

# Anticipating the future carbon economy

Between defending the refinery and embracing change

1

Recycle



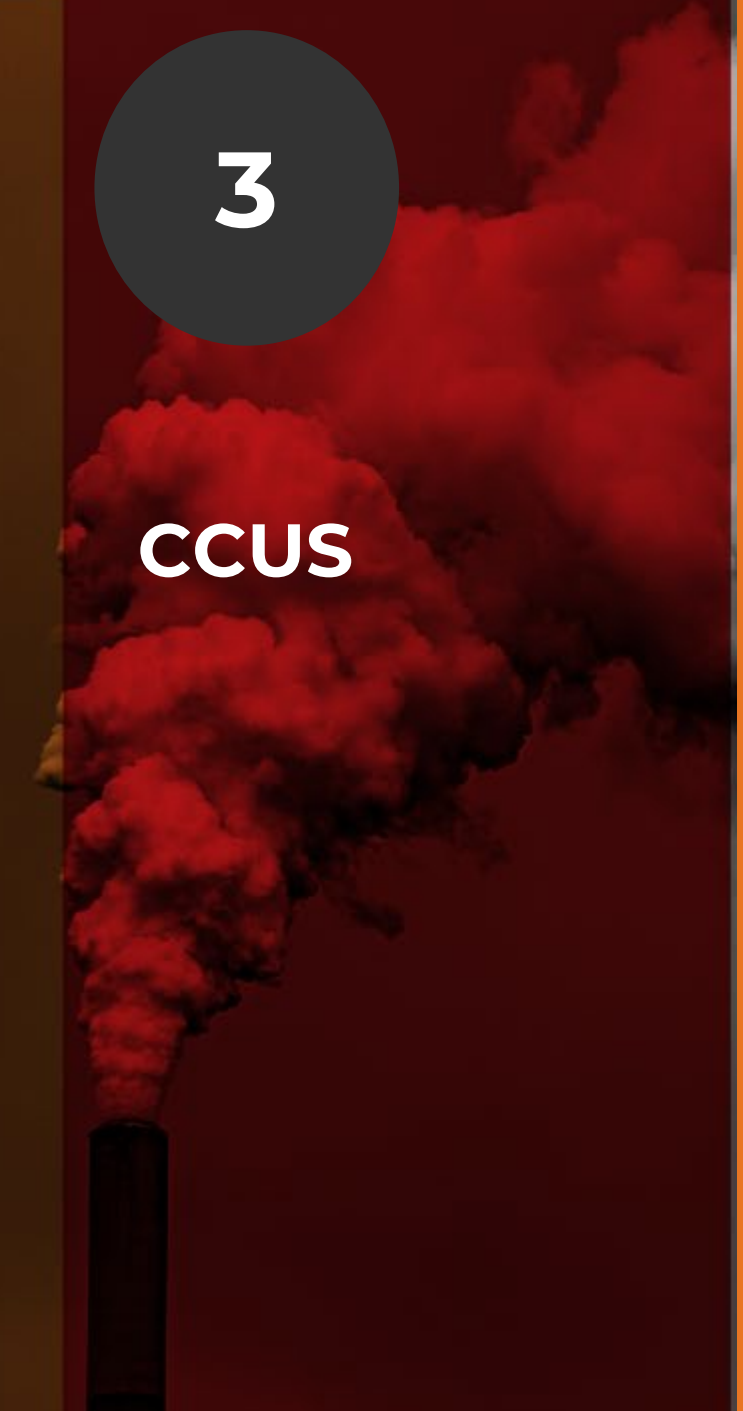
2

Biomass

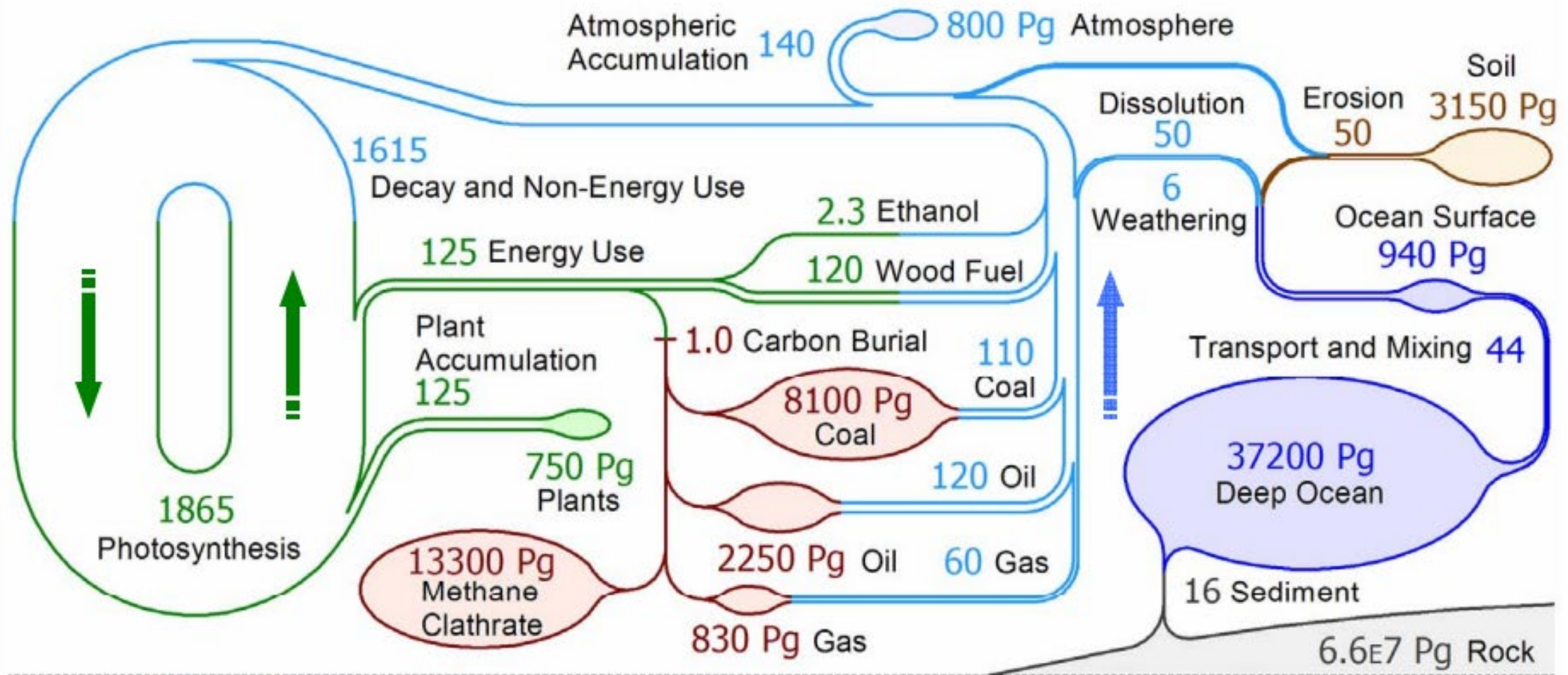


3

CCUS







Carbon Dioxide  
Aqueous Carbon

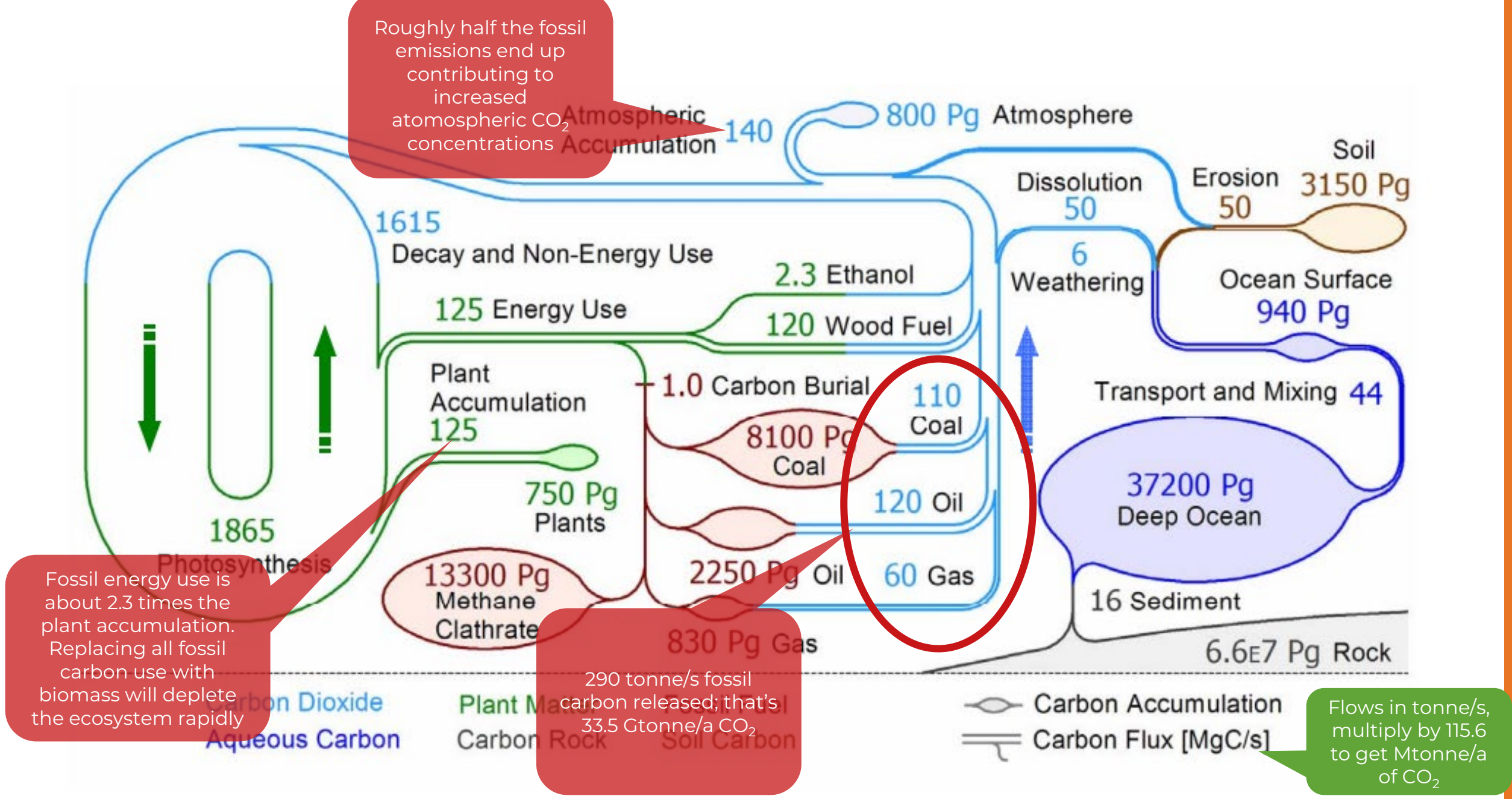
Plant Matter  
Carbon Rock

Fossil Fuel  
Soil Carbon

Carbon Accumulation  
