Deep decarbonization pathways in MEXICO

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Lessons from the EU-funded research project IMAGINE

1

Table of contents

Introduction

This work takes place in a context where:

- *the implementation of policies to achieve NDC targets has been limited, due to a lack of national climate action from the current administration. The administration will leave office in December 2024.*
- *in November 2022, Mexico submitted its Updated NDC targets, replacing the former from 2020, itself replacing a first submission in 2016. However, both 2020 and 2022 updates establish less ambitious targets than the 2016 NDC.*
- *Despite that the 2022 NDC update increases the percentage reduction of the unconditional target from 22% to 35% (30% with own resources and an additional 5% from agreed international support) by 2030 and from 35% to 40% conditional on additional international support, the business-as-usual (BAU) baseline, against which the targets are defined, has been revised upwards. In addition, Mexico expects a higher contribution of emissions sinks in forests to achieving the target. Hence, the new target can be met even if emissions excluding those of LULUCF exceed the old 2016 emission target.*
- *Mexico has not submitted a Net-Zero target. The targets presented in the 2022 NDC update are solely focused on 2030.*

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

- **The Delayed NDC (D-NDC) :** this scenario illustrates the policies needed to achieve Mexico's NDC targets, with implementation starting in 2025. It represents the current administration action and does not allow to reach all greenhouse emissions neutrality before 2050.
- **The Delayed Deep Decarbonization Pathway (D-DDP) :** this scenario illustrates the transformations needed to reach net-zero all greenhouse emissions around 2050. It shows a delayed implementation of the mitigation actions, with most of the efforts made between 2030 and 2050, in to reflect the current administration's delay. This scenario shows systemic changes : decarbonization is associated with positive impact on socio economic indicators (reducing poverty and inequalities, food security, improvement of the quality of life …)

Research questions for scenario framing

1) What are the additional transformations required to reach net-zero CO_2 emission before 2050 in the current Mexican context of delayed mitigation actions?

2) What are the potential impacts on other socioeconomic dimensions from engaging on a deep decarbonization pathways, even with delayed action?

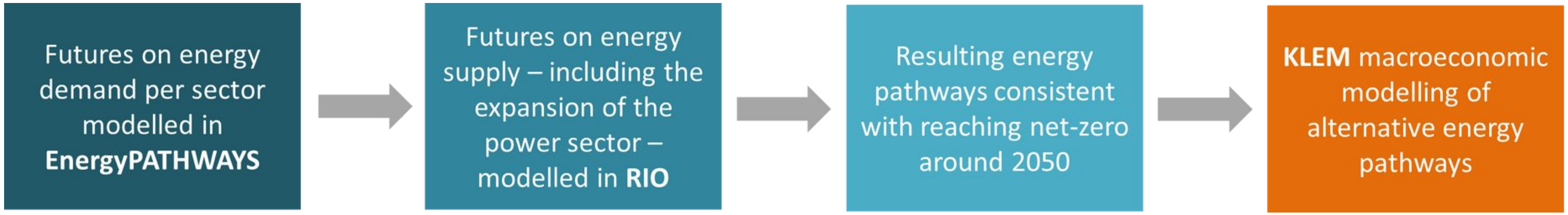
- The comparison of D-NDC with D-DDP will inform us on the additional transformations required to reach net-zero CO_2 even with the current delayed implementation of mitigation policies.
- The comparison of D-NDC with D-DDP will inform us on the potential macroeconomic impacts of decarbonizing. It is expected to show what type of policies should be designed in order to avoid negative impacts of decarbonization and create opportunities to achieve socio-economic objectives.

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

- What are the main emitting sectors and what sectors should be particularly address 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?
- What potential co-benefits (such as energy or food security) could be associated to a decarbonization pathway, even at a qualitative level?

Modelling architecture & improvements

- KLEM estimates the value-add resulting from any energy productivity improvements contained in the (exogenous) energy pathway and, to be conservative, removes it from the GDP to ensure the model does not present “free” efficiency gains.
- However, in instances such as structural change, energy productivity can improve as a co-benefit of other processes, without additional investments (AIEE or “Autonomous Improvements in Energy Efficiency”). Therefore, KLEM includes a parameter named “Energy Productivity Gains” that allows the economy to reflect “free” improvements to some degree.
- The IMAGINE scenarios include several different energy productivity improvements:
    - Structural changes as Mexico’s GDP shifts from 64% to 70% services
    - Better decision-making leading to more cost-effective choices (e.g. PEMEX v solar)
    - Energy fleet improvements, both through gradual renewal (e.g. new car more efficient than the old one) and through accelerated technology shifts (e.g. ICE to EV vehicles)
- Each of these drivers of energy productivity should be considered in turn for each scenario to determine if they are “free” as part of our approach to energy system investments. (*)



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

- *KLEM key publication under redaction.*
- *Energy modelling in Energy PATHWAYS and RIO: Evolved Energy Research. (2019). 350 ppm Pathways for the United States.*

Nowadays, the power sector, AFOLU and passenger transport are the most emitting sectors in Mexico

The power sector, AFOLU and passenger transport are the most emitting sectors nowadays in Mexico, considering GHG emissions.

- The power sector is the most emitting sector (GHG & CO_2) in Mexico due to the high reliance on gas-power plants. See slide 23 for the power generation and slide 24 for extractive activities.
- AFOLU is the second most emitting sector (GHG) in Mexico, mostly due to agricultural activities (enteric fermentation, maize production, synthetic fertilizer application) and related deforestation : see slide 27 & 28 for AFOLU decarbonization strategy.
- For the passenger transport: this is mostly due combustion emission from liquid fuels (see slide 16 for passenger transport decarbonization pathway).

Figure 1. Main indicators for 2018

Indicator	Value in 2018
GHG emissions ($MtCO_2$)	673
CO_2 emissions ($MtCO_2eq$)	484
CO_2 emissions per capita ($MtCO_2$/cap)	4
Non-CO_2 emissions ($MtCO_2eq$)	189
Final energy consumption per capita (GJ/cap)	41
Population (Million)	125
GDP (billion $ 2010)	1283
Most emitting sectors (GHG)	power, AFOLU, passenger transport
Most emitting sectors due to combustion (CO_2)	power and passenger

Part 1

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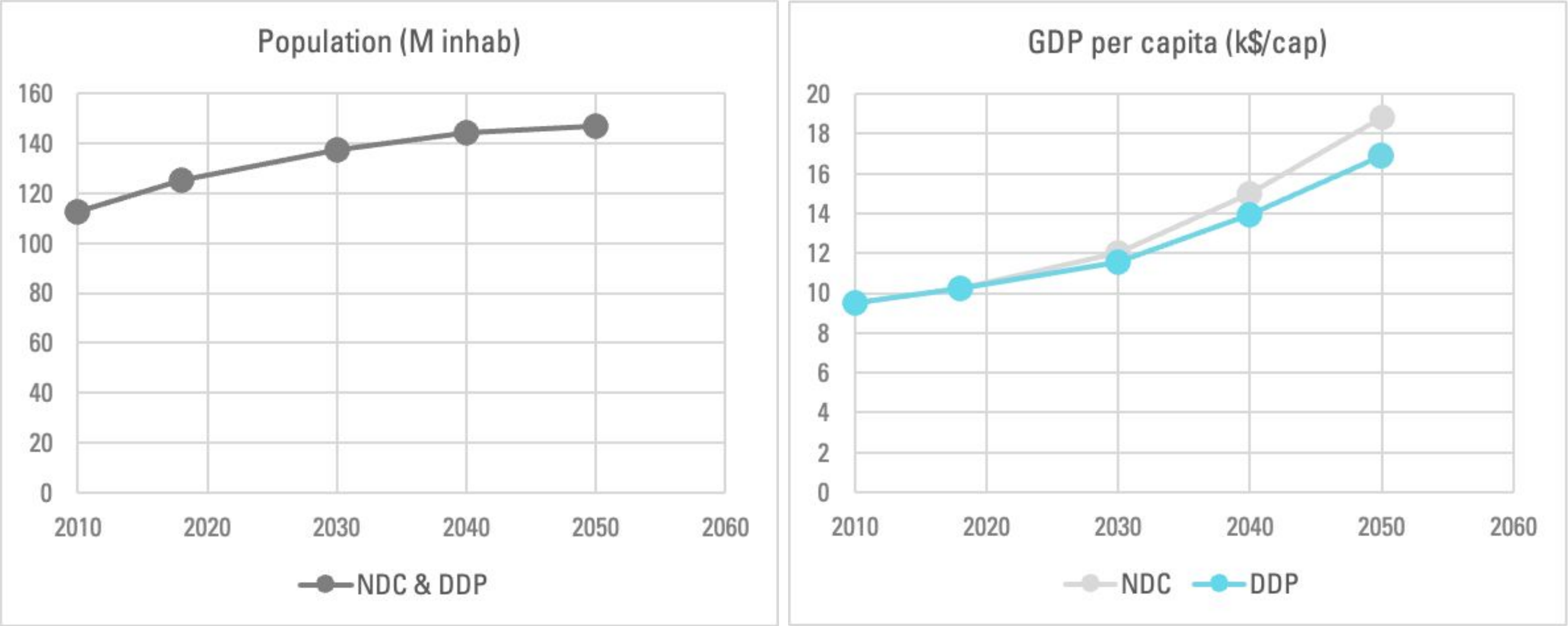
National overview of the deep decarbonization pathways

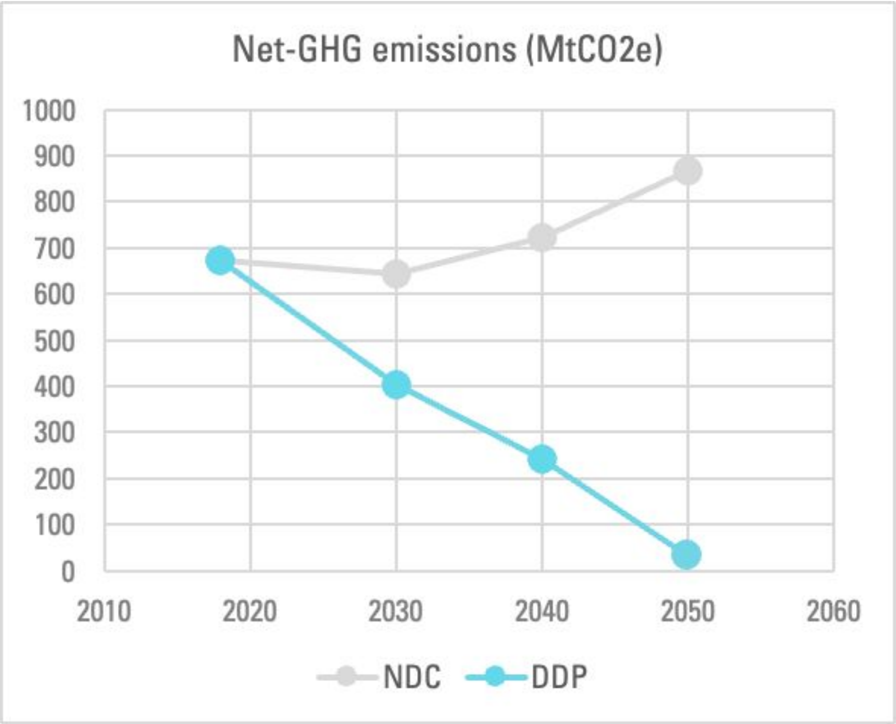
Reaching net-zero GHG emissions by 2050 is feasible, while ensuring socio-economic development

Figure 2. Socio-economic indicators (population, GDP per capita)



- Population growth is starting to slow down from 112 million in 2010 and 125 million in 2018 to 138 million in 2030.
- In the D-NDC scenario, the estimation of the impact on economic growth for the reduction of emissions committed in the NDC will be around 4% of the GDP (compared to the natural growth) in 2030; and 5% in 2050.
- In the D-DDP scenario, the estimation of the impact on economic growth for the reduction of emissions committed in the DDP will be around 3% of the GDP (compared to the natural growth) in 2030; 9% in 2050.

