Decarbonization pathways for ASEAN: A model analysis

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Background

- Due to growing concerns over climate change, governments of many countries have announced very ambitious targets to reduce greenhouse gas (GHG) emissions.

- Many advanced economies, e.g., European Union, the United States, and Japan, have targets to reduce GHG emissions by 100% by 2050. In addition, emerging countries have also set ambitious targets, such as China that aims to achieve carbon neutrality by 2060.

- Identifying the pathways to achieve these targets, as well as estimating the risks and costs related to them, should be regarded as one of the most urgent policy challenges for all countries in the world.

- In this study, we exploited an linear programming model to calculate the cost-optimal pathways achieving carbon neutrality in 2050-2070, focusing on energy-related CO_2 emissions in the ten ASEAN countries, and assuming future deployment of advanced technologies such as hydrogen and negative emission technologies (NETs).

Selected low-carbon technologies in the model

Renewables	Solar PV, Onshore wind, Offshore wind, Hydro, Geothermal, biomass
Nuclear	Light water reactor
CCUS	**CO_2 capture**: Chemical absorption, Physical absorption, Direct air capture **CO_2 utilization**: Methane synthesis, FT liquid fuel synthesis **CO_2 storage**: Geological storage
Hydrogen	**Supply**: Electrolysis, Coal gasification, Methane reforming, H_2 separation from Ammonia, H_2 trade among ASEAN countries, H_2 imports from non-ASEAN countries **Consumption**: H_2 turbine, Natural gas-H_2 co-firing, FCEV, H_2 based DRI+EAF, Fuel cell ship, H_2 aviation, H_2 heat for industries, Fuel synthesis (methane, FT liquid fuel, ammonia)
Ammonia	**Supply**: Ammonia synthesis, NH_3 trade among ASEAN countries, NH_3 imports from non-ASEAN countries **Consumption**: Ammonia turbine, Coal-ammonia co-firing, H_2 separation
Negative emission technologies	Direct air capture with CCS (DACCS), Biomass-fired power generation with CCS (BECCS)

Direct air capture (DAC)

- Direct air capture technologies extract CO_2 directly from the atmosphere.
- The captured CO_2 can be permanently stored in deep geological formations (Negative emission), or it can be combined with hydrogen to produce synthetic fuels (Carbon recycling).
- There are currently 15 DAC plants operating worldwide, capturing more than 9,000 tCO_2/year. (source) IEA https://www.iea.org/reports/direct-air-capture
- DAC requires massive energy input so that the cost is currently very high at 600 USD/tCO2. However, it can be cost competitive with high carbon prices aiming for carbon neutrality.

(source) climeworks

Assumptions for DAC in 2050

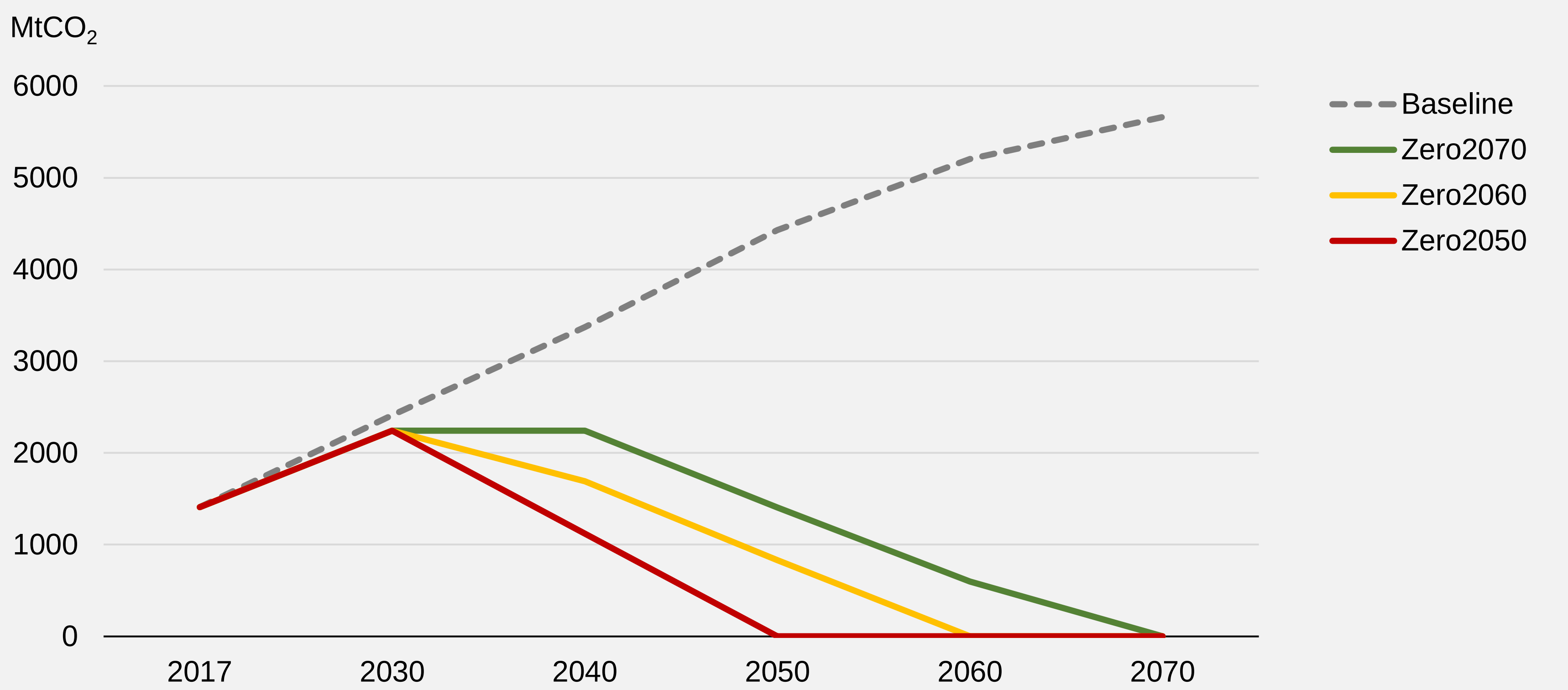
item	value	unit
Capital cost	694	$/($tCO_2$/yr)
O&M cost	35	$/$tCO_2$
Electricity consumption	1.5	MWh/tCO_2
Capturing cost*	**253**	$/$tCO_2$

* Electricity price is assumed to be 0.1$/kWh.

