Deep decarbonization pathways in INDIA

February 2024
Lessons from the EU-funded research project IMAGINE

Prof. Amit Garg
Saritha Sudharmma Vishwanathan
Vidhee Avashia
Omkar Patange
Tirthankar Nag

Table of contents

Introduction

This work takes place in a context where:

- *In August 2022, India submitted two targets for NDC objectives: reducing its emissions intensity by 45% below 2005 levels by 2030 (excluding LULUCF) and increasing the share of non-fossil power capacity to 50% by 2030.*
- *In November 2022, India has submitted a Long Term Low Emissions Development Strategy (LT-LEDS), pledging to become net zero by 2070. It has not been clarified whether the target is CO2 neutrality or GHG neutrality.*

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

- **The Current Policies Scenario (CPS) :** The scenario encompasses all the on-going policies captured under the baseline scenario and the policies implemented after the NDC submission in 2015. In 2016, the government announced a major set of national sustainable development targets following the global Agreement on Sustainable Development Goals (SDG) in New York. These include but are not limited to electricity for all by 2019, 25 million LPG connections by 2019 (about 100 million achieved by February 2022), universal public health, universal primary education, and housing for all by 2022. This is in addition to selected sectoral, energy and climate action policies, with relevant Sustainable Development Goals (SDG) to be achieved by 2030. In 2019, the 2030 target of non-fossil power capacity share was further ratcheted up to 450 GW (from 175 GW in Baseline). As the implementation had been gradual, for this study we assumed the solar target to be increased to 250 GW. Reduction in T&D losses improves to 8–10%, and old, inefficient power plants are phased down by 2030. In the industry sector, the government has rolled out six PAT cycles until 2025 with a total of 1073 designated consumers (DCs) widening to the 13 sectors, thus increasing the climate ambition in the industry sector relative to Baseline. In the transport sector, the share of ethanol blending increases to 10% by 2022. In the buildings sector, about 26 electric appliances are covered under mandatory and voluntary policy regimes.

- **The (Enhanced NDC) :** The scenario ratchets the on-going policies and NDC targets to capture the pledge made by India at COP26 in order to shift towards net-zero emissions by 2070. This includes the targets below outlined in the Indian NDC as submitted in COP26. In particular: a) a further reduction of emission intensity of Indian GDP to 45% during 2005–2030; (b) an increase in the share of non-fossil-based energy resources to 50% of installed electric generation capacity; (c) to install 500 GW of renewable power generation capacity by 2030; (d) to mitigate 1 billion tons of carbon dioxide equivalent (btCO2e) by 2030 compared to NDC 2015 estimates [3]. In this scenario, after 2030 all countries (including India) are assumed to implement ambitious climate policies aiming to meet the Paris Agreement goals of well-below 2 °C (and make efforts to below 1.5 °C).

Emissions perimeter: Due to analytical limitations, this set of scenario does not cover GHG emissions related to the waste sector, to the fugitive emissions from extractive activities, to the energy-related emissions coming from the energy industries: extraction and other fuel transformation activities. According to India's Third National Communication, in waste sector, these emissions represented about 2.65% of Indian emissions in 2016. Petroleum refining accounts for 3.5% while solid fuel manufacture amounts for 0.03% of GHG share (without LULUCF). Fugitive emissions contributed to 1.75 % of which 46% from coal mining and 54% were from oil & natural gas systems.

Research questions for scenario framing

1) What are the additional transformations required by 2050 to reach net-zero GHG emission before 2070 in the current Indian political context?

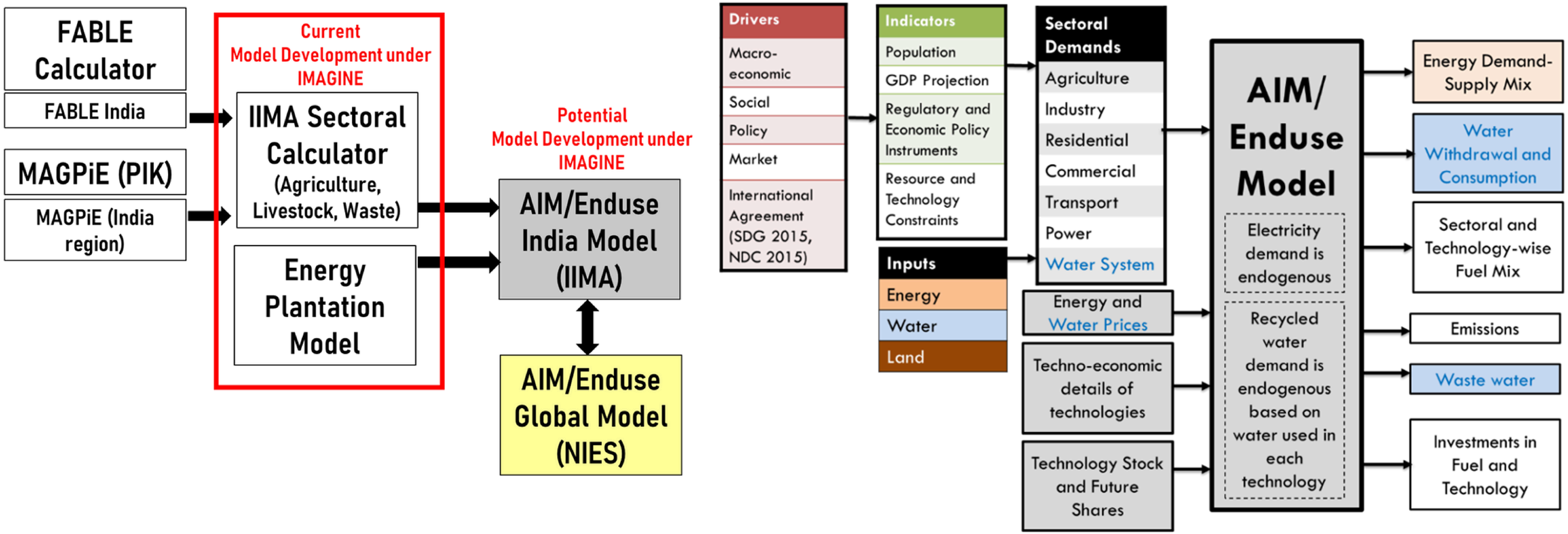
2) How will the non-CO2 emissions from agriculture, and landuse evolve in future under the current and alternate policy scenarios?

- The comparison of CPS with EnNDC will inform us on the additional transformations to implement in order to reach GHG neutrality by 2070.
- The Enhanced NDC scenario assumes that 0.5% wasteland in India is made available for energy plantations.

Other key country-specific questions aim to be informed by this work:

- What are the main emitting sectors and what sectors should be particularly adress if we include all greenhouse gas emissions in the carbon neutrality target?
- How could this work support the revision of national development and climate policies and future UNFCCC's commitments?
- 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?

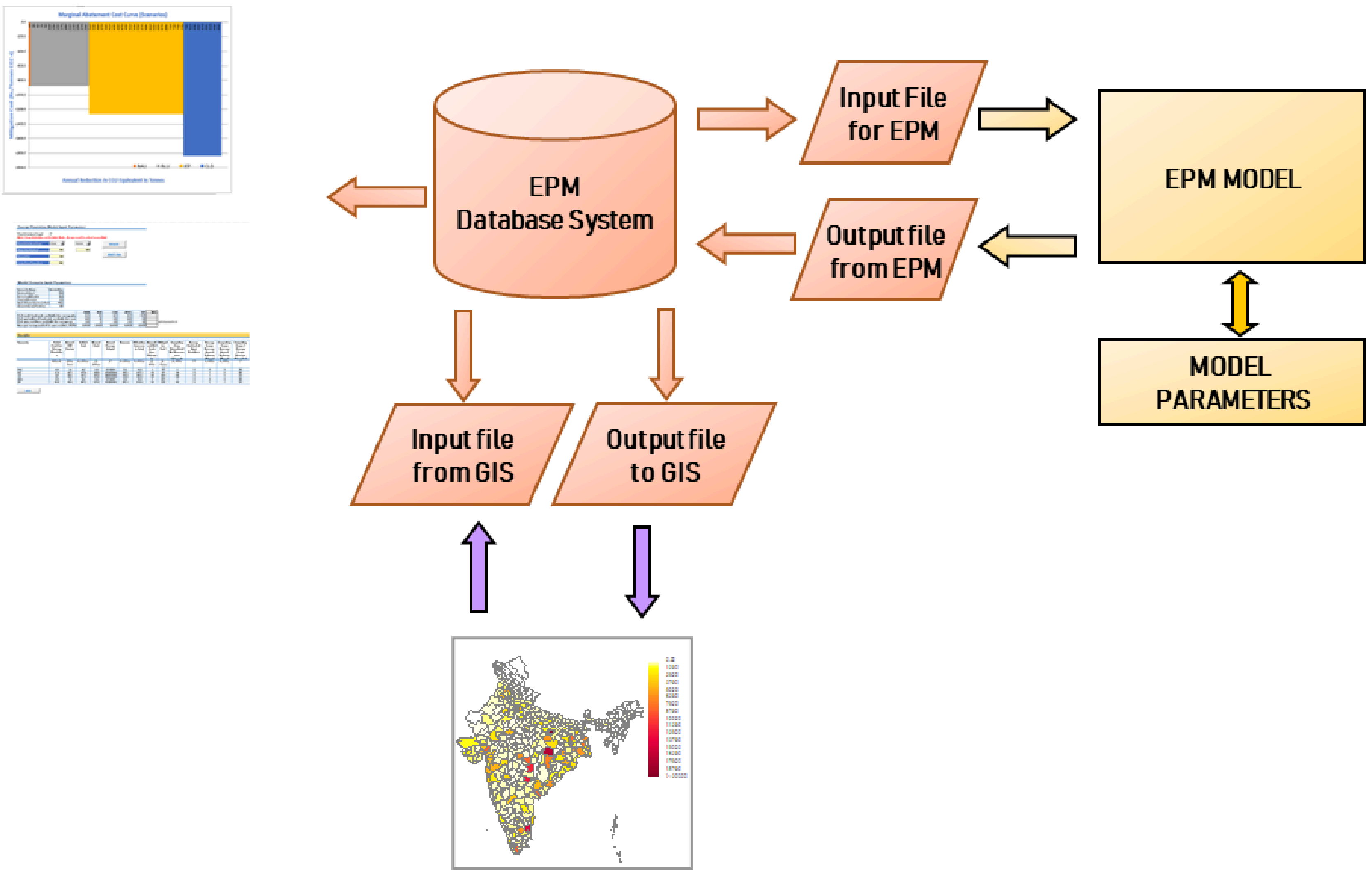
Modelling architecture & improvements



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

- *Modified AIM/Enduse Water-Energy-Land (W-E-L) Modelling Framework. Source: Vishwanathan et al. 2021*

Modelling architecture & improvements : AFOLU specific



GIS DATA INPUT /OUTPUT

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

- *Document is being updated*

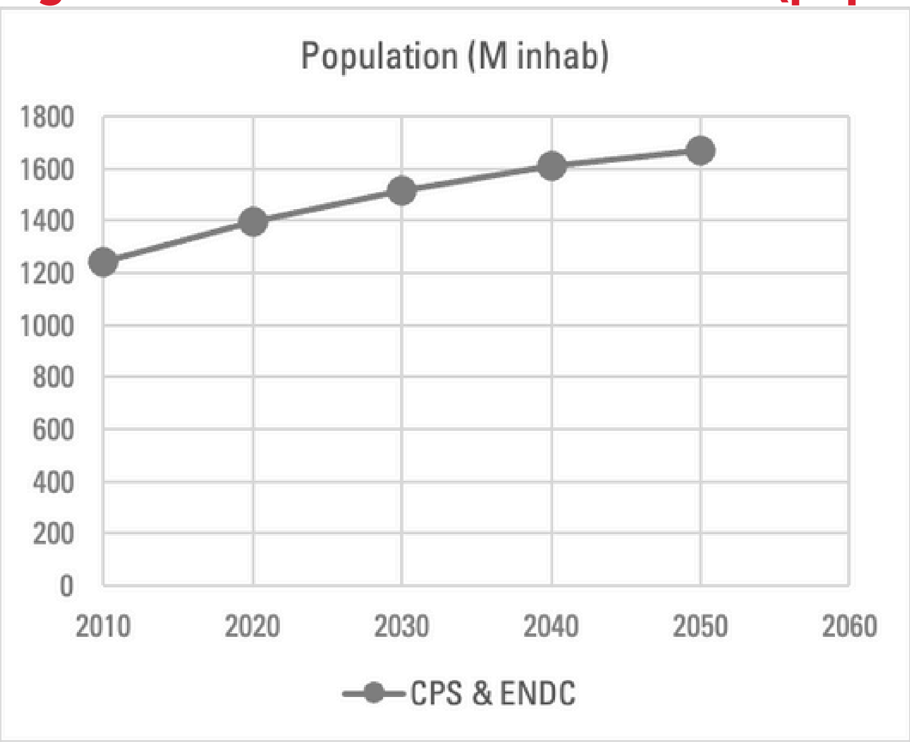
Part 1

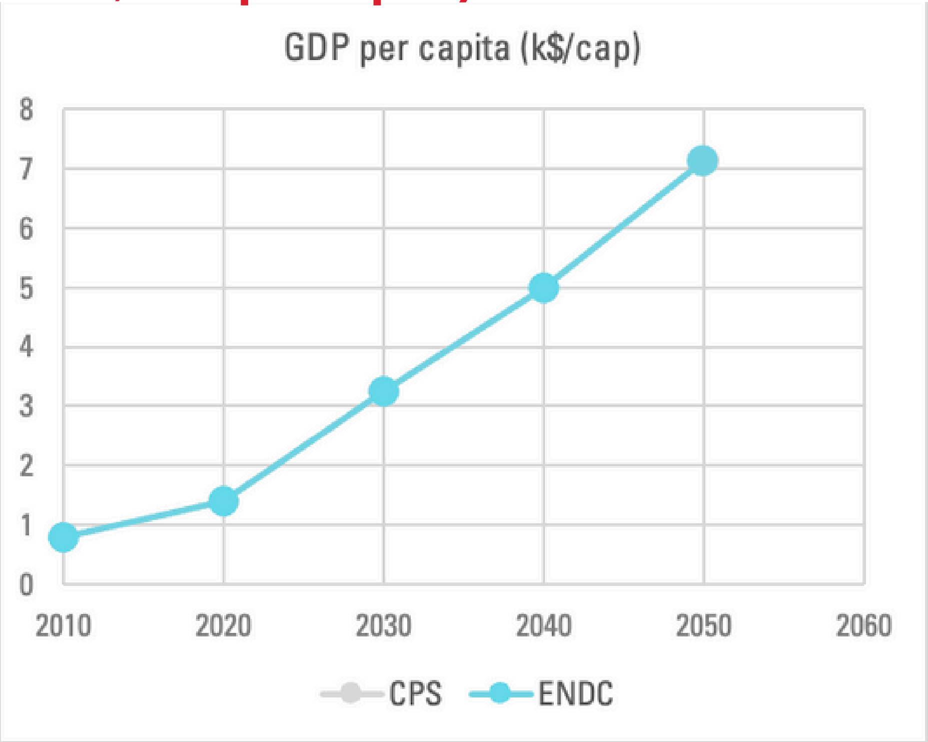
-

National overview of the deep decarbonization pathways

Reaching net-zero GHG emissions by 2070 is feasible, while ensuring socio-economic development

