Wind turbines on the Seagreen offshore wind farm (Scotland)

TotalEnergies

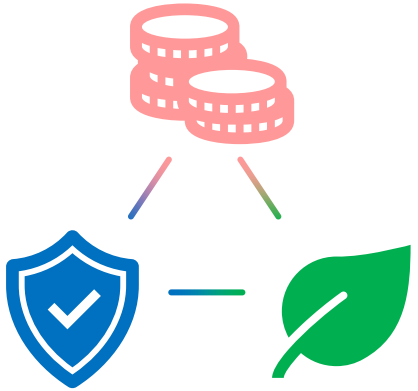
TotalEnergies
Energy Outlook 2023

The energy transition: challenges and opportunities

13 november 2023

The energy transition’s three challenges

Ensuring that the world's growing population has access to the **affordable energy** necessary for human development



Ensuring **energy security** in every country
(risk of unavailability and soaring prices)

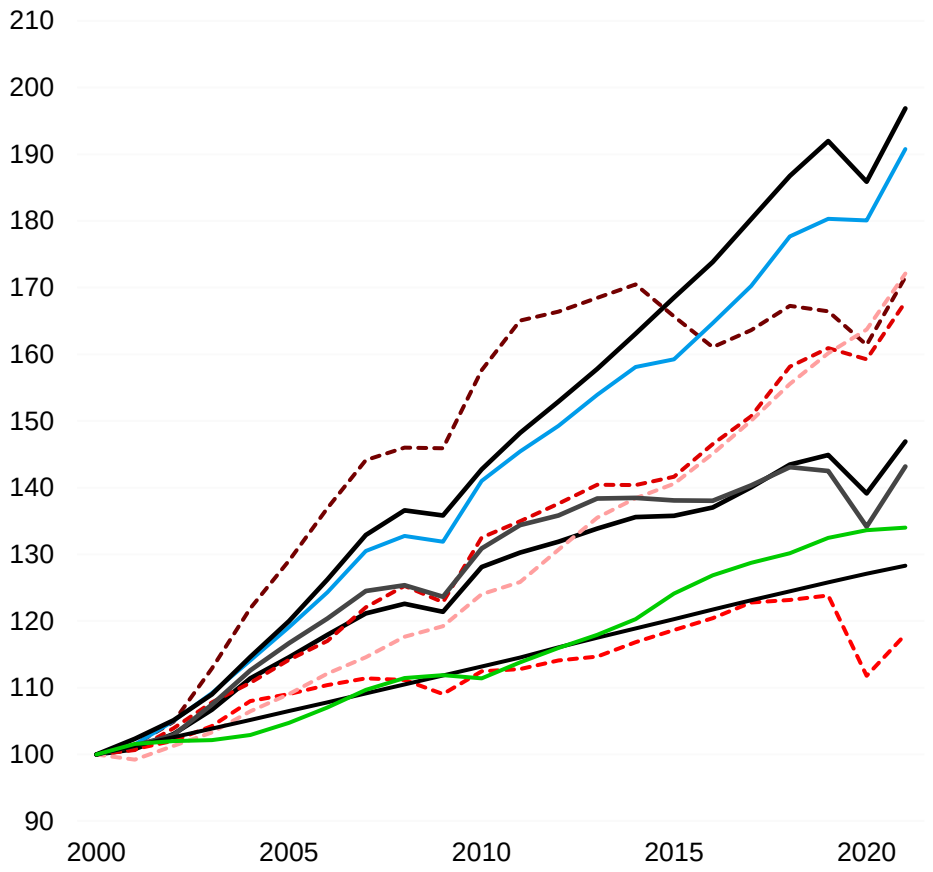
Decarbonising energy to limit the effects in terms of Greenhouse Gases (~2/3 of which come from energy)

The energy transition has started

Primary energy demand and emissions* are growing less rapidly than GDP

Evolution of a selection of indicators

2000=100



Compound Annual Growth Rate (CAGR) 2000/2021

GDP	3,3%
Electricity demand	3,1%
Renewable energy supply	2,6%
Coal demand	2,6%
Natural gas demand	2,5%
Total primary energy demand	1,8%
CO_2 emissions *	1,7%
Energy efficiency	1,4%
Population	1,2%
Oil demand	0,8%

Over the last 20 years, better energy usage has led to decoupling energy demand growth from GDP growth

This decoupling has been visible since 2000 for oil demand which has grown at the same pace as population until 2019, and since 2015 for coal (which, however, has grown at the same rate as renewables over 2000-2021)

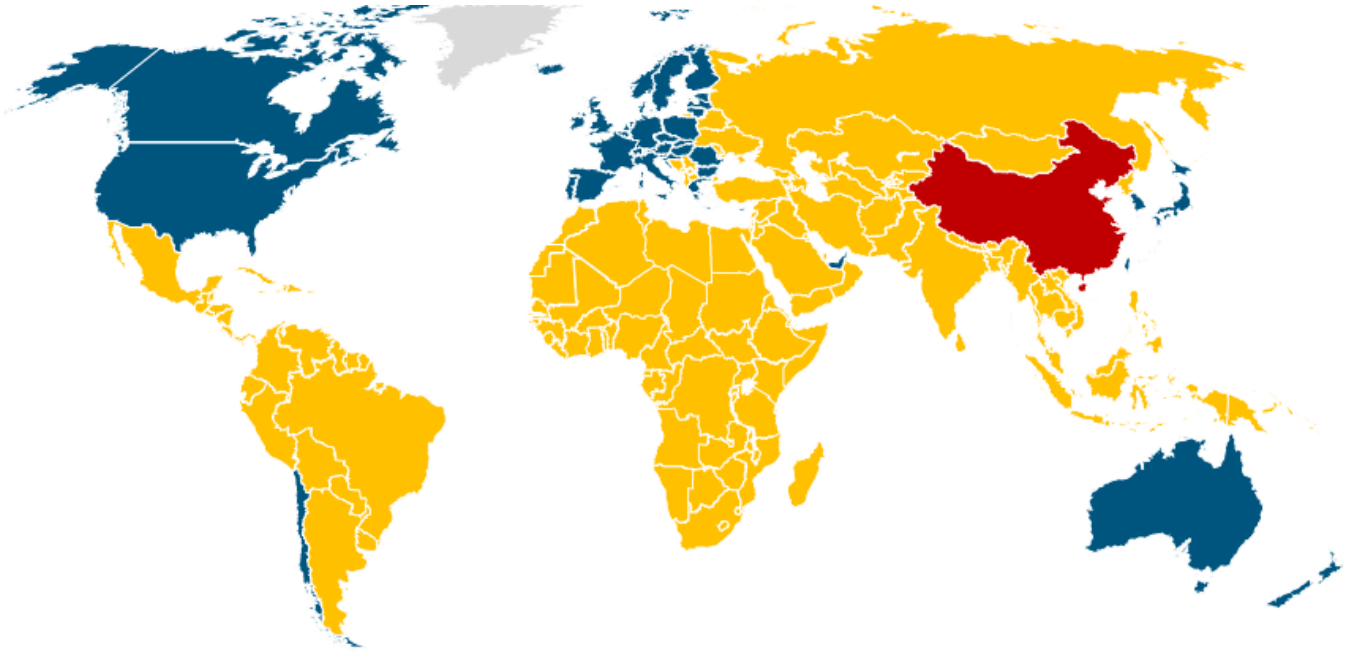
Over the past five years, the increase in renewable energy production has met 40% of the growth in primary energy demand

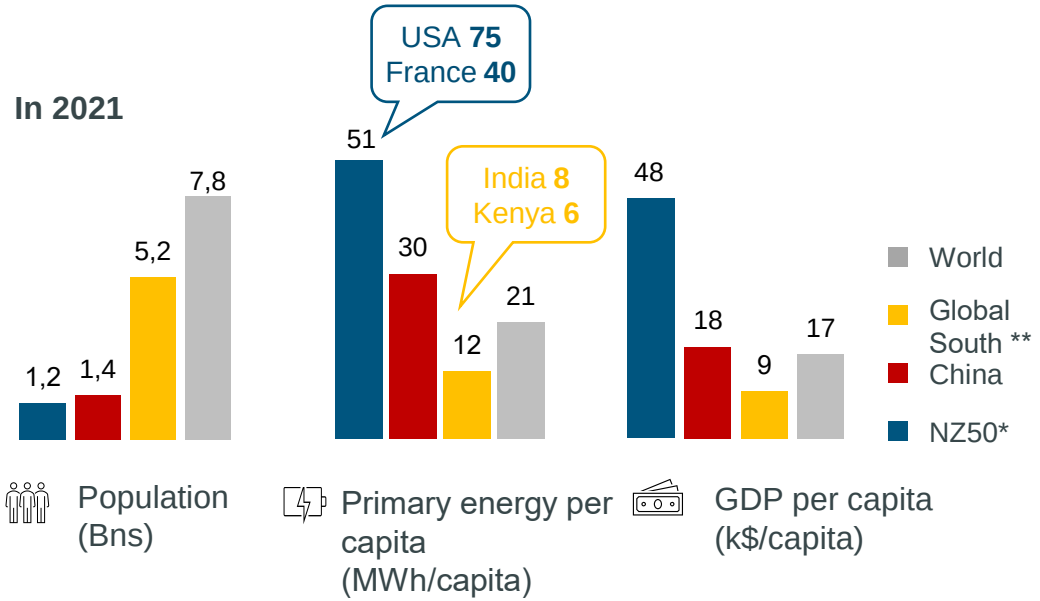
** From fossil fuels combustion*

Current situation

The energy transition will differ across countries

Analysis in three blocks



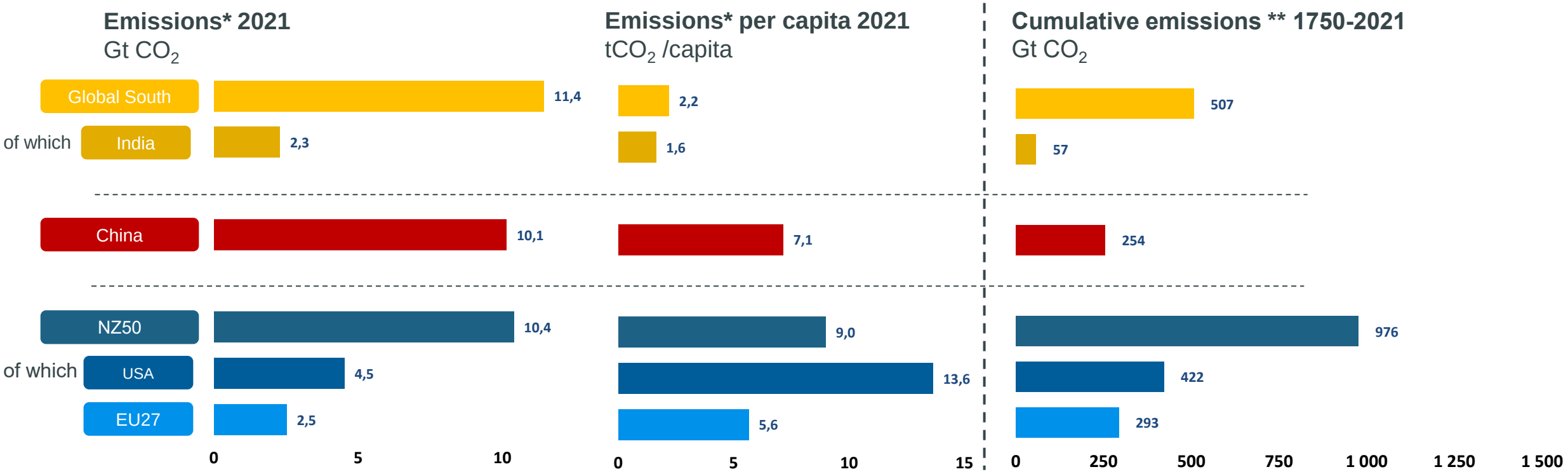


- **The energy transition does not have the same meaning for NZ50* countries' inhabitants and those in Global South** who have access to less than 10 MWh/year on average (~4 billion out of 5.2 billion)**
- **It must meet the Global South's** legitimate aspiration to higher living standards: poverty alleviation, access to health and education, which means first and foremost access to energy**