Case setting

- Baseline case does not assume any CO_2 emission reduction targets.
- The Zero2070 case achieves net zero energy-related CO_2 emissions by 2050 in BRN and SGP, by 2060 in THA and MYS, and by 2070 for the rest of the countries. The Zero2060 and Zero2050 cases assumes that all the countries achieve net zero by 2060 and 2050, respectively.

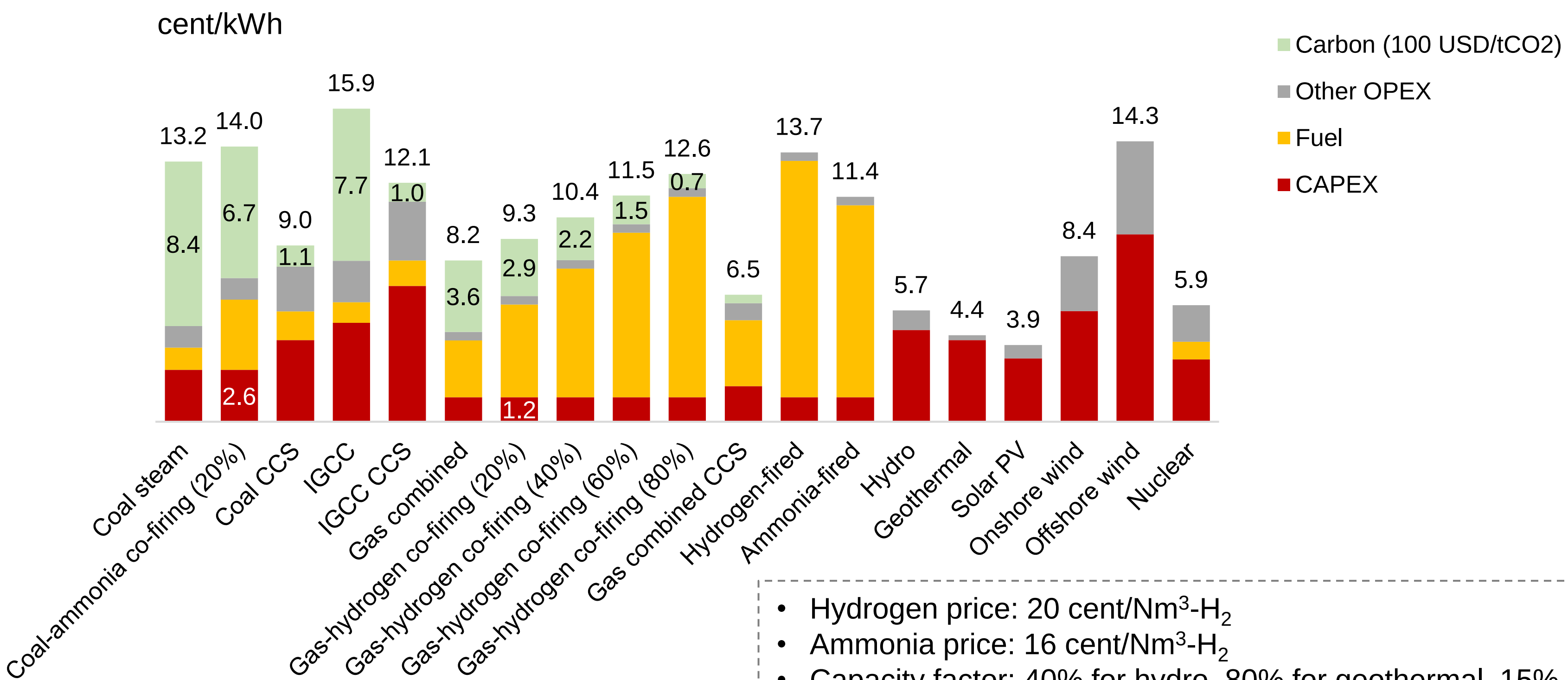
Energy-related CO_2 emissions in ASEAN



Power generation cost in 2050

Levelized Cost of Electricity (LCOE) for ASEAN

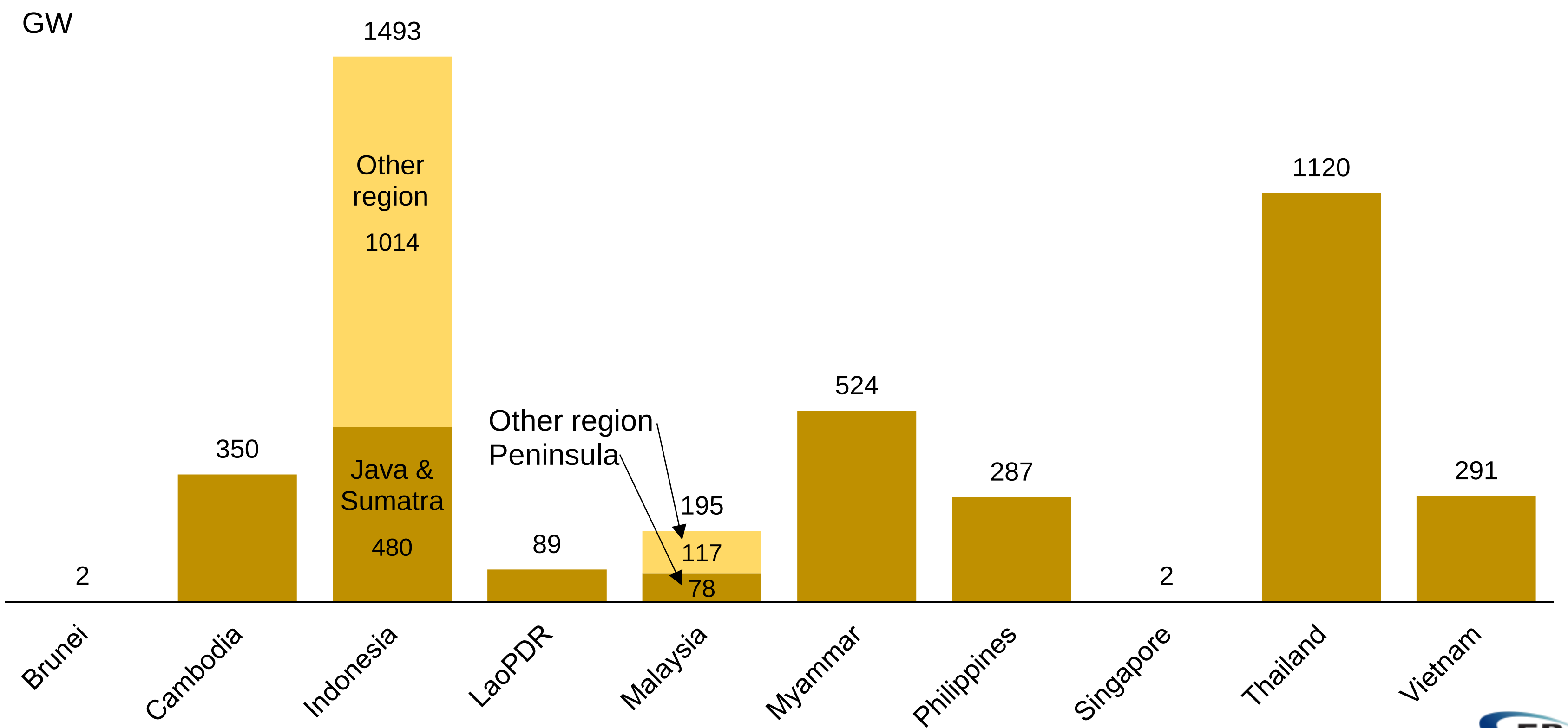
- Note that the level of carbon price varies by case setting (the figure below assumes 100 USD/tCO_2 as an example). Capacity factor is endogenous variable in the model
- The cost of Li-ion battery has been assumed to decline to 156 USD/kWh and 117 USD/kWh by 2050 and 2070, respectively.



- Hydrogen price: 20 cent/Nm^3-H_2
- Ammonia price: 16 cent/Nm^3-H_2
- Capacity factor: 40% for hydro, 80% for geothermal, 15% for solar PV, 20% for onshore wind, 30% for offshore wind, 80% for nuclear, 60% for the rest of the technologies