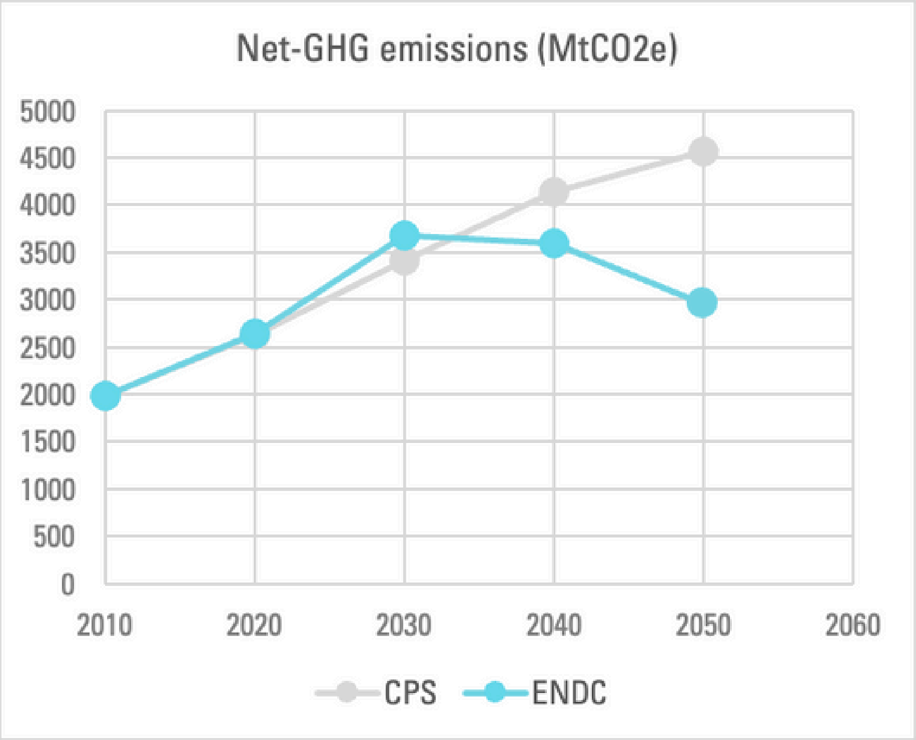
Figure 1. Socio-economic indicators (population, GDP per capita)





- The Indian population is expected to increase to 1,7 billion inhabitants by 2050. Working poulation of India (20-59 years of age) constitutes nowadays 50.5% of the total population and is expected to peak around 2040 with 58.9% share
- The estimated size of Indian economy,the fifth largest economy, is 2.9 Trillion USD (2019). India aims to achieve a 5 Trillion USD economy by 2024-25. The average annual growth rate and inflation from 2014-19 is 7.5% and 4.5% respectively.
- The GDP per capita increases with a faster pace after 2020, to reach 3k$/cap in 2030 and 7k$/cap in 2050; the GDP per capita is similar in the CPS & ENDC.

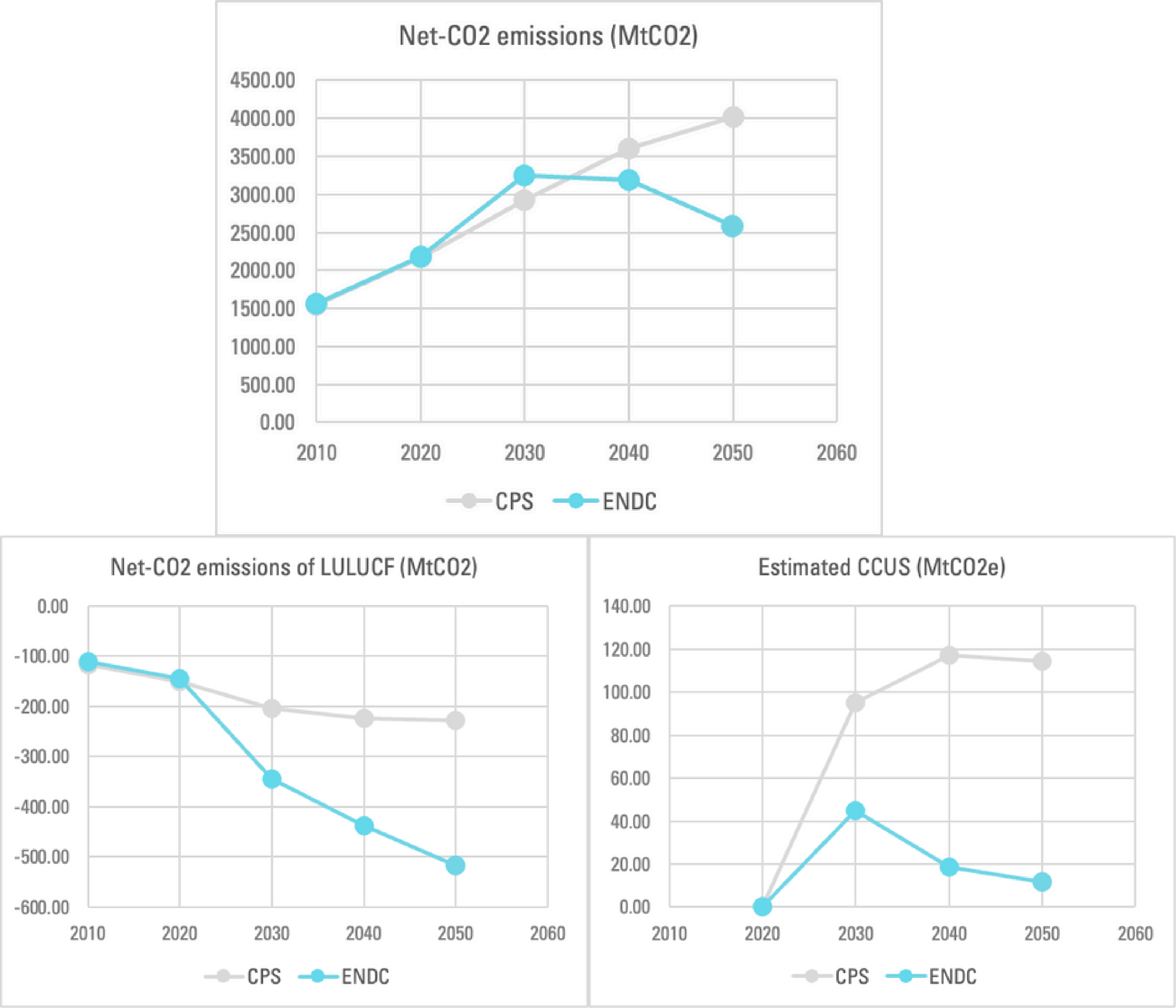
Figure 2. National net GHG emissions



- Emissions will continue to increase from 2010 to 2050 in the CPS, reaching 4,9GtCO2eq in 2050.
- In the ENDC, emissions will peak in 2030 at 3,6 GtCO2eq. Emission level in 2050 is still a higher than 2010 emission level: 2,7GtCO2eq in 2050 and 2GtCO2eq in 2010.
- Only the ENDC scenario allows to meet NDC objectives, it does not allow to meet all greenhouse gas neutrality because projection stops in 2050.

Total net-CO2 emissions represent about 83% of all net-GHG emissions and would decrease by 36% by 2050

Figure 3. National net-CO2 emissions. Top: net-CO2 emissions. Bottom: net-CO2 emissions of LULUCF (left) & estmated CCS (right)



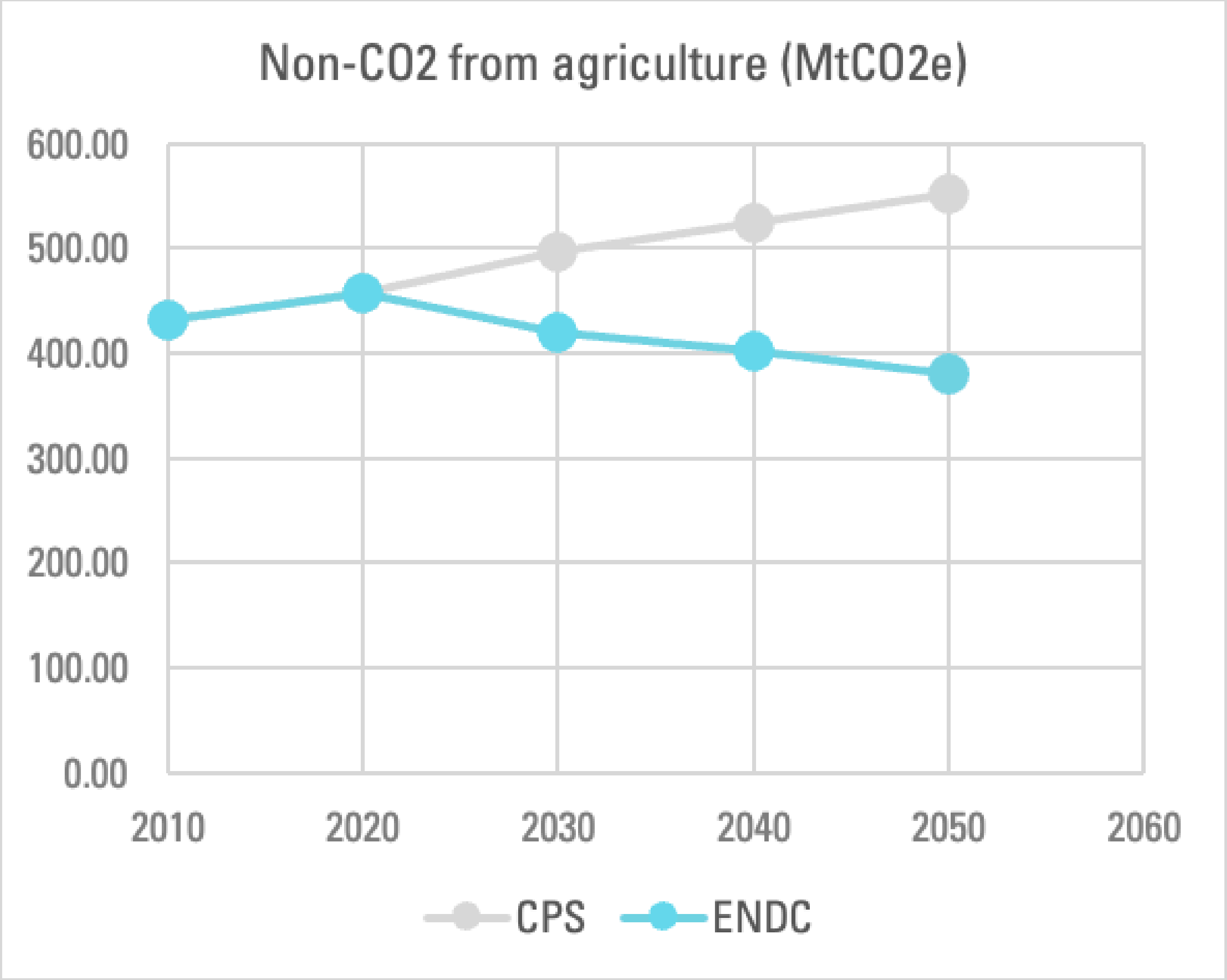
- Excluding LULUCF, 98% of CO2 emissions comes from fuel combustion and are mainly driven by the energy consumption and the current reliance on fossil fuels notably on crude oil and natural gas (processed emissions are included in this figure, and not desagregated from the energy-related emissions). 2% of the CO2 emissions comes from agriculture. Emission from waste rare not represented in the CO2 emissions here.

- CO2 emissions excluding LULUCF increasing in both scenarios until 2030; the ENDC reaches a higher emission level than the CPS in 2030 with 3,6GtCO2eq. The increase in emissions in 2030 is due to increase in industry (due to increase in manufacturing), and building (due to increase in residential and commercial building stock) sector. After 2030, shift to renewables, electrification, increase in EE play a significant role in emission reductions. Emissions in the ENDC are 27% lower in 2050, in comparison to the CPS.
- Emission level in 2050 in the NDC is equivalent to the emission level in the same scenario, between 2020 and 2030.

- LULUCF negative emissions represent 7% of CO2 emissions in 2020. LULUCF emissions are negative in both scenarios between 2010 & 2050. They are 2,5 times lower in the ENDC than in the CPS in 2030, 4,5 times lower in 2050.
- Carbon capture and storage technolologies absorb 3% of the of CO2 emissions in 2030 in the CPS, excluding LULUCF. Those capacities absorb emissions from the power supply : coal and gas power plants.

