Deep decarbonization pathways in INDONESIA

February 2024

Lessons from the EU-funded research project IMAGINE

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Introduction

This work takes place in a context where Indonesia:

- aims to achieve the status of “developed” country by 2045 as detailed in **the Golden Indonesia 2045 Vision** and escape from the middle-income trap. The country targets to reach 4% unemployment rate.
- committed to reach net-zero GHG emissions by 2060 (NZ2060) as spelt out in its long-term strategy (**LTS-LCCR**) submitted to the UNFCCC in 2021. The LTS-LCCR details the required efforts for the national low-carbon transition and highlights the key domestic and international enablers. However, current policies seem insufficient to reach this goal.
- submitted a first nationally determined contributions (**NDC**) in 2016 and an Enhanced NDC (**ENDC**) in 2022. The ENDC is the transition towards the country Second NDC currently in preparation which will be aligned with the objectives defined in the LTS-LCCR and Golden Indonesia 2045 Vision. The 2022 ENDC provided an unconditional emission target of 1.95 GtCO2 and a conditional target of 1.63 GtCO2 by 2030.
- has agreed to take specific objectives related to the transition of the power sector in the framework of the **JETP Investment Plan as one of accelerated NDC programs**. These objectives are not included in this work.

In this context and under the EU-funded research project IMAGINE, we defined a set of three development pathways :

- **The Current Policy Scenario with Low Growth (CPS LOW):** this scenario represents the current policies in place and ongoing transformational trends which after the country reach ENDC in 2030 conditional targets there is no additional policies and/or efforts to drive deep decarbonization transformations to reach long-term policy objective beyond 2060.

- **The DDS LOW Scenario (DDS LOW):** this scenario follows the same socio-economic growth than the CPS but considers additional policies and/or efforts to drive deep decarbonization transformations reaching ENDC conditional target and net-zero GHG emissions by 2060.

- **The DDS HIGH Scenario (DDS HIGH):** this scenarios considers a higher socio-economic growth for the country but considers additional policies and/or efforts to reach net-zero GHG emissions by 2060 and the ENDC conditional target by 2030.

Research questions for scenario framing

1) What are the short-term additional policies needed to reach the long-term national net-zero and sustainable development objectives?

2) How would the deep decarbonization pathways be affected under the current uncertainty related to the country economic growth ?

- The comparison of BAU with DDS LOW or DDS HIGH will inform us on the additional policies and transformations required to reach long-term net-zero and development objectives.
- The comparison of DDS LOW with DDS HIGH will inform us on the impact on energy demand, the additional decarbonization effort required by 2060 and policy adjustement needed to still reach ENDC unconditional target.

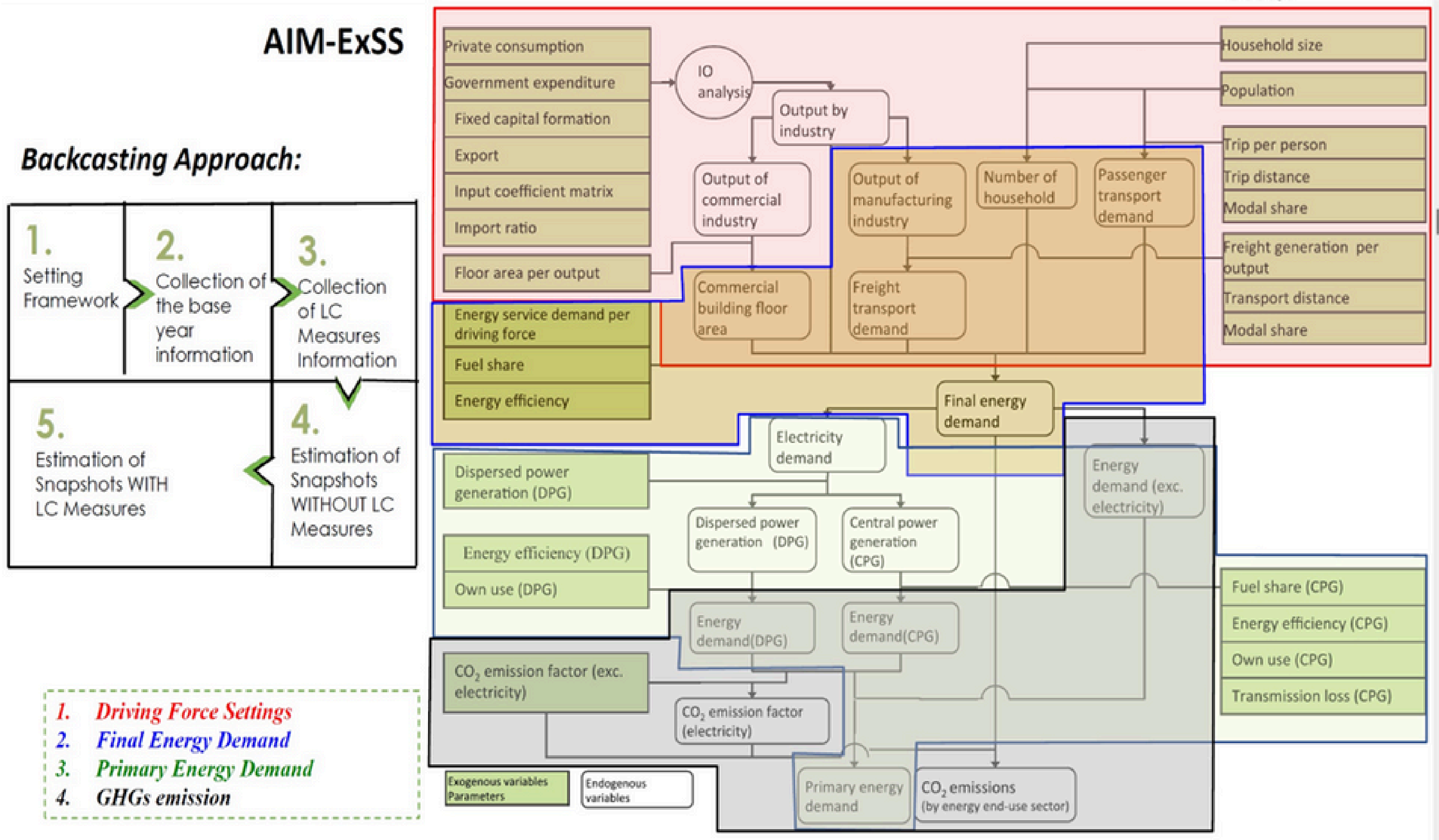
Additional and country-specific questions informed by this work:

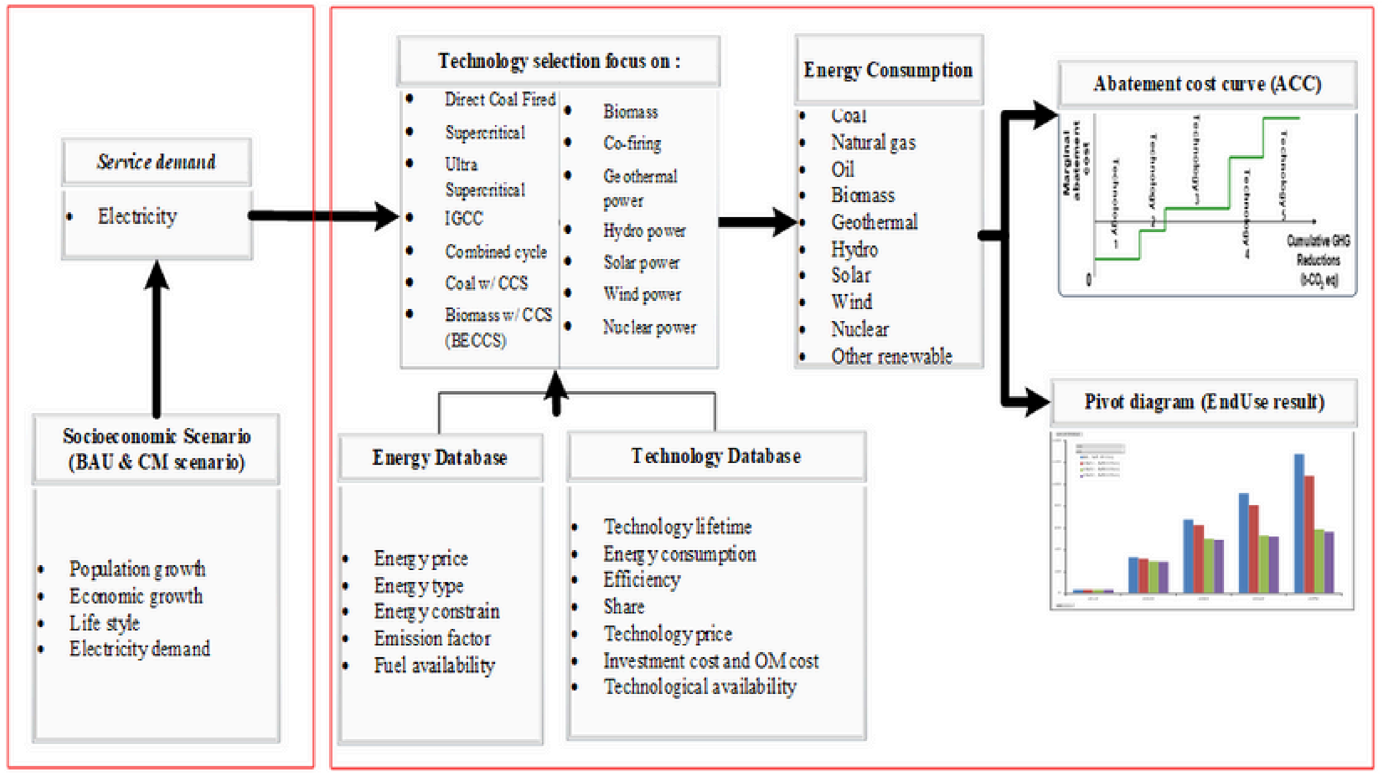
- On which sectors should the economy rely on if we want to maintain socio-economic development and reach net-zero by 2060?
- What key global and sectoral transformations must be considered to enable national Paris-compatible pathways?
- What are the key international enablers and cooperation needs for these sectoral transformations?
- How a developing country that relies on fossil (coal) economy could move its peak emissions earlier than 2035 and could achieve NZE sooner than 2060? How the country could cope with the problems of stranded assests?
- If the target ENDC as well as NZE commitments can not be achived by all countries, what is the punishments?

Modelling architecture & improvements

The AIM-ExSS model is used to estimate rational projections of energy demand (electricity) by the user side (industrial, commercial, residential, and transportation).

The AIM-EndUse model is a bottom up model developed by CREP ITB, NIES (Japan), and Mizuho (Japan) for solving linear optimization equations for technology selection with a minimum cost approach and some restrictions (capability, availability of energy supply, technology penetration, emissions target, etc.).

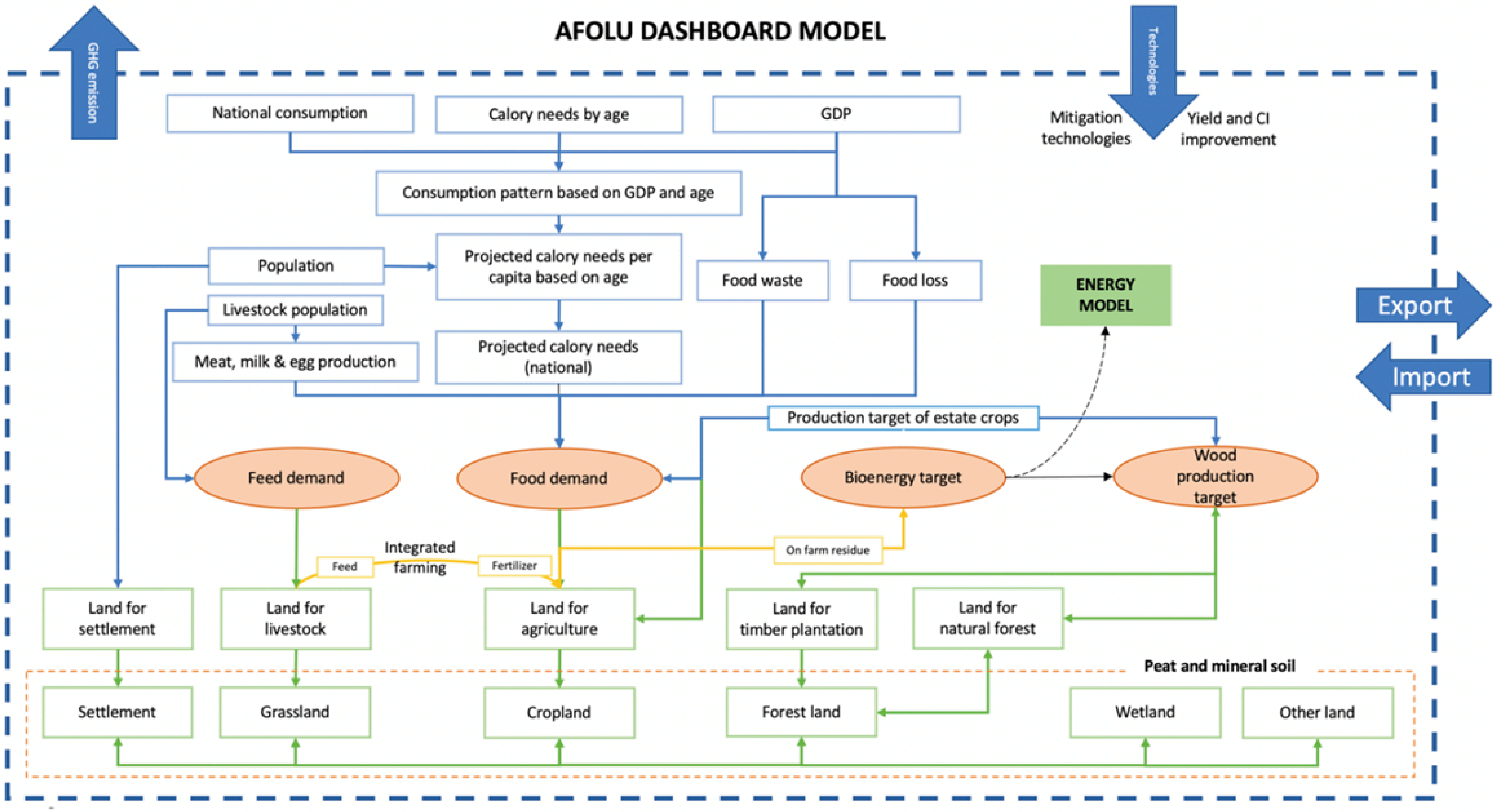




Here are the key academic publications and references on the modelling structure :