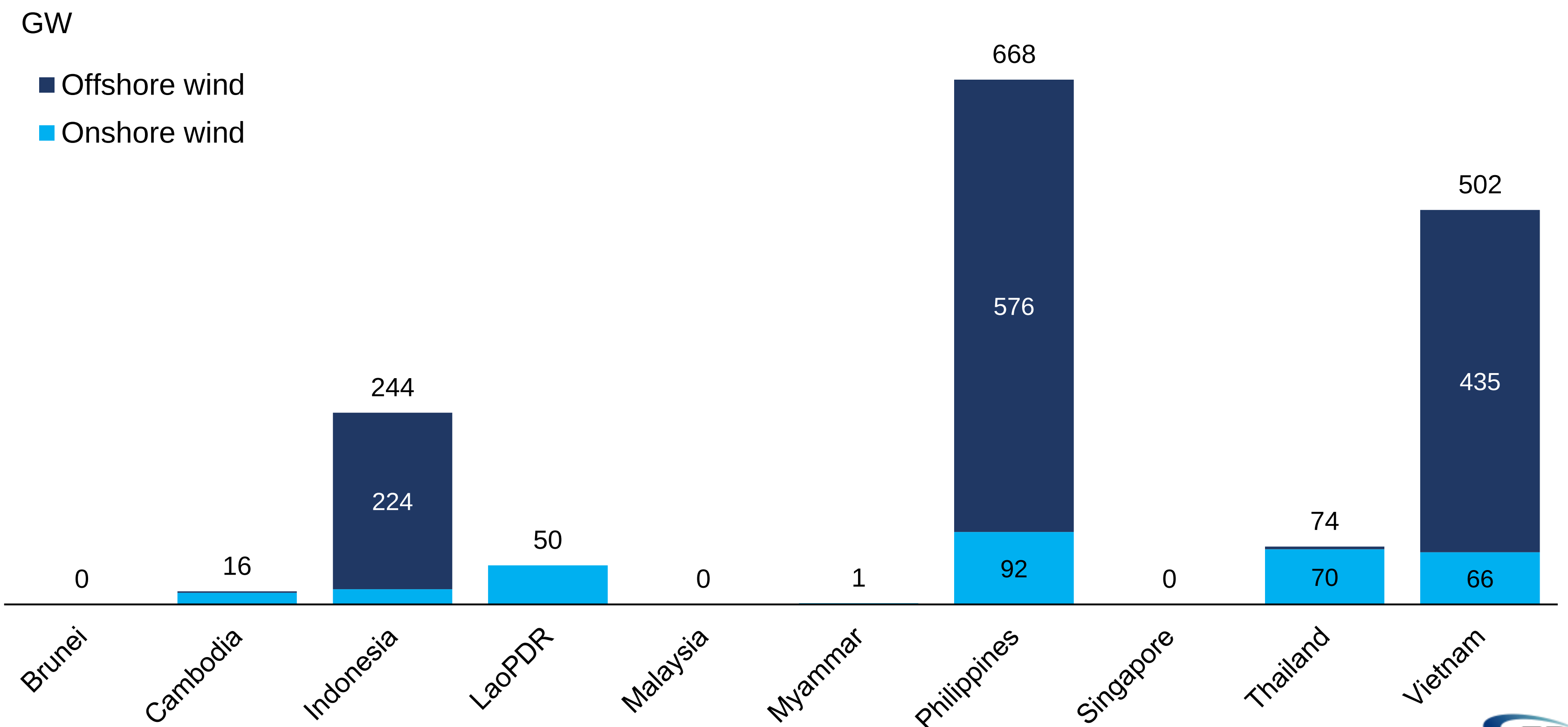
Solar PV potential

- Total 4359 GW in ASEAN, estimated by the IEEJ based on GIS data
- Solar PV potential in Indonesia is divided into “Java & Sumatra” and “other” to reflect regional imbalance of electricity demand and renewable energy
  - Solar PV in the “other” region is assumed for hydrogen production
- Potential in Malaysia is also divided into “peninsula” and “other” in this model



Wind power potential

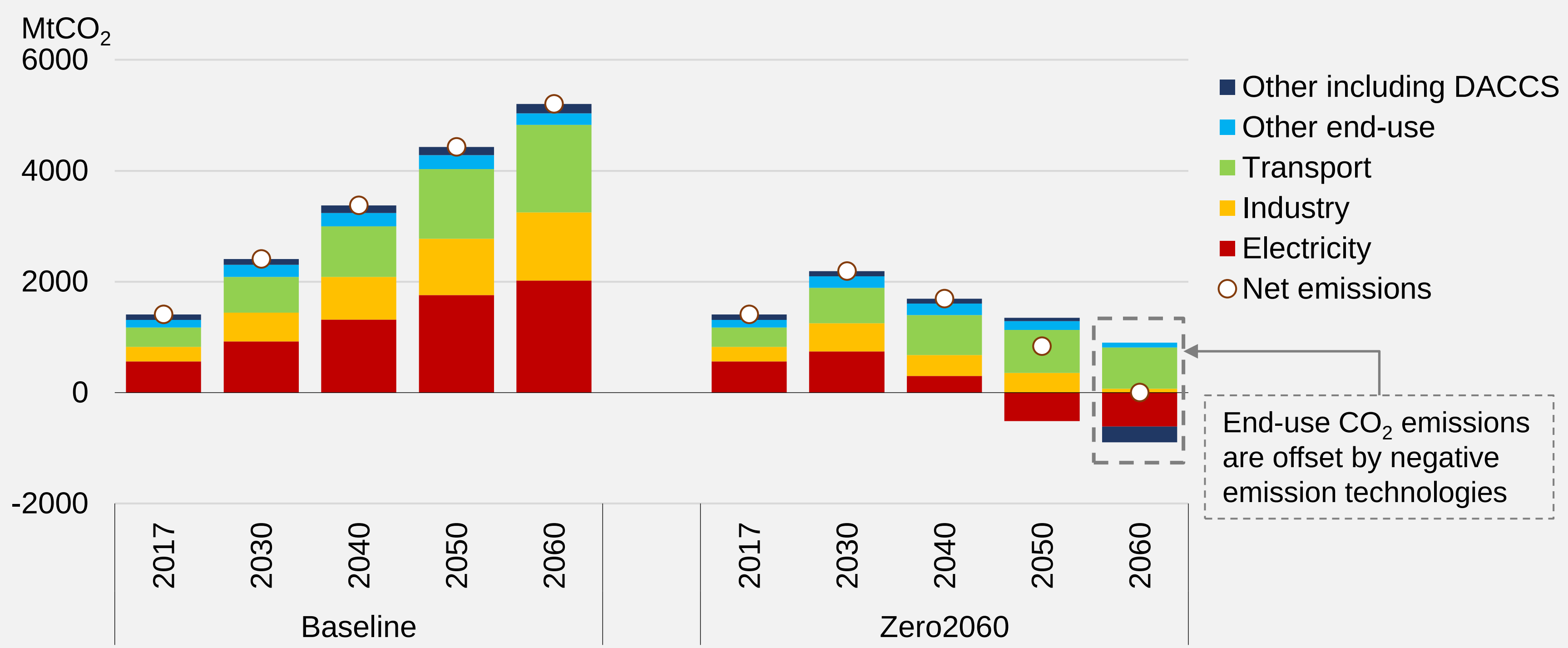
- Assumed onshore wind potential is 313GW and offshore wind is 1241GW in ASEAN, estimated by the IEEJ based on GIS data
- Onshore wind and offshore wind in Indonesia is divided into “Java & Sumatra” and “other region” to reflect regional imbalance of demand and resources
  - Wind power in the “other region” is assumed for hydrogen production



Sectoral CO_2 emissions: Zero2060 case

- 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 decarbonized by 2050, while the CO_2 from transport, especially bus and truck, remain in the Zero2060 case because of high costs of alternative vehicles.