Total non-CO2 emissions represent 17% of all GHG emissions and could be reduced by 18% by 2050

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

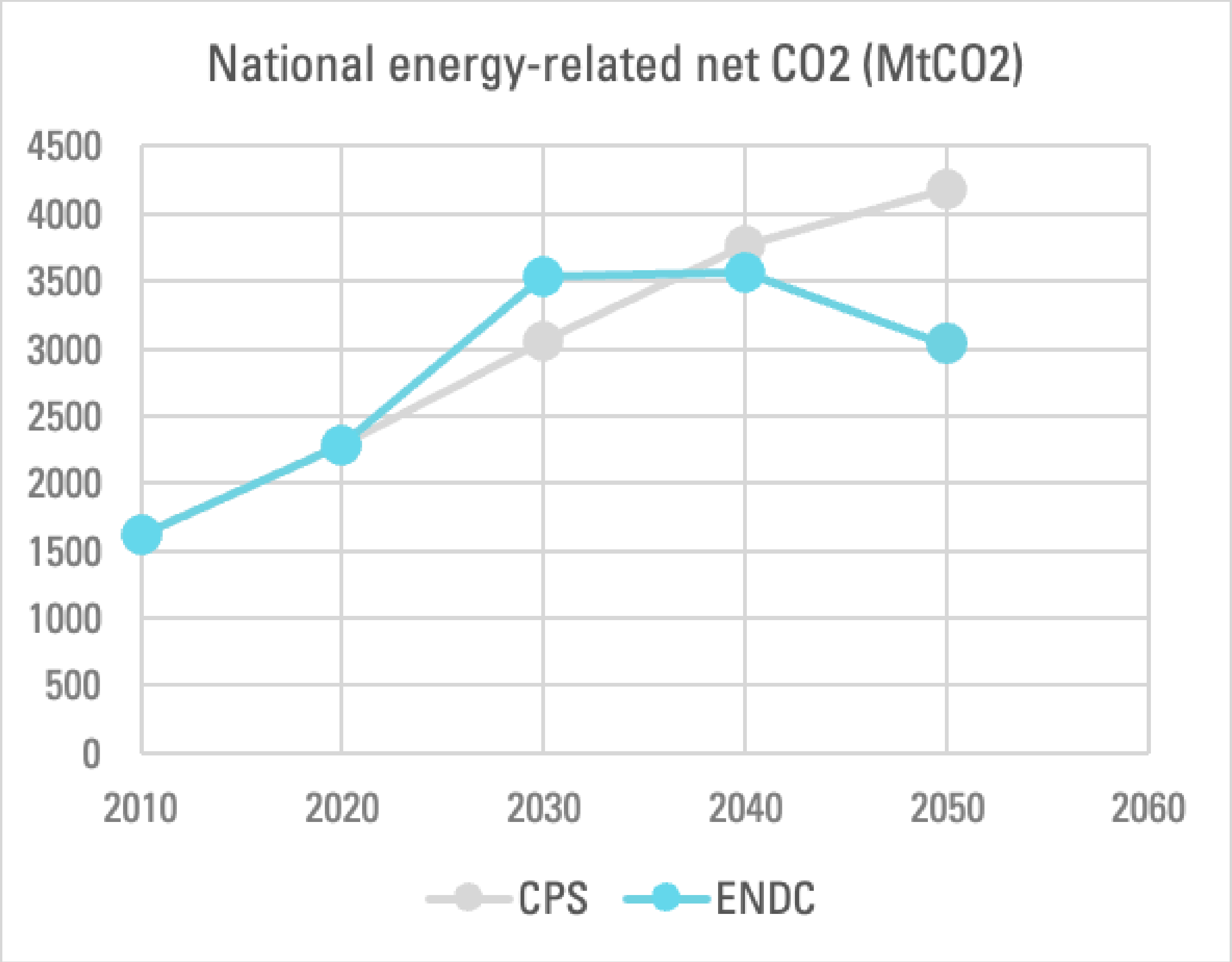


- Non-CO2 emissions accounted for in the scenarios come exclusively from agriculture, as the analysis has not included other key emitting sectors of non-CO2 (eg waste).

- **CPS:** Cropping intensity:Average crop harvesting intensity will increase from 1.1 in 2010 to 1.3 tonne/ha/yr in 2030 and will remain constant at 2030 level for the rest of the period. Livestock productivity increases.
- **Enhanced NDC:** Crop productivity is expected to increase for all the crops, here we focus on the rice systems and yields as the objective of the assessment is on non-CO2 emissions. Low carbon emission methods such as System Rice intensification and soil enriching measures need to be taken. Soil health card scheme has been brought in the government of India, this is expected to provide the farmers with scientific estimates on the fertility status of the soil as well as support informed decisions on use of the quantum of fertilizers and other soil enriching substances. Thus, the crop rotation systems may also evolve to ensure enriched soils.

Total energy-related CO2 emissions represent 87% of all GHG emissions and would decrease by 29% by 2050 (1/3)

Figure 5. National energy-related CO2 emissions



- Energy-related C02 emissions represent 98% of the CO2 emissions here, excluding LULUCF.

- Energy-related CO2 emission increasing in both scenarios until 2030; the NDC even reaches a higher emission level than the CPS in 2030 with 3,5GtCO2eq. After 2030, those emissions reduce in the NDC while they continue to increase in the CPS ; emission in the NDC decrease by 30% in comparison to the CPS in 2050.
- Emission level in 2050 in the NDC is equivalent to the emission level in the same scenario, between 2020 and 2030.

The main decarbonization drivers are simiar to CO2 emissions decarbonization drivers : mainly the development of non-fossil energy production (solar, nuclear and hydroelectric) and the construction of CCS infrastructures.

Emissions perimeter: Due to analytical limitations, this set of scenario does not cover GHG emissions related to the waste sector, to the fugitive emissions from extractive activities, to the energy-related emissions coming from the energy industries: extraction and other fuel transformation activities. According to India's Third National Communication, in waste sector, these emissions represented about 2.65% of Indian emissions in 2016. Petroleum refining accounts for 3.5% while solid fuel manufacture amounts for 0.03% of GHG share (without LULUCF). Fugitive emissions contributed to 1.75 % of which 46% from coal mining and 54% were from oil & natural gas systems.

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 . Energy consumption (PJ/capita)

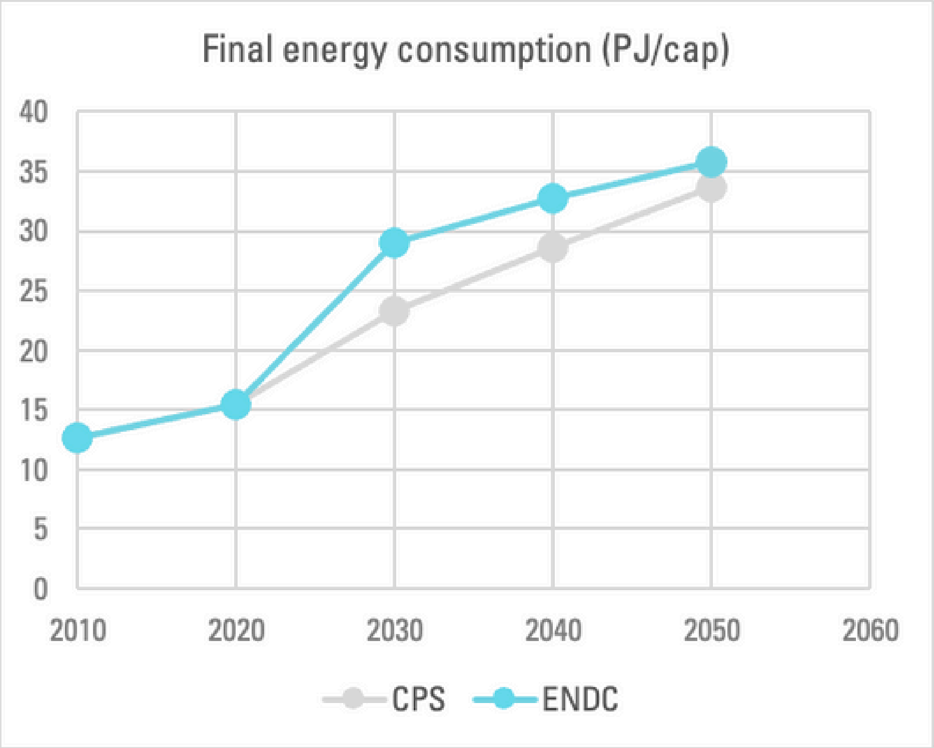


Figure 7. Energy consumption (PJ/GDP)

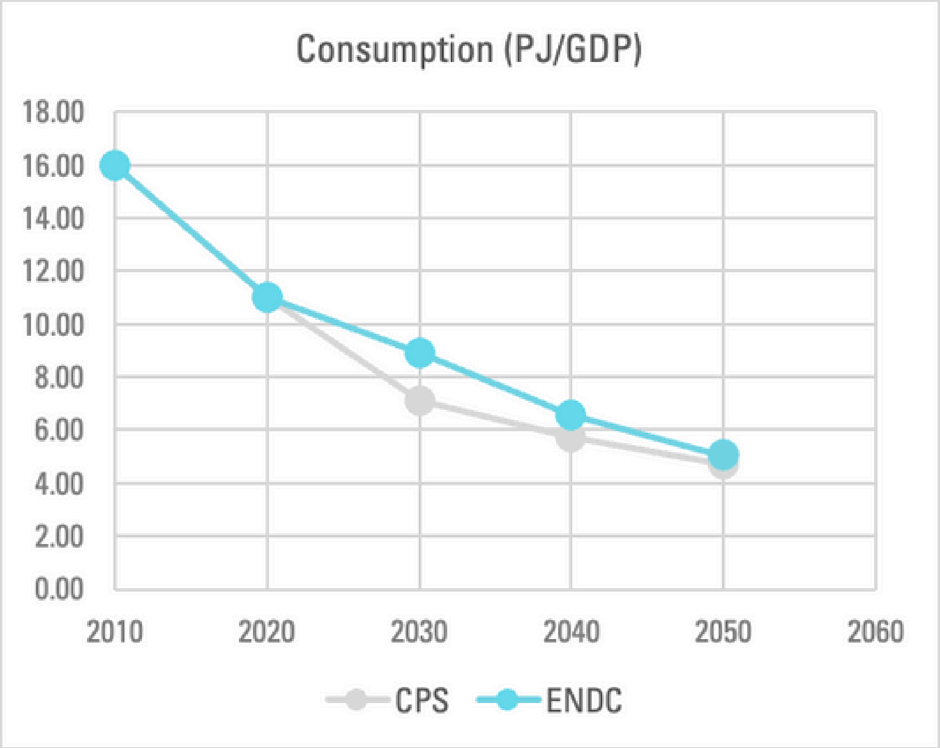
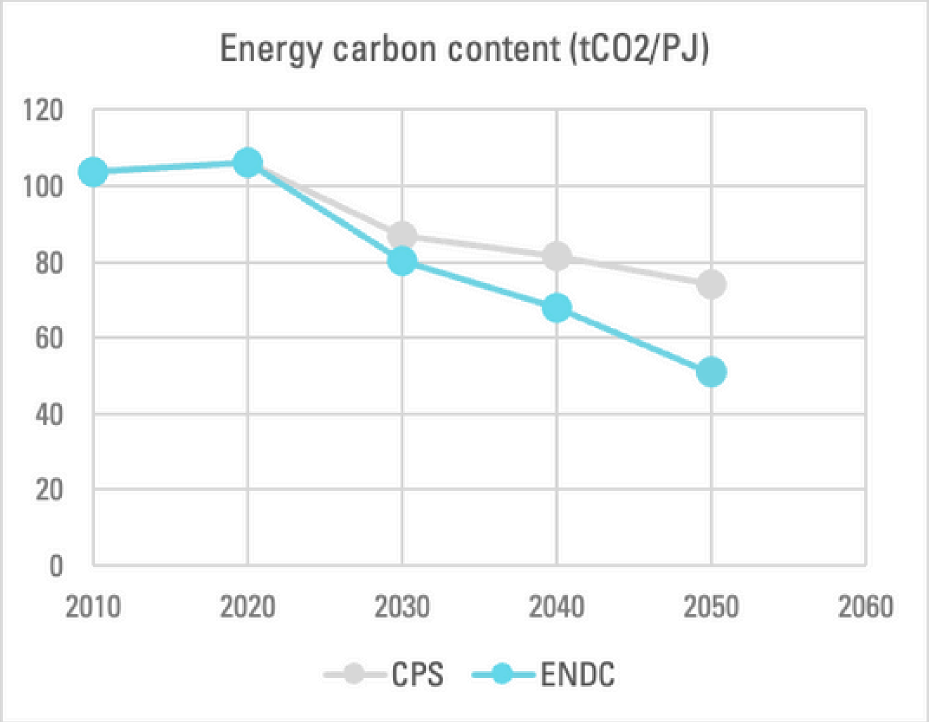


Figure 8. Energy carbon content (gCO2/PJ)



- The energy consumption per capita is increasing in both scenarios by 2050, and is higher in the ENDC. In the CPS, it grows at a slower pace, to reach 29PJ/cap in 2030 and 36 PJ/cap in 2050.