- *Fujimori, S. et al. (2017). An Assessment of Indonesia's Intended Nationally Determined Contributions. In: Fujimori, S., Kainuma, M., Masui, T. (eds) Post-2020 Climate Action. Springer, Singapore.*
- *Dewi, R.G., Siagian, U., Hendrawan, I., Boer, R., Anggraeni, L., Bakhtiar, T. (2016). Low-Carbon City Scenarios for DKI Jakarta Towards 2030. In: Jupesta, J., Wakiyama, T. (eds) Low Carbon Urban Infrastructure Investment in Asian Cities. Cities and the Global Politics of the Environment. Palgrave Macmillan, London.*

Modelling architecture & improvements



This bottom-up AFOLU model is softly linked to the AIM-ExSS and AIM-EndUse model through: XXX Please explain how this is connected (bioenergy, GDP growth?)

Here are the key academic publication and references on the modelling structure :
XXX Please complete information here!

Part 1

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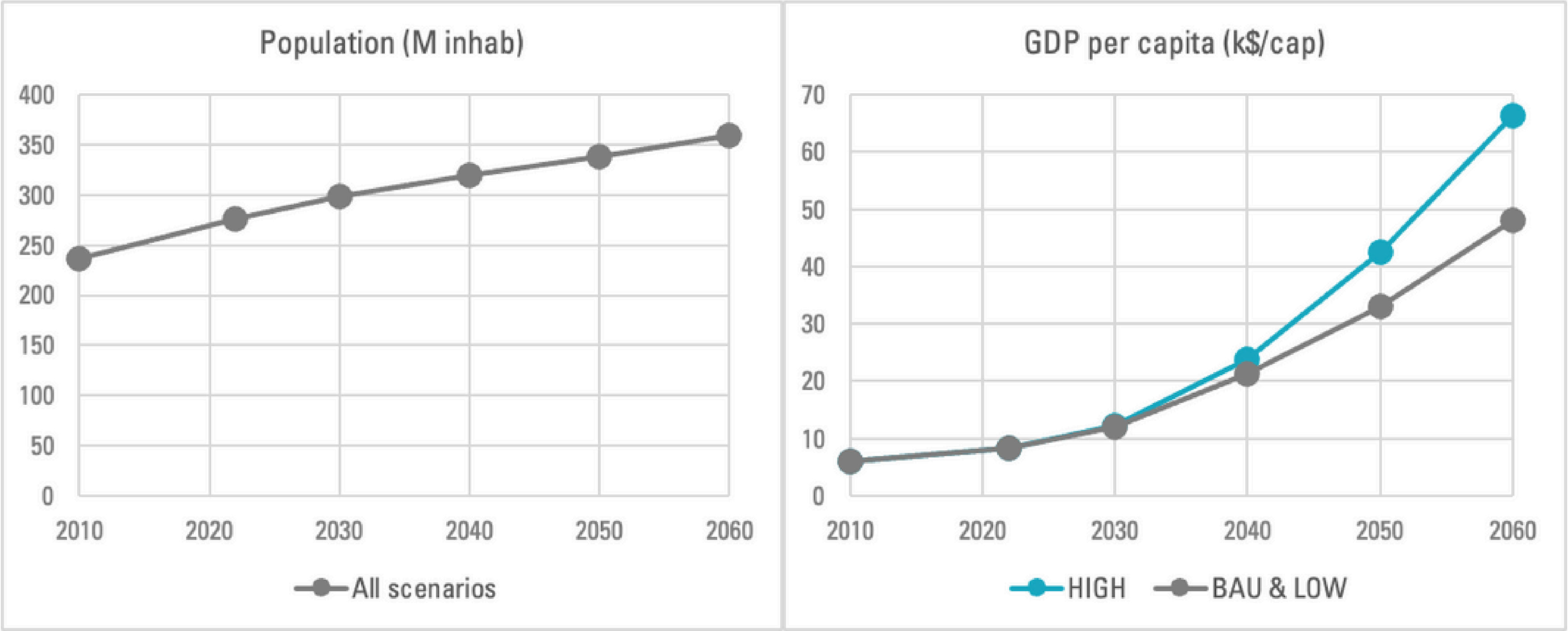
National overview of the deep decarbonization pathways

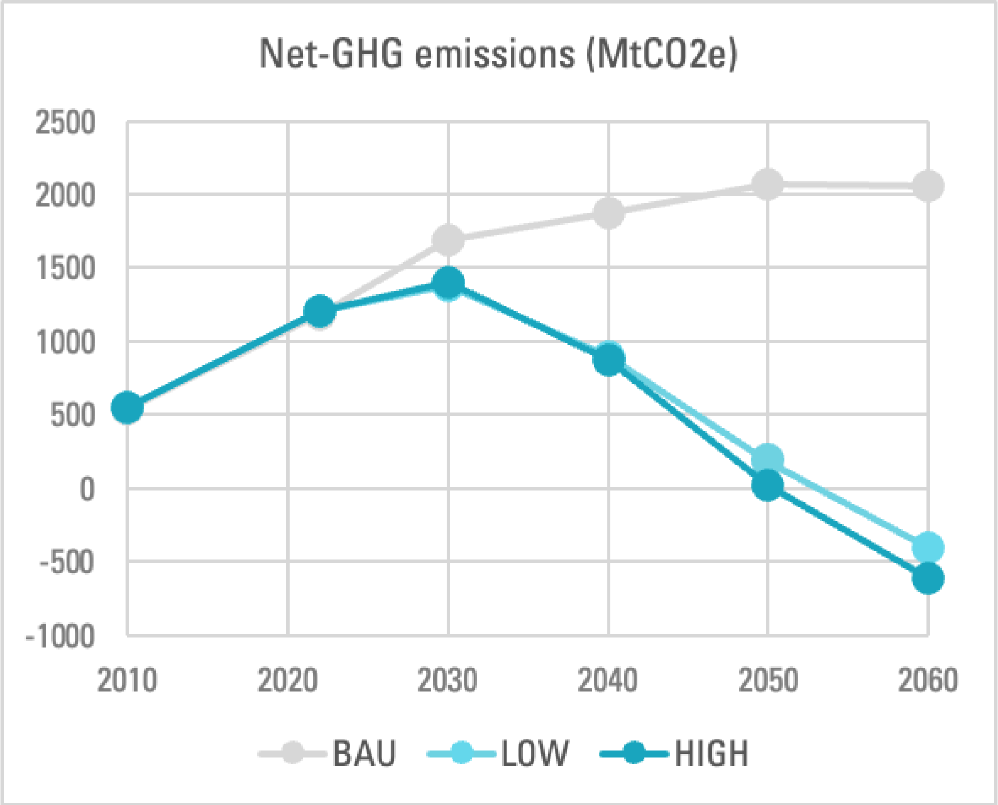
Reaching net-zero GHG emissions by 2060 is feasible, while ensuring socio-economic development

Figure 1. Socio-economic indicators (population, GDP per capita)



- Indonesian population is expected to grow in all scenarios from 237 million to about 360 million in 2060.
- The GDP per capita will increase up to $48k in the BAU & DDS LOW scenarios and further up to $66k in the DDS HIGH scenario by 2060 in order to reach a "developed" country equivalent level by 2045 of $25k GDP per capita, which aims to quit from middle income trapped with manufactur industries will be the key source to generate the Indonesia GDP.

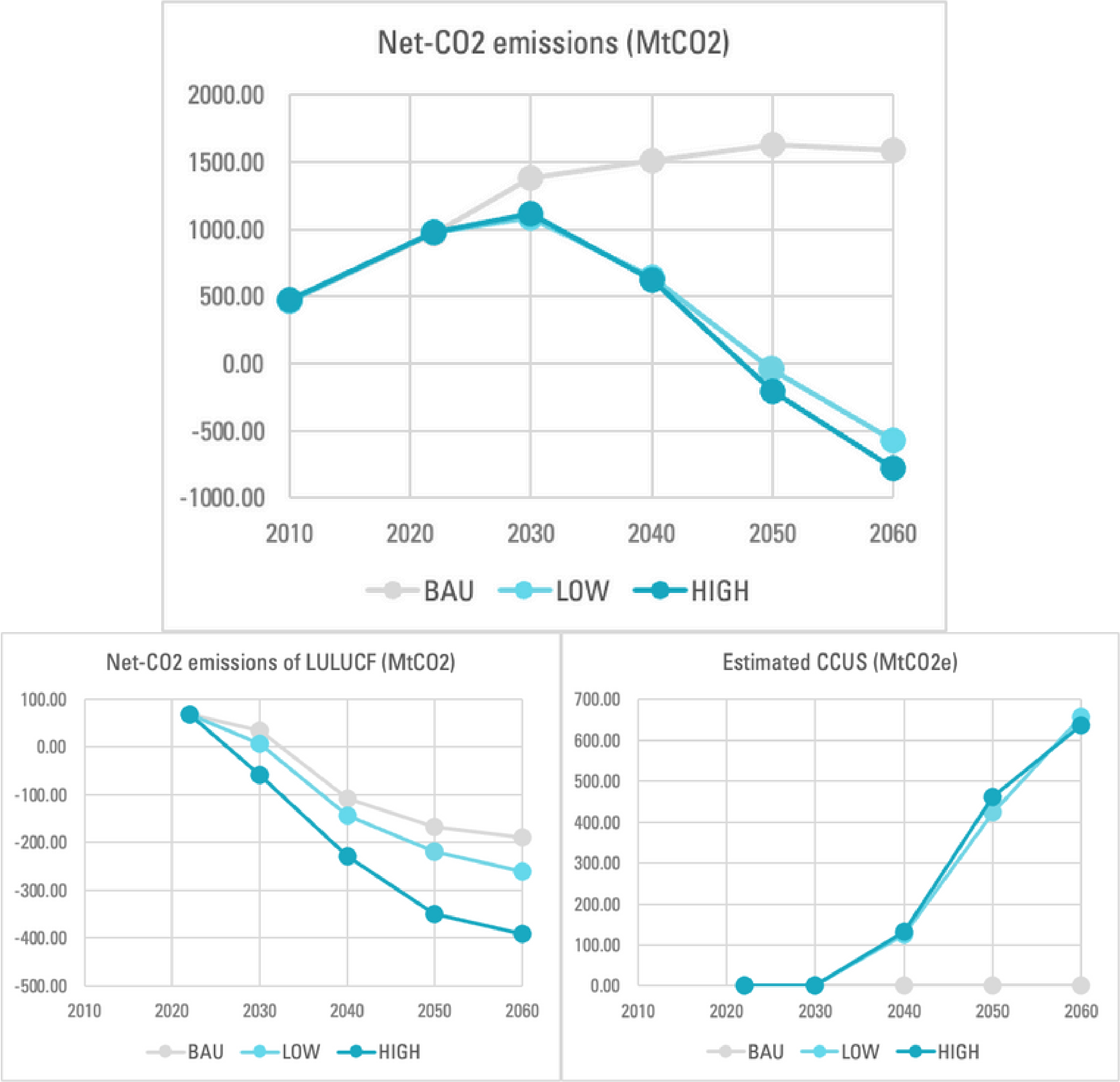
Figure 2. National net GHG emissions



- BaU is extended of unconditional ENDC with no additional policies/efforts to drive deep decarbonization transformations to reach long-term policy objective beyond 2060
- Both DDS reaches their peak by 2035 (2030-2040) and NZE 2060 with remaining GHG emissions of energy sector is 129 MTCO2e in 2060.
- The DDS HIGH is not sufficient to reach the Enhanced NDC conditional target, but sufficient to reach the ENDC unconditionnal target (ca. 2GtCO2) and net-zero between 2055 and 2060.
- The DDS LOW reaches a lower emission peak in 2030 compatible with the Enhanced conditional target (ca. 1.6GtCO2) and net-zero earlier than the DDS HIGH.

