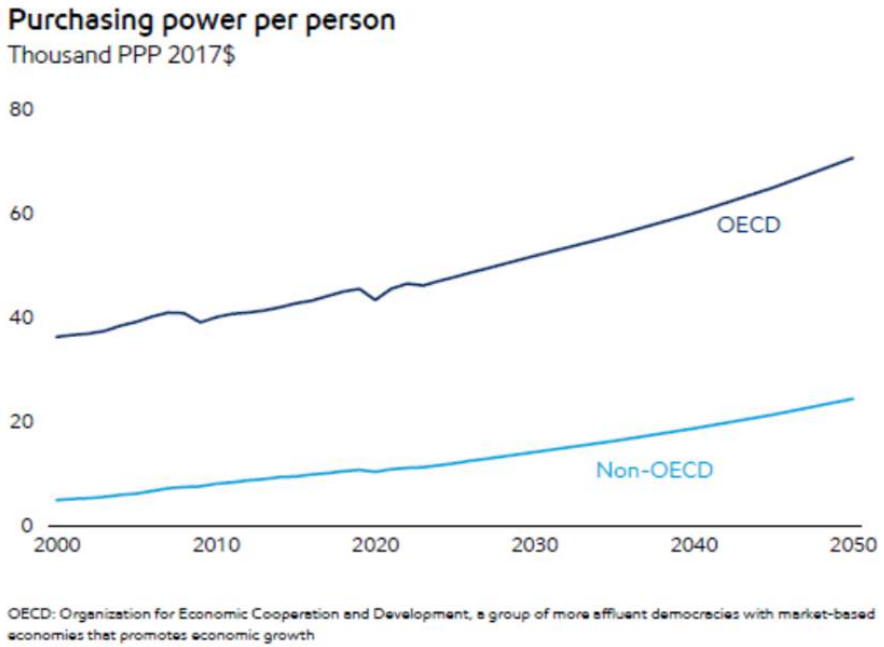
The sustainability paradox – can oil be a critical bridge in the route to net zero?’

Dr Paul Kerwin CChem FRSC

VSN Meeting, Fort Sint Gertrudis Haven 54 in Geertruidenberg

4th October 2023 (1145)

BRENNTAG



‘’Energy use and economic development are inseparable. Where there is energy poverty, there is poverty. And where energy availability rises, living standards rise…’’

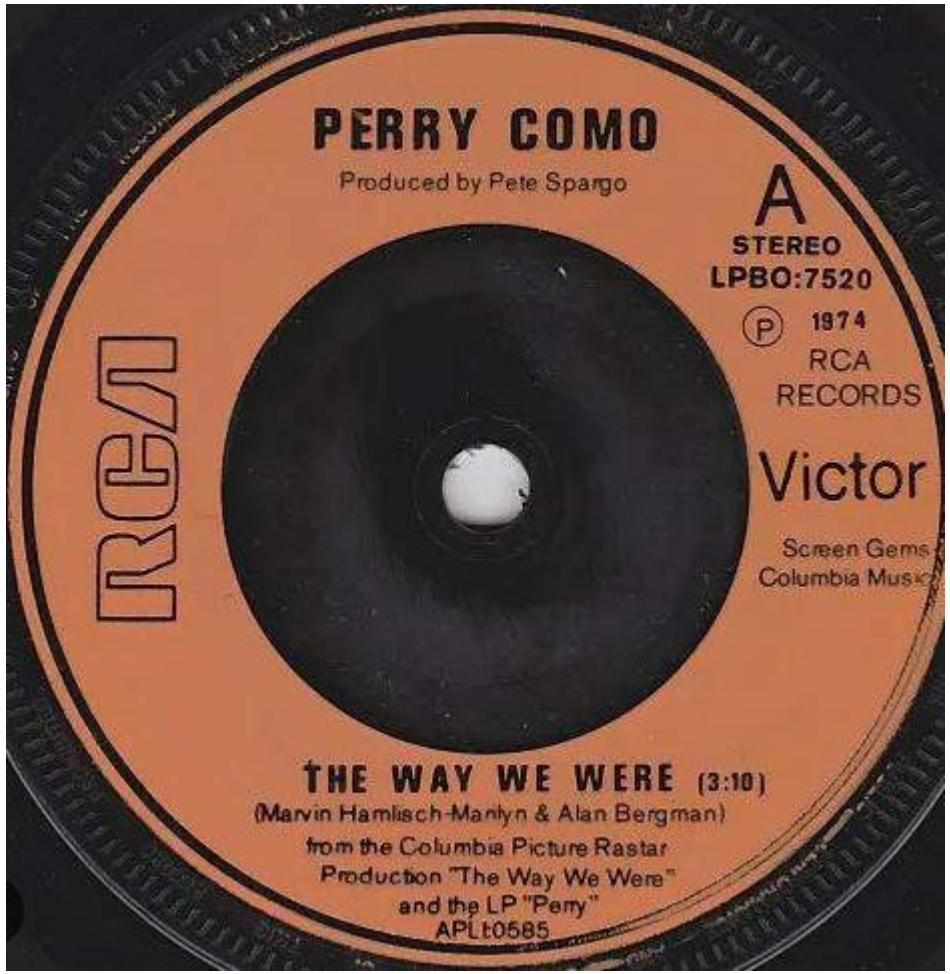
ExxonMobil World Energy Outlook 2022

Sustainability

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

Brundtland Report ("Our Common Future") - 1987

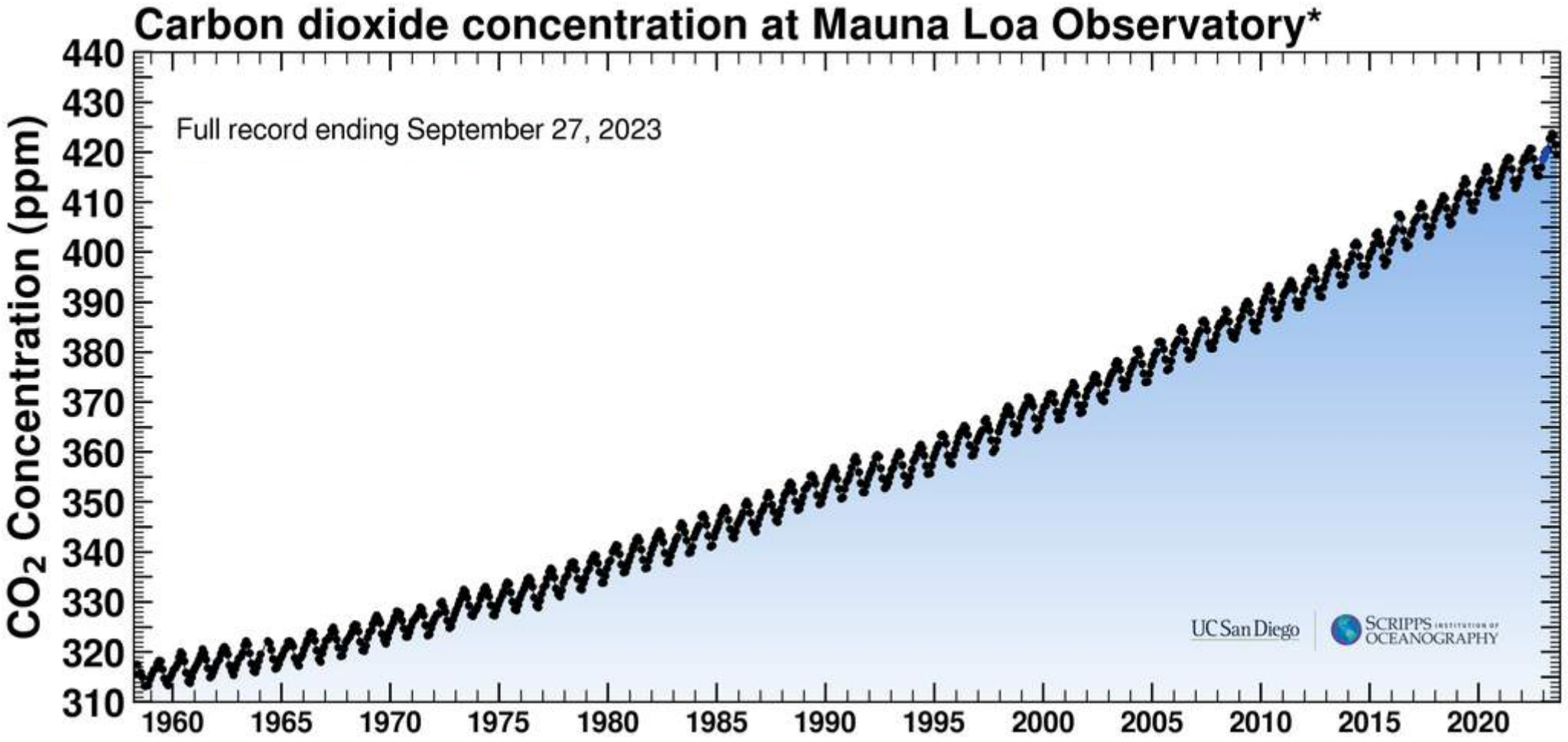
Sustainability



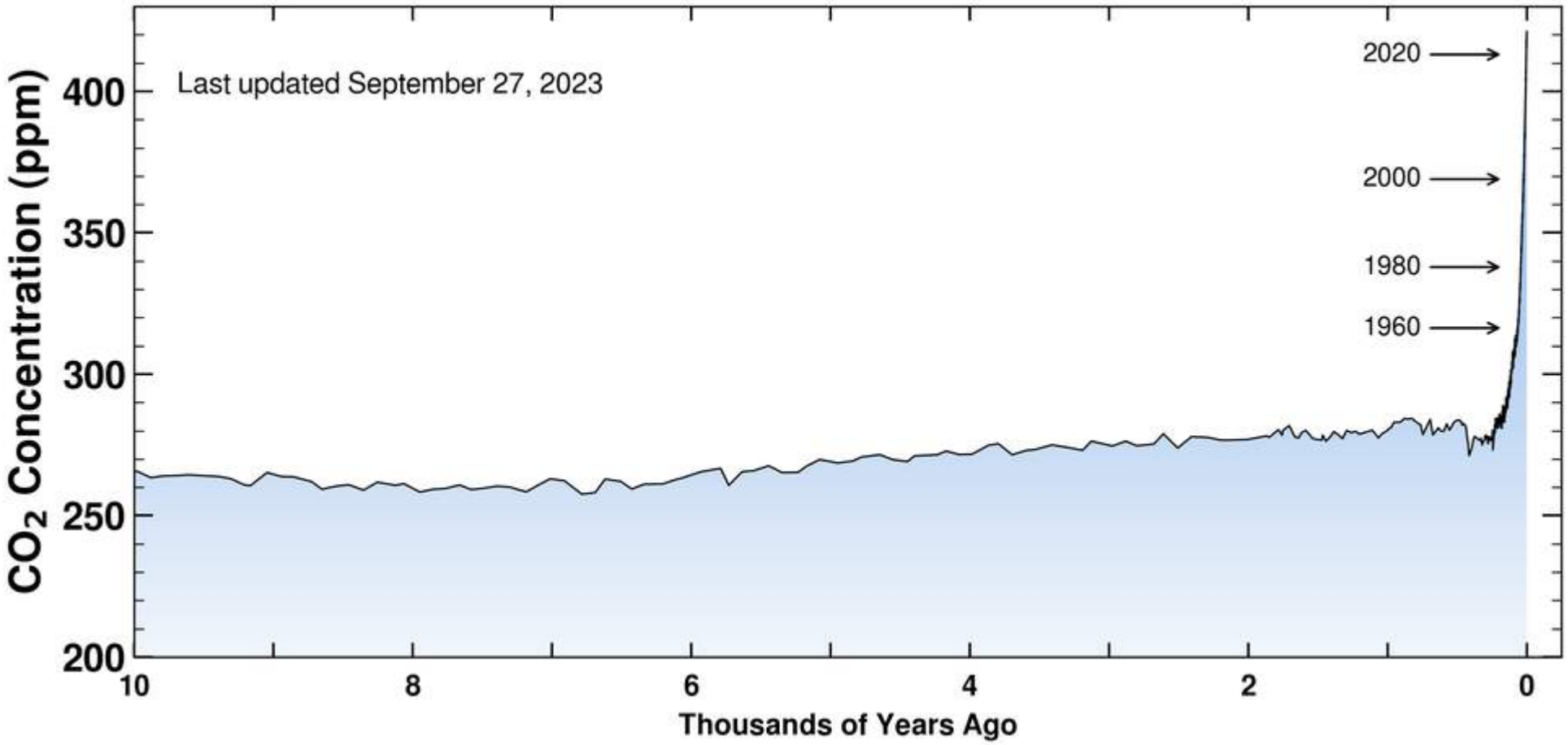

1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

CO_2 Emissions

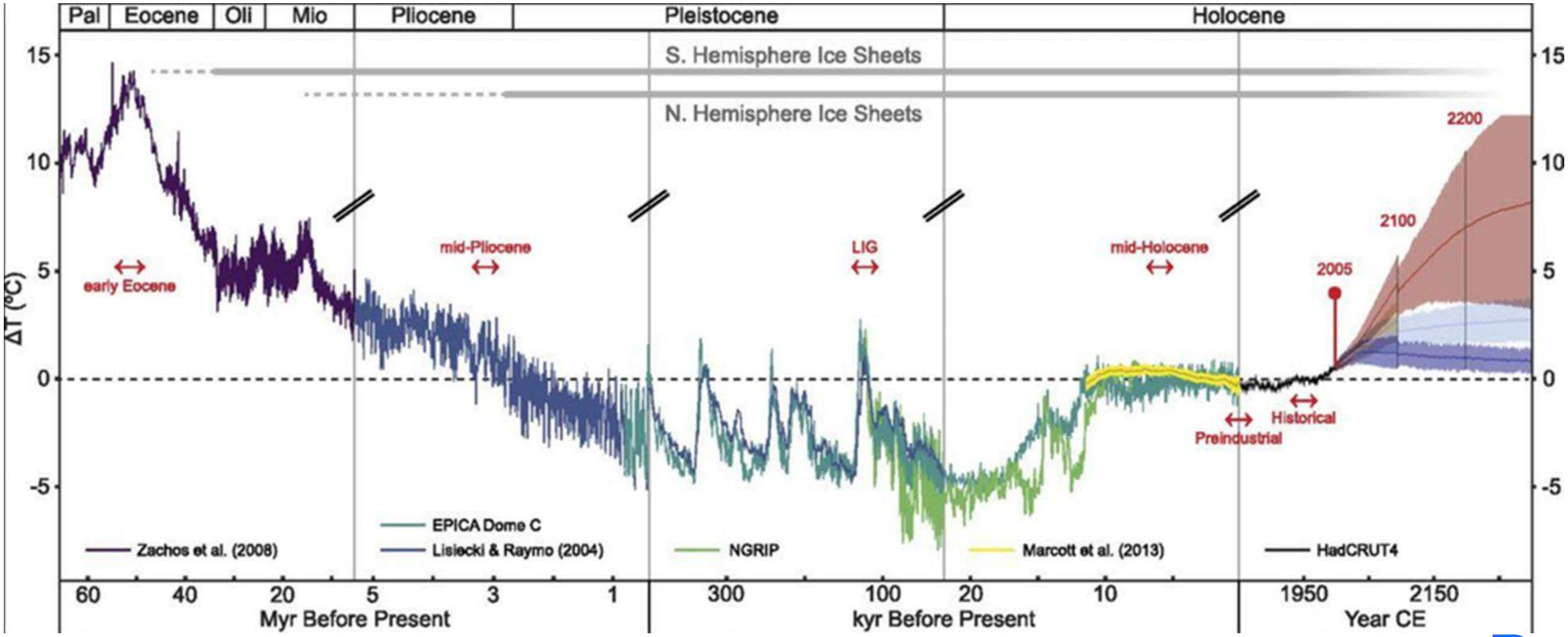
*Latest CO_2 reading: 418.00 ppm



CO_2 Emissions – 10k years



Earth Temperature - Paleoclimatology



Net Zero

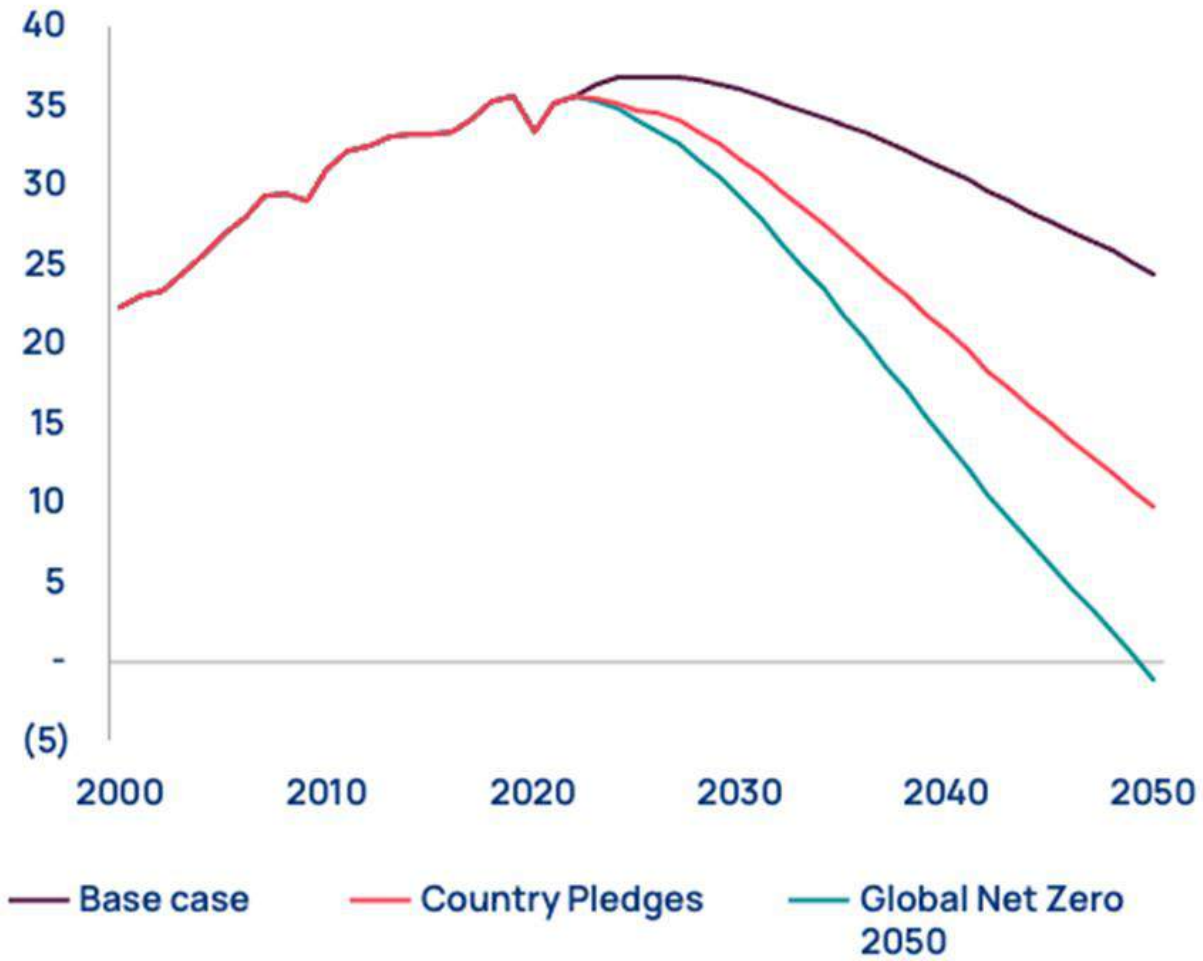
"Put simply, net zero means cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance."