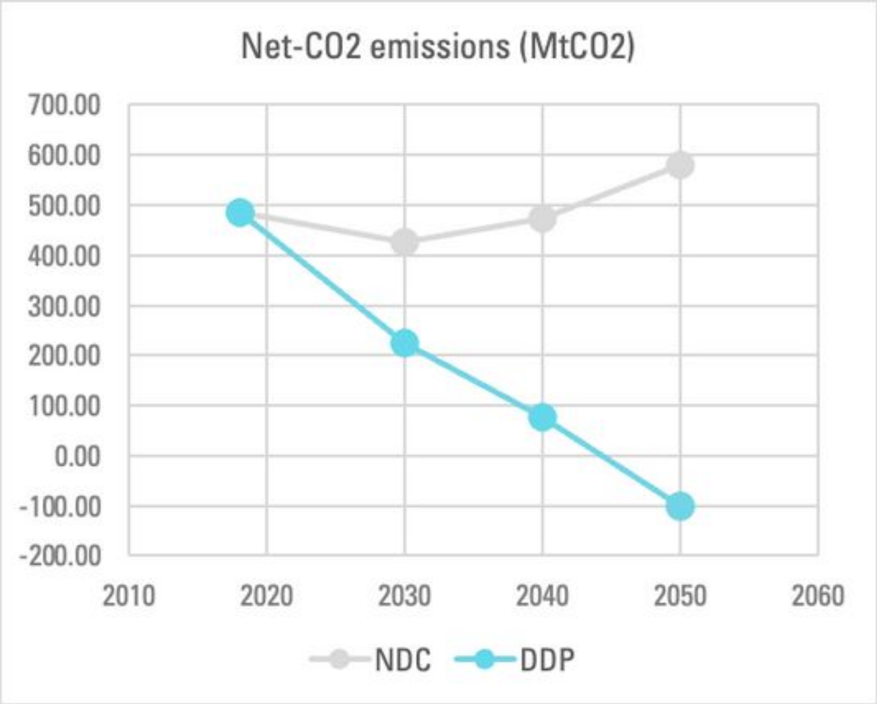
Figure 3. National net GHG emissions

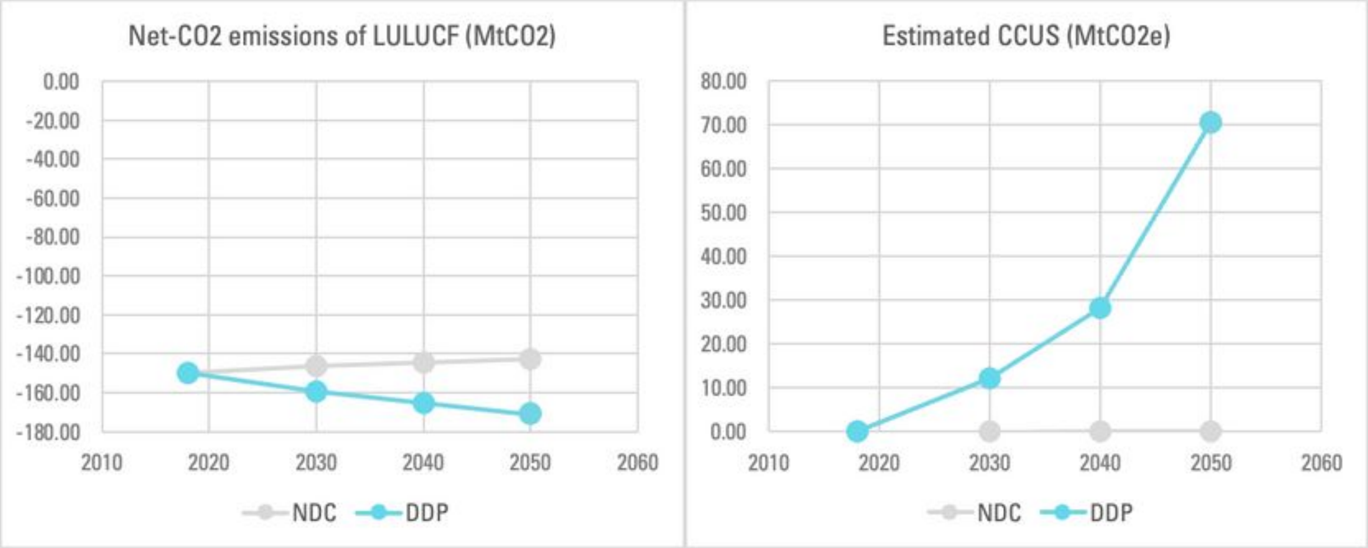


- While the D-NDC scenario holds back emissions growth through to 2030 – primarily through deployment of renewable energy until it reaches [35]% of generation – it has limited additional measures to counter GDP growth, leading to a slow but continuous increase in emissions from 2030 onwards. This scenario is therefore highly inconsistent with carbon neutrality goals
- By contrast, the D-DDP scenario starts with a faster renewable rollout, increasing penetration through to 2050, alongside significant measures in all other sectors, leading to consistent year-on-year absolute emissions reductions from the first year, and approaching net zero by 2050.

Total net-CO2 emissions represent about 72% of all net-GHG emissions and could become net-negative by 2050

Figure 4. National net-CO2 emissions. Top: net-CO2 emissions. Bottom: net-CO2 emissions of LULUCF (left) & Estimated CCUS (right)





Around 95% of GHG emissions (excluding LULUCF) 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. Emissions from industrial process represent around 3% of the CO2 emissions. Agriculture and waste represent respectively 1% and 0,15% of the total CO2 emissions.

LULUCF sinks capture 40% of the CO2 emissions in 2030, to 60% in 2040 in the DDS & NDC scenarios, respectively. Carbon capture and storage are supposed to capture 10% of CO2 emissions in 2030 and 50% in 2050 in the DDS.

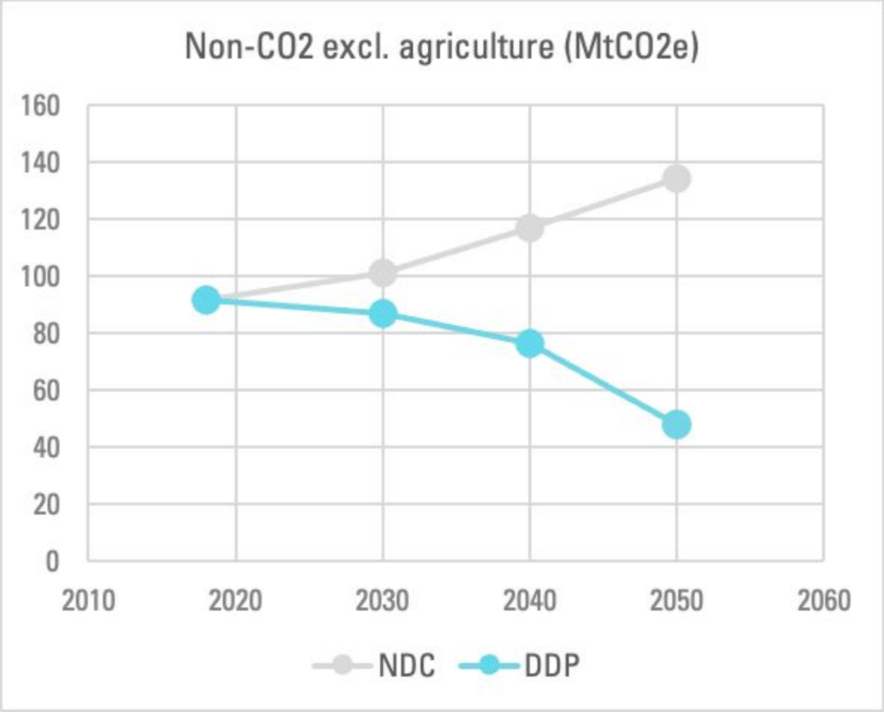
CO2 emissions sources excluding LULUCF are expected to decrease and then increase again in 2050 in the D-NDC. Emissions only decrease in the D-DDP to reach carbon neutrality in 2050.

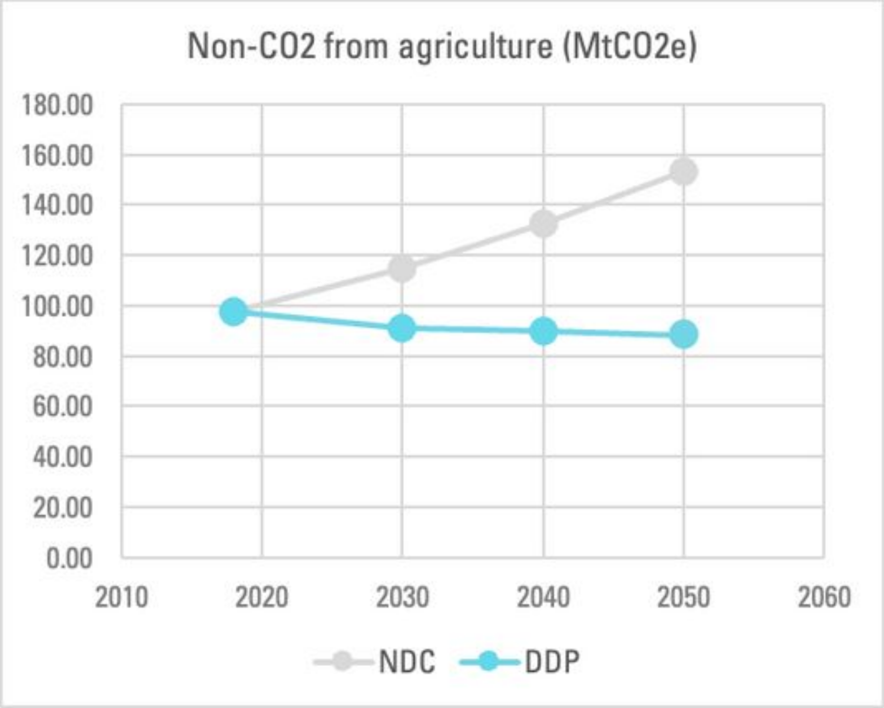
The main decarbonization drivers are :

- the development of renewable energy production (mainly wind and solar),
- the electrification and use of efficient and less energy consuming technologies notably in the industry and transport sectors.
- the deployment of CCS capacities, to reach 24 MtCO2 captured in 2030 and 120 Mt in 2050 in the D-DDDP. It will allow to capture gas and biomass power plants' emissions in both scenarios; and energy-intensive and light industries in the D-DDP only.
- increasing LULUCF absorption in existing forests and a/reforestation.

Total non-CO2 emissions represent 28% of all GHG emissions and could be reduced by 30% by 2050

Figure 5. National non-CO2 emissions.





Agriculture

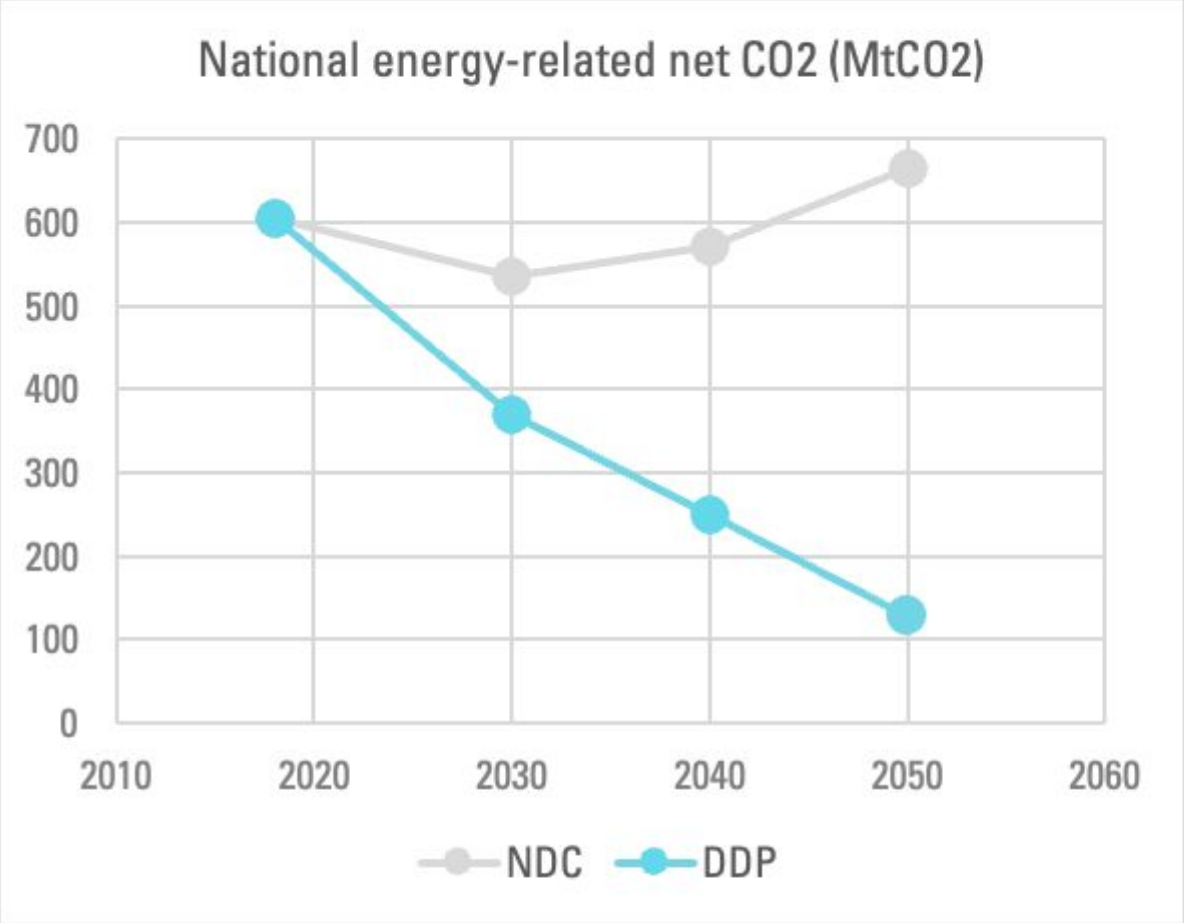
- Agricultural emissions increase significantly (58%) in the NDC scenario and reduce by 17% in the DDP scenario. The main emission sources are CH_4 from enteric fermentation and N_2O from synthetic fertilizer application.
- The main difference is that in the DDP scenario, EF emissions decrease while other sources are stable, while in the NDC scenario, many sources increase significantly (EF, manure management, synthetic fertilizer application)

Other sectors

- In the NDC scenario, emissions increase by 52%, while in the DDP they reduce by 30%.
- Solid waste disposal and wastewater treatment are behind the main reductions in the DDP, and behind the main increases in the NDC.
- Non-CO2 emission are also coming from processed emissions in the energy-intensive and light industries.

Total energy-related CO2 emissions represent 96% of all GHG emissions and could be reduced by 80% by 2050 (1/3)

Figure 6. National energy-related CO2 emissions



- Energy demand is expected to increase in the D-NDC, leading to an increase of the energy-related CO2 emissions, due to a lack of climate policies. Those emissions will decrease in the D-DDP due to lower level of energy demand and to higher mitigation ambitions. Energy-efficiency measures also allow a reduction of the energy-related CO2 emissions.

- In 2030, D-DDP shows a lower level of energy-related CO2 emissions than the BAU, by 31%. It goes until a difference of 82% in 2050.

- Energy-related CO2-emissions represent most of the CO2 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 and the deployment of CCS technologies.