Total net-CO_2 emissions represent about 85% of all net-GHG emissions in 2022 and could become net-negative by 2060

Figure 3. National net-CO_2 emissions. Top: net-CO_2 emissions. Bottom: LULUCF net emissions & estimated CCUS



More than 90% of GHG emissions (excluding LULUCF) comes from fuel combustion and are mainly driven by the explosion of energy consumption and the current reliance on fossil fuels. Emissions from industrial process represent 7% of the CO_2 emissions, and 0,4% are waste emissions. CO_2 emissions sources excluding LULUCF are expected to peak by 2035.

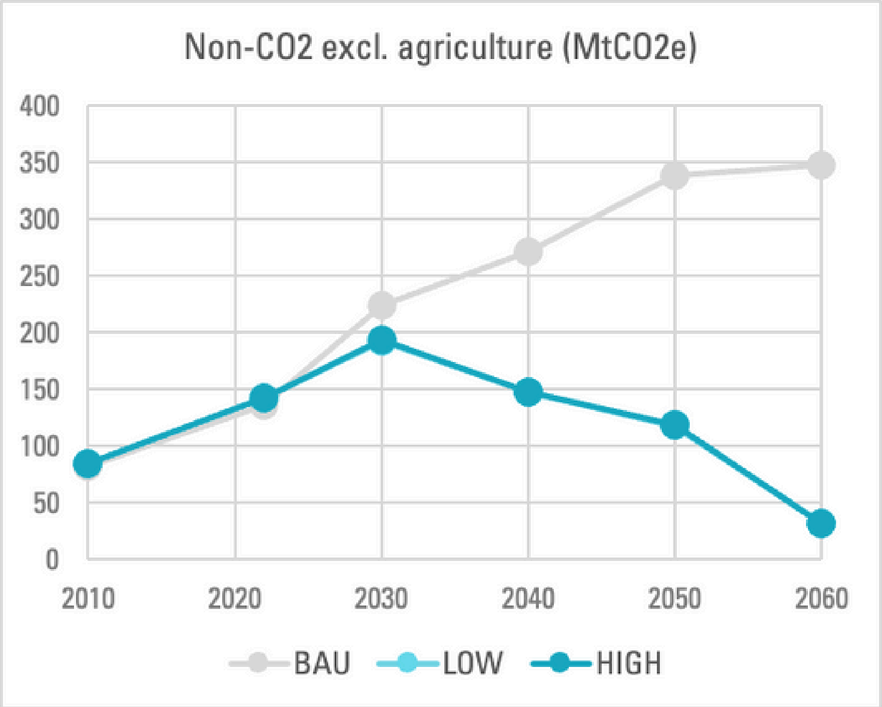
14% of total CO_2 emissions come from LULUCF in 2020. LULUCF emissions come mainly from peatlands (fires & degradation) and deforestation. Both forests (reforestation and standing forests) and cropland and grassland sequester CO_2 in 2020. As emission sources reduce and sinks increase, the sector turns net negative before 2030 in DDP-High, and between 2030-2040 in DDP-Low and BAU, reaching between -200 and -400 $MtCO_2$ by 2060.

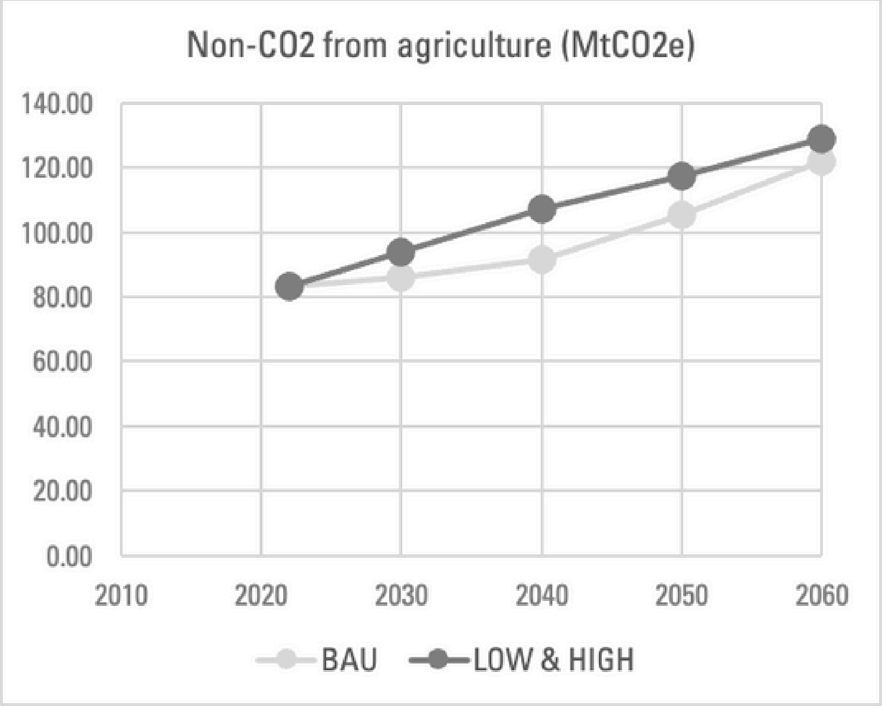
The main decarbonization drivers are :

- the development of renewable energy production, the use of efficient and less energy consuming technologies, the utilization of carbon capture and sequestration (CCS) in the power sector and energy-intensive industries as well as bioenergy coupled with CCS (BECCS) technologies in the power sector. It is expected to capture and store from 25Mt of CO_2 in 2030 in the DDS LOW and HIGH and more than 324 to 258 Mt by 2060. CCS capacities are therefore higher in the LOW
- For LULUCF, the main drivers are reducing the degradation of peatlands and improving the conditions for carbon sequestration by forests.

Total non-CO2 emissions represent 15% of all GHG emissions and could be reduced by 30% by 2060

Figure 4. National non-CO2 emissions.
Top: Non-CO2 emissions excluding Agriculture.
Bottom: Non-CO2 emissions of Agriculture





11% of all GHG emissions comes from non-CO2 emissions, mostly from agriculture and waste sectors. The waste sector represents 67% of non-CO2 emissions in 20020, and agriculture represents 37%. Other sectors (energy and IPPU) represent 3%. Total non-CO2 emissions peak in 2035.

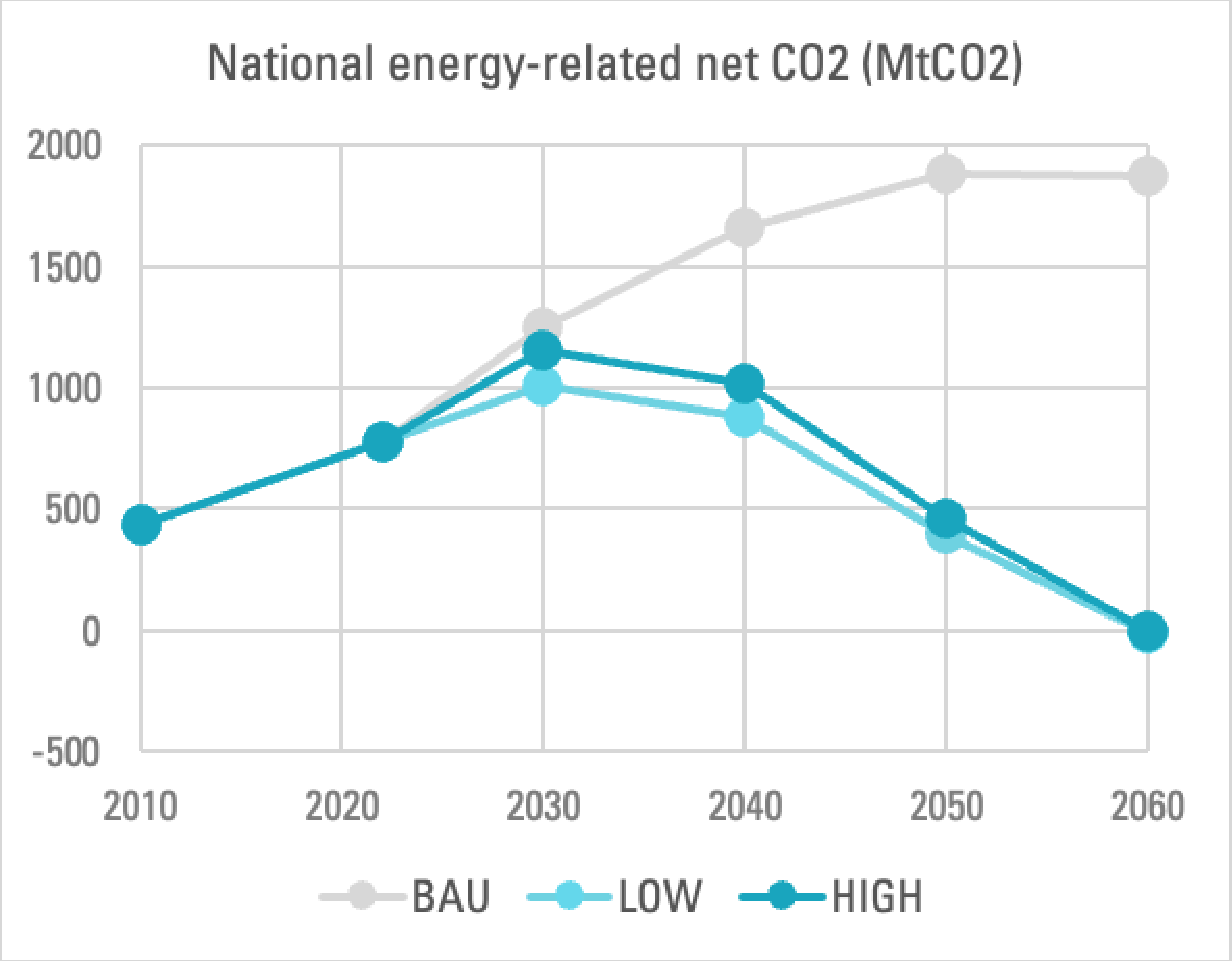
- Non-CO2 emissions froms agriculture increases continuously until 2050 in all scenarios. In BAU by 47% and in the 2 DDS by 54%. Non-CO2 emissions are lower in the BAU than in the 2 DDS scenarios, with the main difference is majorly due to manure management, incl manure left on pasture (N2O). The explanation to the difference is that agricultural activities increase significantly in the DDS scenario to support economic development and improved food security. The main drivers of emission increases are increased livestock herds and production of animal products (meat, dairy).

- Non-CO2 emissions excluding the agricultural sector peak in 2030, and start to decrease after that in the DDS LOW and DDS HIGH to reach 31 MtCO2eq in 2060. Before that, non-CO2 emissions excluding agriculture could be reduced by 18% by 2030.

- The main decarbonization drivers are the reduction of solid waste disposal assets and a better wastewater management (reuse & recycling practices, waste-to-energy practices such as Municipal Solid Waste (MSW) power plants, refused-derived fuels (RDF), solid-recovered fuels (SRF)…). The reduction of wastewater emissions will be notably implemented through the use of aerobic treatments for sceptic tanks

Total energy-related CO_2 emissions represent 79% of all GHG emissions and could become net-negative by 2060 (1/3)

Figure 5. National energy-related CO_2 emissions



- While the overall energy demand is increasing throughout the years, driven by the socio-economic and demographic development, the decarbonization of the energy used is therefore the main challenge that Indonesia will be facing, notably from the main emitting sectors : the power sector and light industries.

- In 2030, DDS LOW shows a lower level of emissions than the DDS HIGH, by 20%. This is the result of a lower energy demand mostly in the power and light industries, combined with an accelerated penetration of renewable energy.

- Energy-related CO_2-emissions represent the majority of the CO_2 emissions, the drivers of decarbonization are therefore similar : the increasing share of new and renewable energy sources, the use of efficient and less polluting technologies. CCS largely contributes to reaching neutrality in 2060, mostly developed in the power sector on coal fired-plants.