Sectoral energy-related CO_2 emissions in ASEAN



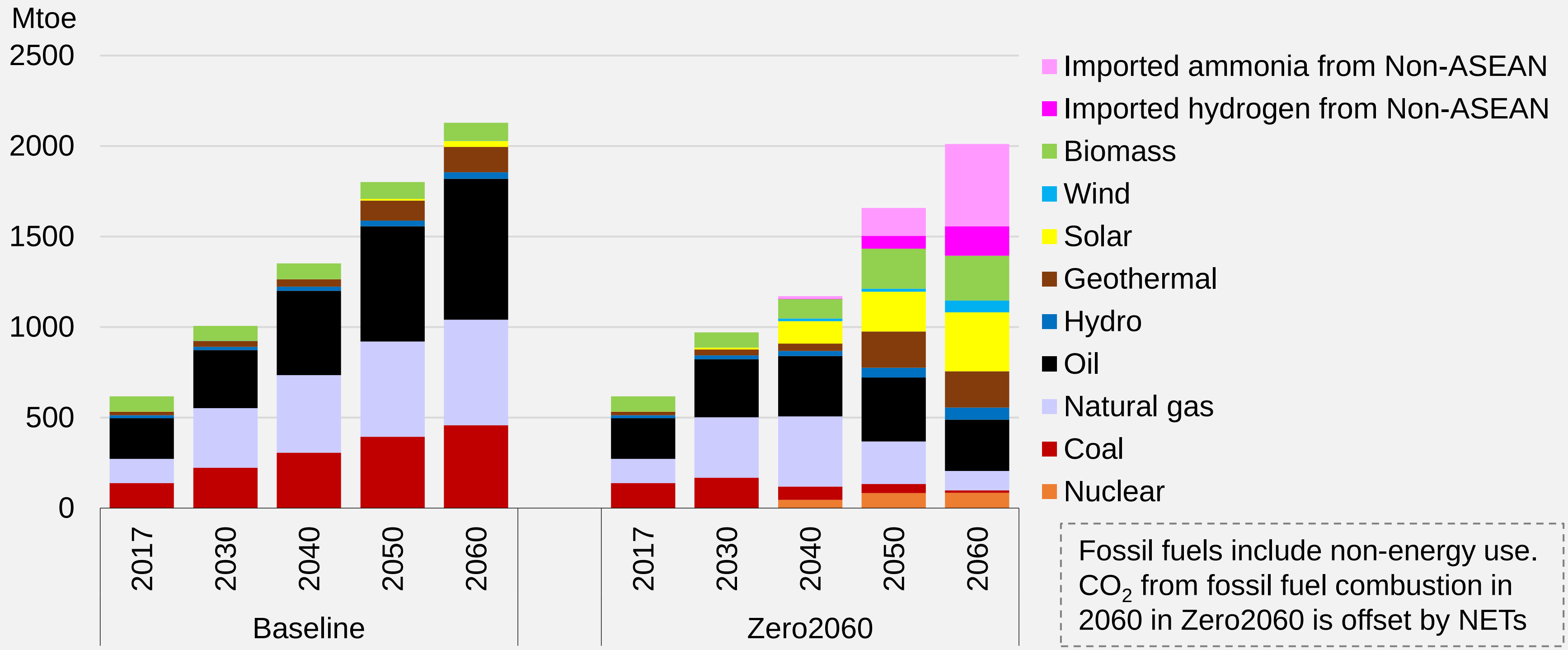
1 BECCS and DACCS

Calculation results

Primary energy supply: Zero2060 case

- A wide range of technologies, including renewables, nuclear, CCS and import of hydrogen and ammonia, are necessary for deep decarbonization.
  - Share of these technologies collectively reach 80% of primary energy supply in 2060 in the Zero2060.

