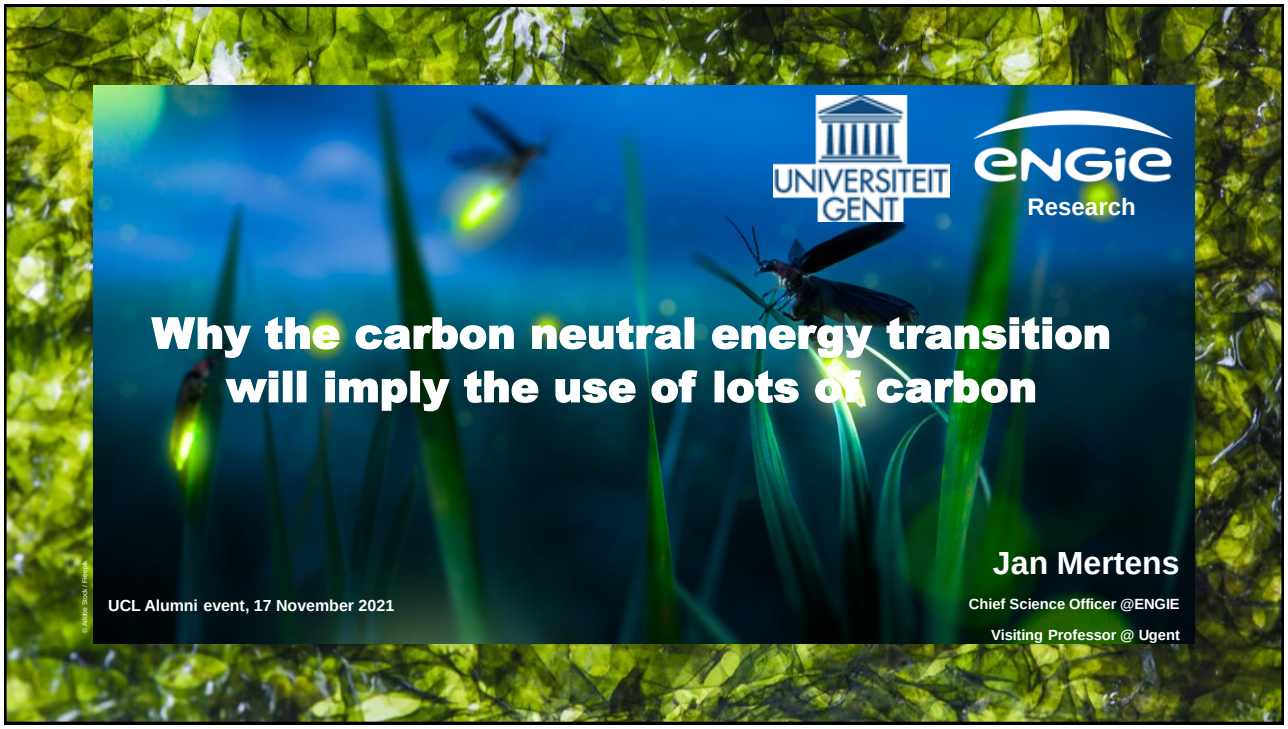

Content

1. **Context: what does the 2 Degree Scenario mean?**
2. **ENGIE Research**
3. **3 pathways towards Carbon neutrality**
   - Increase energy efficiency and increase circularity where waste becomes a feedstock
   - Electrify as much as possible (far beyond electric cars)
   - The need for molecules: (green) hydrogen and synthetic hydrocarbons
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1

Context: what does the 2 Degree Scenario mean?

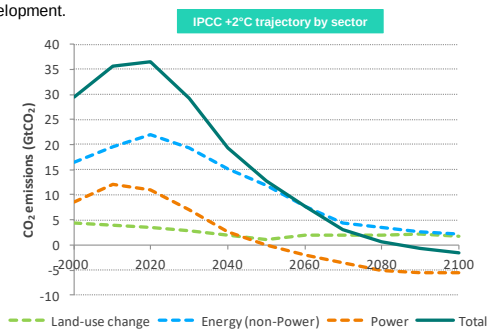
In December 2015 (@ CoP21 in Paris), 161 member states agreed upon the 2DS

- For the first time in December 2015, 161 states officially adopted in Paris at the CoP 21 the target of max temperature increase 2°C by 2100.