Total energy-related CO2 emissions (2/3): Reducing energy-related CO2 emissions requires systemic and technological changes to improve energy efficiency and reduce the fuel carbon content

Figure 6 . Final energy consumption (GJ/capita)

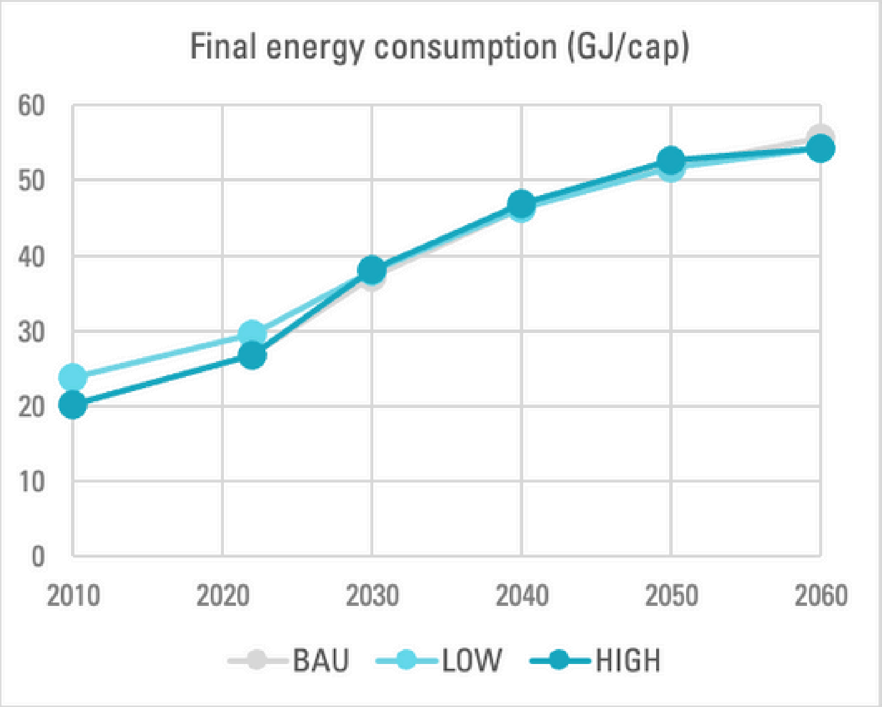


Figure 7. Final energy consumption (MJ/$)

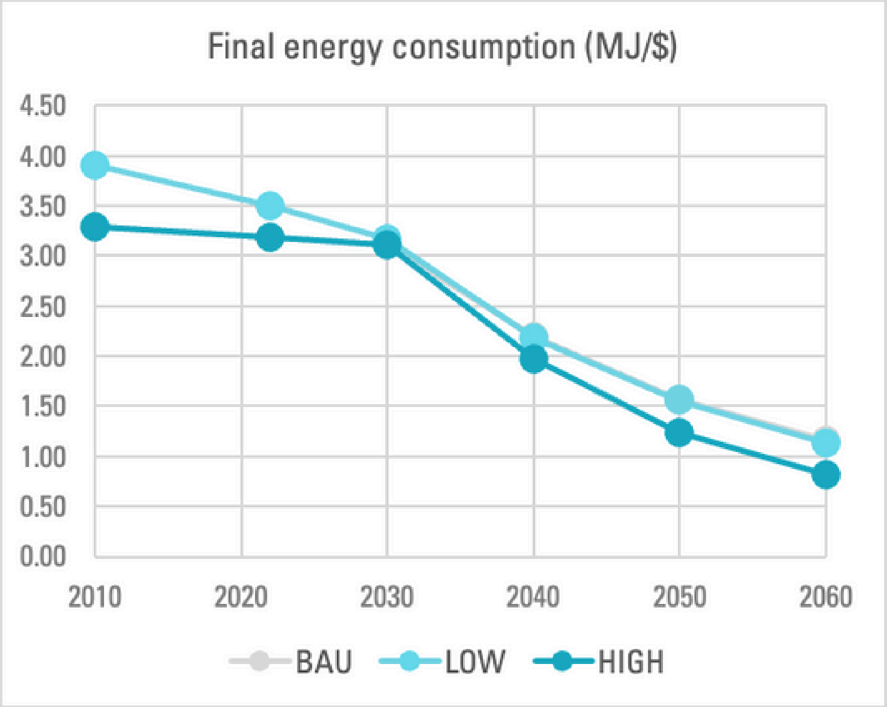
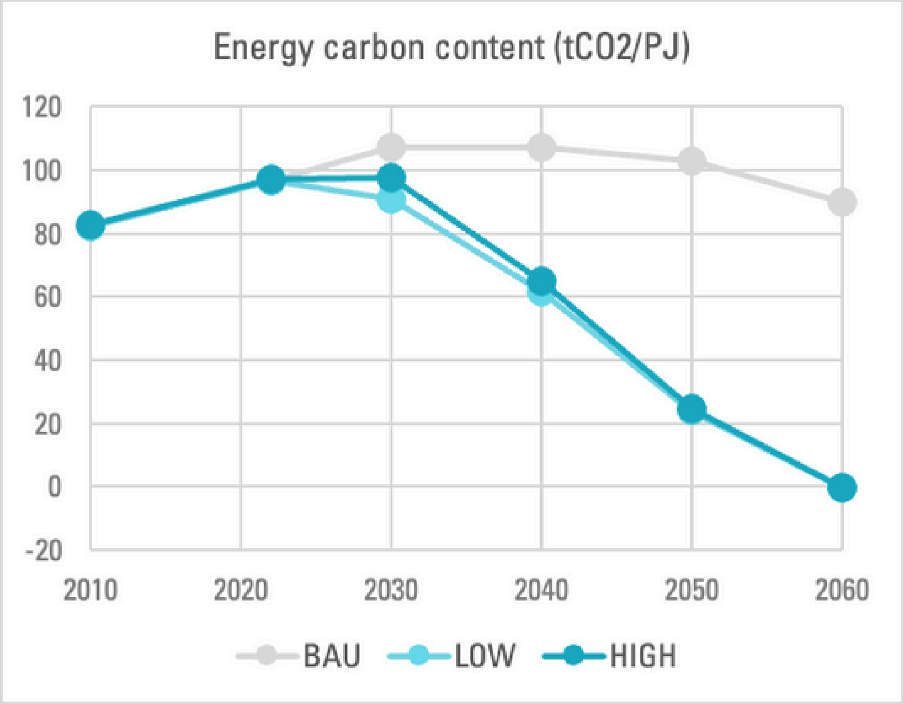


Figure 8. Emissions per final energy unit (gCO2/PJ)

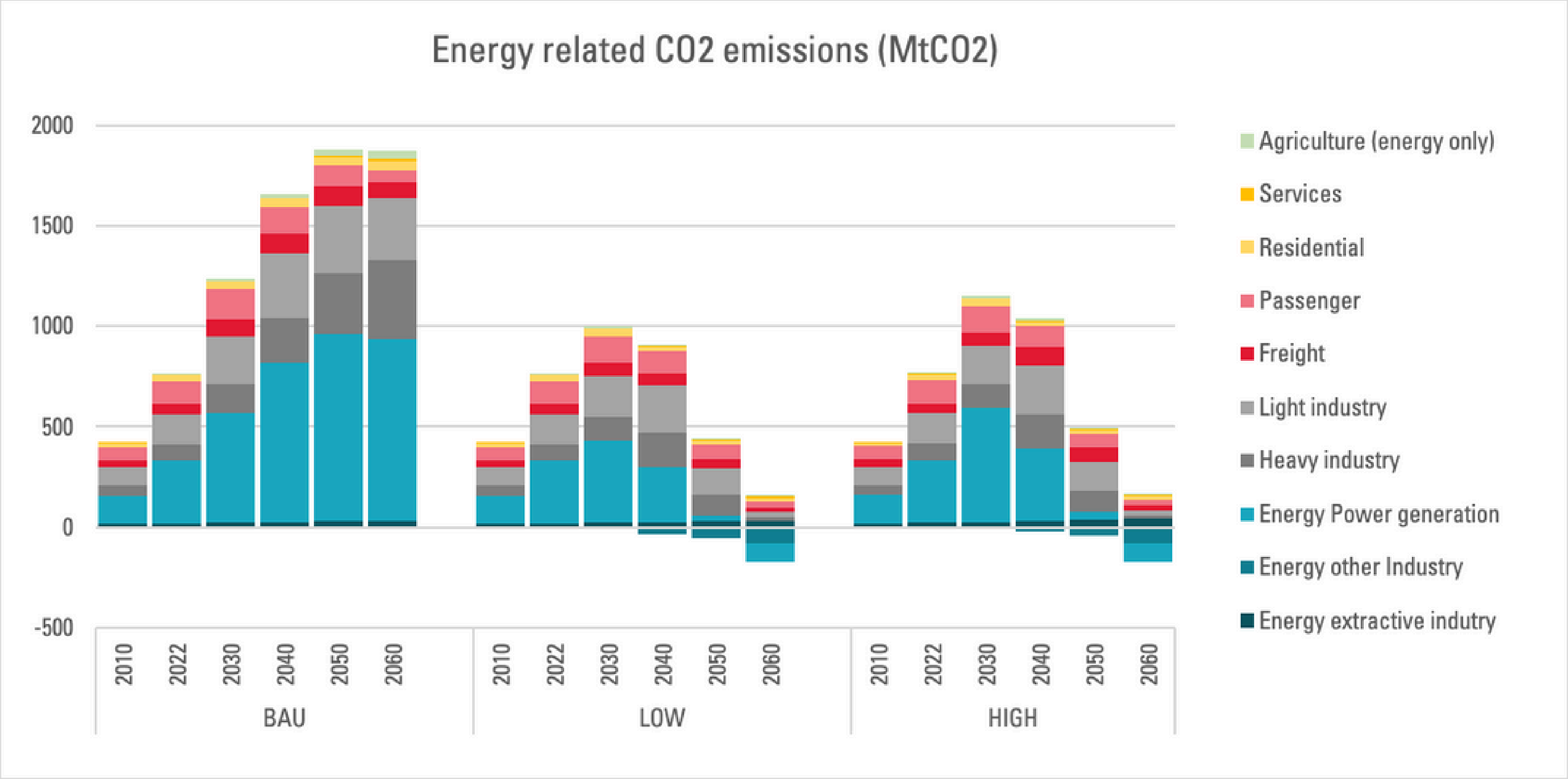


- The energy consumption per capita is multiplied by two by 2060, mainly driven by the economic development. We don't observe an improvement of energy efficiency levels at the national level.
- Energy intensity reduces (PJ/GDP), due to the even bigger explosion of GDP across time.

The shift towards zero-emission fuels will enable to decrease the carbon content of fuels, to become negative in 2060. This can be achieved with large-scale deployment of renewables and utilisation of CCS technologies.

Total energy-related CO2 emissions (3/3): The key energy-related sectors for deep decarbonization are the power sector and the light industries

Figure 9. Energy related CO2 emissions



- From nowadays until 2030, the most emitting sectors are the power sector and light industries. To reach ENDC objectives, the majority of the efforts needs to adress those sectors' emissions. This will allow to engage on a diminishing emissions curve (DDS HIGH & LOW). This will notably be thanks to the development of renewable capacities & the decarbonization of the fuel carbon content in light industries.
- If the GDP growth rate is higher (DDS HIGH), emission reduction will mainly come from industrial sectors (energy-intensives & light, and freight transports) and less from the power sector (from BAU to HIGH).

