The role of hydrogen power generation in the low-carbon electricity grid

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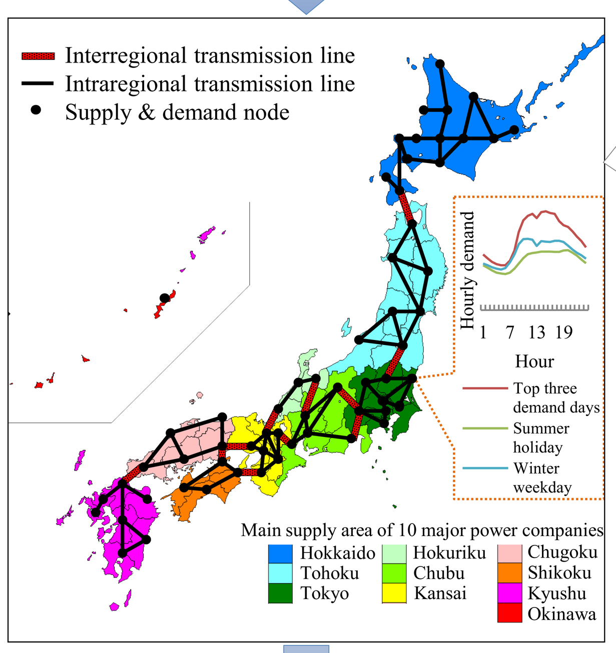
Introduction

- Hydrogen is expected as a new option for a zero-carbon energy carrier.
- Although some existing studies[1,2] investigate the impact of imported carbon-free hydrogen in the electricity grid, the role of domestic hydrogen is not quantitatively analyzed.
- Research questions:
  - What will be the impact of hydrogen power generation on the generation mix in 2050?
  - What will be the impact of hydrogen power generation on generation costs in 2050?

Methods

- Multiregional optimal-generation planning model[3]

Input: Electricity demand, fuel prices, capital costs, CO_2 targets…



Output: Generation mix, generation costs, carbon price…

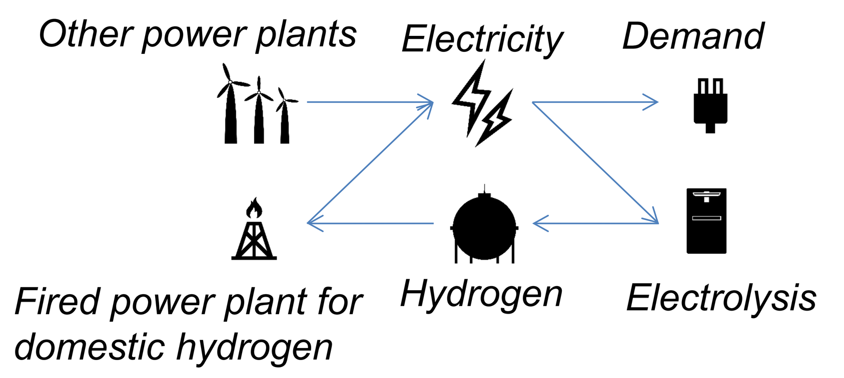
Region: 10 regions
Year: 2050
Optimization: Recursive dynamic
Generators: Coal (boiler, IGCC, - w/CCS), Oil (boiler), Gas (boiler, NGCC, -w/CCS), Hydro (Conventional, pumped), Nuclear, Solar PV, Wind (Onshore, offshore), Biomass, Imported hydrogen
Power system stabilization measures: Economic load dispatching control (EDC), Load frequency control (LFC), Interregional transmission, Pumped hydro, Battery for long-term fluctuation (LFSB), Battery for short-term fluctuation (SFSB), Curtailment, Domestic hydrogen

- Modeling hydrogen power generation

Two types of hydrogen power generations were newly incorporated.

1) Power plants using imported carbon-free hydrogen.
Capital costs, thermal efficiency: same as NGCC
Fuel price: 20JPY/Nm³ in 2050[4], **CO_2 emission intensity:** 0 kg CO2/MJ
Maximum volume: 10 million tons in 2050[4]

2) Power plants using domestic hydrogen produced by electrolysis.
Modeled as an interseasonal and daily storage
Generation: Capital costs, thermal efficiency: same as NGCC
Electrolysis: Capital costs, conversion efficiency: 50,000 JPY/kW[4], 70%[4]