** The 40 countries, mainly OECD countries, that have committed to net carbon neutrality by 2050*
*** « Global South » here does not include China, since its energy demand's evolution is now closer to NZ50 countries*

Current situation

The current distribution of CO_2 emissions differs from the historical distribution



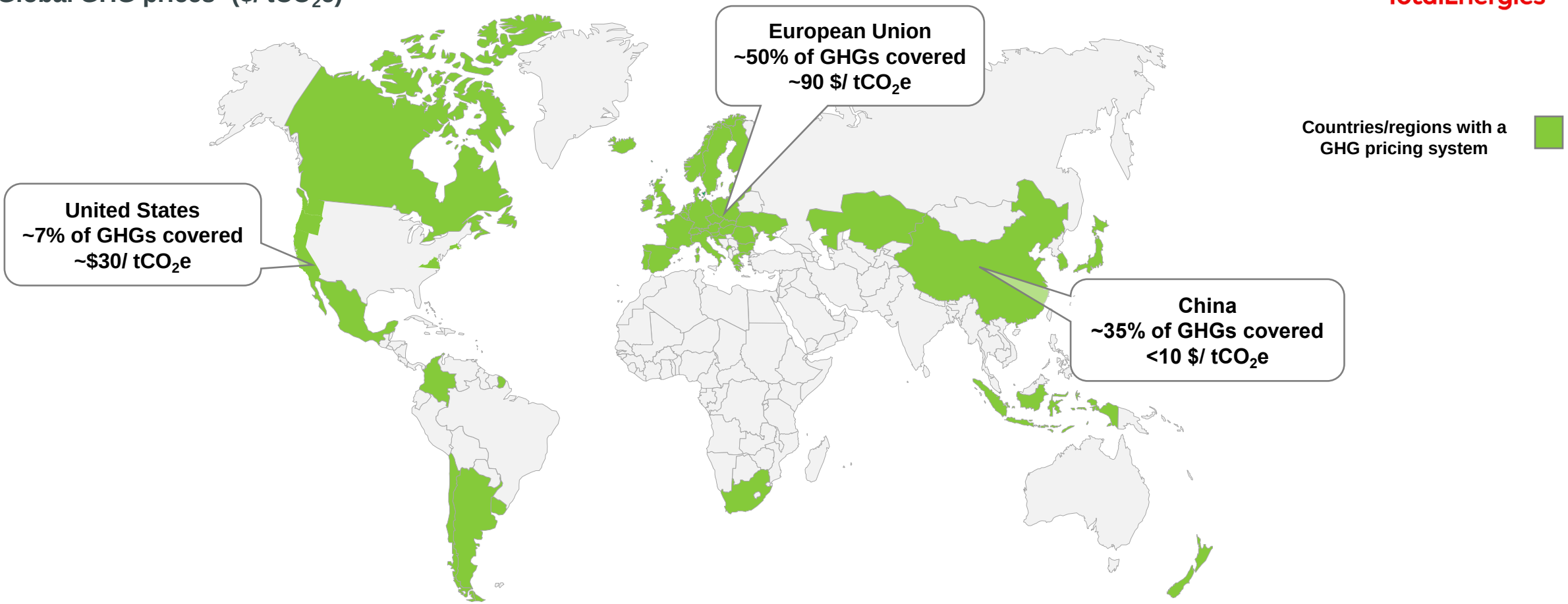
- **Global South demands the right to development, even if it means using fossil fuels as NZ50 countries did (especially if they are available locally)**
- **Climate justice requires supporting the energy transition in Global South: financing, but also technology transfer and training**

** Emissions from combustion; Source: Enerdata*
*** Emissions including industrial processes emissions; Source: Our World in data,*

Current situation

Few countries have introduced Greenhouse Gases (GHG) pricing

Global GHG prices* ($/ tCO_2e)



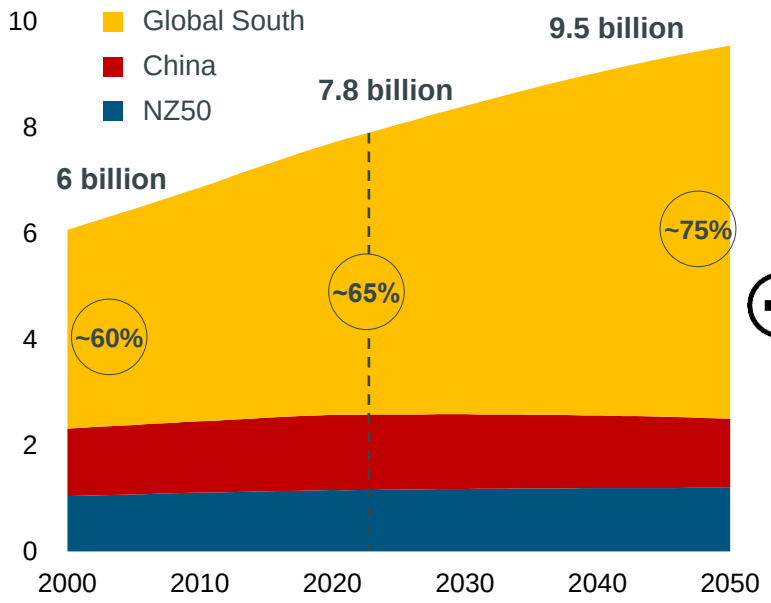
- Today, **around 20% of worldwide** Greenhouse Gases **emissions** are covered by a pricing system, of which only 4% (in Europe) at a level sufficient to modify behaviors
- In Europe, the Carbon Border Adjustment Mechanism (CBAM) aims to restore the carbon competitiveness of domestic production against imports

** Market price (e.g. ETS) or tax.*
Sources: I4CE, Global Carbon accounts in 2022, World Bank - State and trends of Carbon Pricing 2023

Current situation

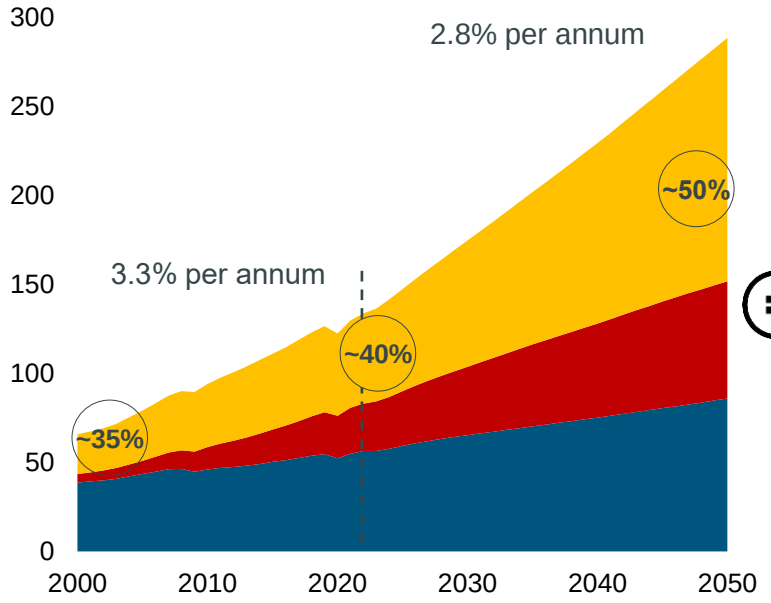
What can we expect for the next thirty years?

Population
Billions of people



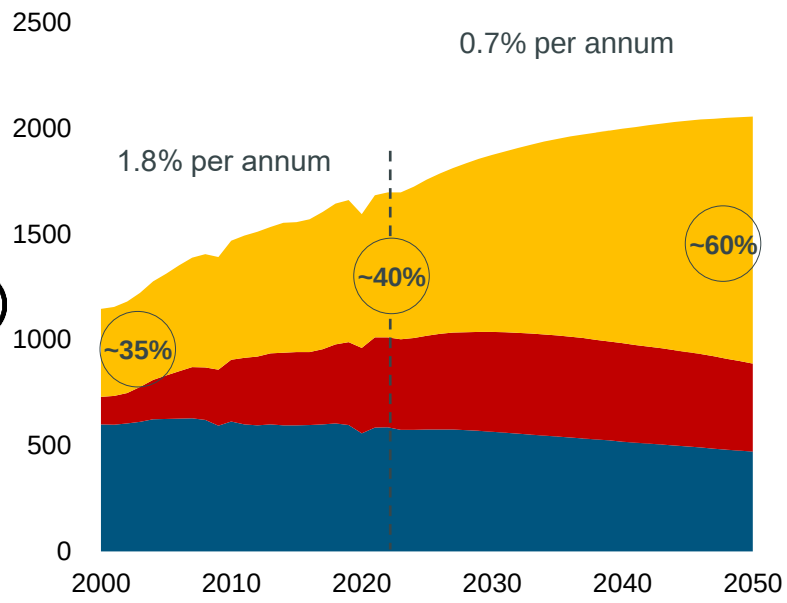
Between 2022 and 2050, the entire growth in the world's population will come from Global South

GDP
Trillions of dollars$_{2015}$



By 2050, the economy of Global South will be as large as those of NZ50 countries and China combined

Total Primary Energy Demand
PJ/d



By 2050, energy demand in Global South would increase by x1.7, even with optimistic assumptions for energy efficiency: 2.0%/ year, in line with the past 5 years' average, compared with 1.4% over the past 20 years

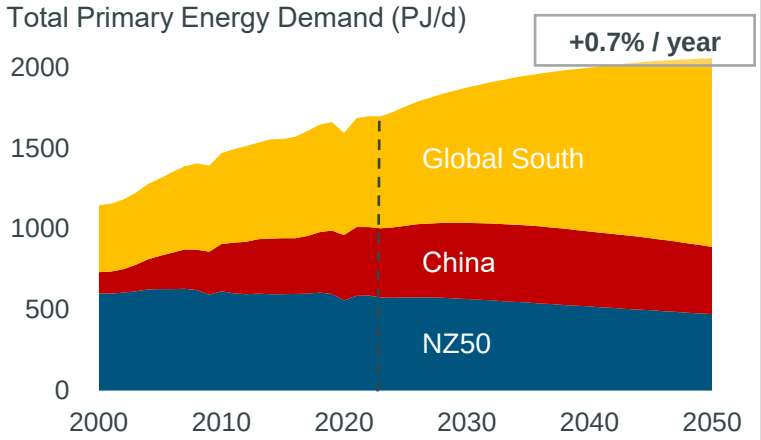
Source: Oxford Economics, Enerdata, analysis by TotalEnergies

Which trajectory?