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 7 . Energy consumption (PJ/capita)

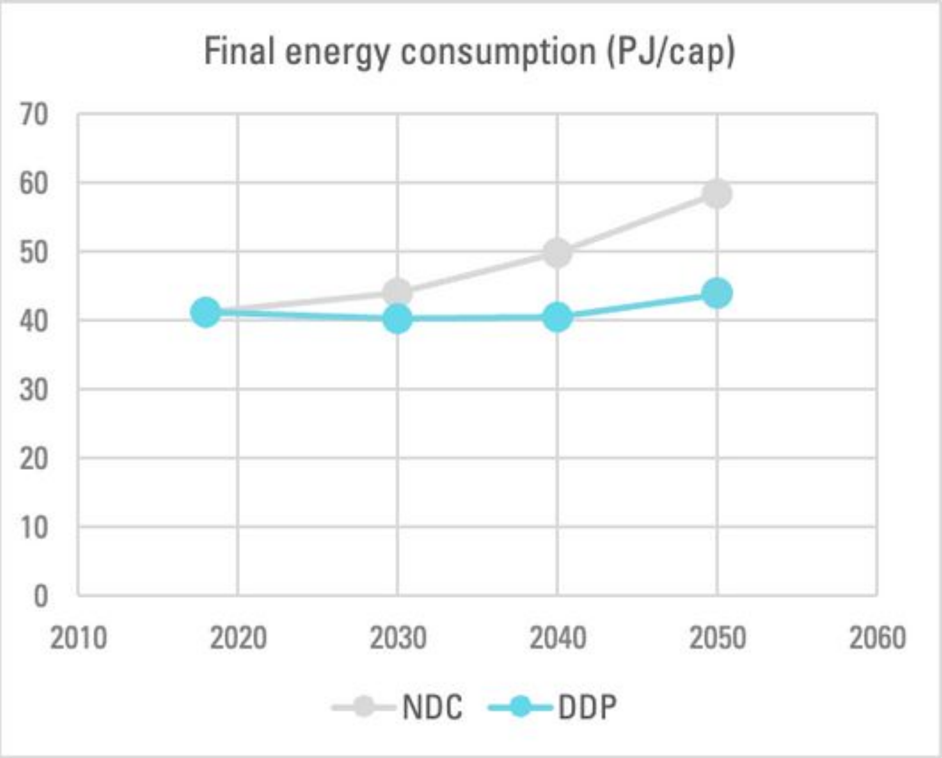


Figure 8. Energy consumption (MJ/$)

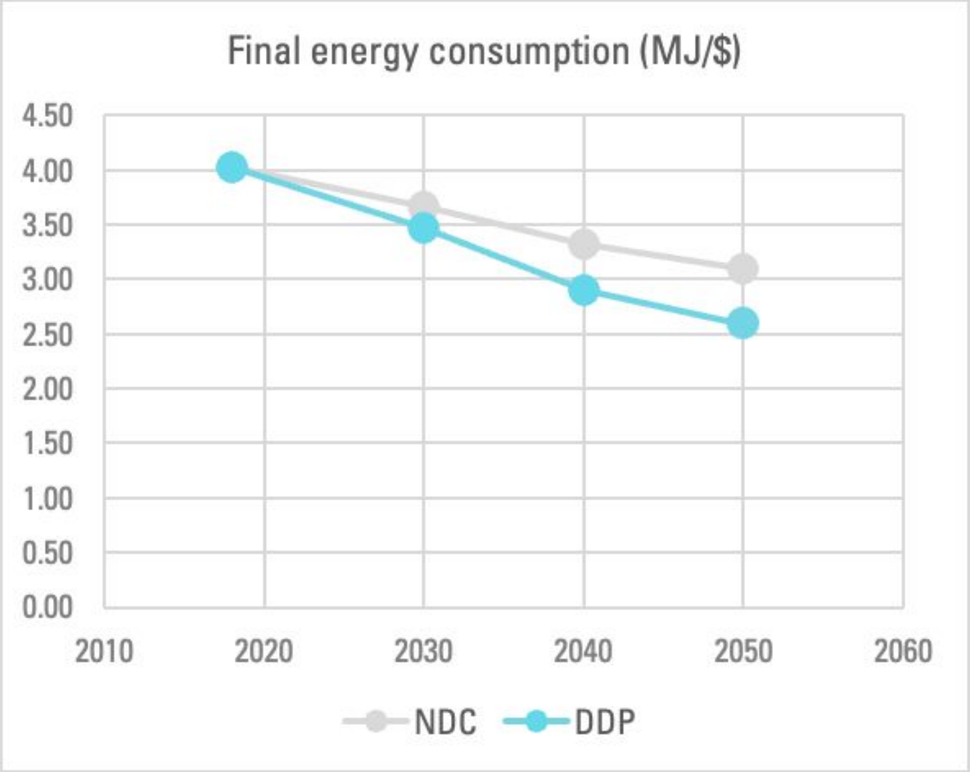
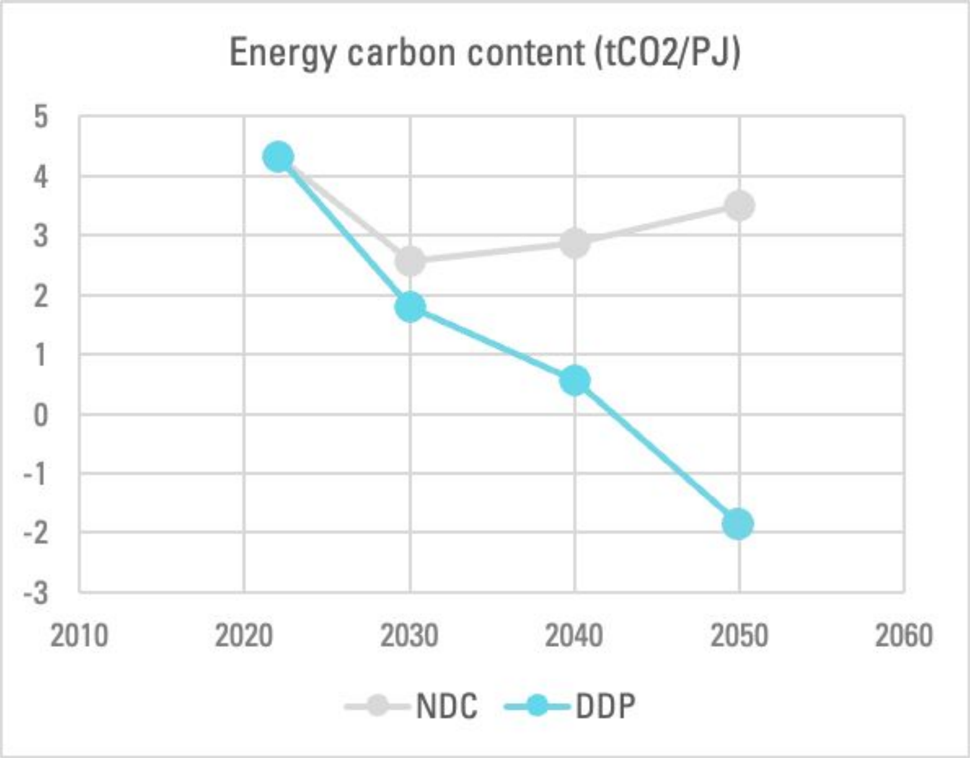


Figure 9. Energy carbon content (tCO2/PJ)



- The energy consumption per capita is increasing in both scenarios by 2050, the D-DDP shows a lower increase (close to a stabilization) of the energy consumption per capita.

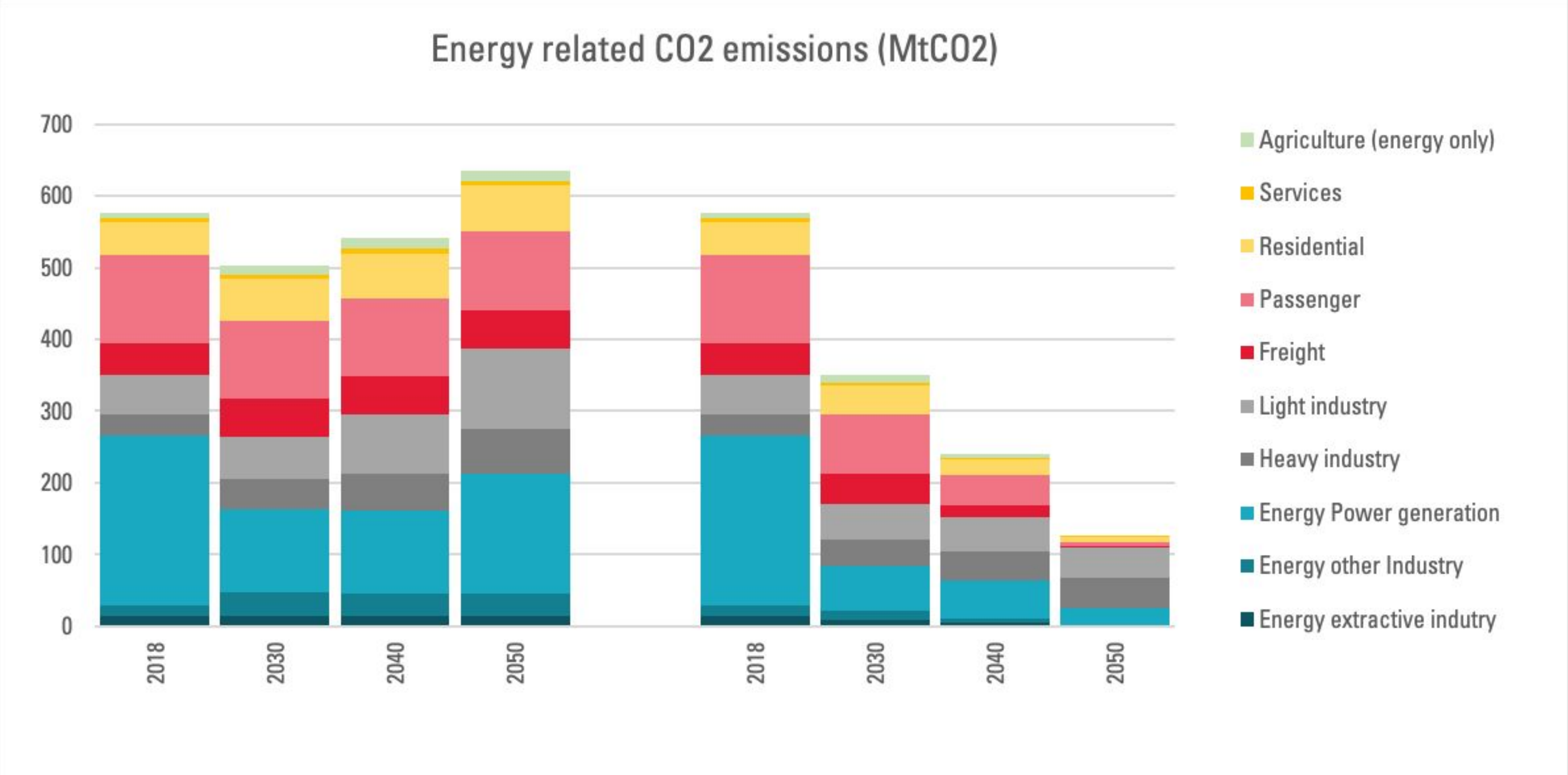
- Energy intensity reduces to 3,1 MJ/$ in 2050 in the D-DDP, reaching a lower level that the ENDC (2,6 MJ/$).

The shift towards zero-emission fuels and CCUS capacities will enable a decrease in the carbon content of fuels.

Carbon content decreases by 24% in 2030 in the D-DDP in comparison to the D-DDP, and then by 75% in 2050.

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

Figure 10. Energy related CO2 emissions



- From nowadays until 2030, the sectors with the highest emissions are the power sector and passenger transport. To get closer to the NDC objectives, most of the efforts needs to address those sectors' emissions. This will allow to engage on a diminishing emissions curve (D-DDP). This will notably be thanks to the development of renewable capacities & the decarbonization of the fuel carbon content in transports.

- If the climate ambitions are higher (D-DDP), emissions' reduction is already strongly engaged in 2030. In 2050, the main emissions cuts comes from the main emitting sectors but also from light industries.

Part 2

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Sectoral deep decarbonization pathways in the D-DDP scenario