UN.org

The three ETO scenarios

The world needs to reach net zero before 2050 to meet the goals of the Paris Agreement

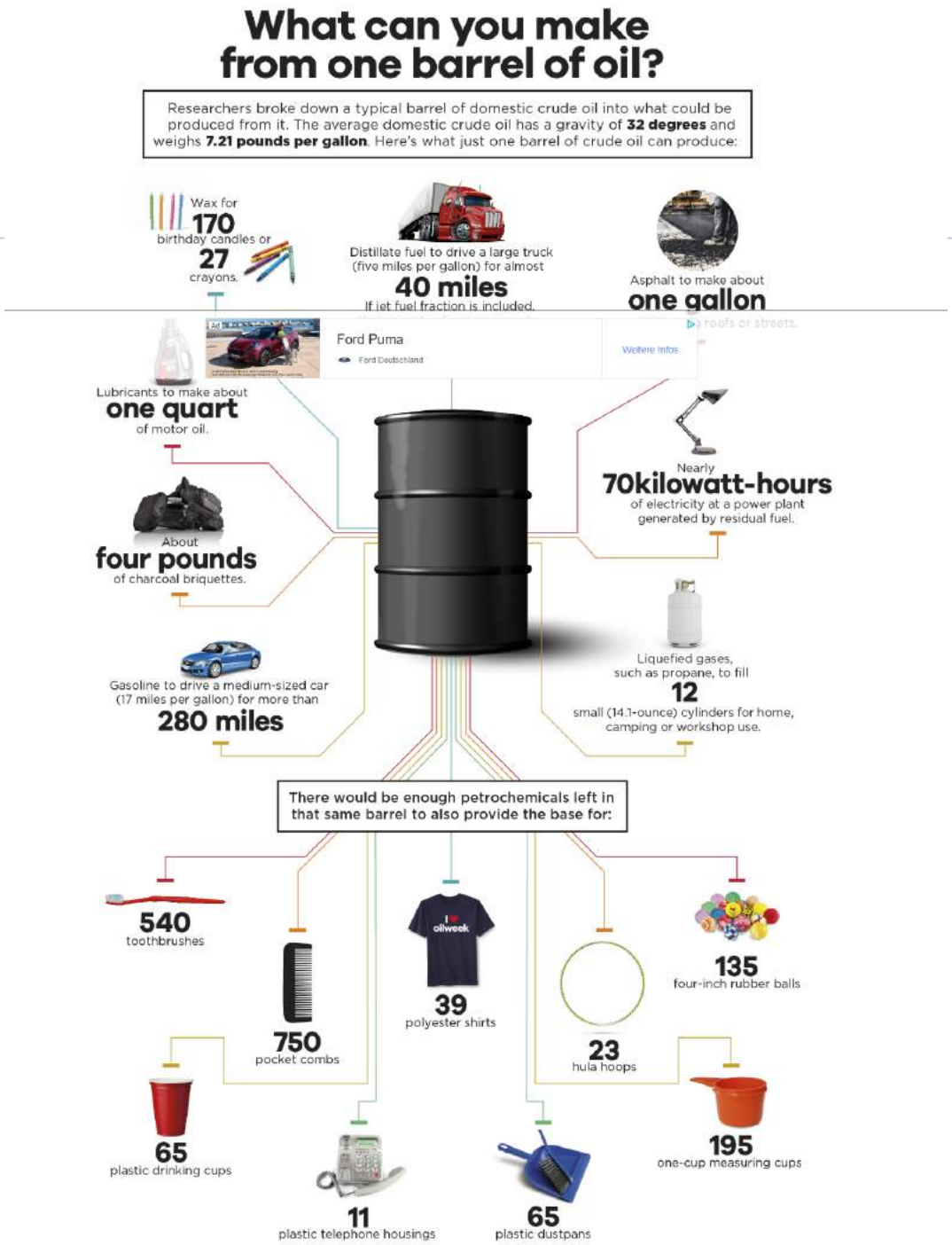
Global energy-related CO_2 emissions, Billion tonnes (Bt)



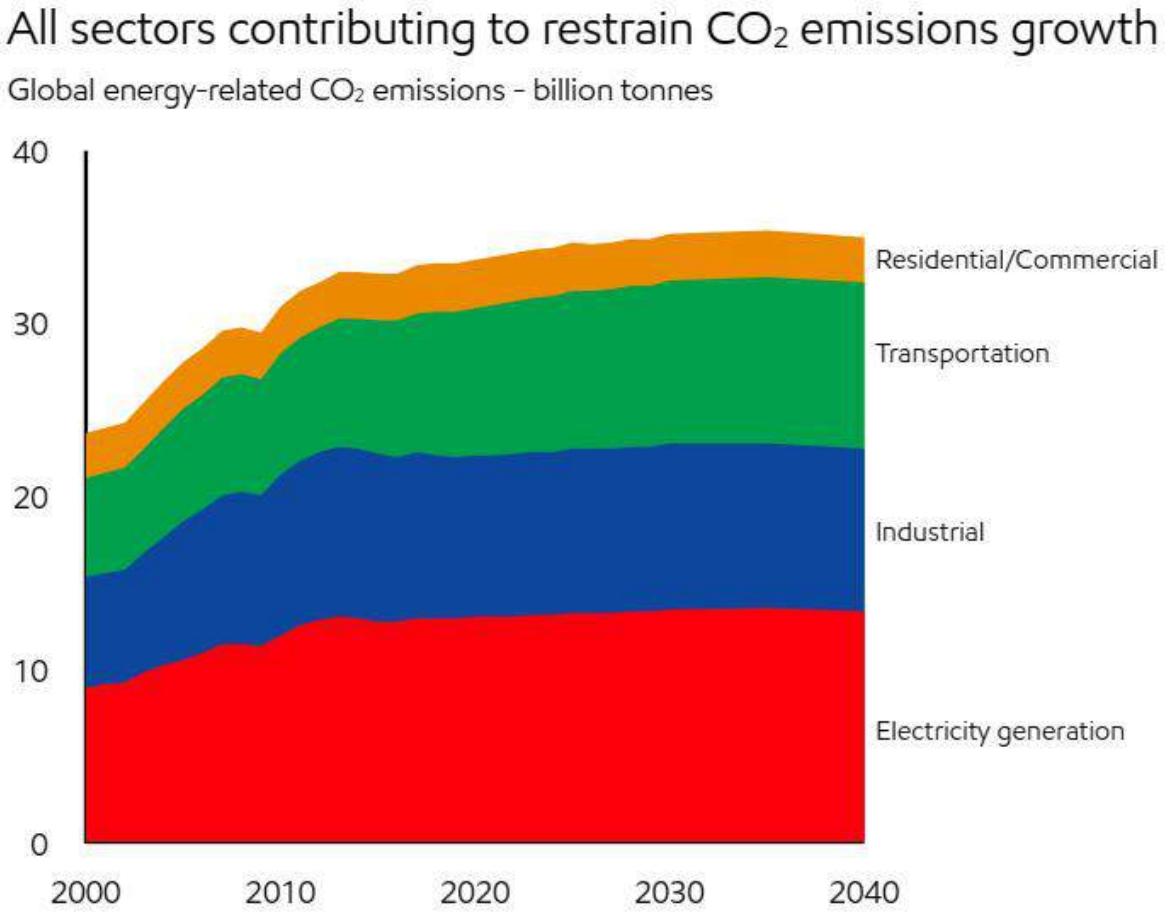
Outlook	Trajectory	Policy	Enablers
Base case	Consistent with 2.5 degrees global warming	Evolution of current policies and aligns with our commodity outlooks released in H1 2023	Steady advancement of current and nascent technologies
Country Pledges	Consistent with below 2 degrees warming (Global net zero by 2060)	Aligned with net zero pledges announced in the run up to COP28	Incorporates policy response to the current energy crisis, and geopolitical challenges facing global economy
Global Net Zero 2050	Consistent with 1.5 degrees warming (Global net zero by 2050)	Aligned with most ambitious goal of Paris Agreement	Immediate peak energy; rapid hydrogen and carbon removal deployment; consumer shift

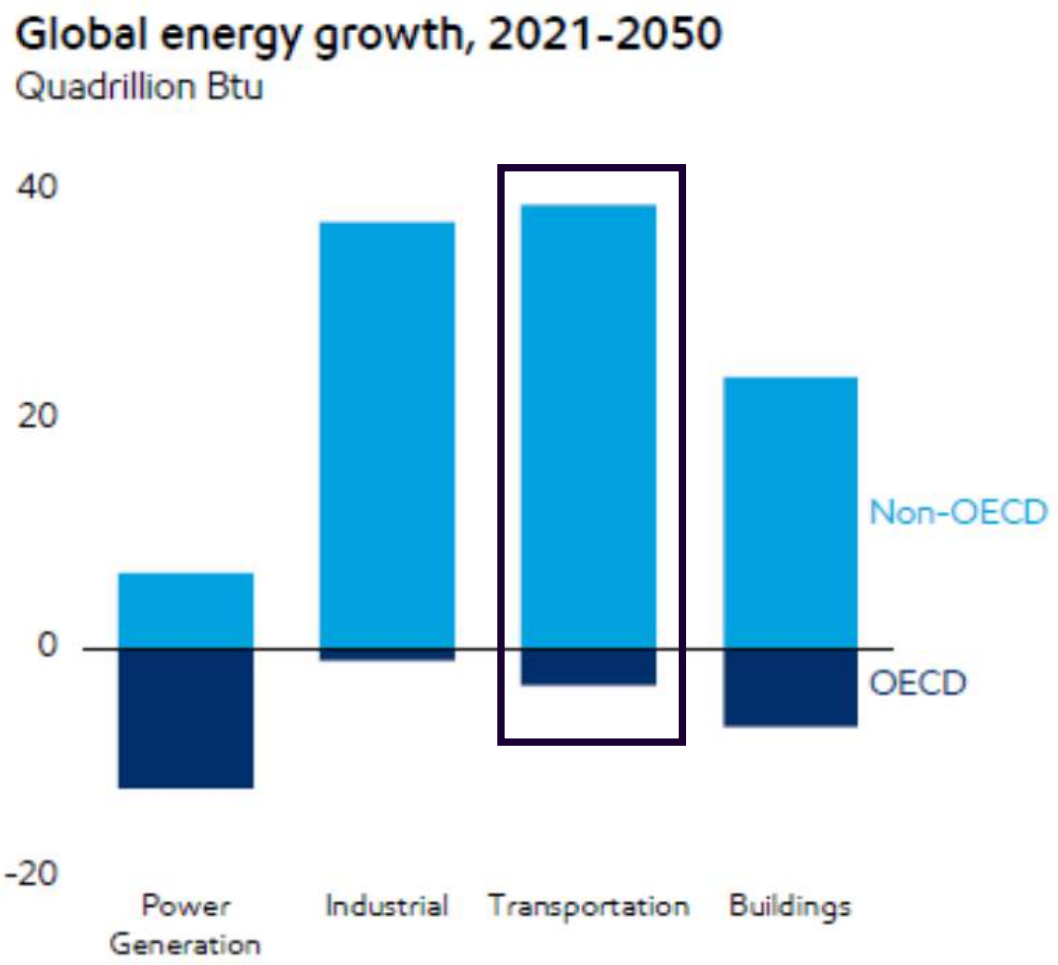
Source: Wood Mackenzie

Context


What can you make from one barrel of oil?
Researchers broke down a typical barrel of domestic crude oil into what could be produced from it. The average domestic crude oil has a gravity of 32 degrees and weighs 7.21 pounds per gallon. Here's what just one barrel of crude oil can produce:
Wax for 170 birthday candles or 27 crayons.
Distillate fuel to drive a large truck (five miles per gallon) for almost 40 miles
If jet fuel fraction is included.
Asphalt to make about one gallon
Ford Puma
Ford Deutschland
Weitere Infos
Lubricants to make about one quart of motor oil.
Nearly 70kilowatt-hours of electricity at a power plant generated by residual fuel.
About four pounds of charcoal briquettes.
Gasoline to drive a medium-sized car (17 miles per gallon) for more than 280 miles
Liquefied gases, such as propane, to fill 12 small (14.1-ounce) cylinders for home, camping or workshop use.
There would be enough petrochemicals left in that same barrel to also provide the base for:
540 toothbrushes
750 pocket combs
39 polyester shirts
23 hula hoops
135 four-inch rubber balls
65 plastic drinking cups
11 plastic telephone housings
65 plastic dustpans
195 one-cup measuring cups

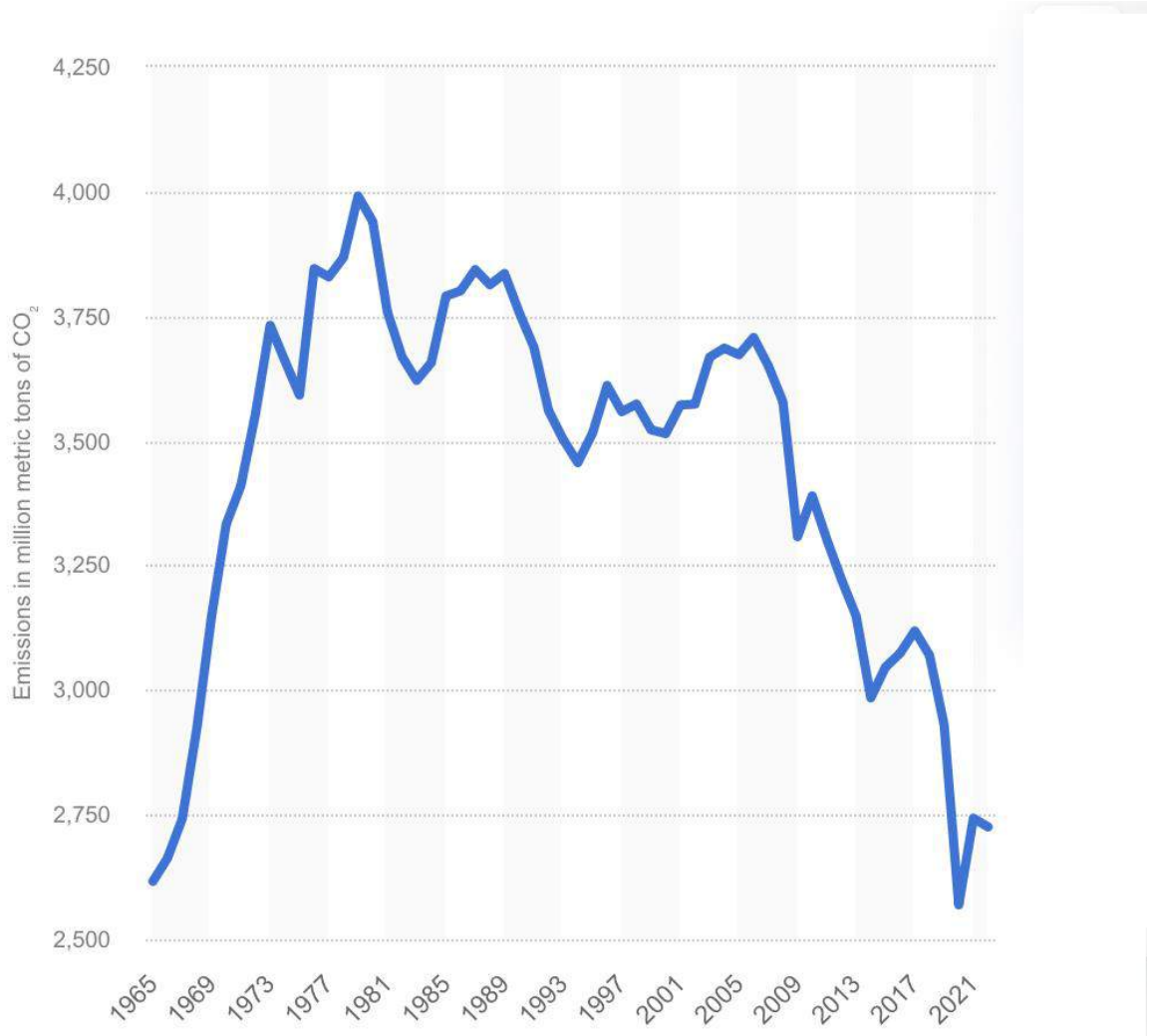
Global CO_2 Emissions ~ 36.8 billion tonnes in 2022 (IEA)
Transportation CO_2 Emissions ~ 7.5 billion tonnes





