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Issues and Challenges of Fuel Ammonia in EAS Region

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What's EAS Energy Outlook?

- EAS stands for East Asia Summit and one of fora in Asia Pacific region like APEC (Asia Pacific Energy Cooperation)
- EAS member countries consists following two groups;
  - ASEAN: 10 MS
  - +8: Australia, China, India, Japan, Korea and New Zealand, and Russia & the United Dates joined later in 2012
  - But EAS Energy Outlook just covers its 17 countries except Russia
- EAS Energy Outlook has been updating since 2008 and its purpose is to assess effectiveness of aggressive EEC and RE targets being reported by EAS countries under the workstream 1 of EAS-ECTF and EAS-EMM

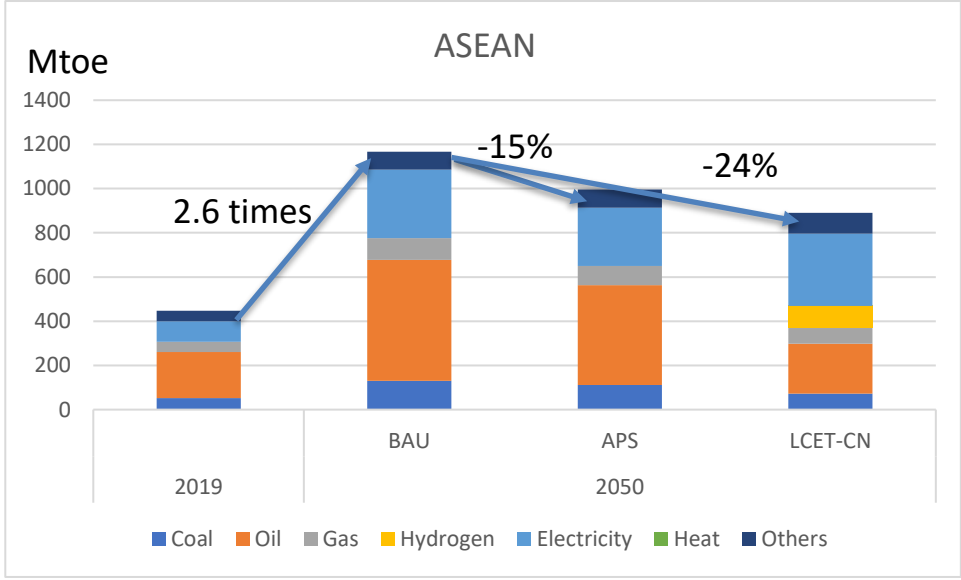
What's EAS Energy Outlook?

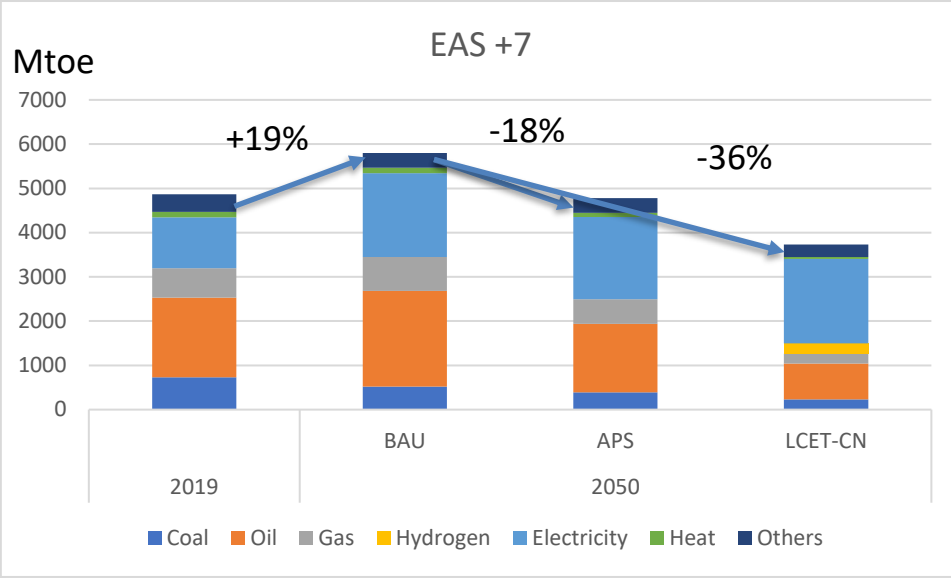
- EAS Energy Outlook produces two scenarios applying econometrics approach; BAU and APS, and APS reflects aggressive EEC and RE targets reported by EAS countries
- Energy saving and CO2 reduction potentials are defined as BAU – APS in terms of energy consumptions and CO2 emissions
- Latest EAS Energy Outlook updated in 2021-22 tries to produce Low Carbon Energy Transition – Carbon Neutral (LCET-CN) additionally;
  - Accomplish carbon neutral by 2050 or 60
  - Carbon neutral is defined as CO2 emission from fossil fuel combustion < carbon offset by forest

What's EAS Energy Outlook?

- EAS Energy Outlook produces future energy balance tables of each EAS country until 2050;
  - Primary supply sector: production of primary energy is exogenous and demand-supply balance is taken by net import (+: import, -: export)
  - Transformation sector: power generation by each power source is defined as assumed parameters which are installed capacity, capacity factor, thermal efficiency, etc.
  - Final energy consumption sector: energy demand is induced by economic activities which are divided into industry, transport and residential-commercial sectors;
    - Ex. Electricity demand in industry sector = f(IIP, electricity price for industry /WPI, lag)
- This presentation shows forecast of ammonia demand in power sector until 2050 based on the EAS Energy Outlook results to focus on ASEAN 10 countries.

Final Energy Consumption





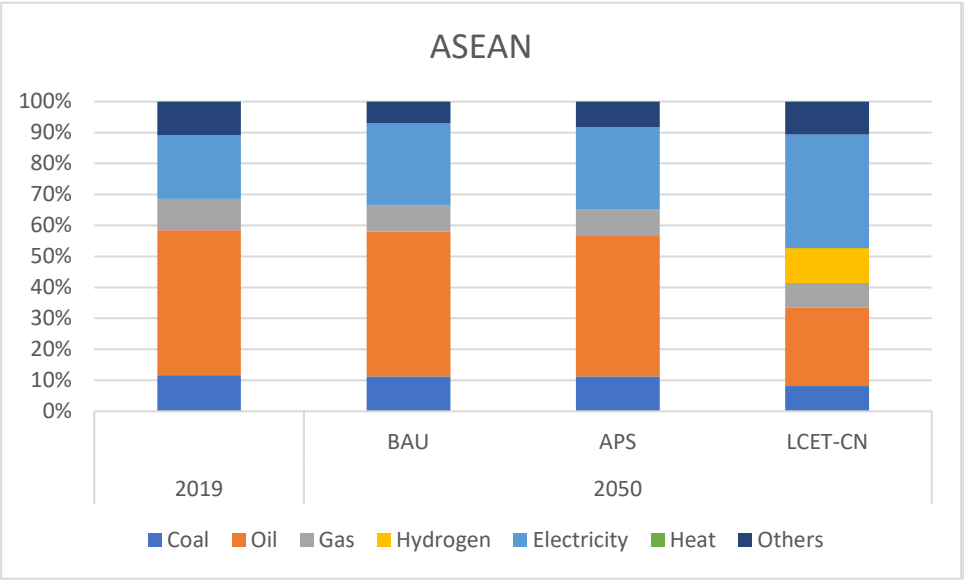
In ASEAN, TFEC of BAU will increase significantly at 2.6 times from 2019 to 2050 due to stable economic growth assumption (4.1% PA in 2019-50) but APS will decline 15% from BAU in 2050 and LCET-CN will also decline 24% due to **aggressive EEC targets.** However, TFEC of LCET-CN in 2050 will be still more than 2019 and it will be double of TFEC in 2019.