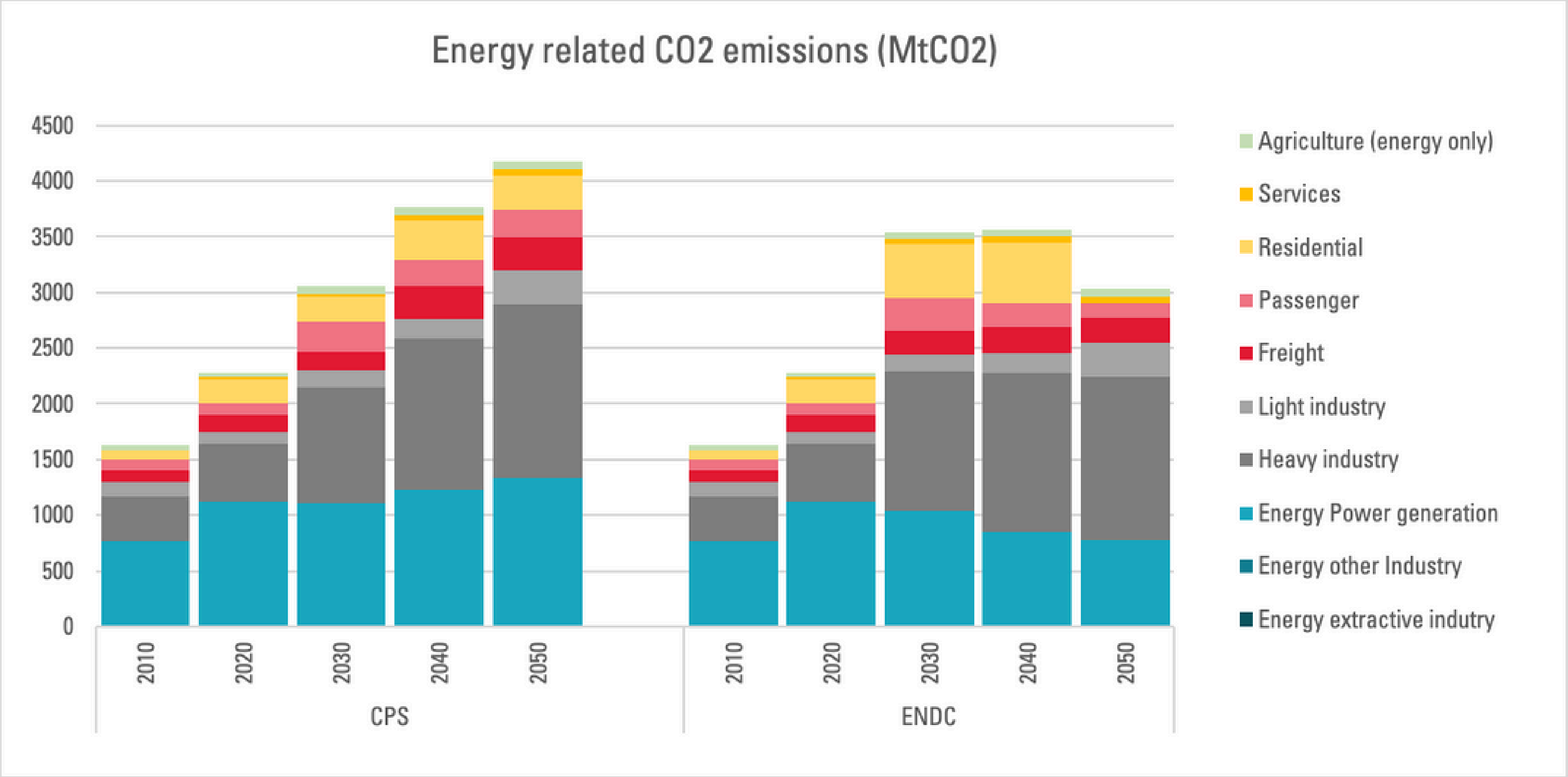
- Energy intensity decreases: energy demand increases but lower than the increase of the GDP (at the denominator).
- Energy intensity reduces (PJ/GDP) until 2050 in both scenarios. The ENDC reaches 5 PJ/ GDP unit in 2050. 2030 is the period where we observe the biggest difference between the ENDC & the CPS energy intensity.

The shift towards zero-emission fuels will enable a decrease in the carbon content of fuels; such as CCS technologies in coal and gas power plants.

Carbon content is higher in the ENDC than in the CPS until 2030. Then it decreases by 32% in 2050 in the ENDC in comparison to the CPS.

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

Figure 9. Energy related CO2 emissions



- Energy-related emissions from extractive and energy energy industries are not accounted here.
- From now until 2030, the energy-consumption sectors with the highest emissions are the power sector, the energy-intensive industries and the light industries.
- A majority of mitigation efforts must be concentrated in these sectors to reach the NDC objectives. Mitigation efforts in the power sector in the ENDC center on development of renewable capacities. However for the other most emitting sectors, energy-intensive industry & residential buildings, energy-related emissions are higher in the ENDC than in the CPS before 2030
- When comparing the CPS and the ENDC in 2050, we see that emissions cuts comes from all the main emitting sectors. Mitigation efforts are made in freight and passenger transports between 2030 and 2050 mostly.

Part 2

-

Sectoral deep decarbonization pathways in the ENDC scenario

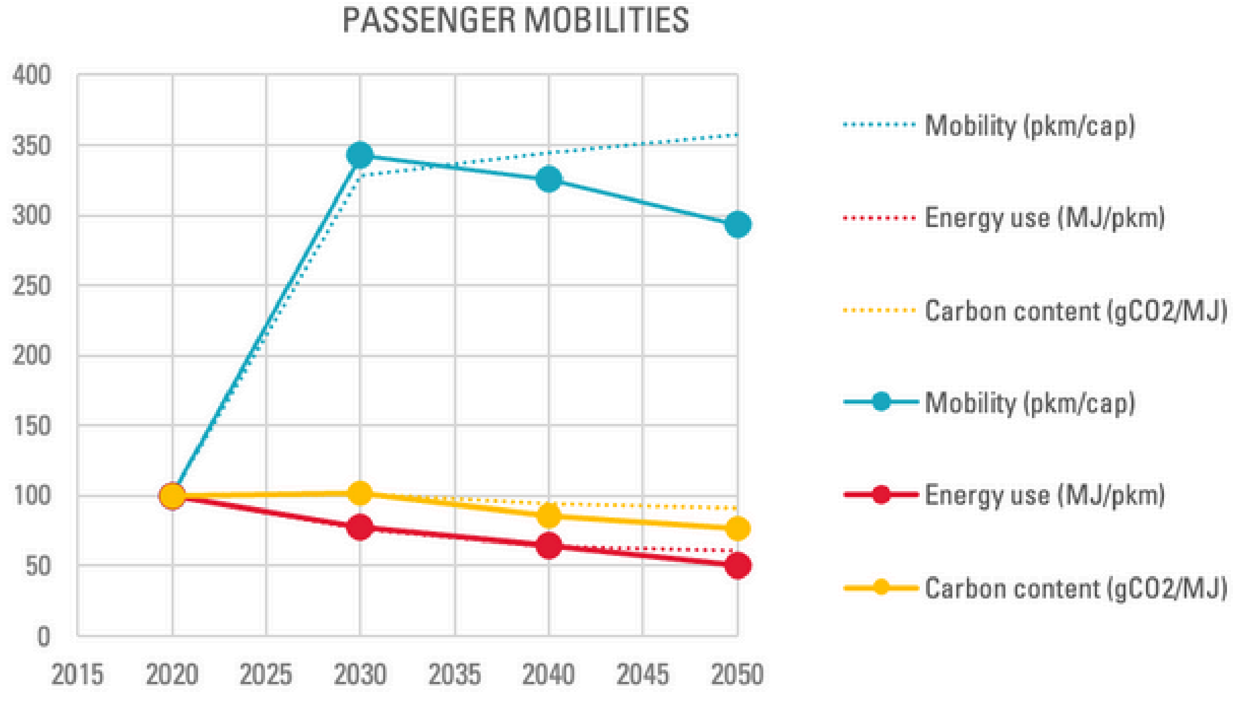
Part 2.1

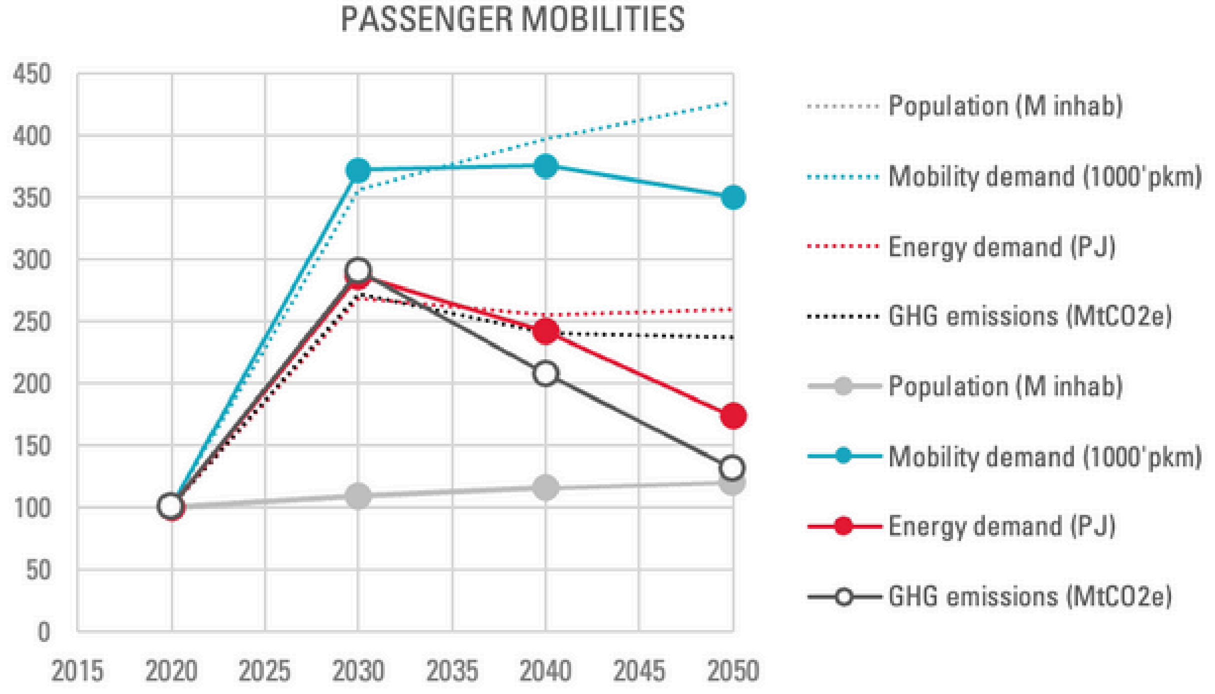
-

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

Developing Paris-compatible PASSENGER MOBILITIES

Figure 12. Sectoral emission drivers and main aggregates (Index, 2020 base year)





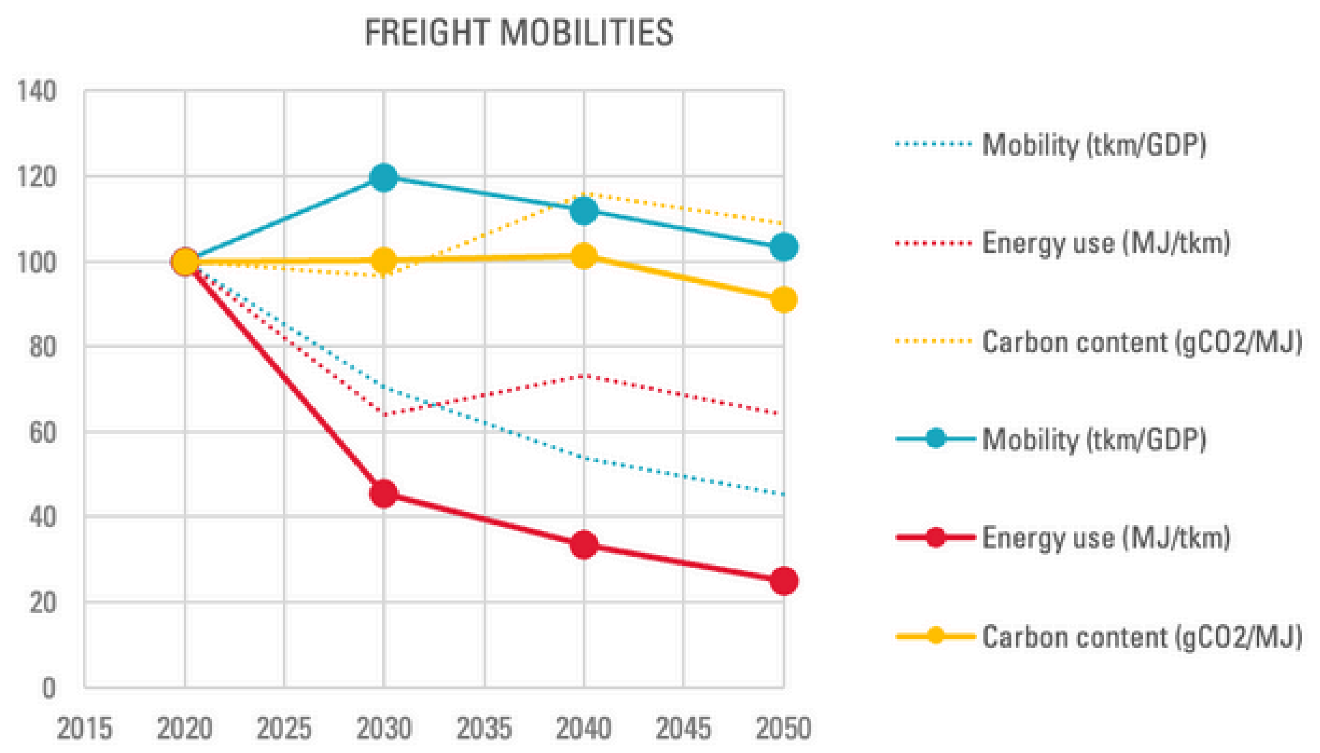
- In both scenarios, mobility demand per capita is expected to more than tripling in the next decade, reaching up to ca. 17'000 pkm/cap by 2030, due to increase in transport demand. However in the EnNDC, this demand will degrow until 2050, while it will continue to grow but more slowly in the CPS. This is due to new planning policies to limit urban sprawl in better designing land use policies with transport infrastructures and services; a development of teleworking supported by governmental tax rebates for companies). In addition, the urban forms of mobility are completely transformed in the EnNDC compared to the CPS, because federal and local governments are establishing mass transit metrorail by 2035 in all cities with population higher than 1 million and developing subsidies to reduce public transport fares.