Three possible scenarios in 2050

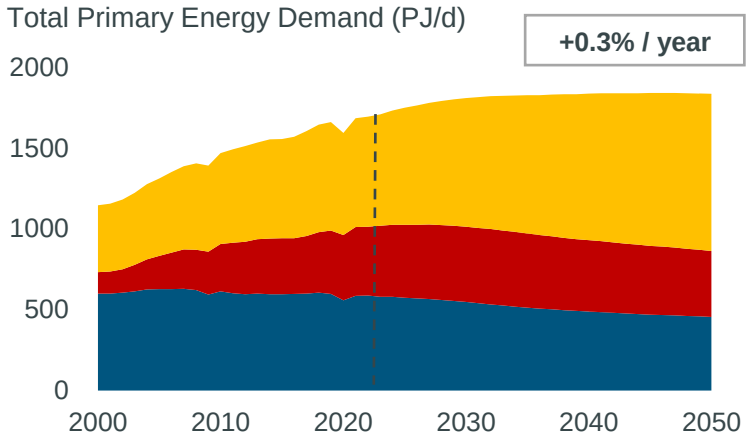
Population 9.5 billion in 2050, economic growth 2.8% / year until 2050

Current Course and Speed



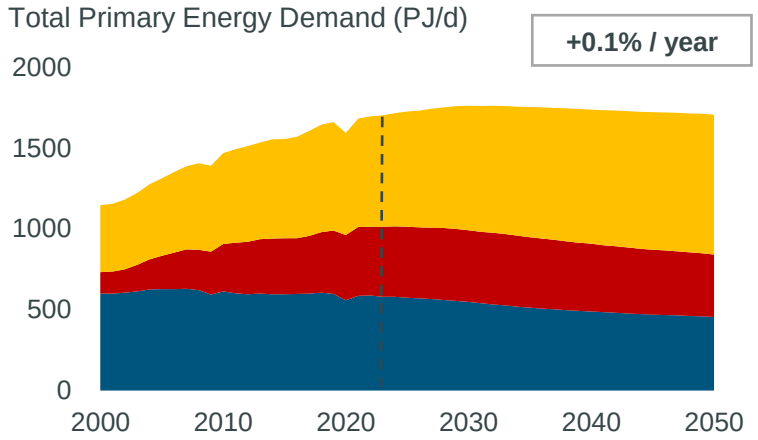
- Energy system transformation scenario based on current trends
- NZ50 countries and China fail to reach their 2050/2060 objectives, and Global South is developing without decarbonizing
- Temperature increase by 2100 is **higher than 3°C**

Momentum



- NZ50 countries and China reach their 2050/2060 targets
- In Global South, low-carbon energies meet around half of the growth in energy demand
- Temperature increase by 2100 is **~2.1-2.2°C**

Rupture



- Global cooperation integrates Global South in the race to Net Zero: growth in demand there is met mainly using low-carbon energies with high energy efficiency gains
- Temperature increase by 2100 is **~1.7-1.8°C**

Our collective challenge: move away from the "Current Course and Speed" scenario without compromising growth in emerging countries

Which trajectory?

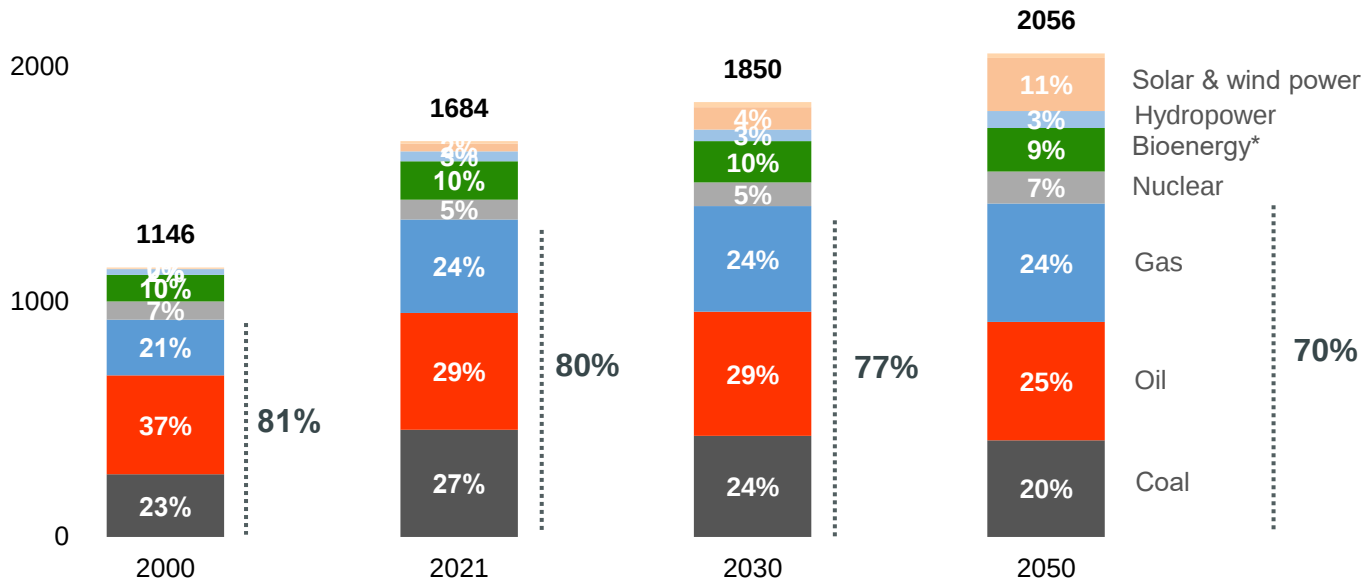
Current Course and Speed

The energy system changes, but not fast enough to meet countries' decarbonisation targets

Current Course and Speed

- Since 2000, share of fossil fuels in primary energy has remained ~80%
- Between 2021 and 2050 in this scenario, primary energy demand increases by 0.7% / year, while energy efficiency increases by 2.0% / year
- Low-carbon electrification and energy efficiency are progressing in NZ50 countries and China, but far too slowly
- Demographic and economic growth in Global South is largely powered by fossil fuels

World Primary Energy Demand (projection)
PJ/d



Temperature increase by 2100 is **higher than 3°C****

This scenario is not sustainable: it generates too many emissions

* *Biomass, waste, biofuels, biogas...*
** *Since pre-industrial era, comparing the energy-related CO_2 emission trajectories with the IPCC AR6 scenarios, at P66*

Which trajectory?

Momentum

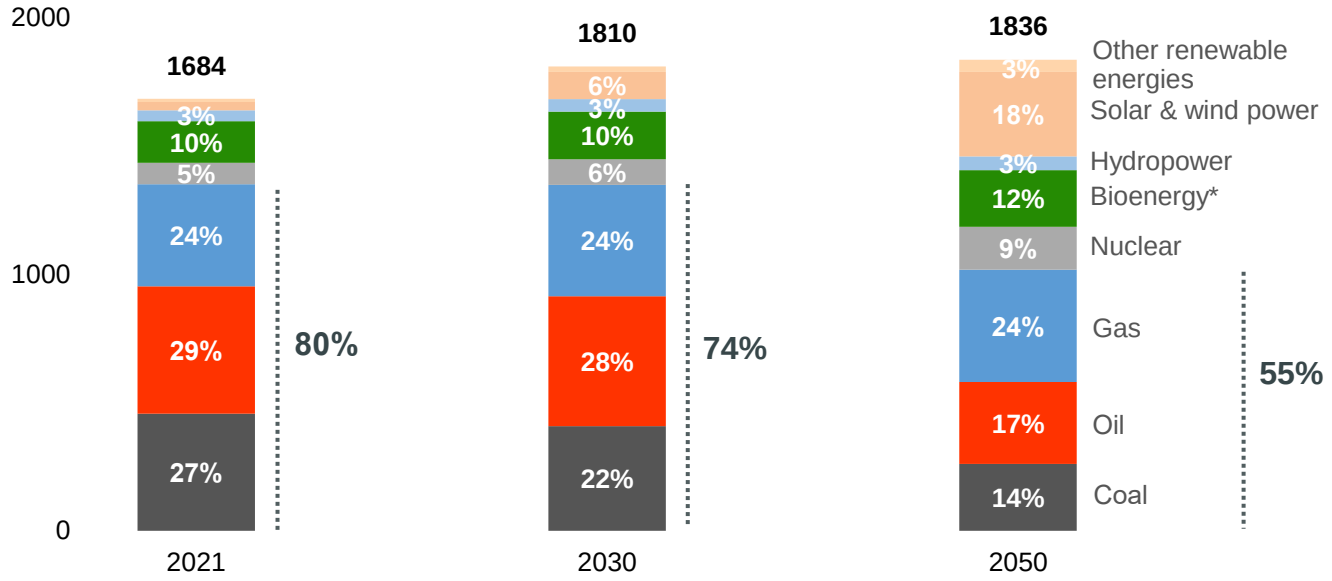
NZ50 countries and China step up their efforts to achieve their objectives, but with limited support to the Global South

Momentum

- Energy efficiency increases by 2.4% / year between 2021 and 2050, containing the increase in energy demand to 0.3% / year
- NZ50 countries exit coal and China significantly reduces its usage
- Electrification of end uses, particularly road transport, makes significant progress in NZ50 countries and China
- Around half of the growth in Global South continues to be met by fossil fuels
- In all countries, natural gas is used as a transition energy for electricity and industry

World Primary Energy Demand (projection)

PJ/d



Temperature increase by 2100 is **~2.1-2.2°C****

Decarbonizing NZ50 countries and China is necessary, but not sufficient to comply with the Paris Agreement

* *Biomass, waste, biofuels, biogas...*

** *Since pre-industrial era, comparing the energy-related CO_2 emission trajectories with the IPCC AR6 scenarios, at P66*

Which trajectory?