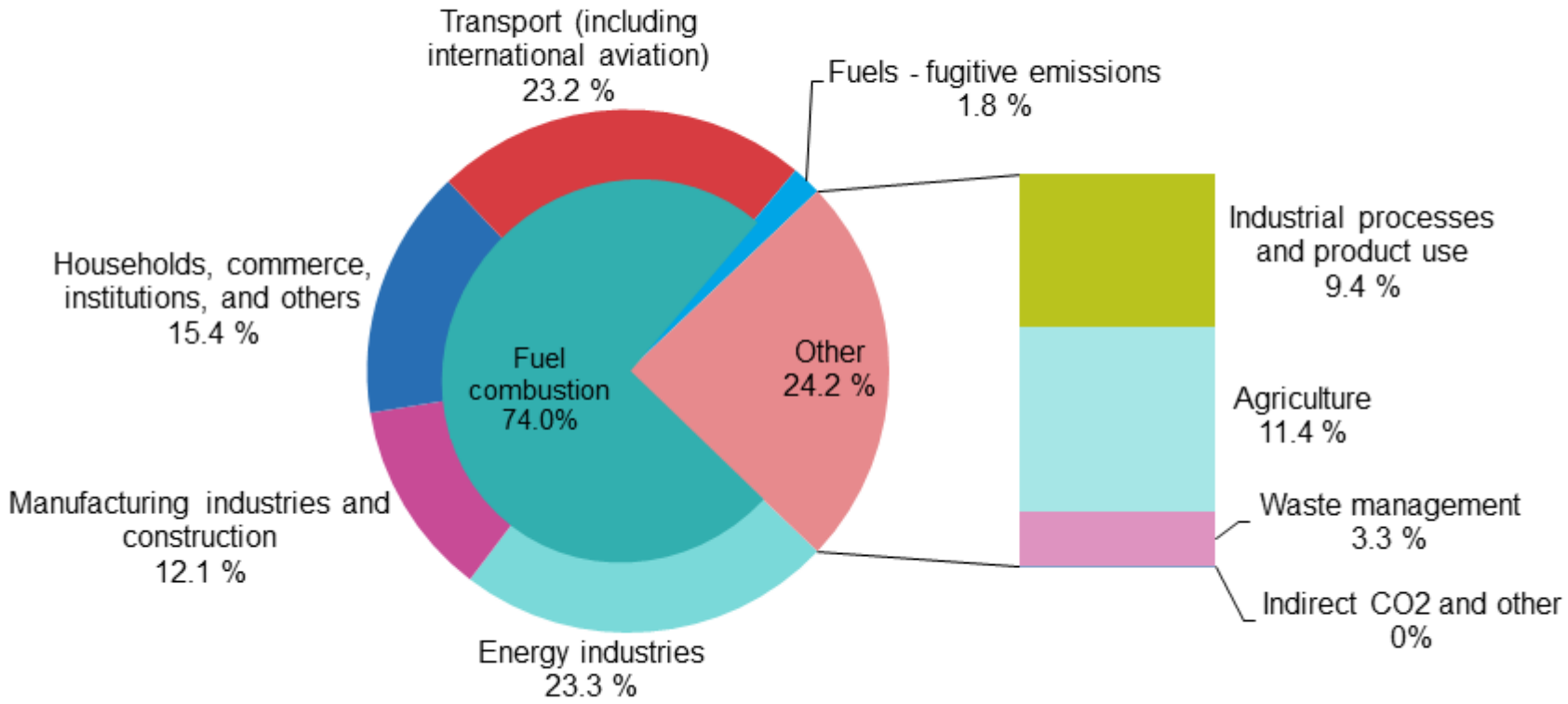
ExxonMobil WEO 2022

European CO_2 Emissions ~3 billion tonnes



European CO_2 Emissions ~ 3 billion tonnes

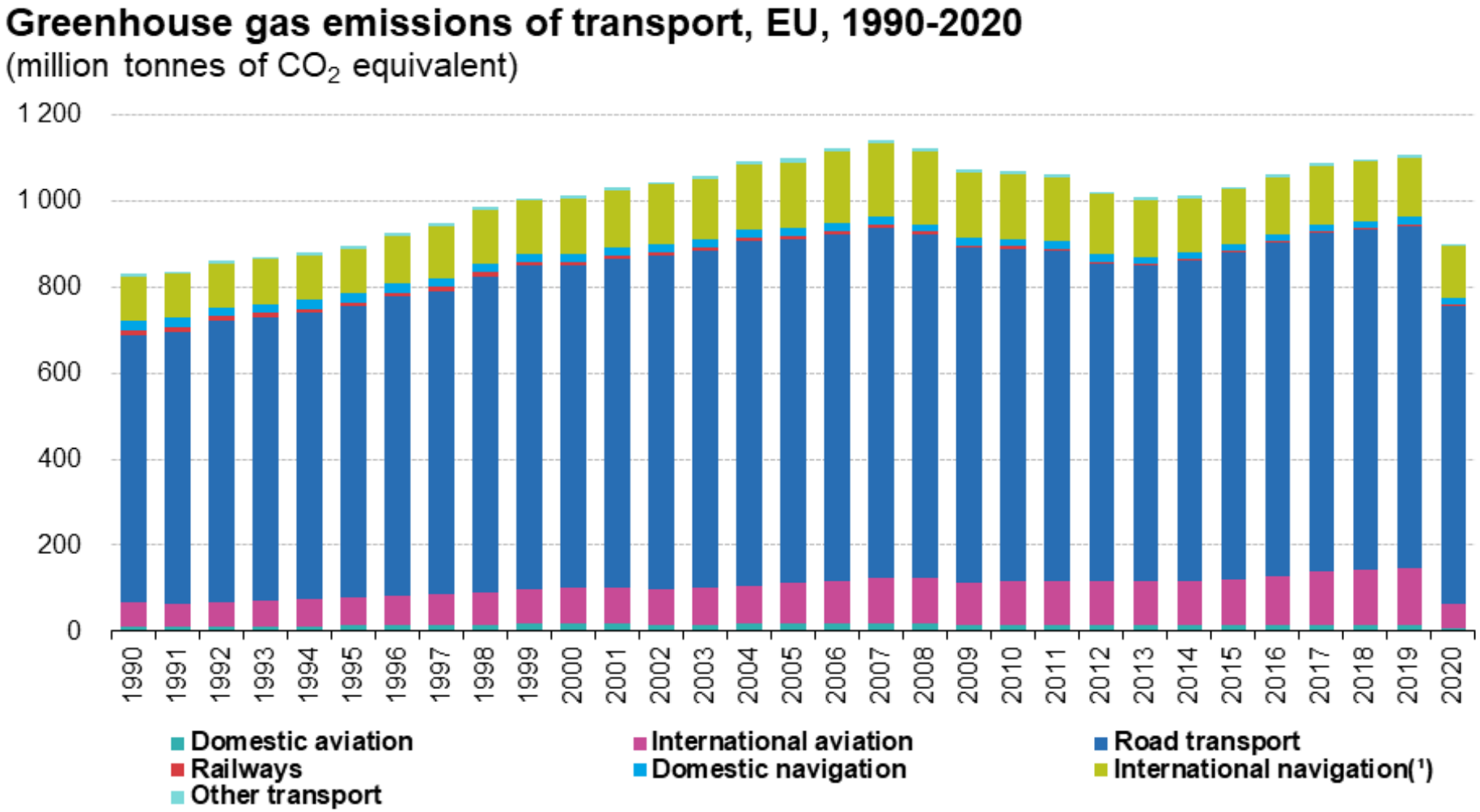
Greenhouse gas emissions by source sector, EU, 2020



Source: EEA, republished by Eurostat (online data code: env_air_gge)

eurostat

European Transportation CO_2 Emissions ~ 1.1 billion tonnes

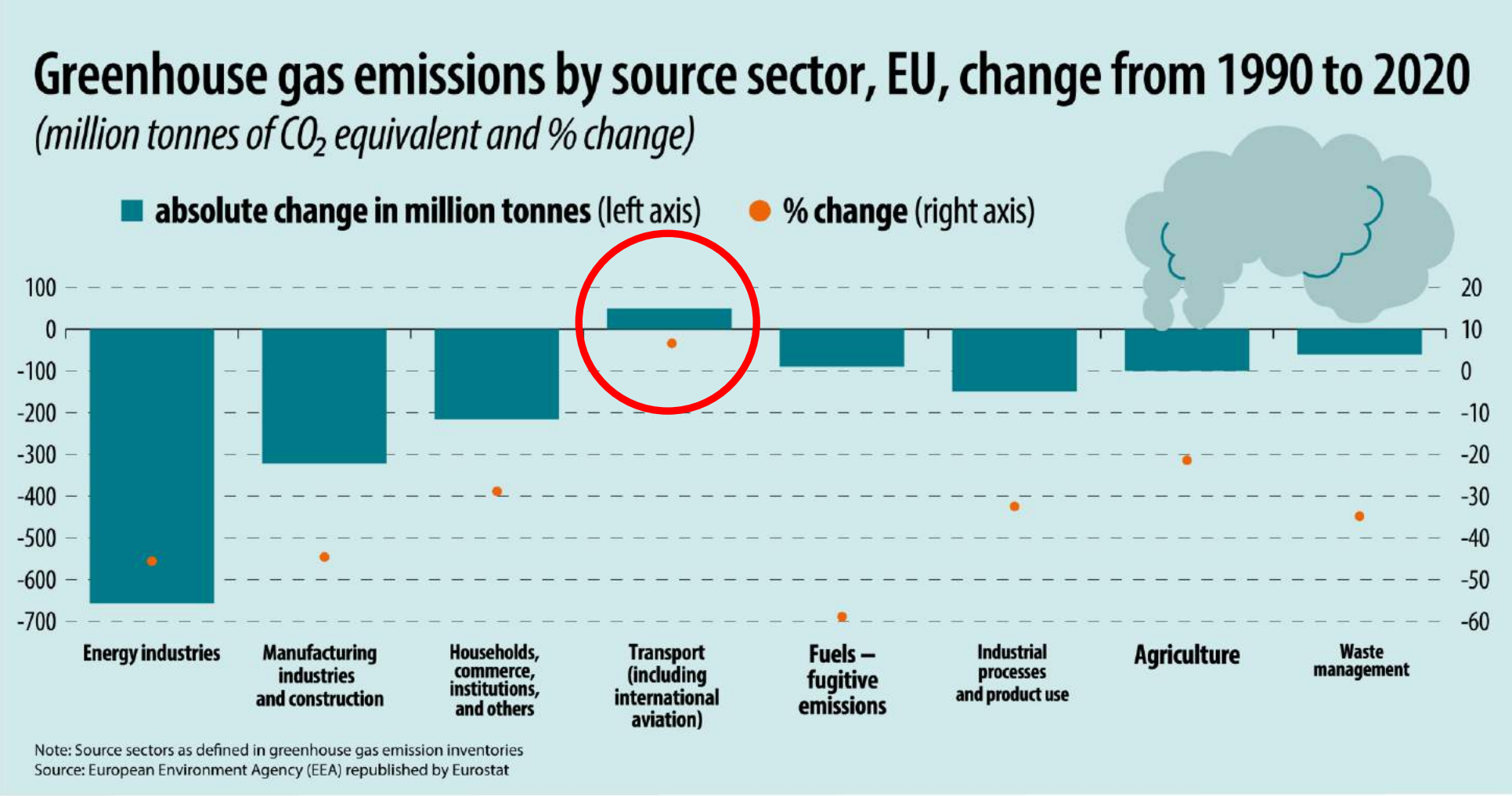


(1) Not included in the EU emissions totals relevant for the energy and climate packages

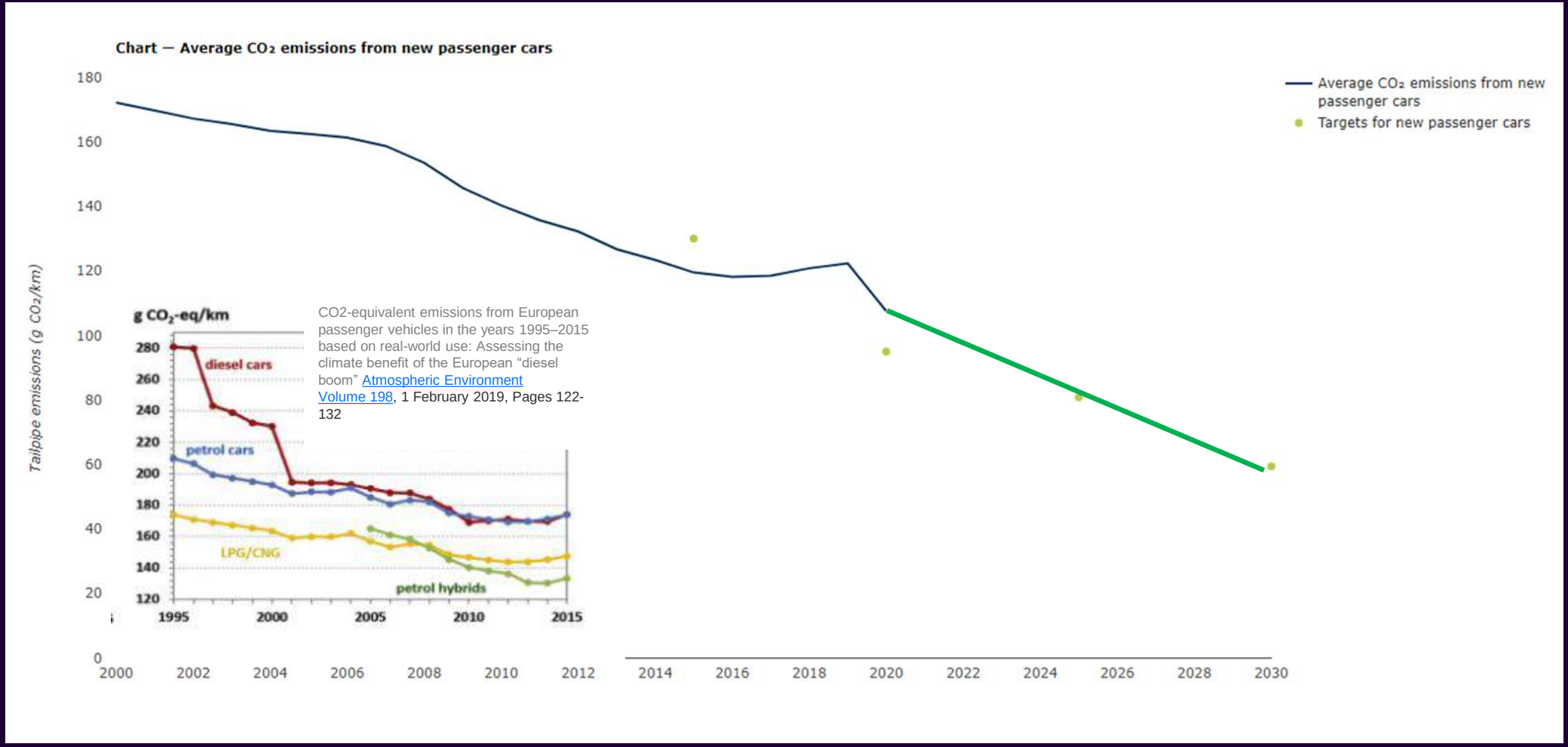
Source: EEA, republised by Eurostat (online data code: env_air_gge)

eurostat

EU CO_2 Emissions
Transportation Presents a Challenge



Perspective
CO_2 Emissions Evolution over 30 years



www.eea.europa.eu/data-and-maps/daviz/average-emissions-for-new-cars-8#tab-chart_1