DDP

Part 2

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Sectoral deep decarbonization pathways in the DDS LOW scenario

Part 2.1

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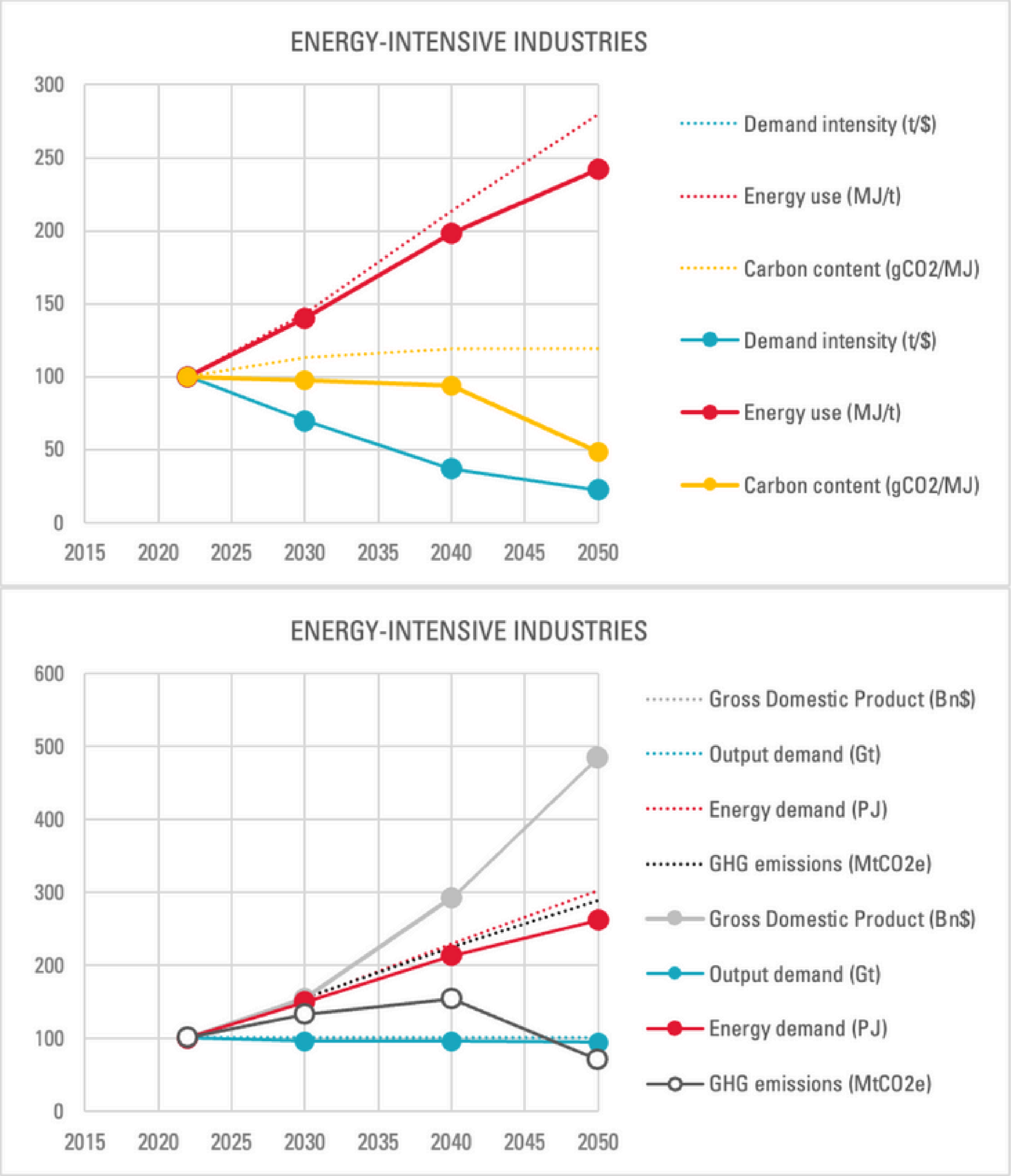
Transition of energy-related emission sectors: Transport, Buildings, non-energy producing Industries

Developing Paris-compatible ENERGY-INTENSIVE INDUSTRIES

Figure 14. Sectoral emission drivers and main aggregates (Index, 2022 base year)



- The decarbonization strategies rely essentially on the reduction of the carbon content of fuel used, coupled with energy-efficiency measures. The carbon content drops until 4 CO2/MJ by 2060. Both DDS scenarios follow a similar path. However, some additional energy efficiency measures and and a lower demand intensity in the DDS LOW enables to reduce even more the emission of the sector.

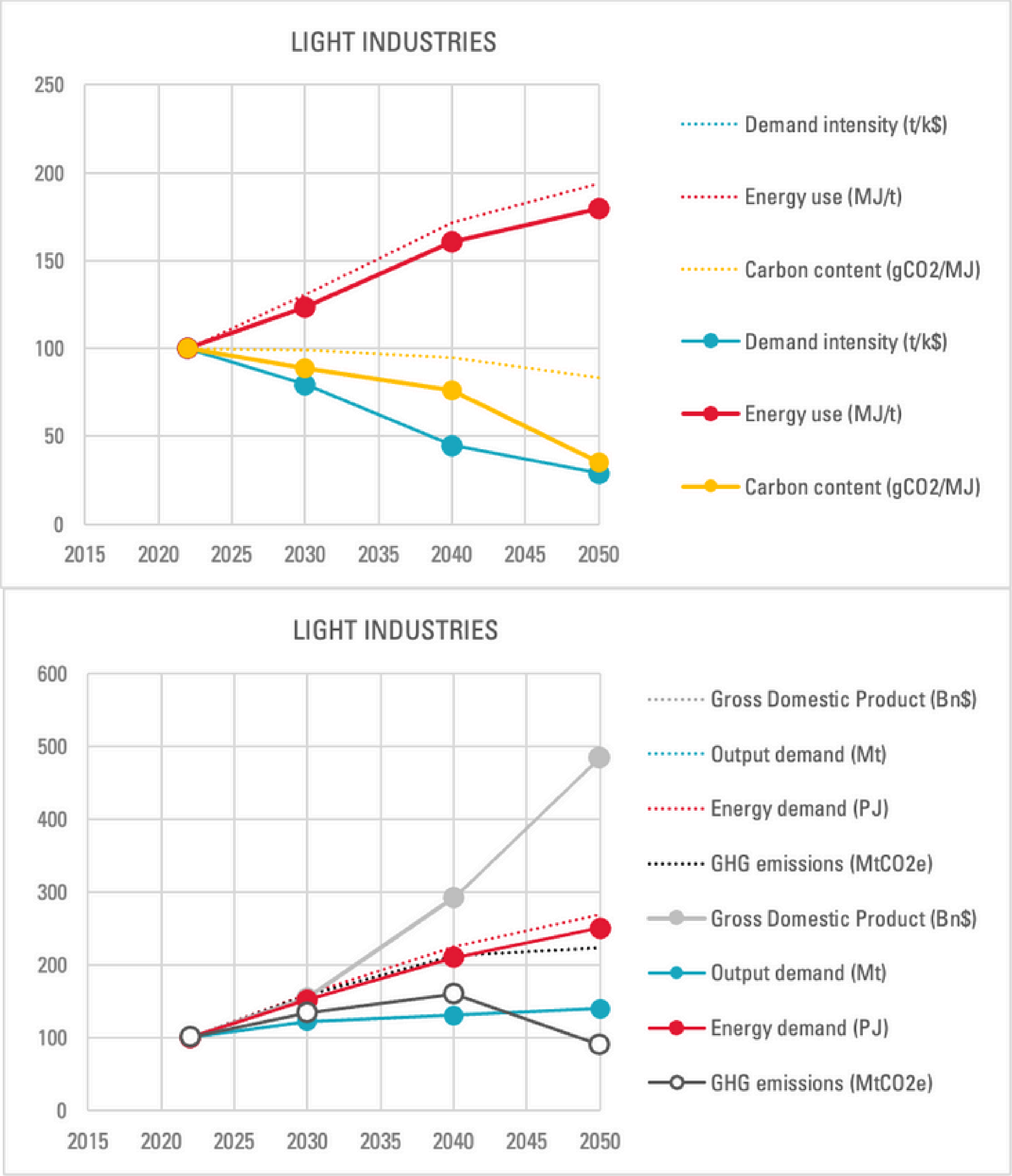
The main drivers are:

- the electrification in all energy-intensive industries.
- the augmentation of biomass fuels mostly in the cement production.
- the development of CCS infrastructures.

- The key additional policies to compared to the BAU should focus on the the electrification of all energy-intensives industry usages, the augmentation of biomass fuels and the development of CCS infrastructures.

Developing Paris-compatible LIGHT INDUSTRIES

Figure 15. Sectoral emission drivers and main aggregates (Index, 2022 base year)



- The decarbonization strategies rely essentially on the reduction of the carbon content of fuel used, coupled with energy-efficiency measures. The carbon content drops until 4g CO_2/MJ by 2060. Both DDS scenarios follow a similar path. However, some additional energy efficiency measures in the DDS LOW enables to reduce even more the emission of the sector.

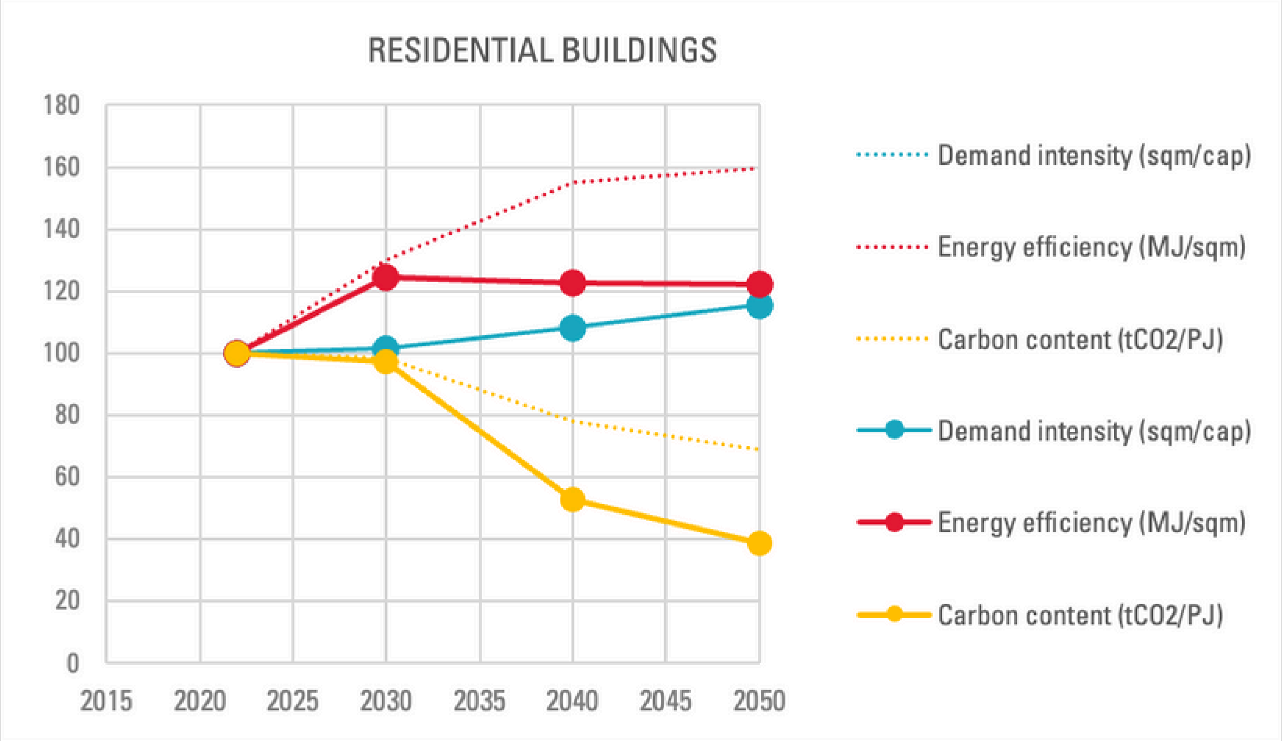
The main drivers are:

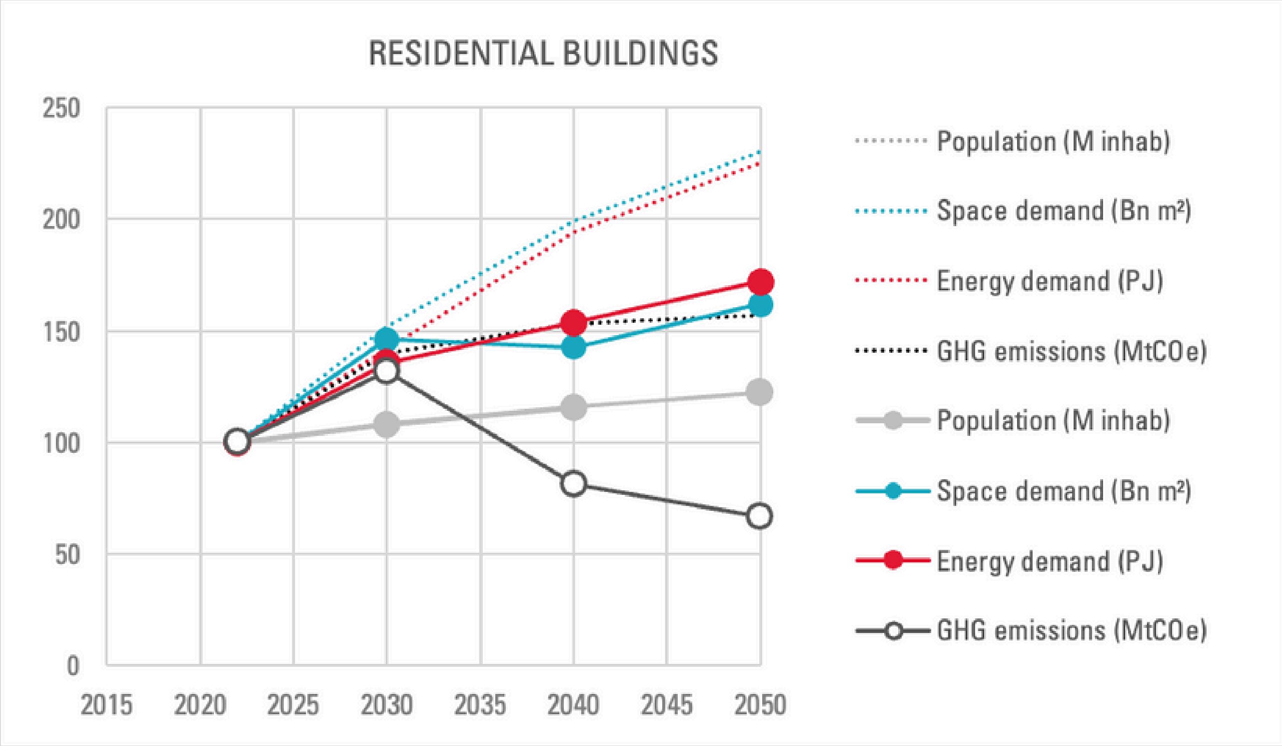
- the decarbonization of the power use and the augmentation of biomass fuels in all light industries. Future economic structure will rely on heavy manufacture industries (Food and Tobacco, Chemical and Pharmacy, Metal, Computer, Electronics, Optics, Electrical Equipment, Transport Equipment, Textile & Garment) that are mostly intensive energy and rely on fossil. It is expected that those industries will become more efficient in energy utilization and more rely on renewable and low emiting carbon energy with time.
- there is a reduction of processed emissions.

