1st Asia Green Growth Partnership Ministerial Meeting (AGGPM) to be held on 25th April 2022

Decarbonization of ASEAN Energy System: The Optimum Technology Selection Model Analysis up to 2060

Presented the results on behalf of ERIA & IEEJ

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Overview

- ERIA/IEEJ is analyzing a roadmap for net zero emissions of the ASEAN energy sector by 2060, which is broadly consistent with the long-term goal of the Paris Agreement.
- This study employs a techno-economic energy system model that illustrates the cost-optimal deployment of energy technologies for the whole ASEAN region.
- Various mitigation options, including efficiency, renewables, nuclear, CCS, hydrogen, ammonia and negative emission technologies, play a crucial role.
- During transition periods, “lower-carbon” measures, such as fuel switching from coal to natural gas and co-firing with hydrogen or ammonia in the electricity sector, contribute to reducing CO_2 emissions effectively.
- However, simulation results also imply significant economic challenges associated with decarbonization.
- Technological innovations through international R&D cooperation would be the key to achieve carbon neutrality in an affordable manner.

Methodology

- Applying IEEJ-NE linear programming model: The aim is to minimizes the total cost of the energy system when various constraints such as CO2 emissions and power supply-demand balance are given.

- The model covers the entire energy system including the energy conversion and end-use sectors (industry, transport, households and commercial), and incorporates more than 350 technologies in these sectors.

- The model evaluates combinations of performances of and each cost of energy technologies and emission constraints, in order to arrive at results of a combination of the scale and the operational patterns of individual energy technologies to be introduced in each scenarios of the carbon neutrality.

- Key assumptions included: cost of low-carbon technologies, discount rate, country's emission reduction targets, CO2 storage, cost reduction of low carbon technologies, ASEAN power grid, potential of solar and wind and battery storage, imported of ammonia and hydrogen from outside ASEAN.

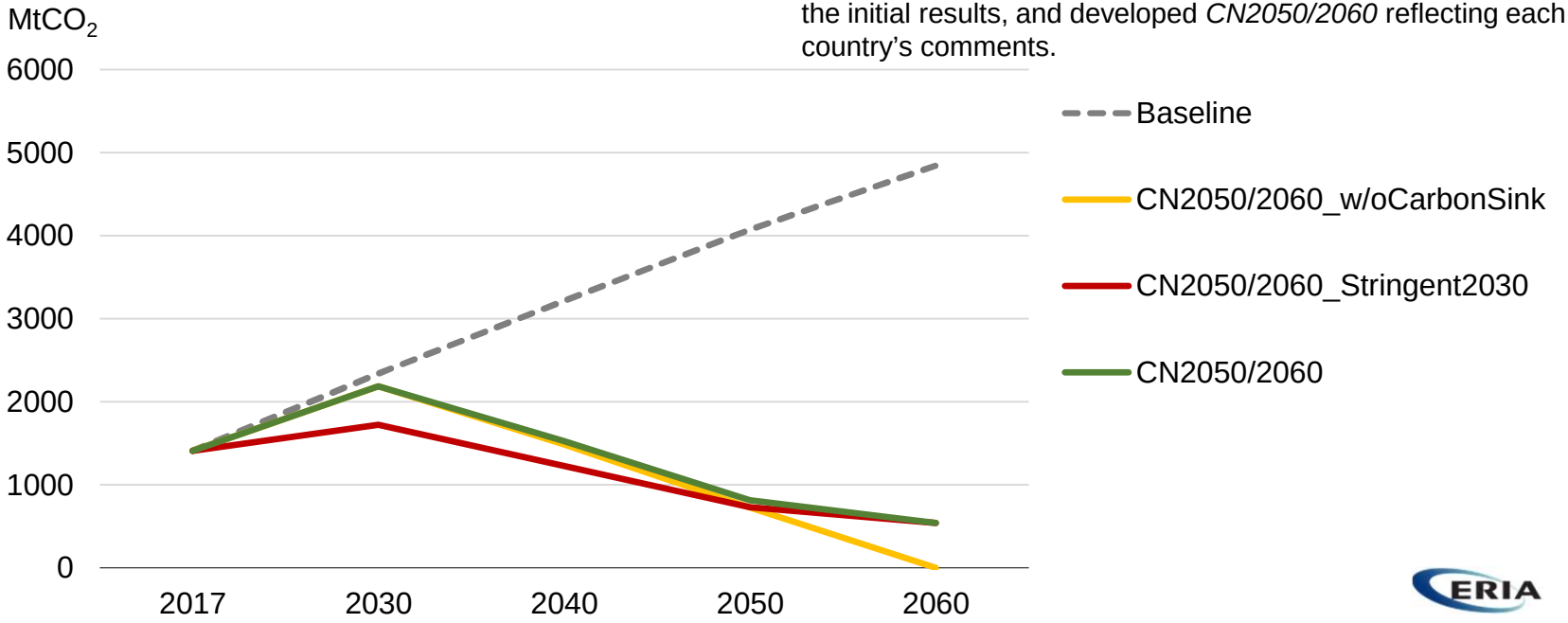
- Case setting of the carbon neutrality scenarios based on conditions and circumstances such as national vs international supports to carbon neutral targets.

Case settings

- ***Baseline*** does not assume any emission constraints by 2060.
- ***CN2050/2060*** assumes energy-related CO_2 emission constraints by country and achieves net zero CO_2 emissions with natural carbon sink by 2060 in ASEAN.
  - ***CN2050/2060_Innovation cases*** are for evaluating the impact of technological innovation in the *CN2050/2060*. **(sensitivity analysis 1)**
  - ***CN2050/2060_Stringent2030*** puts more stringent emission constraints by 2030 in the *CN2050/2060*. The emission in 2030 is consistent with IEA SDS. **(sensitivity analysis 2)**
- ***CN2050/2060_w/oCarbonSink*** assumes net zero energy-related CO_2 emissions by 2050 in BRN and SGP and by 2060 in the rest of the countries. This is the case we initially assumed.