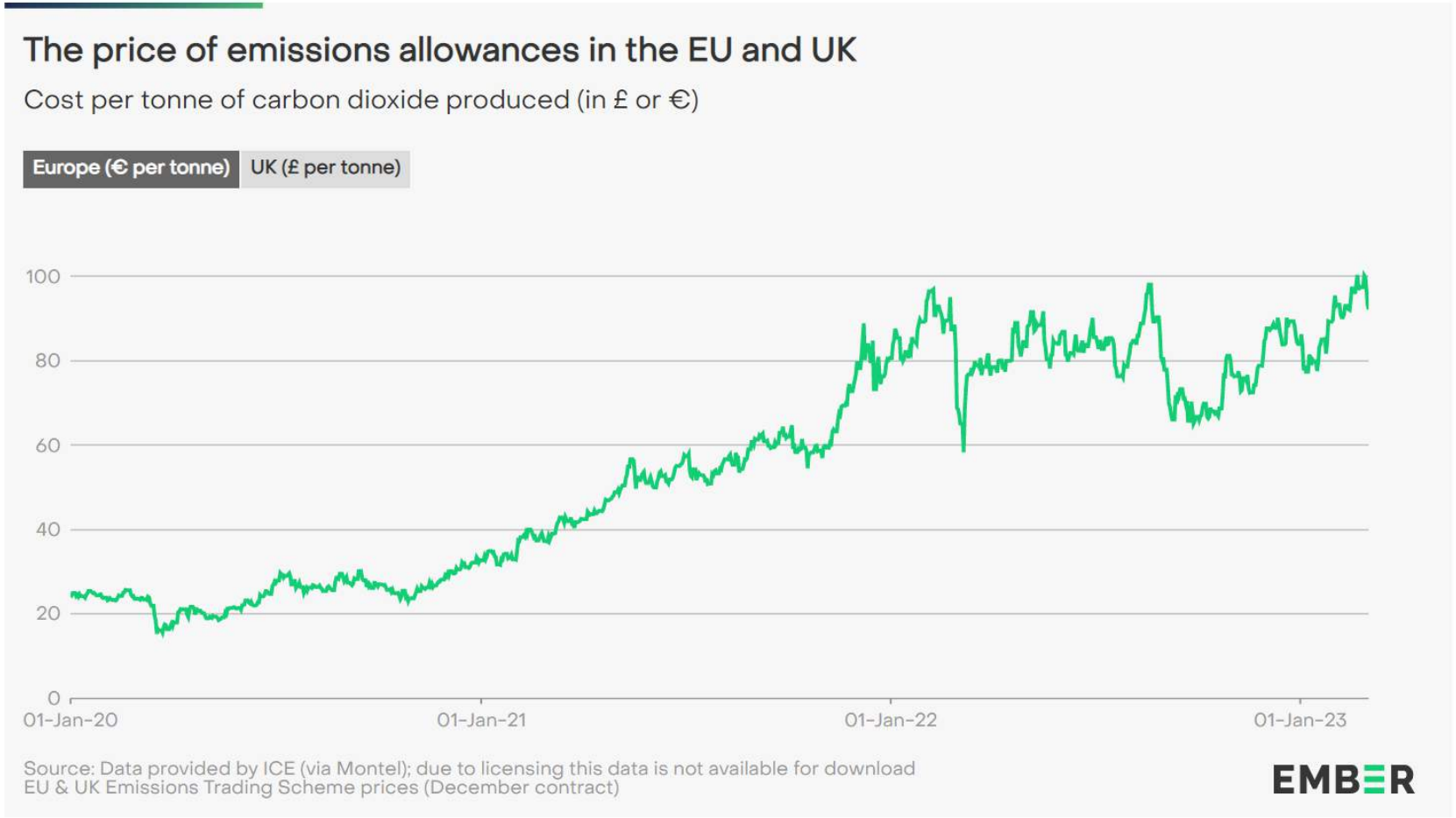
Moving from XW-40 to 0W-XX improves FE ~ 3.5%
→ Theoretical 11 mio tonnes of CO_2 or ~$1 billion in EUA

Europe	Car / Van	Truck	
Vehicles	350,000,000	12,000,000	
gCO_2/km	100	700	
Av. km	10,000	70,000	
$tCO_2/v/y$	1	49	
Fleet tCO_2/y	**350,000,000**	**588,000,000**	938,000,000
3.5%	12,250,000	20,580,000	32,830,000
			$2,954,700,000

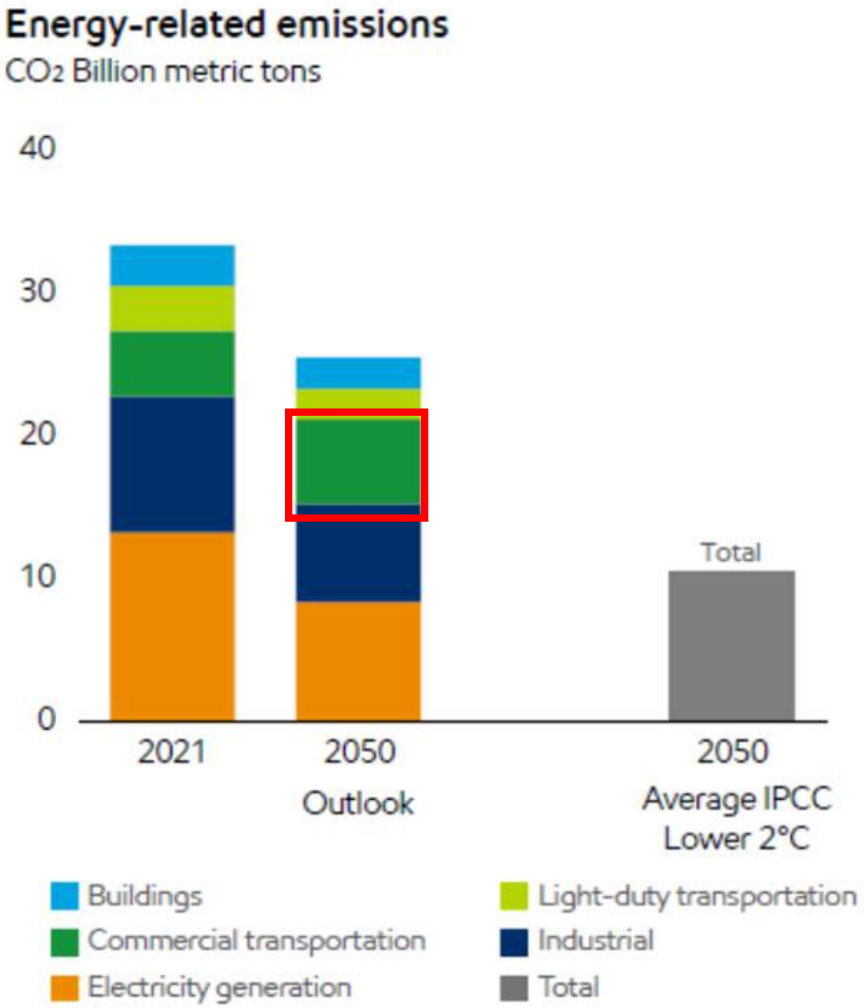
ICE EUA @ $90/t

Approximately 1/3 of EU fleet is 10W-XX in 2020 (Kline)

EU Emission Allowances



0W for PC12?



Source: IPCC: AR6 Scenarios Database hosted by IIASA release 1.0 average IPCC C3: "Likely below 2°C" scenarios; ExxonMobil analysis

0W for PC12?

- The U.S. Environmental Protection Agency (EPA) announced new proposed federal vehicle emissions standards that will accelerate the ongoing transition to a clean vehicles future in the United States
- The first set of proposed standards for 2027 for Light-Duty and Medium Duty Vehicles builds on EPA's existing emissions standards for passenger cars and light trucks for Model Years (MY) 2023 through 2026.
- The proposed MY 2032 light-duty standards are projected to result in a **56% reduction in projected fleet average greenhouse gas emissions target levels compared to the existing MY 2026 standards**. The proposed MY 2032 medium-duty vehicle standards would result in a 44% reduction compared to MY 2026 standards.
- The proposal is expected to avoid **7.3 billion tons of CO_2 emissions through 2055**, equivalent to eliminating all greenhouse gas emissions from the entire current U.S. transportation sector for four years and would also deliver significant health benefits by reducing fine particulate matter that can cause premature death, heart attacks, respiratory and cardiovascular illnesses, aggravated asthma, and decreased lung function.
- The second set of proposed standards, the "Greenhouse Gas Standards for Heavy-Duty Vehicles – Phase 3," would apply to heavy-duty vocational vehicles
- The proposal is projected to **avoid 1.8 billion tons of CO_2 through 2055**, equivalent to eliminating all greenhouse gas emissions from the entire current U.S. transportation sector for an entire year, and deliver additional health benefits by reducing other pollutants from these vehicles.
- The standards would result in improved air quality nationwide, and those who live near major roadways and are disproportionately exposed to vehicle pollution and heavy-duty activity, which often includes low-income populations and communities of color, would benefit most directly.

U.S. EPA proposes stricter federal vehicle emission standards - F&L Asia (fuelsandlubes.com)

0W for PC12?

Reduction in fuel consumption and GHG emissions compared to MY 2017 baseline	MY 2021	MY 2024	MY 2027
Combination Tractors	13%	20%	25%
Trailers	5%	7%	9%
Heavy Duty Pickup Trucks and Vans	2.5%	10%	16%
Vocational Vehicles	12%	20%	24%
Separate Engine Standards (tractor, vocational)			4-5%

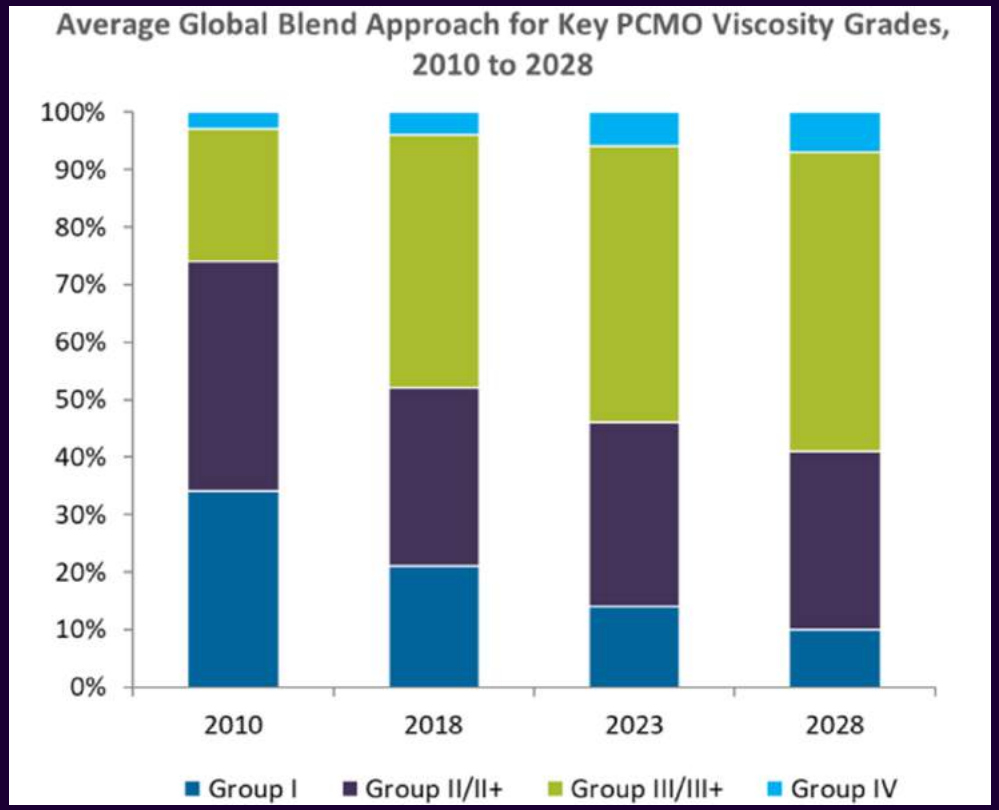
Proposed CO_2 Emission standards [Grams/ton-mile] for MY 2027 through 2032+ for various vehicle types

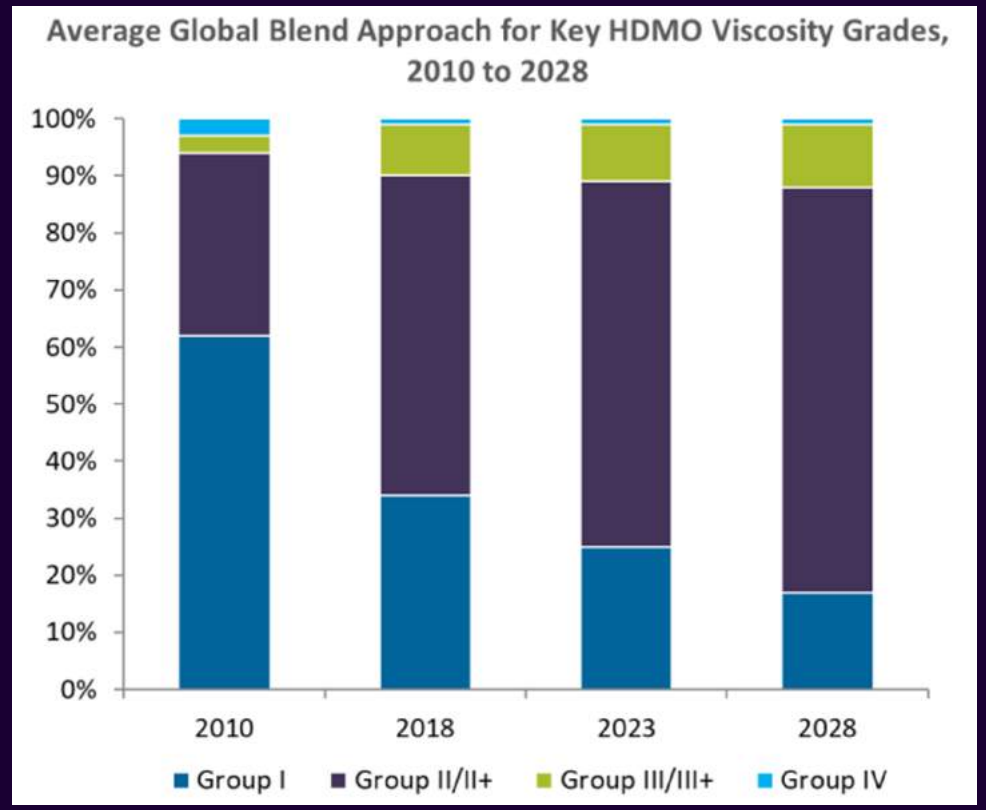
Model year	2027	2028	2029	2030	2031	2032+
Light-heavy	257	238	218	201	182	142
Medium-heavy	190	186	179	172	165	153
Heavy	193	189	186	161	154	138
Class 8 Day cab*	70.2	68.6	66.3	62.4	54.6	51.5
Class 8 Sleeper cab*	69.6	69.6	69.6	62.6	55.7	52.2
Heavy haul tractor	48.3	48.3	48.3	43.0	42.5	41.1
Coach bus	205	205	205	185	164	154
Refuse Hauler	253	241	232	221	212	191

*mid-roof
These data are for compression ignition engines, in the multipurpose use subcategory, please note there are other standards for urban and regional subcategories and for spark ignition engines.
Source www.govinfo.gov Federal Register/Vol. 88, No. 81/Thursday, April 27, 2023/Proposed Rules

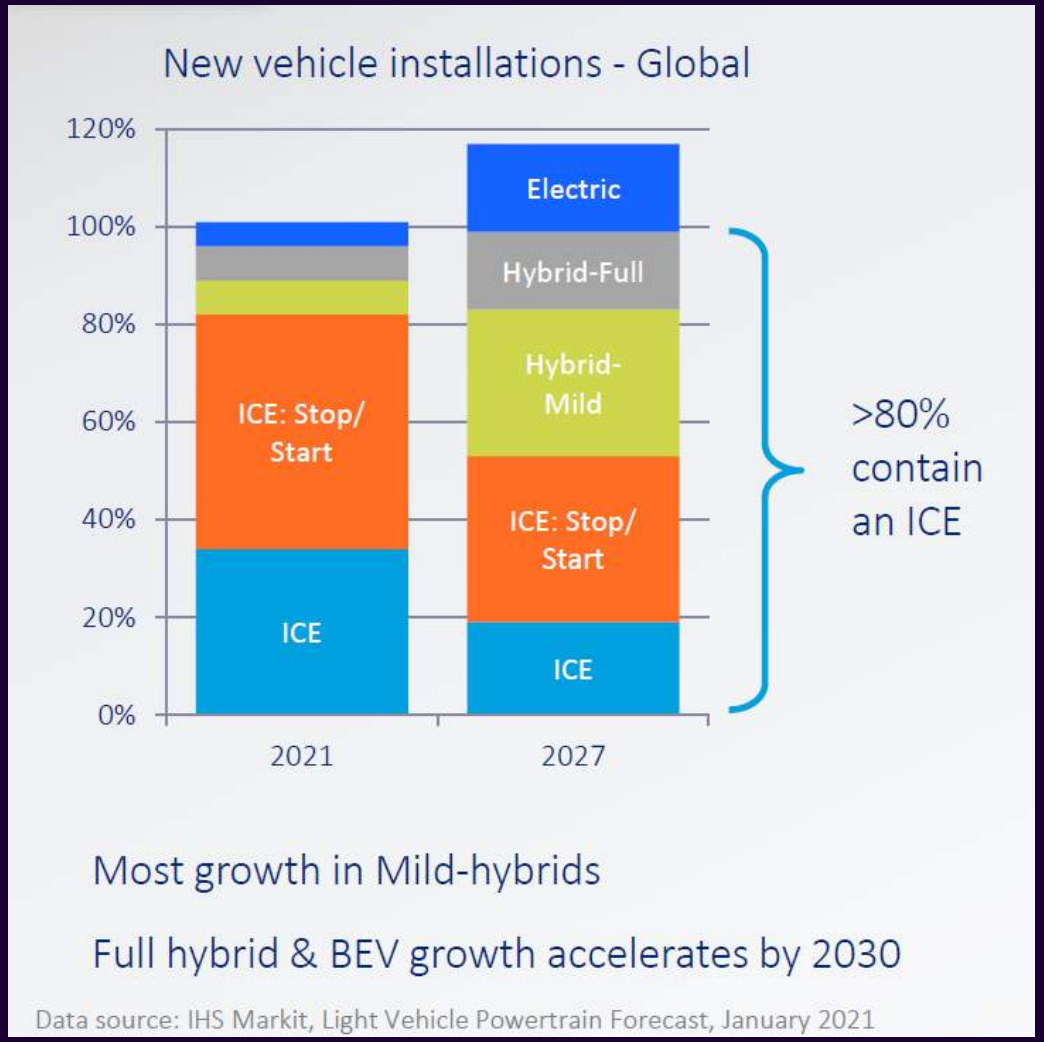
Market Update – Grp III / IV
Global 0W Growth