Rupture

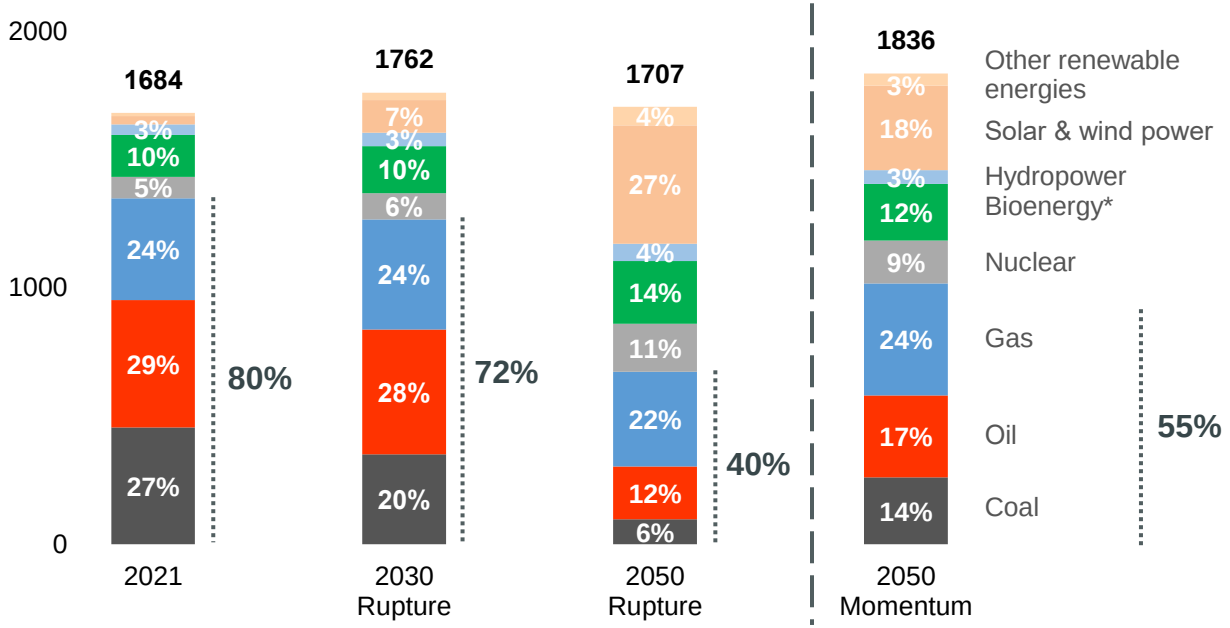
Global South is included in the race to Net Zero

Rupture

- Energy efficiency grows even faster, at 2.7% / year between 2021 and 2050, limiting the increase in energy demand to 0.1% / year
- Global South applies the decarbonization levers of NZ50 countries, and exits traditional biomass (Africa, South-East Asia)
- Biogas and biofuels meet ~1/6 of energy demand; gas and renewables are also used to produce low-carbon hydrogen and synthetic fuels
- Demand for liquids (oil and biofuels) falls from 100 Mb/d in 2022 to 71 Mb/d in 2050 in Momentum and 51 Mb/d in Rupture

World Primary Energy Demand (projection)

PJ/d



Temperature increase by 2100 is **~1.7-1.8°C****

To comply with the Paris Agreement, OECD countries must support Global South

* *Biomass, waste, biofuels, biogas...*

** *Since pre-industrial era, comparing the energy-related CO_2 emission trajectories with the IPCC AR6 scenarios, at P66*

Which trajectory?

How to unlock the energy transition's potential?

OPPORTUNITIES

- Mounting public awareness
- "Green competition" amongst countries and industries
- Electrification growing rapidly
- Existing "clean" technologies already having significant impact
- Recent acceleration in energy intensity gains

ROADBLOCKS

- Too few public policies focused on demand and changing consumer behaviour
- Distribution of transition costs not fair enough: energy must remain affordable
- Planning, permitting and people bottlenecks
- Not enough "clean" technologies and R&D
- Global South far from sufficiently funded

Which trajectory?

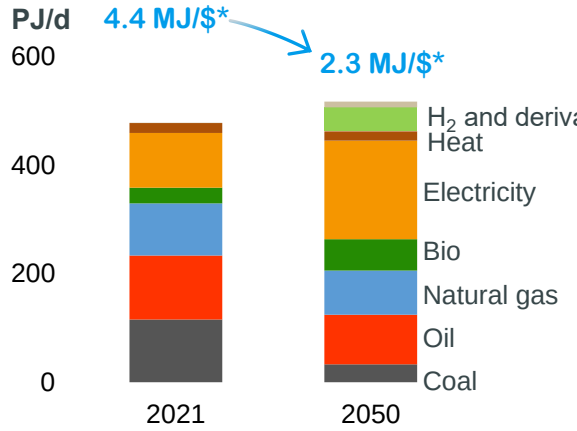
The challenges of transforming energy demand

How can we consume less and better in industry and in residential & commercial sectors?

Change in industrial demand (Rupture scenario)

41%

Industry share of final demand, 2021



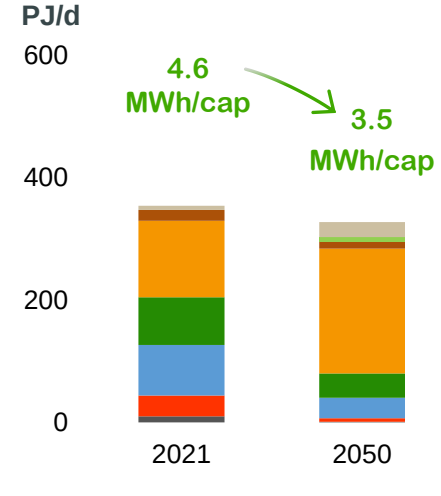
CO2 Decarbonization of the energy mix Behavior change / energy efficiency

- CO2 + Electrify production processes – primary decarbonization levers
- CO2 For sectors where electrification is not possible or sufficient, use gas instead of coal, which reduces emissions by a factor of 2
- CO2 Capture CO_2 or use low-carbon H_2 to gradually reduce these residual emissions

Change in residential and commercial demand (Rupture scenario)

30%

Residential & Commercial share of final demand, 2021



- CO2 + Replace traditional biomass (~85% of bioenergy by 2021) with modern energy sources in the Global South
- CO2 + Electrify as much as possible
- Improve energy efficiency (e.g., buildings insulation)
- Change consumer behavior (target temperature level, etc.)

** MJ per $ of industrial GDP*

Which trajectory?

The challenges of transforming energy demand

How can we consume less and better in transport?

26% Transport share of final demand, 2021

Change in transport demand (Rupture scenario)

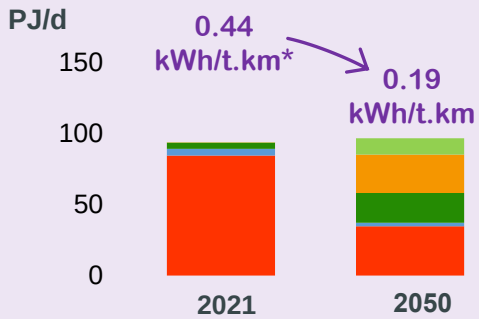
CO2 Decarbonization of the energy mix

Behavior change / energy efficiency

Light Vehicles

- Develop public transport
- CO2 Replace internal combustion vehicles with electric vehicles, invest in the charging network

High Duty Vehicles

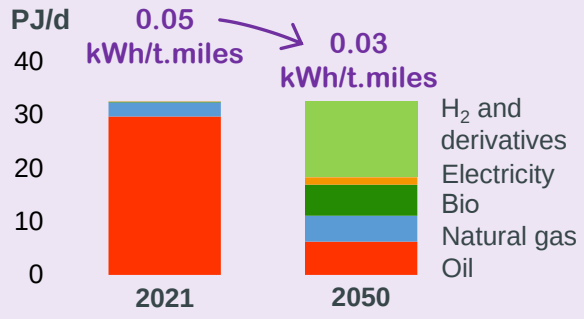


- CO2 Replace internal combustion vehicles with low-carbon vehicles
- CO2 Invest in electric and hydrogen charging networks
- CO2 Continue to innovate, particularly in batteries

Aviation

- CO2 Massively increase biojet production (priority allocation of bio-feedstocks)
- CO2 Invest massively to develop e-fuels
- Increase overall energy efficiency

Marine



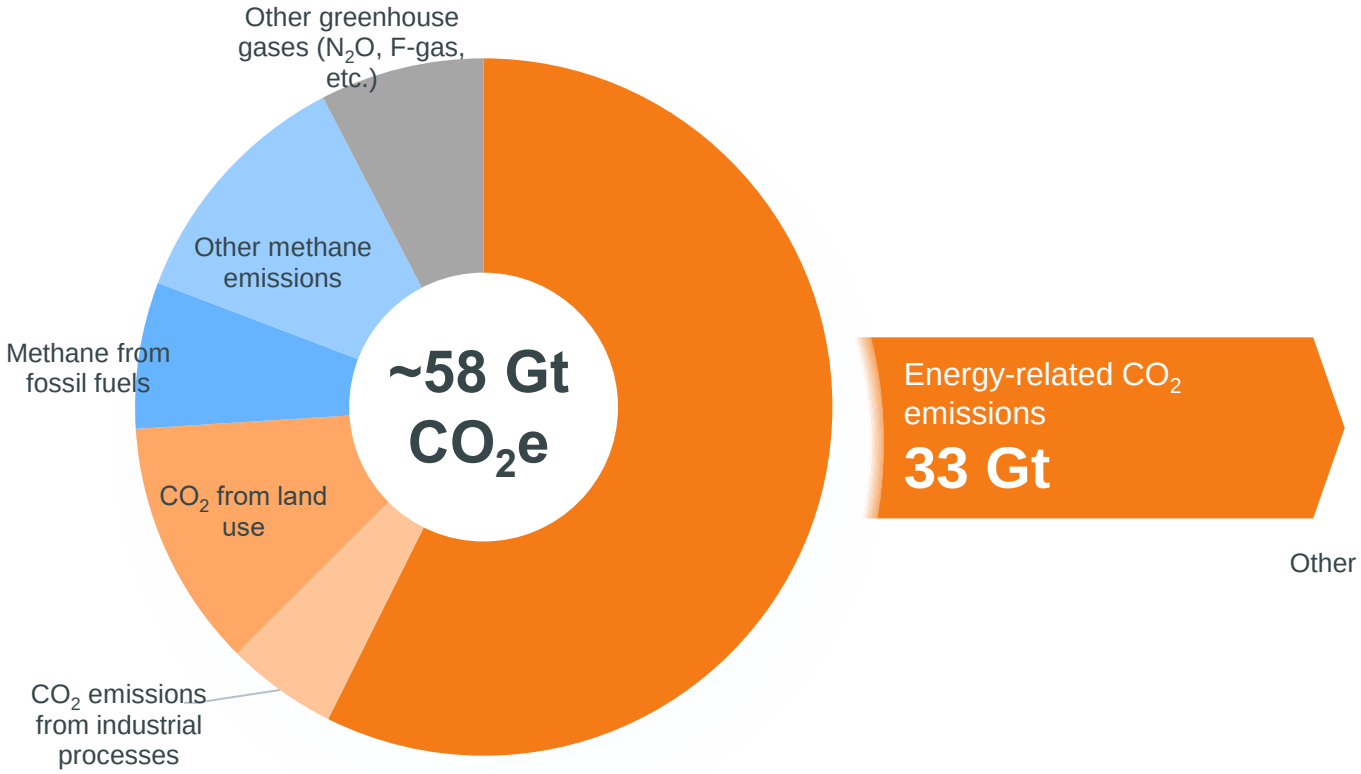
- CO2 Develop a diversified mix of low-carbon marine fuels to replace oil
- CO2 Invest massively in hydrogen-derived fuels, including e-ammonia and e-methanol
- Increase overall energy efficiency

