



MODELLING TOOLS:
How to quantify your energy-climate pathways?

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January 31st, Online webinar

Enerdata

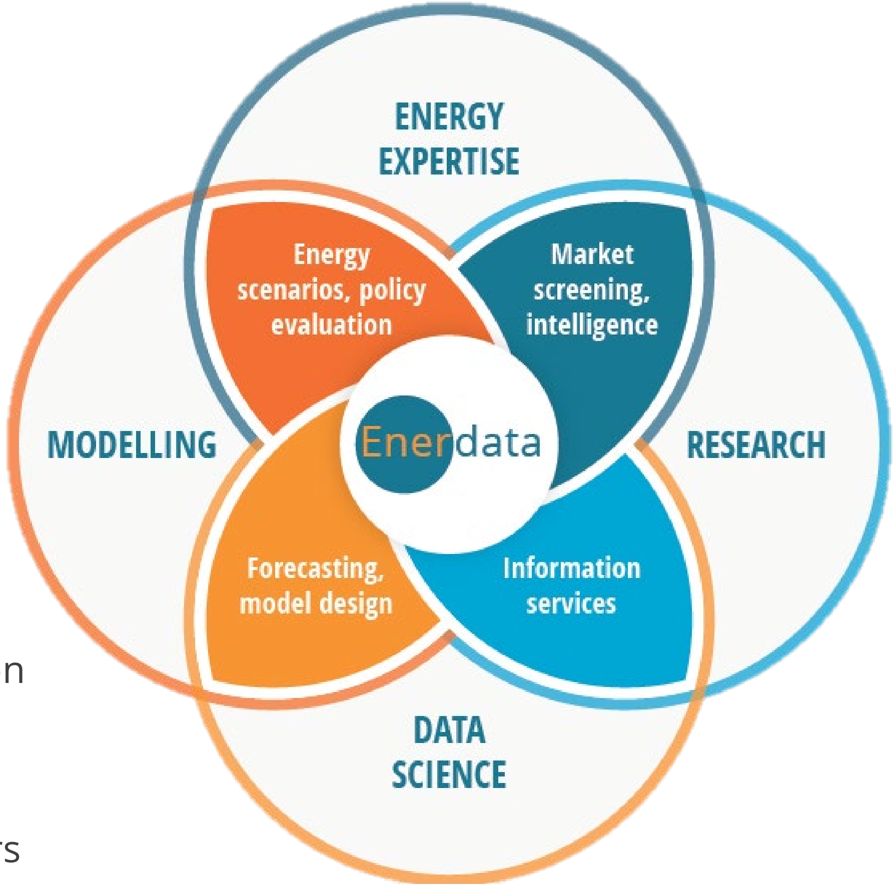
Our services – Combining fields of expertise from research, data science to modelling

Modelling

- Creation of E-C scenarios, climate alignment trajectories
- Identification of alignment pathways by sector and by country

Expert in energy / climate

- Knowledge of market drivers
- Expertise covering all energy transition pillars: mix decarbonisation, energy efficiency, sufficiency, and flexibility (assets and markets)
- Deep coverage: all energies, all sectors and 150+ countries



Market intelligence

- Market Research
- Business intelligence
- Energy market watch
- Tracking of E-C policies worldwide

Data science

- Gathering, consolidating and analysing energy data
- Market forecasts: supply, demand and prices

A wide portfolio of services & products

INFORMATION SERVICES

- Databases
- Market reports
- Long-term forecasts
- Market watch

CUSTOM SERVICES

- Tailor-made research platform
- Tailor-made forecasting models

CONSULTING

- Market studies & diagnostics
- Strategic analysis
- Due Diligences
- Tailor-made forecasts
- Regulatory studies
- Feasibility studies

TRAINING

- Energy prices
- Energy statistics
- Modelling
- Energy Efficiency
- Climate change

Agenda of the webinar

- Introduction to energy systems models
- Overview of a selection of Enerdata's modelling tools
- Case study: Clean Energy Transitions in the Sahel
- Conclusion and Q&A session

Speakers' introduction

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Energy Modelling Expert

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Project Manager & Senior Analyst

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Introduction to energy systems models

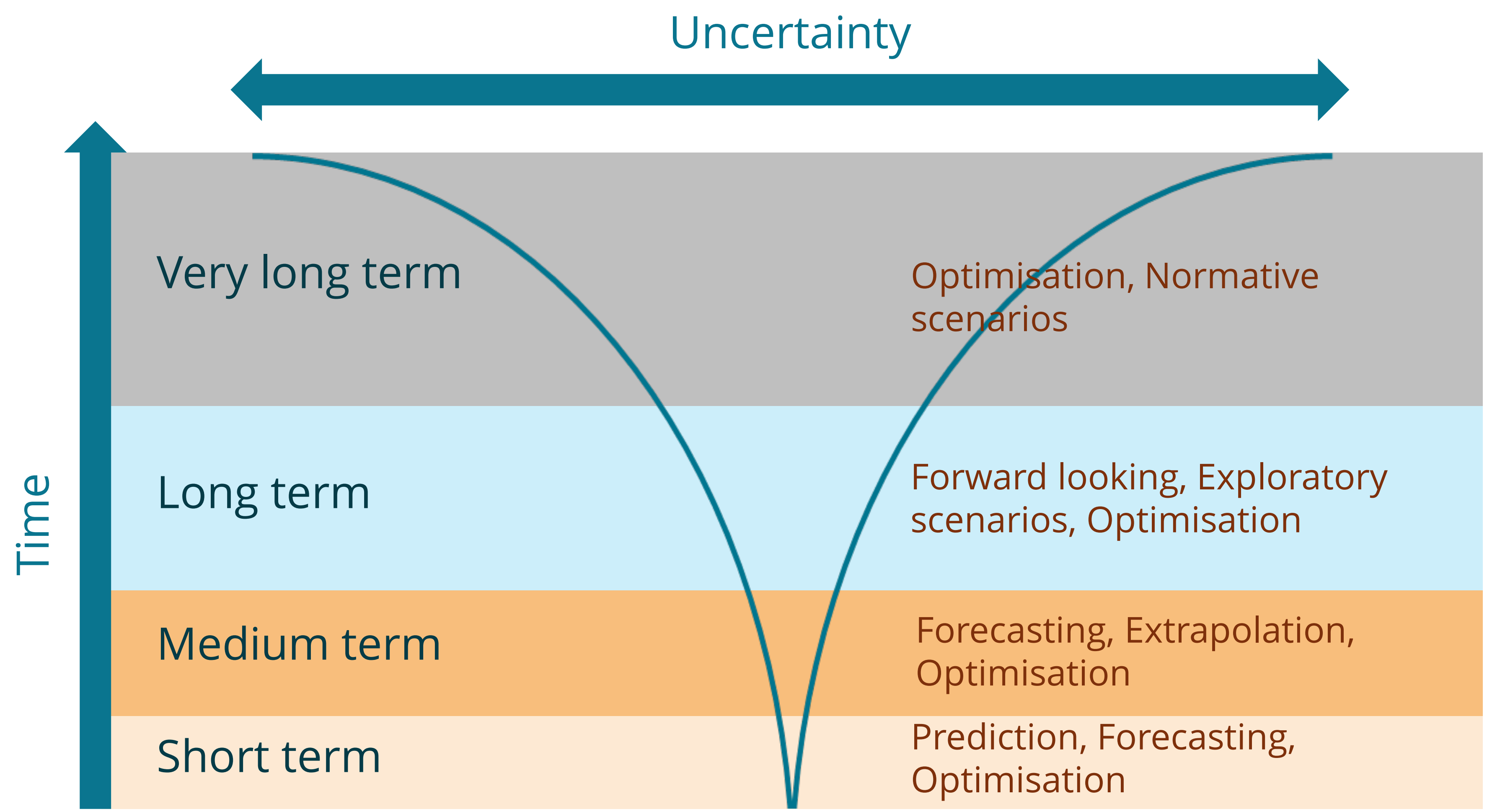
Why use models?

- **Models are a representation of reality**
  - Models **depict a system in a simplified manner**
  - They are used to better understand its functioning and the **relationships between variables** at play

- **Energy system models offer insights to a variety of actors**
  - Business actors use them to manage…
    - Spot market and hedging strategies in the short-term
    - **Production and dispatch** in the short- to medium-term
    - **Capacity planning** and investment strategies in the medium- to long-term
  - Governments rely on models to plan their long-term energy strategy
    - Design and implementation of **energy and climate policies**
    - Optimisation of national resources utilisation under environmental constraints
    - Ensuring security and affordability of supply

- **But models are limited by definition…**
  - The boundaries of models mean they rely on **exogenous assumptions** which are subject different degrees of **uncertainty**
  - The methodology itself is imperfect as it does not necessarily perfectly reflects reality

From forecasting to exploratory analysis: different tools for different uses



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Energy system models: varying scopes, methodologies and levels of granularity

- **Physical models: what happens if…**
  - Offers a faithful depiction of a system or a sub-system to assess its sensitivity to different assumptions
  - No decision-making involved in such models

- **Techno-economic models: bottom-up assessment of energy systems**
  - Detailed depiction of technologies involved
  - Extremely valuable to **technological progress** affecting energy demand over time
  - Typically a high reliance on exogenous assumptions

- **Econometric models: a top-down approach**
  - Energy systems are modelled at a macro level, **energy demand is expressed a function of key drivers**
  - Without explicit account for technologies, accuracy relies on historical trends (not well suited to address technological shifts)

- **Methodological characteristics**
  - Optimisation vs. simulation
  - Agent-based or centralised decision-making

- **Model hybrids and coupling of different models often used to properly assess energy systems**

Overview of a selection of Enerdata's modelling tools

POLES-Enerdata: our main tool for energy and emissions prospective

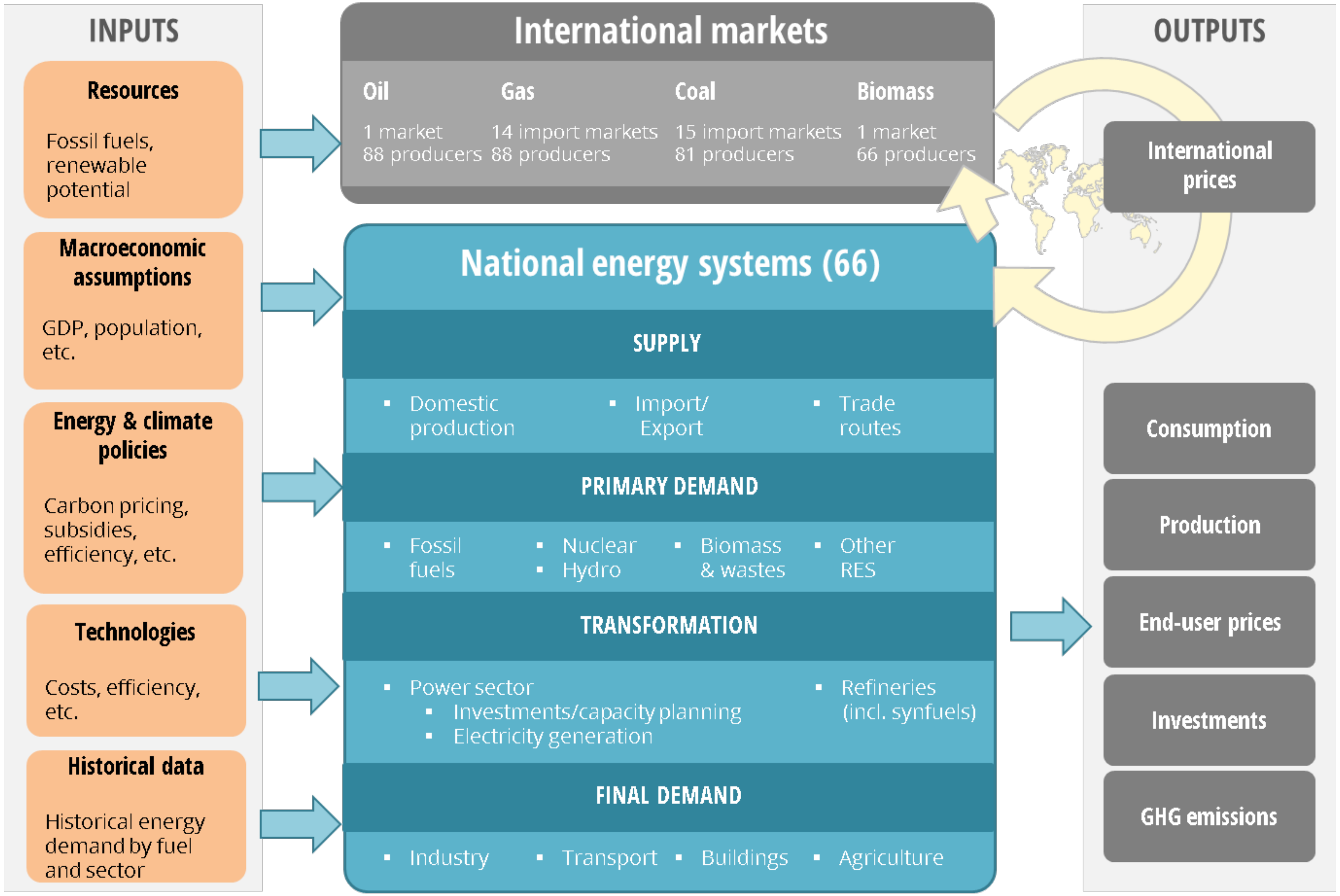
POLES-Enerdata is a partial equilibrium model, with global coverage, for long-term energy and GHG emissions projections

- The time horizon is up to 2070 (mainly used up to 2050), with an annual resolution
- The model uses a recursive simulation: all variables are calculated for year t before calculating year t+1. Results from year t impact the calculations in year t+1.
- The modelling of energy demand is a **mix of econometric and techno-economic**.
- The model is simulated using the Vensim software, a simulation software developed by Ventana systems.