Energy-related CO_2 emission constraints in ASEAN

Note: *CN2050/2060_w/oCarbonSink* is the case we initially assumed. We had discussions with ASEAN countries based on the initial results, and developed *CN2050/2060* reflecting each country's comments.



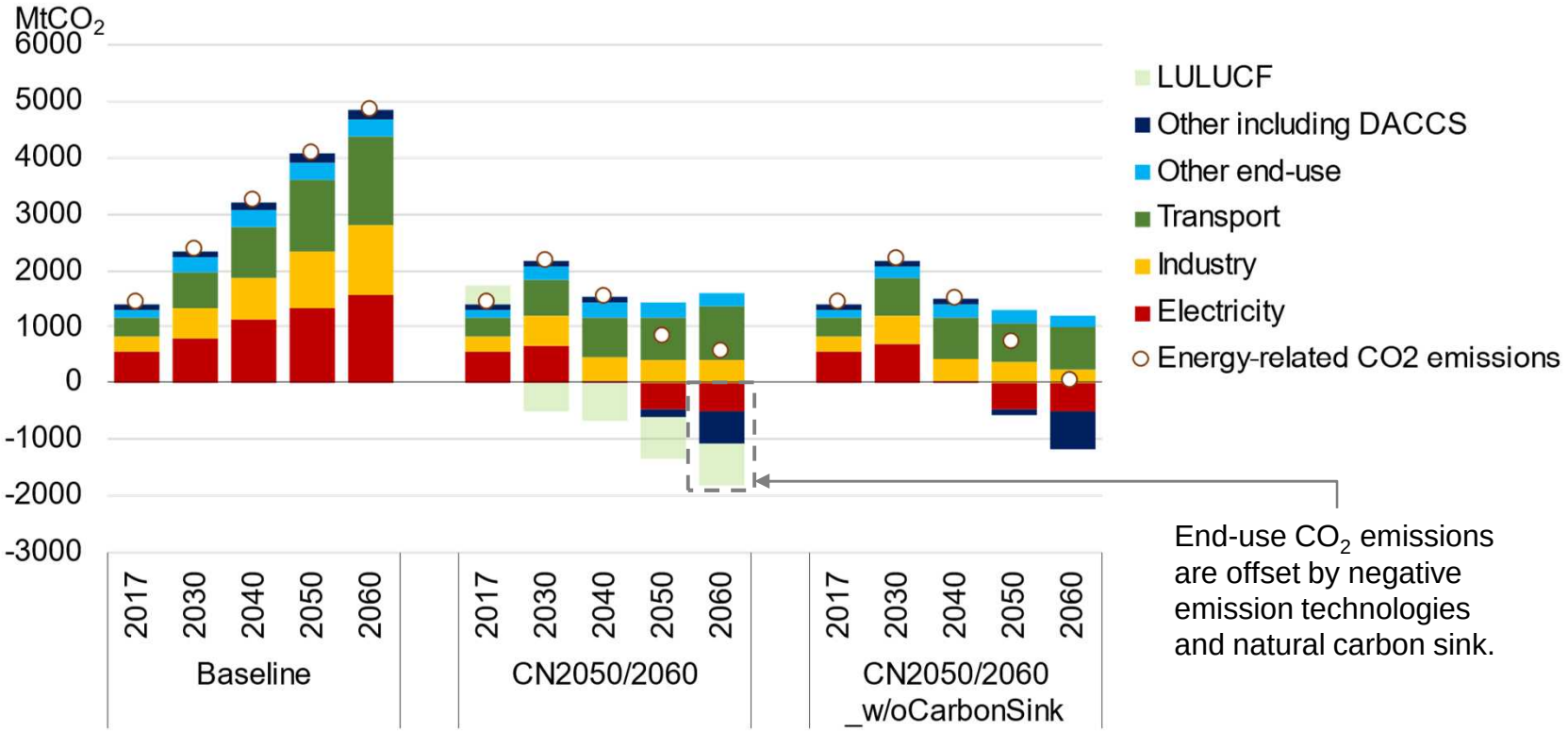
Outline

- Methodology
- **Results for ASEAN**
  - **Energy mix for decarbonizing ASEAN by 2060**
  - Sensitivity analysis 1: Technological innovation
  - Sensitivity analysis 2: Strengthen CO_2 emissions constraints in 2030
- Key messages

Sectoral CO_2 emissions

- End-use emissions reduction, combined with negative emission technologies[1], is estimated to be a cost-efficient strategy for ASEAN carbon neutrality.
- Power sector is almost decarbonized by 2040, while the CO_2 from the transport, especially bus and truck, remain in the *CN* cases because of high costs of alternative vehicles.