- The key additional transformations to compared to the BAU should focus on the decarbonization of the power use, the augmentation of biomass fuels, and energy-efficiency measures.

Developing Paris-compatible RESIDENTIAL BUILDINGS

Figure 16. Sectoral emission drivers and main aggregates (Index, 2022 base year)





- According to the BAU, cooking, cooling and lighting are the main emission sources and will make up to 85% of the sector's emission by 2060. Demand intensity is increasing due to the improved level of life. The DDS LOW's decarbonization strategy rely therefore on a reduction of both carbon content and energy consumption.

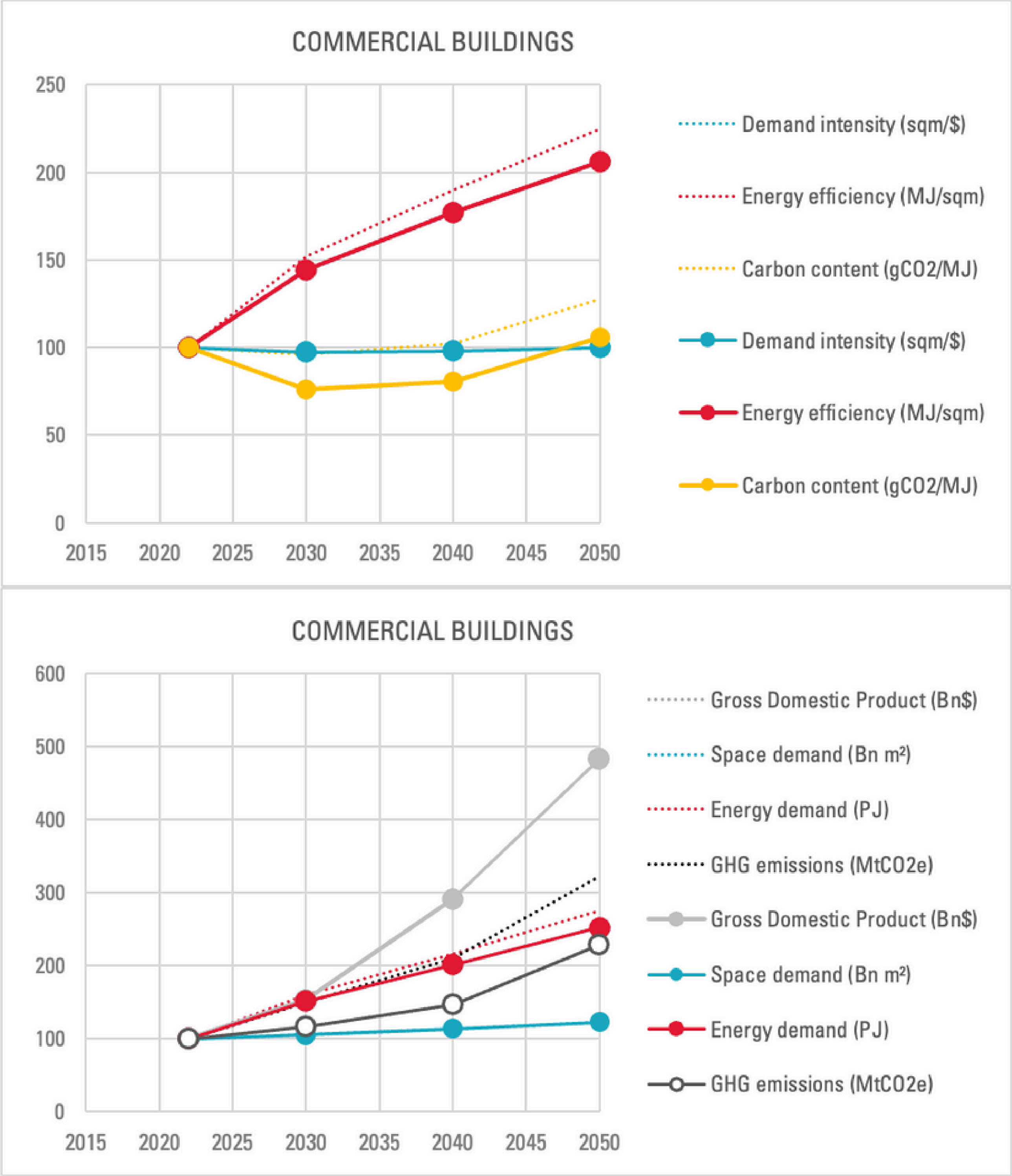
The main drivers of decarbonization are:

- the decreasing carbon content due to the decreasing use of gas an liquid fossils coupled with an increasing electrification. There is notably a switch from LPG to DME. The carbon content of fuels drops until 9g CO_2/MJ by 2060.
- the decrease of energy consumption in comparison to the BAU, thanks to energy -efficient systems such as the deployment of electric stoves uses and air conditioning coupled with heat water systems.

- The key additional policies to compared to the BAU should focus on reducing energy consumption and increase the electrification for the main emitting residential usages.

Developing Paris-compatible COMMERCIAL BUILDINGS

Figure 17. Sectoral emission drivers and main aggregates (Index, 2022 base year)



- According to the BAU, cooking and lighting are the main emission sources and will make up to 54% of the sector's emission by 2060. The demand intensity stays stable across the period. The decarbonization strategies rely essentially on a drastic shift of fuel supply, such as for residential buildings. The carbon content drops until 9g CO2/MJ by 2060.

The main drivers are :

- the decreasing carbon content due to the decreasing use of liquid fossils coupled with an increasing electrification. However, in all scenarios there is a strong deployment and use of a natural gas network, notably in cities, for cooking usages. The gas usages gets multiplied by 9 between 2010 and 2060 in the LOW.

- The key additional policies to compared to the BAU should focus on the electrification of space cooling and lighting, the main emitting commercial usages.

DDP

Part 2.2

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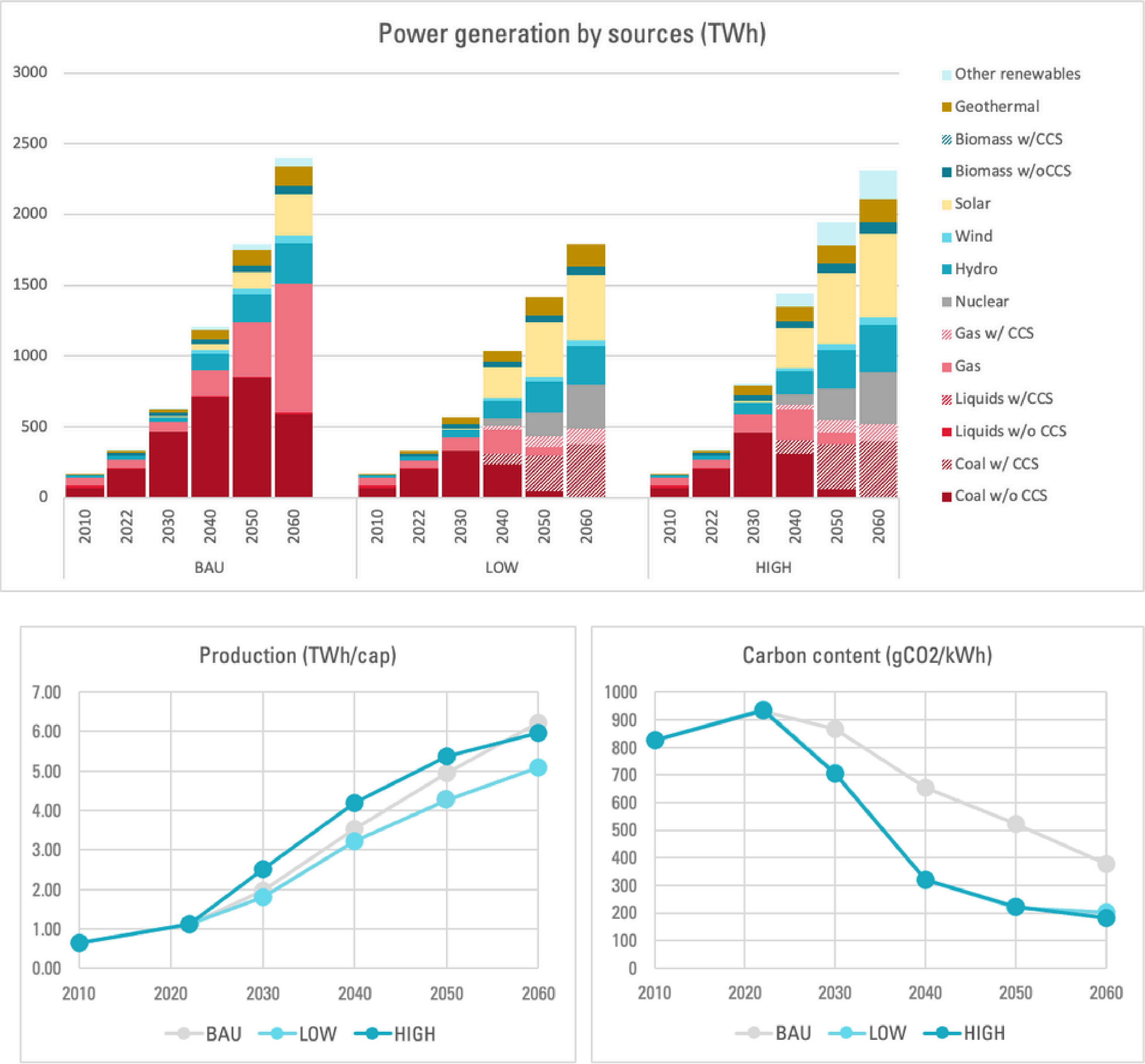
Transition of energy-related emission sectors: Power generation, Extractive energy industries, Other energy production industries

Decarbonizing POWER GENERATION

Figure 18. Power generation by sources (Top, in TWh) and production emissions / electricity carbon content (Bottom, in MtCO2 & TWh/cap) .



- Power production is expeced to increase in all three scenario. However, we observe in the DDSs scenarios a strong decarbonization of the power production. The carbon content decrease to net-zero in 2060.