- The CoP 21 agreement includes **three goals** :
  - Containing the rise of global mean temperatures "well below 2°C above pre-industrial levels, and to pursue efforts" to limit the warming to 1.5°C.
  - "Increasing the ability to adapt to the adverse impacts of climate change" by promoting resilient and low-carbon development.
  - Making financial flows "consistent" with a low-carbon development.

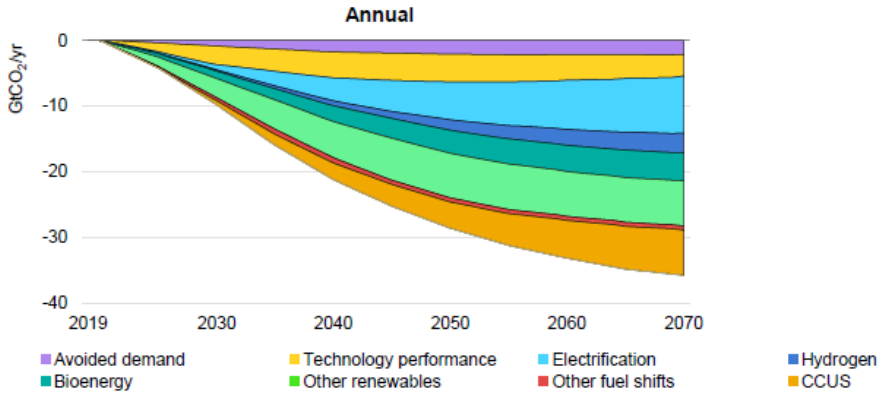
Source: ENGIE Corporate Strategy CODIR 20/07/2015 scenario for a +2°C target - Adapted from IPCC, AR5-WG1 and AR5-WG3

- **Scenario from the IPCC shows that the power sector should become CO_2 negative by 2050 if we are to achieve the 2°C target**



Electrification, CCUS, bioenergy and hydrogen-derived fuels contribute to more than half of cumulative emissions reductions

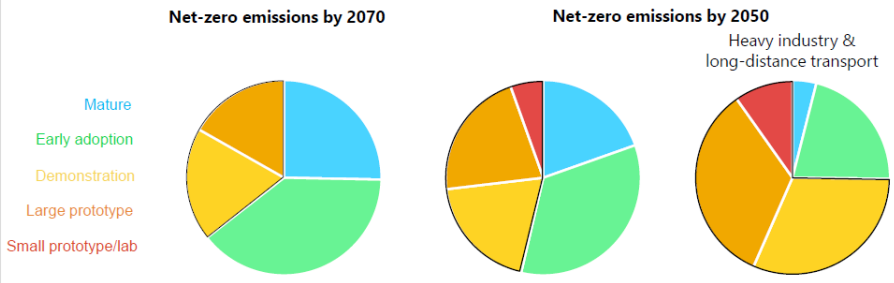
Figure 2.2 Global energy sector CO_2 emissions reductions by measure in the Sustainable Development Scenario relative to the Stated Policies Scenario, 2019-70



More than half of the emission reduction will have to come that are today not mature: Innovation and R&D are crucial and need to speed up!

Clean energy technology progress hinges on innovation iea

Cumulative emissions reductions relative to baseline trends by technology maturity



Almost half of the emissions reductions required to reach net-zero by 2050 rely on technologies that are not yet commercial today. The share jumps to three-quarters for heavy industry and long-distance transport.

Fatih Birol, IEA September 2020: 'CCUS, Batteries and H_2 are today where PV was 10 years ago. GOVERNMENT need to support their development now!'

2

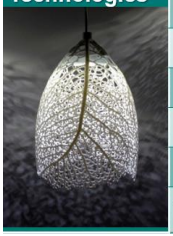
ENGIE Research

ENGIE has 900 researchers, ENGIE Research organized in 23 Thematic Labs

New Energies

- Biomass, Biogas and Biowaste
- Solar
- Wind, Hydro & Marine
- Hydrogen
- Small Scale Liquefaction
- Geo Energy
- Green Thermal Generation (NEW)

Enabling Technologies



- Computer Science & Artificial Intelligence
- Nanotech, Sensors & Wireless
- Environment & Society
- Energy System Simulations
- Robots & Drones
- Advanced Materials Technologies (NEW)