Sectoral energy-related CO_2 emissions in ASEAN

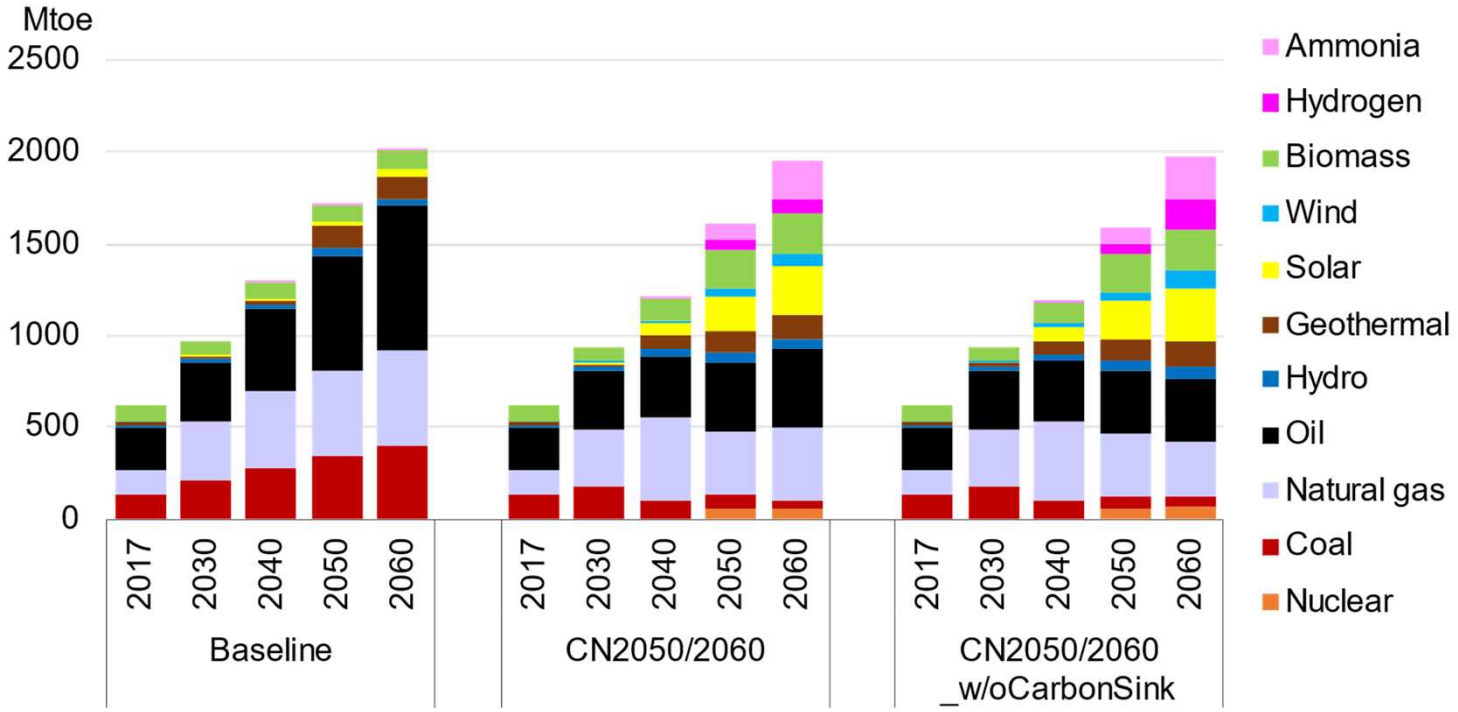


1 BECCS and DACCS

Primary energy supply

- A wide range of technologies, including renewables, nuclear, CCS and import of hydrogen and ammonia, are necessary for deep decarbonization.
- Zero emission energies together contribute to 56% of primary energy in 2060 in the *CN2050/2060,* and 65% in the *CN2050/2060_w/oCarbonSink*.

Primary energy supply in ASEAN



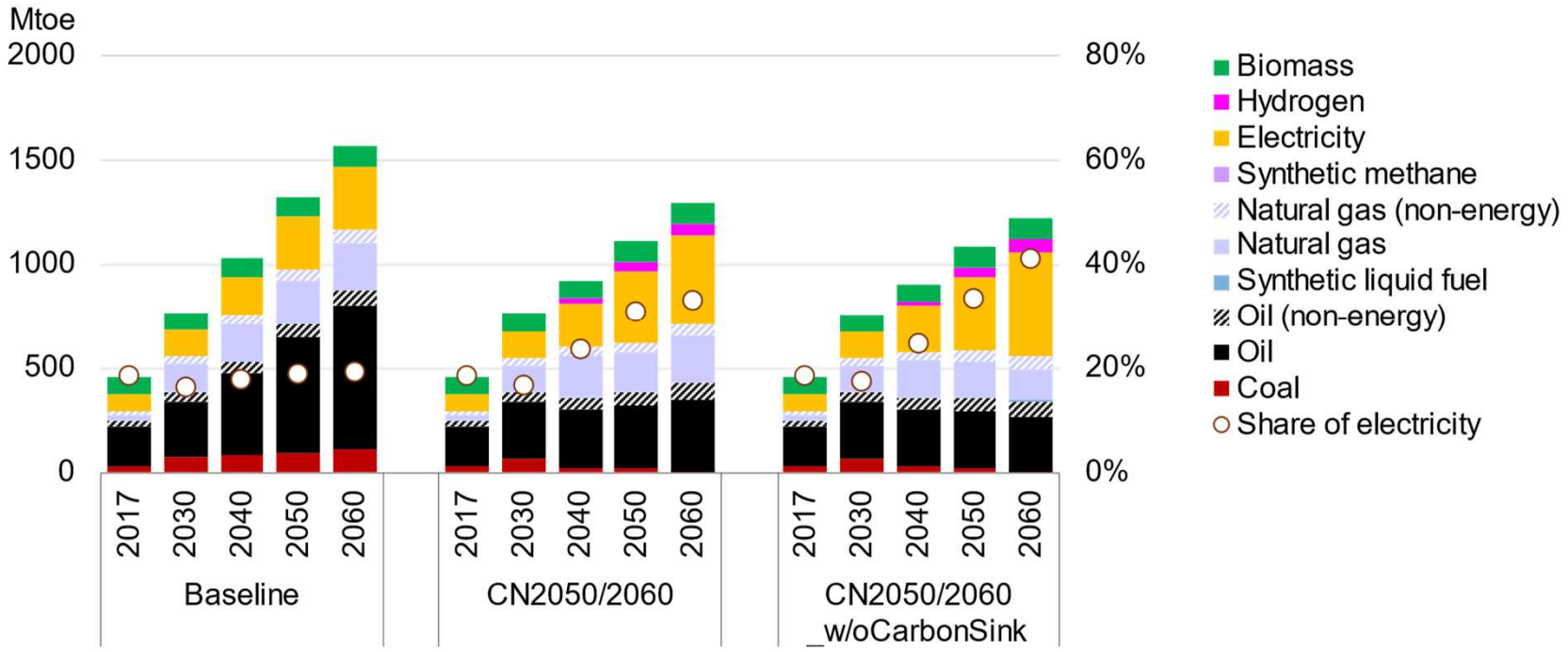
1 NETs = Negative Emissions Technologies

Fossil fuels include non-energy use. CO_2 from fossil fuel combustion in 2060 in CN2050/2060 is offset by NETs and natural carbon sink.