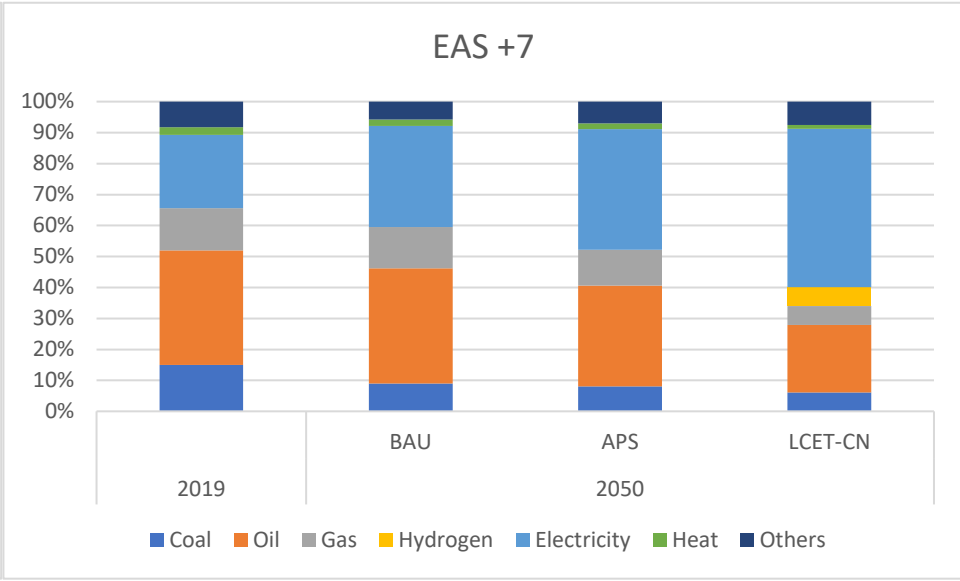
In EAS+7, TFEC of BAU will increase just 19% in 2019-50 even though 3.2% of economic growth assumption. On the other hand, APS will decrease 18% from BAU in 2050 and LCET-CN will decrease 36% from BAU due to a**ggressive EEC targets**. As a result, TFEC of APS in 2050 will be 2% lower than 2019 land LCET-CN will be 23% lower than 2019.

Key Finding**: Innovative EEC** is indispensable in terms of technology and policy for achieving carbon neutral in EAS region especially EAS+7. In addition**, electrification** will contribute to **promote energy saving.**

Source: EAS Energy Outlook 2021-22

Final Energy Consumption (Share)





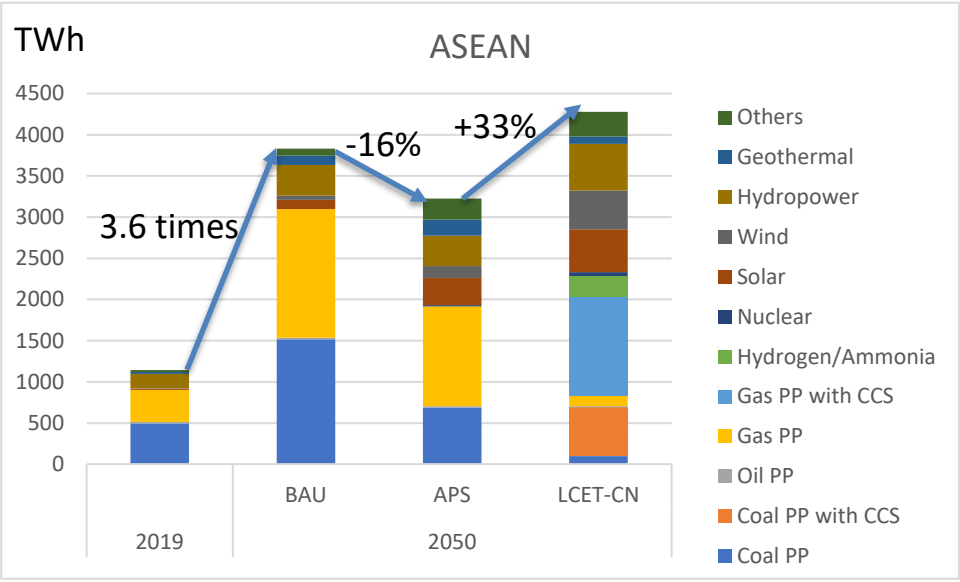
In ASEAN, share of fossil fuel, in case of BAU and APS, will be around 65% compared to 69% in 2019 but LCET-CN will reduce to around 40%. On the other hand, **electricity share** will increase to 26% by 2050 from 21% in 2019, in case of BAU and APS, as well as 37% of LCET-CN. **Hydrogen** will start to be consumed after 2040 in final sector, and its share will be 11% of TFEC in LCET-CN .

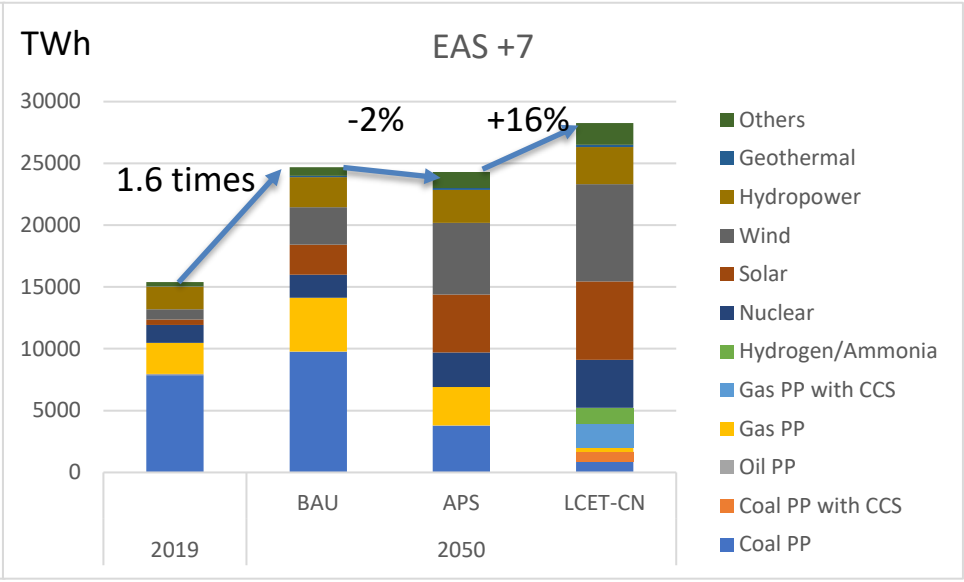
In EAS+7, fossil fuel share of BAU and APS will be 60% and 52% in 2050 respectively compared to 65% in 2019 but LCET-CN will sharply decline to 34%. On the other hand, **electricity share** of BAU, APS and LCET-CN will increase 33%, 39%, 51% in 2050 respectively compared to 24% in 2019. **Hydrogen use** in final sector will be appeared in 2050 and its share will be 6% but absolute value of hydrogen use will be more than double from ASEAN.

Key Finding: **Hydrogen and electrification across the sectors** are also **important energy transition technologies** to accomplish carbon neural in final sector.