New Uses of Energy

- Future Collectivities & Homes
- Future Building & Cities
- Future Industry
- Energy Storage
- Smart Grids & Industrial Cybersecurity
- Green Mobility
- CO_2 as a resource
- Air Quality
- Lighting
- Water & Chemistry Lab (NEW)

Pilot projects with academic, industrial and government partners are important to co-develop, test and demonstrate new solutions

Pilots are key for ENGIE and a large part of the research budget

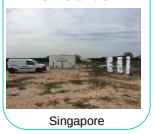
Biomass gasification Gaya
gaya
France

Battery Storage

Belgium

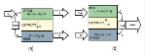
Bifacial Solar testing

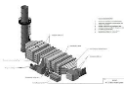
Chile

Decentralized Energy System for Islands

Singapore

H_2 co-combustion in gas turbine

Belgium

High temperature SOEC/SOFC

France

Supercritical CO_2 cycle

US

Solar-H_2 panels

France

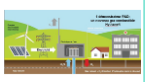
OPV for Buildings Heliatek
Heliatek
HeliaFilm®
Global

Floating Wind turbine

Portugal

High Altitude Airborne Wind

Germany

H_2 injection in natural gas grid

France

Power to methane

France

Solar cooling

France

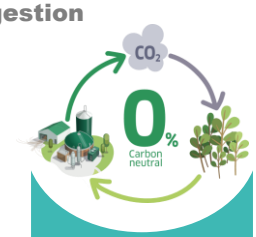
3

3 pathways towards Carbon neutrality

3 pathways towards Carbon neutrality

(i) Increase energy efficiency and increase circularity where waste becomes a feedstock

From waste TO green GAS : clean, local, circular…
…but the challenge is to achieve volume production at scale



Biomethane is considered carbon-neutral

CO_2 from the atmosphere is captured by organic waste used to produce biomethane

Its combustion produces biogenic CO_2 emissions

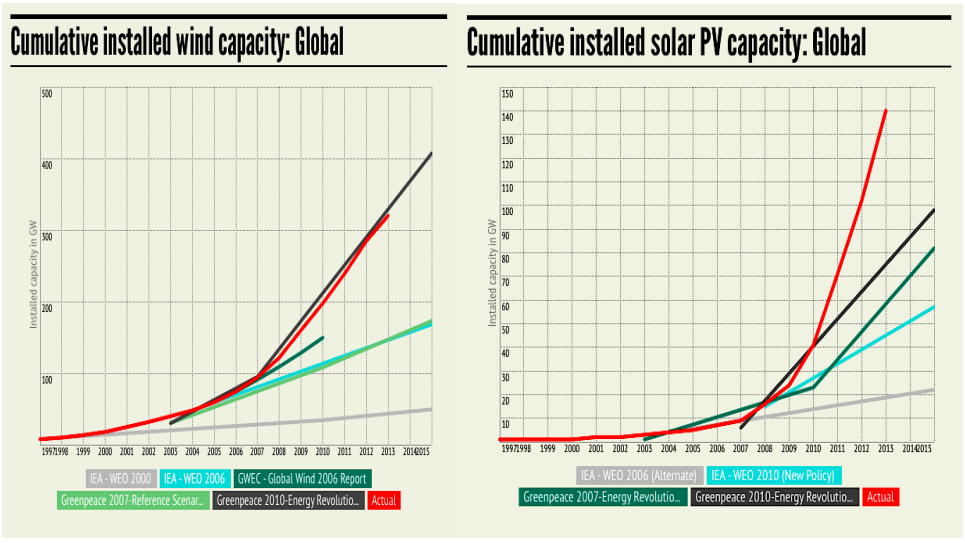
Compensation effect: almost no impact on greenhouse gas emissions.

3 pathways towards Carbon neutrality

(i) Increase energy efficiency and increase circularity where waste becomes a feedstock

(ii) Electrify as much as possible (far beyond electric cars)

We have proven the roadmaps wrong…



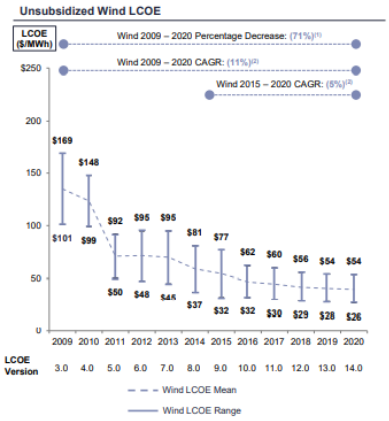
Price of PV and Wind coming down at speed which was not foreseen!

