Zero carbon by 2050: a highly unlikely outcome

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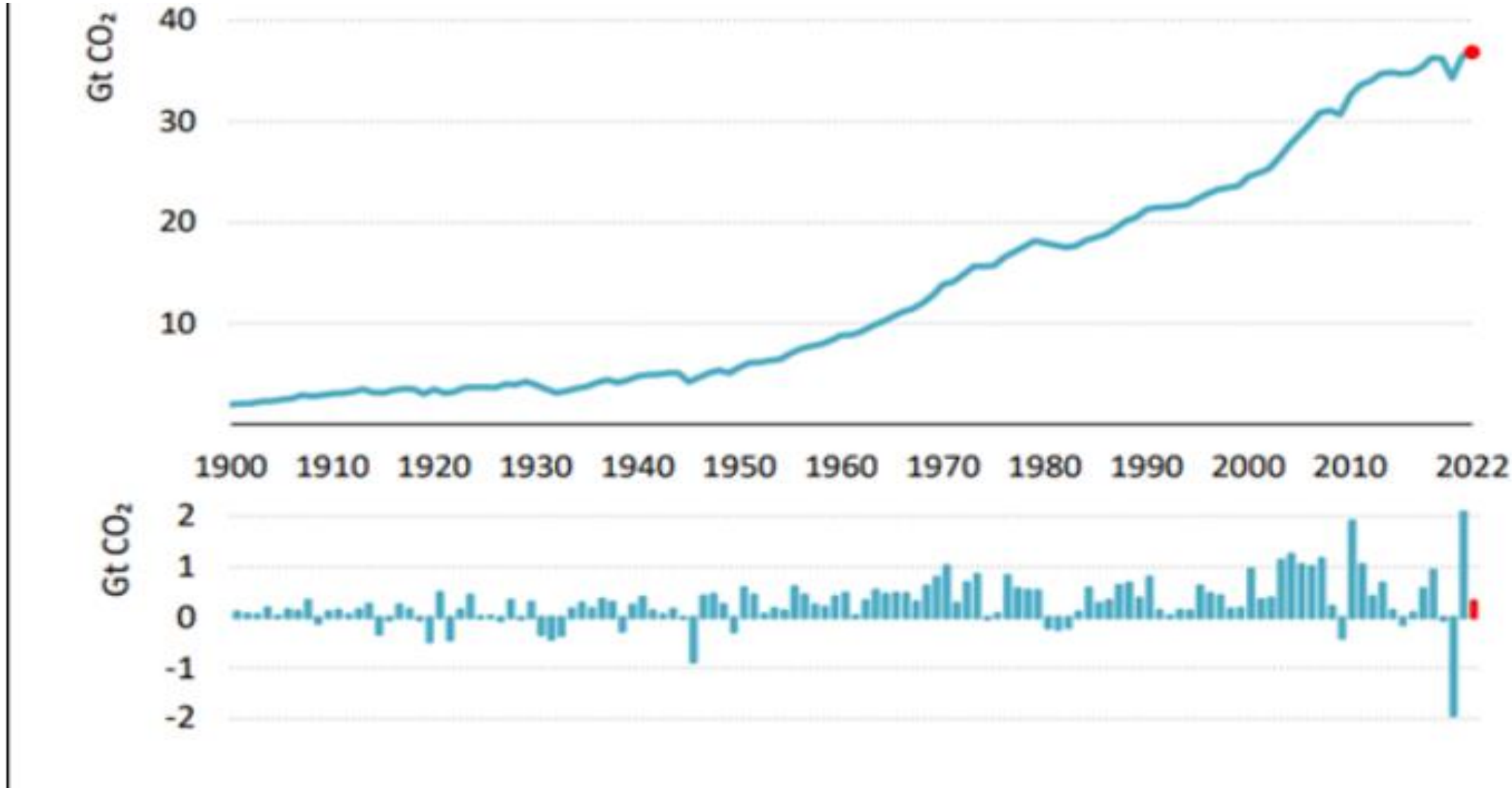
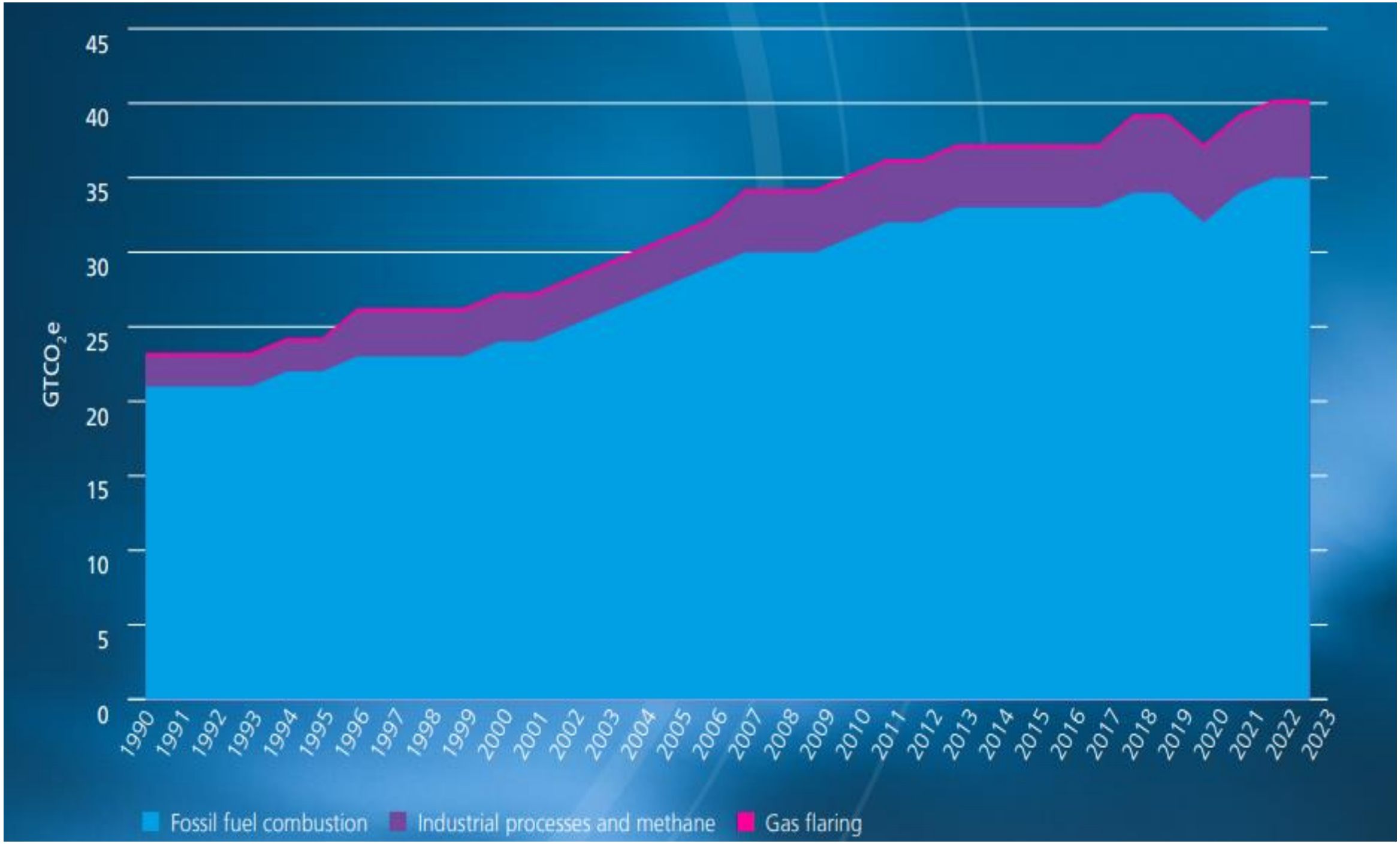
Recent dynamics of energy-related carbon emissions