A wide-scope energy system model

- **POLES-Enerdata coverage**
  - Covers 66 national and regional entities (54 individual countries + aggregates for residual countries)
  - **Integrated approach**: whole energy value-chain is endogenously modelled

- **A hybrid model**
  - Energy demand is given as an **econometric function of key drivers specific to each sector**
  - Several sectors include a techno-economic representation of the different technologies competing (e.g. power generation, road transport and steel-making)



How do we build long-term energy scenarios

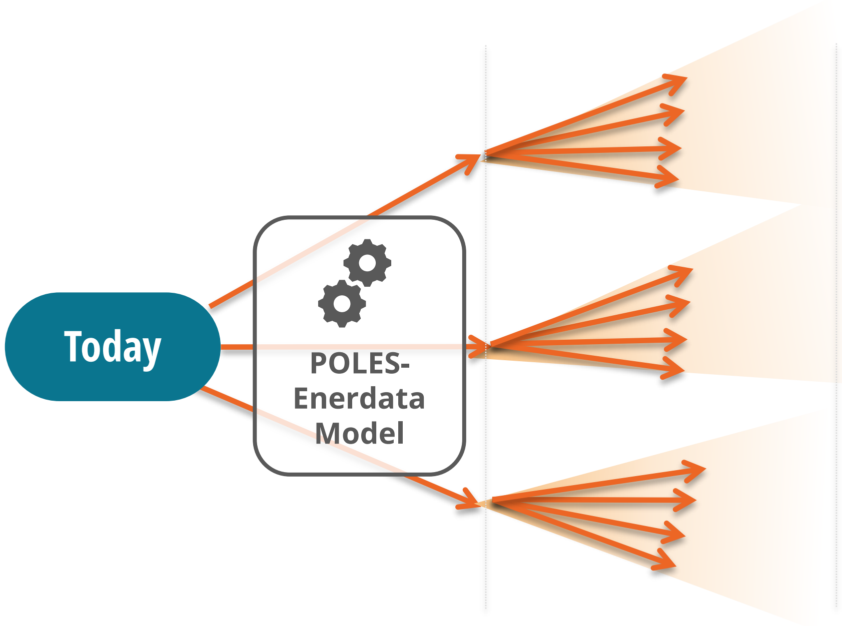
- **Reference and variant scenarios**
  - Energy prospective often starts with the development of a **reference scenario**
    - Often defined as a **BAU scenario** (Business-As-Usual), it depicts a future with no particular changes in policies
    - This results usually in a **prolongation of historical trends** are usually prolonged, with economic activity and demography driving energy consumption (not meant to represent to most likely outcome)
  - Variant scenarios are usually based on the reference scenario but incorporate key changes, such as:
    - Additional **energy and climate policies**
    - Breakthrough of specific game-changing technologies
    - Variation in the **macro-economic framework** (alternative trajectories for economic growth and population)
  - Importance of developing a consistent set of assumptions
    - Identify **key drivers** of energy demand and build a general **storyline** around them
    - Importance of accounting for **regional and sectoral specificities**
- **Back-casting approach: particularly suited for deep-decarbonization pathways**
  - Starting from an ultimate goal (e.g. net-zero emissions) and **deriving assumptions specifically to reach this goal**
  - The **drivers become levers to reach a target**, rather than based on informed assumptions (though more of a hybrid approach in practice)

EnerFuture: Global energy scenarios through 2050 with differentiated climate ambitions

Assumptions for key drivers: resources, climate and energy policies, available technological options, etc.

With or without change in the activity/macroeconomic framework

(GDP, demographics, industrial production)



2050

Demand
Global & regional dynamics, fuel mix, efficiency…

Supply & Prices
Availability, self-sufficiency, trade, bills…

Sustainability
GHG emissions…

Allowing to explore different pathways for energy markets

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EnerFuture scenarios: key indicators

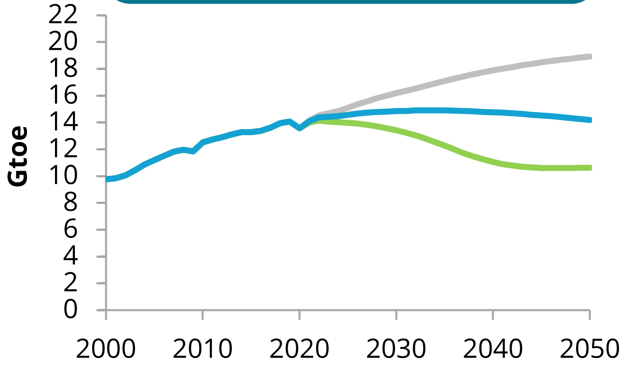
+5-6°C **EnerBase**: existing measures, extrapolation of historic trends

+3-4°C **EnerBlue**: additional realistic measures, aligning with NDC (Nationally Determined Contributions) emission targets

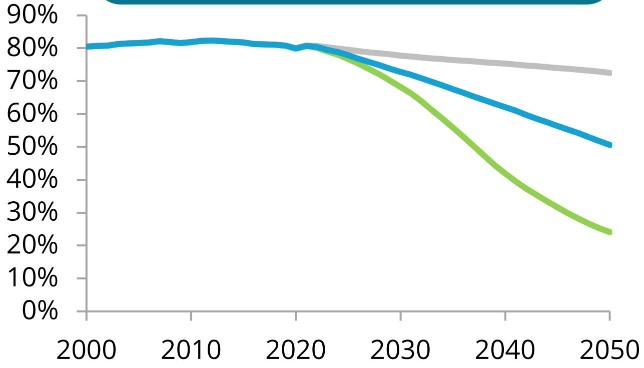
+2°C **EnerGreen**: scenario compatible with a temperature increase below 2°C

Average evolution (%/a)	1990 - 2020	*2010 - 2020*	2020-2050			
			+5-6°C	+3-4°C	+2°C	
Carbon intensity	-1.5%	*-2.1%*	-1.9%	-3.0%	-7.3%	*CO_2 emissions released to produce one unit GDP*
Energy intensity of GDP (final)	-1.4%	*-1.7%*	-1.6%	-2.1%	-3.7%	*Energy consumption necessary to produce one unit of GDP*
Carbon factor	-0.1%	*-0.4%*	-0.3%	-0.9%	-3.7%	*CO_2 emissions released for an average unit of energy consumption*

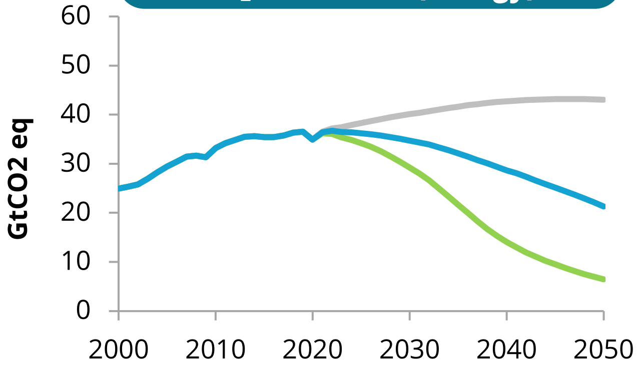
Global primary consumption



Share of fossil fuels



CO_2 emissions (energy)



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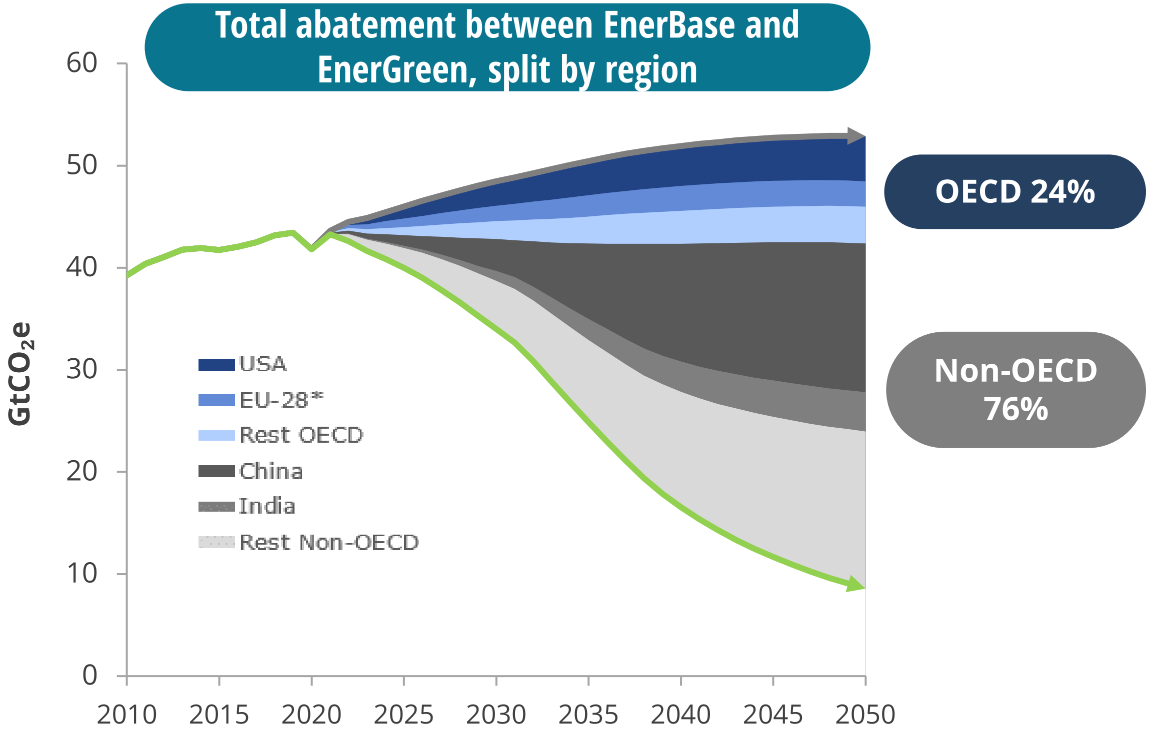
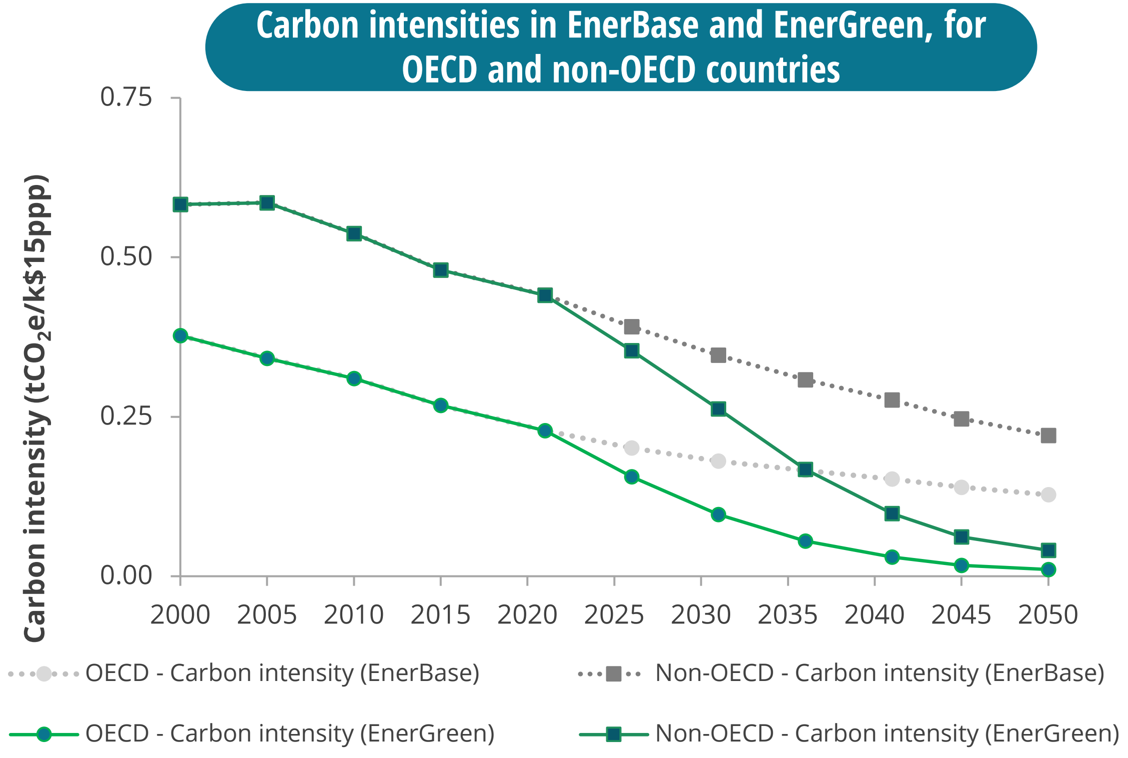
EnerFuture's main takeaways (1/2): need to decorrelate economic development and GHG emissions