Primary energy supply in ASEAN

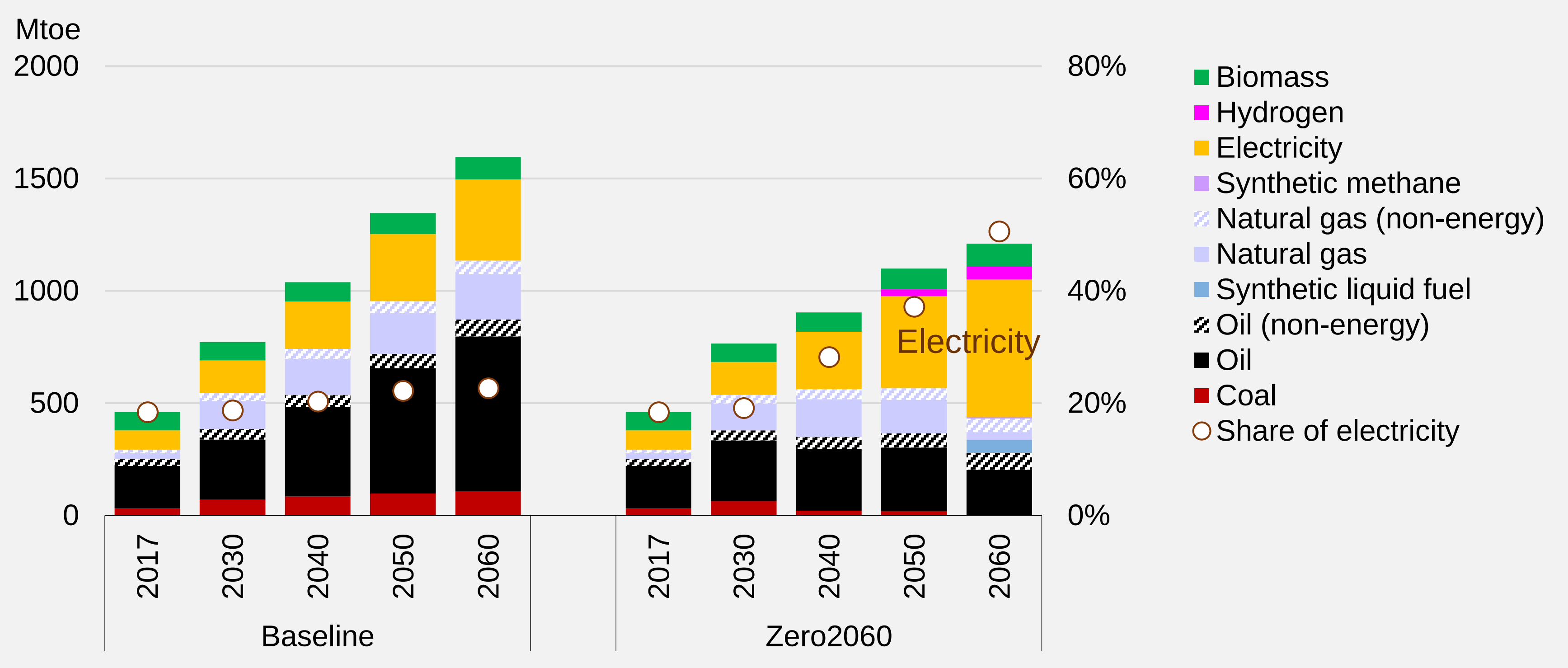


Fossil fuels include non-energy use. CO_2 from fossil fuel combustion in 2060 in Zero2060 is offset by NETs

Final energy consumption: Zero2060 case

- Energy saving and electrification are core strategies for decarbonizing end-use sectors.
- Electricity becomes the largest end-use energy source by 2060.

Final energy consumption in ASEAN

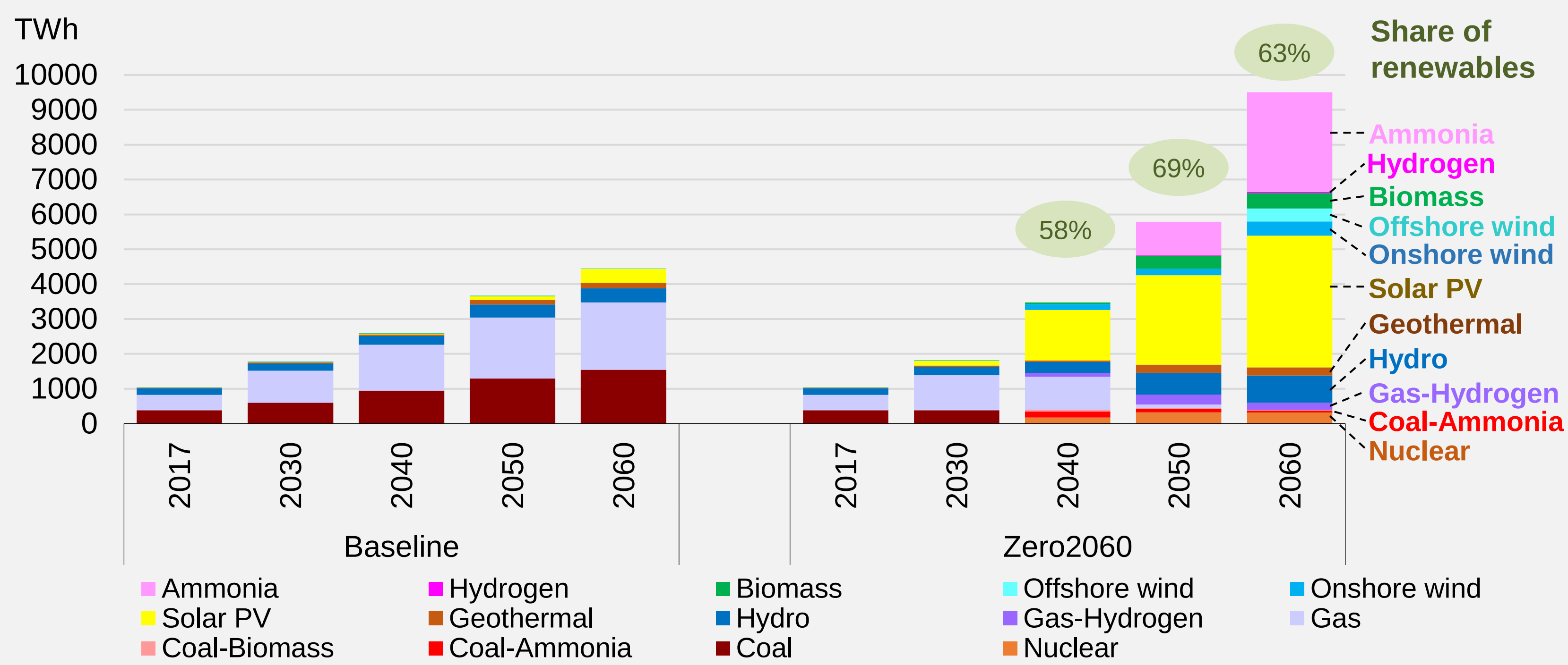


Calculation results

Power generation: Zero2060 case

- Renewables become the main power source in the Zero2060, accounting for 63% in 2060.
- Hydrogen and ammonia, including co-firing, could also be a part of the power generation mix.