Long View
Base Stocks

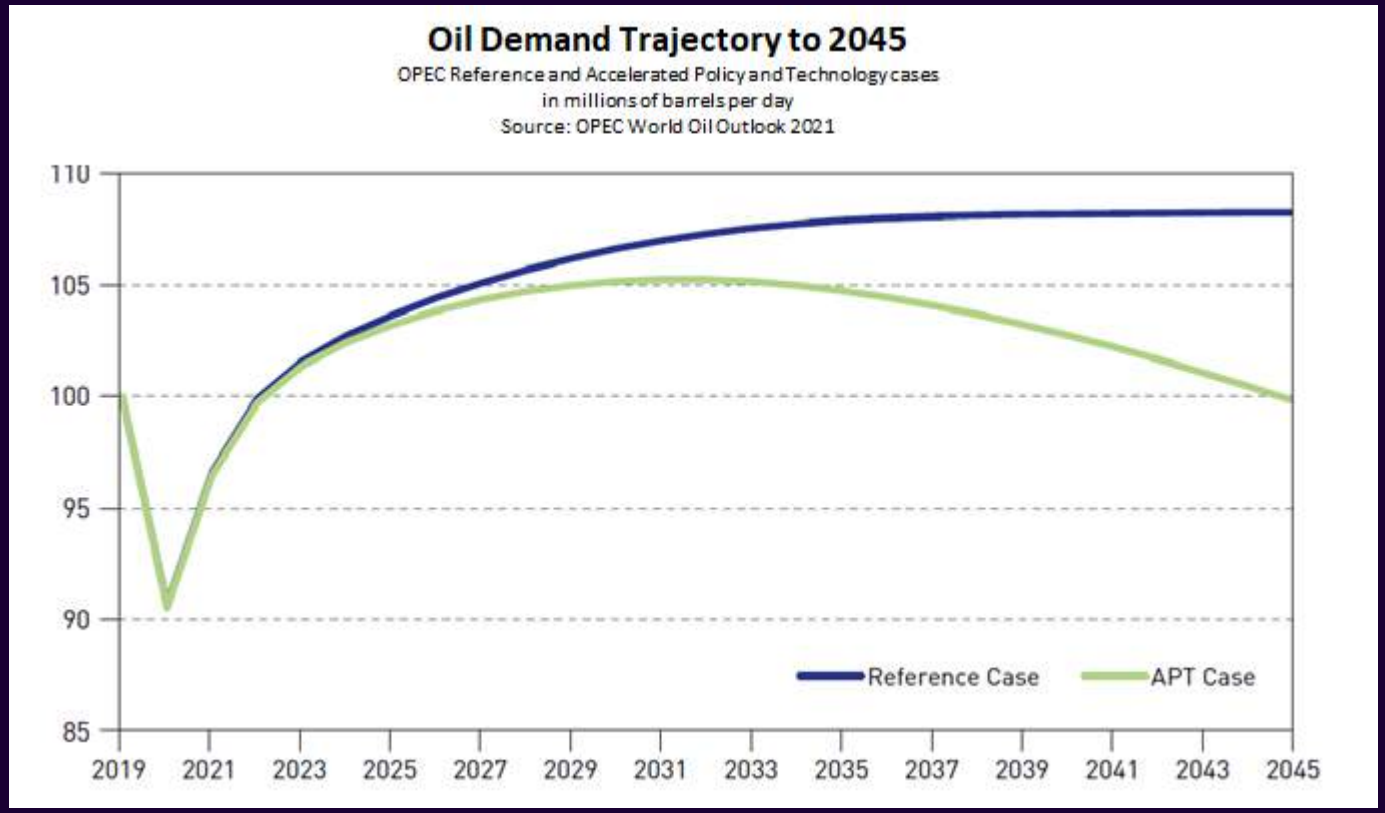




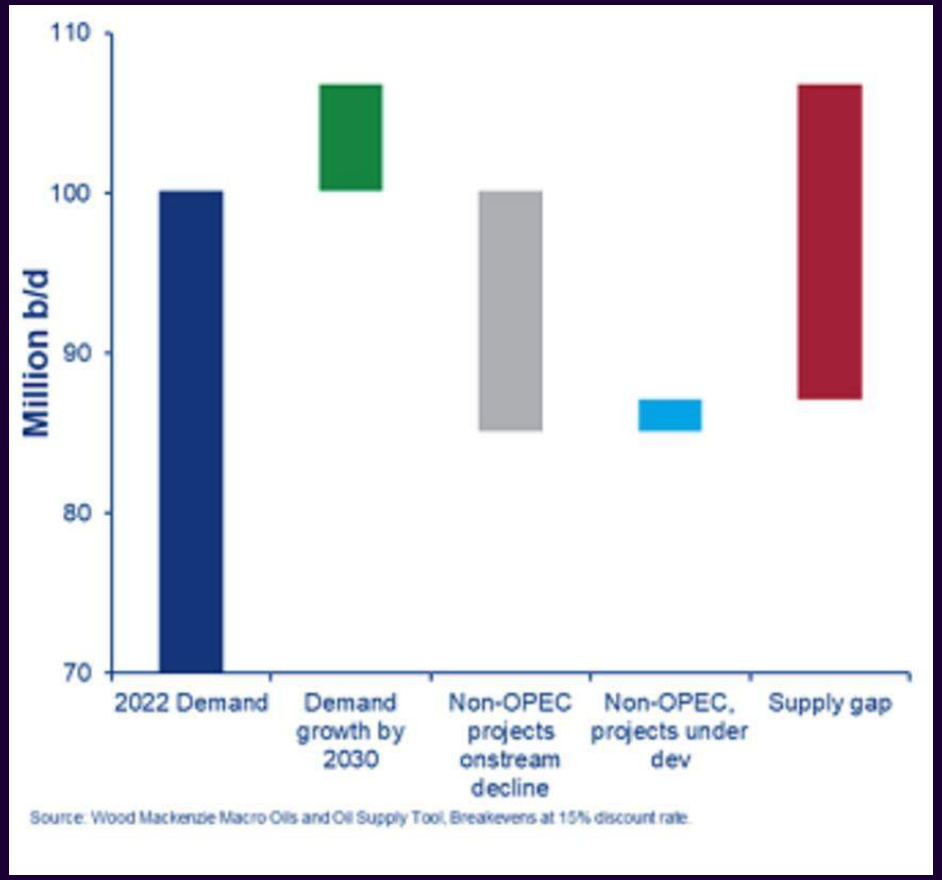
Perspective
ICE Future



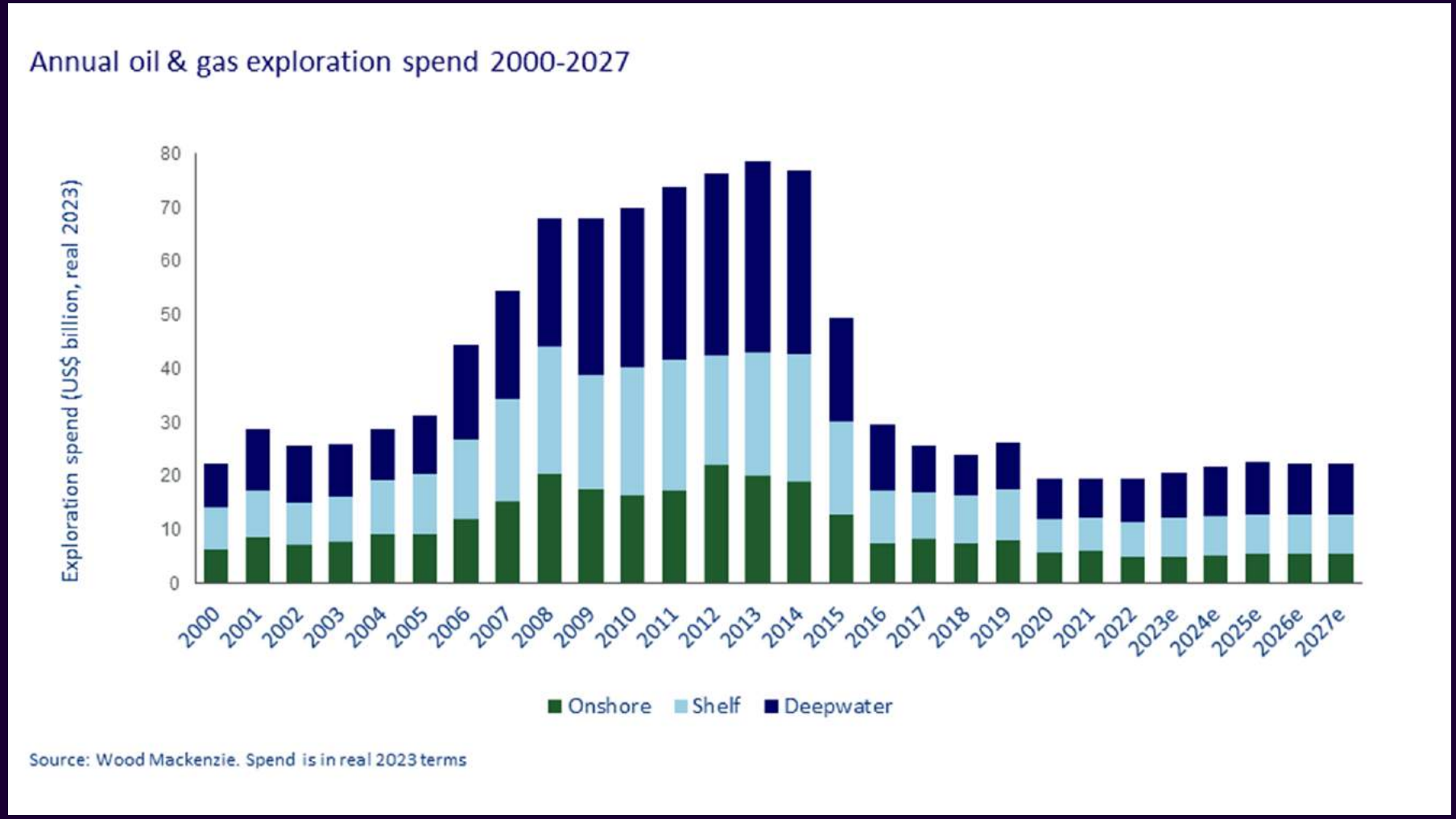
Perspective
Future Oil Demand



Long View
Refining : 15 mio bbl/d supply gap....

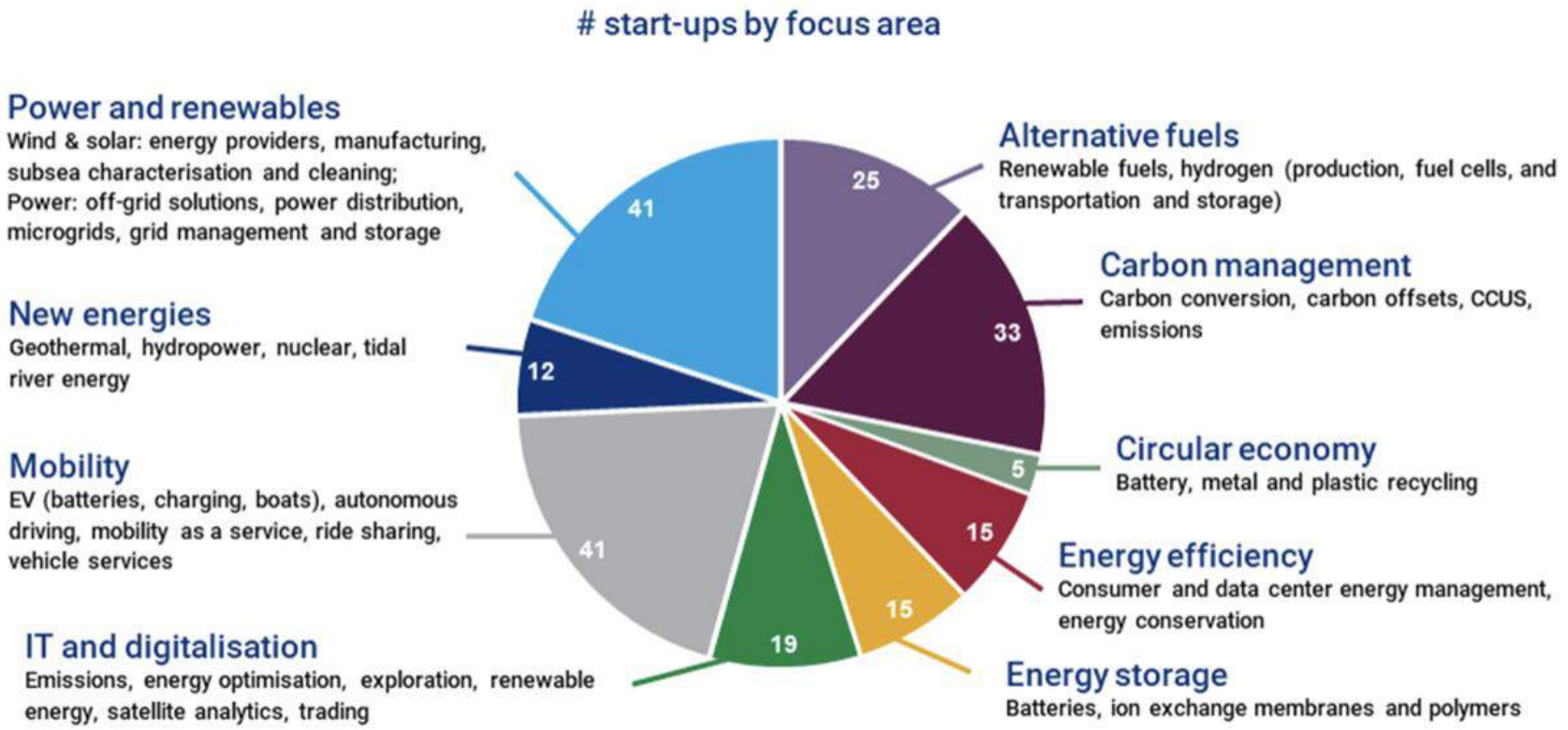


Long View
Refining : 15 mio bbl/d supply gap....



Global Oil Majors ET Investment

The Majors have focused investment in nine areas of the energy transition



Source: Wood Mackenzie

1.