- **Emerging economies key to deep-decarbonisation pathways**
  - Non-OECD countries account for the majority of the expected abatement
  - Need to **uncouple development and GHG emissions**
  - **Energy independence** as a major co-benefit of a more sustainable development

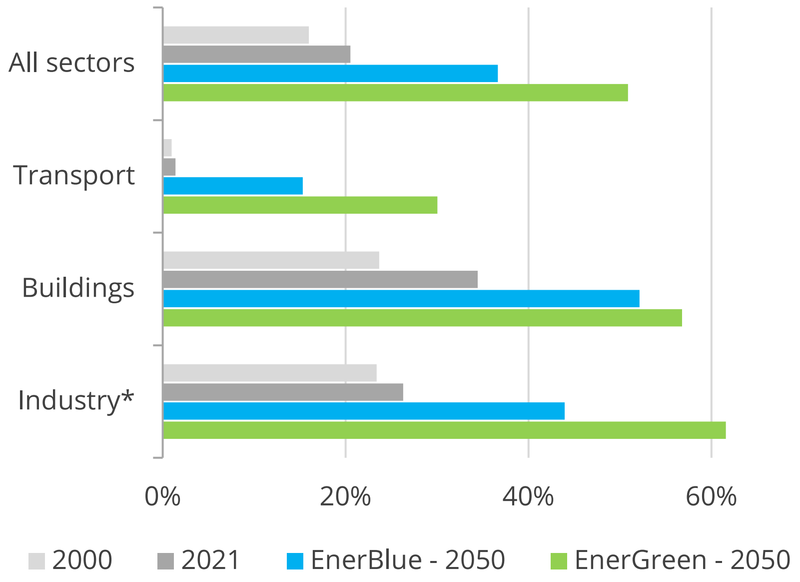




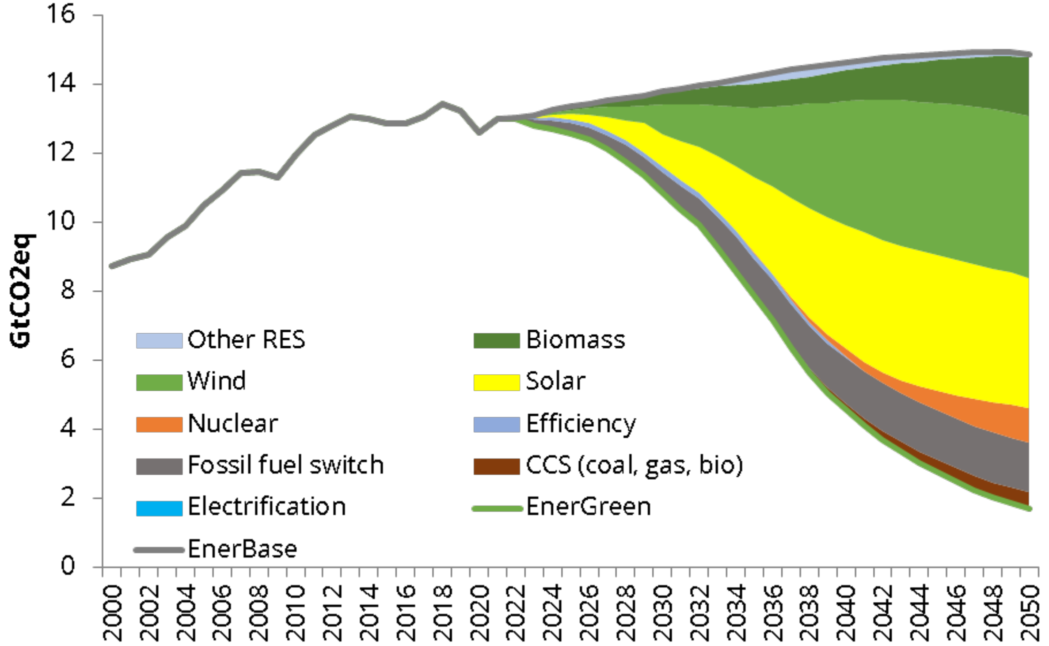
EnerFuture's main takeaways (2/2): electrifying energy uses while decarbonizing electricity

- **Electrification is essential to reach ambitious climate targets**
  - **High potential for decarbonization** through renewables of nuclear and often leading to **significant energy efficiency improvements**
  - Electrification is **achievable in a lot of uses**…
  - …but relies on highly innovative technologies in others => key to not neglect other key drivers to decarbonization (**demand-side measures, gas decarbonization**, etc.)

Share of electricity by sector (World Average)



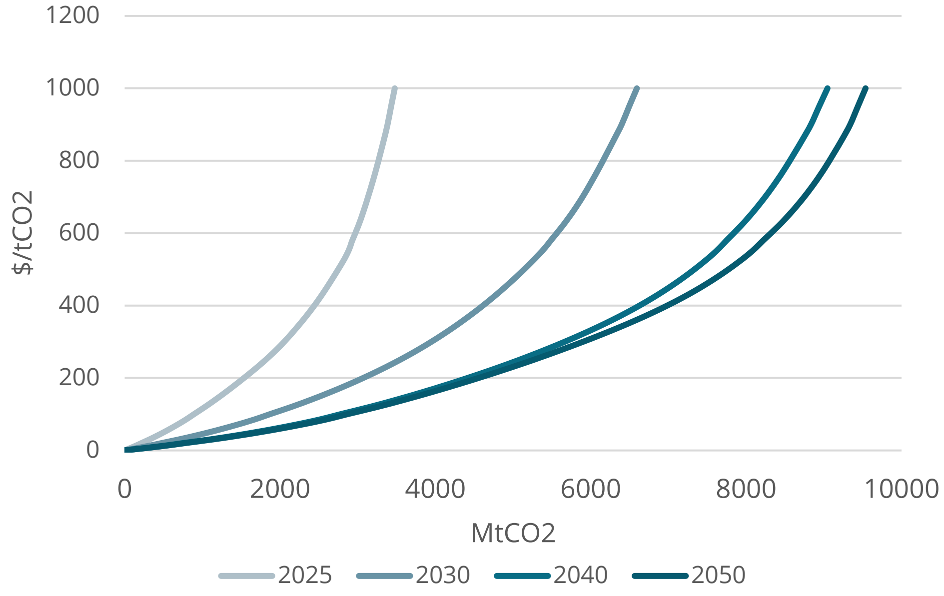
Total abatement between EnerBase and EnerGreen, split by technology or driver



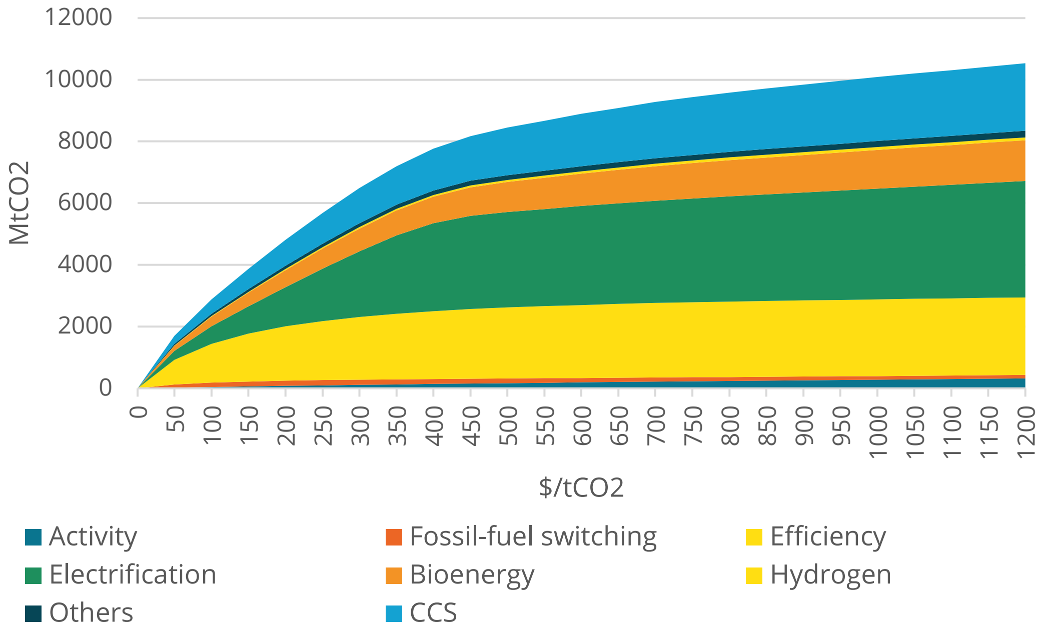
AERO: producing sectoral Marginal Abatement Cost Curves

- **Marginal Abatement Cost Curves (MACCs): a major output of Enerdata's modelling tools**
  - Derived from the POLES-Enerdata model, the MACCs reflect the **abatement observed at a given year after the introduction of carbon prices**
  - The **AERO** model breaks down the **abatement by technology** or option
  - The combination of POLES-Enerdata and AERO allows to keep the benefits of an integrated approach while also displaying technological insights

Total abatement for given years (industry sector)



Abatement options



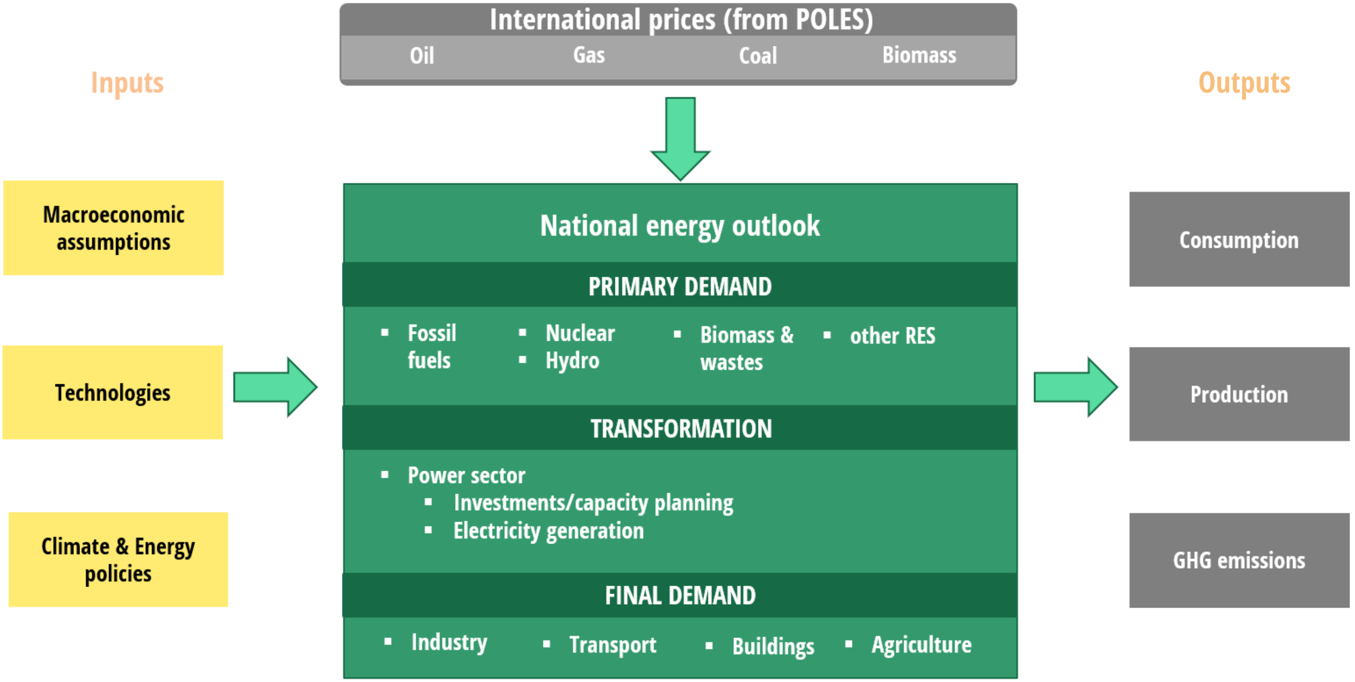
EnerNEO: a flexible Excel-based model inspired from POLES-Enerdata