Part 2.1

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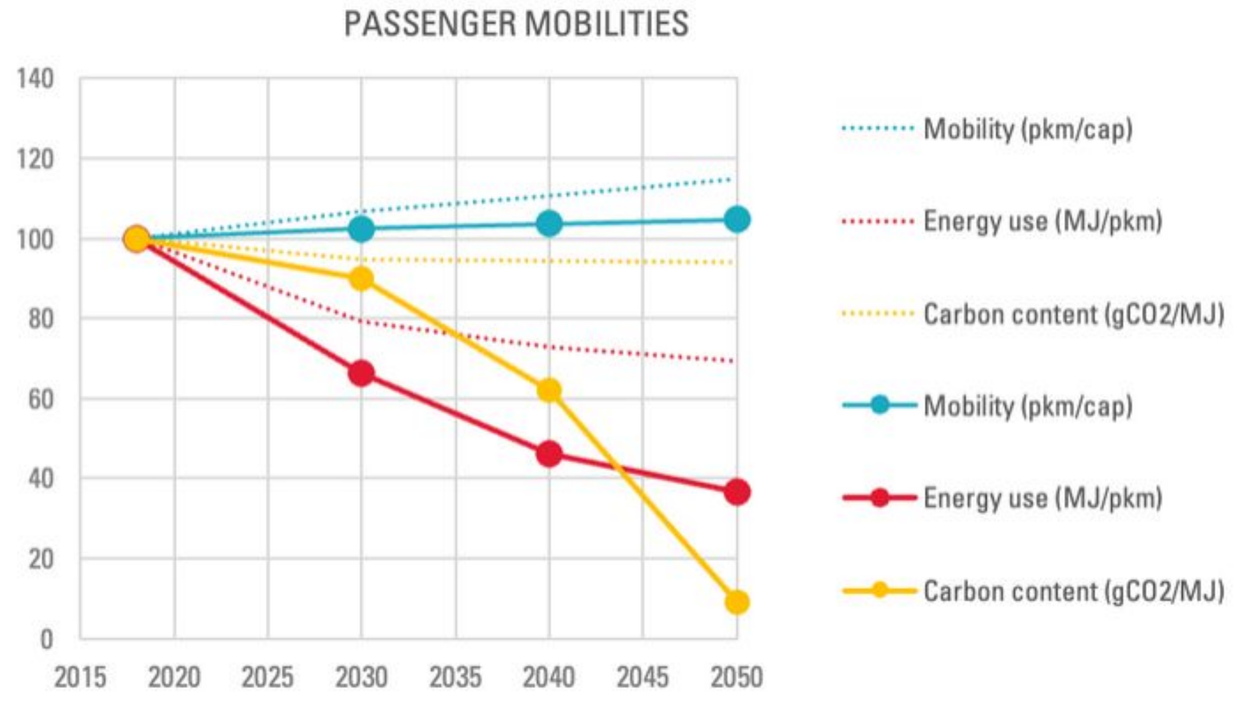
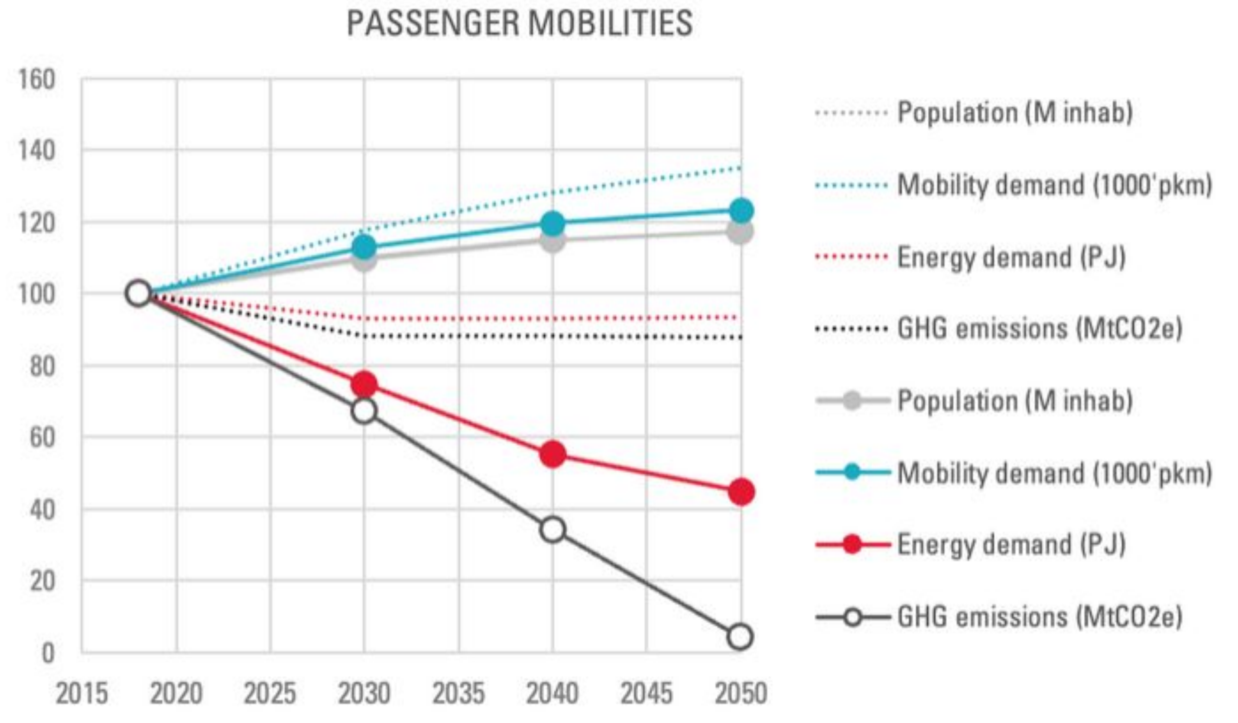
Transition of energy-related emission sectors: Transport, Buildings, non-energy producing Industries

Developing Paris-compatible PASSENGER MOBILITIES

Figure 11. Sectoral emission drivers and main aggregates (Index, 2018 base year)





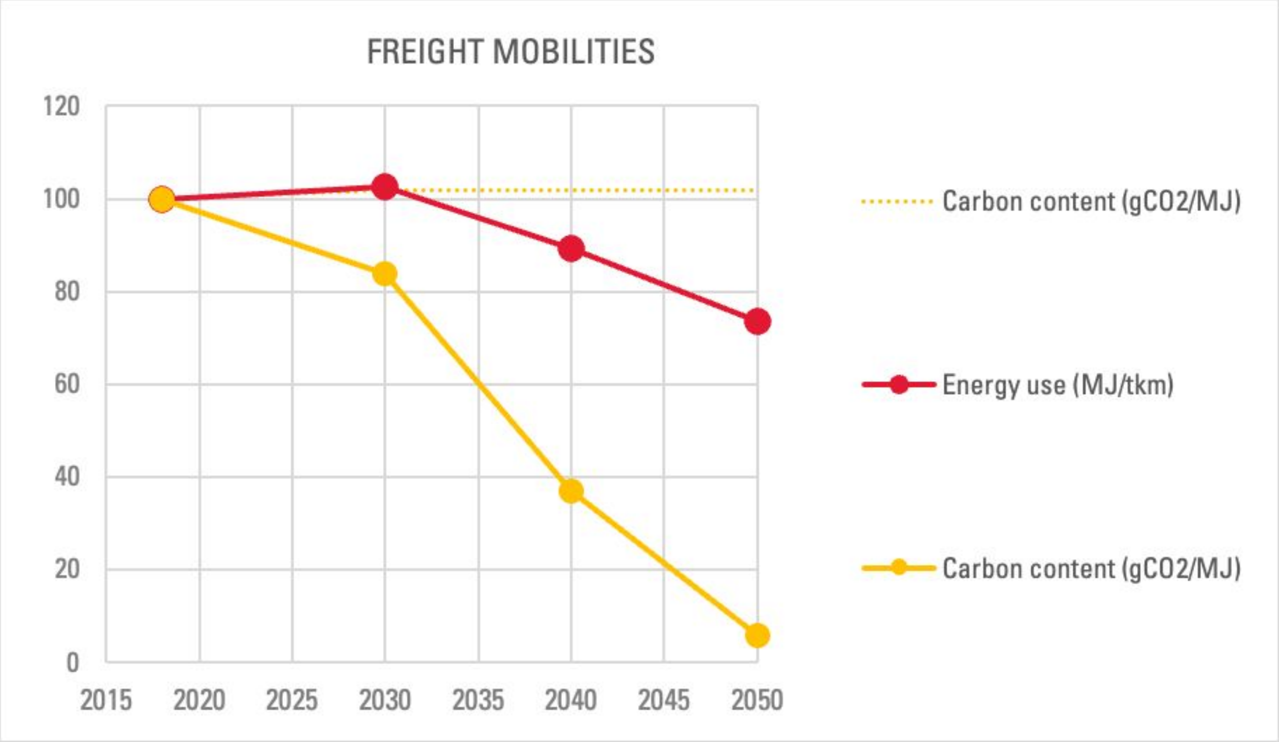
- The current DDS is articulating all key strategies to reach a structural and deep decarbonization of the sectors with measures to moderate mobility demand, reduce energy consumption and shift to zero-emission vehicles.

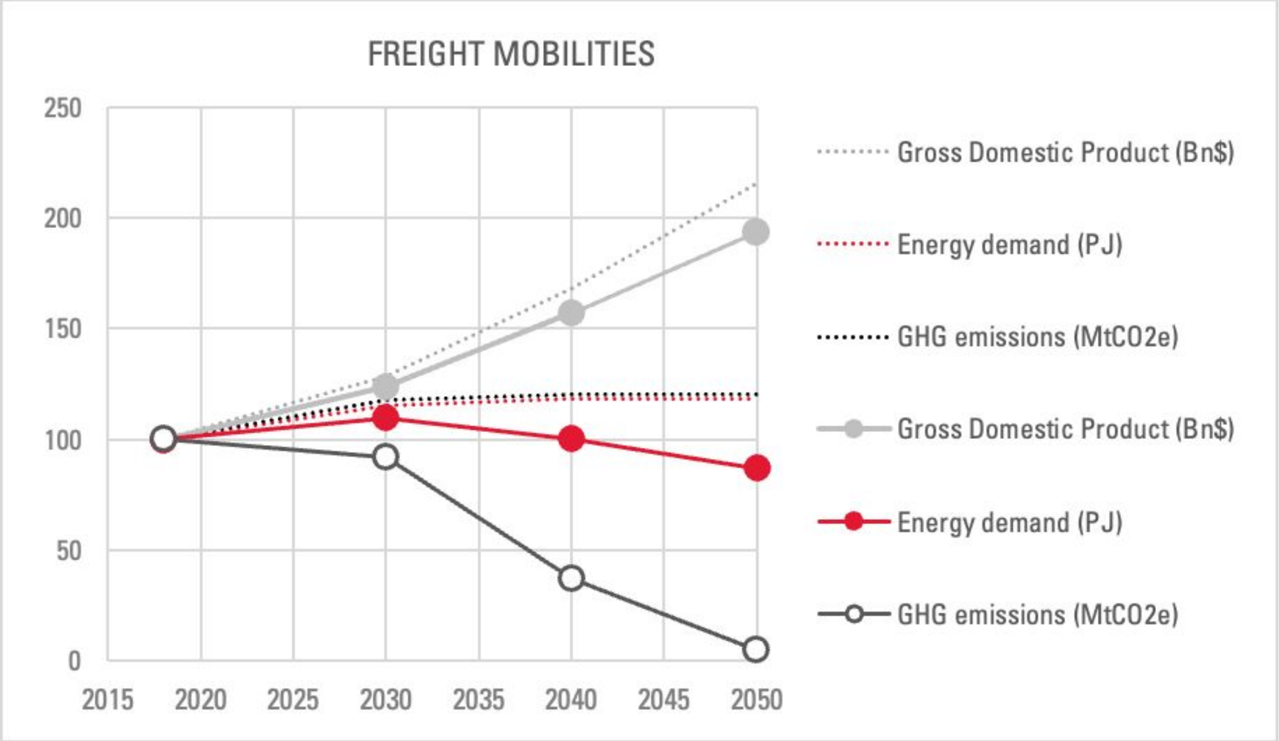
- The per capita mobility increase, and the role of car mobility are moderated compared to the current development patterns of the CPS. There is a complete shift of urban and transport policies bringing closer services and opportunities to all citizens and facilitating access through non-motorized or public transport.. As distances are also reduced, there are immediate effects on congestion relief, travel times reduction, air quality and road safety improvement, and investment and customer revenue are also boosted towards higher quality public transport routes, infrastructure, fleets and overall services and experience.

- Finally, the DDS is pushing on the development of zero-emission technologies using electricity, electro-fuels and biofuels. Non-fossil fuel energy could represent up to 91% by 2050 compared to less than 10% in the CPS. The electrification of vehicles is playing a huge role: 100% of 2Ws, 100% of trains, 97% of buses and 88% of cars. Sustainable aviation fuel will supply 100% of air mobility and liquid biofuels will represent about 57% of blended liquid fuels. Urban reorganization and these technological changes could cut final energy consumption by 55%. Such a shift is made possible by strong private investments in EV industries, and the development of a hydrogen industry linked to renewable energy developers.

Developing Paris-compatible FREIGHT MOBILITIES

Figure 13. Sectoral emission drivers and main aggregates (Index, 2018 base year)





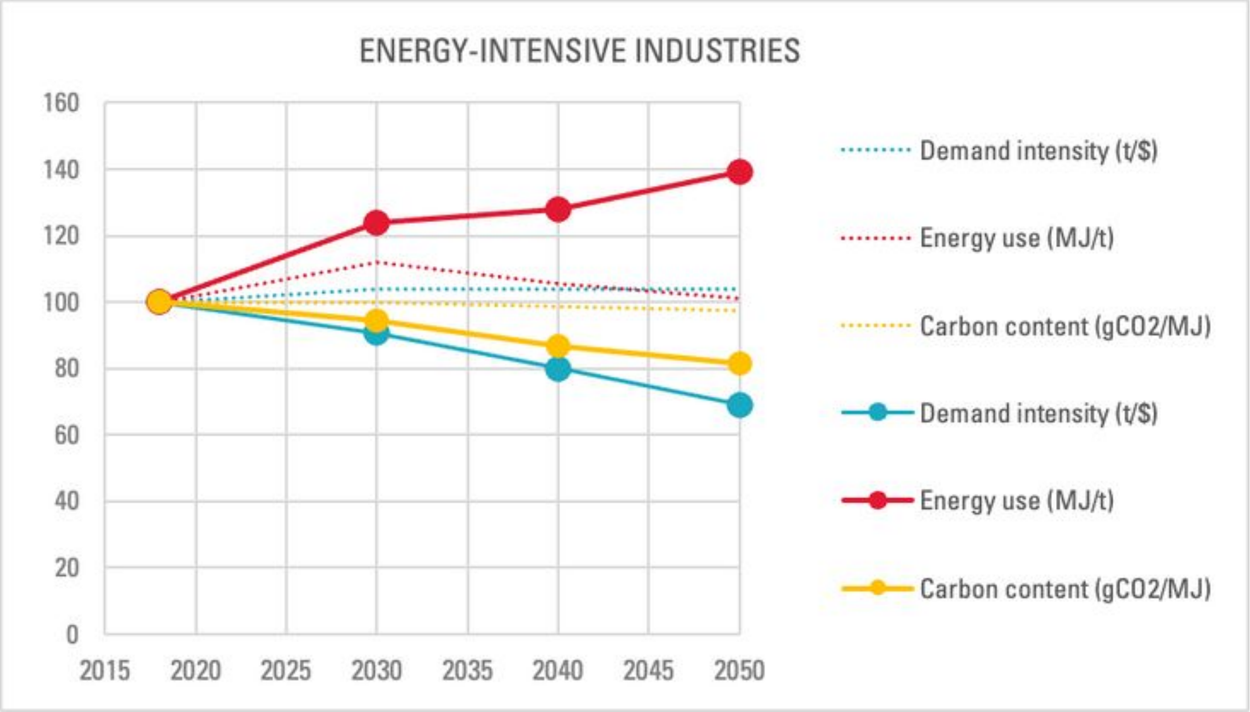
- In both scenarios, the increased economic and trade activities drive a similar industrial development and projection of freight transport demand, increasing from 403 to 476 Gtkm by 2050. No measures are currently explored to transform the current supply chain structure and distances, as well as consumption behaviors.

