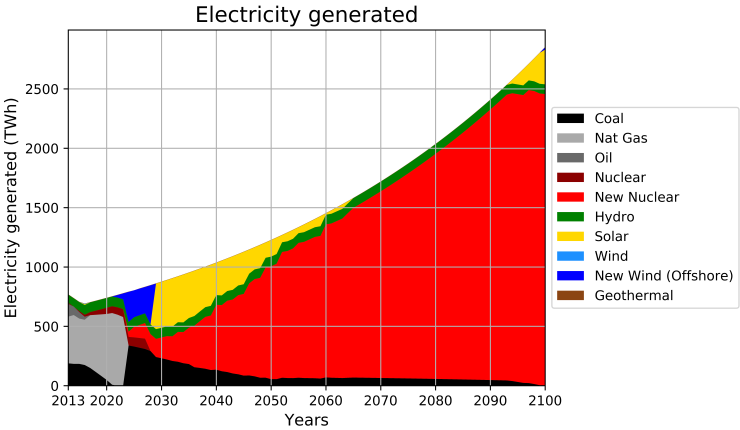

Figure 6: Scenario 3 Electricity Generation.

Scenario 3: With I^{2}CNER technology and new nuclear

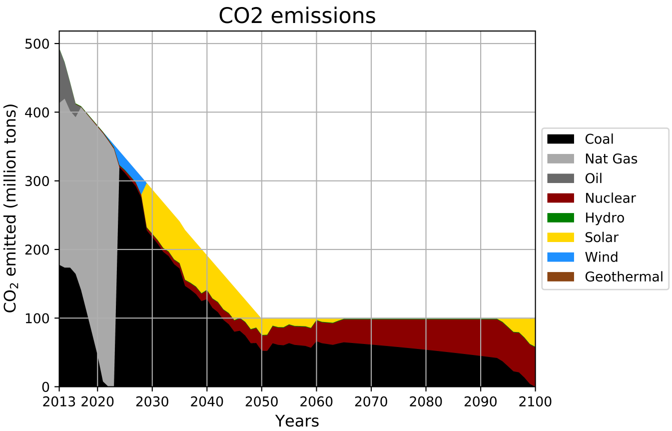

Figure 7: Scenario 3 CO_2 emissions.

Scenario 4: With I^{2}CNER technology, no new nuclear

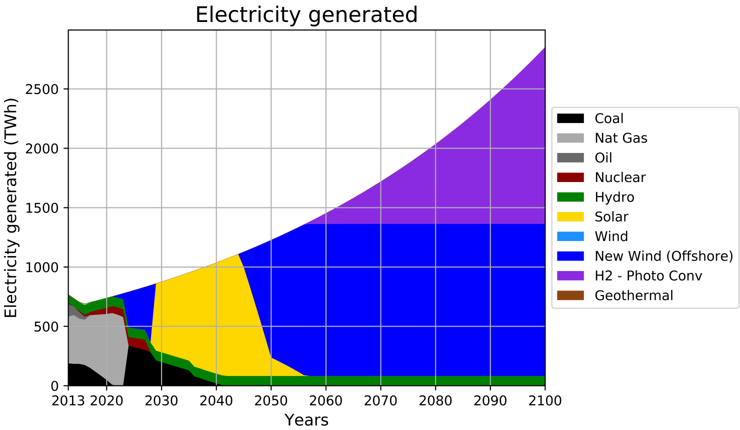

Figure 8: Scenario 4 Electricity Generation.

Scenario 4: With I[2]CNER technology, no new nuclear

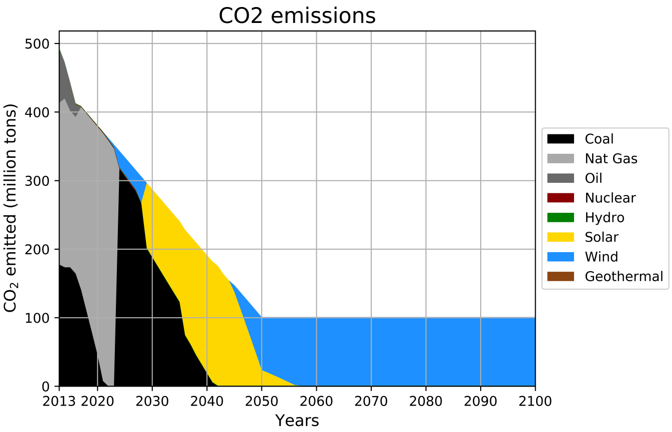

Figure 9: Scenario 4 CO_2 emissions.

Outline

Conclusions

- Highest impact (so far): nuclear, offshore wind, photocatalytic H_2, solar.
- Transition scenario cost (from least to most expensive):
  1. Scenario 1 (conventional with nuclear) = Scenario 3 (I^2CNER with nuclear)
  2. Scenario 2 (conventional without nuclear)
  3. Scenario 4 (I^2CNER without nuclear)
- H_2 and wind can meet I^2CNER goals at high cost without nuclear.
- Nuclear is the cleanest, cheapest source of energy.
- Without novel technology, solar and wind are deployed in a 1:2 ratio.

Outline

Future work

- Fix premature retirement bug.
- Develop a scenario with more restricted nuclear (similar to METI projections).
- Transition from model creation to model refinement.
- Capture realistic, gradual transitions.
- Incorporate fluctuations in demand.
- Add energy storage to supplement renewables and H_2.
- Incorporate more I^2CNER technologies.
- Conduct sensitivity and cost analysis.

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