Source: EAS Energy Outlook 2021-22

Power Generation





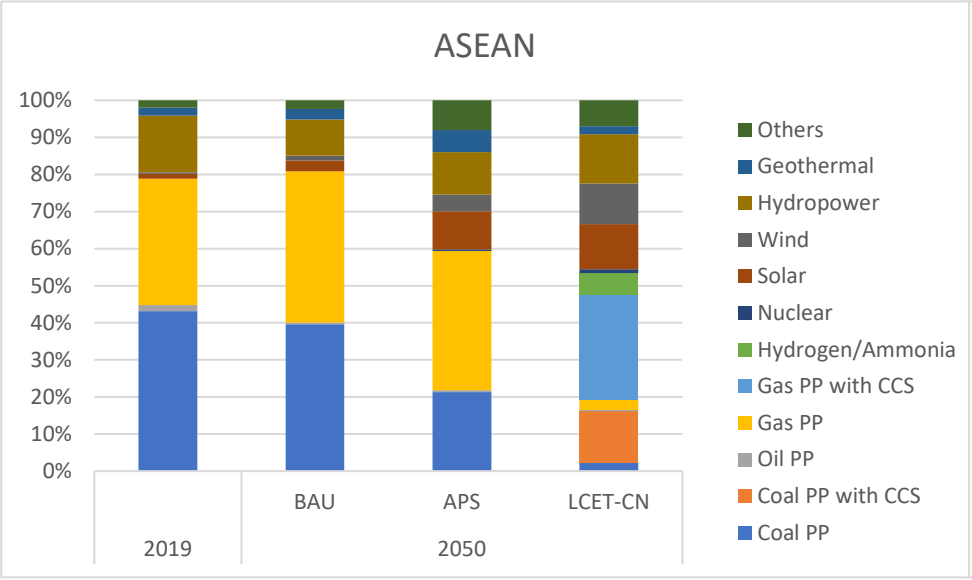
Power generation in ASEAN region will increase 3.6 times from 2019 to 2050 in BAU due to significant increase of electricity demand in this region but APS will decrease 16% from BAU due to EEC promotion. LCET-CN will increase again 33% from APS for shifting electricity from fossil fuel as mentioned before.

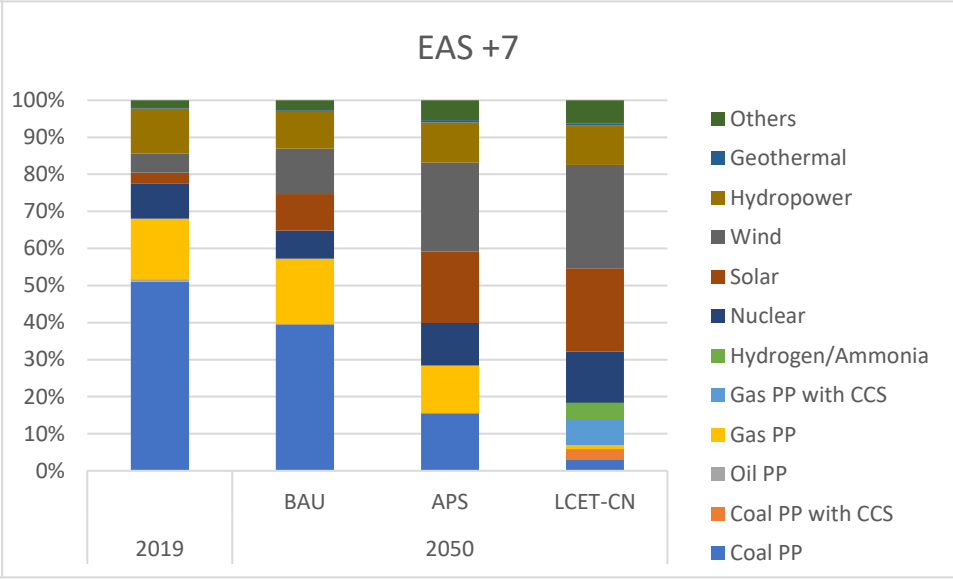
In EAS+7, power generation of BAU will increase 1.6 times from 2019 to 2050 due to electricity demand growth and APS will be almost same as BAU because electricity demand of APS will be same as BAU in 2050 (refer to the previous slide). But LCET-CN in 2050 will surely increase 16% from APS due to electrification.

Key Finding: Due to remarkable electrification in final sector, **power generation will also largely increase in LCET-CN** compared to BAU and APS in 2050.

Source: EAS Energy Outlook 2021-22

Power Generation (Share)





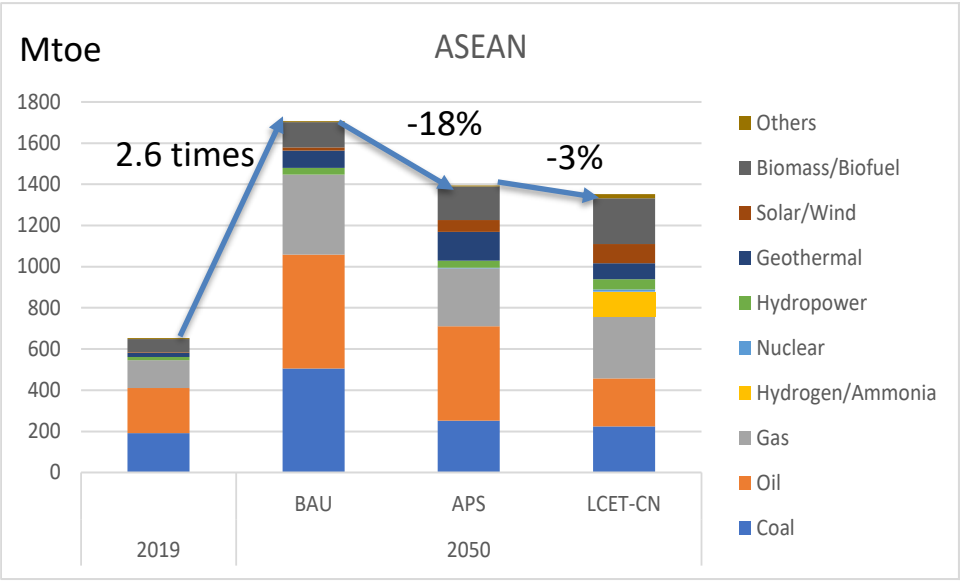
In ASEAN, coal and gas power generation share of APS in 2050 will decrease to 59% from 79% in 2019 due to its EEC and RE targets and LCET-CN will accomplish further decrease to 47% by 2050 but share of ordinary thermal plant (without CCS) will be only 5%. On the other hand, VRE(Solar & Wind) share will increase to 15% in APS and 23% in LCET-CN by 2050. RE share including hydropower and geothermal will also increase to 40% in APS and 45% in LCET-CN by 2050.

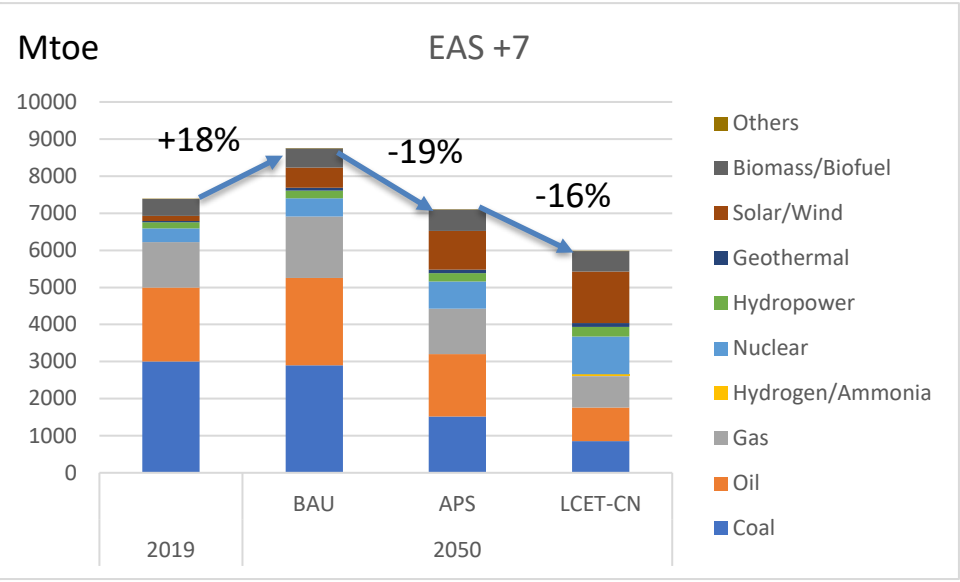
EAS +7 will achieve to shift from fossil fuel to renewable energy. Share of thermal power generation was 68% in 2019 and it will sharply decline to 28% in APS and 14% in LCET-CN by 2050. On the other hand, VRE share in 2019 was 8% but it will increase to 43% in APS and 50% in LCET-CN by 2050. In LCET-CN, nuclear power share will be 14% in 2050 and on the other hand, hydrogen share will be 5%. In 2050, thermal power plant with CCS will be just 9%.