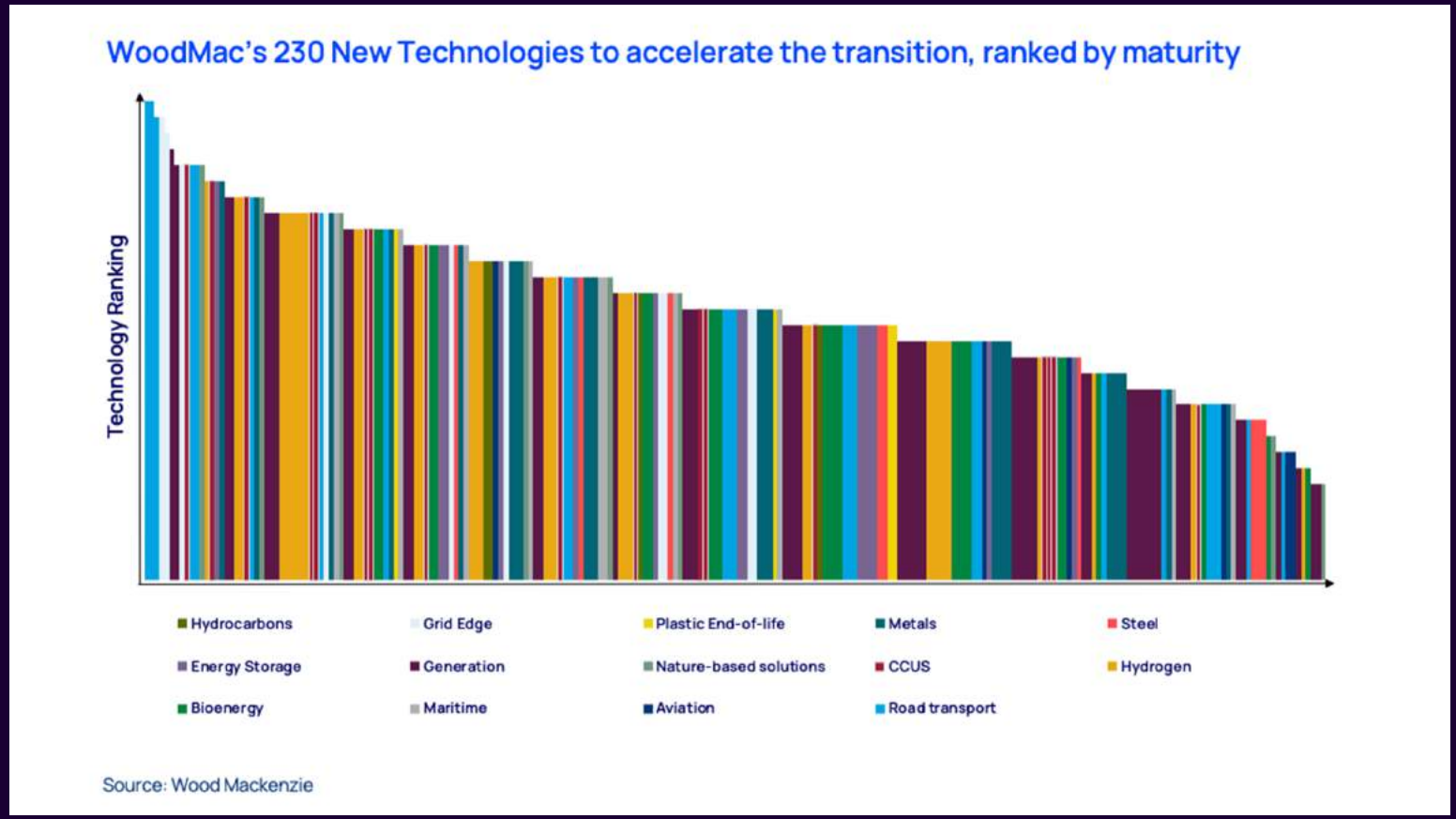
2.

3.

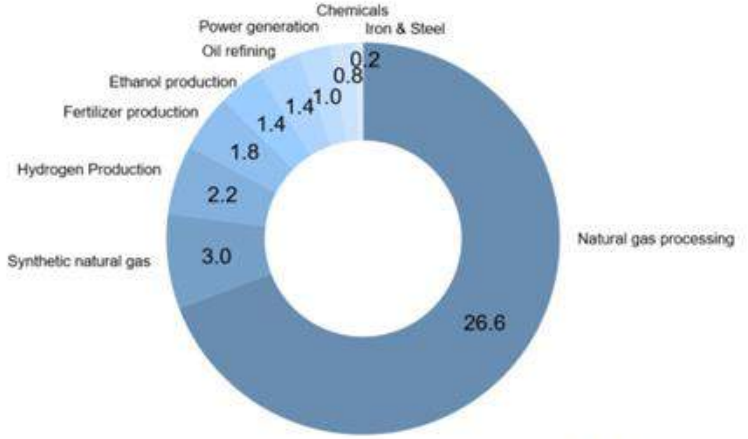
4.

5.

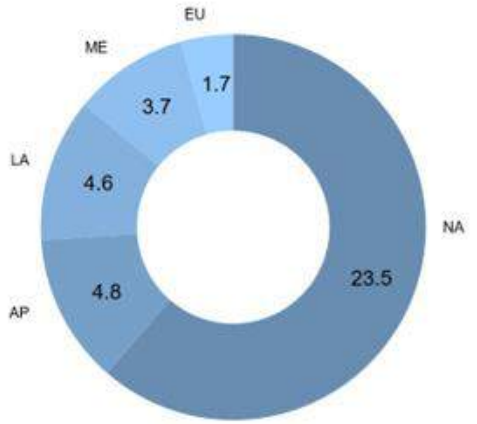
Wood Mackenzie Ranked 230 New Low Carbon Technologies for the Global Energy Market



Long View
CCUS



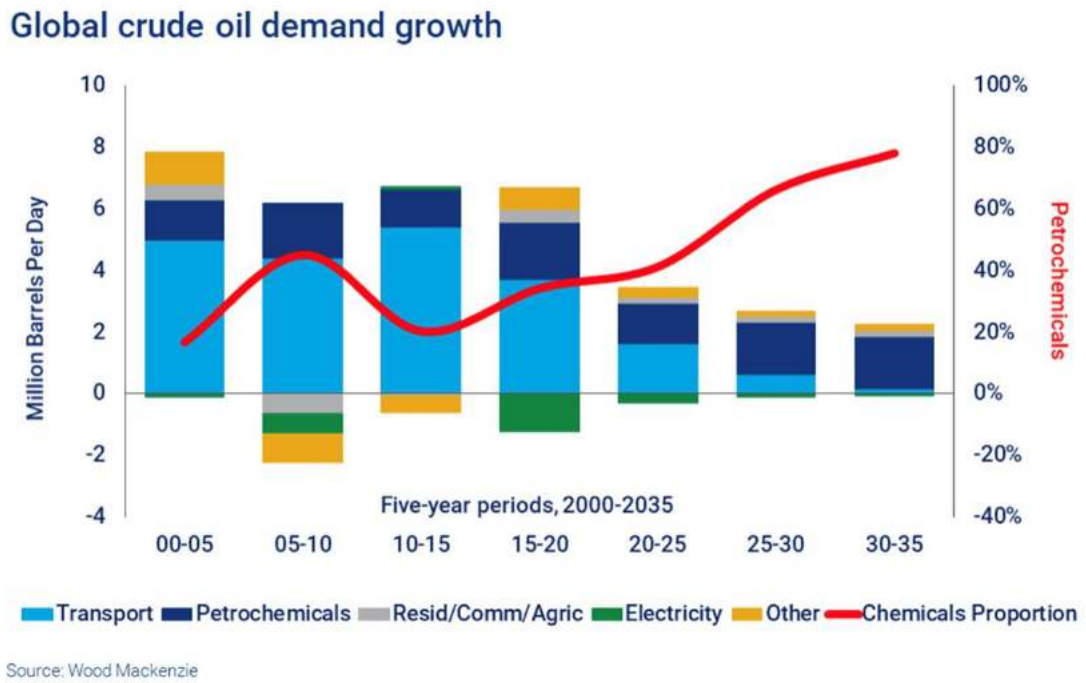
Carbon capture capacity by application in 2020
(Million tons of CO_2 captured)



Carbon Capture Capacity by Region in 2020
(Million tons of CO_2 captured)

CCUS Stratos

Long View – Future Refining
COTC



Source: Wood Mackenzie

The refinery of the future will need to be both greener and more integrated with chemicals. With regards to the former we are seeing refiners invest in three areas as they seek to transition their assets from fossil-fuel-machines to low carbon fuel manufacturing hubs. The first is deeper bio-integration, including bio-conversions. The second is investment in electrolysis, which will reduce the carbon intensity of the hydrogen used by refiners and potentially create a building block for less carbon intensive fuels. The third is carbon capture, utilisation and storage (CCUS). Some refiners are seeking to tie their assets into CCUS systems. With regards to petrochemical integration, we are seeing some refiners shift operations to increase the output of petrochemical feedstock and product, whilst others are investing into base and speciality chemical production."

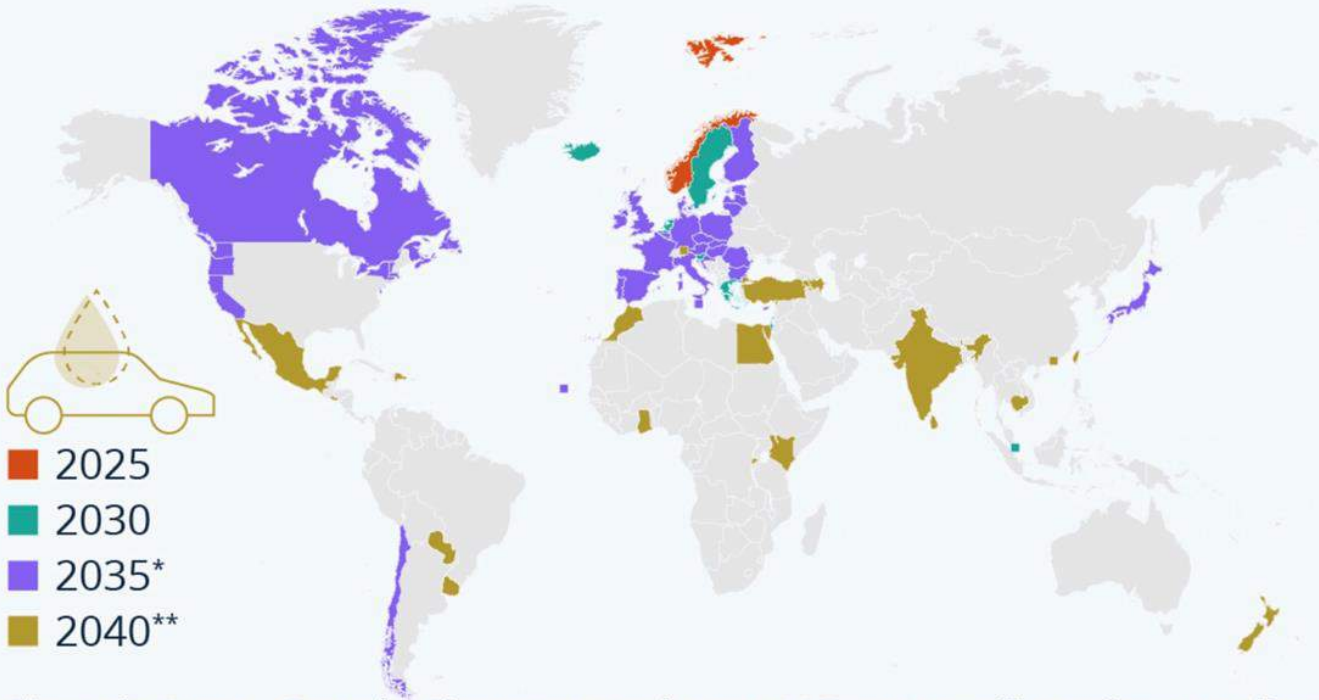
Long View
Refining & Base Stocks

kt/a Nameplate	Global		Global		Regional	
Group IV	Exxon	150	CP Chem	110*	Ineos	350
Group III++			Novvi	30		
Group III+	SK	400	Chevron	20		
Group III	SK	2,100	Chevron	550	S Oil	800
Group II	Exxon	3,300	Chevron	3,400	Motiva / S Oil / Luberef	3,600

*Rising to 170kt in 2024

Combustion Going Bust: Global Phase-outs of Gasoline Cars

Approximate official targets for the complete phase-out of the sale of new internal combustion engine cars, by country



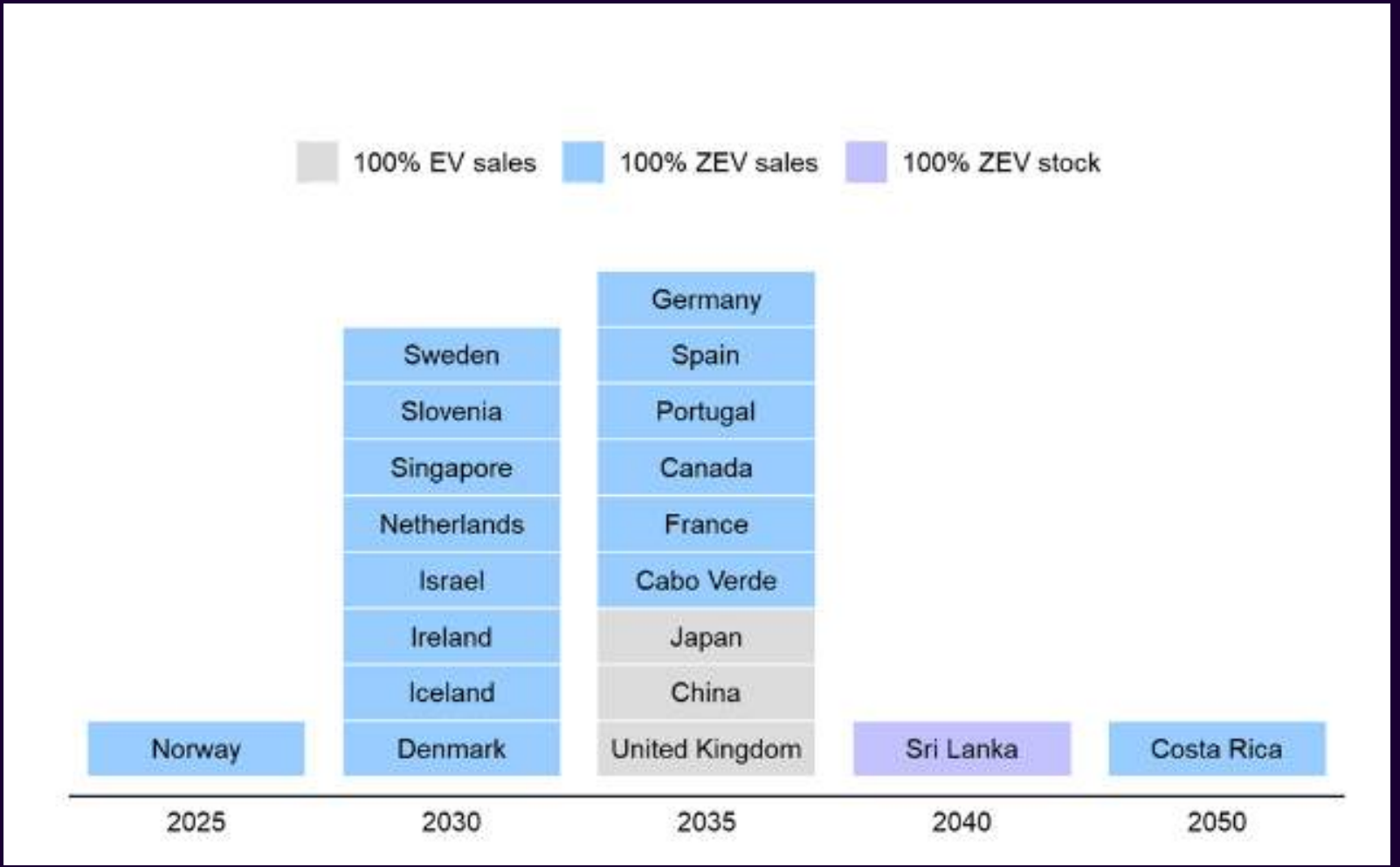
Slovenia, Japan, Canada, Singapore and some U.S. states will continue to allow sale of hybrids. Sri Lanka: combustion road ban