Final energy consumption

- Energy saving and electrification are core strategies for decarbonizing end-use sectors.
- Electricity becomes the largest end-use energy source by 2050.

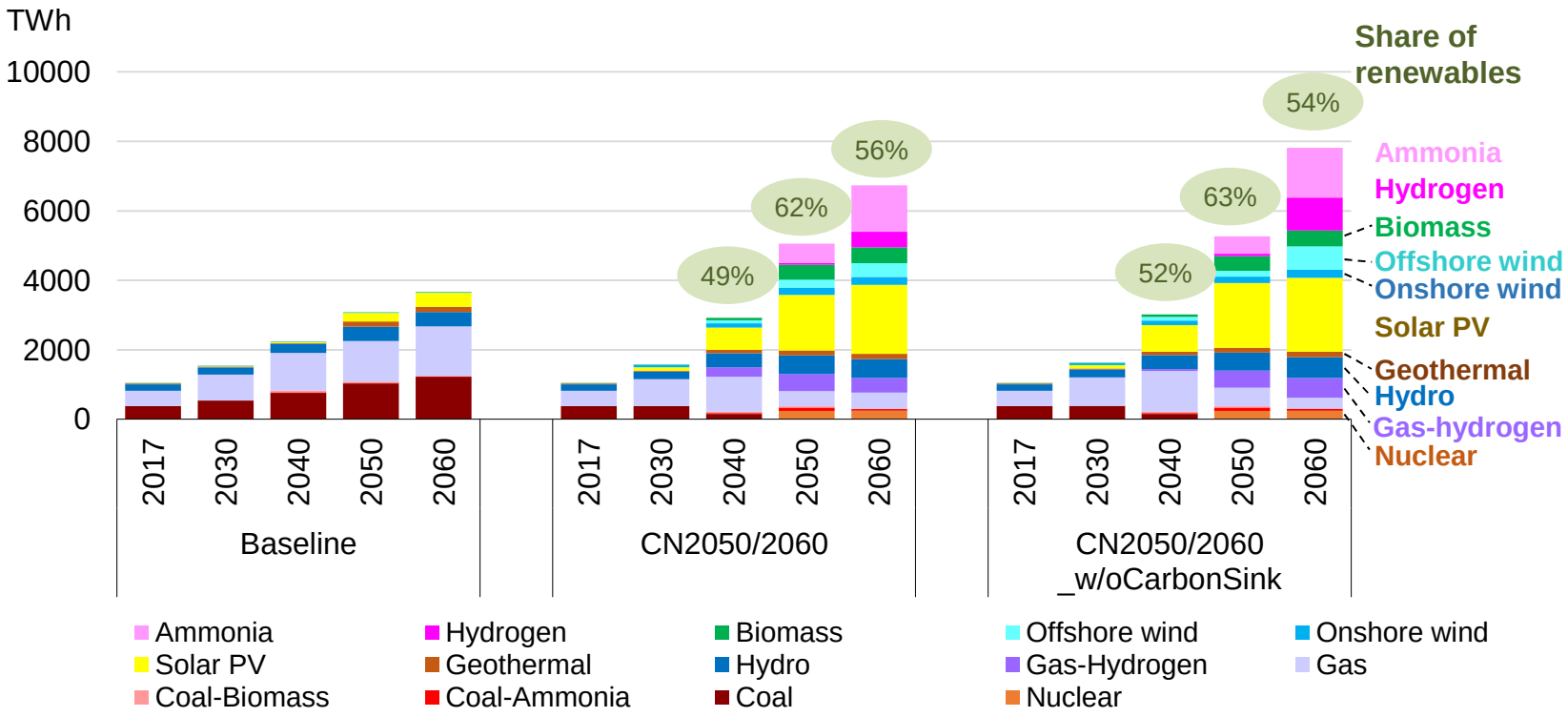
Final energy consumption in ASEAN



Power generation

- Renewables become the main power source in the *CN* cases.
- Hydrogen and ammonia, including co-firing, are also projected to be a part of the power generation mix for net zero emissions by 2060.