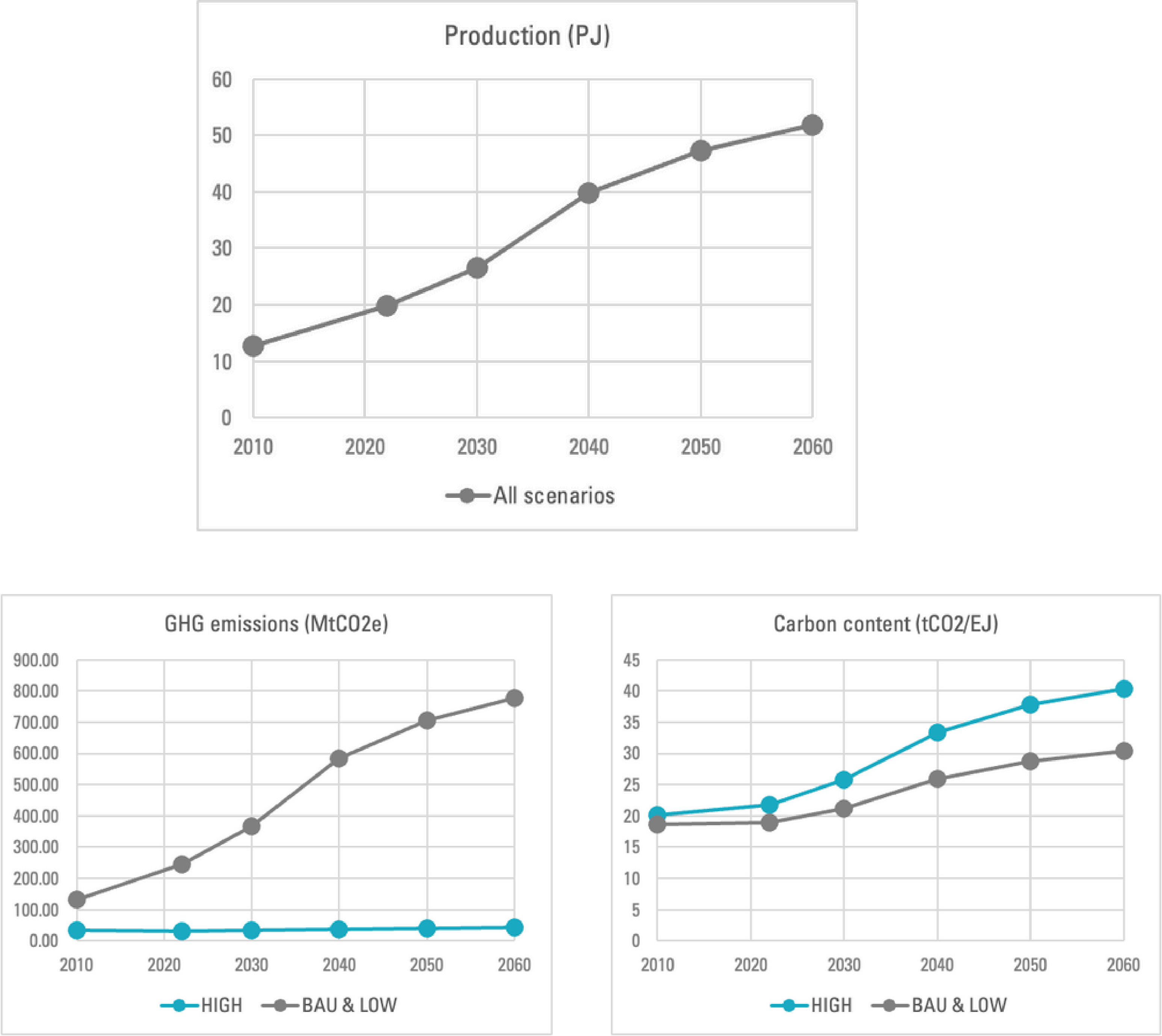
The main drivers are :

- a massive electrification, as show the augmentation of final power delivered per capita (LEV, heat pumps...). It is mainly due to the increase of productions (light industries) and the improved social quality of live that requires modern infrastructure relying on electricity. Electricity consumption increases from over 1 MWh/capita in 2020 to 8.5 MWh/capita by 2035.
- the decarbonization of electricity production. This can be achieved with large-scale deployment of renewables (solar, hydro, nuclear, geothermal) and utilisation of CCS technologies (for coal and gas plants). Those are the key transformations considered, compared to the currrent CPS.

The key additional transformations to compared to the BAU should focus on the large-scale deployment of renewables and CCS technologies.

Decarbonizing EXTRACTIVE ENERGY INDUSTRIES

Figure 19. Coal, Oil and Gas production (Top, PJ) and production emissions / carbon content of energy produced (Bottom, in MtCO2e & MtCO2e/MJ)



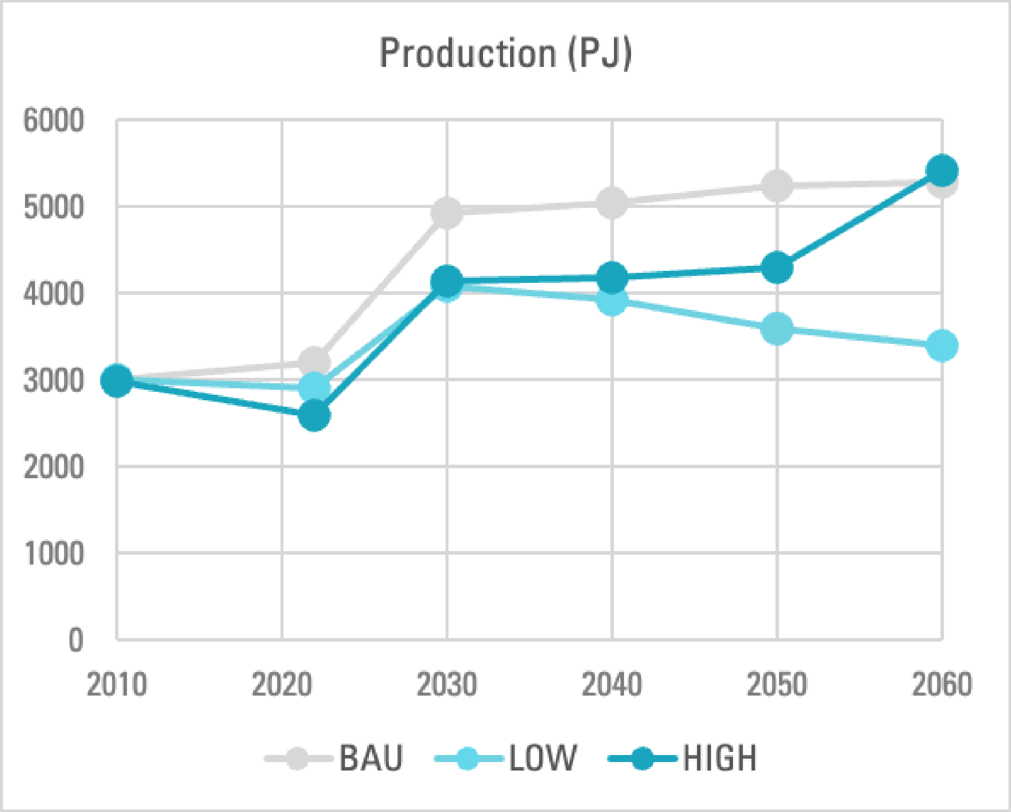
- In all scenarios, there is a increase of the emissions from the extractive industries across time and an increase of production. All 3 scenarios show similar trends for extractive energy industries.

- Most of the emissiosn comes from the extraction of coal - from 15 EJ in 2022 to 50 EJ in 2060. The majority of the emissions are therefore non-CO2 fugitive emissions from the coal extraction.
- A large share of this production is intented to be exported : 80% of the production is exported in 2060.

- Oil and natural represent a small share of the extractive activites planned in Indonesia by 2060. Those production diminish across time.

Decarbonizing OTHER ENERGY PRODUCTION INDUSTRIES

Figure 20. All other final fuel production (Top, in PJ) and production emissions / carbon content of energy produced (Bottom, in MtCO2e & MtCO2e/MJ)



- For now the work is focusing on showing the production of other energy industries and does not include the emission accountability. There is a higher total production of other energy industries in the BAU than in the LOW.

- There is a similar production of liquids from crude oil (gasoline, kerosene, diesel & LPG) in all scenarios, of 0,65 EJ total production in 2060. This production decreases across time, starting at 1,64 EJ in 2022.
- There is a lower production of biodiesel & biomethanol in the LOW in comparison to the BAU : from 0,8 EJ in the LOW to 4,6 EJ in the BAU, in 2040.
- There is a H2 production in the LOW scenario : the blue H2 production is similar to the BAU but the green H2 production is higher: 1,81 EJ in 2060, from solar, hydro & nuclear power generation (while green H2 production in the BAU is null).

Part 2.3

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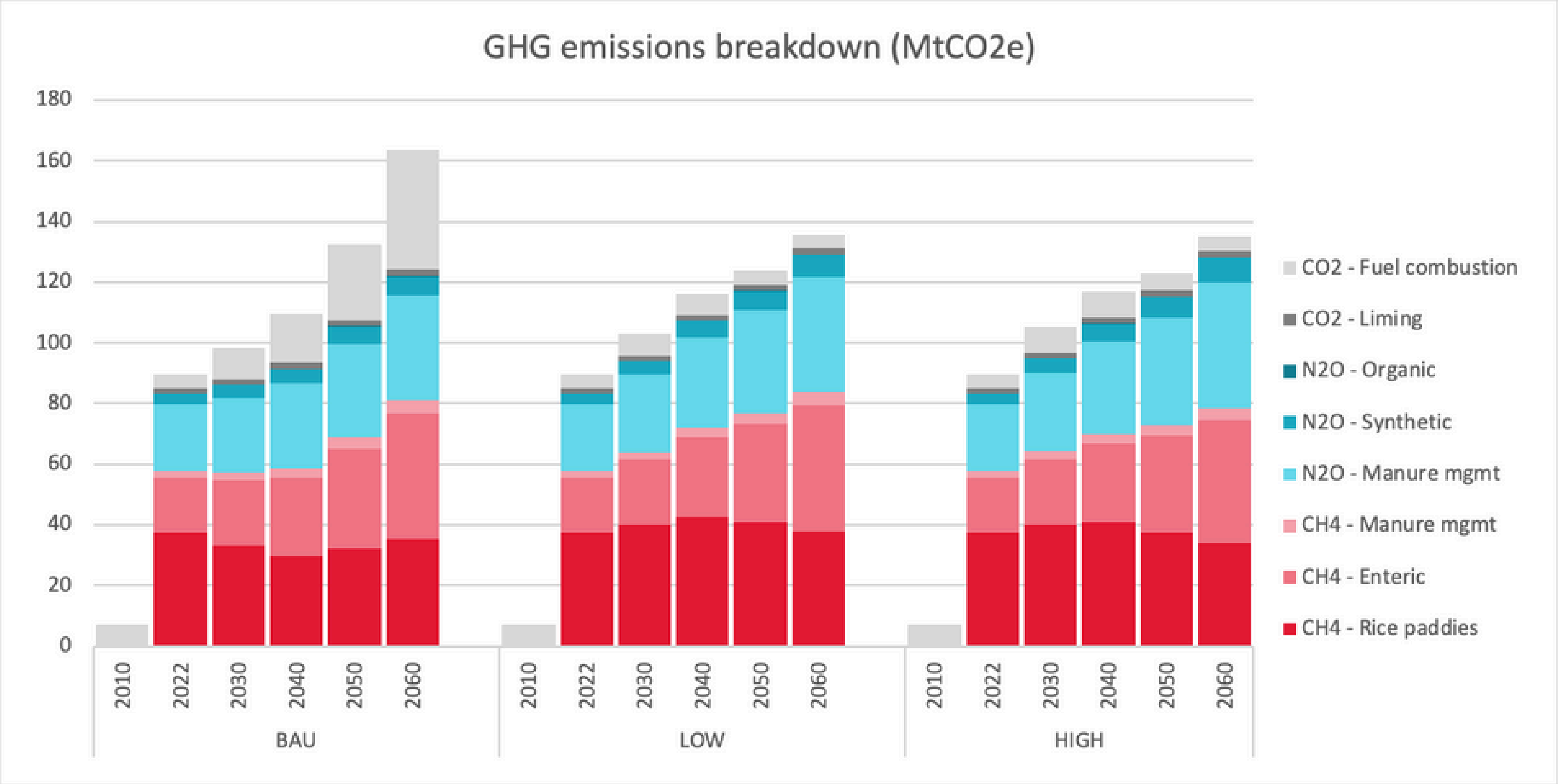
Transition of non-energy related emission sectors: Agriculture, Forestry and Land use change, Waste

Developing a Paris-compatible AGRICULTURE sector

Figure 20.