- **Quantified evaluation of climate and energy policies medium- and long-term**

- **Simulation model, derived from POLES-Enerdata**
  - annual time-step
  - 2050-time horizon
  - Microsoft Excel
  - national or regional level

- **Modelling**
  - energy demand
  - electricity generation sector
  - primary supply of energy & corresponding GHG emissions

- **User-friendly tool**
  - even non-specialist users can build their own custom scenarios and sensitivities
  - intuitive interfaces
  - easily be transferred, with corresponding training



Case study:
Clean Energy Transitions in the Sahel

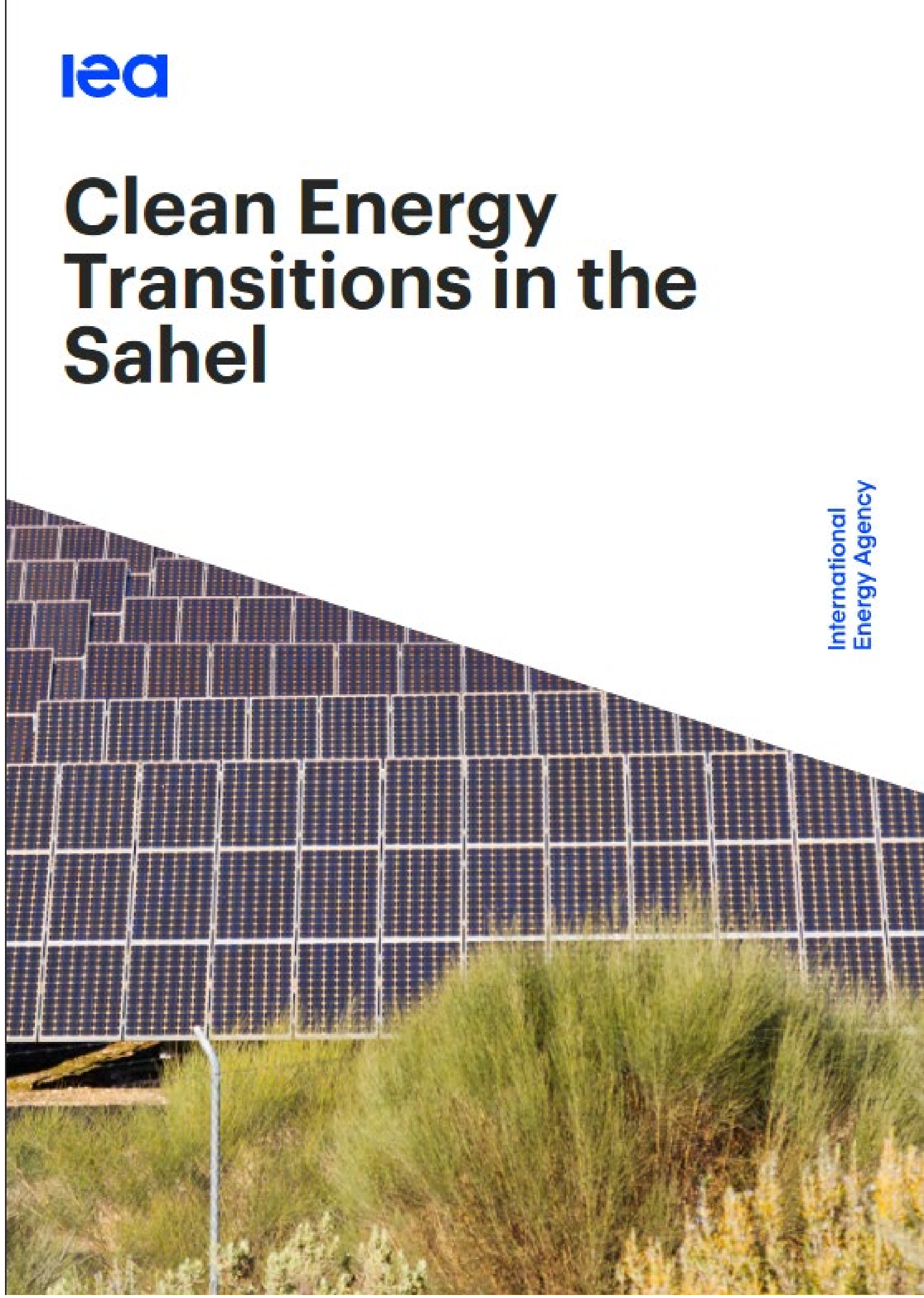
Context & objectives of the study

- **Financing under the Clean Energy Transitions Programme of the International Energy Agency (IEA)**
  - Part of an initiative with the aim to support clean energy transitions in Africa, through regional energy sector collaboration.
  - Production of a comprehensive report on a region in the Sahel
    - Analysing the current state of development and recent energy trends,
    - Exploring two different transition pathways to 2030,
    - And leveraging this analysis to identify key policy recommendations and best practices.

- **Contribution of Enerdata: production of the outlook to 2030**, with 2 contrasted scenarios

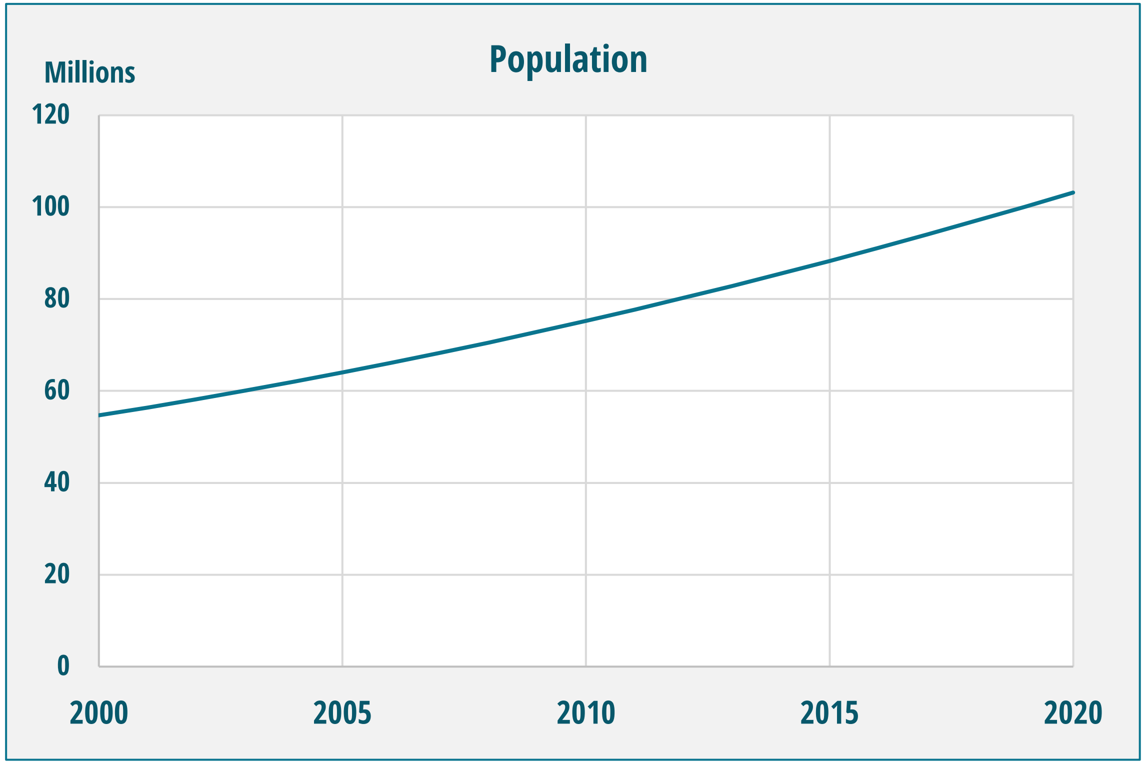
- **Geographical scope: Senegal, Mauritania, Mali, Burkina Faso, Niger, Chad** (hereafter referred to as « the Sahel »)
  - For the modelling, split into Senegal and G5 Sahel

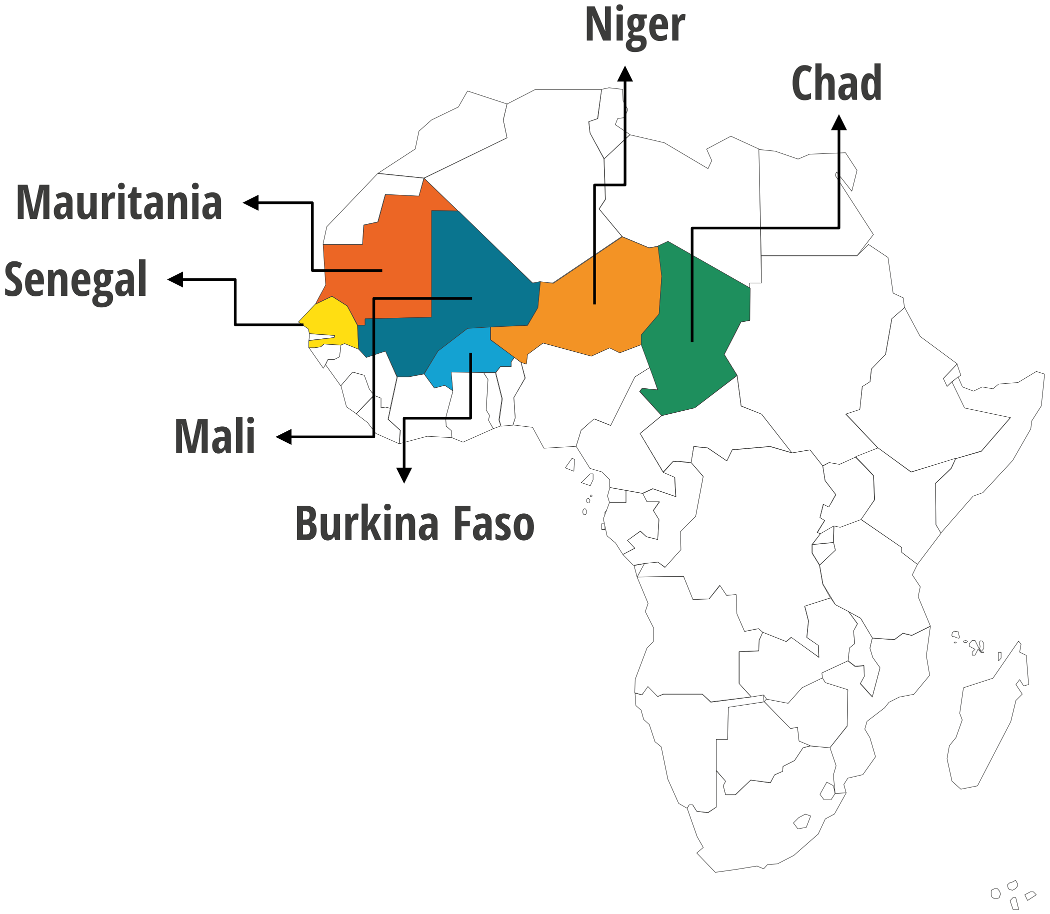
- **Study conducted in the summer of 2021, report published in September 2021**



Taking a step back: recent trends in the Sahel (1/6)

- **Demographic trends:**
  - Population **doubled since 2000**, reached **100 Millions** in 2019
  - Fertility rate is very high around **5.4 births/woman**
  - Population expected to reach **140M in 2030** and **230M in 2050**