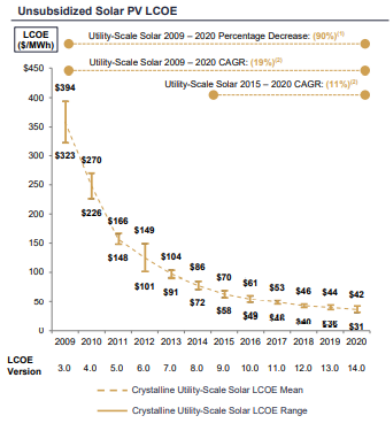
LAZARD

LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 14.0

Levelized Cost of Energy Comparison—Historical Renewable Energy LCOE Declines

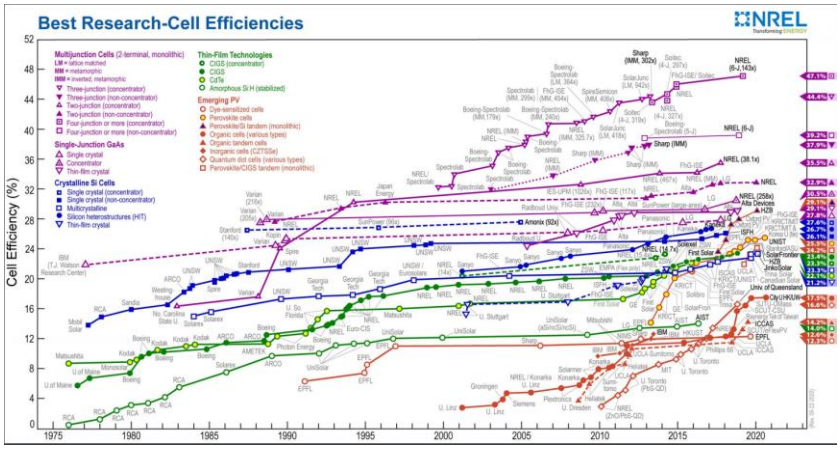
In light of material declines in the pricing of system components and improvements in efficiency, among other factors, wind and utility-scale solar PV have exhibited dramatic LCOE declines; however, as these industries have matured, the rates of decline have diminished





PV efficiency will continue to increase, thanks to the industry's continuing R&D efforts

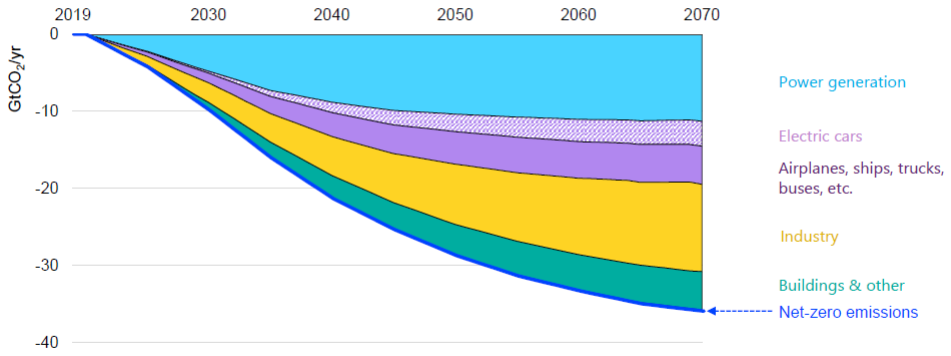
- Over the last 4 decades, the PV industry has continued to find ways to increase the efficiency of the photovoltaic effect and this will not stop. But the real challenge is the cost: even for Silicon-based PV, significant R&D is necessary to reach the efficiencies between 24 and 26% in a cost-effective way.