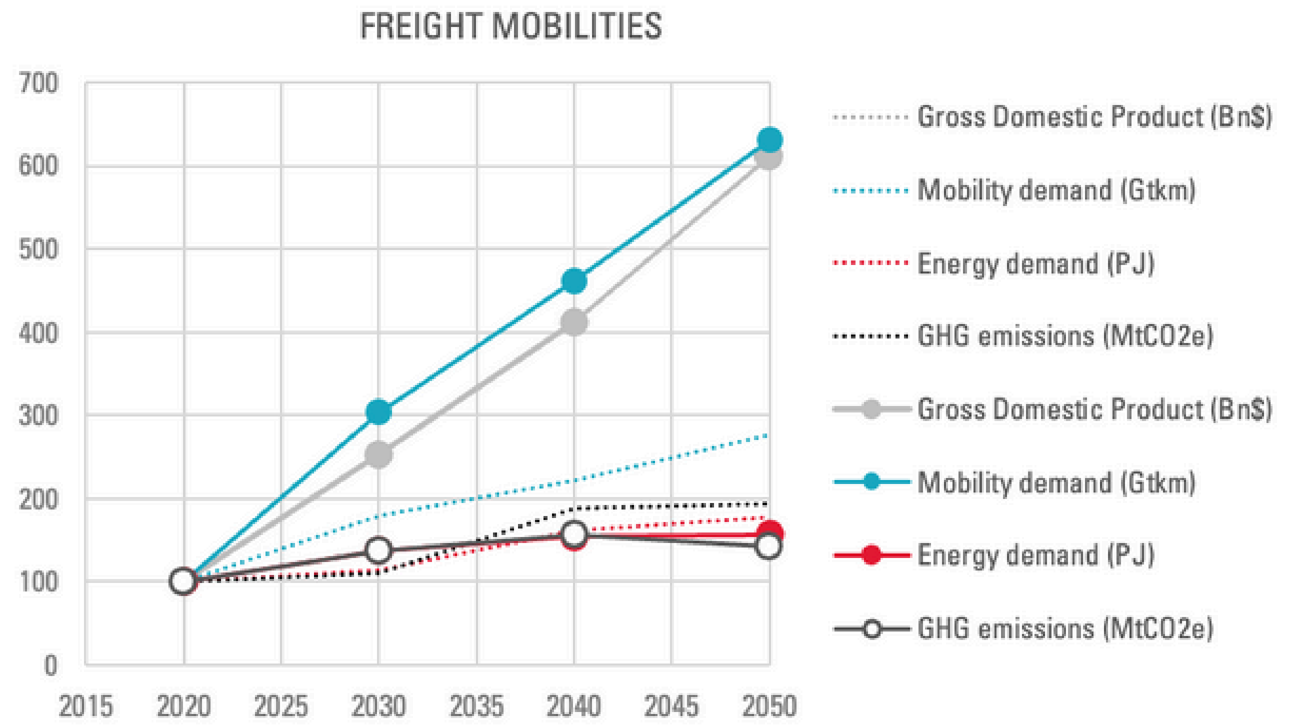
- Regarding the vehicle and fuel transition, the share of electrification increases to by 2050 compared to in the CPS. This is due to an increased electrification of cars, 2W and buses. The exponential growth of electric cars takes the stocks share to nearly 70% by 2050, 43% coming from Battery Electric Vehicles (BEVs), and 27% coming from Plug-In Hybrid Electric Vehicles (PHEVs). Sales continue to increase at the same rate as advancement in technology makes the long-term operational cost for EVs much lower. However, the penetration of EV cars in rural areas will be slowed down compared to urban areas due to lack of adequate charging infrastructure available at suitable locations. In the 2W market, the lead-acid EV scooters will remain more popular in rural areas because subsidies, opposed to the Lithium-Ion models in urban areas. Finally, biofuel will play a role in the transition of the country with blended diesel and petrol. Biofuel will represent in average up to XX% of all transport liquid fuels.

- Combined these transformations enable to moderate passenger transport energy consumption, peaking around 2030 in both scenarios, but decreasing stronger until 2050 compared to a small decrease at stabilisation over 2030-50 in the CPS. In addition, it enables to peak emissions around 2030 in both scenarios, but descreasing stronger until 2050 to ca. 1.3 times the emission level of 2010, and a small decrease and stabilisation at 2.4 times the emission level of 2010 in the CPS.

Developing Paris-compatible FREIGHT MOBILITIES

Figure 13. Sectoral emission drivers and main aggregates (Index, 2020 base year)





- In both CPS and EnNDC scenarios, the freight transport demand is exploding due to high economic and population growth of the country, being multiplied by 6 and 8. The freight demand intensity to GDP will be slightly higher in EnNDC than CPS, which comes from increase in overall freight demand.

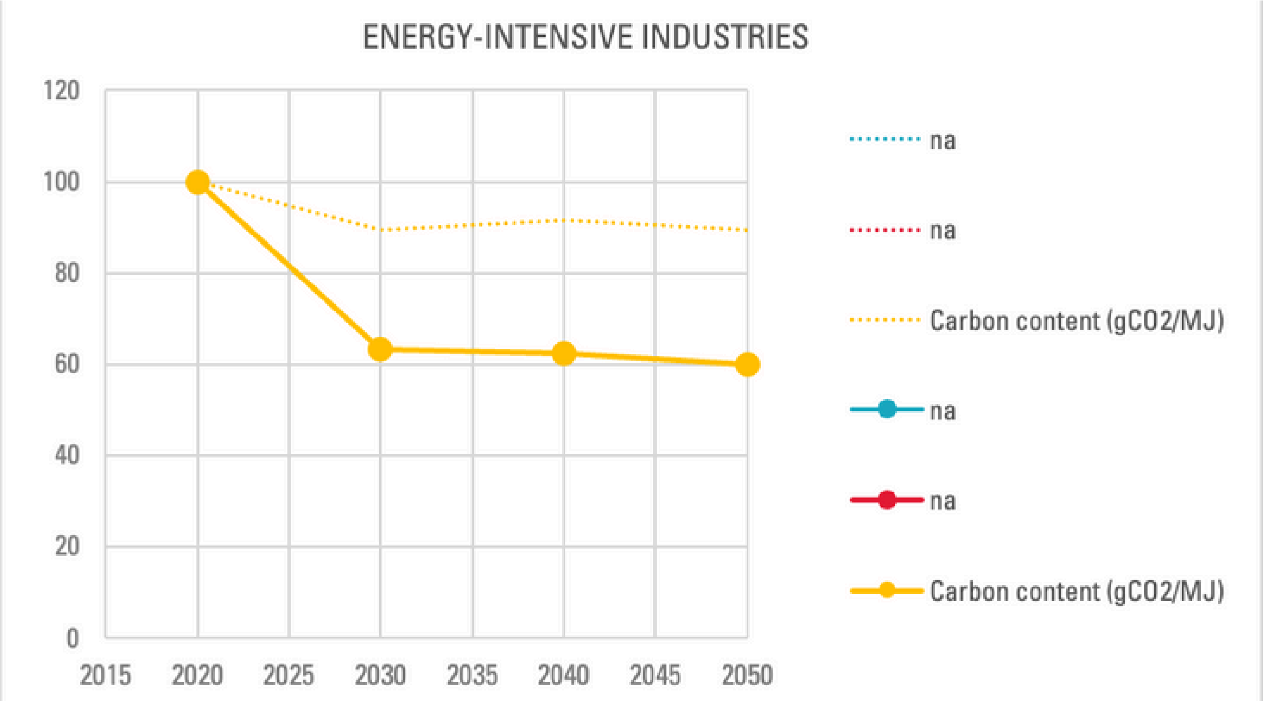
- The country has a dedicated target to increase the share of rail freight transport to reach 25% by 2030, while road freight represents currently about 60% of freight mobility. In both scenarios, there is a significant modal shift towards railways, reaching up to 35% in the CPS and 45% in the EnNDC by 2050thanks to rail technological innovations such as roll on roll off, road-railers; double stack dwarf container train etc, and investments in infrastructures such as DFCs (Dedicated Freight Corridors) on all freight routes and intermodal transhipments hubs to improve convenience, speed and timely delivery thus making companies shift to rail for inter-regional transport of goods like bulk cement, steel, automobiles, FMCG etc.

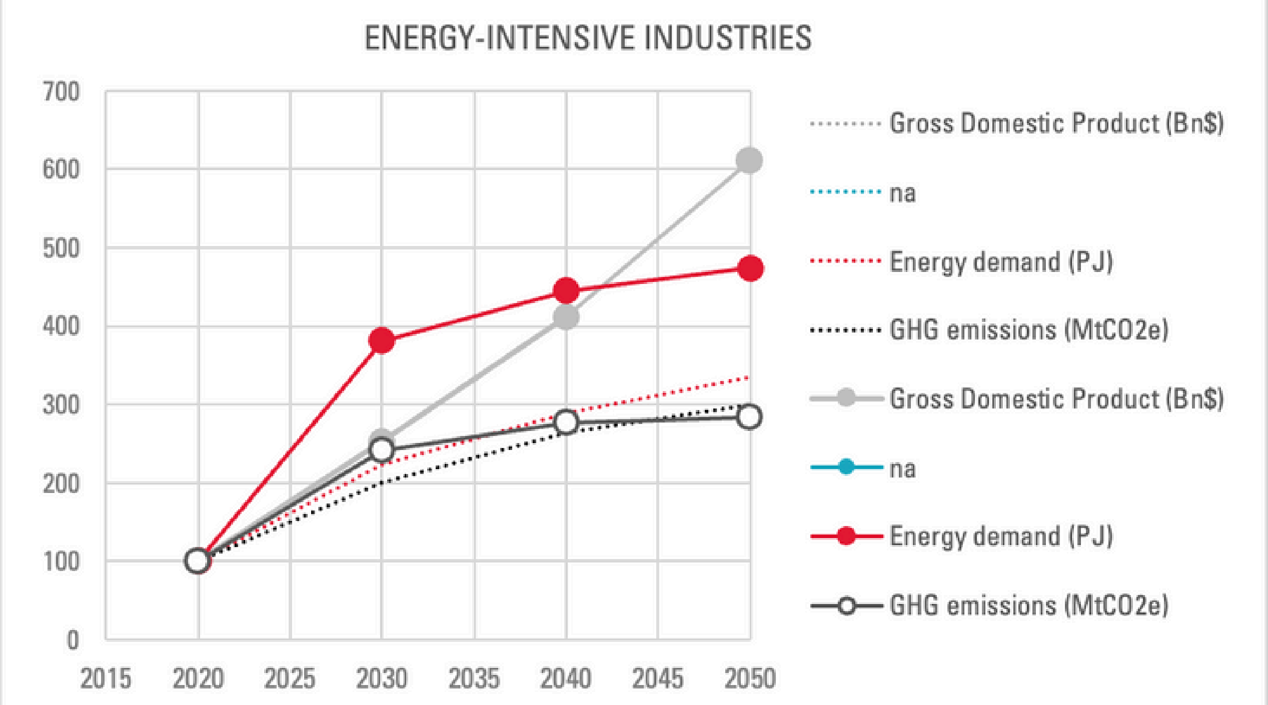
- Regarding the vehicle and fuel transition, the share of electrification increases by 2050 compared to in the CPS. Hydrogen is expected to play a key role in the trucking industry in India until 2040. Nevertheless, EV increase at a substantial rate, making up over 40% of the total market share by 2050 and expected to overtake Hydrogen based vehicles by 2055.

- Combined these transformations enable to slightly moderate the increase of freight transport energy consumption and emissions. In both scenarios, freight transport related emissions are expected to triple in the CPS and double in the EnNDC by 2050.

Developing Paris-compatible ENERGY-INTENSIVE INDUSTRIES

Figure 13. Sectoral emission drivers and main aggregates (Index, 2020 base year)





- Energy intensive industries which includes aluminium,cement, chlor-alkali, fertilizer, iron and steel,pulp and paper, and textiles accounts for more than 60 % of energy consumption of the industry sector.
- Emissions are higher in the ENDC than in the CPS until 2045-2050 : there is no major decarbonization strategy or even decrease of emissions in this sector. We notice an improvement of the carbon content.