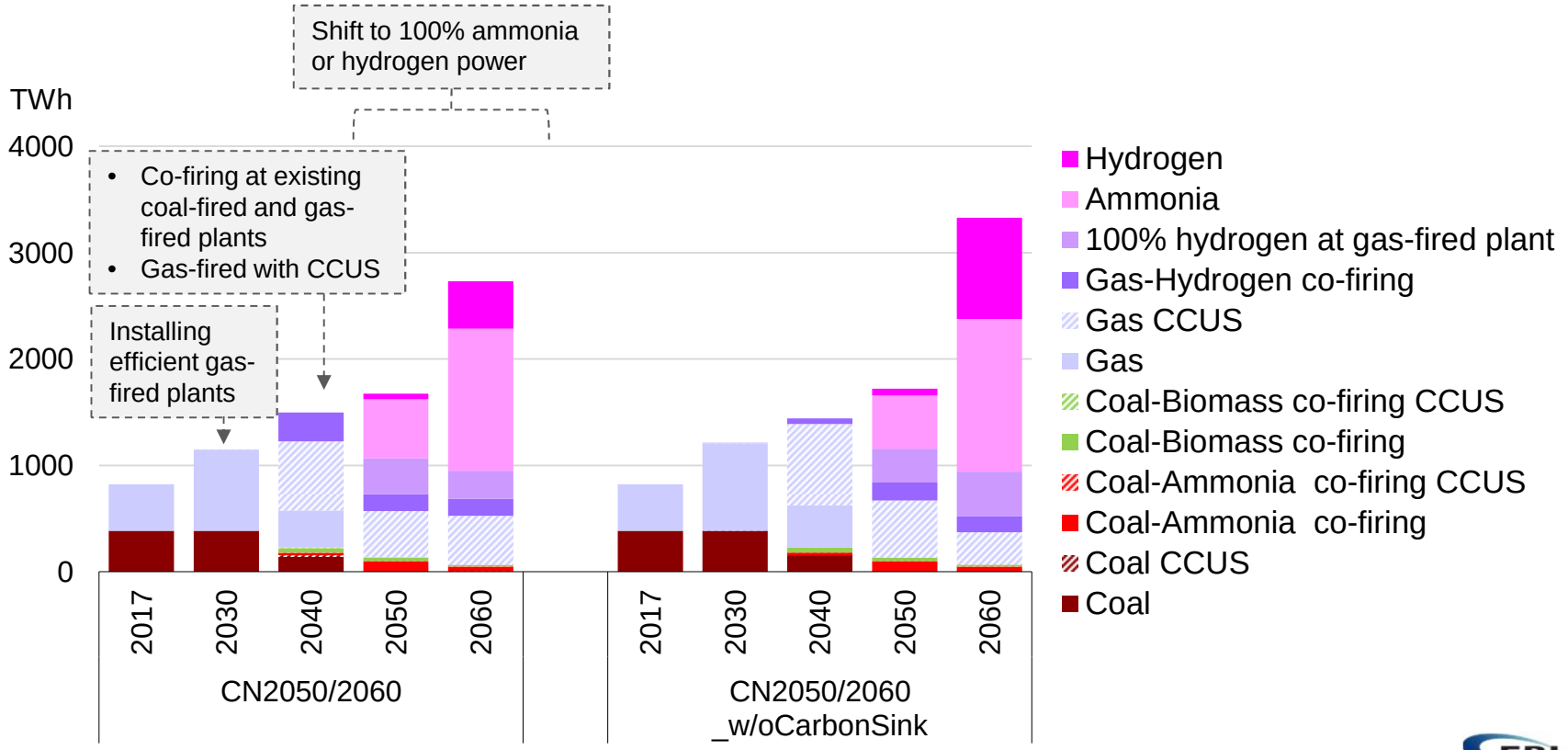
Power generation in ASEAN



Transition from fossil fuels to NH_3 & H_2 power generation

- In the short- to medium-term, such as 2030~40, efficient gas-fired plants is estimated to contribute to curbing CO_2 emissions from power generation.
- In the longer-term, gas-fired with CCUS, co-firing with ammonia or hydrogen, and 100% ammonia and hydrogen power would be candidates.

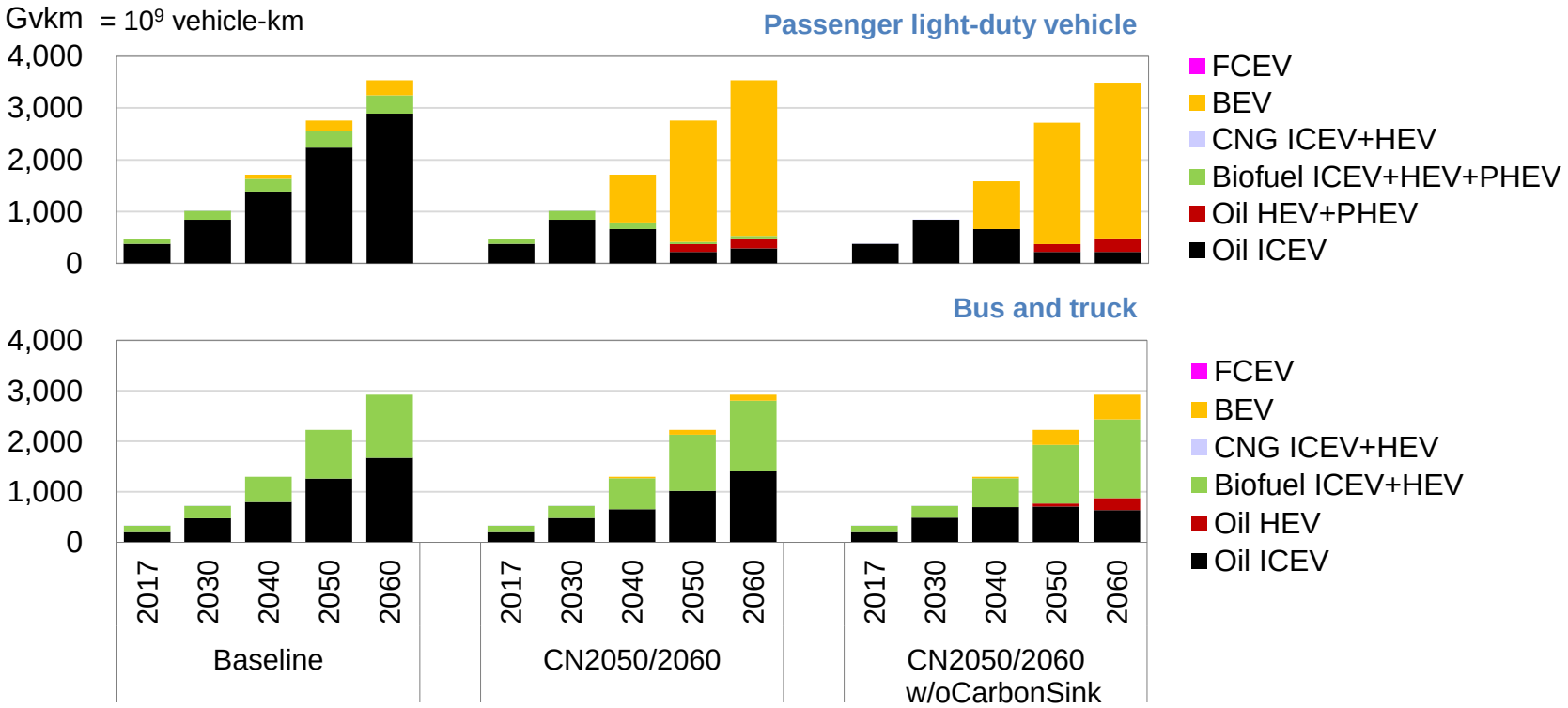
Power generation from coal, gas, ammonia and hydrogen in ASEAN