- Steady post-1950 rise with only eight years of declines
- Nearly seven-fold increase between 1950 and 2024
- In 2023 the world consumed nearly 55% more fossil carbon than it did in 1997 (the year of the Kyoto agreement)

- **2023 set new record for energy-related carbon emissions as they surpassed, for the first time, 40 Gt**


Gt CO_2
40
30
20
10
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2022
Gt CO_2
2
1
0
-1
-2


45
40
35
30
25
20
15
10
5
0
GTCO2e
1990
1991
1992
1993
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1997
1998
1999
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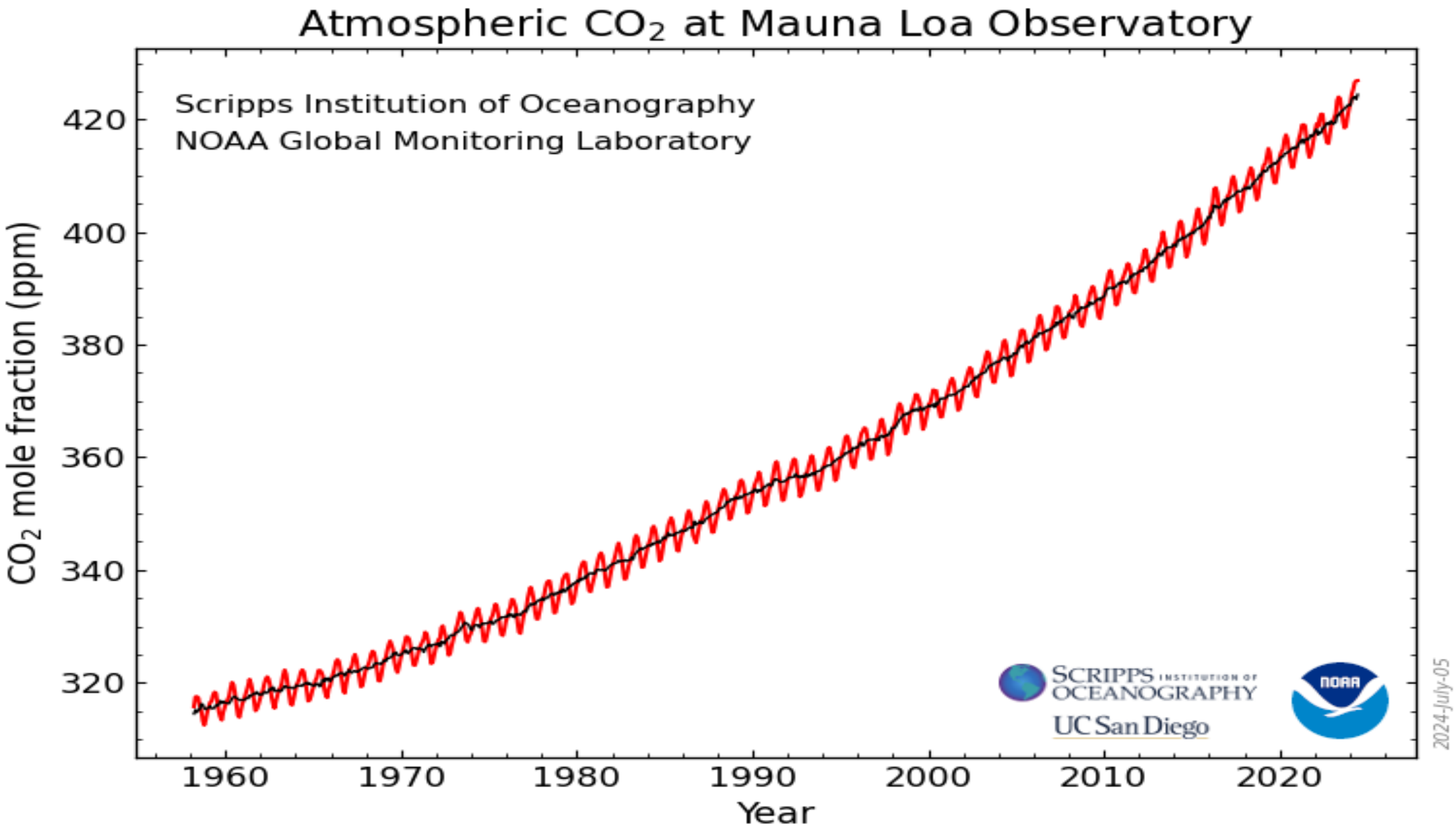
2017
2018
2019
2020
2021
2022
2023
Fossil fuel combustion
Industrial processes and methane
Gas flaring