Carbon Flux [MgC/s]

Flows in tonne/s, multiply by 115.6 to get Mtonne/a of CO<sub>2</sub>

Roughly half the fossil emissions end up contributing to increased atmospheric CO<sub>2</sub> concentrations



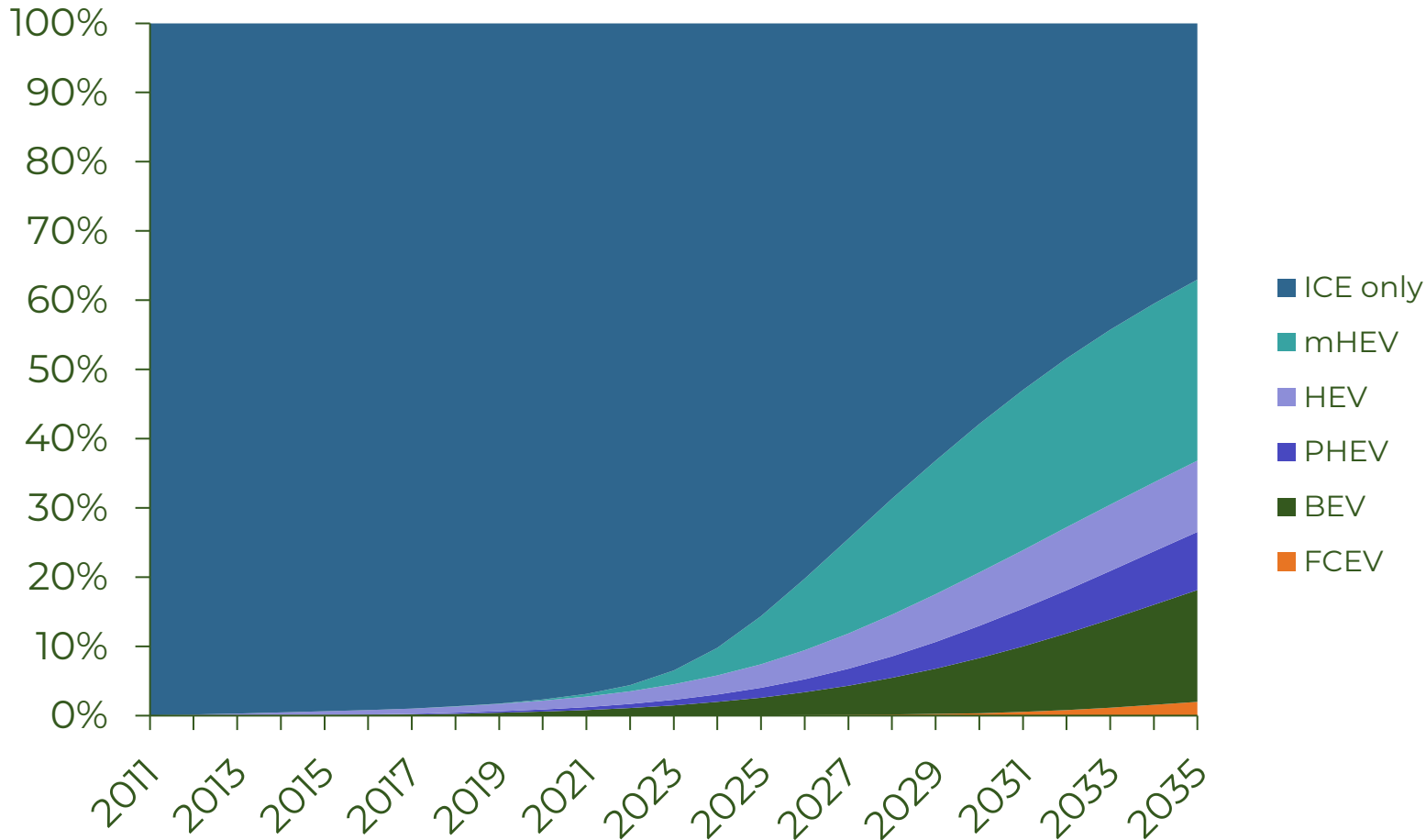
Fossil energy use is about 2.3 times the plant accumulation. Replacing all fossil carbon use with biomass will deplete the ecosystem rapidly