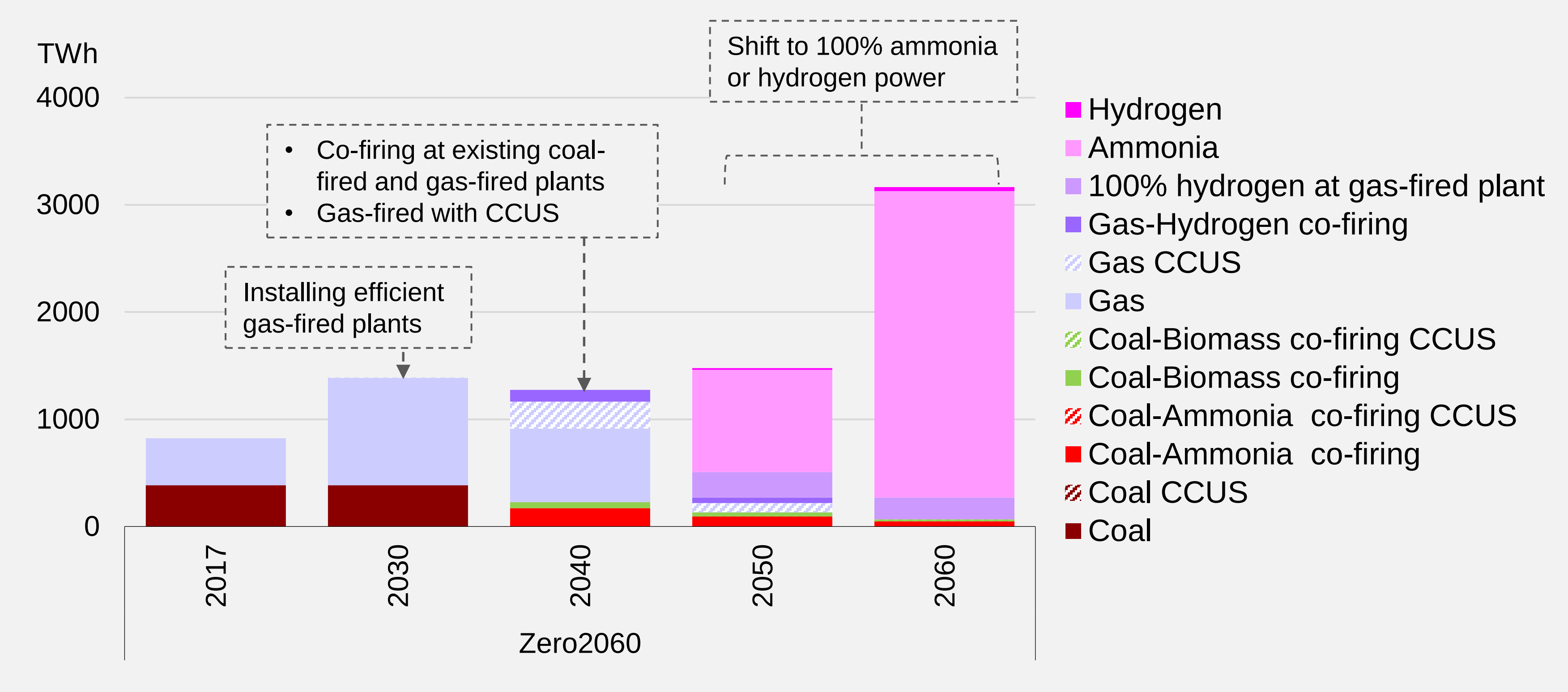
Power generation in ASEAN



Transition from fossil fuels to NH_3 & H_2 power: Zero 2060

- 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.

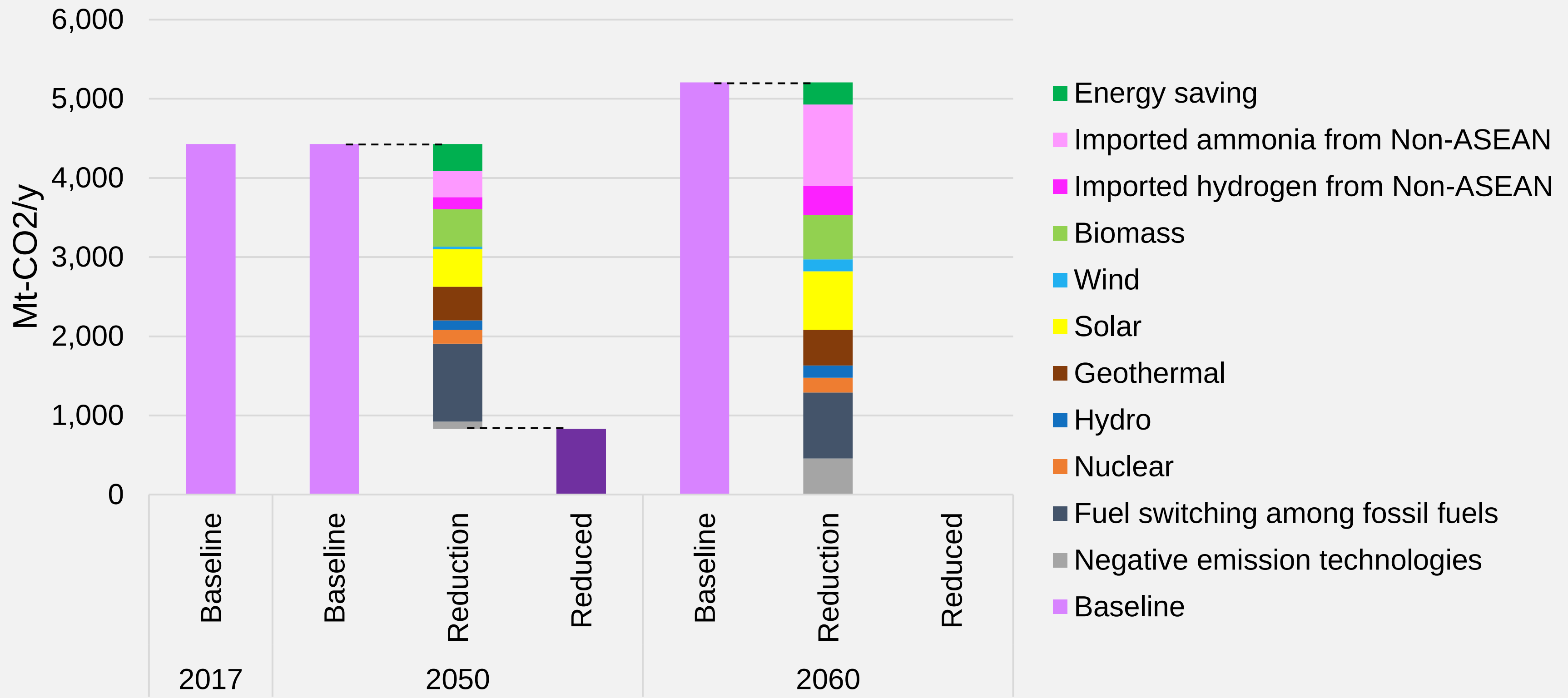
Generated electricity from coal, gas, ammonia and hydrogen in ASEAN



Contribution of mitigation measures: Zero2060 case

- Carbon neutrality in the *Zero2060* case are achieved by combining various mitigation technologies.