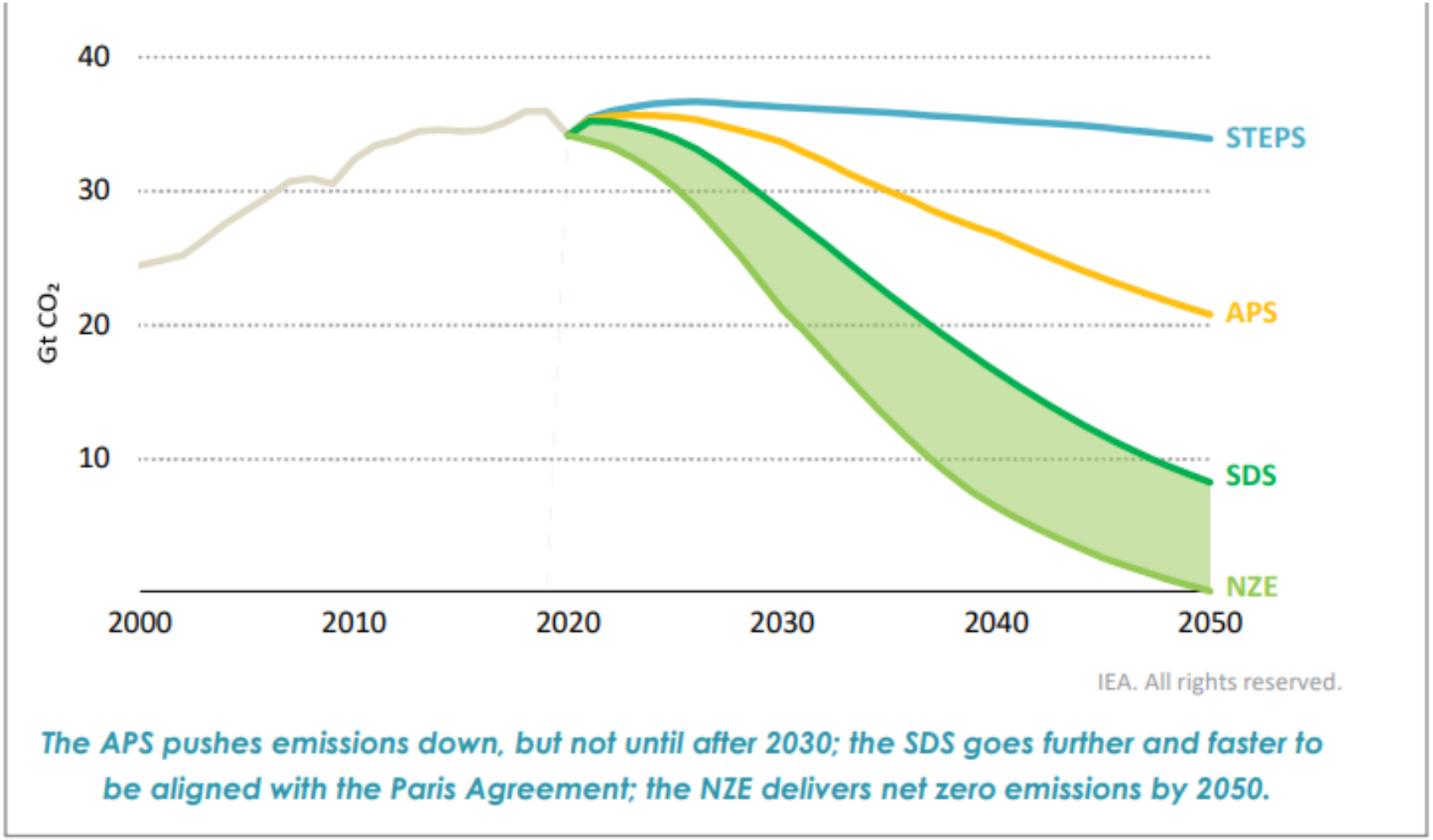
This resulted in uninterrupted rise of CO_2 levels