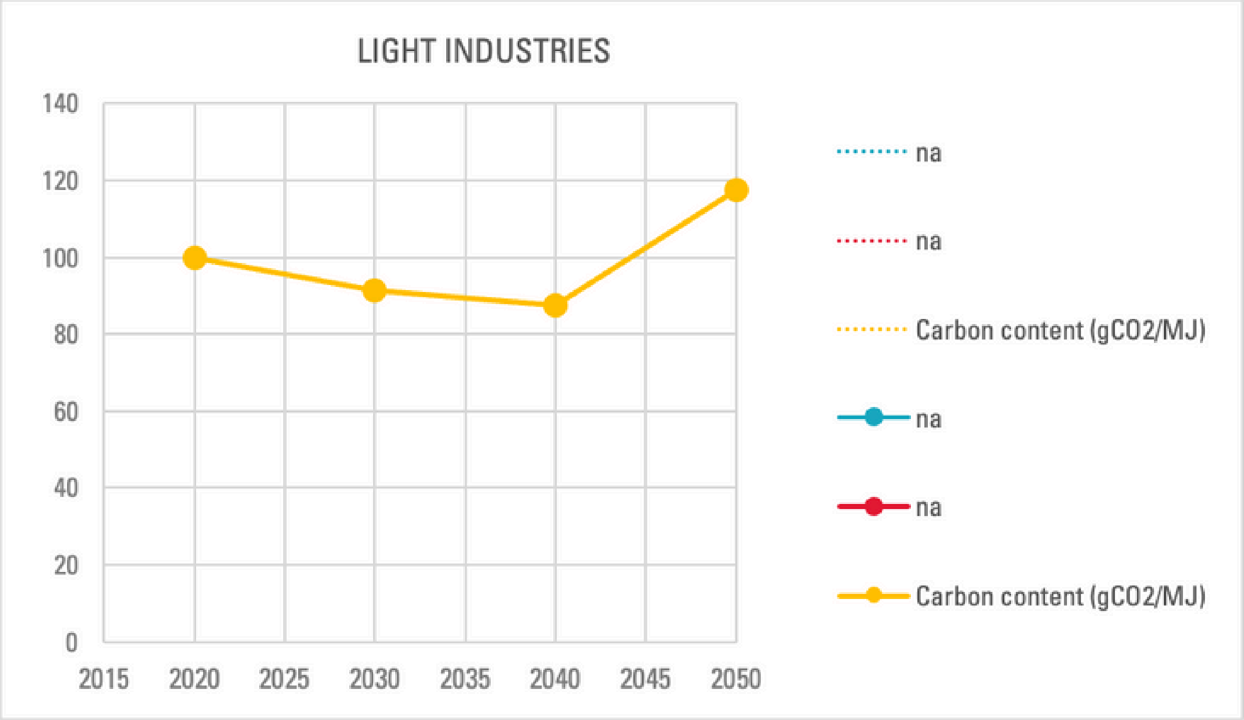
The main drivers of GHG emissions pathways are:

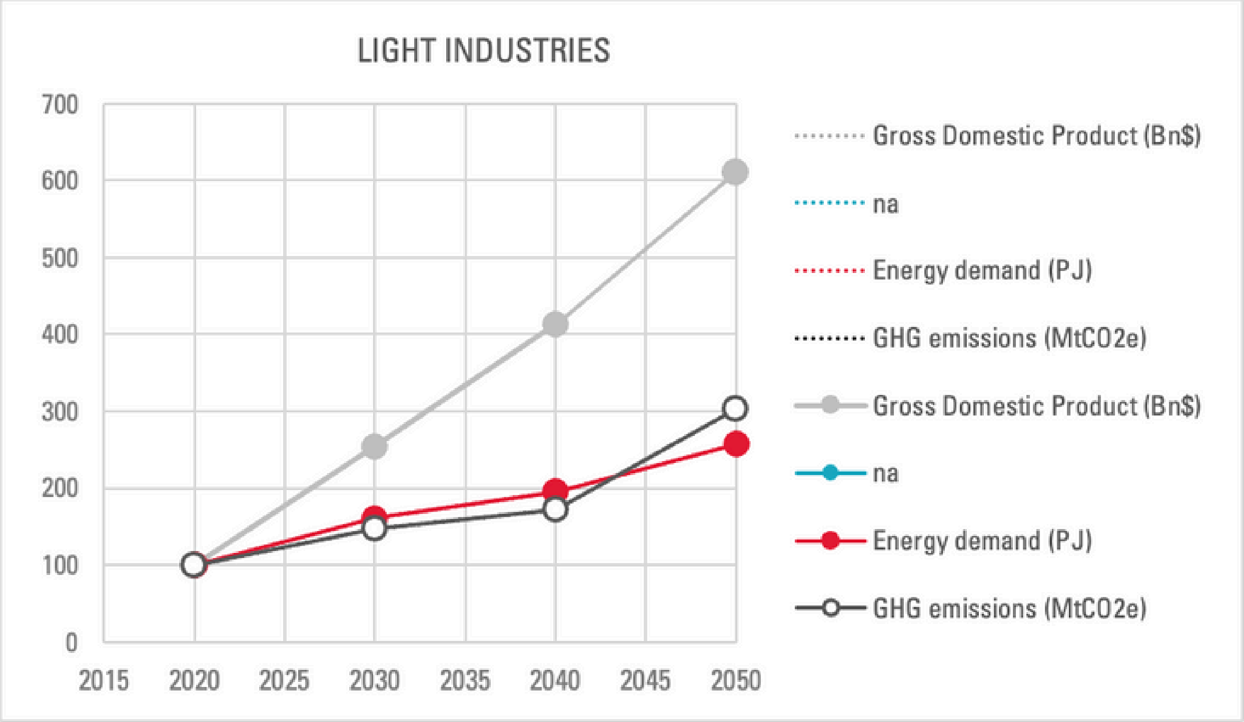
- the increase of the energy demand,
- the electrification in all energy-intensive industries and switching from fosssil fuels and gas to renewable energies.
- energy efficient systems.

- The key additional policies to compared to the BAU should focus on energy efficiency, fuel switching, and the introduction of new feedstocks in the industry

Developing Paris-compatible LIGHT INDUSTRIES

Figure 15. Sectoral emission drivers and main aggregates (Index, 2020 base year)

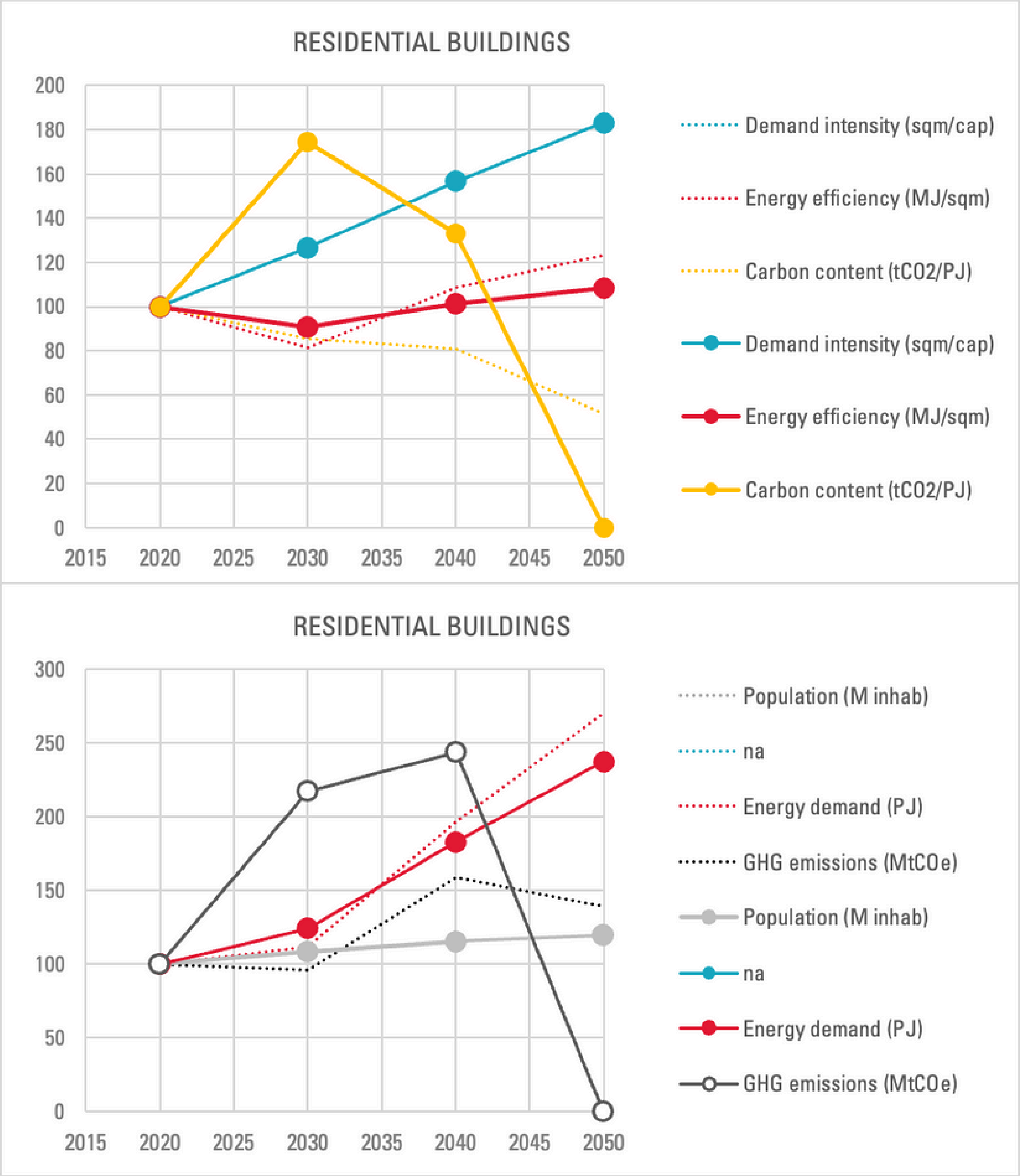




- There is no mitigation strategy for the light industries : emissions are similar in the CPS & in the ENDC. They start at 135MtCO2eq and reach 315MtCO2eq in 2050.
- The carbon content decreases until 2040 before increasing until 21gCO2/ MJ in 2050.

Developing Paris-compatible RESIDENTIAL BUILDINGS

Figure 16. Sectoral emission drivers and main aggregates (Index, 2020 base year)



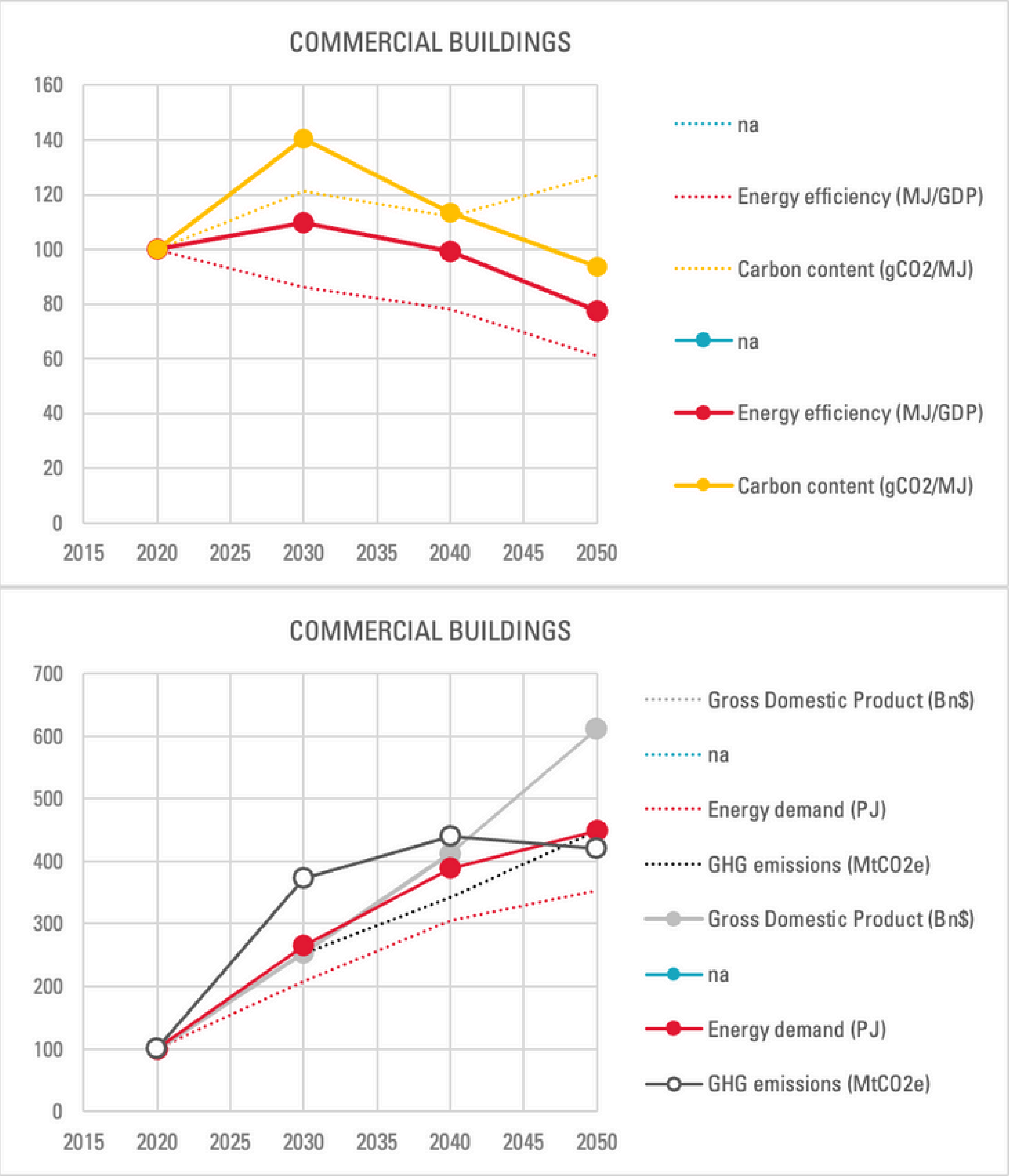
- Urbanization rate increased from 27.7% to 31% in 2020, is estimated to 52.8% in 2050. Buildings in residential and commercial sectors consume over 35% of India's electrical energy. About 75% of the buildings expected to exist in India in 2030 have not been built. In this context, India offers a huge opportunity to avoid carbon lock-in associated with new buildings.
- Decarbonization strategy in the ENDC mainly comes from the reduction of the carbon content and the reduction of the energy consumption.

The main drivers of decarbonization are:

- a total electrification : the residential sector is completely electrified. There completed phase out of kerosene, bbiomass, and LPG.
- the decarbonization of the carbon content. It start decreasing in 2030, before then the use of LPG leads to an increase of the carbon content.
- The deployment of energy efficient systems, leading to a decrease of the energy consumption in the ENDC in comparison to the CPS.

Developing Paris-compatible COMMERCIAL BUILDINGS

Figure 17. Sectoral emission drivers and main aggregates (Index, 2020 base year)



- There is no decarbonization strategy for the commercial building sector : emissions are higher in the ENDC than in the CPS until 2045.

- Carbon content is not clearly decreasing between 2010 and 2050.
- Energy efficiency is higher in the ENDC scenario than in the CPS: respectively 528 MJ/GDP & 416MJ/GDP in 2050.