Road transport vehicle

- Passenger light-duty vehicles are projected to be largely electrified by 2050.
- Oil consumption remains in bus and truck transport in the *CN* cases mainly due to high price for alternative vehicle technologies.

Travel distance by vehicle technology in ASEAN

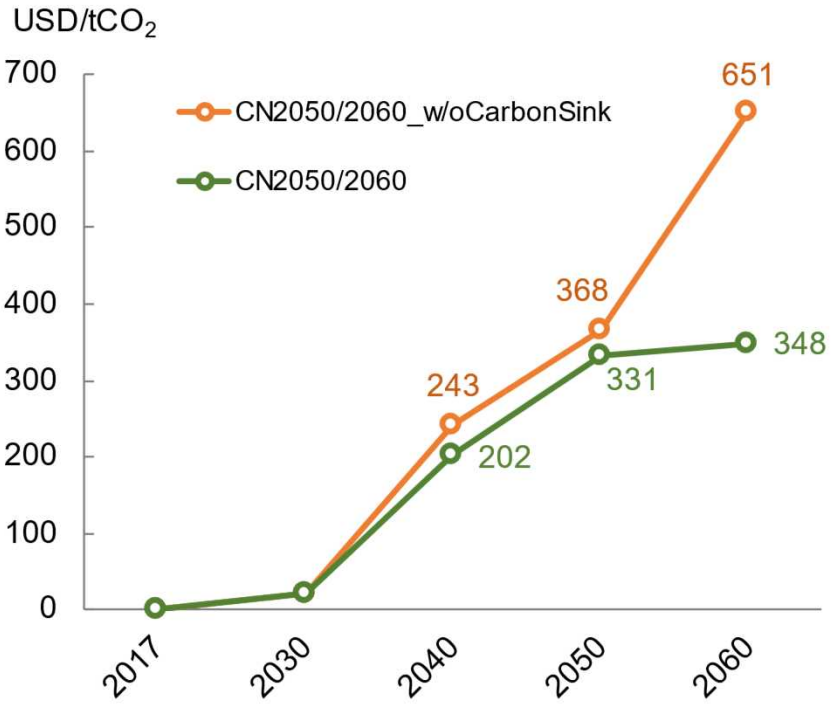


Note: biofuel includes bioethanol and biodiesel mixed with petroleum fuel.

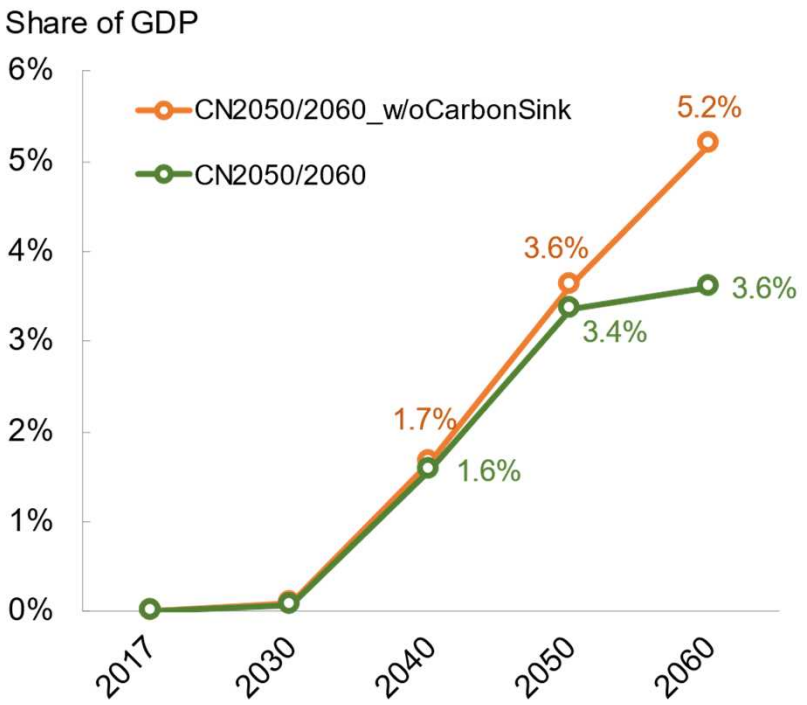
Costs for reducing CO_2

- Marginal abatement cost, which represent the intensity of decarbonization policies, would be 348 USD per tCO_2 in the *CN2050/2060*, and 651 USD in the *CN2050/2060_w/oCarbonSink*, implying economic challenges for net zero emissions.
- Additional annual cost from the *Baseline* to the *CN2050/2060* and the *CN2050/2060_w/oCarbonSink* is estimated to be about 3.6% and 5.2% of ASEAN GDP in 2060.