* *kWh per ton.km*
** *kWh per passenger.km*

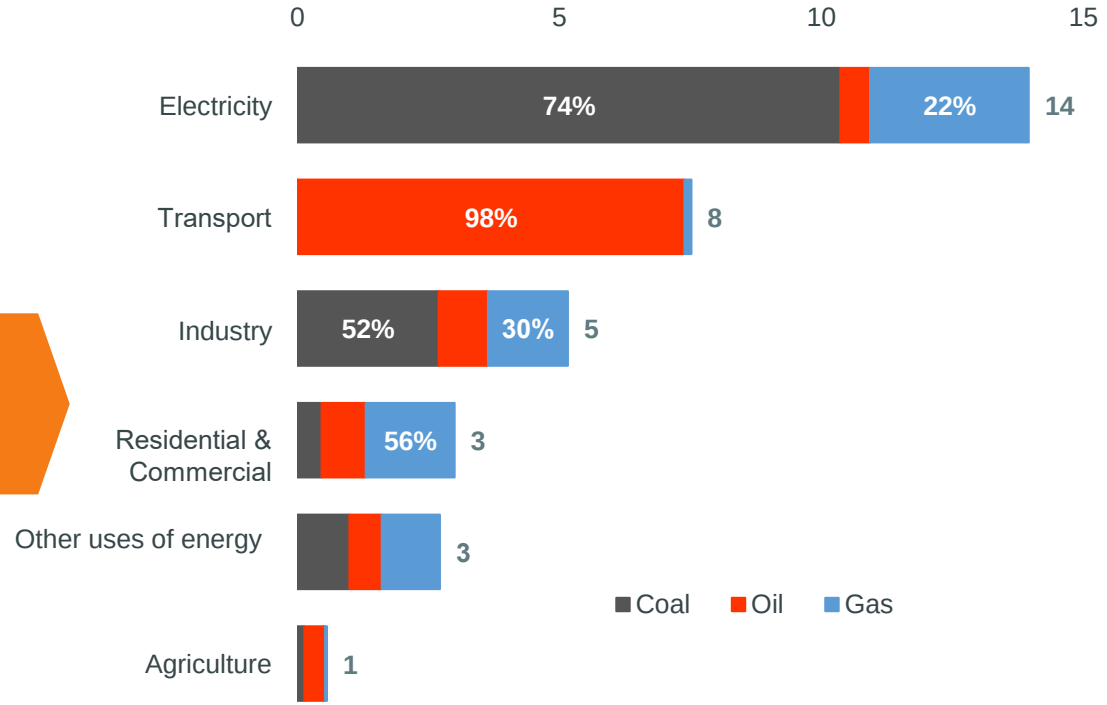
Which trajectory?

High impact actions to curb emissions

Global anthropogenic GHG emissions 2021
$GtCO_2e$



Global CO_2 emissions from fossil fuel combustion 2021
$GtCO_2$



Eliminate coal from the electricity system (~10 Gt CO_2)

Eliminate methane emissions from fossil fuels production (~4 Gt CO_2e)

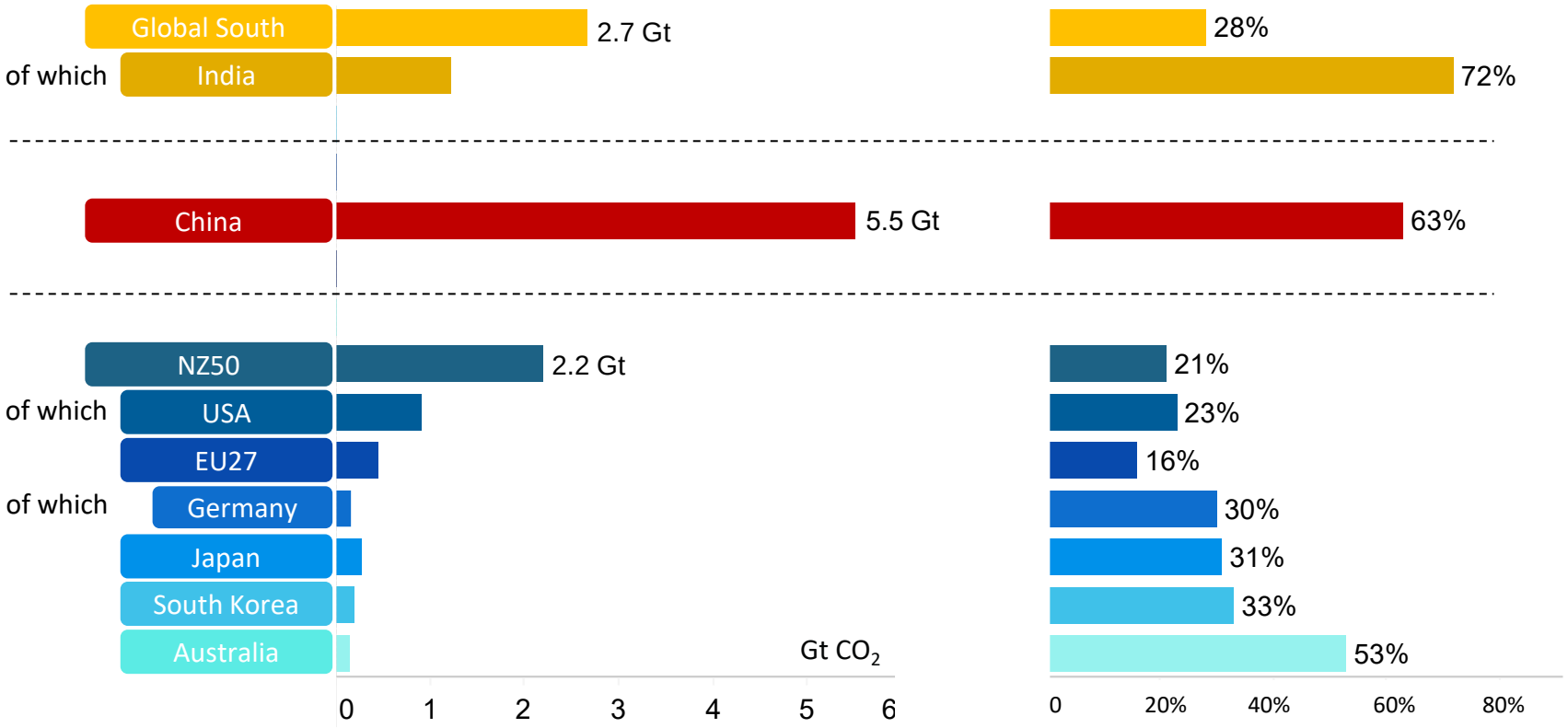
Decarbonize transport, in particular the road sector (~80% of emissions, ~6 Gt CO_2)

Sources: IEA, IPCC, Our World in Data, Edgar, TTE analysis.

High-impact actions

Coal still too important in the electricity generation mix of many countries

Emissions from coal-fired power generation 2021
Gt CO_2



Share of coal in the electricity generation mix 2021
%

Many countries in the Global South are using locally available coal to fuel their economic growth

Coal still generates more than 20% of the electricity in NZ50 countries

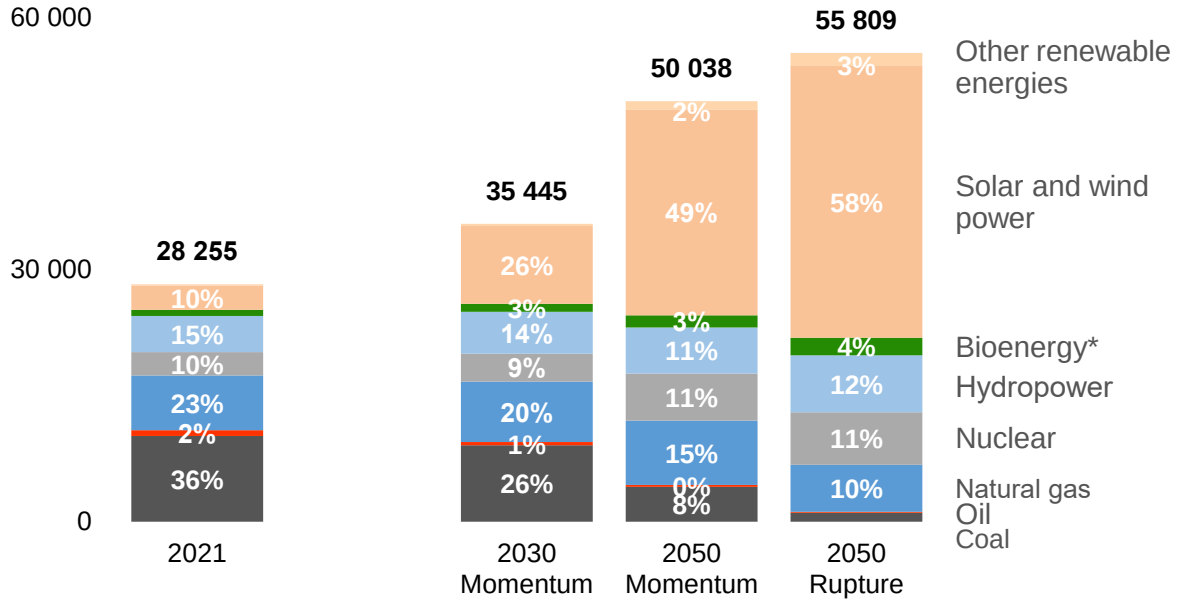
- **Priority: eliminate coal from the electricity generation mix in NZ50 countries**
- **Challenge: how can Global South follow an energy development path different from China in the 2000s ?**

Source: IEA, Enerdata, Analysis by TotalEnergies

High-impact actions

The opportunity: massively develop RENs and accelerate the replacement of coal by natural gas

Electricity generation, excluding green H_2
TWh



- Thanks to the growth of renewables, emissions per MWh of electricity** will fall between 2021 and 2050 by 76% in Momentum and by 96% in Rupture
- Natural gas contributes to a low-carbon electricity system:
  - as an immediate substitute for coal and 2 times less polluting
  - as a flexible and controllable complement to intermittent and seasonal renewable generation (alongside batteries)

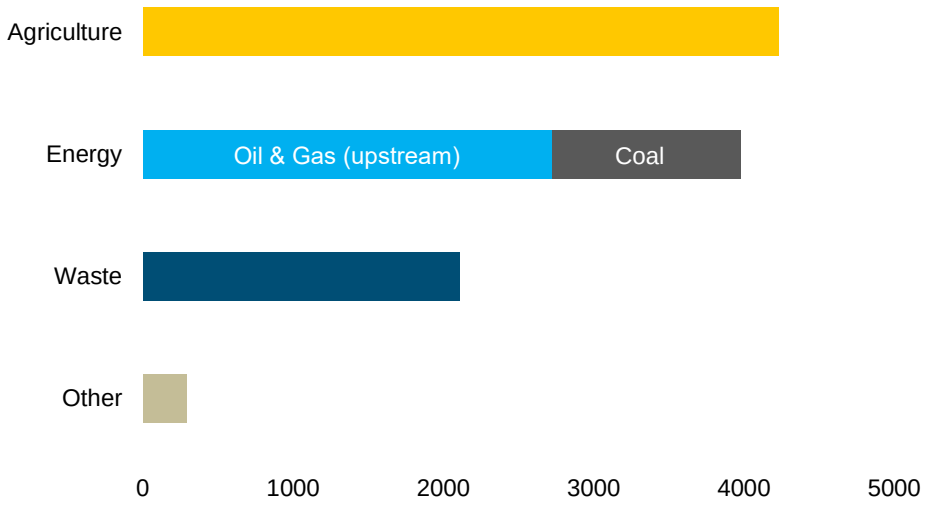
This generation mix requires massive investment in electricity networks and their adaptation to the complexity of the low-carbon electricity system