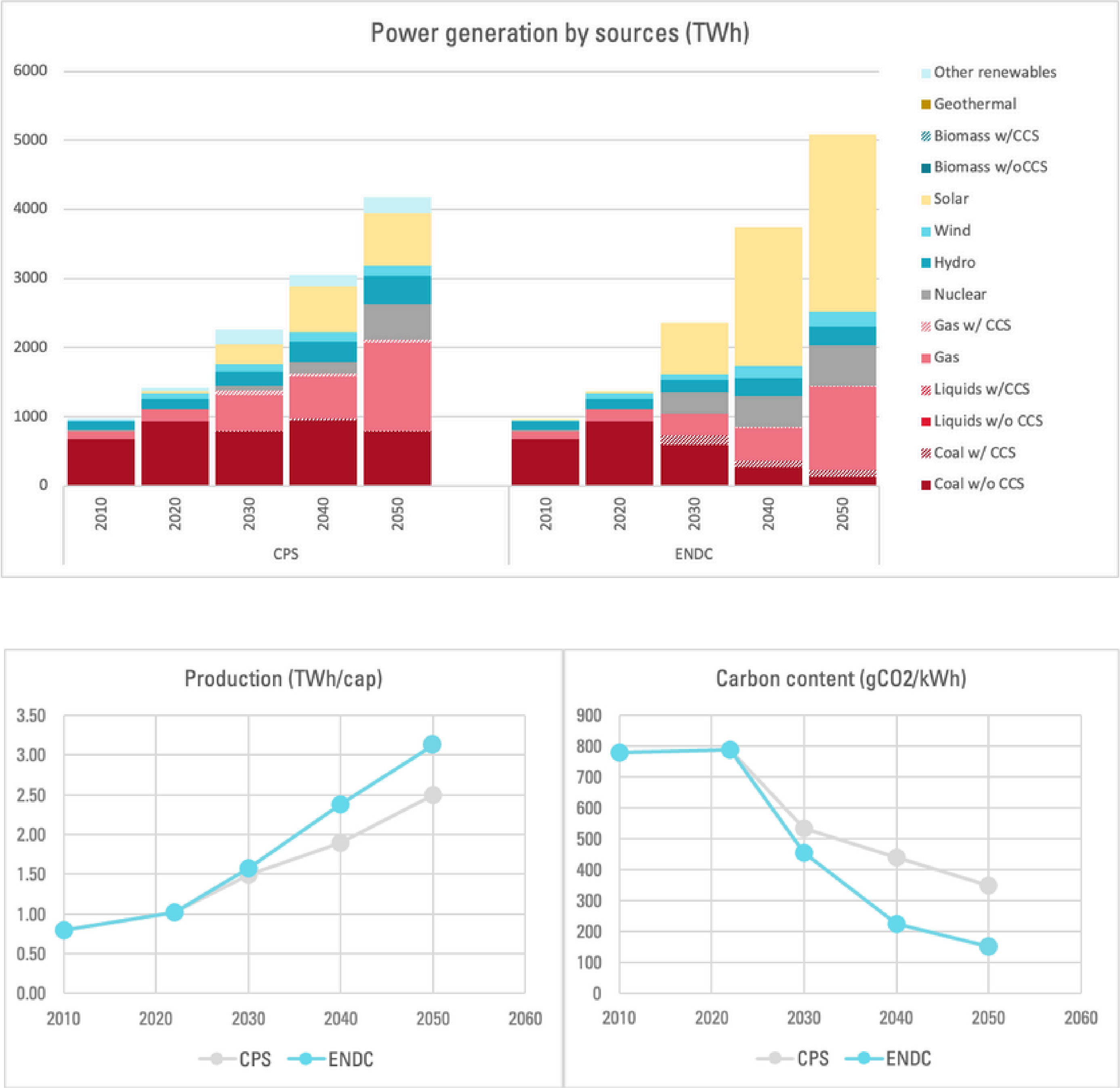
Part 2.2

-

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 TWh/cap & gCO2/kWh) .



- India has recently achieved universal household electrification and current efforts are focused on further improving the quality and reliability of supply, especially in rural areas. Power production is expected to increase in both scenarios, similarly until 2030, to 2,5TWh/cap.
- After 2050, the ENDC shows a deeper electrification, until 3,3TWh/cap, whereas the CPS production per capita stays stable to 2,5 TWh/cap. Moreover, in the ENDC, we observe a deeper decarbonization of the power production, and an improvement on energy efficiency.

The main drivers are :

- a massive electrification, notably in industries and building sectors.
- the decarbonization of electricity production. This can be achieved with large-scale deployment of renewables: hydro, solar and nuclear notably. The ENDC reaches the NDC target of 50% of non-fossil fuel capacity by 2030 with 71%. The CPS shows 45%. The carbon intensity has seen a substantial decline, dropping from 900gCO2/kWh in 2020 to 500gCO2/kWh in 2030, and it continues to decrease further, reaching 150gCO2/kWh by 2050.
- the development of energy-efficient power plants and grid flexibility to minimize T&D losses and its effects on the electricity cost.

The key additional transformations to compared to the NGPS should focus on promoting electrification, developing smart grids and smart meters; the increase of climate investment for the support the develoment of the power system.

Decarbonizing EXTRACTIVE ENERGY INDUSTRIES

- Petroleum refining accounts for 3.5% while solid fuel manufacture amounts for 0.03% of GHG share (without LULUCF). Fugitive emissions contributed to 1.75 % of total GHG emissions. So, 0.08% has been estimated from coal mining while 0.094% were from oil & natural gas systems.

- Coal consumption can be estimated to be 1.2 billion tonnes (bt) by 2030 to about 1.4 bt in 2050 in CPS. The consumption is estimated to 1.1 bt by 2030 and reduced to less than 1 bt in 2050 in CPS. The import of coal can fluctuate between 10-18% based on global and national circumstances.

- India imports about 80-85% of oil. India was the second top net crude oil (including crude oil products) importer of 205.3 Mt in 2019.

- In 2022, 7.0 billion cubic feet per day (Bcf/d) of natural gas was consumed across the residential, commercial, industrial, transportation, and electric power sectors. In 2022, the industrial sector accounted for more than 70% of total consumption, followed by the electric power sector at 17%. In 2022, about half of the natural gas consumption in India's industrial sector was used to produce basic chemicals, mostly ammonia for fertilizer.About 50-60% of gas will be imported.

Decarbonizing OTHER ENERGY PRODUCTION INDUSTRIES

- Green Hydrogen Mission is to make India the Global Hub for production, usage and export of Green Hydrogen and its derivatives.

- India plans to produce at least 5 Million Metric Tonne (MMT) of Green Hydrogen per annum by 2030, with potential to reach 10 MMT per annum with growth of export markets.

- The Mission will support replacement of fossil fuels and fossil fuel based feedstocks with renewable fuels and feedstocks based on Green Hydrogen.

- This will include replacement of Hydrogen produced from fossil fuel sources with Green Hydrogen in ammonia production and petroleum refining, blending Green Hydrogen in City Gas Distribution systems, production of steel with Green Hydrogen, and use of Green Hydrogen-derived synthetic fuels (including Green Ammonia, Green Methanol, etc.) to replace fossil fuels in various sectors including mobility, shipping, and aviation.

- The Mission also aims to make India a leader in technology and manufacturing of electrolysers and other enabling technologies for Green Hydrogen.

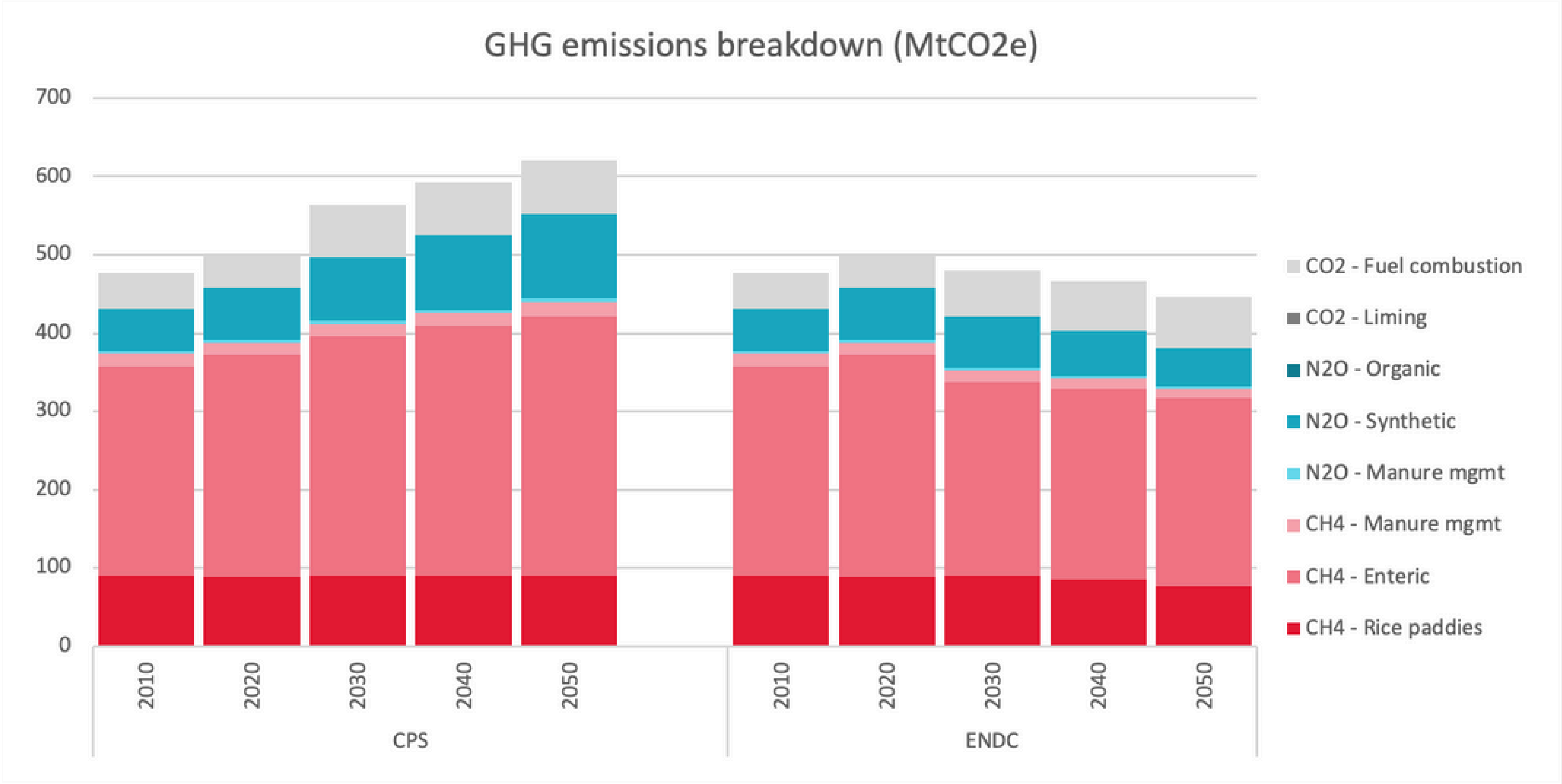
Part 2.3

-

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

Developing a Paris-compatible AGRICULTURE sector

Figure 20.