Marginal CO_2 abatement cost (MAC)
ASEAN weighted average



Additional annual cost
ASEAN total



Note: The costs presented here do not include costs to enhance emissions reductions in the LULUCF sector.

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Impacts of technology innovation

Five technology innovation cases (*PowerInov*, *CCSInov*, *H2Inov, DemInov and Combo*) to investigate their impacts on energy mix and mitigation costs.

Case	CN year	Key technology assumptions
CN2050/2060	2060	• Reference technology cost • International power grid extension is constrained by planned ASEAN Power Grid capacity • CO_2 storage up to 1.6GtCO_2/year in 2060
PowerInov	2060	• Cost reduction of Li-ion battery (-25% in 2040 and -50% after 2050, from the reference level) and international grid extension • No upper limit for international power grid extension • Large-scale electricity exports from Myanmar to Thailand
CCSInov	2060	• Cost reduction of DAC (-25% in 2040 and -50% after 2050) • CO_2 storage up to 2.7GtCO_2/year in 2060
H2Inov	2060	• Cost reduction of coal gasification, methane reforming and electrolyzer (-25% in 2040 and -50% after 2050) • Cost reduction of hydrogen consumption: H_2 based DRI-EAF and FC ship (-25% in 2040 and -50% after 2050), FCEV (comparable to hybrid electric vehicle price in 2060)
DemInov	2060	• Cost reduction of advanced end-use technologies (-50% in and after 2040)
Combo	2060	• Combination of all the above

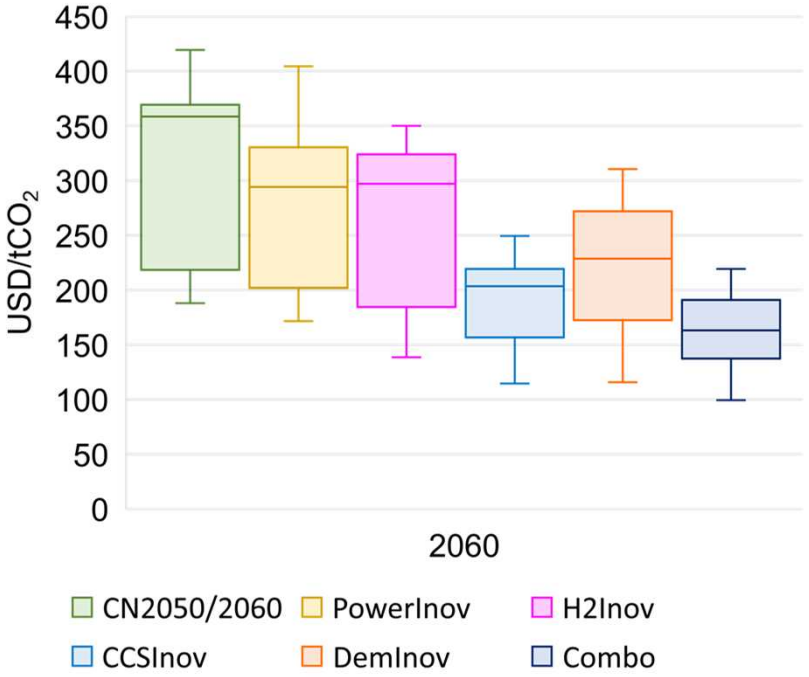
DRI-EAF: Direct Reduced Iron-Electric Arc Furnace, FC: Fuel Cell, FCEV: Fuel Cell Electric Vehicle

Innovation and mitigation costs

- Technology innovation, as well as ASEAN energy cooperation such as APG, significantly reduce marginal abatement costs and electricity prices.
- Future research & development and cooperation is crucial for realizing net zero emissions.

Marginal CO_2 abatement cost (MAC)