290 tonne/s fossil carbon released; that's 33.5 Gtonne/a CO<sub>2</sub>

Flows in tonne/s, multiply by 115.6 to get Mtonne/a of CO<sub>2</sub>

# The fleet composition trails behind sales, but inevitably leads to less fuel sales

Share of vehicles in the fleet



Based on the Lux assessment of the inflection point for EV sales, we can model fleet composition.

For Light Duty vehicles:

- By 2035, at least 18% of vehicles globally on the road are BEV
- Average fuel consumption of vehicles with an ICE decrease by 29% (due to hybrids)
- The number of vehicles still increases, however.

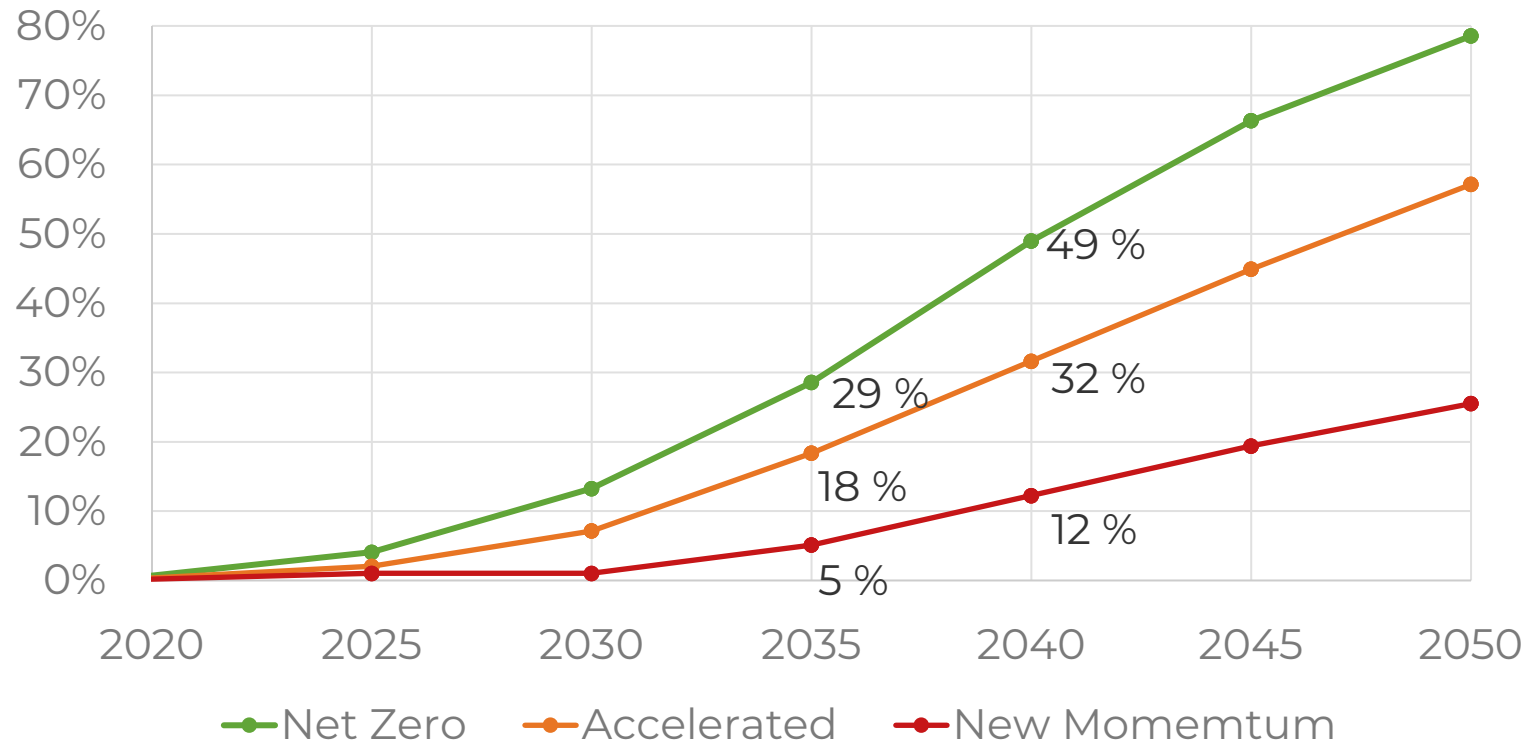
**Overall fuel consumption will be at least 15% less than today**



# The BP energy outlook 2023 predicts the same

## Decrease in oil demand

(% of 2019 demand)



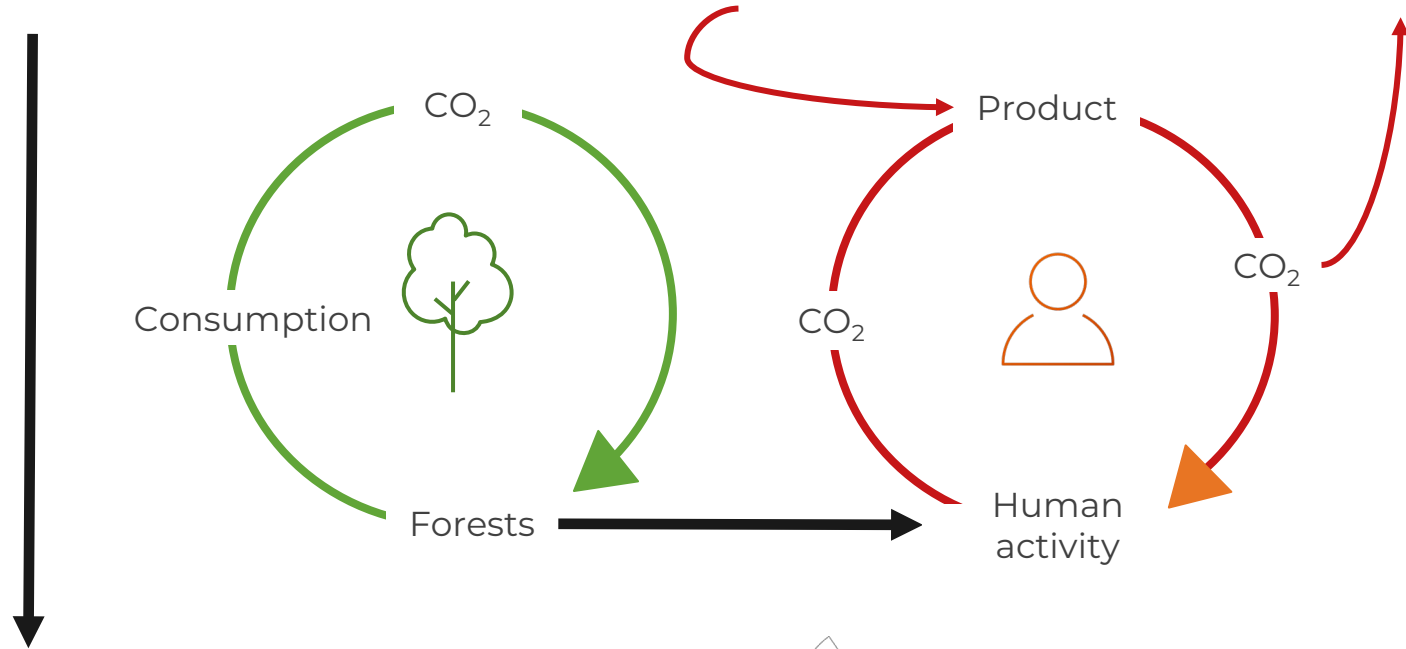
Suppose for 2040:

Oil demand 32% less  
Coal demand 30% less  
Gas demand 12% less

**Fossil demand is still 1.6x  
plant accumulation in 2040**

# The global carbon cycle requires three levels of carbon-negative interventions

Atmospheric CO<sub>2</sub>



Nonatmospheric CO<sub>2</sub>



Refossilizing carbon

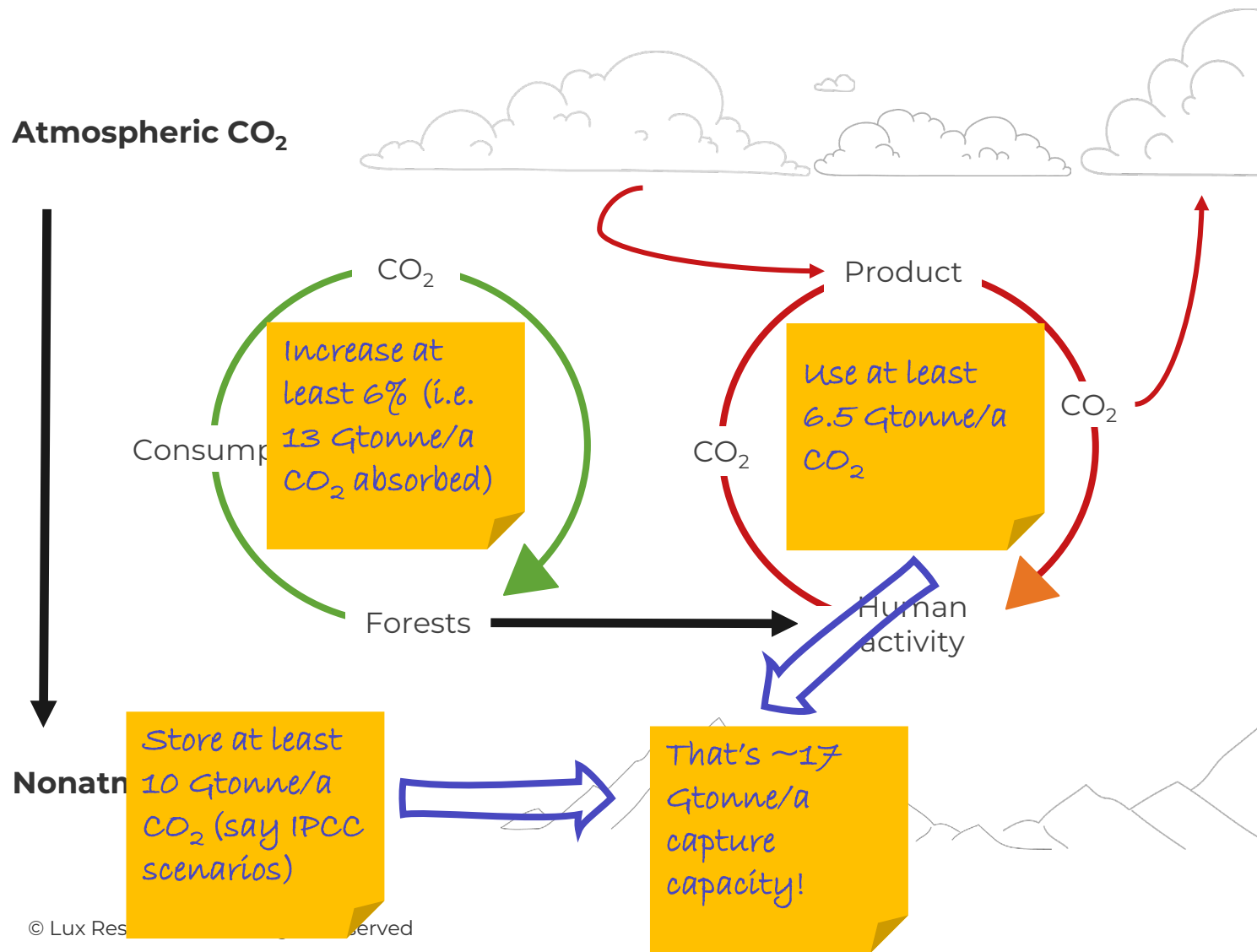


Complementing the natural carbon cycle



Augmenting the natural carbon cycle

# CCUS will be at least as big as biobased



Refossilizing carbon



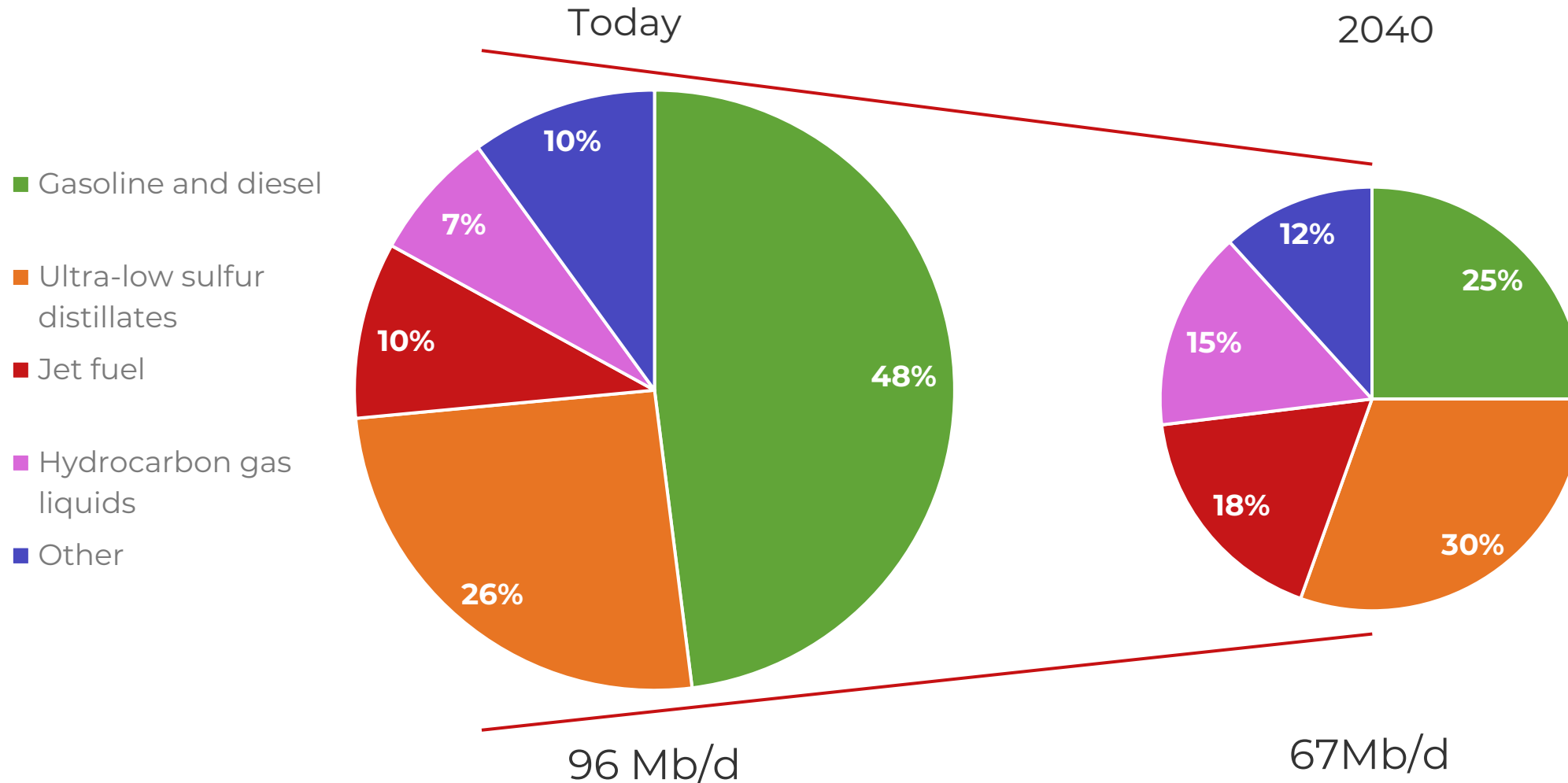
Complementing the natural carbon cycle



Augmenting the natural carbon cycle



# The refinery needs a major shift in product mix



# Future-proofing existing assets is in full swing already

NEWS COMMENTARY

**Anellotech announces new process to convert mixed plastic waste directly to chemicals**

NEWS COMMENTARY

**Shell and Dow join forces for electric cracking technology**

NEWS COMMENTARY

**Saudi Aramco signs agreements with 12 South Korean companies to secure Arabian crude demand via hydrogen and crude-to-chemicals**

NEWS COMMENTARY

**Saudi Aramco partners with TechnipFMC and Axens for catalytic crude-to-chemicals technology**

NEWS COMMENTARY

**LyondellBasell uses renewable feedstock from Neste to produce over 30% bio-based polyethylene and polypropylene at commercial scale**

NEWS COMMENTARY

**BASF commits to its largest pyrolysis oil supply deal with Arcus**

NEWS COMMENTARY

**Olefy, a VTT spin-out, develops technology to optimize polymer yield from plastic waste**

NEWS COMMENTARY

**Honeywell will build China's first UpCycle plastics pyrolysis facility, indicating opportunities abound in the region**