- Mauna Loa concentrations rising from 318 ppm in 1958 to 427 ppm in July 2024
- Not a single year with declining concentration

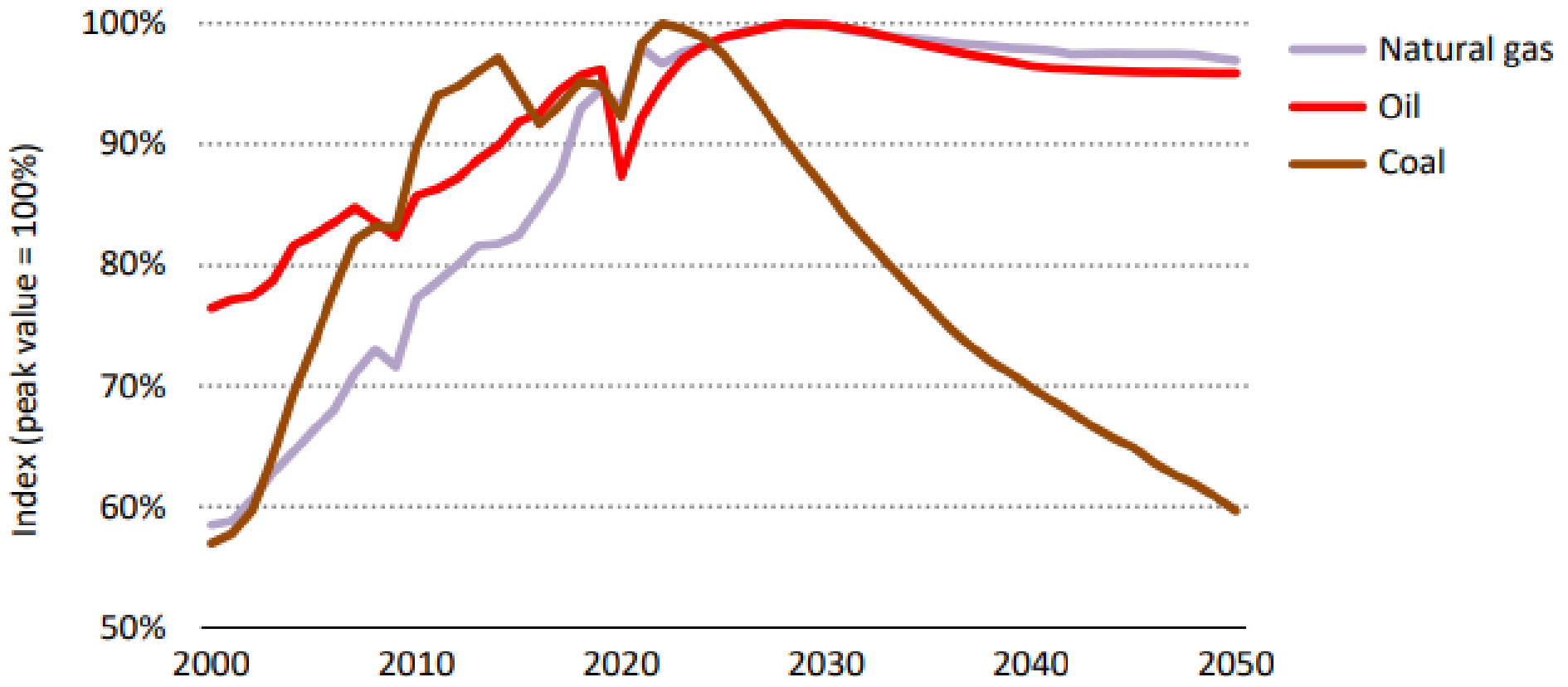
- The average annual rise has been 2.2 ppm during the past decade
- Even with considerable emissions cuts the level is likely to rise to 450 ppm by 2050
- Even with zero carbon by 2050 the level would be still ~ 400 ppm by 2100