* including EU-wide ban ** Including signatories of respective COP26 pledge

Sources: Coltura, Statista research

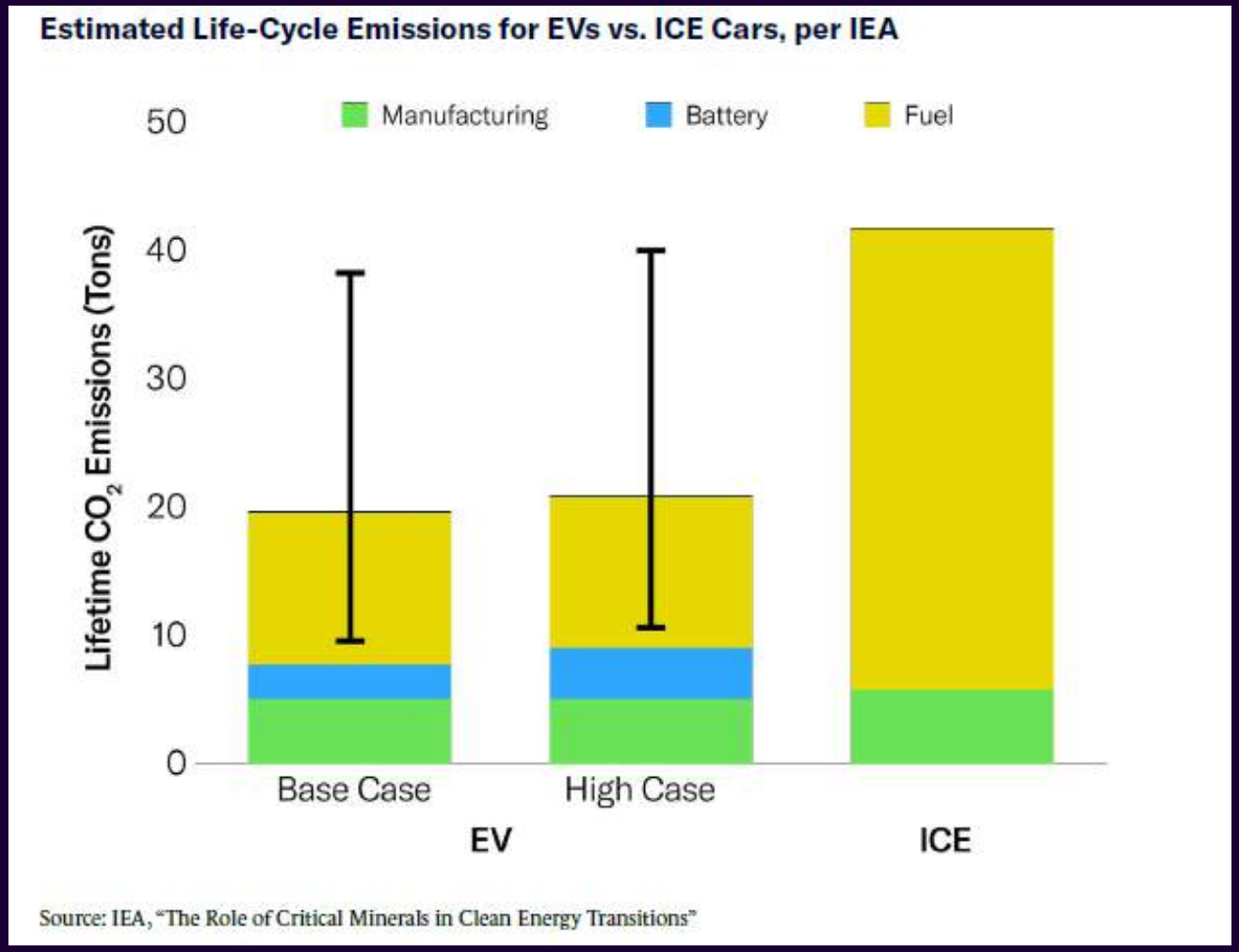
statista

ICE Bans Around the world

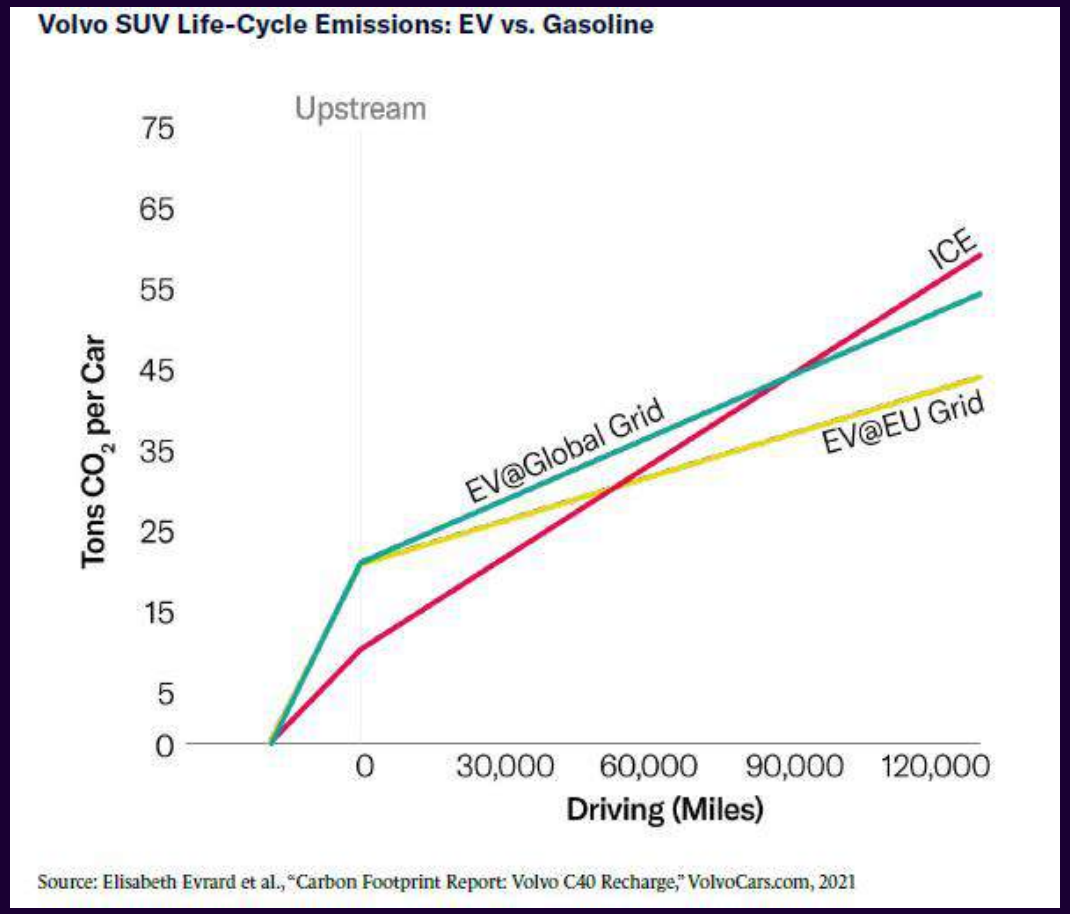


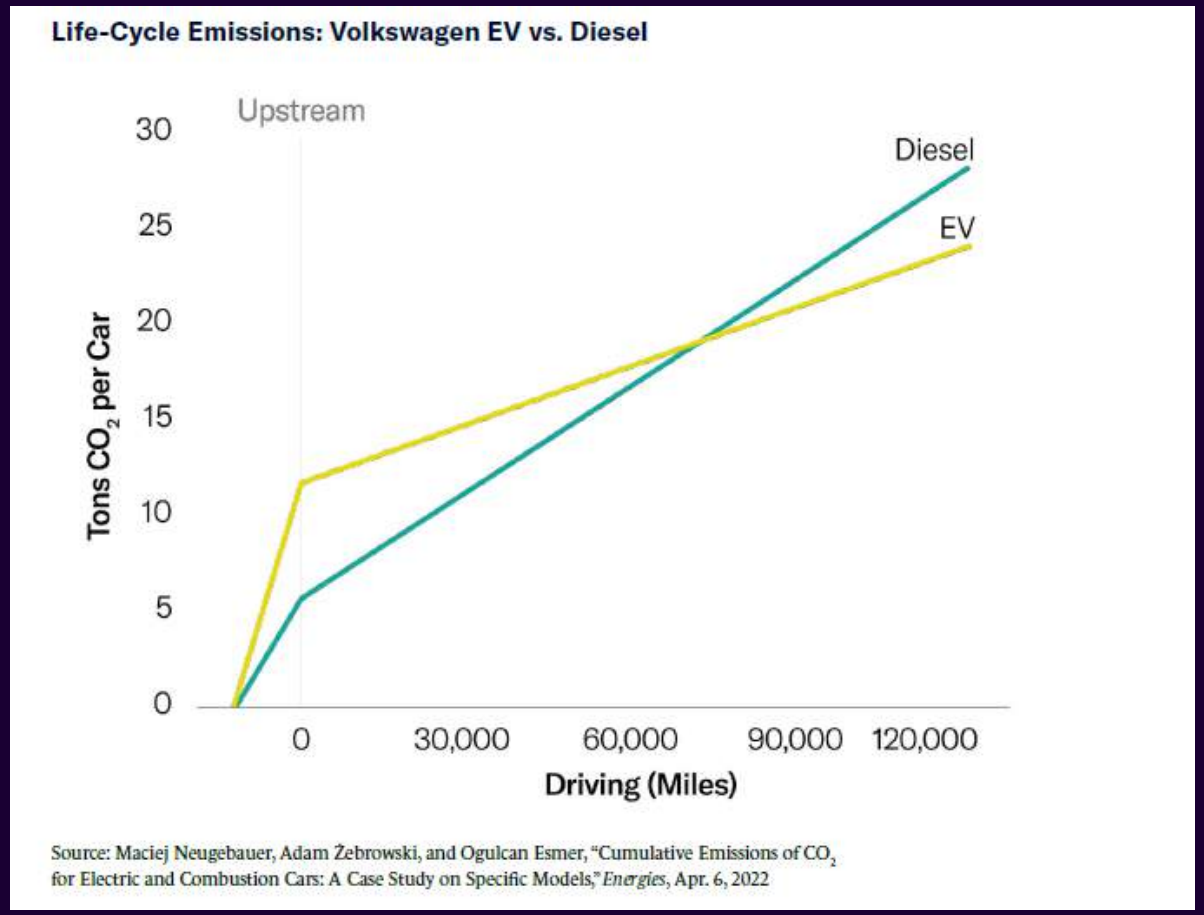
ADI Analytics

LCA Uncertainty on EVs

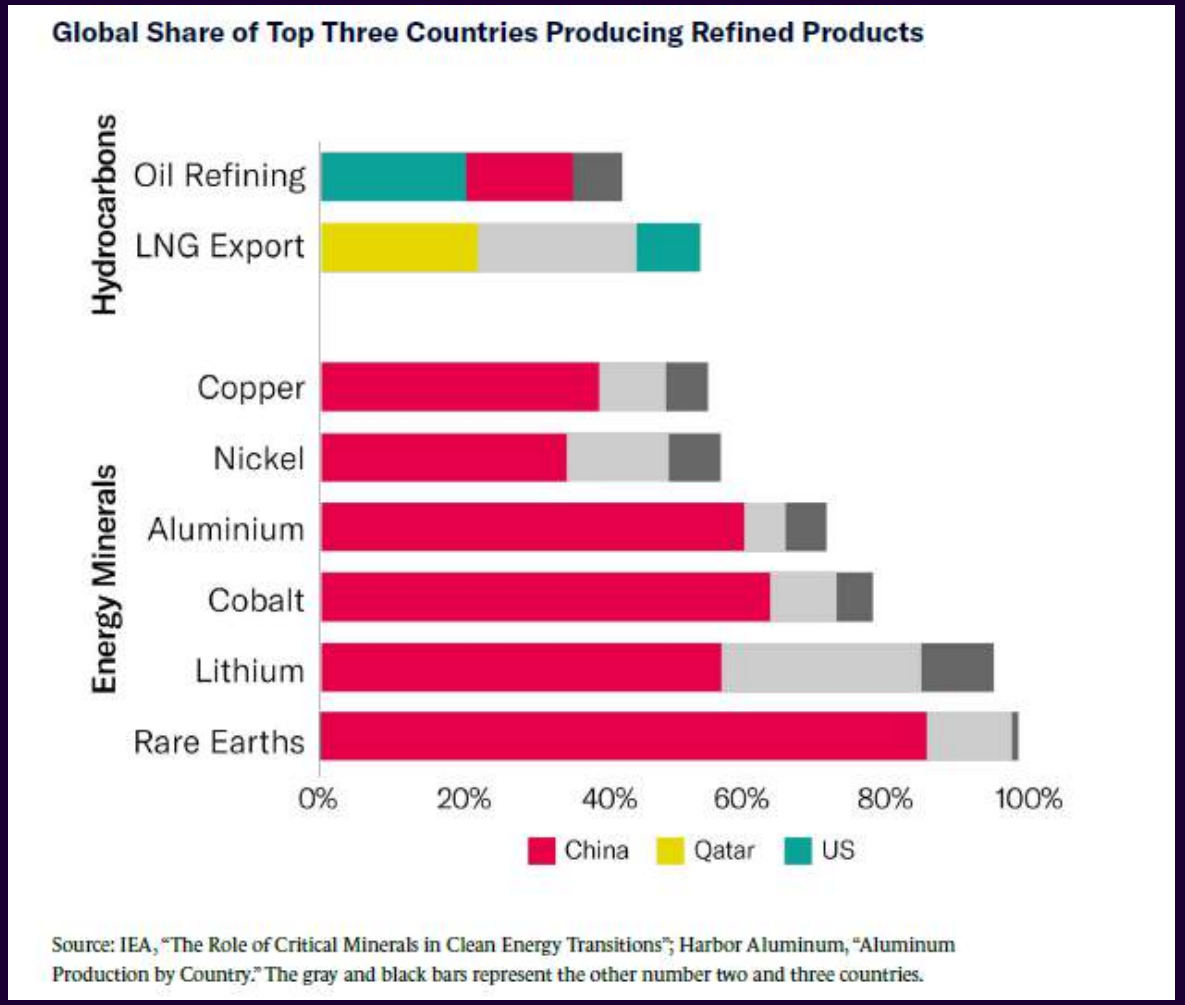


LCA Uncertainty on EVs



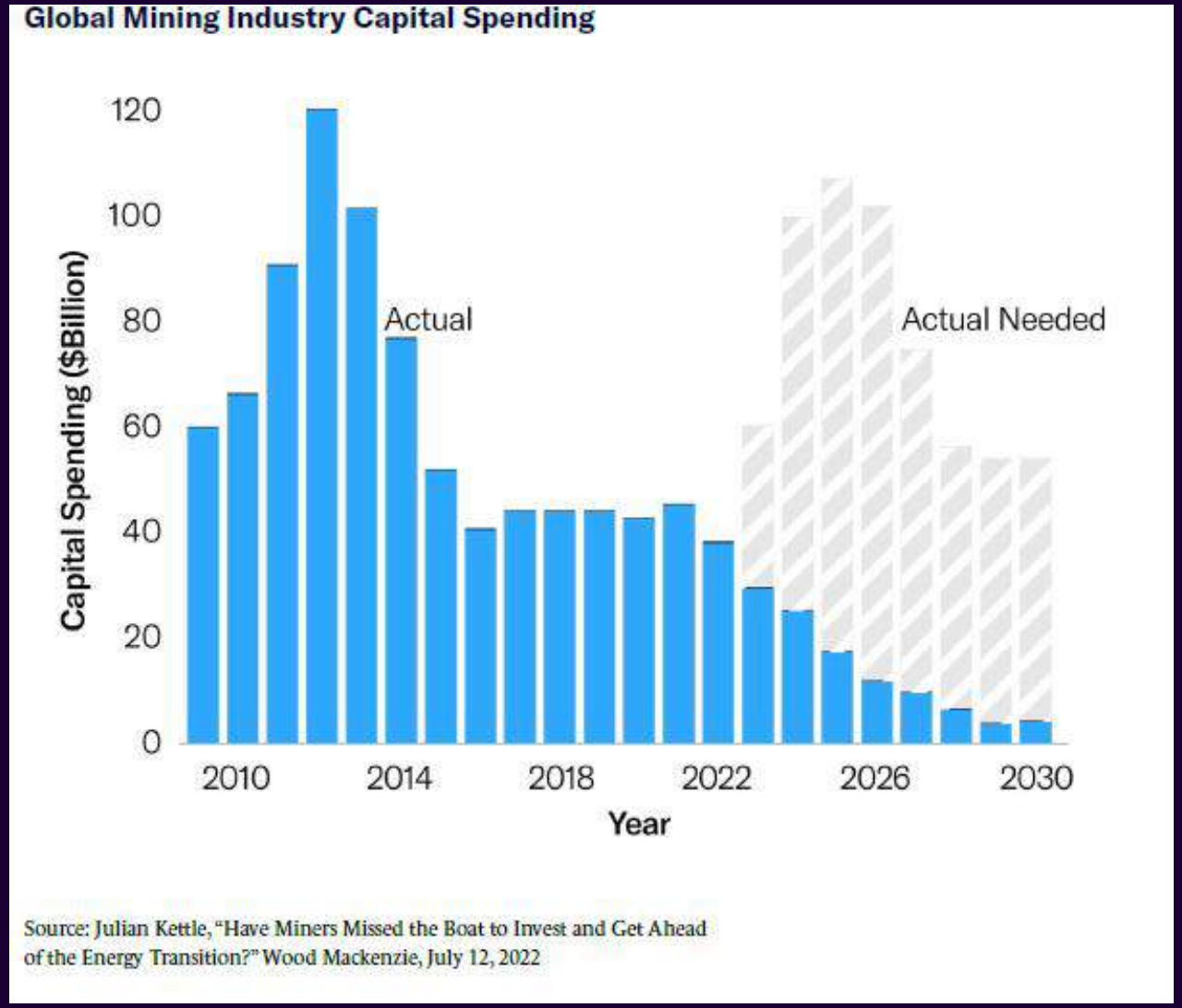


Geopolitical Considerations



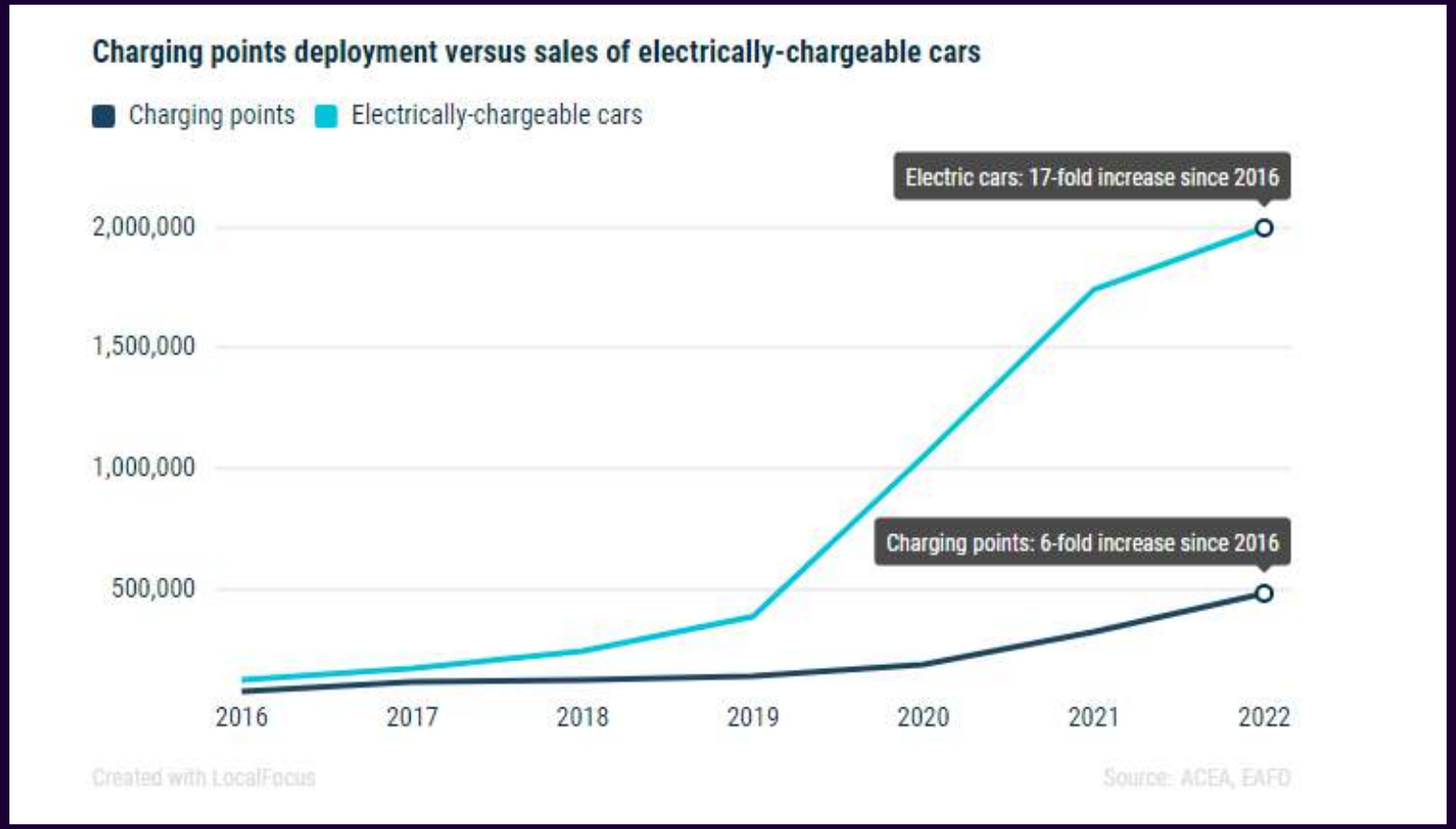
Source: IEA, "The Role of Critical Minerals in Clean Energy Transitions"; Harbor Aluminum, "Aluminum Production by Country." The gray and black bars represent the other number two and three countries.