Contribution of mitigation measures



Impacts of technology innovation

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

Case	Key technology assumptions
Zero2060	• Reference technology cost • International power grid extension is constrained by planned ASEAN Power Grid capacity • CO_2 storage up to 0.9GtCO_2/year
PowerInov	• 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	• Cost reduction of DAC (-25% in 2040 and -50% after 2050) • CO_2 storage up to 1.5GtCO_2/year
H2Inov	• 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)
DemInov	• Cost reduction of advanced end-use technologies (-50% in and after 2040)

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

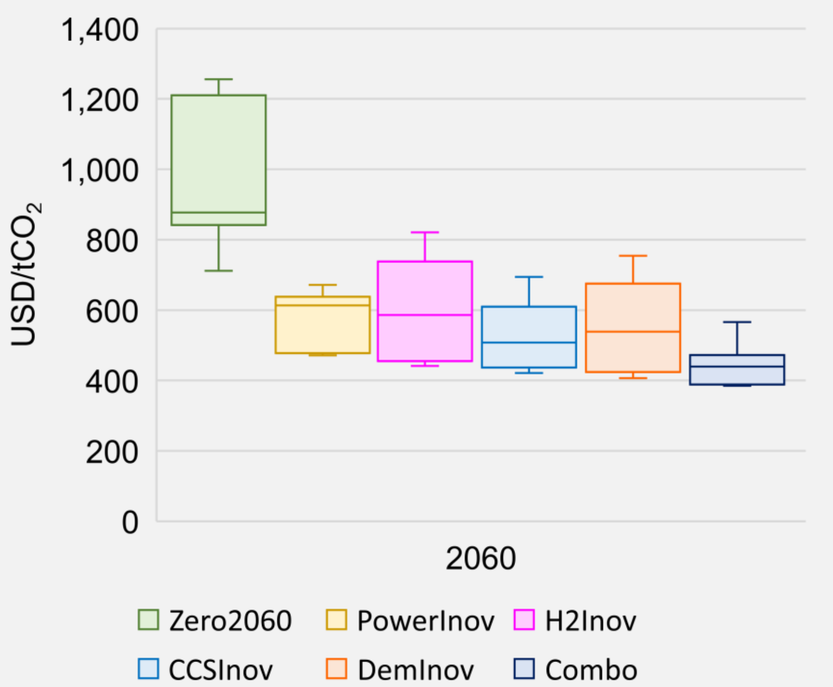
Innovation and mitigation costs: Zero2060 case

- 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.

Note) See page 57 for the case settings

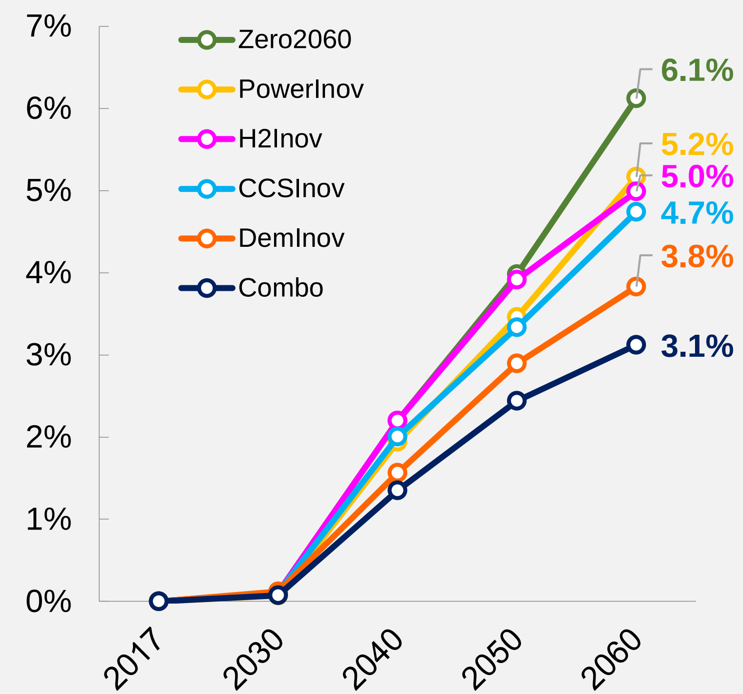
Marginal abatement cost

Range of country marginal cost in 2060



Additional annual cost

ASEAN total
Share of ASEAN GDP



Conclusions and key messages

- 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

- Simulation results would imply significant economic challenges associated with decarbonization.
  - Mitigation costs and energy prices may increase even in the 2070 net zero case.

- 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.

Thank you for your attention!

សូមអរគុណចំពោះការយកចិត្តទុកដាក់របស់លោកអ្នក!

Terima kasih atas perhatian Anda!

ຂອບໃຈ ສໍາ ລັບຄວາມສົນໃຈຂອງທ່ານ!

ဂရုစိုက်တဲ့အတွက်ကျေးဇူးတင်ပါတယ်!

Terima kasih kerana memberi perhatian!

ขอขอบคุณสำหรับความสนใจของคุณ!

Cám ơn vì sự quan tâm của bạn!

Arigato gozaimashita