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
CO_2 mole fraction (ppm)
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
2024-July-05

Which forecast is most likely?



The APS pushes emissions down, but not until after 2030; the SDS goes further and faster to be aligned with the Paris Agreement; the NZE delivers net zero emissions by 2050.



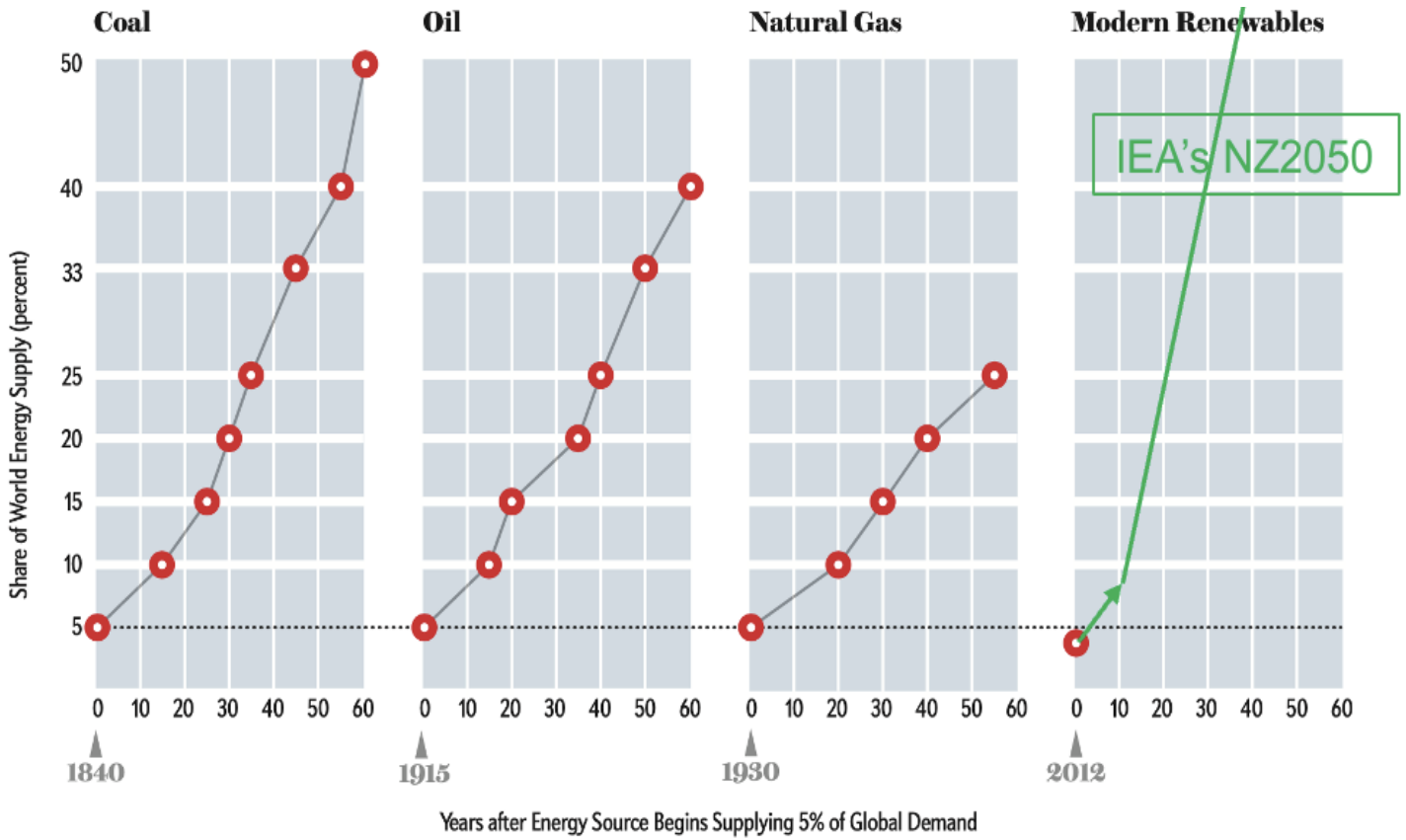
All fossil fuels peak before the end of this decade, with declines in advanced economies and China offsetting increasing demand elsewhere