Key Finding: **ASEAN** will continue to depend **thermal power plants** and finally it attaches **CCS** to both coal PP and Gas PP to reduce CO2 emissions. On the other hand, **EAS +7** will shift to **VRE (solar/wind) and nuclear** from thermal power generation.

Source: EAS Energy Outlook 2021-22

Primary Energy Supply





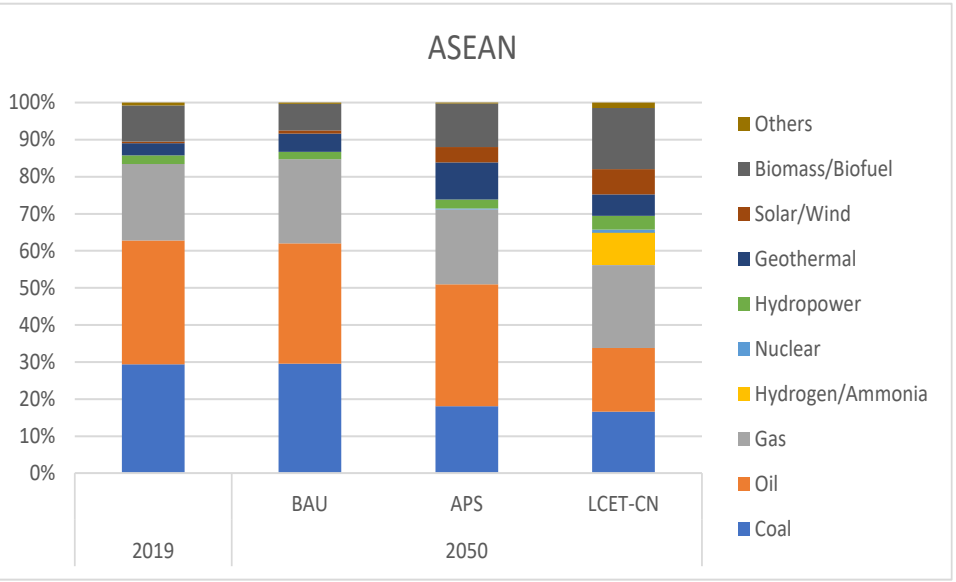
TPES of ASEAN will increase 2.6 times from 2019 to 2050 in BAU. Due to promotion of EEC and RE, it will decrease 18% from BAU to APS in 2050. However, LCET-CN will be same as APS in 2050, but its contents are quite different from APS. In addition, TPES of LCET-CN will be still double from its 2019 level.

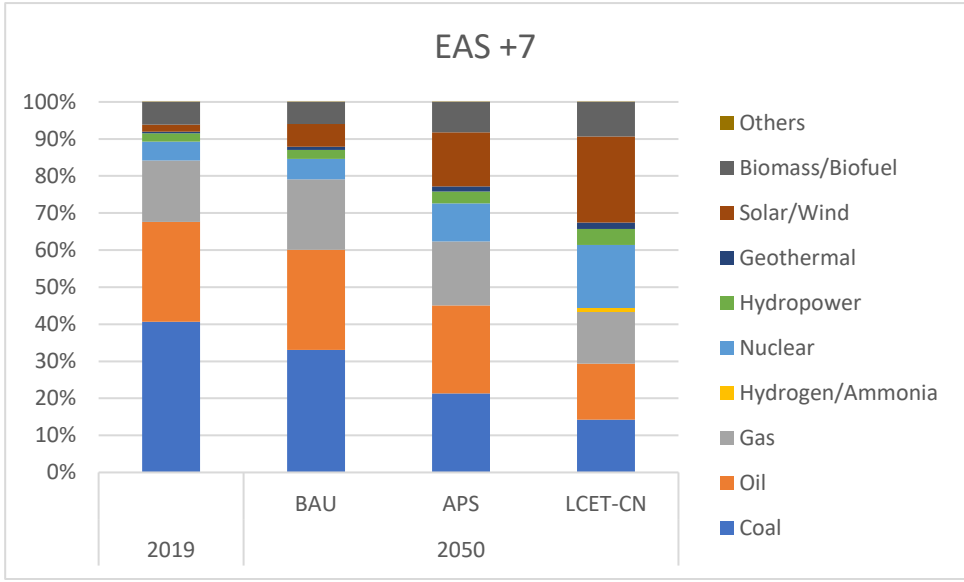
TPES of EAS +7 will increase 18% from 2019 to 2050 in BAU. Due to the same reason of ASEAN, it will decrease 19% from BAU to APS in 2050. LCET-CN will decrease continuously 16% from APS. Consequently, TPES of LCET-CN in 2050 will be about 80% of its 2019 level.

Key Finding: In LCET-CN, TPES of ASEAN will be almost same as APS in 2050 but EAS +7 will be 16% lower than APS. LCET-CN will increase electricity demand and generation largely from APS due to electrification. **ASEAN** will continuously depend on fossil fuel generation at **47%** in 2050, on the other hand, **EAS +7** will depend on fossil fuel at just **14%** in 2050. This might reflect to bring this different result in addition to different EEC targets..

Source: EAS Energy Outlook 2021-22

Primary Energy Supply





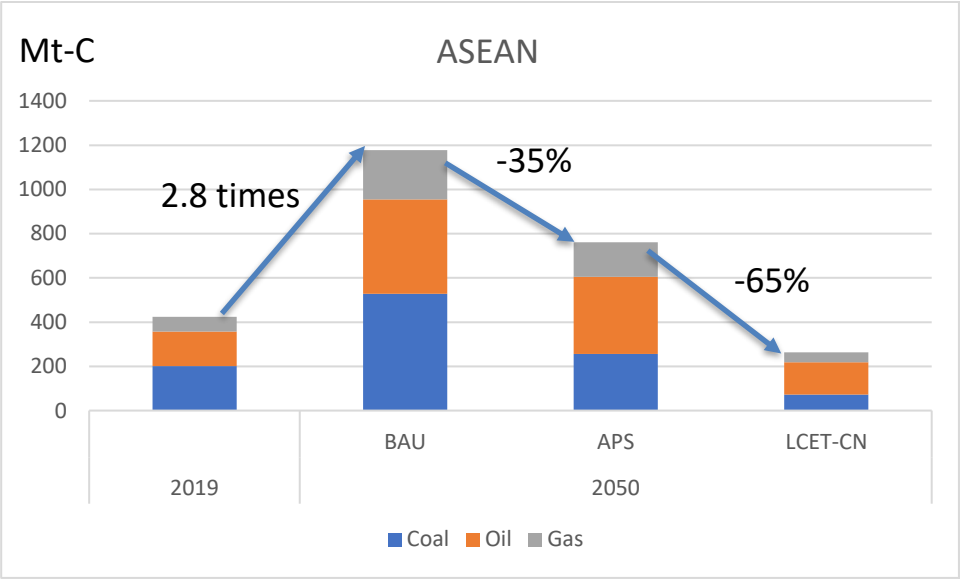
Fossil fuel share of ASEAN in 2019 was 83% and it will slightly increase 85% until 2050 in BAU. Fossil fuel share of APS in 2050 will decrease 71% as well as 56% in LCET-CN. RE's share in 2019 was 16% but it will increase to 33% until 2050 in LCET-CN but its share of VRE (solar/wind) will be just 7% in 2050. In ASEAN, modern use of biomass such as wood chips for power generation and biofuels for transport will still contribute reduction of CO2.