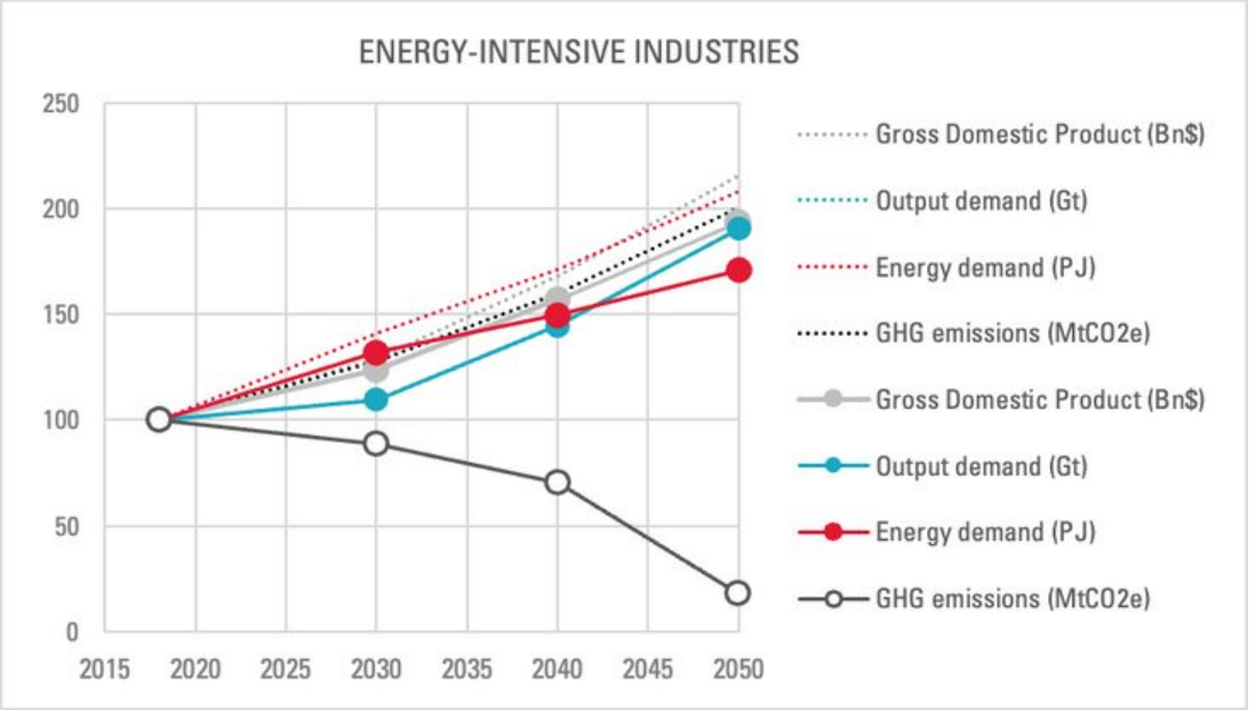
- On the logistics side, the DDS identifies that rail freight could be further developed on high-demand corridors north-south and east-west and represent a shift of ca. 15% of tkm from road to rail. However, it considers relatively constant efficiencies related to loading factors, transportation practices, as well as the evolution of technologies and fleets and no changes in the current paradigms aiming at "lowering the costs of trade". This would imply that "just-in-time" and "client satisfaction" strategies remain prevalent, without relaxing delivery times nor increasing demand complexity (multi-drop operations vs direct supply), and without reducing the frequency of deliveries.

- Therefore, the fuel shift strategy remains an important pillar for Mexico. Compared to CPS which continues to rely on liquid fossil fuels, DDS is shifting to low-carbon fuels and vehicles to increase non-fossil fuel energy (liquid biofuels, electricity, hydrogen and hydrogen-derivatives) up to 83% of the final energy mix. Rail freight is assumed to be completely electrified from 2035 as most of it must be built from scratch and few retrofits are needed. By 2050, road freight uses a mix of electricity, biodiesel, and synthetic diesel derived from renewable hydrogen.

Developing Paris-compatible ENERGY-INTENSIVE INDUSTRIES

Figure 14. Sectoral emission drivers and main aggregates (Index, 2018 base year)





Energy-intensive industry (Iron & Steel, Cement & Chemicals) follows the Mexican economy trajectory, notably the GDP growth evolution. Emissions strongly decrease in the D-DDP in comparison to the D-NDC, by 25% in 2030 and by 66% in 2050. The decarbonization strategies rely essentially on the reduction of the carbon content of fuel used, coupled with a reduction of the demand intensity. The carbon content drops to 51gCO2/MJ by 2050. However, energy efficiency is better in the D-NDC due to lower output of the D-DDP scenario, particularly on cement, which is the main contributor to tonnage.

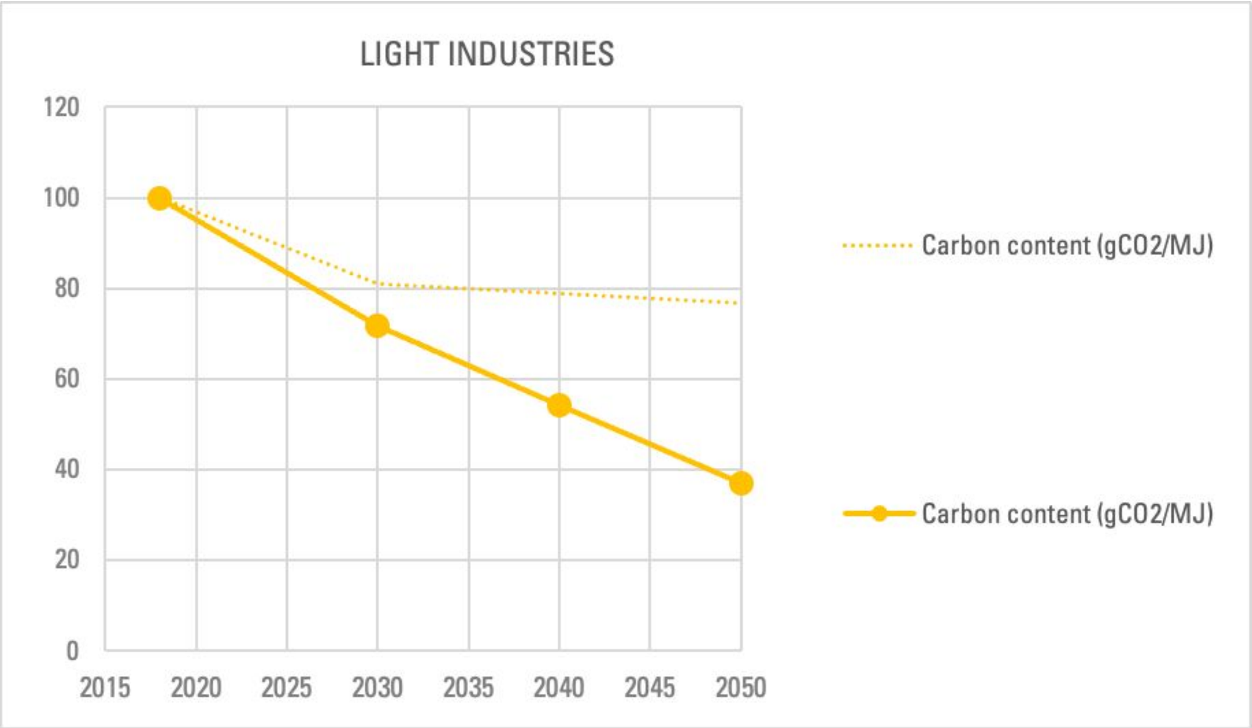
The main drivers are:

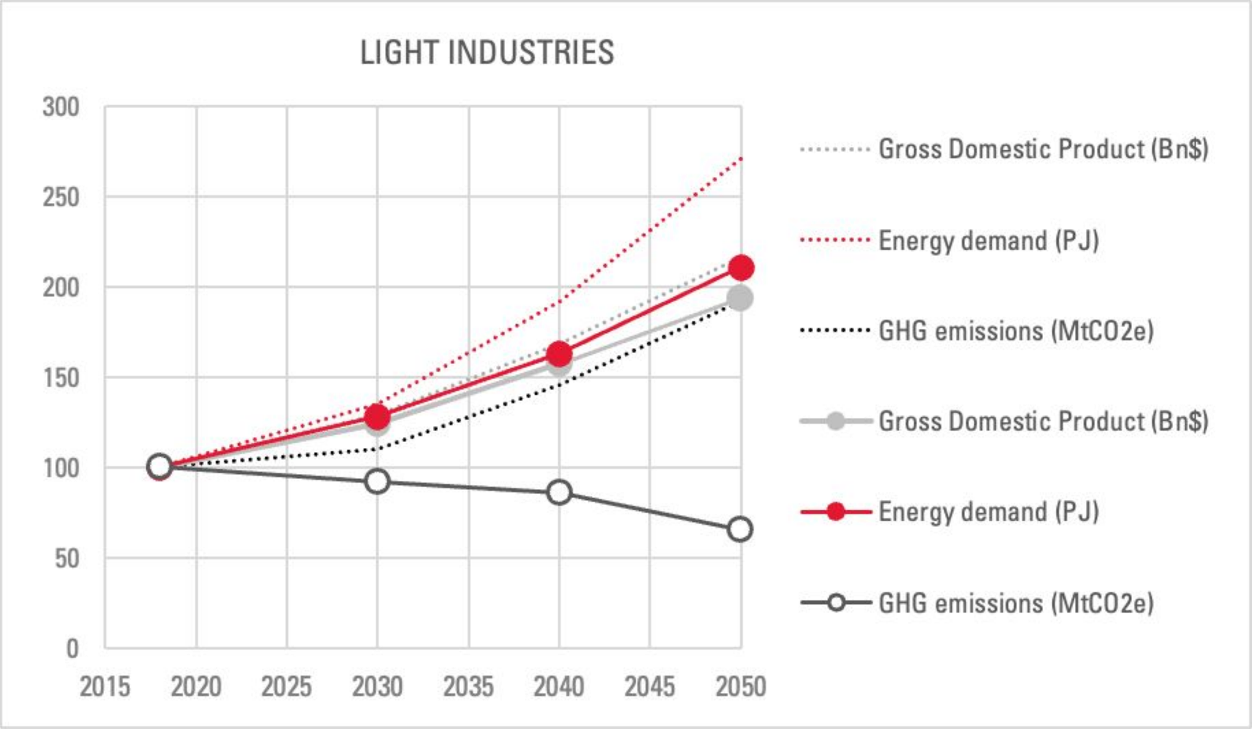
- the electrification in all energy-intensive industries.
- the demand intensity reduction in the cement sector by 40% in comparison to the D-NDC in 2050 thanks to : more recycling (doubling the current concrete recycled to reach 16% of the production in 2050), energy-efficient measures to use less concrete & less clinker. There is also a slow-down of “demolish & rebuild” trends.
- the development of CCS infrastructures.

The key additional policies to compared to the BAU should focus on the rapid electrification of low and medium temperature heat applications (complemented by solar thermal energy), the increased use of recycling to reduce primary steel production, and a strategic approach to green hydrogen technologies within industry (including Hydrogen Direct Reduction of Iron in the Steel sector and H2-based fuels for heat of over 1,400°C (e.g. glass production)) to be complemented by green hydrogen production based on renewable electricity as part of the energy strategy.

Developing Paris-compatible LIGHT INDUSTRIES

Figure 15. Sectoral emission drivers and main aggregates (Index, 2018 base year)





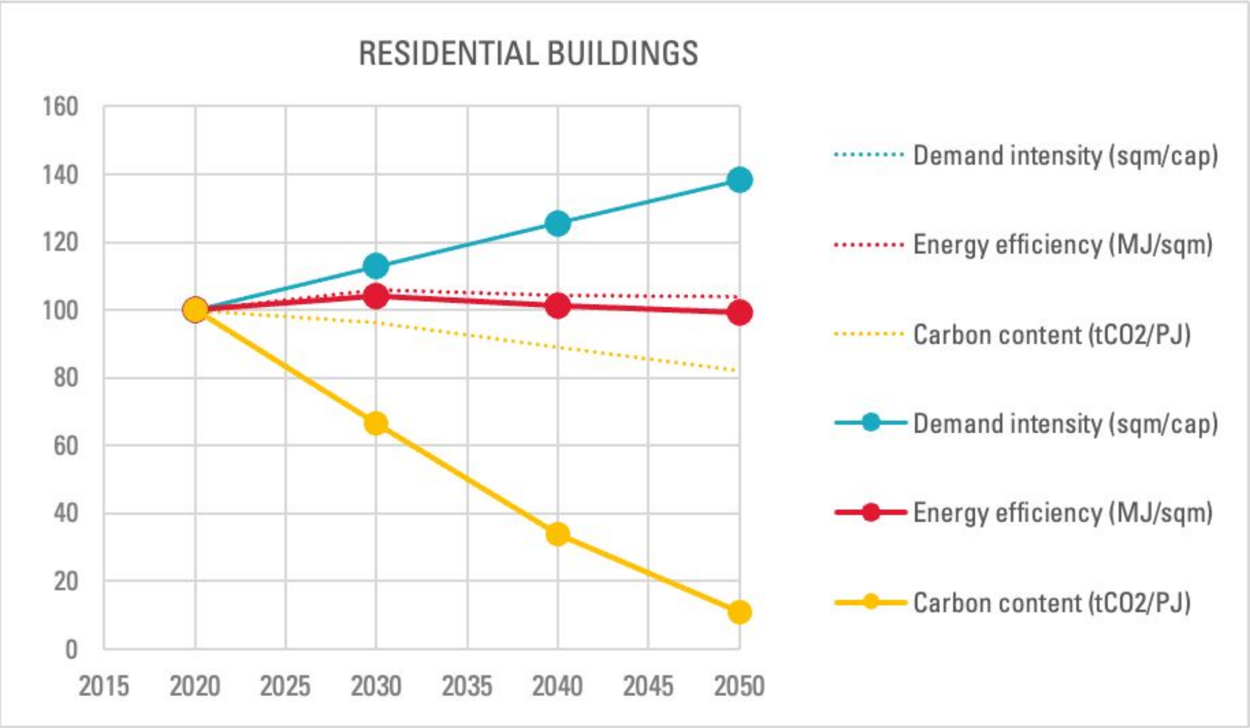
- Other/Light Industries include industries that use primarily low to medium temperature heat, as well as some that use high-temperature heat but have few process emissions. As is the case with intensive energies (iron and steel, cement, and chemicals) other/light industries are projected to follow the Mexican economy behavior, specifically the growth of GDP. The decarbonization strategies rely essentially electrification to reduce the carbon content of energy use.