## However, there are also other, green-field, approaches

NEWS COMMENTARY

**Carbon Clean to capture CO<sub>2</sub> for Ørsted's e-methanol project**

NEWS COMMENTARY

**Mitsui Chemicals announces biomass-to-polypropylene project**

NEWS COMMENTARY

**CEMEX to convert CO<sub>2</sub> from cement flue gas into e-methanol**

NEWS COMMENTARY

**Project Air receives EUR 97 million to produce methanol from captured CO<sub>2</sub>**

NEWS COMMENTARY

**e-Methane produced from Energo's plasma technology successfully injected into the French gas distribution network**

NEWS COMMENTARY

**Chile officially launches pilot synthetic fuels plant**

NEWS COMMENTARY

**Thyssenkrupp joins Enerkem biofuel project with 88 MW electrolyzer**

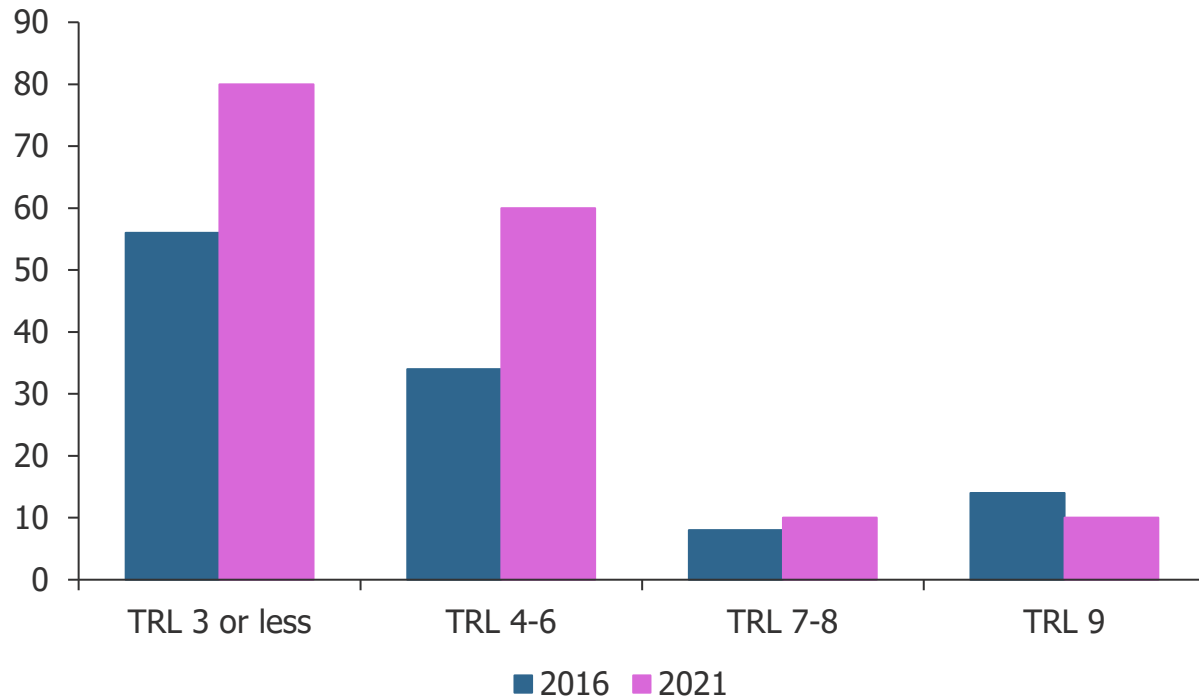
NEWS COMMENTARY

**Raven SR, a waste-to-syngas startup, is launching its first steam/CO<sub>2</sub> commercial facility**

# CO2 utilization is only just getting started

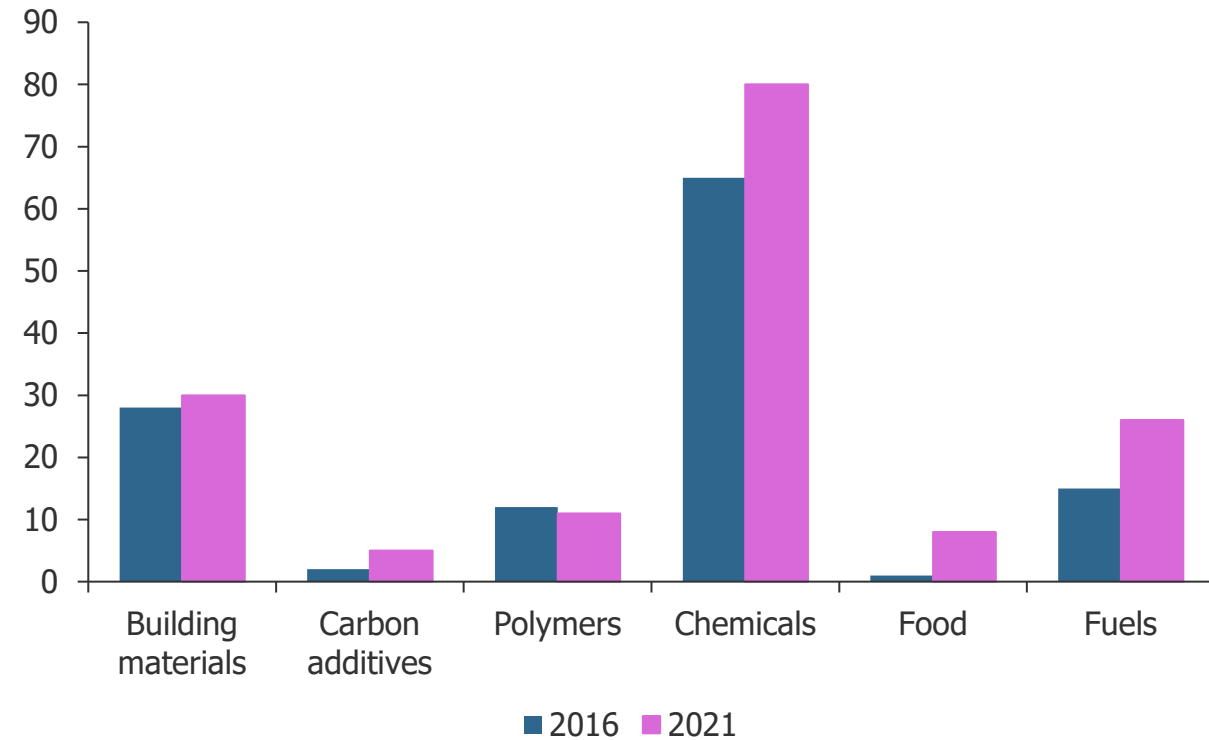
## Rising Number of Early-Stage Developers Will Likely Feed the Commercialization Pipeline