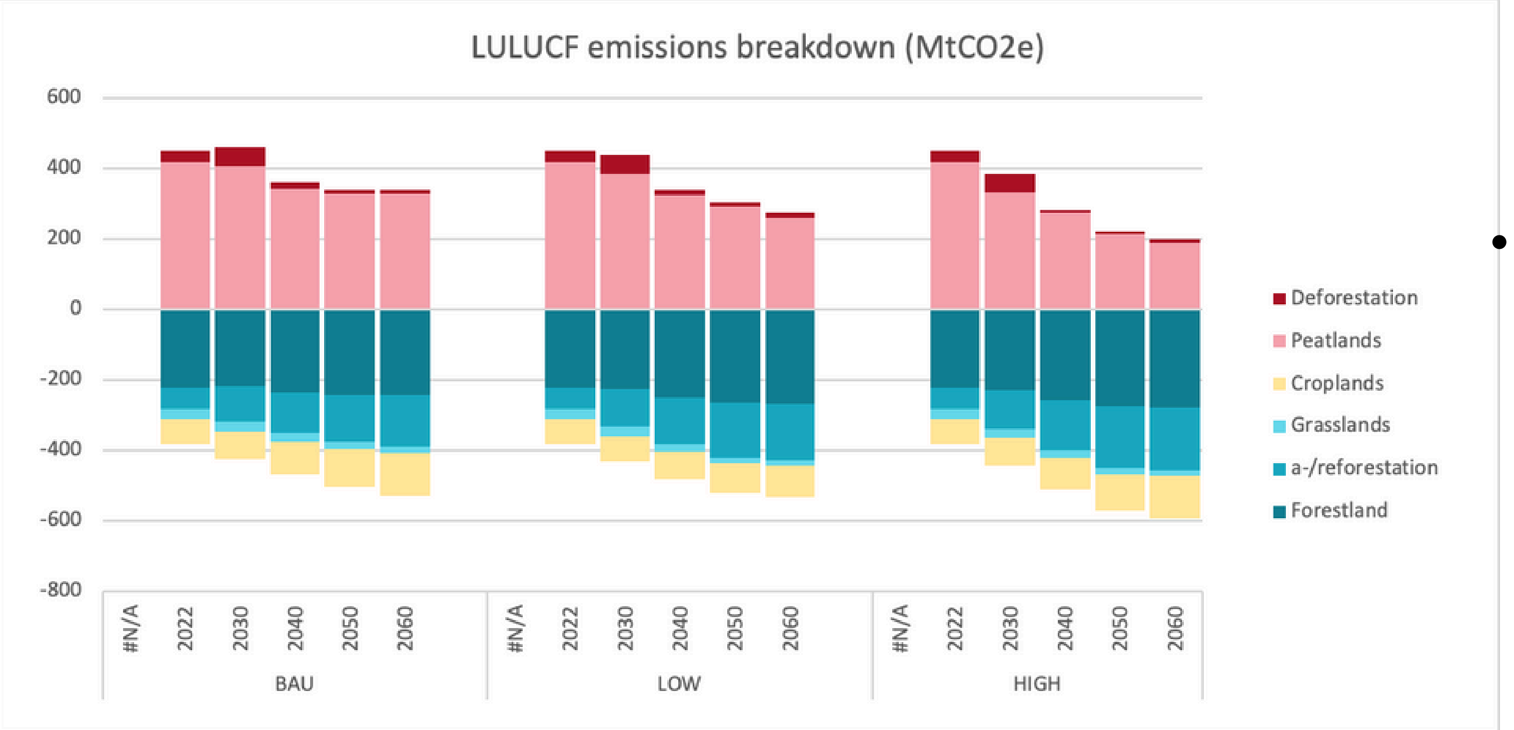
In the DDP LOW scenario, agriculture emissions increase by 55% 2020-2050. Emissions from rice paddies, from enteric fermentation (EF) and from manure management (MM) are the main emissions sources. Emissions from rice paddies increase for 2030 and reduce thereafter to reach similar levels to 2020 in 2050, while emissions from EF and MM increase by 129% and 79% respectively.

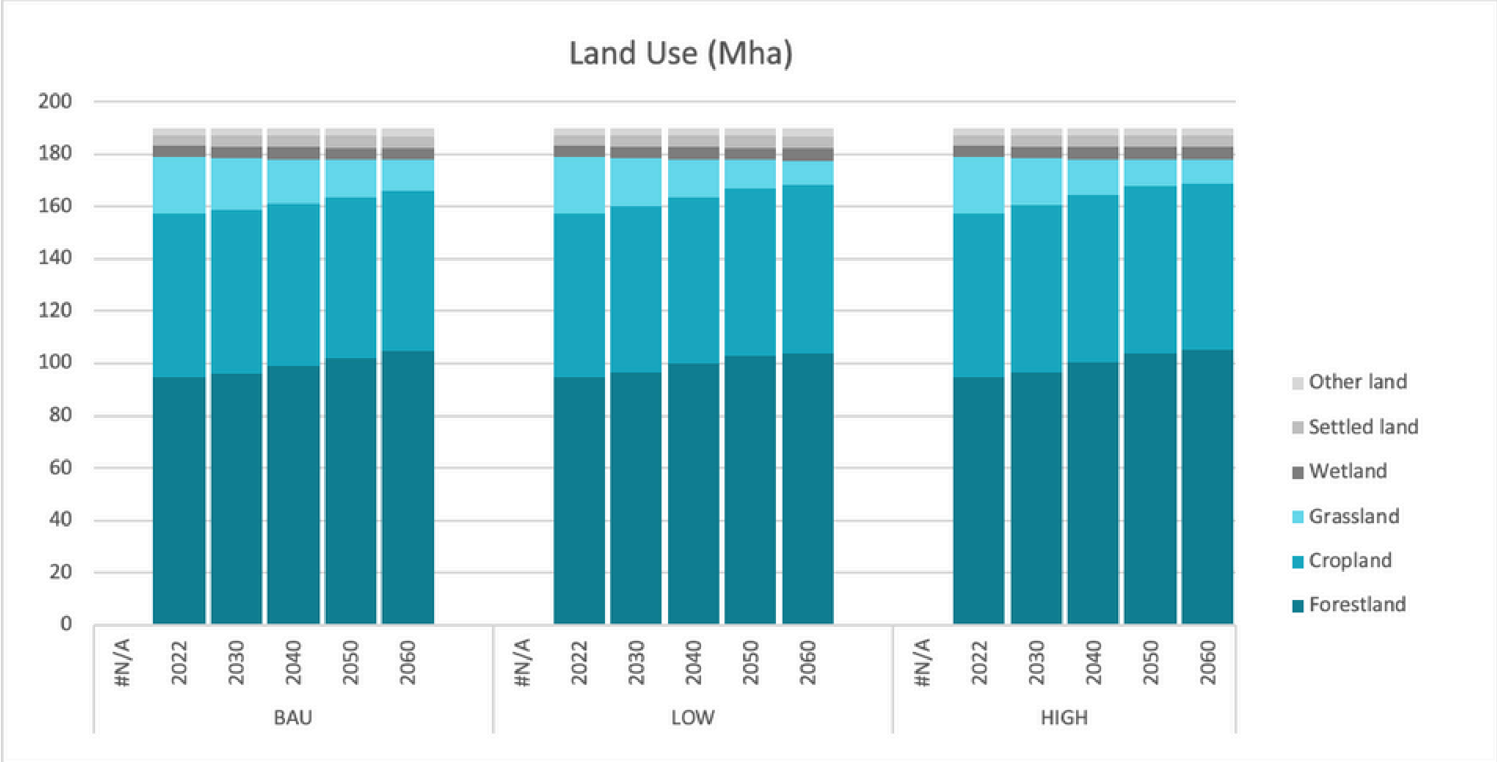
The main drivers of development in the pathway are the following:

- Indonesia targets universal food security in 2045, and the per capita daily food consumption increases by 30% 2020-2050)
- Demand for biomass for energy increase drastically. For palm oil, the demand is 20Mton in 2030 and 65 Mton in 2050. For wood, it is 19Mton in 2030 and 33Mton in 2050. This demand induces a risk of deforestation.
- Farming practices intensify to meet an increasing demand for biomass while reducing deforestation and peatland degradation. Both yields and total production increase significantly.

Developing a Paris-compatible LULUCF sector

Figure 21.



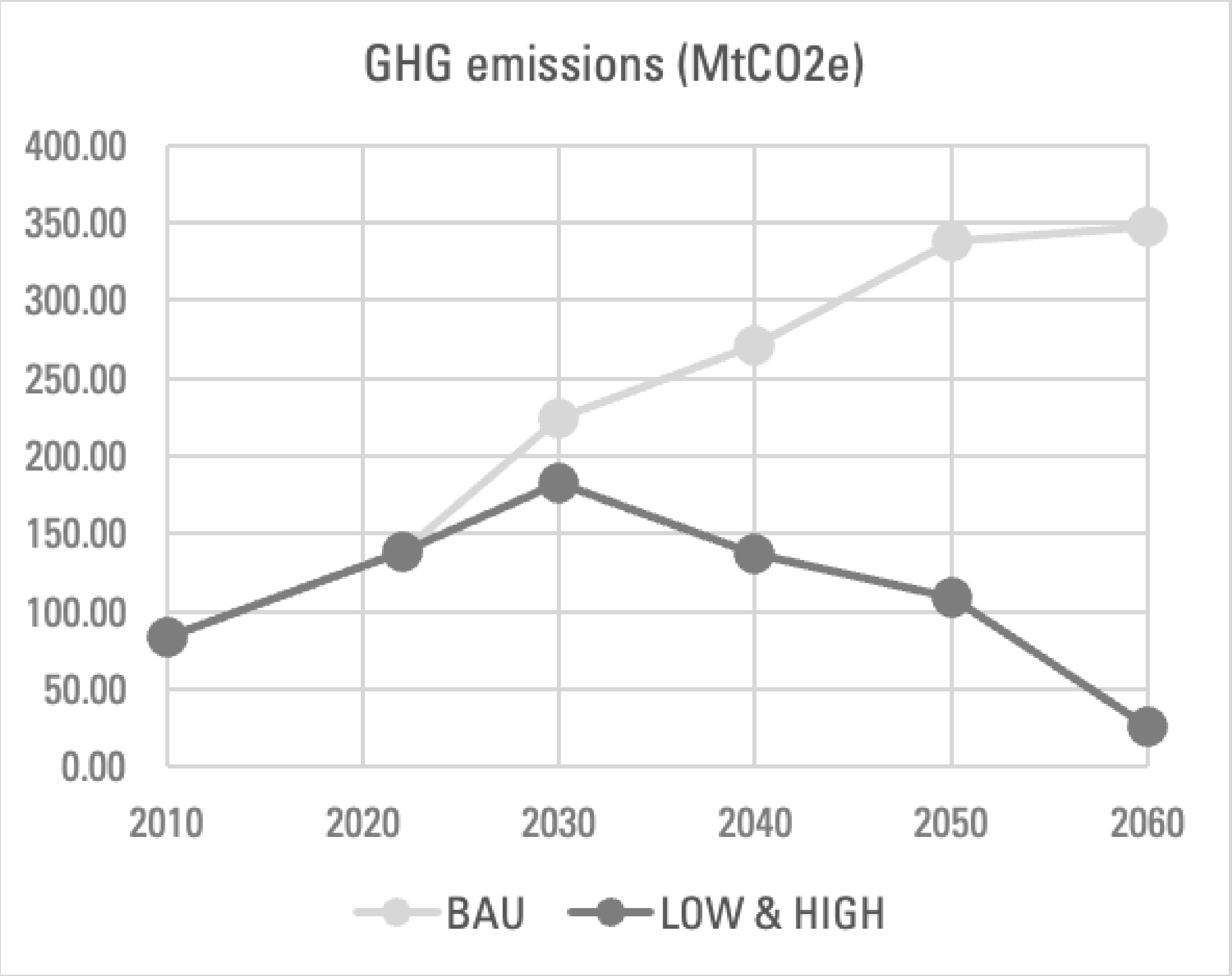


- The LULUCF sector plays a major role toward reaching the net-0 targe. The sector itself is CO2-neutral before 2030, and provides almost 130 MtCO2/yr by 2030 and almost 400 MtCO2/yr by 2060 in negative emissions.

- The main drivers are:
    - A rapid reduction of peatland fires and degradation, and of deforestation. Emissions from peatlands reduce by 38% and those from deforestation by 5% 2020-2060.
    - Afforestation & better forest management further contribute to an increasing forest carbon sink. Forestlands increase by 9% in the scenario, mainly driven by a reduction in the loss of natural forests and an increase in forest plantations.
    - Underlying drivers of these changes is an improved governance of land use and forestry, and improved agricultural practices on peatlands (paludiculture).
    - An intensification of the livestock stocking rates (increasing from 1 to 5 cattle heads per ha of grazing land 2020-2060) and an increasing livestock and crop productivity free up land for afforestation.
    - A policy framework that provides financial incentives to land managers, improves forestry governance and contributes to increasing the forest sink.

Developing a Paris-compatible Waste sector

Figure 21.



- The waste sector is behind 15% of Indonesias total GHG emissions in 2020, and reduce emissions by 81% between 2020-2060, with peak emissions in 2030 in the two DDS scenarios. In the BAU scenario, emissions increase by 150%.

- Key emission sources are unmanaged waste disposal sites (CH_4) and wastewater treatment and discharge (CH_4). Both reduce signicantly, although treatment of domestic wastewater remains a significant emission post in 2060 (71% of waste emissions).

- Compared to the CPS, the DDS shows significant efforts on holding back and reducing emissions from treatment of industrial wastewater. There is also additional actions on unmanaged waste disposal sites, and on treatment of wastewater from households.

Conclusions

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Key lessons for national & international climate and development decision processes

(1 slide = 1 lesson)

Lesson 1 - Key areas or sectors which require additional transformations

To answer: What are the long-term national transformations compatible with the collective Paris-Agreement mitigation objective and country-driven development priorities? How do these Paris-compatible pathways differ from current trends and NDCs? What are the differences in transformations based on your different scenarios?

<u>To move from BAU (e.g. current policy trends) to carbon neutrality DDS:</u>

Example: From nowadays until 2030, the most emitting sectors are the power sector and light industries. To reach ENDC objectives, the majority of the efforts needs to adress those sectors' emissions. This will allow to engage on a diminishing emissions curve (DDS HIGH & LOW). The key additional transformations to compared to the BAU should focus on :

- the large-scale development of renewables & CCS technologies,
- In all industries and particularly in the light industries, the decarbonization of the power use, the augmentation of biomass fuels, and energy-efficiency measures.