Minerals Refining Gap

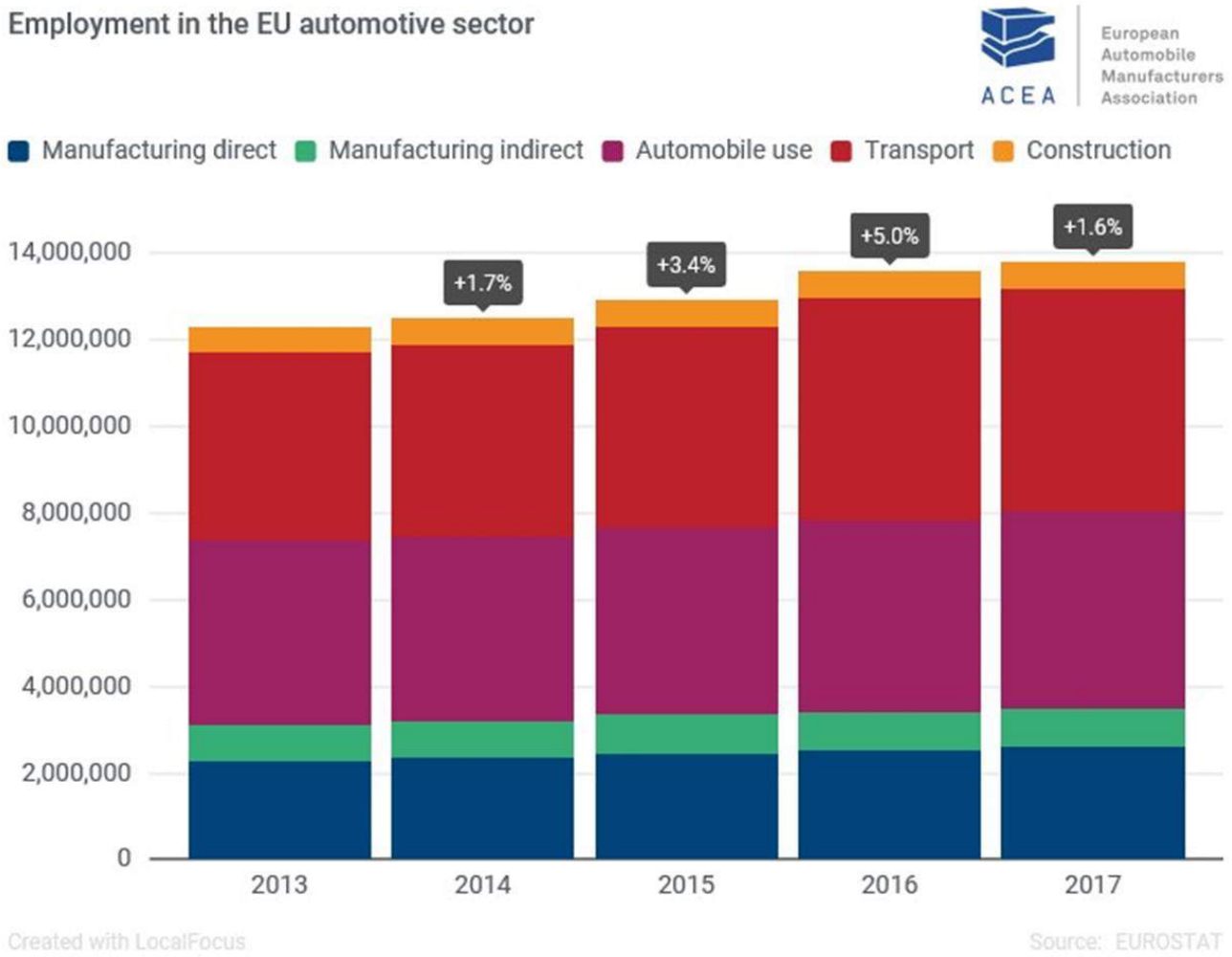


Source: Julian Kettle, "Have Miners Missed the Boat to Invest and Get Ahead of the Energy Transition?" Wood Mackenzie, July 12, 2022

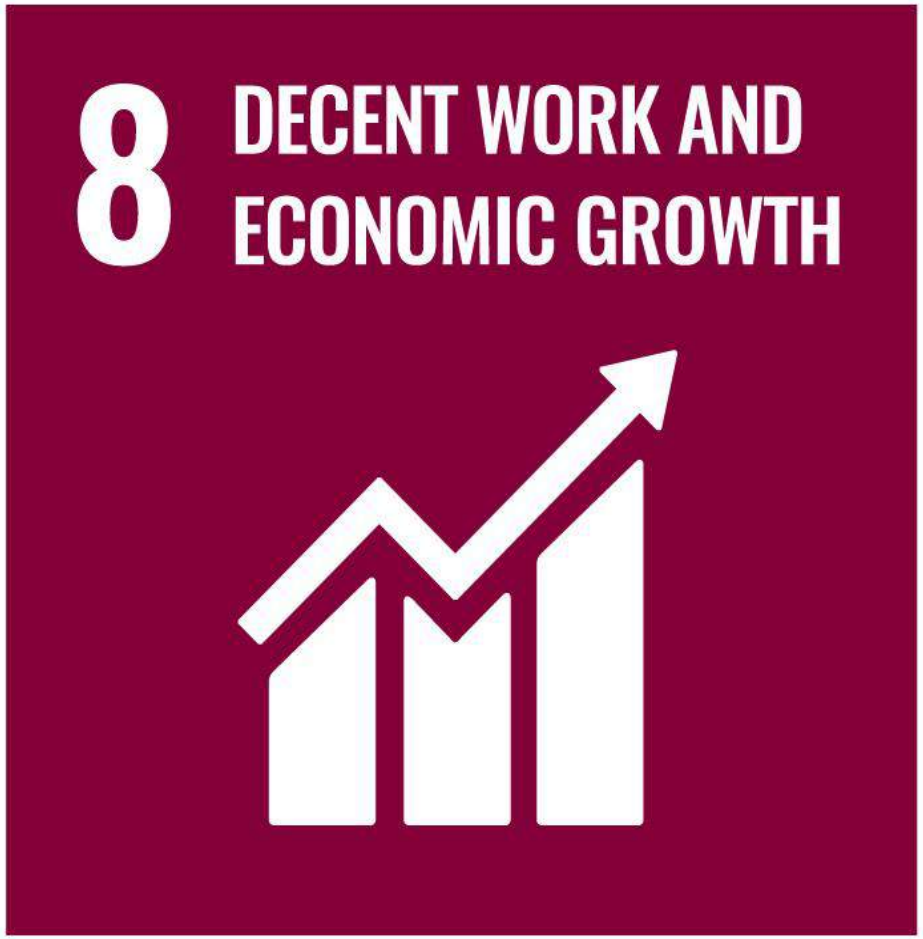
Perspective
New Charge Points (EU)

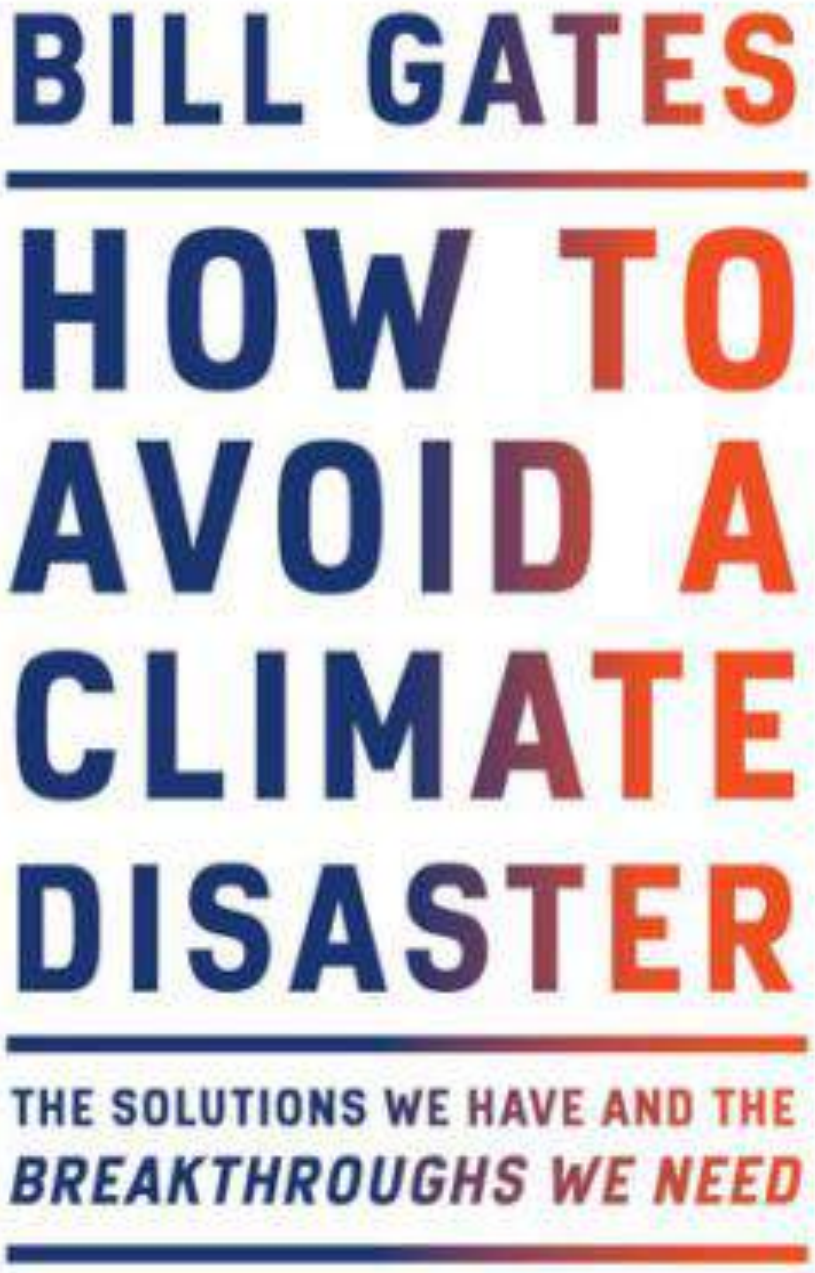


Social Impact




7
AFFORDABLE AND
CLEAN ENERGY


8
DECENT WORK AND
ECONOMIC GROWTH



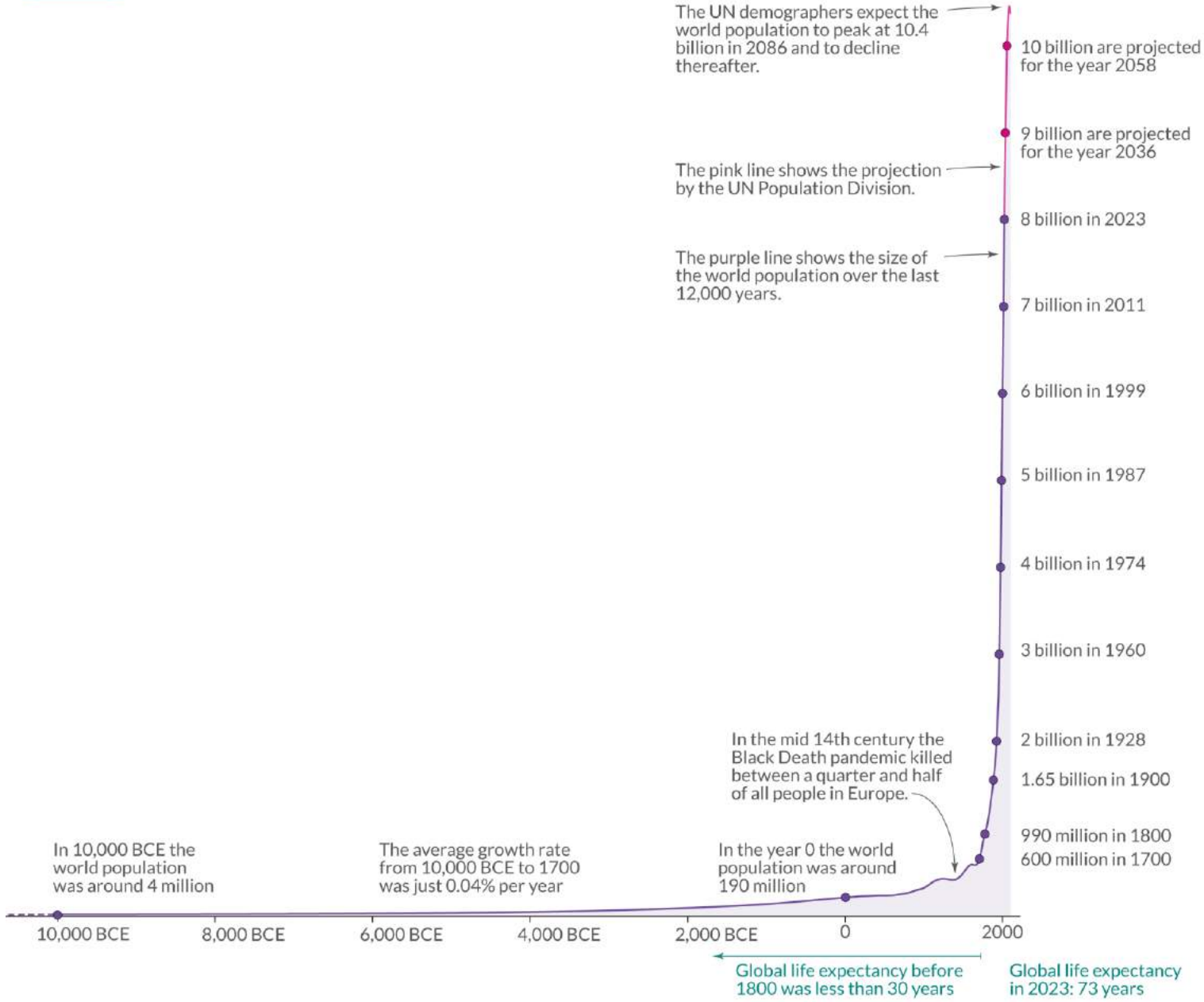
Bill Gates
"Net Zero"

Technologies needed

- Hydrogen produced without emitting carbon → Compressor / Turbine / GEO (+ NH_3)
- Grid-scale electricity storage that can last a full season → Gear / Turbine / Dielectric
- Electrofuels → Optimised ICE
- Advanced biofuels → Compressor / Turbine
- Zero-carbon cement → ??
- Zero-carbon steel → Bio cutting/rolling/forming
- Plant-and cell-based meat and dairy
- Zero-carbon fertilizer
- Next-generation nuclear fission
- Nuclear fusion
- Carbon capture (both direct air capture and point capture)
- Underground electricity transmission
- Zero-carbon plastics → Process
- Geothermal energy → Compressor / Hydraulic
- Pumped hydrothermal storage → Compressor / Hydraulic
- Drought-and flood-tolerant food crops
- Zero-carbon alternatives to palm oil → Bio B/S
- Coolants that don't contain F-gases → Compressor

Our World in Data

The size of the world population over the long-run



Based on estimates by the History Database of the Global Environment (HYDE) and the United Nations.
This is a visualization from OurWorldinData.org.

Thank you for your attention!