Making sure all our electricity generation is green is crucial but is not sufficient as it will only reduce our overall emissions by 38 %.
Industry, transport and building account for half of emissions today! (IEA, ETP 2020)

Focusing on the power sector is not enough to reach climate goals

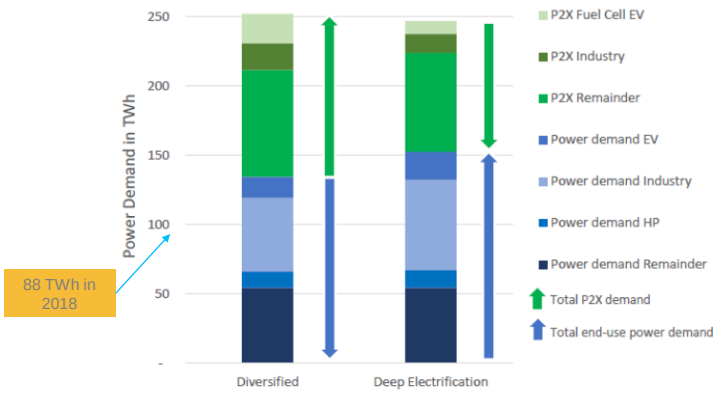
Global CO_2 emissions reductions in the Sustainable Development Scenario, relative to baseline trends



Clean energy technology progress in the power sector and with electric cars is encouraging, but alone not sufficient to reach climate goals. About half of all CO_2 emissions today are from industry, transport and buildings.

Belgian's federal planning bureau estimated that even in the deep electrification scenario (electrify as much as possible also in industry), molecules and import of renewable Energy will be important and need new emerging technologies (P2X)

Graph 7 Total power demand in both scenarios, Belgium, year 2050
TWh



Source: Artelys.
Note: The direction of the arrows indicates the relative level of the specific (P2X or end-use) electricity demand: upwards (downwards) means a higher (lower) level compared to the other scenario.

Both scenarios do not diverge (much) in terms of their annual net import position in 2050: 29.4 TWh in *'Diversified Energy Supply'* and 29.0 TWh in *'Deep Electrification'*

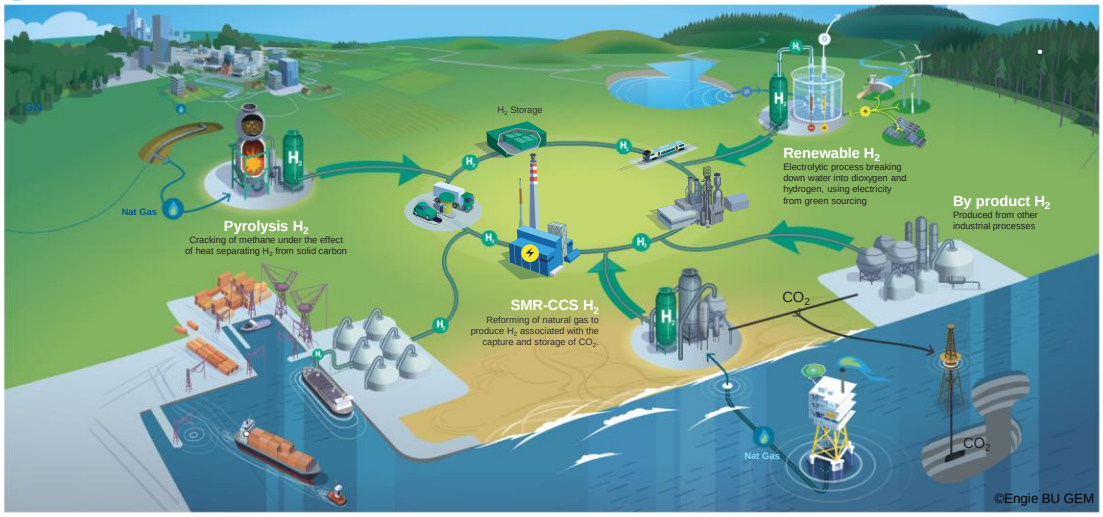
3 pathways towards Carbon neutrality

(i) Increase energy efficiency and increase circularity where waste becomes a feedstock

(ii) Electrify as much as possible (far beyond electric cars)