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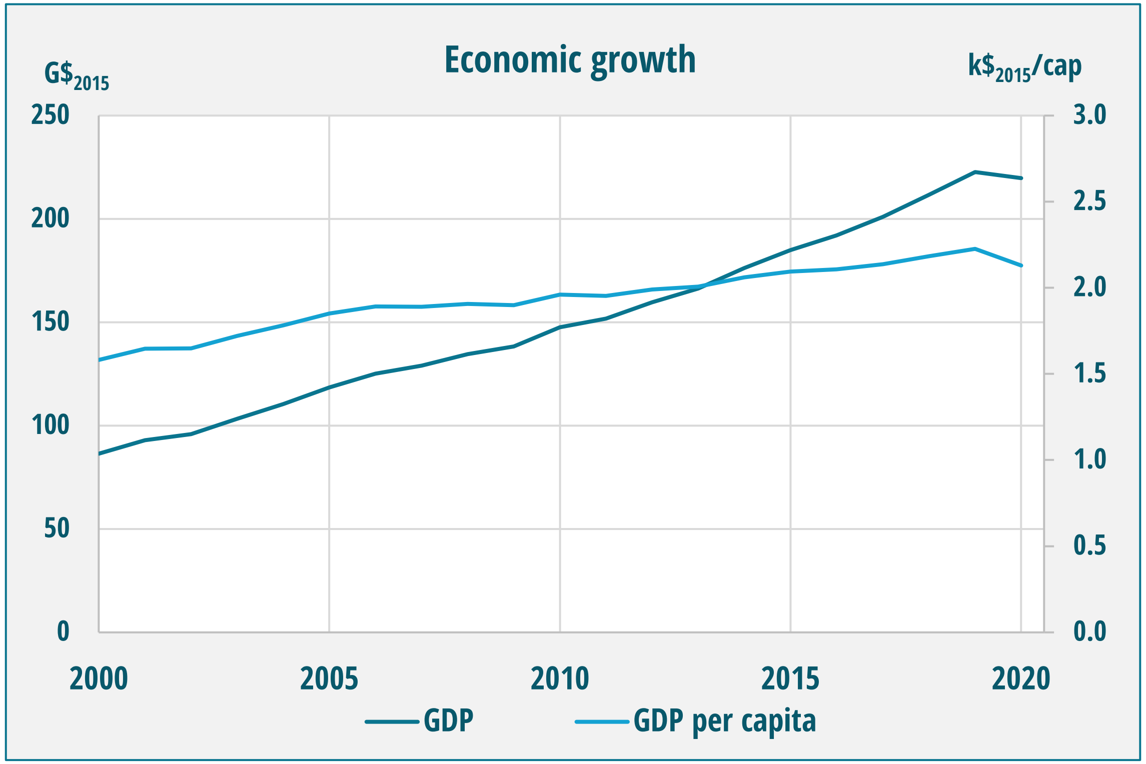
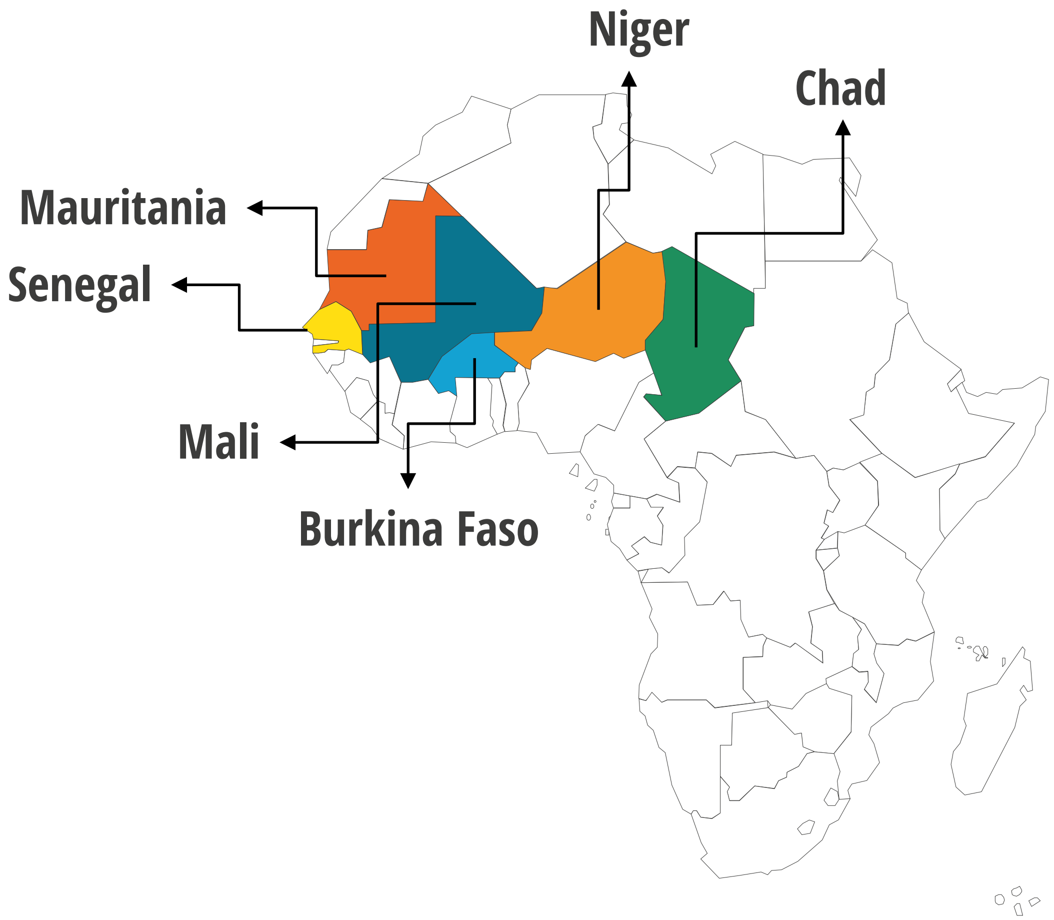
Taking a step back: recent trends in the Sahel (2/6)

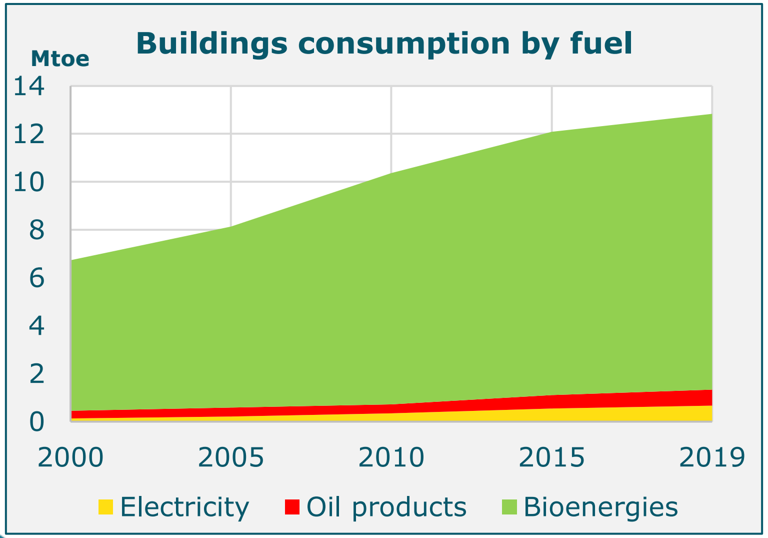
- **Economic trends:**
  - GDP reached **220 billion $$_{2015}$** in 2019 (**x2.5** since 2000)
  - Average GDP per capita progresses (**+40%** in 20 years), but remains low at **2.2 k$$_{2015}$/cap** (close to India, 15 times less than the EU average)

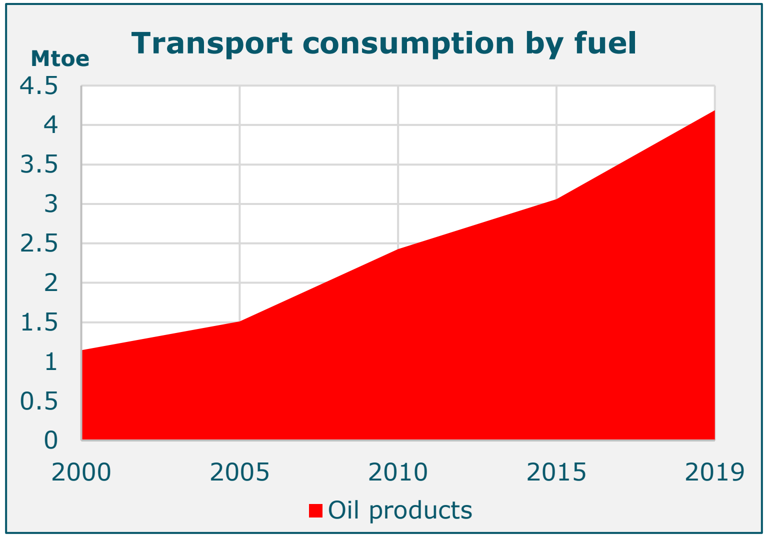


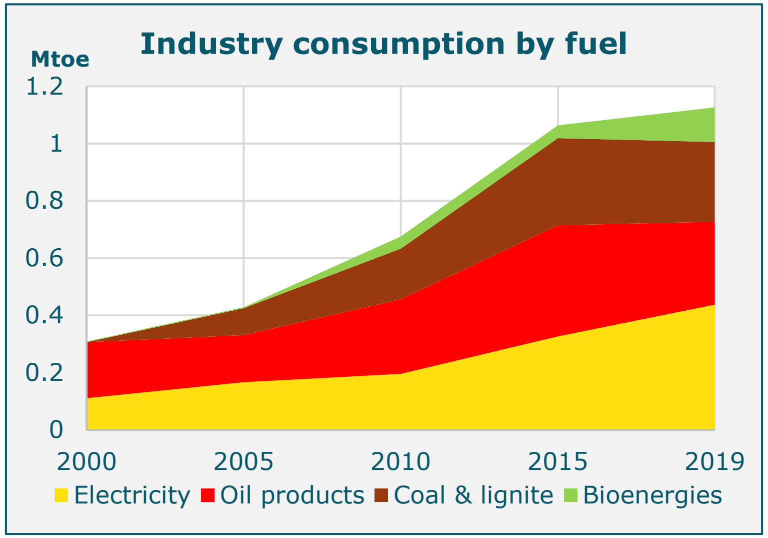


Taking a step back: recent trends in the Sahel (3/6)

- **Final energy consumption:**
  - The total final demand of the region amounts to about **18 Mtoe** in 2019 (+/- like Switzerland)
  - Households consume most of the final demand (around **70%**), mainly for cooking,
    - Traditional biomass remains the main fuel consumed by far (**~85%**)
    - Electricity consumption starts to develop with increasing access, but remains low (5% of energy demand)
  - Fuel consumption in transport in increasing rapidly, and is the main driver of oil consumption
  - Industrial energy consumption remains quite low, and driven by the mining sector