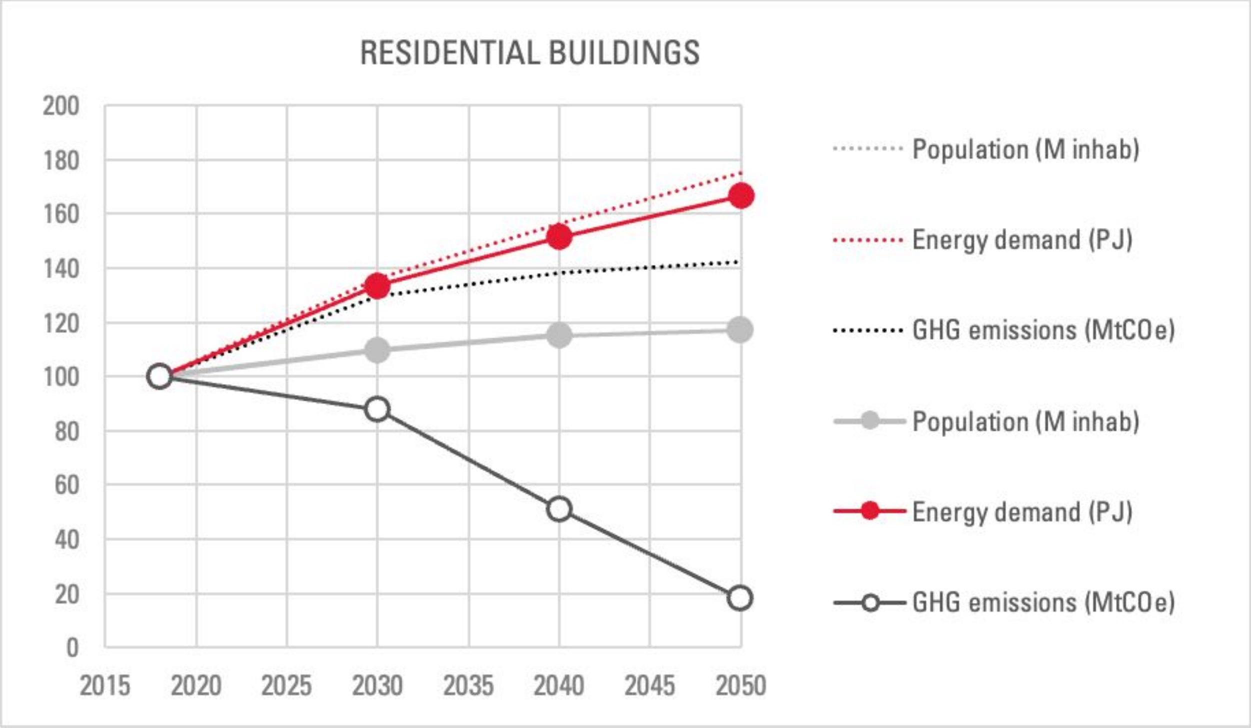
The main drivers are:

- the electrification of the light industries : from 36% in 2018 to 50% by 2030 and 63% by 2050 in the D-DDP. Although natural gas remains the second most used fuel, it's share in this scenario is further reduced to only 24% by 2050. CO2 intensive fuels such as residual fuel oil, coke and coal are eliminated and substituted by electricity and renewables by 2050.
- the decrease of fossil fuel use : residual use of diesel is further decarbonized by eliminating fossil fuels and substituting it with a mixture of bio and zero-carbon synthetic hydrocarbons.

Developing Paris-compatible RESIDENTIAL BUILDING S

Figure 16. Sectoral emission drivers and main aggregates (Index, 2018 base year)





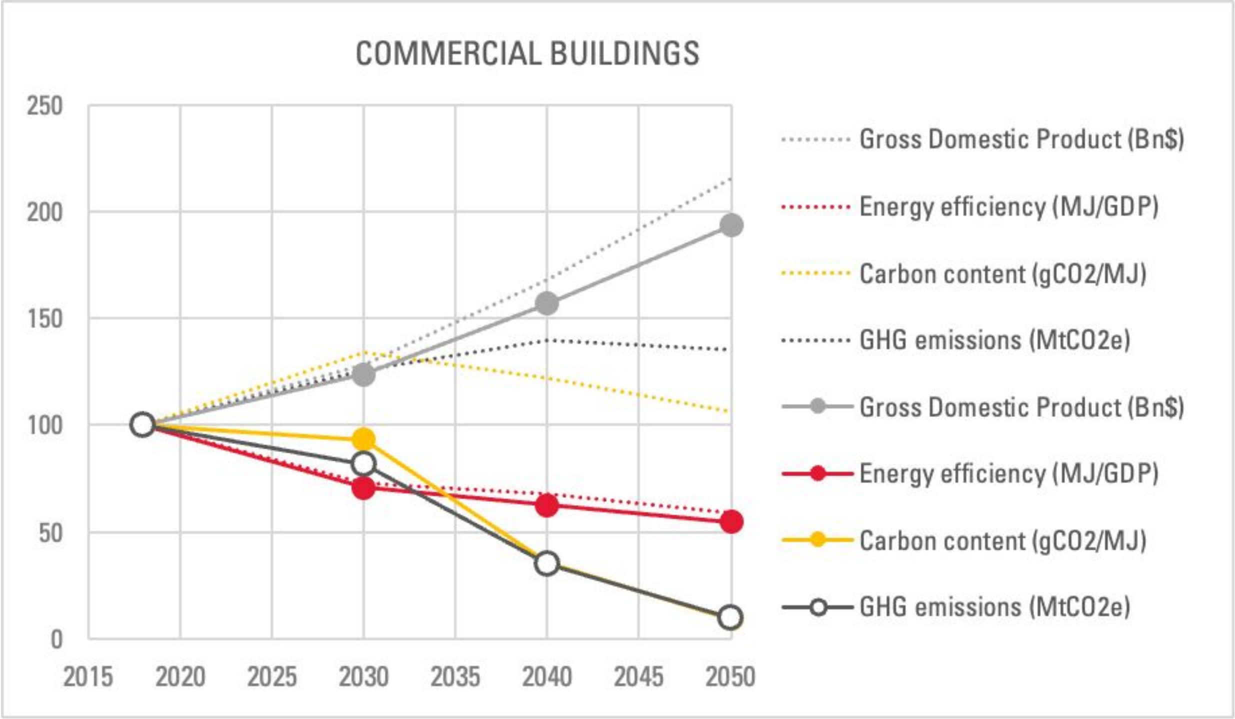
- According to the D-NDC, wood and LPG are the main emission sources and will make up to 83% of the sector's emission by 2050. For several decades population in Mexico has been moving to large and medium size cities, while rural areas and small cities are no growing as fast. Poverty has been reduced in the last 40 years and energy consumption per capita has increased, while average family size has decreased constantly. Although electricity has increased its share within the energy matrix of every household, consumption of LPG and wood are still widespread.
- The D-DDP decarbonization strategy rely therefore mainly on the reduction of carbon content.

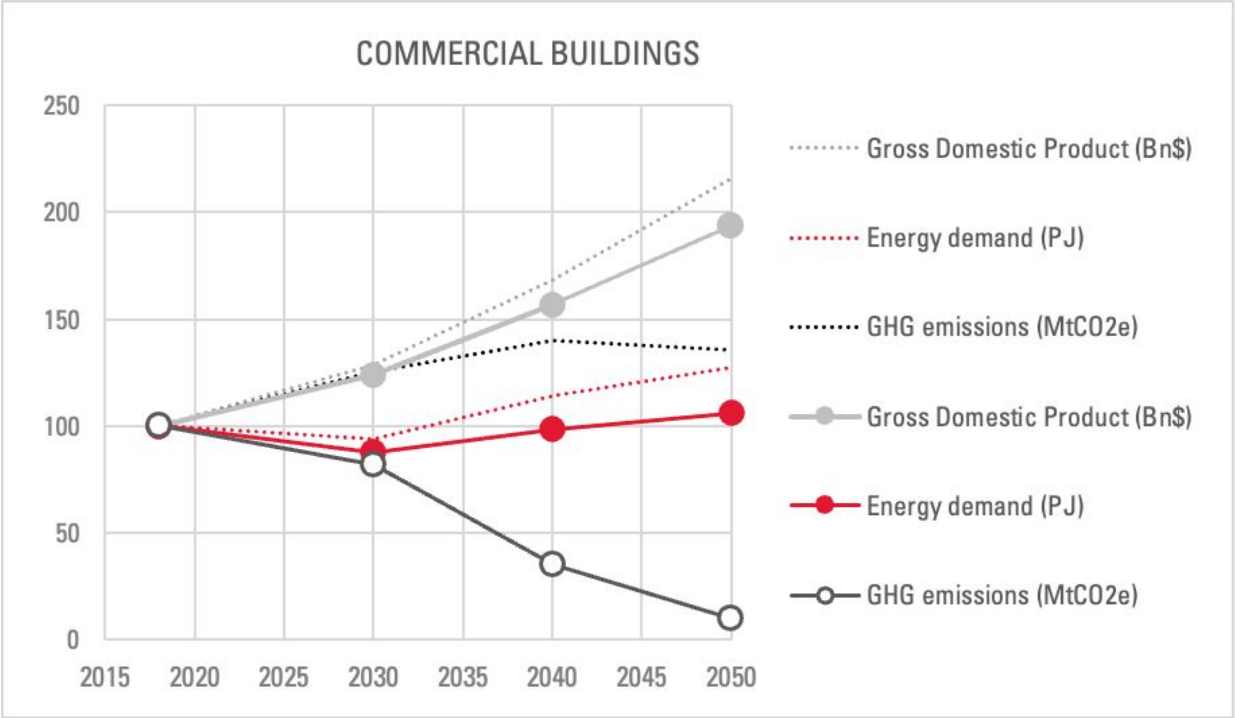
The main drivers of decarbonization are:

- an increasing electrification in households to substitute LPG and wood as sources of energy for cooking and the decentralization of the power production.
- the decrease of wood consumption in comparison to the D-NDC, and its substitution with solar heaters coupled to electric ones.
- electrification of stoves will complete current wood substitution.

Developing Paris-compatible COMMERCIAL BUILDINGS

Figure 17. Sectoral emission drivers and main aggregates (Index, 2018 base year)





- The Mexican economy has been shifting towards the tertiary sector in the last 40 years as cities grow and poverty is reduced. This sector is now the largest of the economy (59%) and is expected to increase even more. While many professional services can be provided remotely (ie. working from home) commercial activity remains a strong driver of the demand for new buildings and energy consumption.
- According to the D-NDC, LPG is the main source of emissions and will make up to 73% of the sector's emission by 2050. The decarbonization strategies rely essentially on a drastic shift of fuel supply, such as for residential buildings. The carbon content drops until 2g CO2/MJ by 2050.

The main drivers are :

- the decreasing carbon content due to the decreasing use of LPG and natural gas coupled with an increasing electrification (and the decentralisation of the power production). However, electrification levels in 2050 is comparable in the D-NDC & D-DDP, while solar thermal helps replace the use of fossil fuels for low heat applications (water heating and steam production, mostly).
- the deployment of energy-efficient measures such as high efficiency electric AC with humidity reduction, centralised cooling for larger buildings, solar reflective coatings, better isolation of buildings, electric stoves.

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 & gCO2/kWh) .