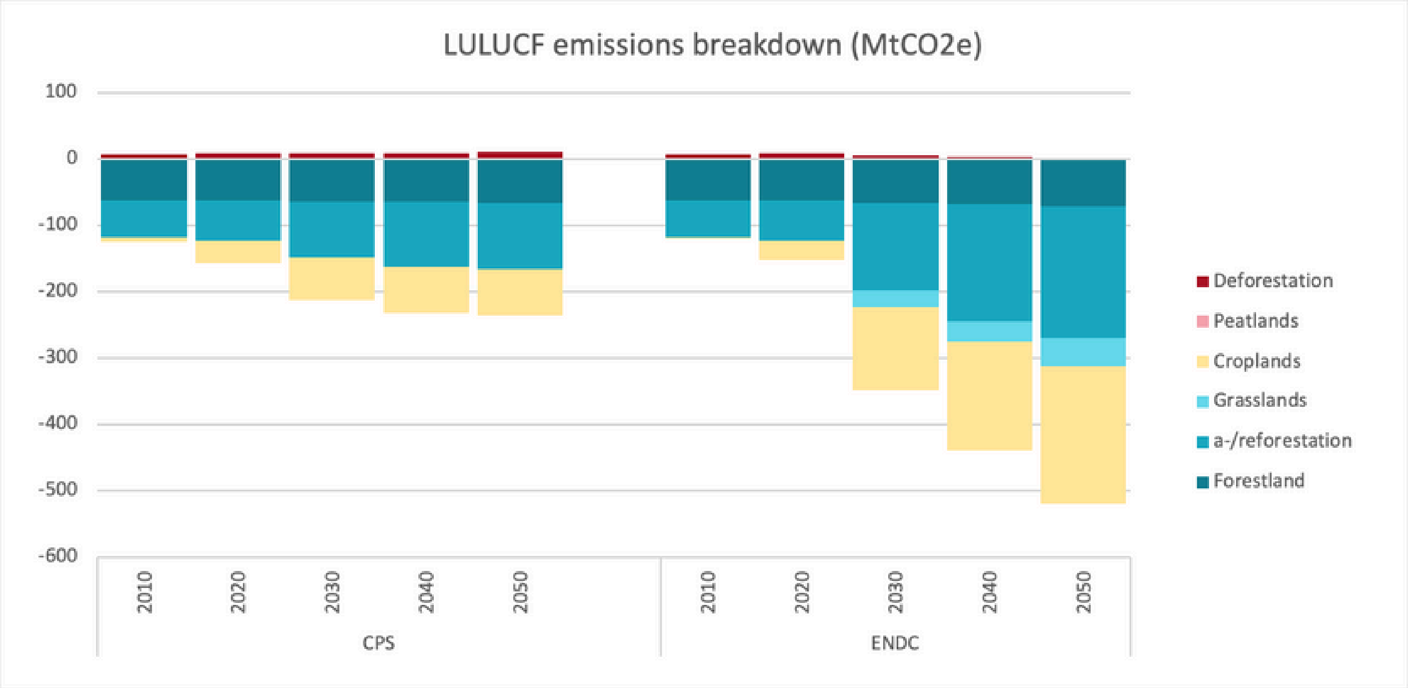


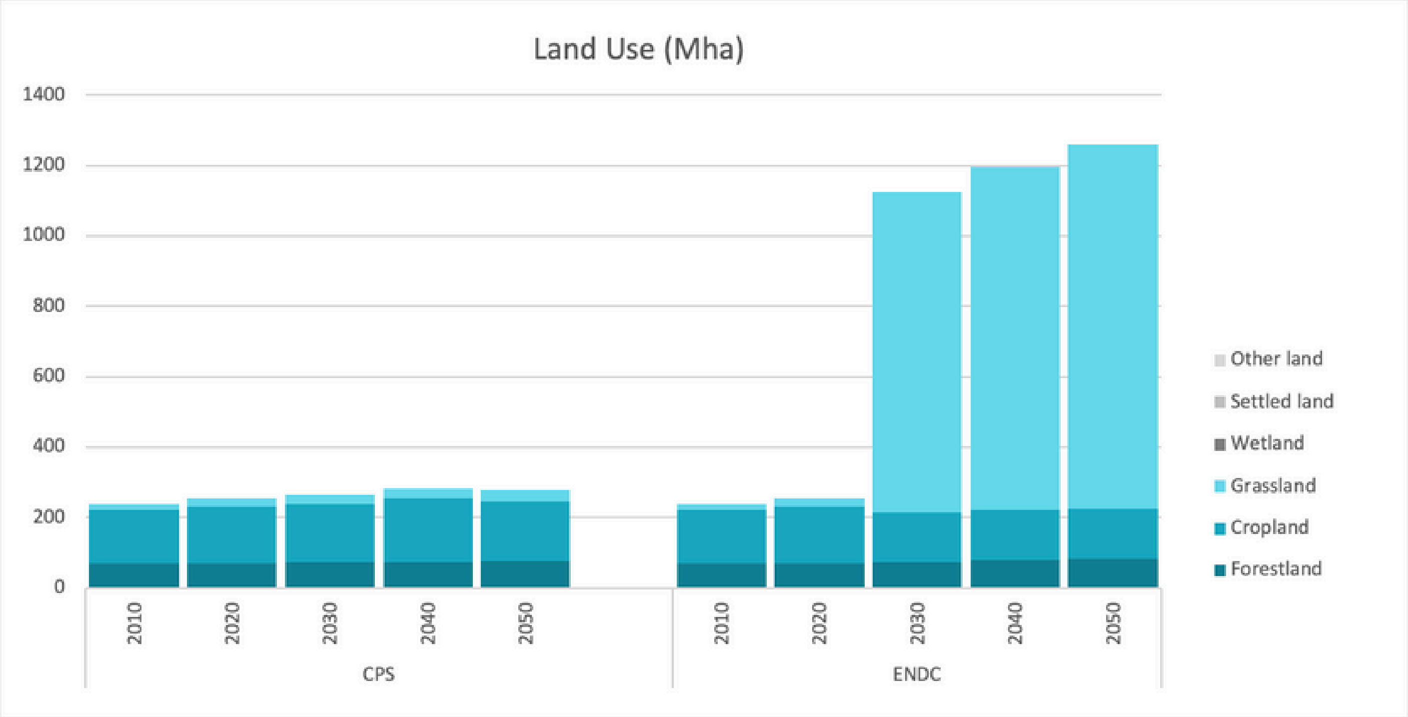
- The main source of emissions in agriculture is enteric fermentation, accounting for >50% of the emissions. Emissions from enteric fermentation reduce by 10% in the ENDC scenario. This reduction is driven by a reduction in the cattle herd (reduces by 14%). Even if the enteric fermentation emissions per head of sheep and goats is much lower than the EF emissions per head of cattle, I am still sceptical to your results showing a reduction in total EF emissions by 10% when the cattle herd reduces by 14% but the goat and sheep herd increases by 1459%. Have you integrated EF emissions from goat and sheep into these projections? Yes, the emissions have been accounted for. The EF considered as per India's BUR-3 for sheep and goat herd is much lower than other non-milk as well as milk cattle.

- The scenario limits agricultural expansion in order to preserve land for forests and bioenergy production. Here, we assume that that 0.5% of waste land and 5% of agricultural land. This is possible due to increases in the cropping intensity, and improved rice productivity. Diets change, and include more animal products following increases in the income of the population. Agricultural management also shifts to practices that allow an increase of carbon sequestration in soils.

Developing a Paris-compatible LULUCF sector

Figure 21.





- In the ENDC, the LULUCF-based carbon sink increases from -144 Mt in 2020 to -517 MtCO2 in 2050, an increase of 260%.

- The main drivers of the increase is an increased carbon storage in croplands, and a/reforestation. There is a significant development of carbon sequestration on croplands, and through in EnNDC. The underlying drivers are an increase in the total surface of forests (from 71 Mha in 2020 to 83 Mha in 2050), and an increase in the application of agroforestry and agricultural practices that allow increasing the carbon storage in soils. There are various agricultural practices that allow for increased carbon sequestration in the soil on croplands including crop rotation practices, application of organic manures and compost, application of biochar, tillage practices, and crop residue management practices to indicate a few. Agroforestry is one such practice that promotes growing different types and varieties of trees on the croplands. Such practice allows for accumulation of more carbon in the soil since it has both forest and grassland storage patterns active on the same piece of land. Agroforestry practices allow for adding high amount of biomass to the soil, reducing the disturbance/tillage and help conserve soil from erosion as well as support water conservation. Hence, it is a practice that helps improve soil carbon sequestration.

Conclusions

-

Key lessons for national & international climate and development decision processes

Lesson 1 - Key areas or sectors which require additional transformations

What are the long-term national pathways 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?

Key findings :

- India's current NDC is consistent with-its on-going development, climate and economic policies. In this study, we focussed on the non-CO2 emissions especially from Agriculture sector as it contributed to 14% of national GHG emissions.
- India's DDS presents that India may achieve carbon neutrality by 2070, however major transformation are required in agriculture and land use sector to achieve GHG neutrality by 2070. As agriculture sector adds 14-16% value to the GDP and employ more than 70% of the population [agriculture and allied sectors], mitigation measures require support to absorb the shock from climate change.
- Coal is reliable and ensures protection of the weaker section of the society in addition to providing energy security. Deep decarbonization of India hinges on its power sector.
- Feasibility of deep decarbonization scenario hinges on numerous factors including availability of the technology, high penetration rate, socio-economic-political consideration and financial support commitments (domestic and international).
- Coal transitions will impact local, subnational regions especially in eastern and south-central part of India.
- Agriculture requires change in feeding stock of livestock, promotion of manure management and significant development of carbon sequestration on cropland through a combination of agroforestry, improved agricultural practices [crop rotation, tillage practices, application of biochar and so on.]

Lesson 2 - Key areas/sectors which require additional transformations to reach net-zero GHG & development objectives

What strategies are needed to get onto those pathways? What would be coherent strategies and policy packages maximising climate and broader sustainability benefits?

- Focus on development policies (and SDGs) when implementing climate actions. India must make electricity affordable in addition to being accessible in the short, medium and long run

- Carbon markets are increasingly the instrument of choice when it comes to market-based solutions for reducing emissions. In this context, the government's proposed amendment to the Energy Conservation Act, the Bill was introduced in the Lok Sabha in 2022, to recognize greenhouse gas emissions is a welcome move. It opens the door for India to create a market to trade in greenhouse gas reductions.

- Challenges: Launching carbon market is time consuming process. There needs to understanding of scope and coverage. India needs to needs to deliberate on who should be allowed to trade. The Indian carbon credits need to be able to trade in international markets. There is a need to calculate baseline carbon emissions for each entity.

- Focus on financial strategies at not only national but also sub-national, local and firm level.: There is a need to establish a clear definition and criteria to make sustainable activities eligible. There is a need to establish an ESG platform to facilitate international ESG investments.

Lesson 3 - Key international conditions to implement them

What key global and sectoral transformations must be considered to enable national Paris-compatible pathways? What are the key international enablers of these sectoral transformations?

- We provide the international conditions required in terms of two technologies essential for Indian deep decarbonization.

CCUS

Given the current stage of CCUS, multilateral agencies and development financial institutions are more likely to be key sources of finance.

- As CCUS matures and the sector de-risks, commercial lenders may also become important financiers. An important component of low-cost finance for CCUS is in the form of outcome-based sustainability loans or sustainability linked loans. Under these mechanisms, proceeds may be borrowed for any activity, but the lending interest rates are lower if certain environmental, social, and governance criteria are being met.

- Green bonds could also be an important source of financing for CCUS.

- The capital-intensive nature of CCUS means that capital incentives would be an important part of policy interventions. For instance, to reduce revenue risks, it is important to have sequestration tax credits in addition to investment tax credits. The former could provide a higher incentive for CO_2 that is not stored/utilized due to absence of market. These credits must be indexed to inflation.

- Climate related financial disclosures are critical to driving investments in CCUS. The Task Force on Climate-related Financial Disclosures (TCFD) sets clear guidelines for such disclosures

Lesson 3 - Key international conditions to implement them

What key global and sectoral transformations must be considered to enable national Paris-compatible pathways? What are the key international enablers of these sectoral transformations?

Battery Energy Storage (BES)

- Green bonds could also be an important source of financing for BES as well.
- Non-monetary or regulatory instruments like subsidies on clean energy technologies and public programs to promote energy storage infrastructure could lso be deployed to promote BES technologies.
- Governments could consider grid-scale battery storage as part of their long-term energy transitions to promote flexibility in power planning and renewable energy integration. In this direction, project tenders from the government agencies that promote the co-location of BES with solar and wind energy projects, with specific annual targets, could be explored.
- In addition, regulatory support to help transmission and distribution companies to use energy storage as an alternative to additional investments in grid infrastructure could be explored.

Challenges: Government of India has recently released a list of 30 minerals critical for India's economic growth and development. Refurbishing, recycling, and mineral recovery would play a vital role in limiting and meeting future mineral demands. India needs to be part of Mineral Security Partnership.

Lesson 3 - Key international conditions to implement them

What key global and sectoral transformations must be considered to enable national Paris-compatible pathways? What are the key international enablers of these sectoral transformations?

- Developed countries and India will need to collaborate for incentivising solar (power, building), wind (power), BECCUS (power, industry, agriculture), and green hydrogen fuel transformation (industry, transport) technologies in the next 2-3 decades.

- There is a need to create a common technology development pool (battery storage, grid integration, electric vehicles, CO2 capture utilization and storage (CCUS), hydrogen, advanced bioenergy and nuclear power) in which industrialized and developing countries are equal partners. These technologies are required to upscale DDS scenarios for even earlier net zero by India.

- South-South collaboration is also possible between India, other developing and least developing countries especially in South East Asia and Africa for solar and bioenergy.

- Presently India has bilateral S&T cooperation agreements with 83 countries. During recent years the cooperation has strengthened significantly with Australia, Canada.

- EU, France, Germany, Israel, Japan, Russia, UK and USA. Nature of access to technology development, production and manufacture depends on ownership of technology and the financial mechanism in which the technology is transferred.

- The types of mechanisms include trade, FDI, JV, licensing agreement, strategicacquisitions and alliances, overseas R&D, joint R&D and local innovation. For example, moving towards a hydrogen fueled economy will become viable only through international support, even as the source of hydrogen (blue or green) will be highly debated for the coming decades.

Lesson 4 - Fair national contributions to the GST outcome

Based on Article 28 of the GST outcome text of COP28, please check all or select the most relevant (a) to (h) outcomes for your country and describe the fair country contributions towards those differents global goals.

a.Tripling RE capacity globally by 2030 and Doubling EE rate by 2030

- India's RE target will only triple its current capacity at 750 GW in 2050 under DDS scenarios
- India's EE rate will increase in the next three decades. The development of energy-efficient power plants and grid flexibility to minimize T&D losses and its effects will play a crucial role.

e. Accelerating efforts towards NZ – RE, nuclear, CCUS, hydrogen

- The ENDC reaches the NDC target of 50% of non-fossil fuel capacity by 2030 with 71%. The carbon intensity has seen a substantial decline, dropping from 900gCO_2/kWh in 2020 to 500gCO_2/kWh in 2030, and it continues to decrease further, reaching 150gCO_2/kWh by 2050.
- The power mix does increase share on RE, nuclear. Emissions from coal is reduced with installation of CCUS.

f. Accelerating efforts to reduce methane emissions by 2030

- Agriculture requires change in feeding stock of livestock, promotion of manure management and significant development of carbon sequestration on cropland through a combination of agroforestry, improved agricultural practices [crop rotation, tillage practices, application of biochar and so on.]

Lesson 4 - Fair national contributions to the GST outcome

Based on Article 28 of the GST outcome text of COP28, please check all or select the most relevant (a) to (h) outcomes for your country and describe the fair country contributions towards those differents global goals.

g. Accelerating efforts to reduce emissions in transport sector

- India's railway sector will be NZ by 2030
- India's freight transportation share will increase to 45% by rail by 2030
- India has policies to shift its 2W, 3W and 4 W fleet to electric vehicles by 2030

h. Phasing out inefficient fossil fuel subsidies

- India removed subsidies from petrol and diesel in 2016
- India has relatively high taxes on petrol and diesel which are intended to acts as carbon tax
- India has increased it tax on coal (also called Clean energy cess) by three times from USD 0.8 per tonne in 2010 to USD 3.2 per tonne in 2016. This translates to about USD 4 per tonne of CO_2.