Number of developers



## Chemicals Remains Dominant End Product for CCU Technology Developers

Number of developers



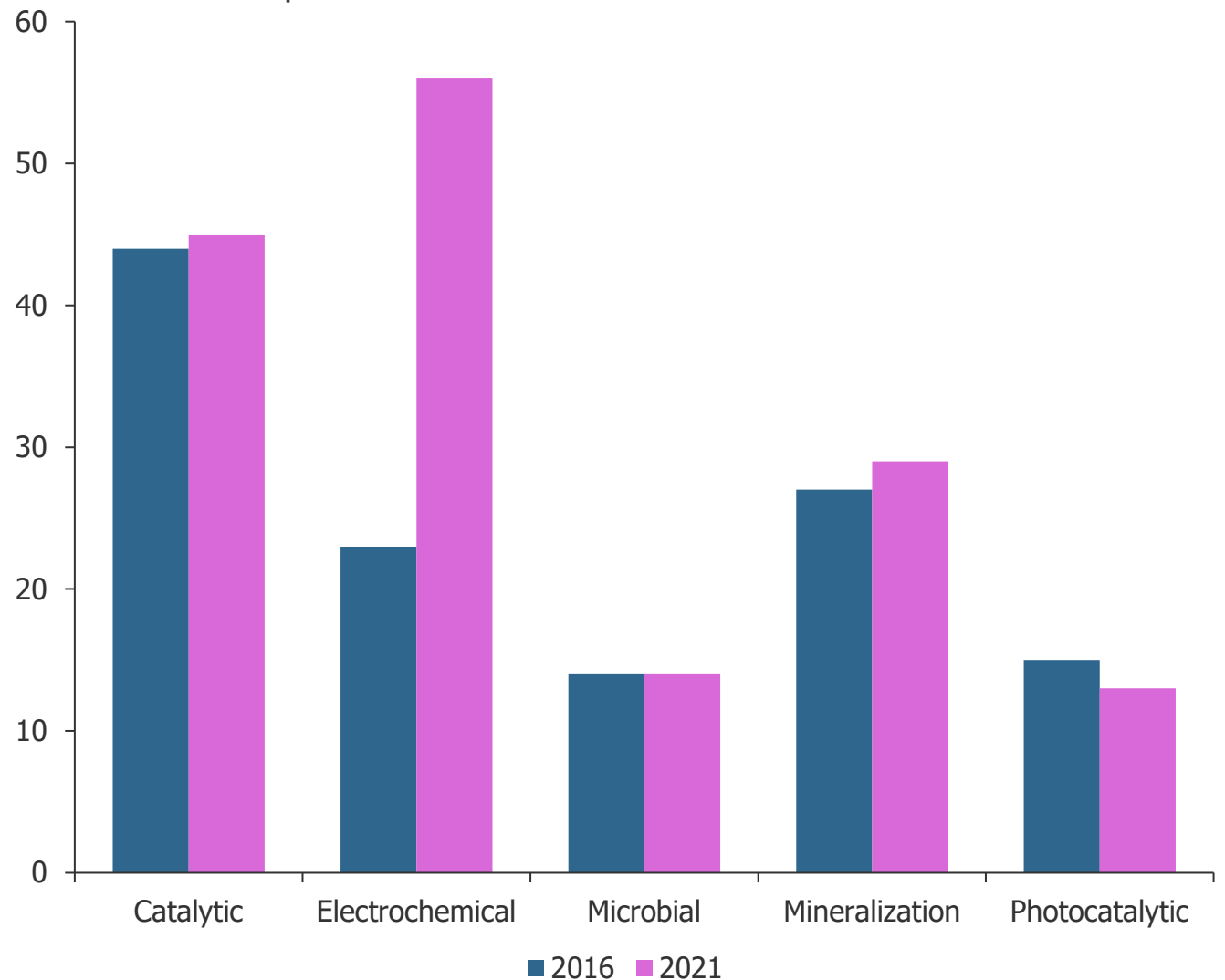


## Electrochemistry activity more than doubled over the past five years

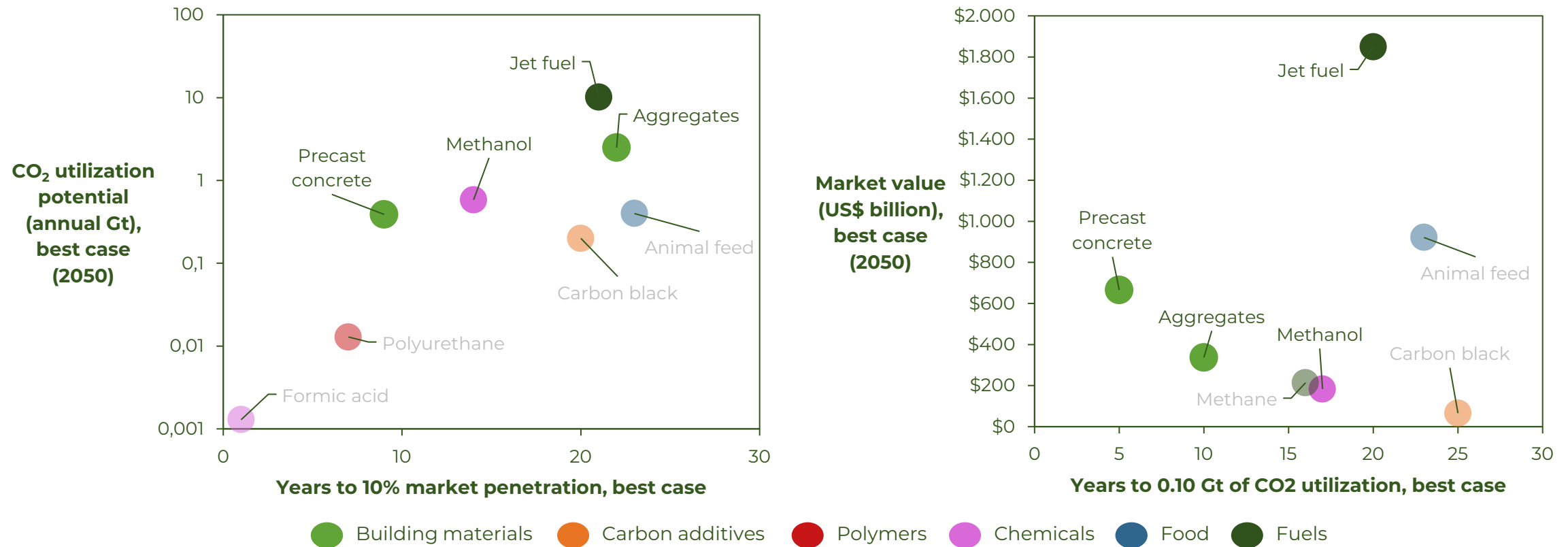
While other conversion pathways remained very active, electrochemical conversion gained popularity.