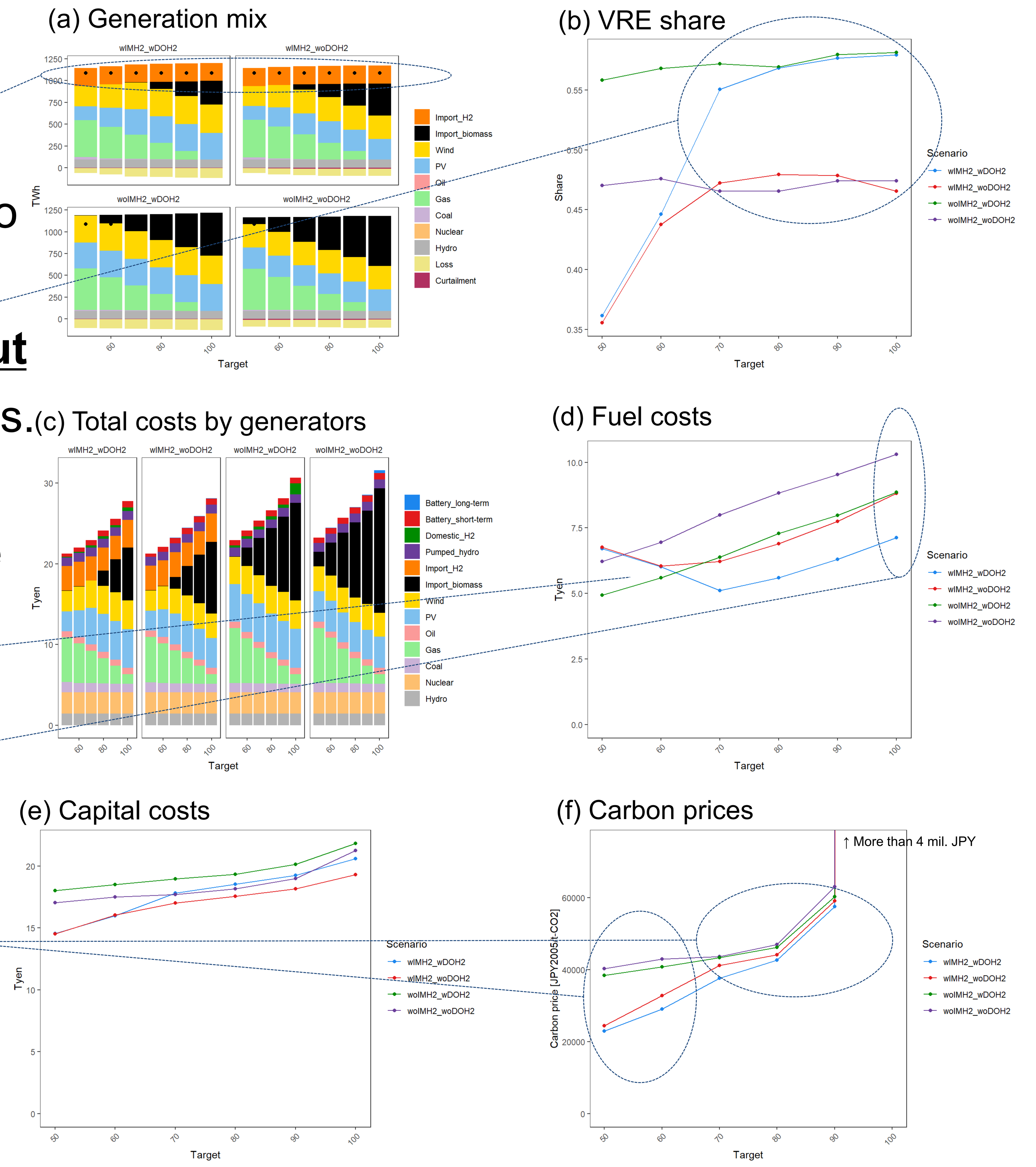


- Scenario

Four scenarios: With/without imported hydrogen × with/without domestic hydrogen
Nuclear & CCS: Assumed not to be available in 2050

Results

- **Imported hydrogen would reach its maximum volume** even in the low reduction target cases thanks to its cost competitiveness.
- **Domestic hydrogen would increase VRE share about 10 percentage points** in the high reduction target cases.
- While fuel costs of "with imported hydrogen scenario" were **higher in 50-60% reduction cases**, they became **lower in more than 70% reduction cases**, due to the price difference of imported biomass and hydrogen.
- **Domestic hydrogen would reduce about 8 trillion JPY of fuel costs** by support to introduced VREs.
- Availability of imported hydrogen would **have large impacts on carbon prices in the 50-60% reduction cases**, but **less in more than 70% reduction cases**.



Discussion

- Although imported hydrogen could be a cost-effective option, its impact on carbon price in the high reduction cases would be limited, due to its upper limit of importable volume.
- Domestic hydrogen would increase VRE share, and thus would improve energy security.
- Future tasks: considering interregional transmission of domestic hydrogen.

AIM ASIA-PACIFIC INTEGRATED MODEL
Asia-Pacific Integrated Model
http://www-iam.nies.go.jp/aim

1) Matsuo, Y. *et al.*, *Energy* **165**, 1200–1219 (2018), 2) Pambudi, N. A. *et al.*, in *Proceeding - ICSEEA 2016*, 66–69, 3) Shiraki, H. *et al.*, *J. Clean. Prod.* **114**, 81–94 (2016), 4) METI, New Strategic Roadmap for Hydrogen and Fuel Cells (2019)

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