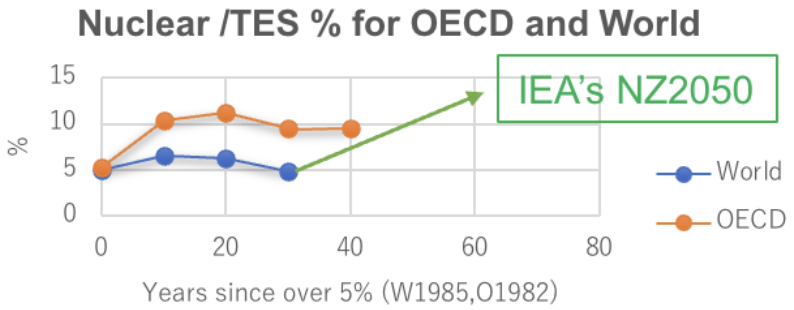
Why is zero fossil carbon by 2050 unlikely?

- New renewables must grow much faster than any other energy source during the past transitions
- At least 40% of the final demand is hard or impossible to electrify
- Converting industrial processes to green hydrogen faces enormous scaling-up challenges
- Non-fuel uses are considerable

- Cement (> 4 Gt/year), primary steel (~ 1.5 Gt/year), plastics (~400 Mt/year), ammonia (~200 Mt/year)
- Eventual green hydrogen demand may be as much as 300-400 Mt/year compared to 0.15 Mt produced in 2023
- Petrochemical feedstocks, lubricants, asphalt, black carbon (total of ~ 750 Mt)

Historic growth of fossil fuel shares compared to how fast the new renewables would have to grow to reach zero carbon in 2050





Vaclav Smil vs IEA's Net Zero by 2050

Life cycles of new investments

Many new fossil-fueled conversions are built to operate for extended periods of time (12-50 years)

- **New coal-fired power plants: 40 years**
- **New container ships: 14-15 years**
- **New blast furnaces: 15-20 years**

Blast furnaces

- 2024 capacity
- Operating: 1,262,000 t
- Under construction: 100,000 t
- Announced: 207,000 t
- ~ 25% capacity increase

- Fueled by coke, coal, natural gas
- Typical operating life spans are 15-20 years

Petrochemical feedstocks for plastics

- About 350 Mt of these feedstocks needed every year
- Plastic production expected to increase by 50% by 2050

- 2024: dominated by ethylene and propylene derived from fossil hydrocarbons
- Even if recycling and plant feedstocks were to rise to 50% of the total, we would need > 260 Mt of fossil feedstocks in 2050