## Electrochemical Pathways Emerge as the Clear Favorite of CCU Developers

Number of developers



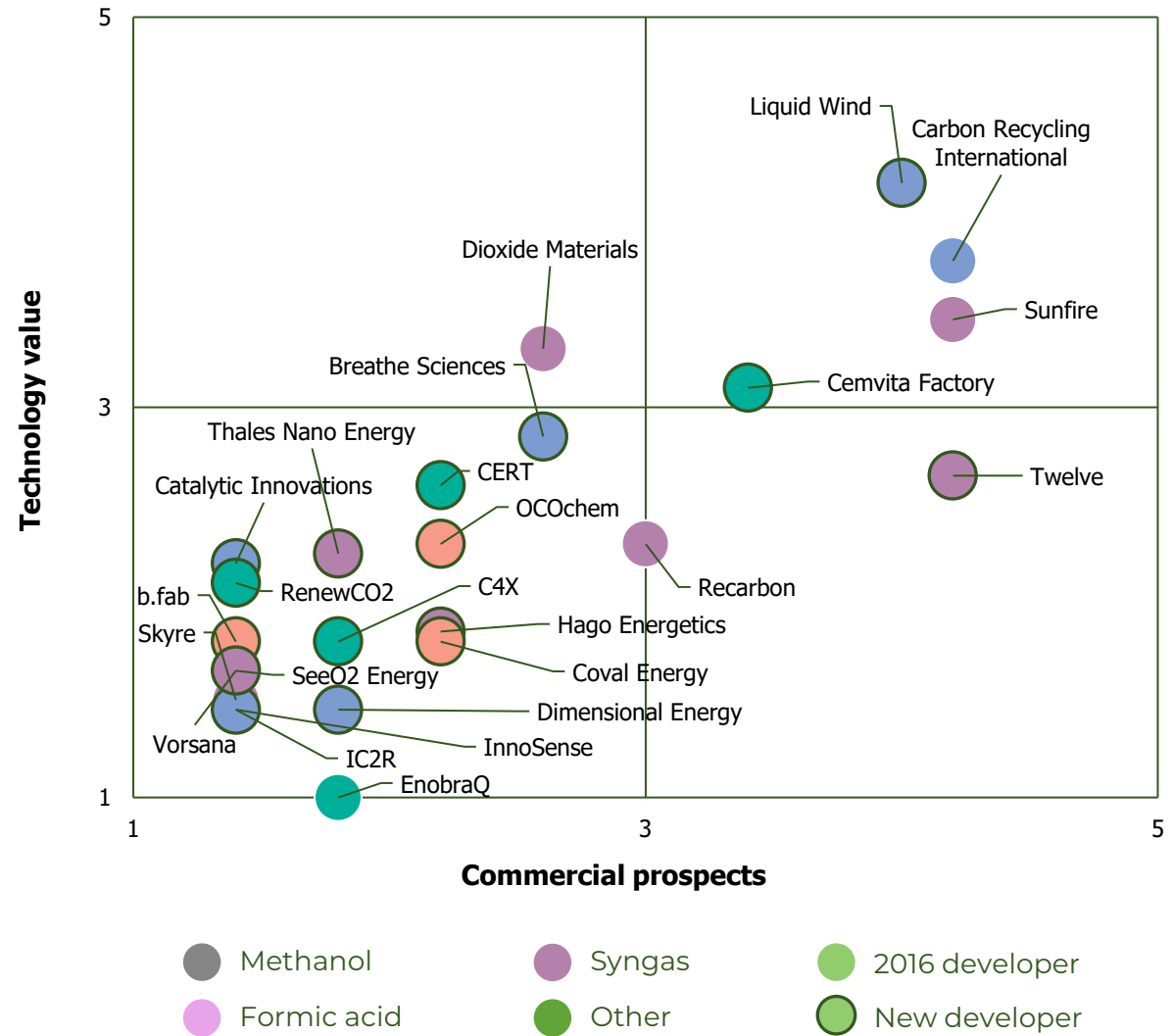
# Concrete can bootstrap capture, while methanol is the nearest market and jet fuel the biggest



# Few stand out in a crowded landscape

There is still enough space for new entrants in the space of CO<sub>2</sub> utilization, if they have a creative solution.