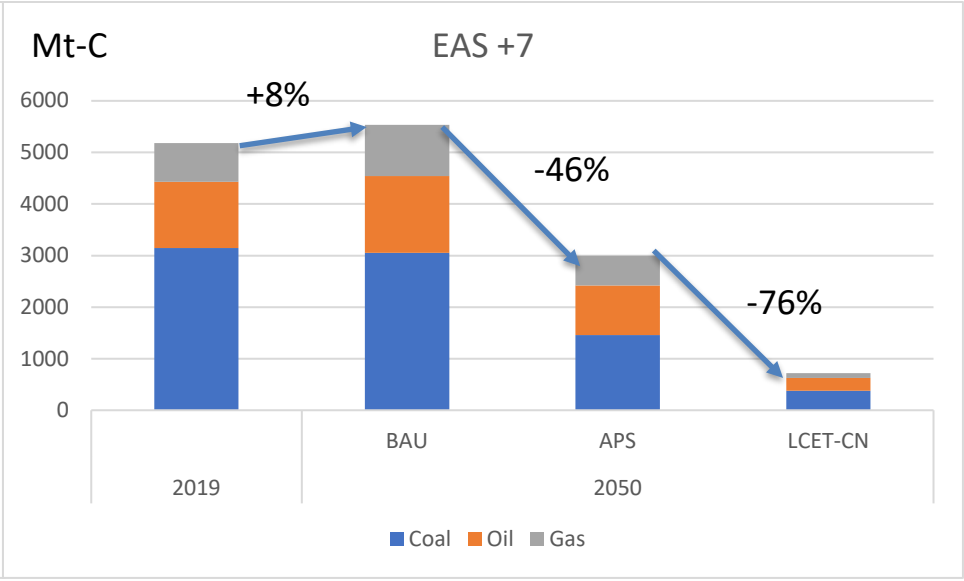
Fossil fuel share of EAS +7 in 2019 was 84% and it will decrease 79% until 2050 in BAU. Fossil fuel share of APS in 2050 will decrease 62% as well as 43% of LCET-CN. RE's share in 2019 was 11% but it will increase to 38% until 2050 in LCET-CN. It will reflect significant increase of VRE share at 23% in 2050. EAS +''s nuclear share at 17% in 2050 will also contribute CO2 reduction

Key Finding: **ASEAN** will depend **fossil fuel** and its share of LCET-CN in 2050 will be **56%** but **CCS** will be attached to coal and gas PP mostly. On the other hand, **EAS +7** will shift **from fossil fuel to RE (38%)** especially **VRE (23%)** and **nuclear (17%)** in 2050.

Source: EAS Energy Outlook 2021-22

CO2 Emissions





CO2 emissions of ASEAN was 424 Mt-C in 2019 and it will increase 2.8 times until 2050 under BAU, which will be 1,177 Mt-C. APS in 2050 will decrease 35% from BAU but it will be still higher than 2019. LCET-CN in 2050 will decrease 65% from APS and it will be 264 Mt-C and much lower than 2019.

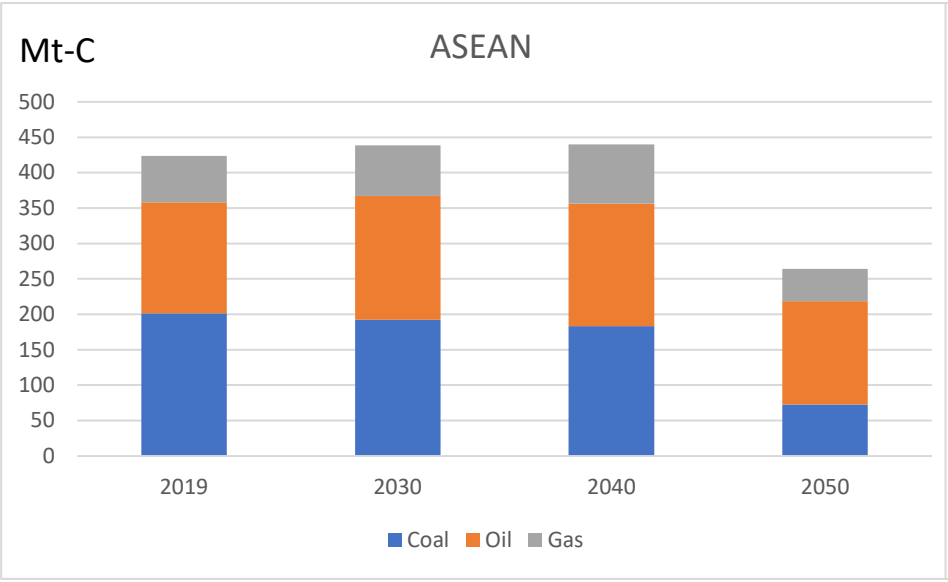
CO2 emissions of EAS +7 was 5,181 Mt-C in 2019 and it will increase just 8% until 2050 under BAU. APS in 2050 will decrease 46% from BAU and LCET-CN will decrease 76% from APS and it will be 725 Mt-C and just 14% of CO2 emissions in 2019.

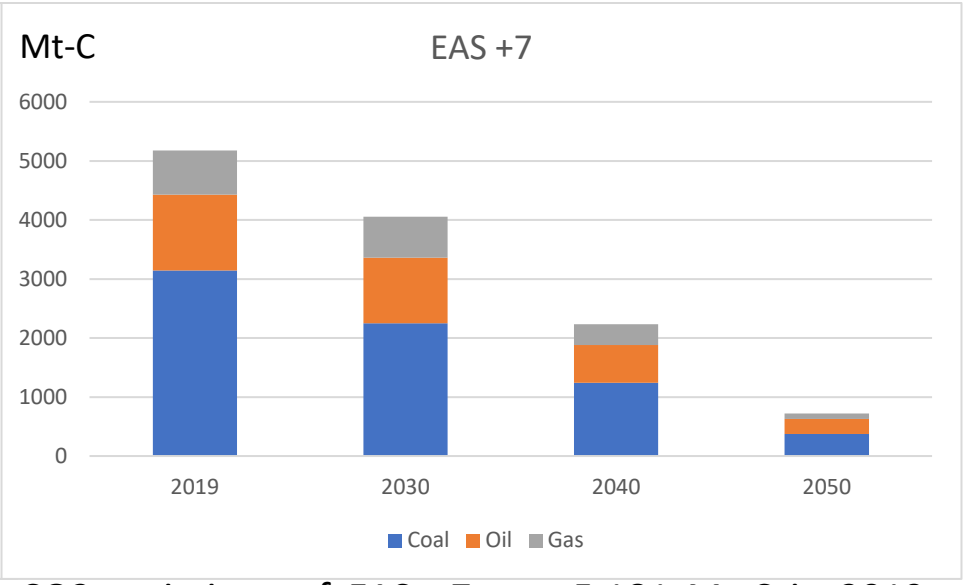
Key Finding**: ASEAN CO2 emissions of BAU** will increase **2.8 times** from 2019 to 2050 but **EAS +7** will just increase **8%** in 2019-50. However, LCET-CN's CO2 emissions of both ASEAN and EAS +7 in 2050 will be **much lower than 2019**, in other words, accomplishment of **carbon neutral by 2050**.

Source: EAS Energy Outlook 2021-22

CO2 Emissions

Historical Trend of CO2 Emissions (LCET-CN)





In LCET-CN of ASEAN, CO2 emissions in 2019 will keep the amount (424 Mt-C) until 2040 and after that its CO2 emissions will largely decrease to 264 Mt-C until 2050 due to aggressive EEC and electrification in final sector and increase of zero emission power sources and CCS for thermal power generation.