* *Biomass, waste, biofuels, biogas...*
** *Excluding production of green H_2*

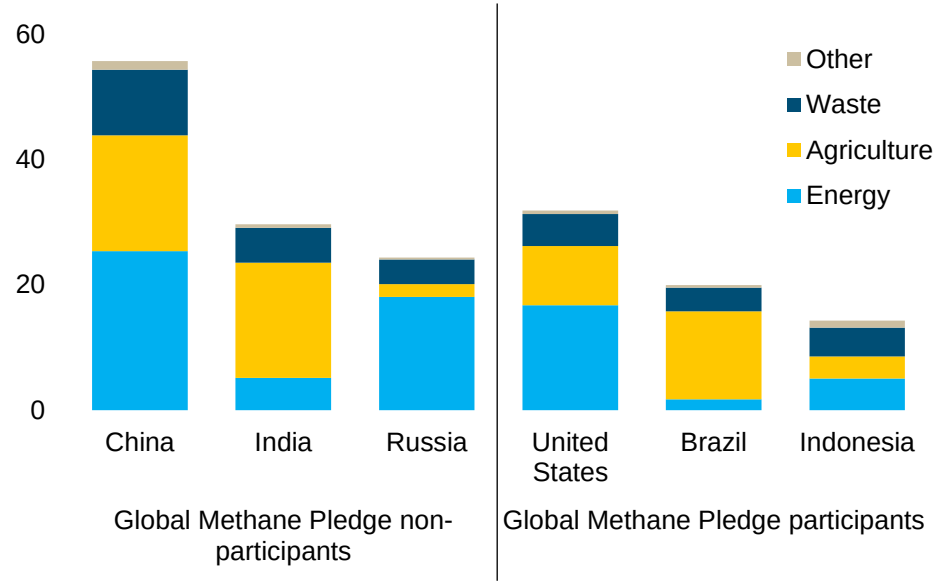
High-impact actions

The opportunity: act now to reduce methane emissions

Main sources of anthropogenic methane emissions 2022*
$MtCO_2e$



Main methane-emitting countries 2022, by source*
$MtCO_2e$



Technologies to eliminate emissions in oil & gas production (venting, flaring and leaking) **exist** and are the easiest to implement
Target : Tend towards zero methane: detection and remediation (drones, satellite imagery, etc.)

Global Methane Pledge :

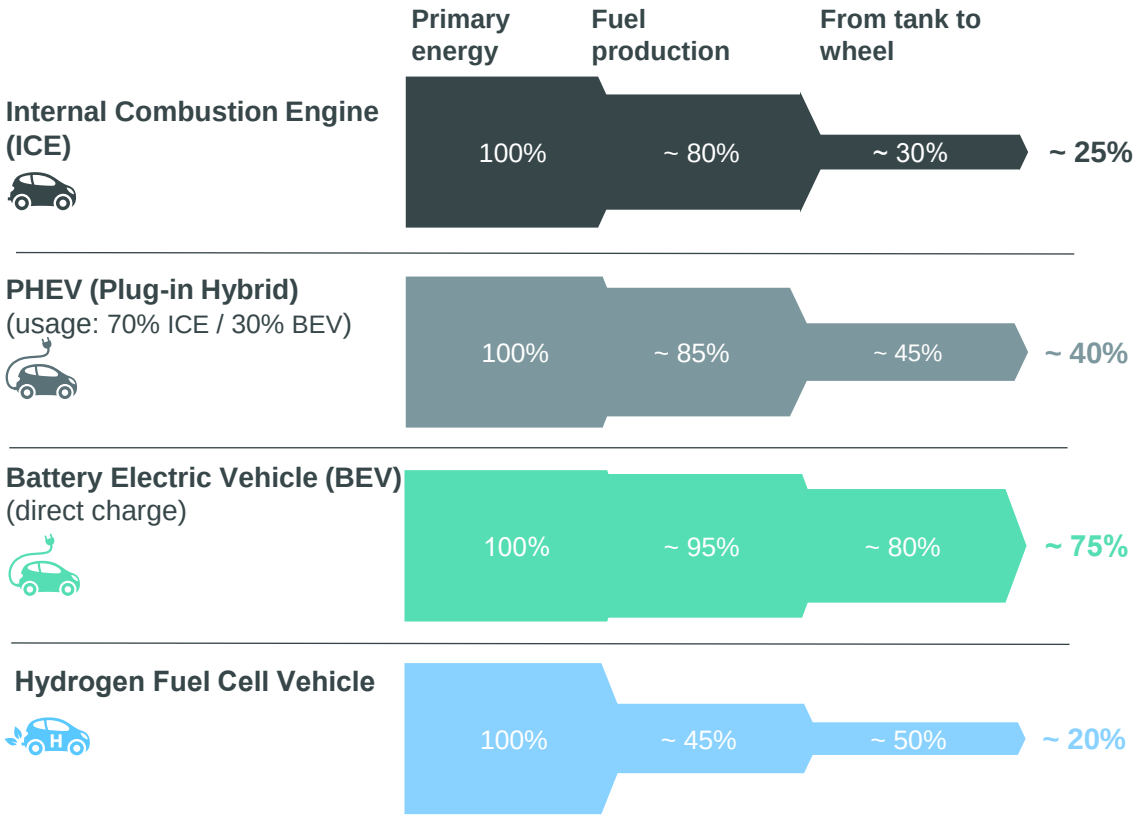
- Following the Glasgow COP, more than150 countries committed to **reducing methane emissions by at least 30% by 2030 (vs. 2020**)
- Positive and rapid impact on global warming, estimated by UNEP at **-0.2°C by 2050**

• *Source: IEA Global Methane Tracker 2023*

High-impact actions

The opportunity: electrifying road transport

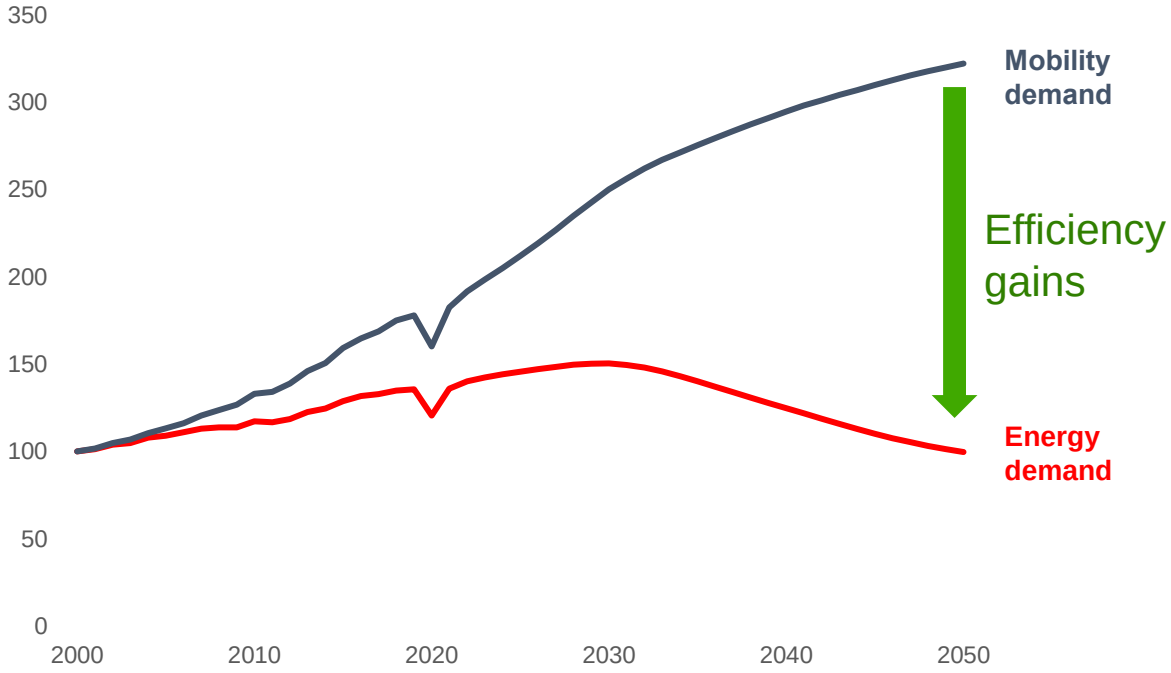
Comparative efficiency of passenger car engines



Electricity is the preferred solution to decarbonize road transport, provided it is low-carbon

Evolution of mobility and energy demands for passenger cars (Momentum scenario)

Mobility demand (vehicles.km) and energy demand (PJ/d)
Base: 2000 = 100



In Momentum, the share of electric vehicles increases very rapidly (particularly in China, the United States and Europe), allowing energy demand to be decoupled from mobility demand

Source: TotalEnergies analysis

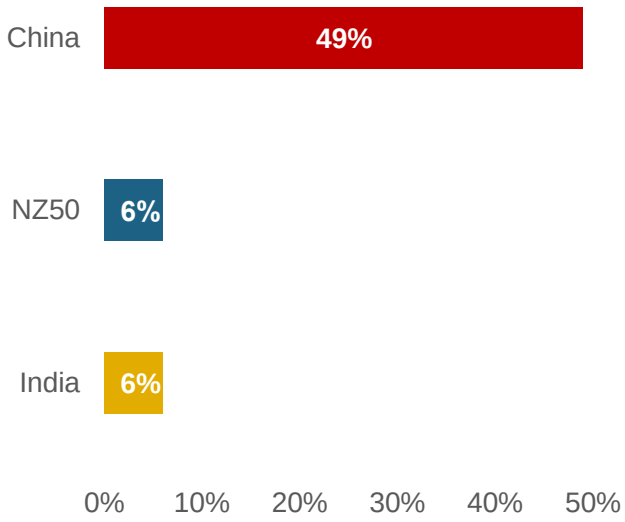
High-impact actions

How rapidly will cars and 2-3 wheelers be electrified?