Moving beyond C1 can be particularly interesting.



# Chemicals: developer spotlight



- The company was founded in 2010 and is based in Germany. Its core product is a stack of high-temperature solid oxide cells that can be used for both water and CO<sub>2</sub> electrolysis; for the latter, the stack operates in co-electrolysis mode to produce syngas from water and CO<sub>2</sub>
- To date the company has raised about US\$200 million; most recently the company closed a US\$126 million Series D funding round led by Lightrock and Planet First Partners
- With regards to its CO<sub>2</sub> electrolyzer, key claims of the organization include a system efficiency of 84% and a stack lifetime of 50,000 hours
- In terms of maturity, the company is at demo scale and offers a 3.0 MW CO<sub>2</sub> electrolyzer; it expects commercial systems above 10 MW by 2025
- Global CO<sub>2</sub> Initiative should regard Sunfire as a leader in CO<sub>2</sub> electrolysis technology and monitor the company's scale-up as it gears up for commercialization



The production of chemicals from CO<sub>2</sub> is still at the development stage. While more mature applications such as CO<sub>2</sub> hydrogenation for methanol have been scaled to the demo stage, new technological approaches such as high-temperature electrolysis or synthetic biology offer interesting commercialization opportunities.



- The company was founded in 2017 and develops a synthetic biology platform; its focus is on engineering cyanobacteria for CO<sub>2</sub> utilization
- To date the company has raised about US\$10 million of disclosed funding; most recently the company closed its Series A funding round of undisclosed amount led by Energy Capital Ventures, Mitsubishi Heavy Industries, and Oxy Low Carbon Ventures
- Key claims include a scale-up timeline of 5 years from initial strain optimization to 10,000-liter demo capacity for engineering cyanobacteria; additionally, the company has a product portfolio of 35 chemicals
- In terms of maturity, the company is at laboratory-scale; it completed strain optimization at the 1-liter capacity for CO<sub>2</sub>-to-ethylene and plans to build a pilot unit by 2022.
- Global CO<sub>2</sub> Initiative should monitor Cemvita as it the first application of synthetic biology for CO<sub>2</sub> utilization technology, however, Cemvita will likely face challenges as it scales from lab to production.



# The way forward

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Efficient land use and autonomy are critical in Europe



# What's the CCUS promise?

Health, food preservation



**Tupperware freshness is our promise.**  
**Look at all the ways we keep it.**

**1970s**

To look at us, you'd think we made a container for every food on earth. And you'd be just about right. But there's always another to challenge us. Take cakes. What do you do when your big three-layer cake doesn't fit into our 10" Cake Taker? Store and serve it in our new Maxi-Cake Taker—just one of over a hundred Tupperware containers that lock in the freshness of food. So come to a Tupperware Party...see why nobody keeps promises like we do. We lock in freshness. **Tupperware**

Have your own Tupperware Party by October 31 and you could receive this special holiday gift: the versatile Decorated Shell Casserole™ by Syrene®. For details phone Tupperware—in the white pages.

Comfort



**Put yourself in this picture!**

**1950s**

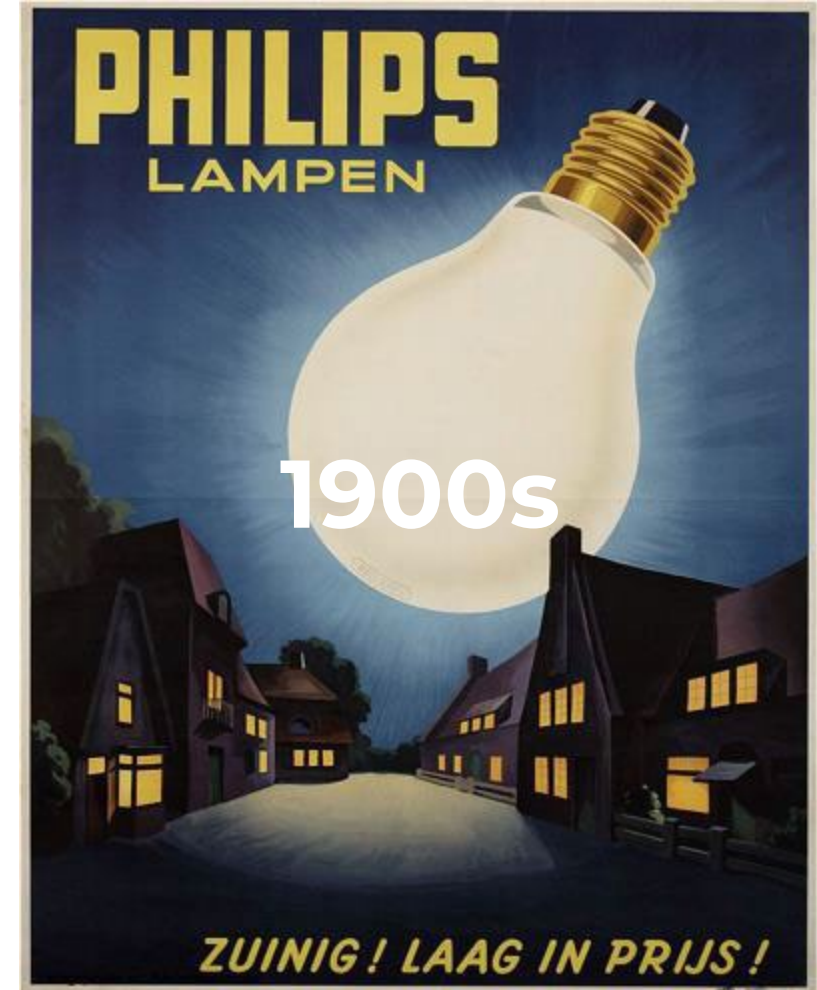
Can YOU imagine anything cosier than the cheery friendliness and hospitality of a healthy **GAS FIRE?**

The beauty, the ease of (relative) fuel, the health benefits...  
At a time of the day it will naturally start to radiate a healthy glow, creating an atmosphere of cheer, friendliness and hospitality for all. There are five accessories to maintain its warmth too. These you wish to ask every home and every type of fireplace—what better fireplace? Register at year for Gaspar's Blackwood.

**GAS** for the **4 BIG JOBS**  
Baking COOKING • Water REFRIGERATION  
Boiling HOT WATER • Beautiful HEATING

The National Gas Association of Australia

Comfort, cost saving



**PHILIPS LAMPEN**

**1900s**

**ZUINIG! LAAG IN PRIJS!**

# Farm productivity drives rural electrification

FEATURE STORY | MARCH 16, 2023

## Solar energy brings water to Niger's farms



*Boubacar Issoufou Alzouma stands beside solar panels. The solar-powered water pumping system enables Alzouma to rotate crops on his farm in Finaré, Niger.*

Even though rural electrification is generally positive, you still need a compelling business case for people to install solar panels.

Irrigation drives the adoption of solar panels across Africa.

Once the panels are there, other uses will appear.



**Better than trees: must be possible....**







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# Thank you

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