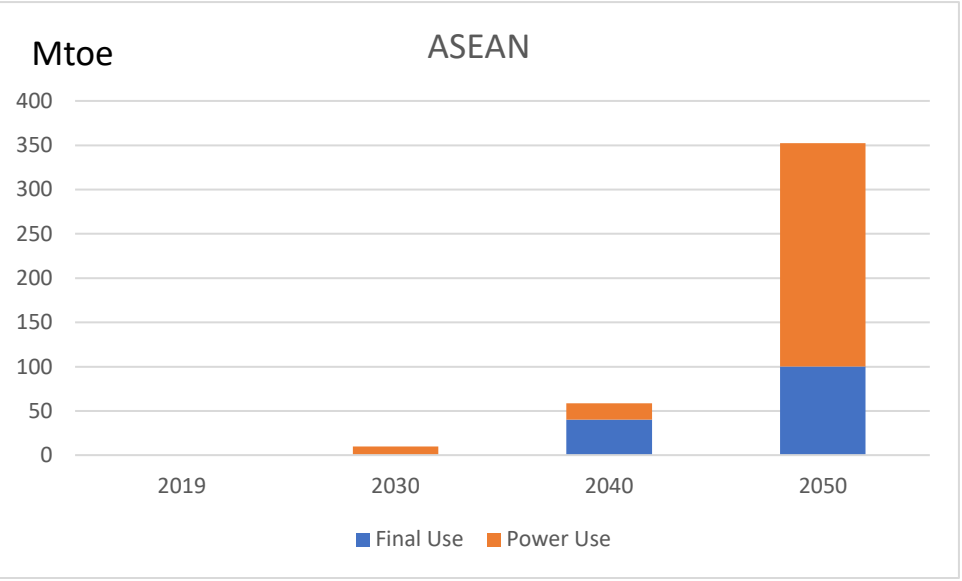
CO2 emissions of EAS +7 was 5,181 Mt-C in 2019 and LCET-CN will decrease its CO2 emissions year by year and eventually its CO2 emissions will be 725 Mt-C until 2050. This results reflect aggressive EEC and electrification in final sector and increase of zero emission power sources which are VRE (Solar/wind), hydro and nuclear power.

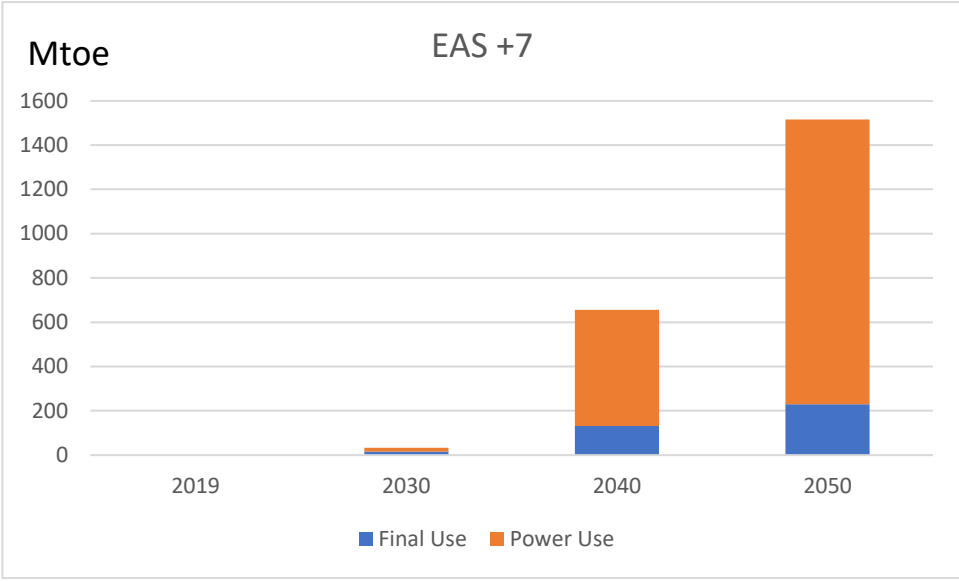
Key Finding: **ASEAN** will keep 2019 level of CO2 emissions **until 2040** and after that **rapidly reduce CO2 emissions to 2050 (**40% from 2040). On the other hand, **EAS +7** will reduce its CO2 emissions **year by year** surely (67% from 2040).

Source: EAS Energy Outlook 2021-22

Hydrogen

- Hydrogen demand



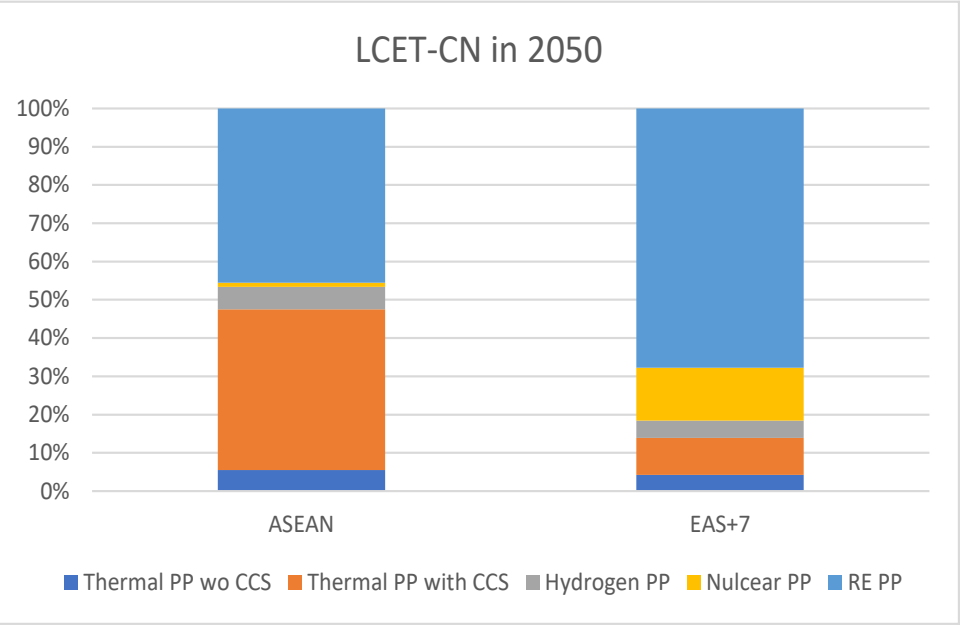


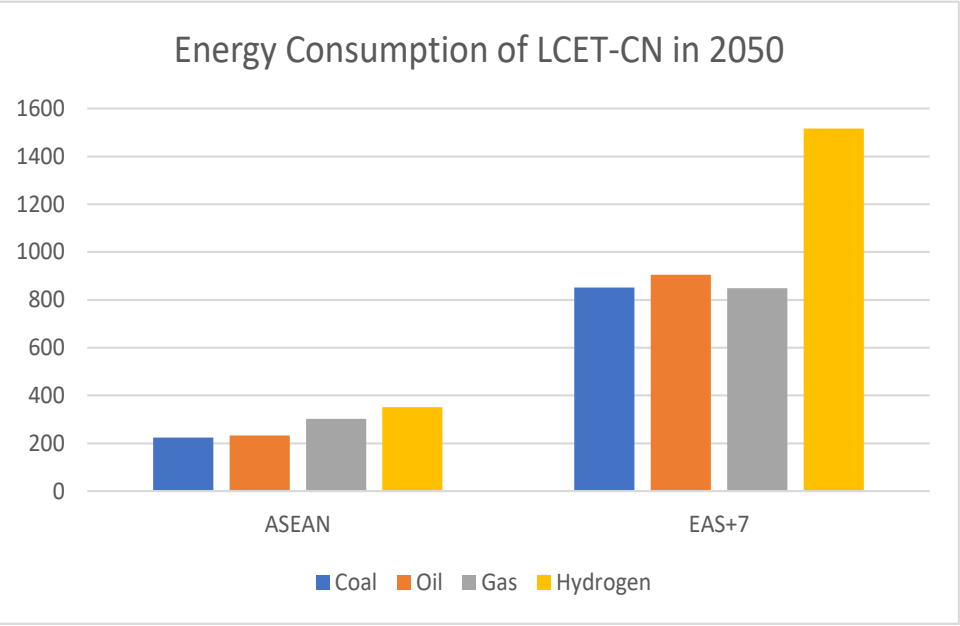
Hydrogen is one of zero emission fuels, and it can be combusted like fossil fuel. Thus, it can be used across the sectors; for heating boiler and furnace in industry sector, for transport fuel in transportation sector, for heating water, space heating in residential & commercial sector and combusting fuel in power sector. Hydrogen will start to consume by both final and power sectors from 2030 and fuel use for power will be dominant in 2050 both ASEAN and EAS +7.