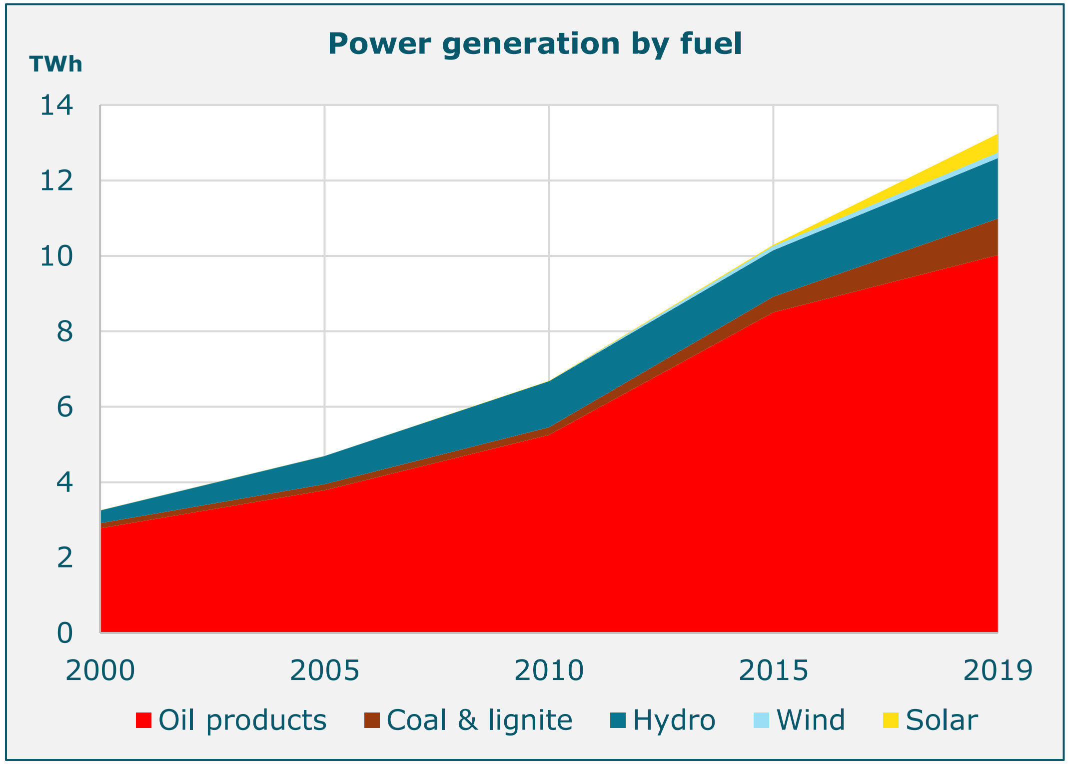






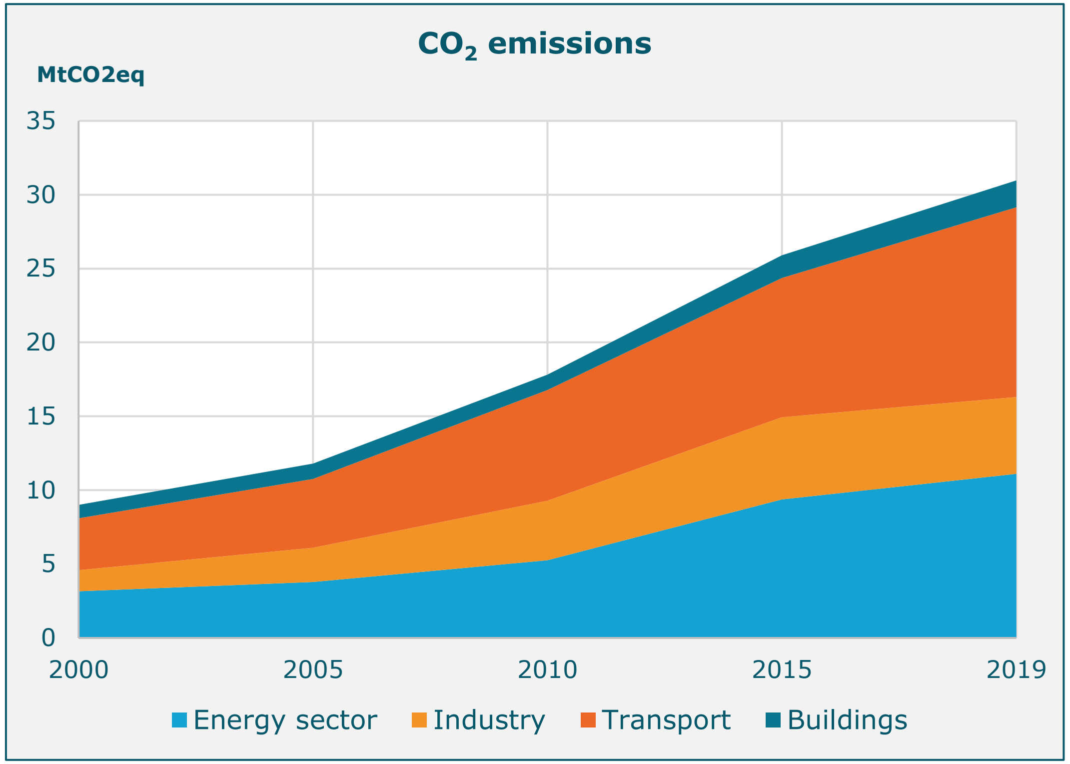
Taking a step back: recent trends in the Sahel (4/6)

- **Electricity generation:**
  - Total electricity generation surged from 3.4 TWh in 2000 to **13.5 TWh** in 2019 (**x4**)
  - Large disparities across countries of the region
    - Senegal 5.2 TWh vs Chad 0.3 TWh
  - The generation mix is **heavily oil-based**, but starts to diversify
    - Oil-fired generation accounts for almost **75%** of the total
    - Hydroelectricity covers **12%** in average in the region, but up to 40% in Mali
    - Coal-fired generation recently rose, with **1 TWh** produced in 2019 (Senegal and Niger)
    - Solar PV recently started to develop, with a **5%** share in 2019
  - Electricity supply still remains far below demand



Taking a step back: recent trends in the Sahel (5/6)

- **CO_2 emissions from fuel combustion :**
  - Total CO_2-energy emissions have grown at an average **7%/year** since 2005 (reaching **32 $MtCO_2$**)
  - Transport and power generation are responsible for most of these emissions, with respectively **38%** and **35%** in 2019
    - Combustion of oil products is therefore the main source of CO_2 emissions,
    - Coal is playing a more limited role, in both electricity generation and industry
  - Average emissions per capita remain very low (**~0.3 tCO_2/cap**), but CO_2 intensity of GDP is increasing (+65% since 2000).



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Taking a step back: recent trends in the Sahel (6/6)

- **SDG indicators :**
  - Access to electricity is increasing but remains low in average: **32% in 2019 from 14% in 2000**
    - Here also, large disparities among countries, with Senegal at 70% and Chad at 8%
    - Electricity access is mostly urban, with rural areas lacking behind
  - Access to clean cooking is low and stagnates since 2000 at around **10%**
  - The share of renewables in the final consumption, excluding traditional biomass, represents only **2%**

	2000	2010	2019
SDG7.1: Access			
Percentage of access of electricity	14%	22%	32%
Percentage of access of clean cooking	9%	10%	9%
SDG7.2: Renewables			
Share of all renewables in final consumption	72%	70%	64%
Share of modern renewables in final consumption	0.5%	1%	2%
SDG7.3: Energy efficiency			
Energy intensity of GDP (toe/M$_{2015}$)	95	91	98

The EnerNEO model, adapted to match the study requirements

- **Enerdata in support of the IEA for the outlook component of the study**
  - As part of the report, the IEA needed a **prospective scenario analysis**
  - The IEA's internal modelling tools (incl. the World Energy Model) do not enable to model the Sahel region separately
  - Hence the need for a model with **flexible geographical perimeter**
  - EnerNEO was therefore found to be a perfect fit for this study

- **Configuration of EnerNEO for the study's specific needs**
  - Creation of two versions of EnerNEO: **Senegal**, and **G5 Sahel**
  - Incorporation of **historical energy balances from the IEA**
  - Completion of the models' input datasets using a combination of data from IEA & Enerdata, and estimations (activity data, model parameters, etc.)
  - Addition of indicators and modelling parameters about **electricity access, clean cooking**

- **Use of EnerNEO to produce the scenarios**
  - Transcription of the scenario assumptions and storylines into the model parameters
  - Extraction of results
  - Creation of a breakdown analysis on road transport

Two contrasted scenarios to explore possible futures for the Sahel (1/2)

Stated Policies Scenario (STEPS)

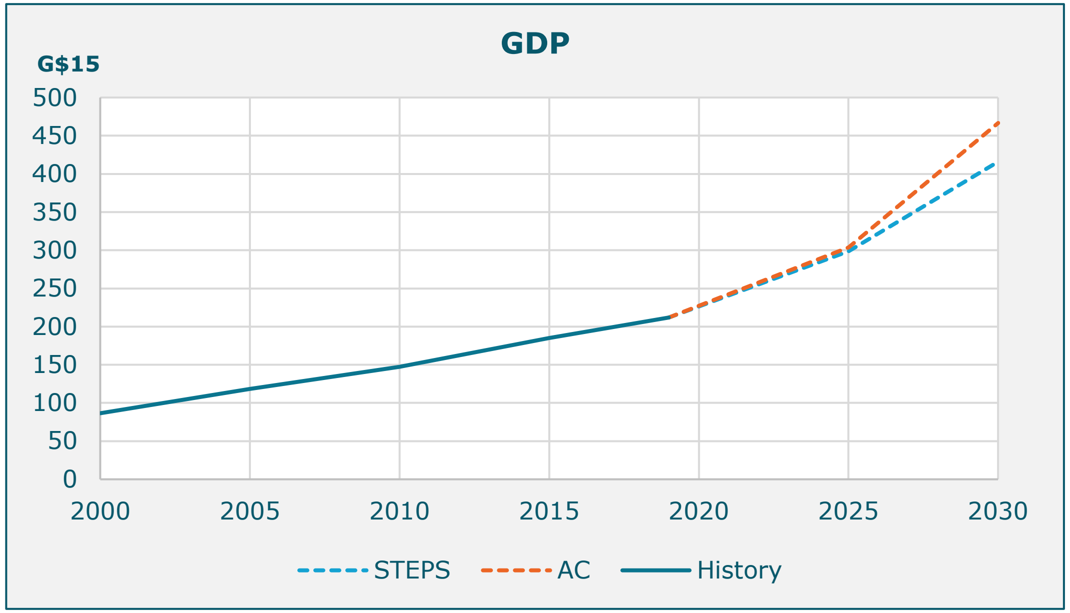
- This scenario reflects **today's policy frameworks and plans**, and their impact on energy development.
- It does not take government goals and pledges at absolute references, but rather assesses whether today's policies are on track to achieve these goals.
- However, this scenario does not focus on achieving any particular outcome: it simply looks forward based on announced policies in various sectors.
- It is aimed to be aligned with other IEA modelling publication referring to STEPS.

Africa Case scenario (AC)

- This scenario is built on the premise of Agenda 2063, and looks at what it takes to realise the African Union's vision for **more rapid economic development** and the achievement of **universal access to electricity and clean cooking by 2030**, for the Sahelian countries.
- Given the development and cost-effectiveness of low-carbon energy solutions over the next decade, it relies on achieving this additional economic growth at minimal additional cost and in a decarbonised manner.
- CO_2 emissions growth is kept in line with STEPS levels, largely by accelerating the decarbonisation of the power sector and by enhanced electrification in end-use sectors.
- Making progress on SDG 7 is the central objective for the Africa Case.

Two contrasted scenarios to explore possible futures for the Sahel (2/2)

- **GDP assumptions:**
  - GDP is assumed to grow by about **5.8%/year** in average by 2030 in the STEPS
  - The AC sees an additional 0.4%/year GDP growth, and therefore an average **6.2%/year** on average by 2030



- **Electricity access:**
  - In Senegal, universal electricity access is achieved in both scenarios, accounting for the country's plan
  - In the G5 Sahel region, the STEPS only records a 32% access rate, whereas the AC achieves universal access, with a much faster deployment of generation capacities, networks, mini-grids and off-grid systems