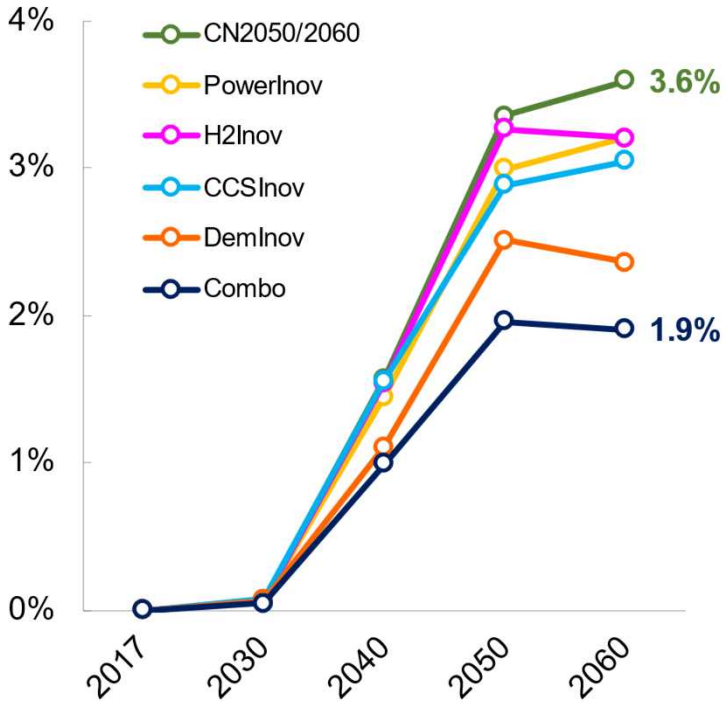
Range of country marginal cost in 2060



Additional annual cost

ASEAN total

Share of ASEAN GDP



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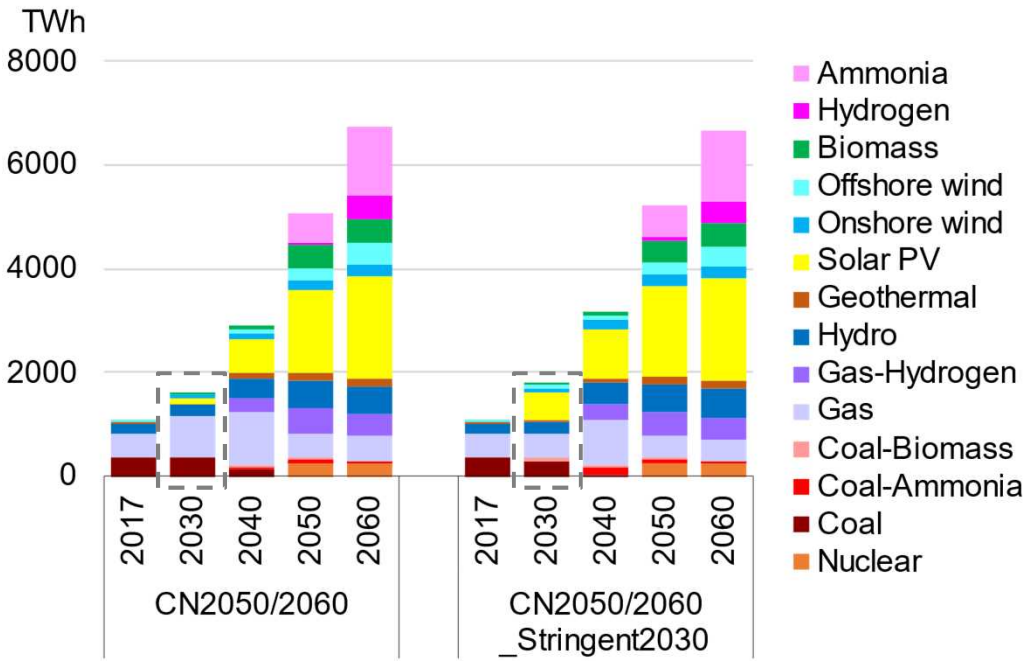
Impacts of strengthening short-term emission constraints

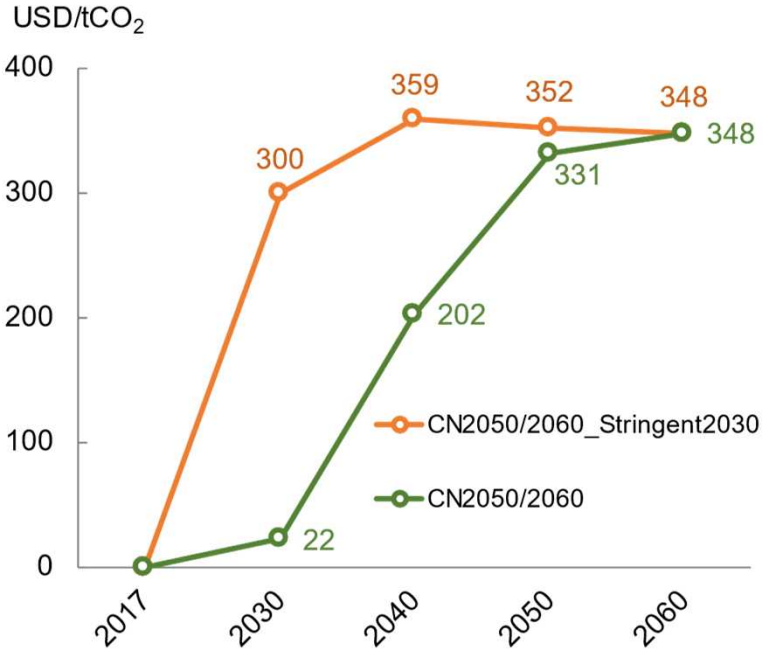
- As for the power generation mix, solar PV increases while gas-fired decreases in 2030 in the *CN2050/2060_Stringent2030* by strengthening short-term emission constraints.
- MAC in 2030 increases significantly to 300 USD/tCO_2, implying the cost hurdle to achieve short-term emission reductions.

Power generation in ASEAN



Marginal CO_2 abatement cost (MAC)

ASEAN weighted average



Note: The value of the objective function is larger in the *CN2050/2060_Stringent2030* than in the *CN2050/2060*.

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Conclusions and key messages (1)

- Energy saving and electrification in end-use sectors, combined with low-carbon power supply, would be core strategies for decarbonizing ASEAN energy systems.
  - Not only VRE, but also other carbon-free technologies including hydro, geothermal, biomass, and nuclear can contribute to carbon neutrality.
  - CO_2-free hydrogen supply, CCS, and negative emission technologies are also important.

- During transition periods, various kinds of “low-carbon” technologies can reduce CO_2 emissions effectively.
  - In the power sector, fuel switching from coal to natural gas, deployment of more efficient turbines, co-firing with hydrogen or ammonia, as well as fossil-fuel fired power generation with CCS can contribute to following paths towards deep decarbonization.
  - Affordable technologies are likely to be introduced in the mid-term. Deployment of more expensive technologies would be required in the last stage of complete decarbonization.

Conclusions and key messages (2)

Simulation results would imply significant economic challenges associated with decarbonization.

- Mitigation costs and energy prices may increase in the *CN* cases.

Cost reduction and international cooperation would be the key to achieve carbon neutrality in an affordable manner.

- Technology innovation and scale merits are essential for cost reduction.
- Regional cooperation would contribute to more efficient deployment of low carbon technologies.
- Future research & development, in cooperation with advanced economies, is crucial for achieving carbon neutrality in the long term.