Key Finding: **Hydrogen will be used for power generation mainly** in both ASEAN and EAS +7 but **hydrogen's contribution** to carbon neutral will be **limited** not like CCS.

Source: EAS Energy Outlook 2021-22

Hydrogen vs CCS in ASEAN



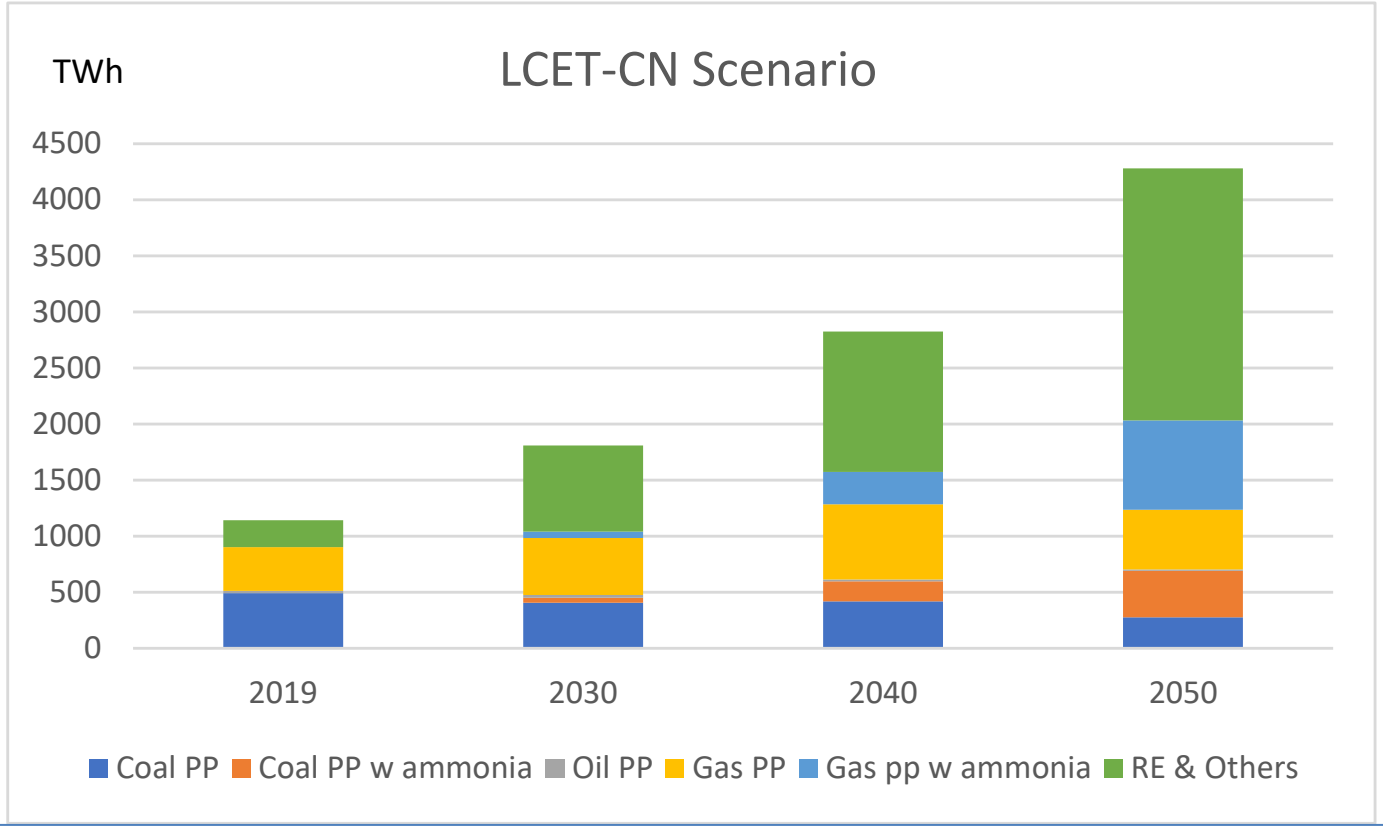


- In ASEAN, thermal PP with CCS will be attractive compared to hydrogen PP and for EAS+7, RE and nuclear will be main power sources compared to thermal PP with CCS and hydrogen PP.
- But hydrogen consumption of LCET-CN in 2050 will be higher than fossil fuel consumptions in both ASEAN and EAS+7. Hydrogen is recognized by EAS countries as a new fuel indispensably for contributing carbon neutral.

Issues of Hydrogen / Fuel Ammonia

- The reasons why EAS especially ASEAN countries will not select hydrogen / fuel ammonia as an alternative combustive fuel;
  - Energy use of hydrogen /fuel ammonia is not well recognized in ASEAN countries;
    - Hydrogen / fuel ammonia use for power PP are not existing commercially so far
    - Hydrogen consumption as transport fuel is considered but limited due to hard competition of BEV
    - High cost of blue and green hydrogen / fuel ammonia
  - On the other hand, CCS is becoming popular in ASEAN region due to presence of Asia CCUS Network

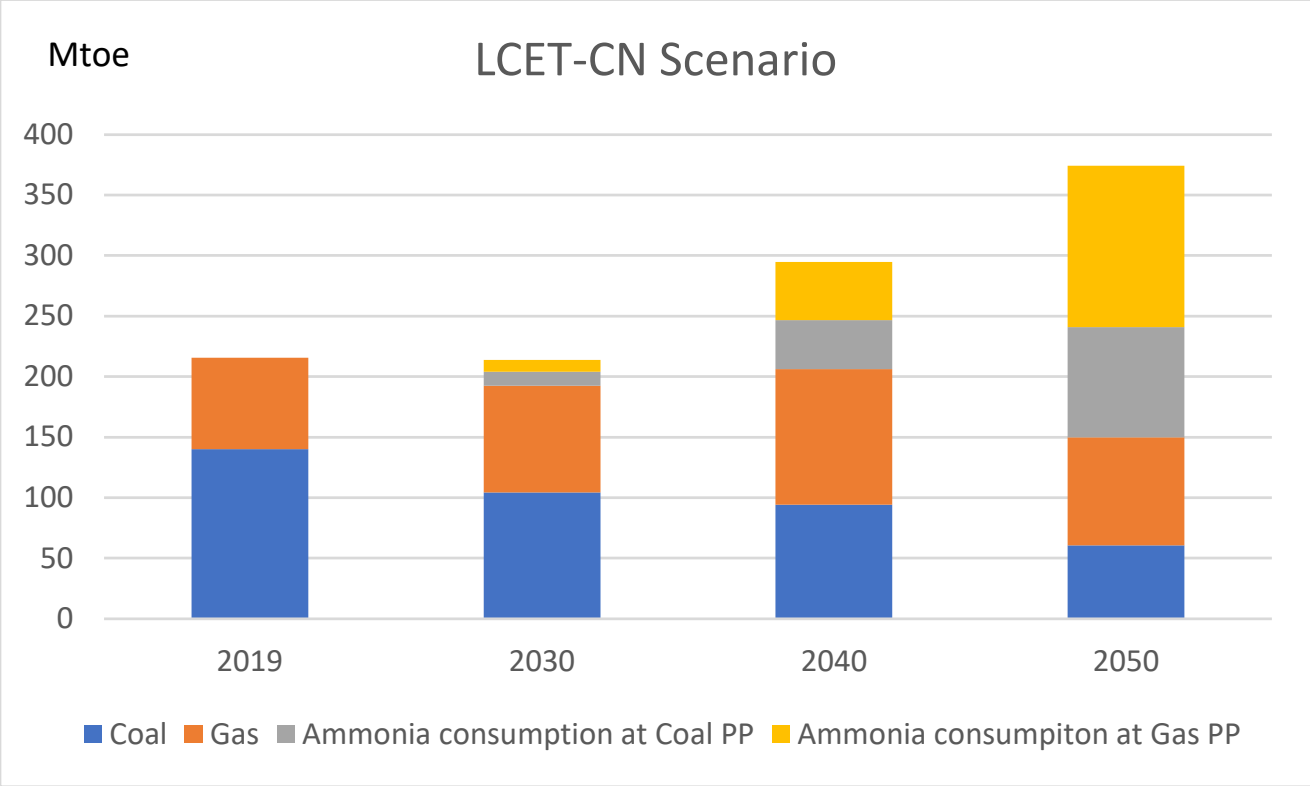
Forecast of Ammonia Cofiring Power Generation in ASEAN