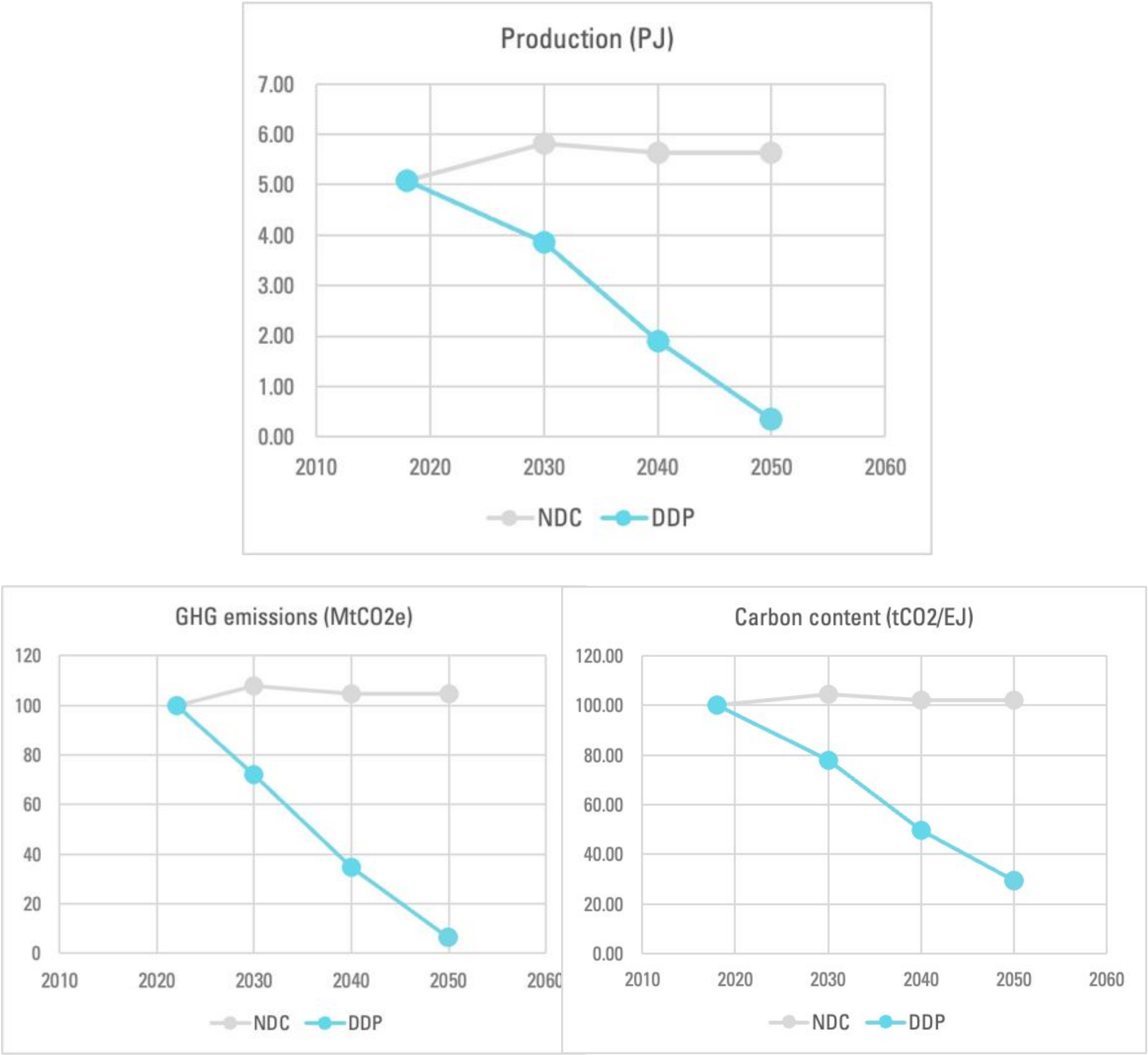
- While power production is expected to increase in all three scenarios, in the D-NDC this is driven by incremental demand growth, while the D-DDP shows a much faster increase to substitute the energy demand left by the rapid reduction of fossil fuel use in transportation, industry, and buildings. Furthermore, in the D-DDP the growth is entirely from renewable sources, leading to a collapse in the carbon content of electricity from 640 gCO2/kWh in 2018 to 23 gCO2/kWh in 2050.

The main drivers are :

- a massive electrification, notably in the industry : nowadays it is the main power consumer with 61% of the production, followed by households (23%) and commercial activities (12%). Electricity demand would almost triple in the D-DDP between 2018 and 2050 to reach close to 1,050 TWh
- the decarbonization of electricity production. This can be achieved with large-scale deployment of renewables : expansion of onshore wind and solar sources occurs swiftly during the first periods, while nuclear and offshore wind will be important from 2035 to 2050.
- the expansion of transmission infrastructures and the development of “smart-grid” usages.
- the utilization of CCS technologies, for gas and biomass plants.
- The key additional transformations to compared to the BAU should focus on the large-scale deployment of renewables, the augmentation of electricity sector investments for power infrastructures & decarbonization, the change away from a centralized production of electricity towards a more active participation of final-users.

Decarbonizing EXTRACTIVE ENERGY INDUSTRIES

Figure 19. Coal, Oil and Gas production (Top, in PJ) and production emissions / carbon content (Bottom, in MtCO2e & MtCO2/MJ) .



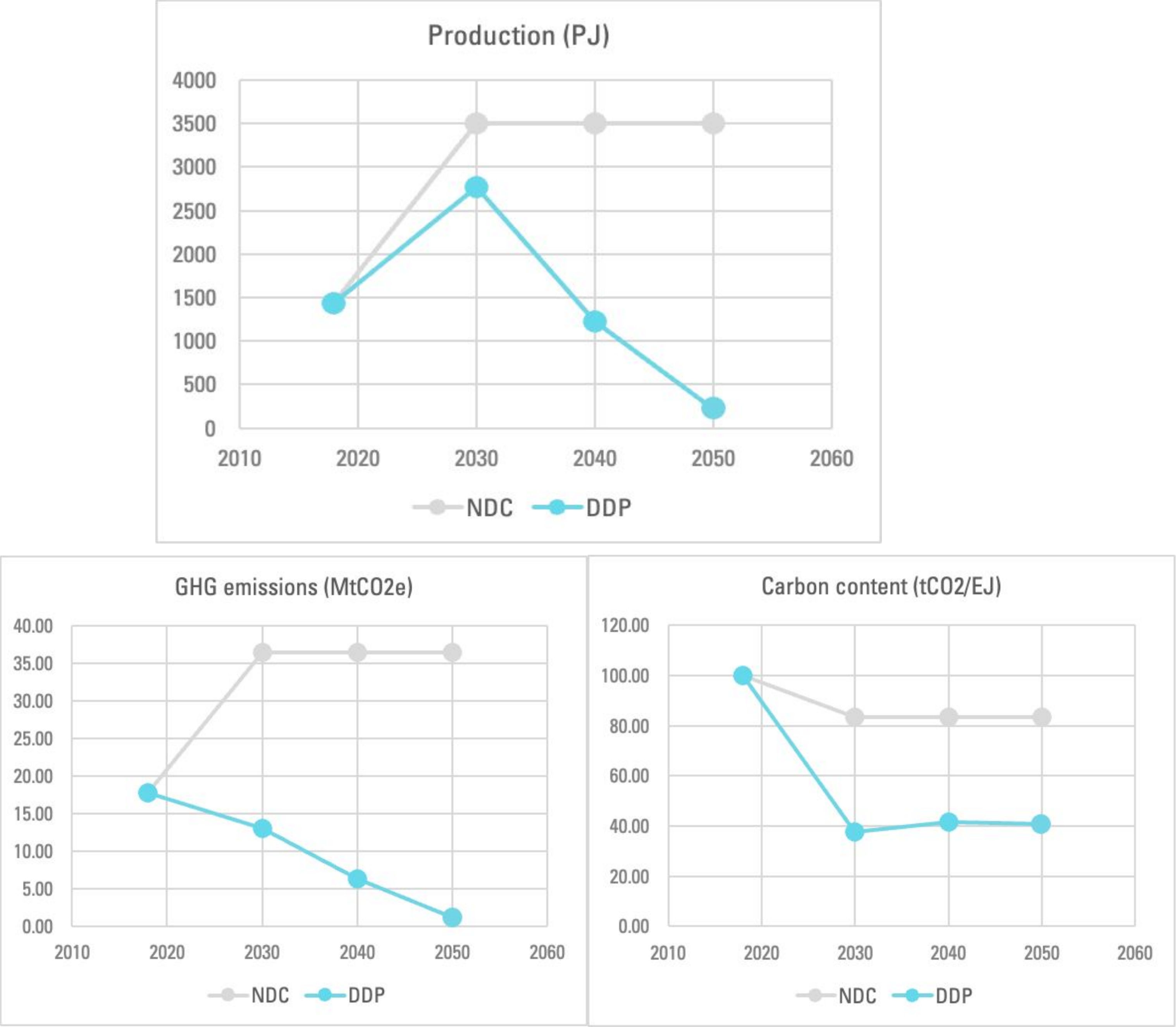
- Mexico is one of the larger oil producers in the world (1.6 million barrels produced daily in 2022). During the late 1970's and 1980's this industry was so large, relative to the domestic GDP, that it became a crucial source of revenue for the government due to the size of crude oil exports and the taxes derived from them.
- The current administration's support to the state-owned oil & gas (O&G) exploiter PEMEX is reflected here with a delayed decrease of extractive activities : the extractive activities decrease at a faster pace after 2030. All production of natural gas in Mexico is associated to crude oil production and most of gas needed for electricity generation, industry and all other final energy uses (68% in 2020) is imported. Natural gas production mimics that of crude oil, considered as a transition fuel by many policy-makers.

- The D-DDP scenario considers the marked reduction in demand of oil-derived products (principally gasoline and diesel) as part of the deep energy transition that is needed to a reach a net-zero carbon future. This demand reduction is reflected in the overall downsizing of the O&G industry by 2050, and particularly in crude oil production to only 7% of that currently observed.
- As national oil production and consumption is decimated in the D-DDP scenario exports of oil also reduce to zero by 2050.

- The key additional transformations to compared to the BAU should focus on translating environmental ambitions into specific extractive O&G energy policies and accompany the strategic phase-out of the O&G assets to the benefit of other energy sectors.

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)



*All other solid, liquid, gaseous final fuel production activities (e.g. refineries, H2 generation, ...)

- Historically and at present Mexico is a crude oil exporter and an importer of refined products (gasoline, diesel and LPG). Intensive road transport and freight has created a dependency on oil products, and electricity generation is mainly carried with natural gas technologies. The current administration is investing in renovating refineries to adequately process crude oil and therefore increase its refining capacities from 591 thousand barrels of oil a day in 2020 to 1,600 barrels in the coming year. This would help to fully satisfy the demand for gasoline and diesel, as in the last five years Mexico has imported an average of 71% of the gasoline and 68% of the diesel consumed internally.

- The D-DDP projects a deep energy transition to reduce the country's CO2 emissions by 90%. Energy uses switch from oil products to renewable electricity on a large scale, and the whole O&G industry is downsized to a tenth of the current one.

- International trade in O&G fuels is neglectable after 2030, except for natural (dry) gas imports that are maintained throughout 2050 for residual consumption in industry and as backup capacity for electricity generation.

Part 2.3

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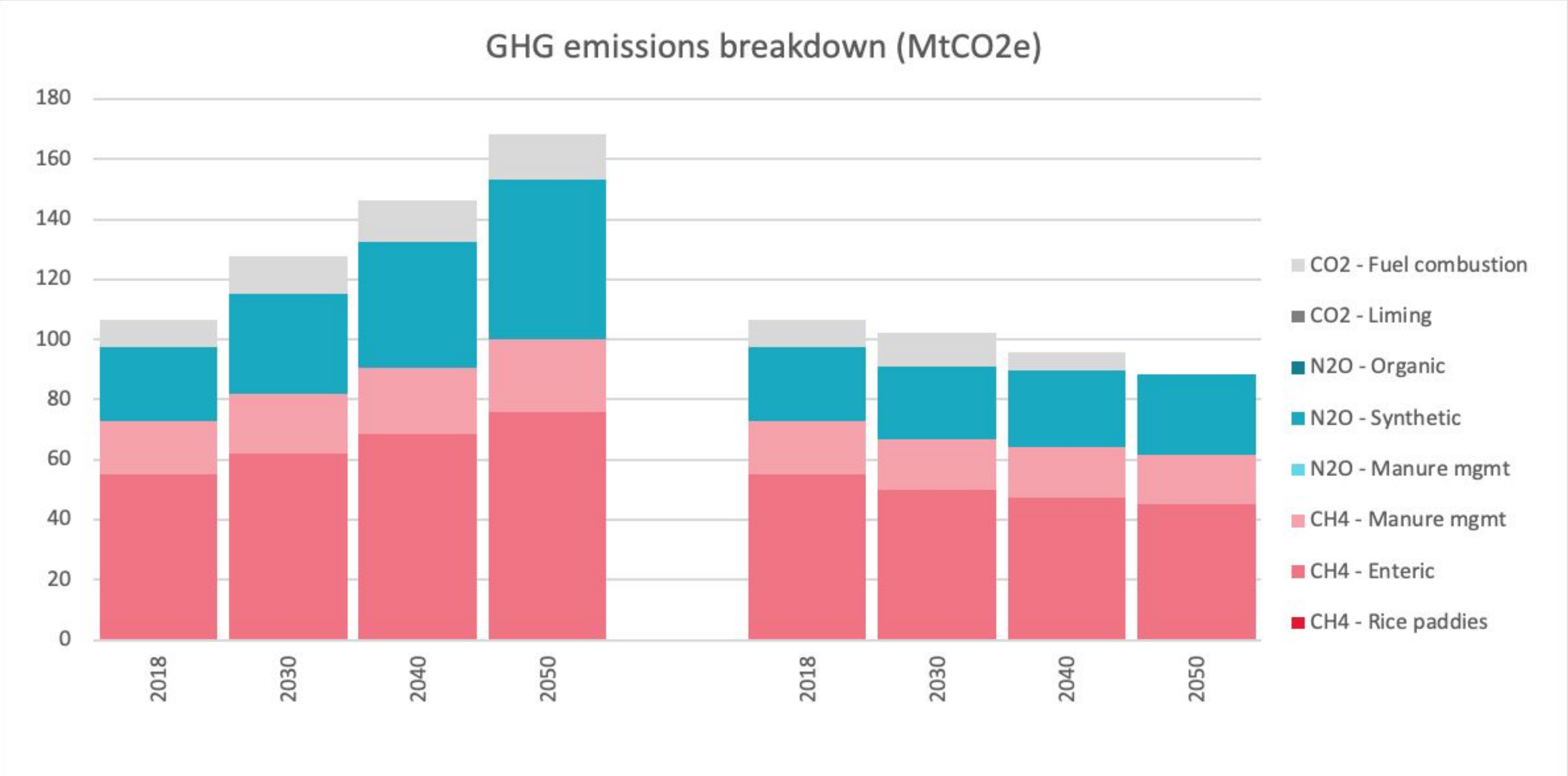
Transition of non-energy related emission sectors:
Agriculture, Forestry and Land use change, Waste