In 2022, Light Vehicles emitted around 4 Gt of CO_2

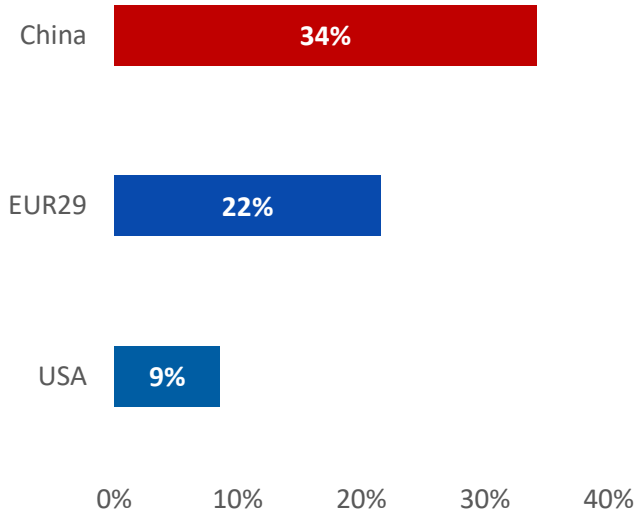
Share of Electric Vehicles in 2-3 wheelers sales 2022

%



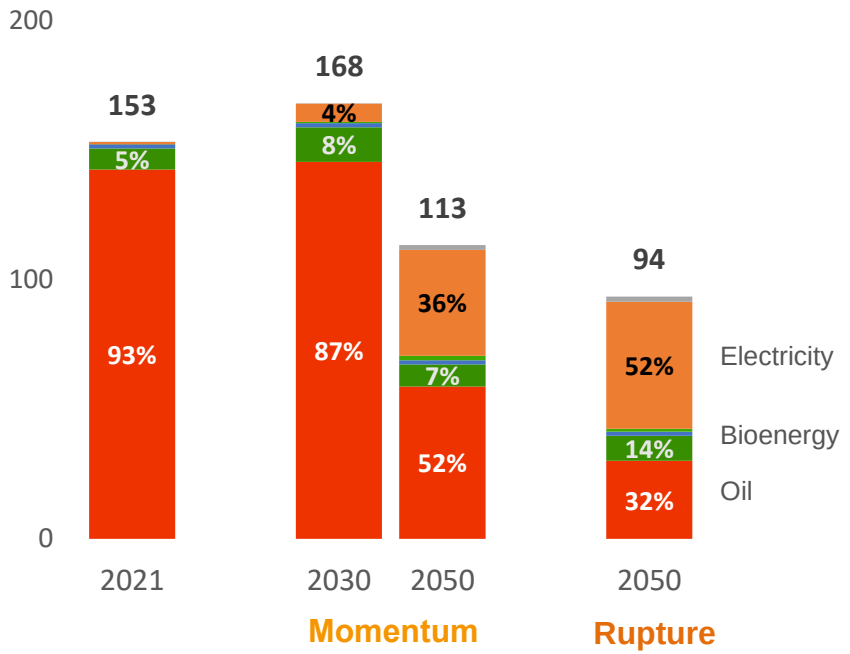
Share of Electric Vehicles in Light Vehicle sales (excluding 2-3 wheelers) January to July-2023*

%



Evolution of the global energy mix for Light Vehicles (including 2-3 wheels)

PJ/d



The electrification of **2-3 wheelers** is a **simple and accessible decarbonization opportunity** in emerging countries, that could displace ~1.5 Mb/d of oil by 2030

China is ahead in the electrification of its car fleet: more than half of all electric cars sold worldwide are sold in China

By 2050, electrification of light vehicles would divide emissions by 2 in the Momentum scenario (from 4 to 1.7 $GtCO_2$) and by 4 in the Rupture scenario (from 4 to 0.9 $GtCO_2$)

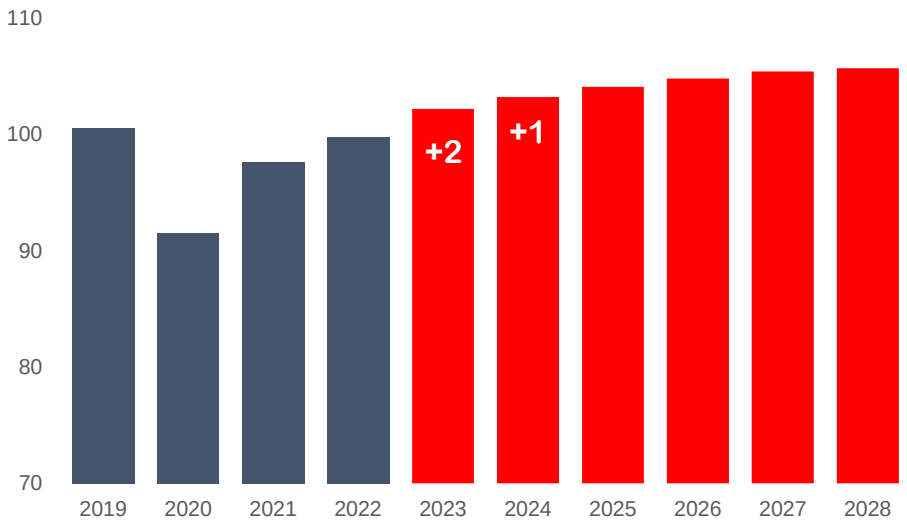
** Source: EVvolumes.com database, July 2023*

High-impact actions

Why do oil demand forecasts are uncertain?

Oil demand*

Mb/d



- Growth in global population and demand for local mobility
- Growth in international mobility (aviation and maritime)

- Penetration of electric vehicles in 2030, 2040 and 2050
- Changes in behavior
- Technological innovation

- **Until 2030, limited uncertainty: liquids are expected to grow by 6 mb/d between 2022 and 2028**
- **After 2030, significant uncertainty about the global penetration of EVs**

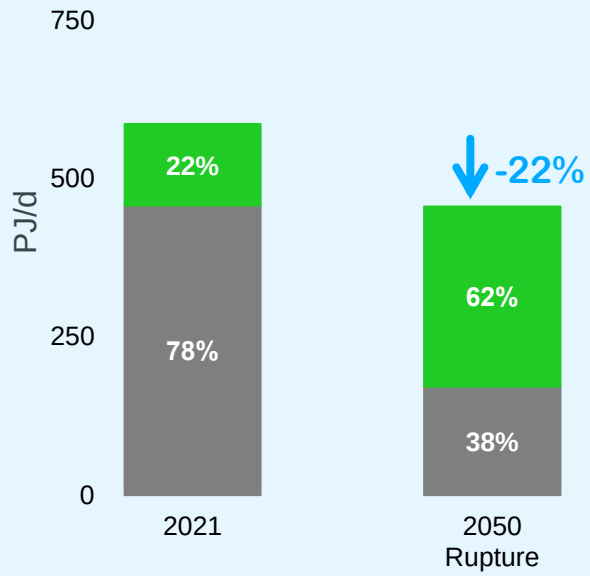
Source : IEA Oil Report 2023 (June 2023)

* *Including biofuels*

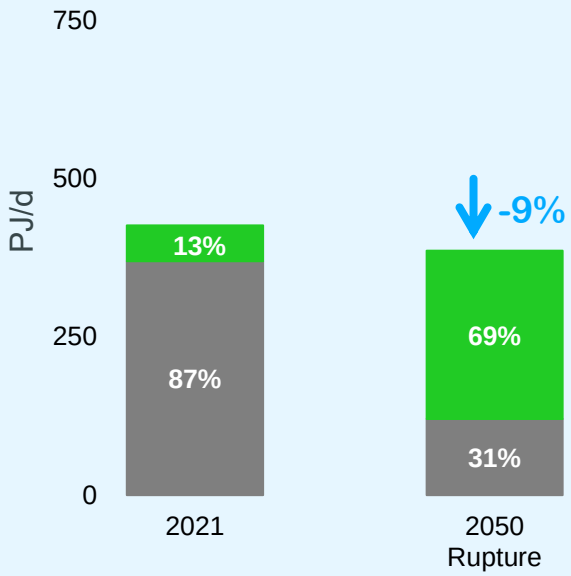
High-impact actions

Specific challenges for each bloc to comply with Paris Agreement

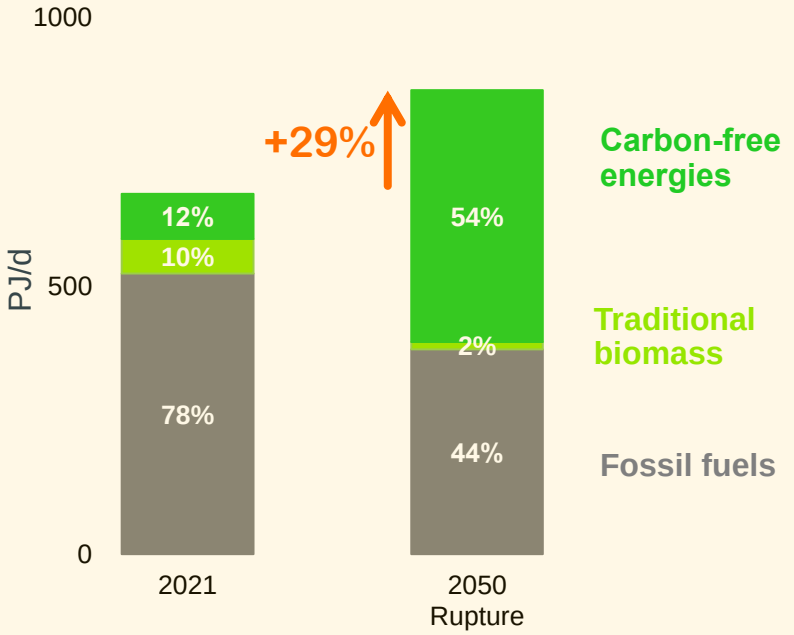
Primary Energy Demand NZ 2050



Primary Energy Demand China



Primary Energy Demand Global South



Contain and change demand through energy efficiency, the deployment of new technologies and behavior changes
Accelerate the construction of a low-carbon energy system, while maintaining the current energy system until demand adjusts

Satisfy fast-growing demand through replacing traditional biomass with modern energies and increasing energy efficiency using technologies from advanced countries (the Current Course and Speed scenario would lead to 75% growth rather than 29%)

Challenges by block

Significant acceleration required in NZ50 countries

to meet the decarbonization targets for 2030

Energy intensity gains to 2030, NZE scenario

x2 → 4.1% per year **until 2030**

2.0% in 2022*

2% per year **over the last five years**

EU solar PV & wind additions REPowerEU 2030 targets

x3 → >100 **GW** per year **until 2030**

51 GW in 2022*

~ 35 **GW** per year **over past 5 years**

High voltage lines additions to decarbonize US power by 2035

x7 → >6000 **mi** per year **until** 2035**

~600 mi in 2022***

<1000 **mi** per year **over past 5 years**

Pace drives scale of the transition in the short term

** Source: IEA - NZE23, September 2023*
*** Source: J.D. Jenkins PhD, REPEAT Project (Princeton University), April 2023*
**** Source: Federal Energy Regulatory Commission, January 2023 (552 miles added in the first 11 months of 2022)*