Year	2030	
Scenario	STEPS	AC
Senegal	100%	100%
G5 Sahel	32%	100%

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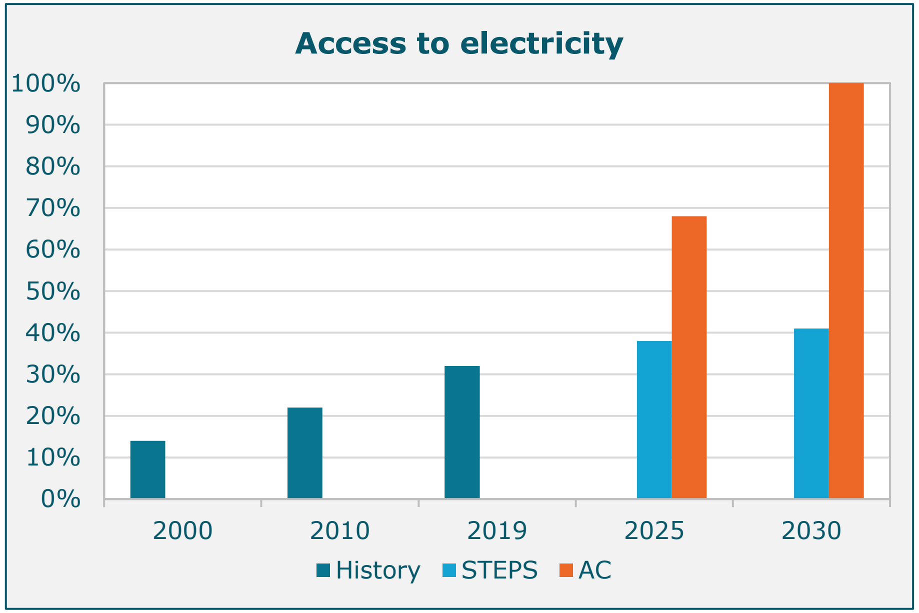
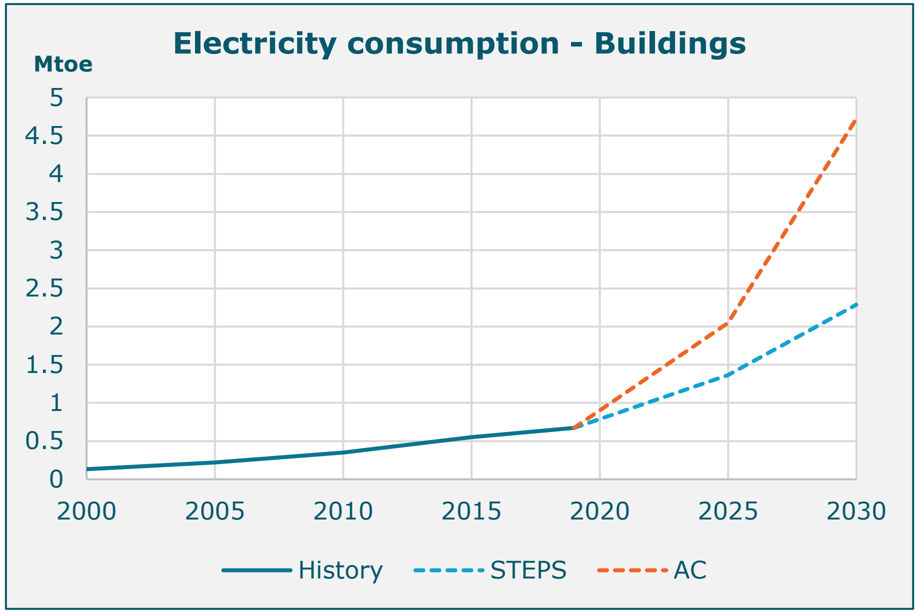
Key insights from the scenario analysis (1/6)

- **Access to electricity**
  - In the STEPS, around **80 million people still lack access** to electricity in 2030 (reaching an access rate of **41%**).
  - In the AC, **universal access** is achieved by 2030, representing **8.5 million people gaining access per year**.
  - This translates into a much higher electricity demand in the buildings sector in the AC (almost double the STEPS).





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Key insights from the scenario analysis (2/6)

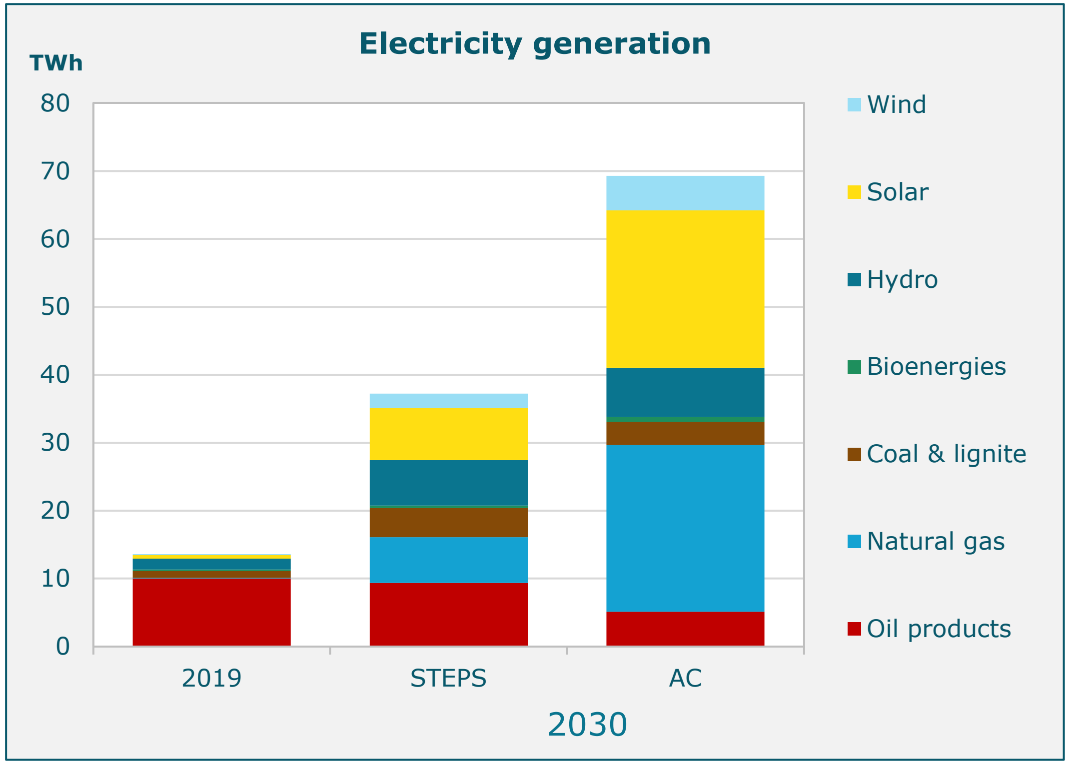
- **Electricity generation**

  – Power generation increases rapidly in the STEPS (**10%/year**), and even faster in the AC (**15%/year**).
  This compares to about 7%/year historically.

  – The majority share of oil-fired generation is expected to decline in both scenarios.

  – In these country with a large solar potential, solar PV capacities develop strongly in the AC, accounting for **33%** of the generation by 2030.

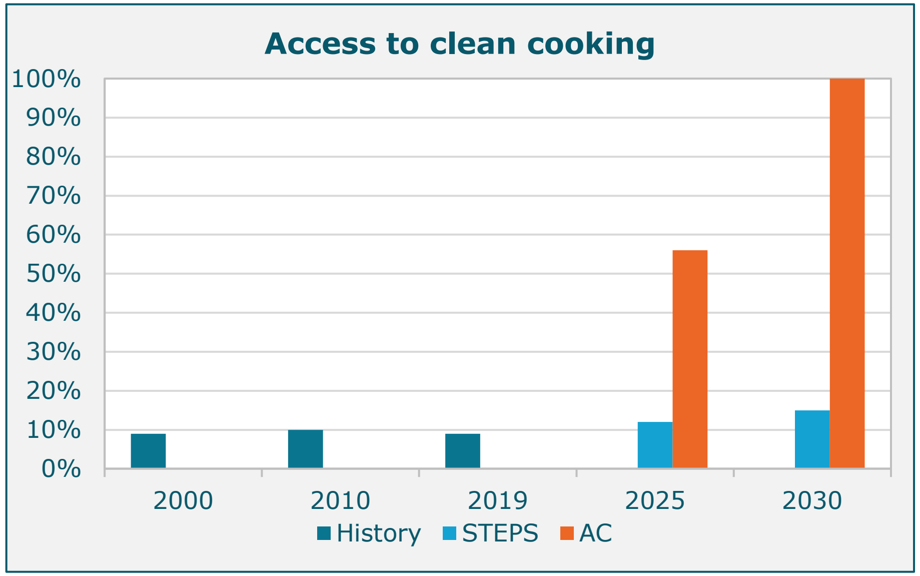
  – Gas-fired generation also becomes a large contributor, especially in the AC with around **35%**.

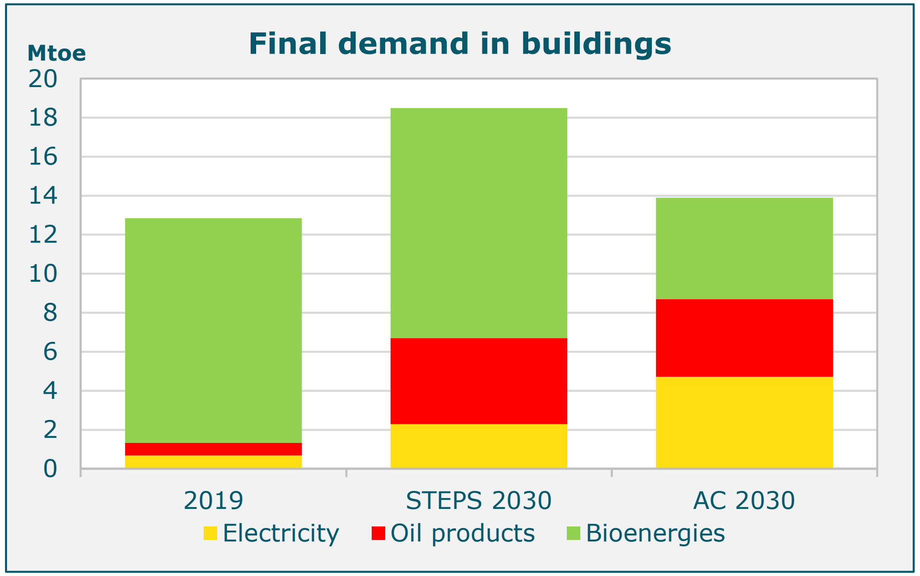


Key insights from the scenario analysis (3/6)

- **Access to clean cooking**
  - In the STEPS, around **120 million** people still lack access to clean cooking equipment in 2030 (access rate of **15%**).
  - In the AC, universal access is achieved by 2030, representing **12 million** people gaining access **per year**.

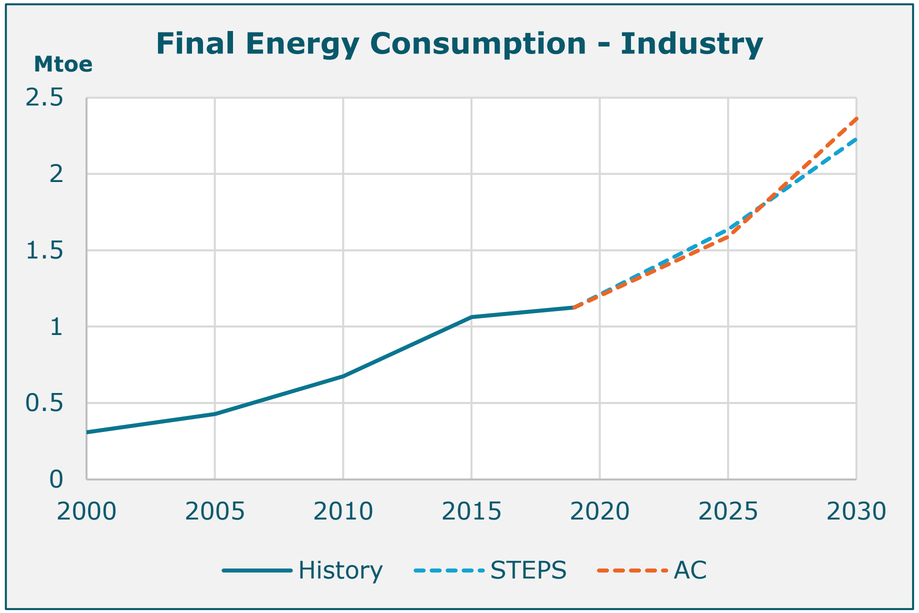
  - This translates into a quickly **declining share of traditional biomass**, with **high efficiency gains**, displaced by:
    - LPG solutions (especially in Senegal and Mauritania, and urban areas)
    - Electric cooking equipment
    - Improved modern biomass cookstoves

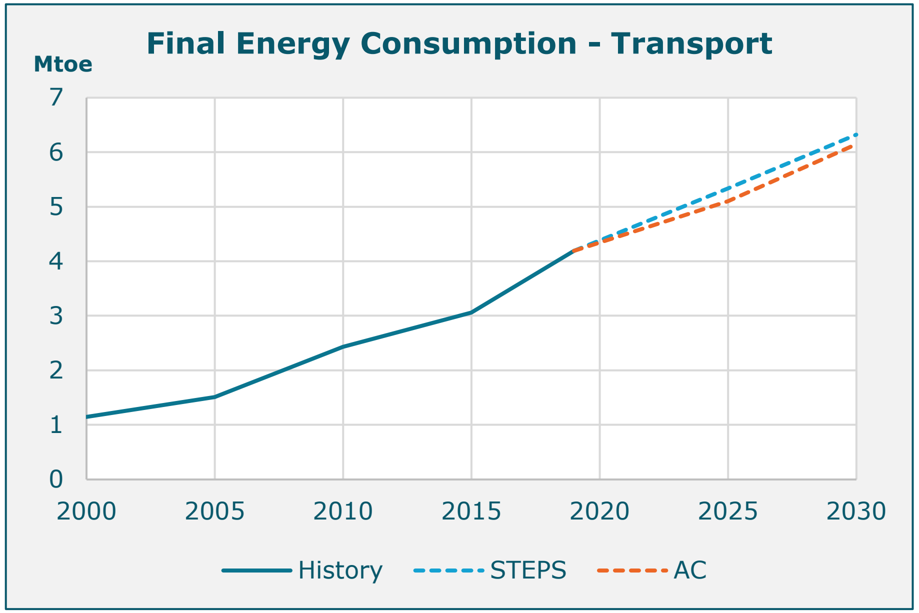




Key insights from the scenario analysis (4/6)