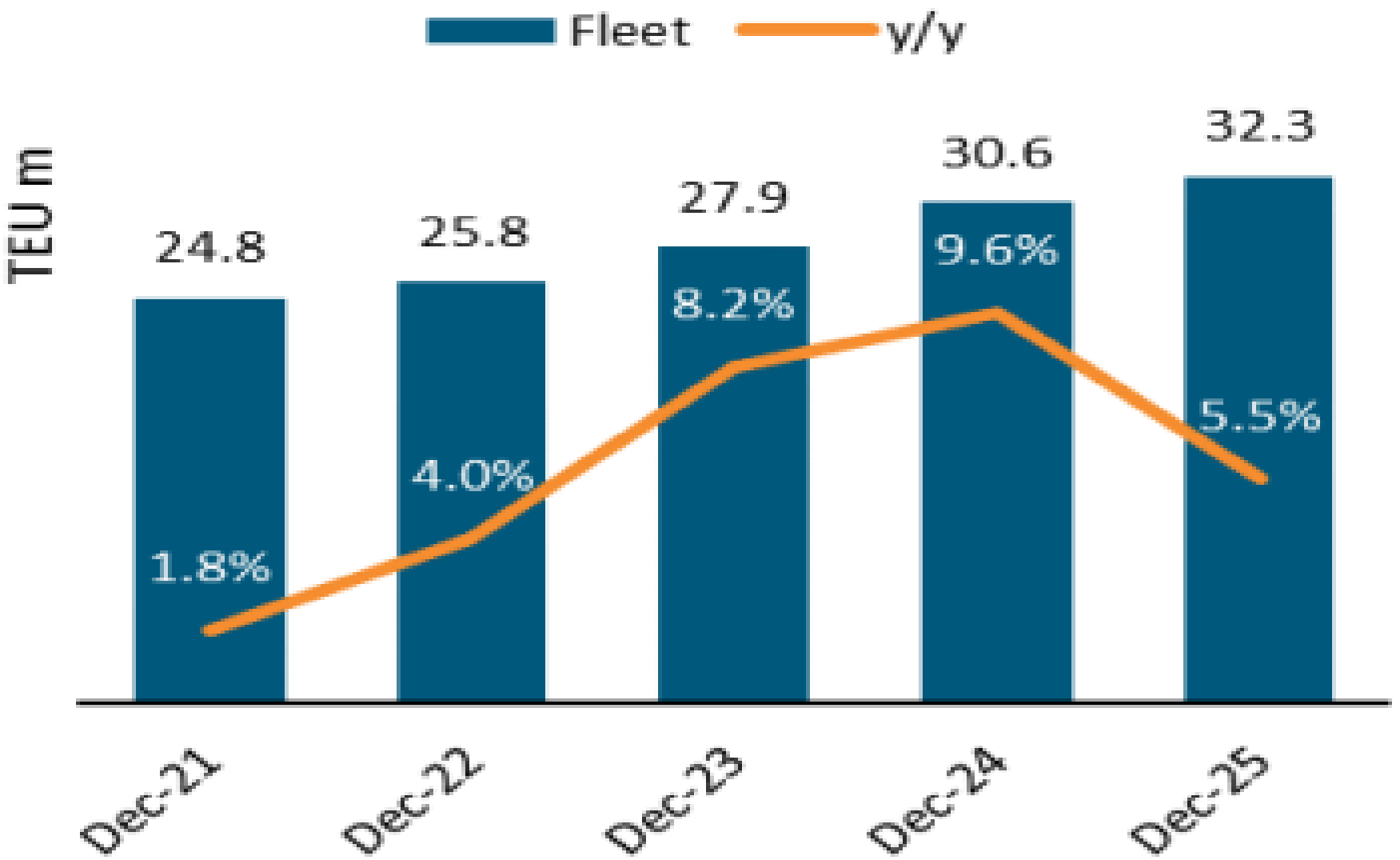

MSC CELESTINO MARESCA
MSC

Container shipping

- Largest container ships now carry > 24,000 TEU boxes
- New capacity is added at record rates
- Ships last for 14-15 years

- Difficult to decarbonize: the ships are powered by the world's largest Diesel engines with capacities of more than 70 MW

Container fleet



Rational progress

Priorities

- Concentrate on decarbonizing final uses that can be readily electrified
- Use newly produced green hydrogen in the most energy-intensive industrial processes

Savings

- Reduce the need for new carbon-based capacities by intensified recycling of concrete and plastics
- Reduce the need for highly energy-intensive plastics by cellulose-based substitutes