We assume ammonia cofiring ratio at both coal PP and gas PP 10% by 2030, 30% by 2040 and 60% by 2050. Forecasted power generation by ammonia cofiring coal PP and gas PP of LCET-CN scenario in 2050 will be 414 GWh (276 GWh of wo ammonia) and 799 GWh (532 GWh wo ammonia) respectively.

Source: Author

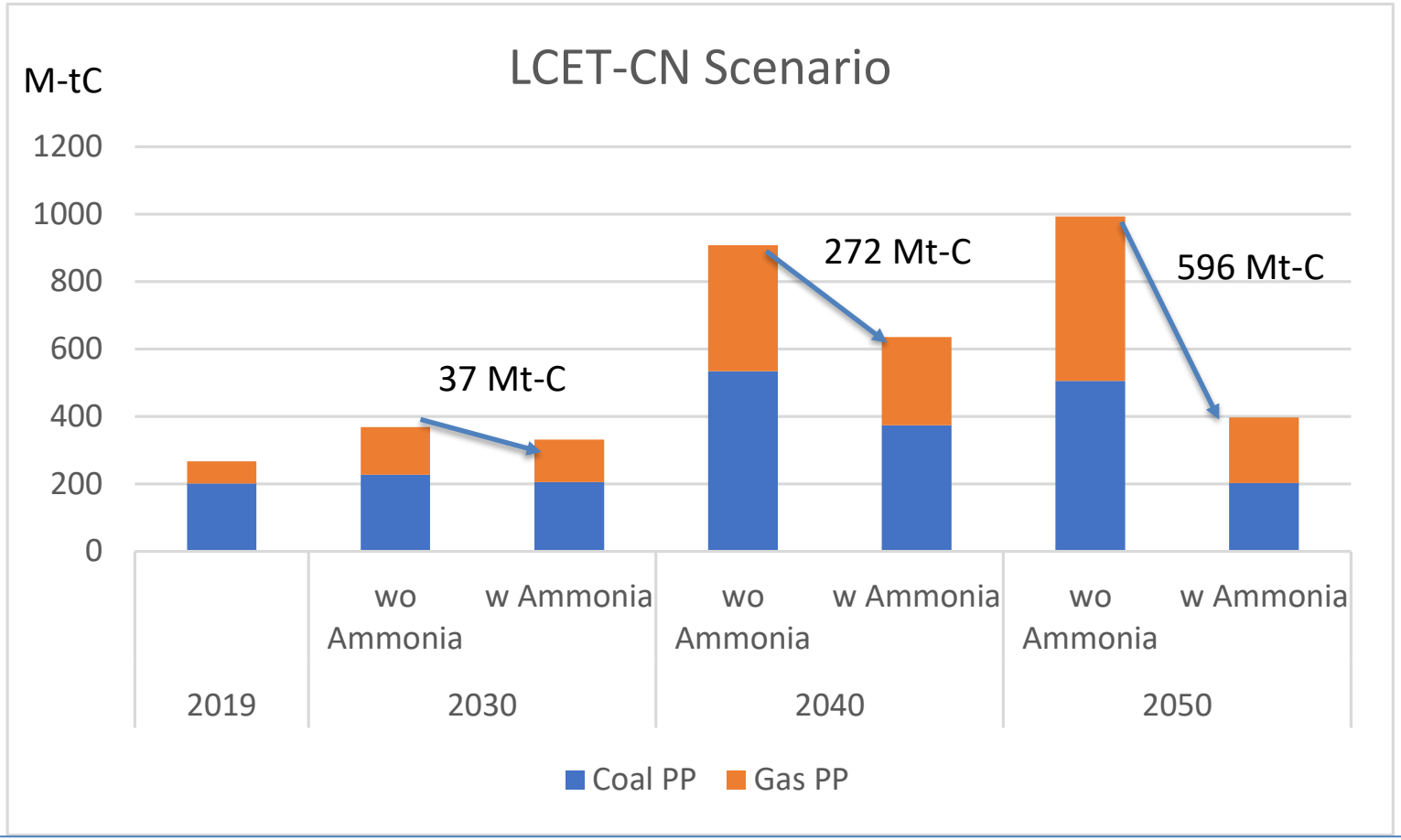
Forecast of Ammonia Consumption in ASEAN



In this regard, forecasted ammonia consumption by coal PP and gas PP of LCET-CN scenario in 2050 will be 91 Mtoe and 133 Mtoe respectively.

Source: Author

Forecast of CO2 Emissions Reduction applying Ammonia in ASEAN



Ammonia cofiring at coal PP and gas PP will bring following CO2 emissions reduction; 37 Mt-C in 2030, 272 Mt-C in 2040 and 596 Mt-C. CO2 reduction effect by ammonia of 596 Mt-C in 2019 will be much bigger than current ASEAN CO2 emissions at 424 Mt-C in 2019.

Source: Author

Hydrogen Carrier

- There are three hydrogen carriers mentioned below;
  - MCH: hydrogenation and de-hydrogenation
    - Liquefy hydrogen by chemical reaction using toluene
    - Compression ratio: 1/500
  - LH_2: Liquefaction and regasification
    - Liquefy hydrogen by high pressure (-253 degree Celsius, compress ratio 1/800)
  - NH_3: $3H_2 + N_2 = 2NH_3$ and direct combustion
    - Haber-Bosch process
    - Easy to change to liquid ammonia
- Advantage of fuel ammonia (NH_3);
  - Existing material being traded
  - Direct consumption (no need of de-hydrogenation and regasification)

Conclusions

- Hydrogen and fuel ammonia will contribute to reduce CO2 emissions in **final energy consumption sectors and power sector** in EAS region. Because both fuels are **combusted same as fossil fuels** but not emit CO2.
  - Alternate fossil fuel.
- Need to increase **awareness of fuel ammonia** through holding forum, conference and workshop in ASEAN region.
- **Demonstrate use of fuel ammonia** such as power generation in ASEAN region.
- Initiate fuel ammonia cofiring coal power generation at low cofiring level such as 5-10% and gradually raise the cofiring ratio year by year.

  => Increase fuel ammonia demand gradually to mitigate cost of fuel ammonia
- Key factors for cost down of fuel ammonia;
  - Expand fuel ammonia demand => seek for **new demand**
  - **Innovative production technologies** of fuel ammonia
    - Shift from Haber-Bosch process to ?

Thank you for your attention!!