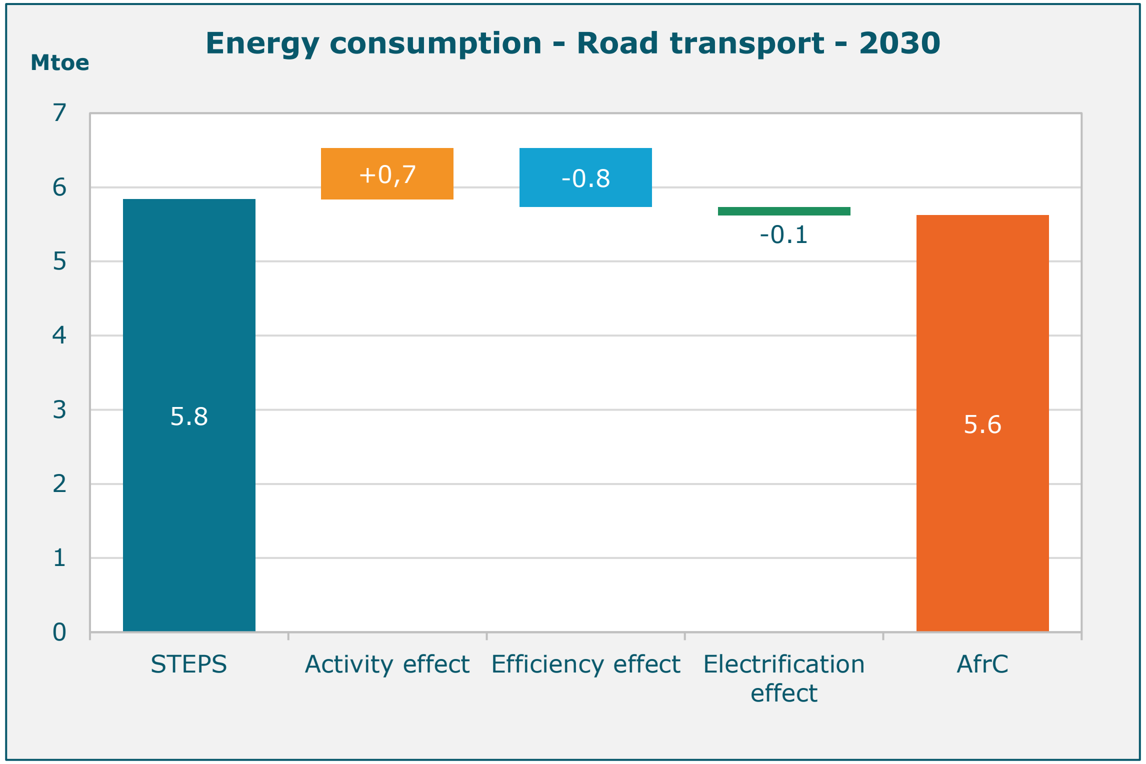
- **Higher economic development balanced by energy efficiency**
  - Energy consumed by the industry sector is increasing in both scenarios, reaching around **2.3 Mtoe** in 2030.
  - The additional economic development is partially balanced by additional efficiency in the AC, limiting the increase in energy demand.
  - In the transport sector, efficiency efforts lead to a slightly lower consumption in the AC.





Key insights from the scenario analysis (5/6)

- **Focus: breakdown of effects in the road transport sector**
  - Analysis of the key drivers explaining the difference between the two scenarios
  - Road transport represents **5.8 Mtoe** in 2030 in the STEPS
  - All other things being equal, the increased development in the AC would drive the consumption up by around **0.7 Mtoe**.
  - The increased average efficiency of vehicles in the AC tends to decrease the consumption by **0.8 Mtoe**.
  - Development of electric mobility, especially for 2-wheelers, in the late 20's, also decreases consumption by around **0.1 Mtoe** (thanks to the higher efficiency from EVs).
  - This leads the consumption to **5.6 Mtoe** in the AC, slightly below the STEPS.



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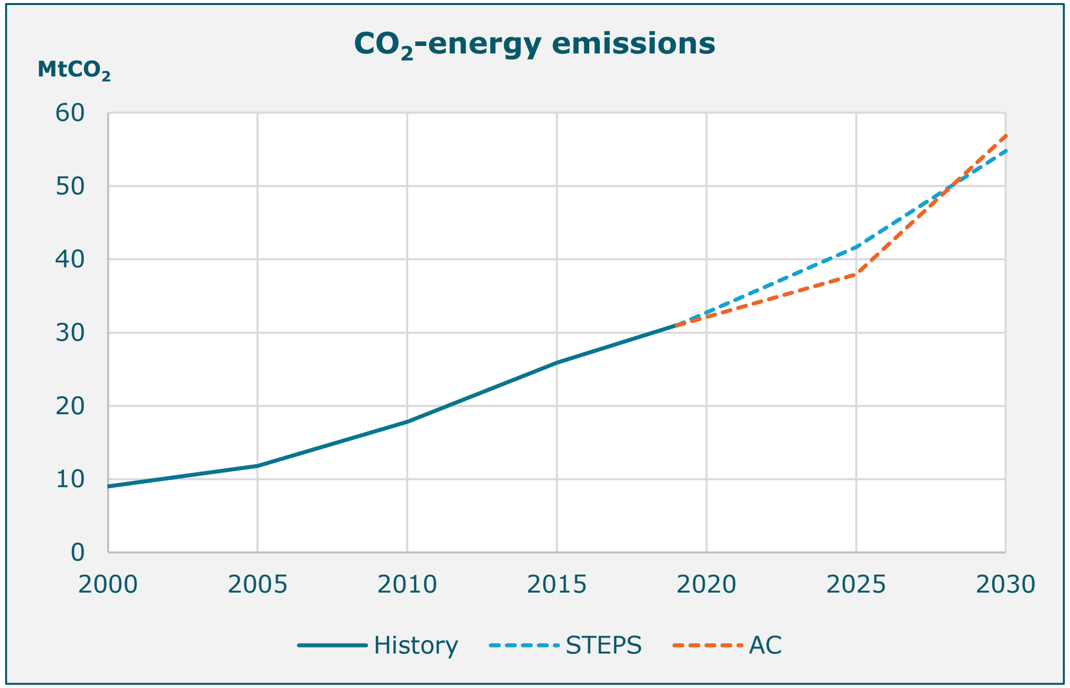
Key insights from the scenario analysis (6/6)

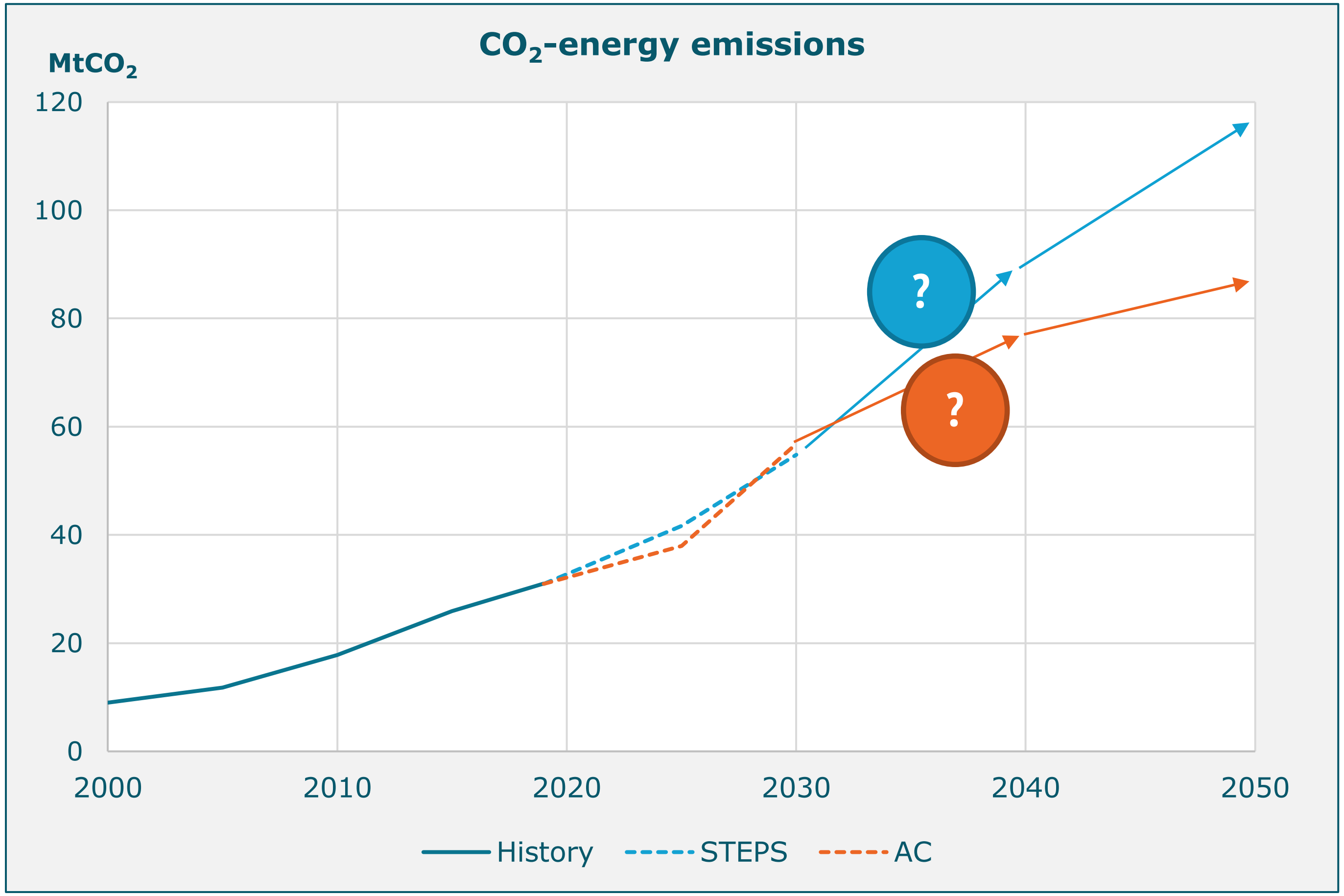
- **Total CO_2-energy emissions**
  - CO_2 emissions from fuel combustion are very close in 2030 in the two scenario, at around **55 $MtCO_2$**
  - Additional efforts towards renewables energy and efficiency enable to limit additional emissions in the AC, despite higher economic development, universal access to electricity, and partial switch from traditional biomass to LPG.



Looking beyond 2030…

- **The scope of the study was limited to 2030, but it would be interesting to look beyond!**

- **Likely outcomes:**
  - Continued increasing access to electricity in the STEPS would drive emissions up
  - Continued switch from traditional biomass in the STEPS would increase LPG consumption and emissions
  - Higher energy efficiency efforts, and development of renewables in the AC would mitigate the emission increase due to additional development
  - We would probably see emissions from STEPS rising to much higher levels than in the AC, where the transition was more anticipated…
    But we would need the model to confirm that!



Conclusion & Q&A

Concluding remarks

- **We presented a concrete example of how we tackled a specific case**
  - Specific geographic scope
  - Focus on sustainable development indicators
  - Integration of the client's own data and assumptions

- **But our expertise and panel of modelling tools allow various approaches to energy and GHG emissions prospective**
  - Off-the-shelf scenarios and MACCs: EnerFuture
  - Customised scenarios: POLES-Enerdata or EnerNEO depending on scope
  - Capacity building: training, delivery of modelling tools to develop in-house expertise

- **Our network of partners enables us to have a complete coverage, by coupling our tools with…**
  - Macroeconomic models
  - High granularity power system models
  - AFOLU models

MODELLING TOOLS: How to quantify your energy-climate pathways?

- Introduction to energy systems models
- Overview of a selection of Enerdata's modelling tools
- Case study: Clean Energy Transitions in the Sahel
- Conclusion and Q&A session

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HELPING YOU SHAPE THE ENERGY TRANSITION

About Enerdata:

Enerdata is an independent research company established in 1991, specializing in the analysis and forecasting of energy and climate issues, at world and country level.

Leveraging our globally recognised databases, intelligence systems and models, we assist our clients in designing their policies, strategies and business plans.

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Thank you for your attention!

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