Developing a Paris-compatible AGRICULTURE sector

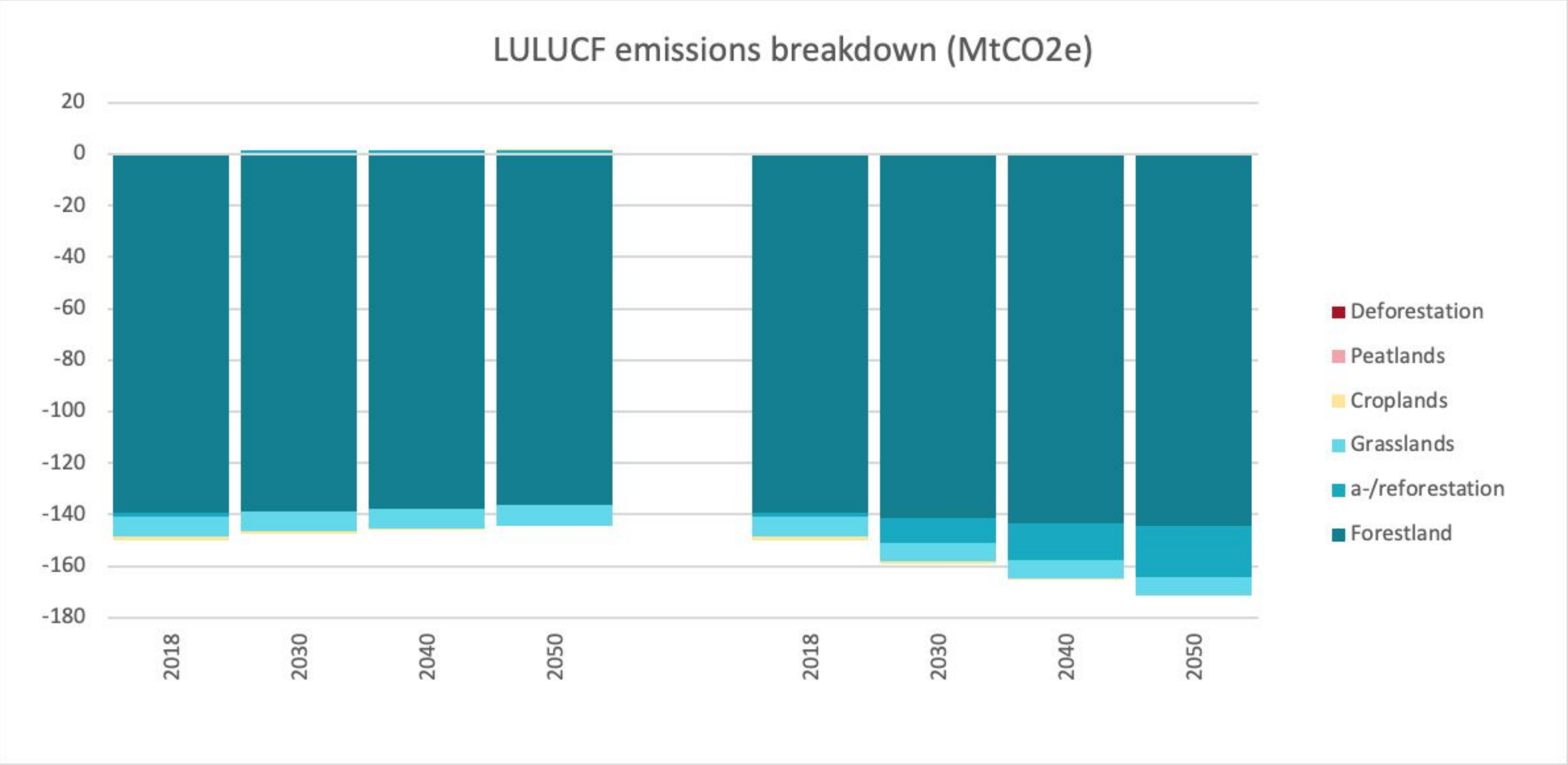
Figure 21. Sectoral emission drivers and main aggregates



- Agricultural emissions reduce by 17% in the DDP scenario. The main sources are enteric fermentation (CH_4), synthetic fertilizer application (N_2O) and manure management (CH_4). CH_4 emissions from enteric fermentation reduce by 19%; while other sources are relatively stable.
- The underlying drivers include a reduction in the livestock herd (particularly cattle) which is consistent with an increase in plant share in diets, and with partial adoption of modern silvo-pastoral systems, where rotational grazing with high livestock densities and brief grazing periods interspersed with long recovery periods for the protein sources, help to increase productivity per head of cattle (ie. survival rates, gains in body weight, and milk production).
- The DDS assumes that historical productivity increases in crop production continue until 2050, which means that total the cropland surface is reduced in the scenario. This results from a combination of two assumptions, on the one hand an expansion in the use of improved seeds from the MasAgro Program – a governmental program currently spanning 19% of the maize cultivated area – and on the other, improved farming practices across several crops to preserve soil nutrients.

Developing a Paris-compatible LULUCF sector

Figure 22. Sectoral emission drivers and main aggregates

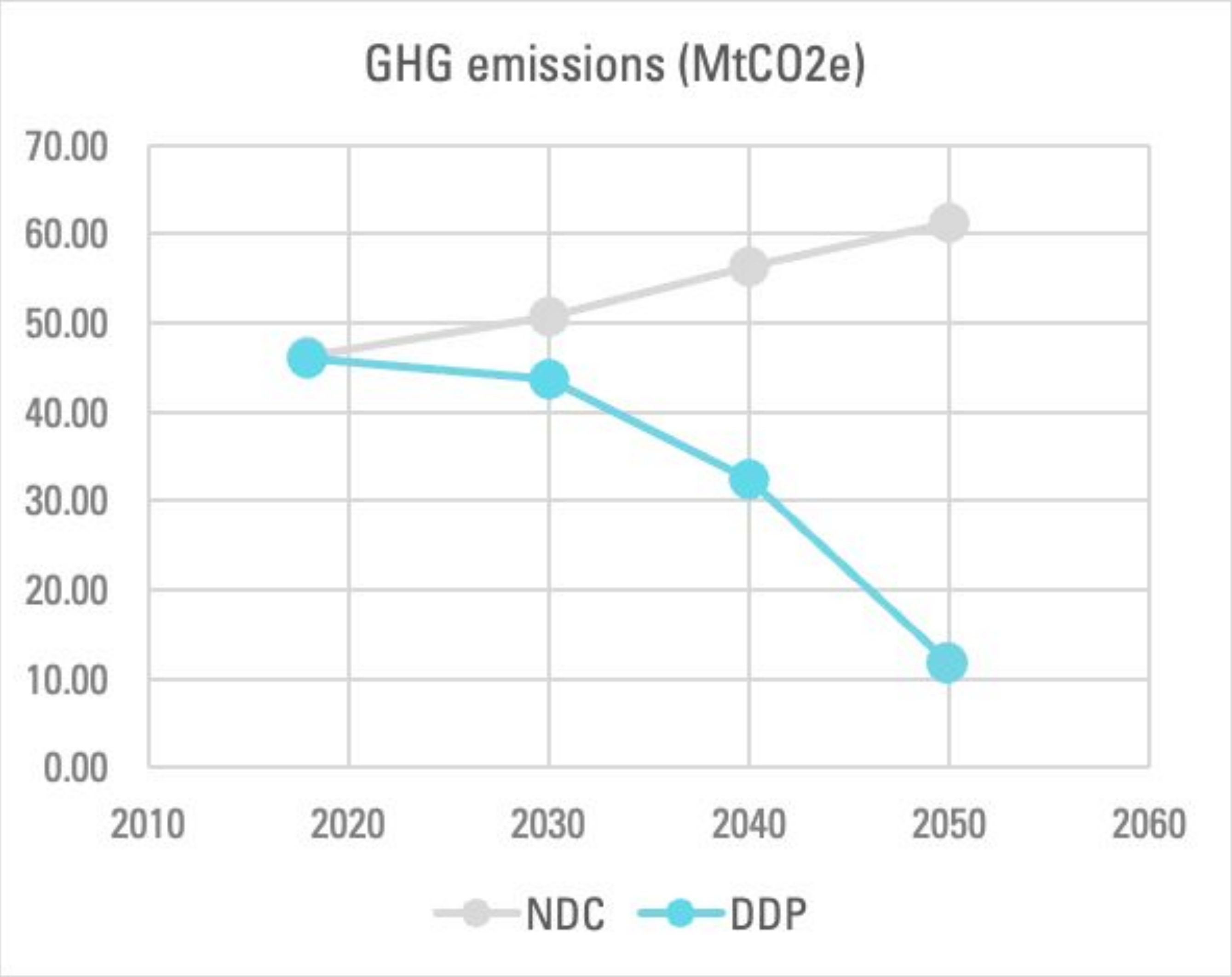


- The LULUCF sector plays a major role toward reaching the net-0 target: 1) 170 MtCO2/yr negative emissions by 2050; 2) almost 160 MtCO2/yr by 2030, in mitigation in the short term. While existing forests is the main sink in 2020, most of the *increase* in the annual sink comes from a/reforestation.

- The main drivers are:
  - Dietary practices: increasing plant share of diets reduce pressures on land conversions to produce animal products (a main driver of deforestation today).
  - Reductions in land use for crop- and animal production
  - Strengthened nature conservation policies
  - Drastic reductions in wood use for energy production at HH level (and some increase in bioenergy use for other purposes).

Developing a Paris-compatible WASTE sector

Figure 23. Sectoral emission drivers and main aggregates



- 32% of Mexico's non-CO2 emissions come from waste in 2020. The waste sector reduce emissions by 74% between 2020-2050, with reductions starting already after 2020.

- Key emission sources are unmanaged waste disposal sites (CH4) and wastewater treatment and discharge (CH4). Both reduce significantly. Managed and unmanaged waste disposal sites remain the most important emission sources in 2050 (71% of waste emissions).
  - Emissions from waste treatment are reduced by 3 drivers: 1) a reduction in HH waste production; 2) an increase in recycling of solid waste; 3) 70% of GHGs from treatment sites is captured for biogas production in 2050.
  - Emissions from wastewater treatment are reduced by drastically increasing the share of GHGs that is captured for electricity production (90% in 2050).

- 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

Lesson 1 about key additional areas or sectors which requires stronger ambition

- Mexico's climate policy commitments as contained in its NDC are inadequate to achieve the Paris Agreement objectives, meaning all sectors require stronger ambition.
- Crucial to aligning Mexico's economic and social development with the Paris aims is the transition away from fossil fuels. For Mexico this means both demand, since about 90% of final energy consumed comes from fossil fuels, and supply, since oil production and export represents an important source of revenue for the Government.
- While Mexico's NDC commits to increasing renewable power generation, recent policy has not favored this shift, nor is the target in line with Paris requirements. There must be an immediate push for a very rapid roll-out of Solar PV to make use of Mexico's abundant solar resource. Closer to 2030, important investments will be required in transmission and storage to ensure the grid can remain reliable with ever higher levels of intermittency in supply.
- Transportation must largely electrify, with urban passenger transport benefiting from infrastructure and shifts in urban form that promote modal shifts to public transport, reduced demand for motorized transport vs current trends, and drive train electrification for public and private vehicle fleets.
- Low and medium temperature energy demand across industry and buildings should be met with solar thermal, electric heat pumps, or electric boilers, as well as integrated systems combining these three technologies.
- Higher temperature industrial heat, as well as industry-specific process emissions, will require important investments in new technologies, for which complementary energy policies, such as grid decarbonization and the promotion of green hydrogen generation, will be requirements. Further policy changes must favor increase recycling, product redesign to reduce material and energy intensity, and market rules which allow industry to recover significant investments through end-product price increases which do not limit firm profitability.

Lesson 2 about short-term policy packages and priorities to enable it

Short-term policy packages to kick off the required systems changes in Mexico include :

- Combined regulatory and investment measures to kick-start renewable generation rollout, including the reinstatement of “clean energy certificates (CELs)” together with renewed, more ambitious yearly targets, and the targeting of CENASE objectives to plan out a future transmission system which will enable the high-renewable penetration grid required for decarbonization.
- Combined development of national guidelines for urban development, coupled with a nation-wide financing program to support cities and municipalities plan out and develop the urban and infrastructure changes needed in Mexican cities to enable low-carbon transport systems.
- Development of a joint national energy strategy where government and private sector agree on options for future investment including distributed renewable generation, energy storage, and a coordinated approach to green hydrogen
- Introduction of carbon pricing across all energy sources and carbon-intensive commodities, to enable pricing signals to shift demand, protect the competitiveness of firms which invest in low-carbon production methods, and to raise funds to support investments in infrastructure to enable the low-carbon transition.
- Development of a trajectory of increased carbon prices over time, to make natural gas options less attractive for longer-term investments without creating high short-term price increases which can be disruptive to economic activity.

Lesson 3 about the global context, conditions, cooperations required

- The energy, transport, industrial, and buildings decarbonization strategies identified in Mexico's DDP are largely attainable with technologies which are currently viable, with some need of near-commercial technologies in heavy industry.
- However, despite the technological availability and the technical capacity of Mexico's workforce, the ability to finance the increased investment required by the DDP presents a significant barrier to implementation.
- For this reason, changes in global finance to increase access and reduce costs of finance for developing countries engaging in a transition to zero-carbon will be a key determinant to Mexico's ability to achieve the Paris Agreement goals.
- Like many countries in Latin America, the Mexican state has limited fiscal space to promote investment at the scale needed, while commercial interest rates within international financial markets make the transition to renewables more expensive for developing countries than for developed countries.
- Global finance must comply with the criteria set out in the IPCC AR6 WGIII report's Chapter 15 if Mexico is to receive the investment needed to implement the low-carbon transition.
- Furthermore, global trade must provide international carbon prices in line with the requirements of a global shift to a low-carbon economy, in to not penalize the competitiveness of Mexican industry that invests in the shift to low-carbon technologies and methods, and to not penalize the Mexican economy for its shift away from fossil fuel exports.
- Finance supply for investment and innovation is quickly becoming strategic under the new polarized global conditions. Efforts should be made to integrate productive chains in the new technologies and business that attract investment to all necessary activities including research and innovation (but also re-training, for example).

Annex 1 : DECARBONIZATION PATHWAY FOR MEXICO - values

MEX	2018	2030	2040	2050
Total GHG emissions (MtCO2e)	673	403	241	34
Total CO2 emissions (MtCO2)	484	225	75	-102
Total energy-related CO2 emissions (MtCO2)	604	370	251	135
Total final energy consumption (PJ)	5157	5527	5829	6434
Total Pop (Million)	125	138	144	147
Total GDP (Billion USD (2015))	1283	1589	2013	2483