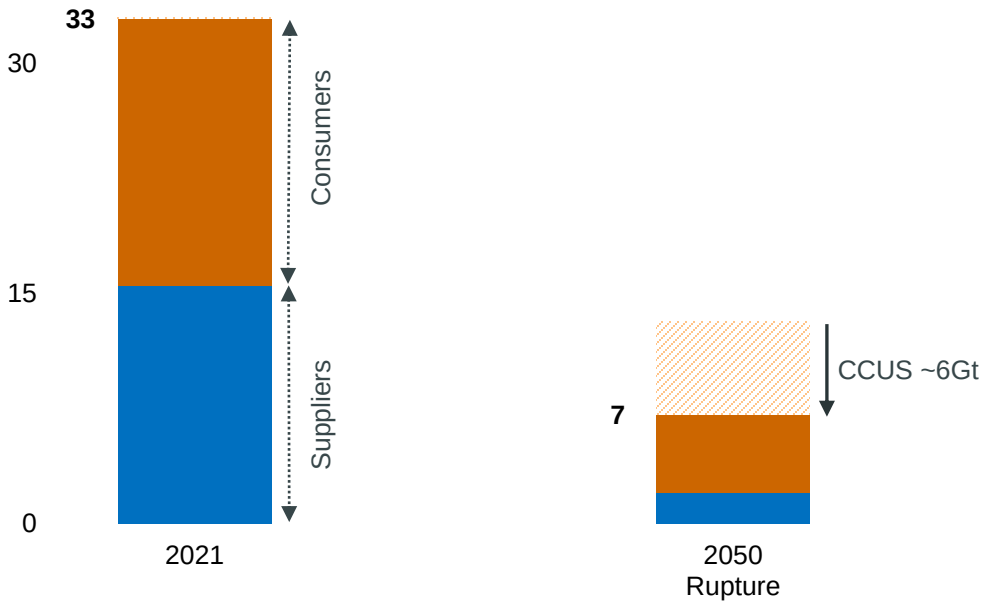
Challenges by block

Deploying CCUS at scale to remain well below 2°C

Necessary to support the transformation of the energy mix

Energy-related CO_2 emissions

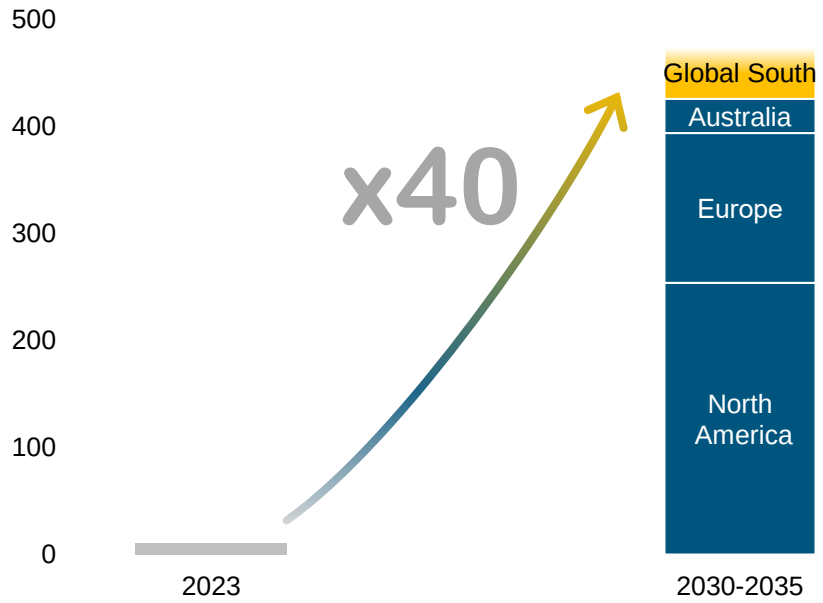
Gt CO_2



- Changes in demand and in the electricity generation mix will divide CO_2 emissions by 2 in 2050 compared with 2021. In addition, ~6 Gt of CO_2 must be captured to meet the climate target
- The CO_2 captured can be stored, transformed into a stable material, or mineralised
- Reforestation is essential to capture residual CO_2

Global CO_2 Storage projects (excluding enhanced oil recovery)

Mtpa



- Project announcements keep increasing: more in 2021 than in the last decade, and more since January 2022 than in 2021
- 80% of announced CO_2 capture projects are in North America and Europe, spurred by favourable regulatory conditions

What role for hydrogen in the transition?

TODAY

- **80 Mt of fossil-fuel based H_2* (grey)** used mainly in refining and chemicals (fertilizers)

TOMORROW

Clean H_2

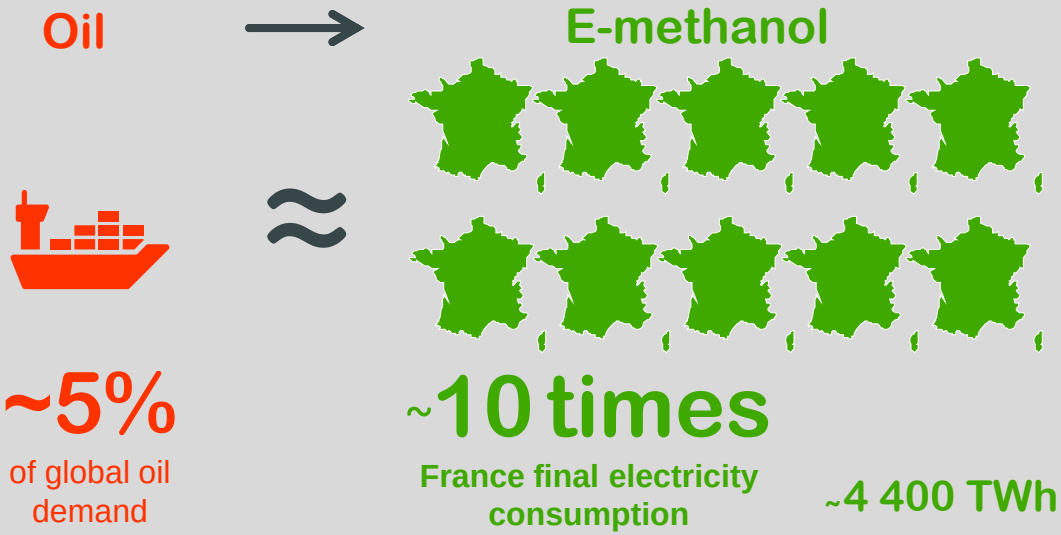
- **Proven demand** to decarbonize specific heavy industries: refining and chemicals (substitution), steelmaking, etc.
- **Demand to be confirmed** as it competes with other energies:
  - Road mobility ↔ Electricity
  - Electricity generation ↔ Natural gas + CCUS

AFTER TOMORROW

- **Demand for hydrogen-derived synthetic fuels (e-fuels)**: aviation, marine and road transport
- The processing chain is long and, to date, inefficient and energy-consuming
- Green H_2 consumes water, space and renewable energy; 4 to 5 times more expensive

EXAMPLE OF A LONG CHAIN

Green electricity required to decarbonize the international maritime sector

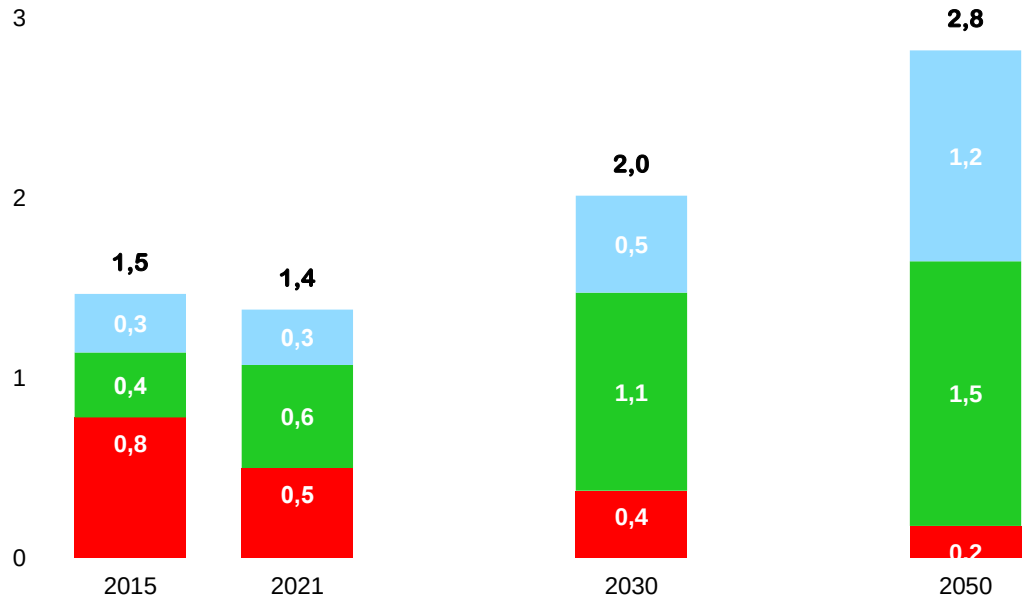


Converting all the world's ocean-going vessels to e-methanol would require as much electricity as the entire current production of the United States or 10 times that of France ... with green electricity only

** Source: IEA 2023*

Significant investment in the energy system required to remain well-below 2°C

Annual investment* (Rupture scenario)
Trillions $\$_{2023}$ per year



Electricity networks

Low-carbon electricity (*solar, wind, batteries, electrolysers, etc.), nuclear, hydro*)

Oil and gas

In the Rupture scenario, investment in the low-carbon electricity system should **more than double by 2030** and **more than triple by 2050**

An effort estimated at **~2% of GDP for NZ50 countries** and **~4-5%** for **Global South** (in competition with health, education, roads, etc.)

Sources: WoodMac, April 2023, IEA WEO22, TotalEnergies analysis
** Not including investment in demand: buildings, industry, vehicles, and EV, H_2 and CO_2 infrastructure*

How can we move forward with the transition?

The pace of the energy transition is not rapid enough: new CO_2 emissions record in 2022

Faced with increasing energy demand, it is impossible to "unplug" the current energy system, as long as carbon free energy system is not developped enough to meet global demand

So, **investment in the new energy system** have to **accelerate sharply**

- In NZ50 block, transition means retiring some existing assets and financing their replacement with new low-carbon ones, while maintaining investment in technological innovation and energy efficiency
- In Global South countries, fossil fuels are often local and the most affordable energies to improve the standards of living of growing populations. Financial transfers are necessary to steer them towards low carbon energies

Accelerating the pace of investment in low-carbon energy requires **strong cooperation between the private and public sectors**

- In the NZ50 countries, simplify and speed up permitting to accelerate the deployment of networks and renewable energies
- Actively supporting the transition of the Global South by :
  - developing multilateral financial guarantees, which are essential for financing projects
  - developing training programs to support local implementation of new technological solutions

The transition will not happen without social acceptability (both between North and South and within the NZ50 countries) and genuine efforts to achieve **climate justice**

- Provide financing, and transfer technology and skills to Global South
- Implement policies to reduce energy demand while protecting low-income citizens in NZ countries
- For example, in France, *if no public support is provided*, a middle-class household renovating its home, installing a heat pump and buying an electric car would face additional cost around € 30k , or ~7.5 times its annual saving capacity*.

** Source: J.Pisani-Ferry / S.Mahfouz, 2023. Les incidences économiques de l'action pour le climat*

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