(iii) The need for molecules: (green) hydrogen and synthetic hydrocarbons

Hydrogen is a low carbon energy solution with a lot of potential but …

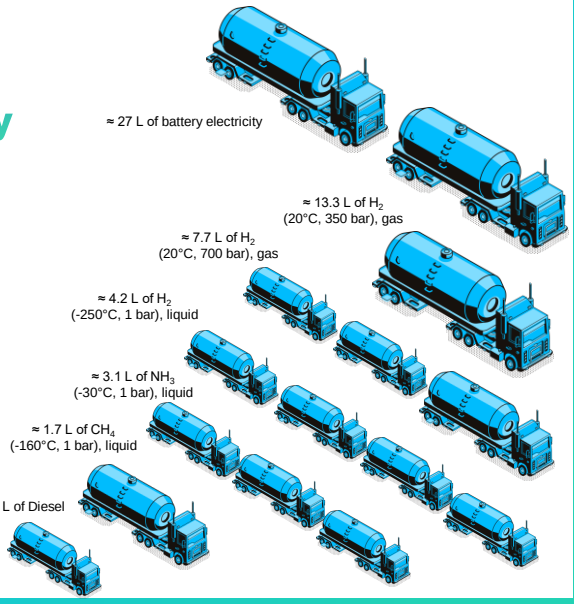


but

Has a very low energy density and is thus extremely hard and expensive to store and move around

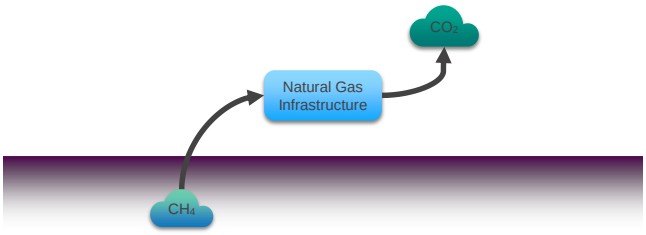
→ Need for synthetic hydrocarbons!*

How to transport or store 10kWh of energy?

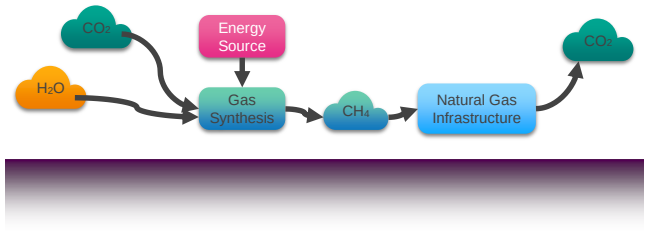


* Mertens, J., R. Belmans and M. Webber, 2020. Why the carbon neutral transition will imply the use of lots of carbon. *C-Journal of Carbon research*, 6 (39), 1-8

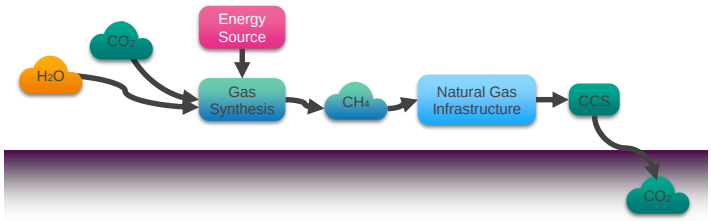
Today's Gas System Takes Carbon From The Earth's Crust and Puts It Into the Atmosphere



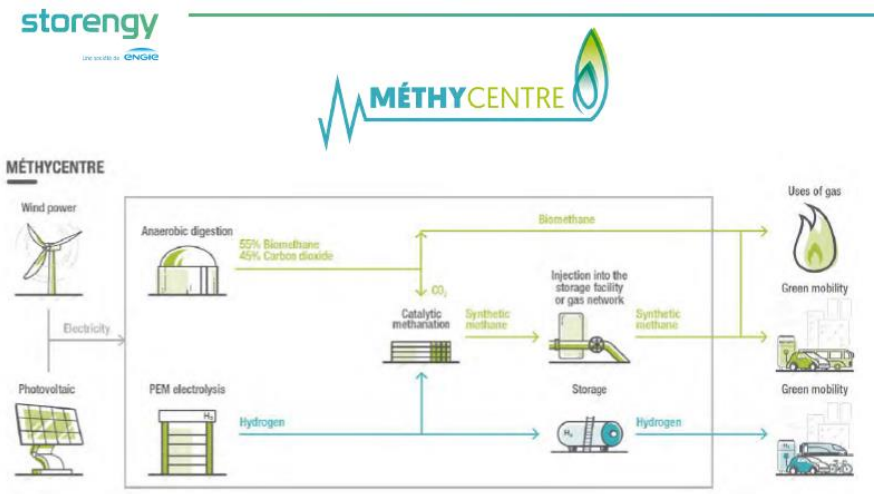
Tomorrow's Gas System Could Take Carbon From The Atmosphere To Make The Gas



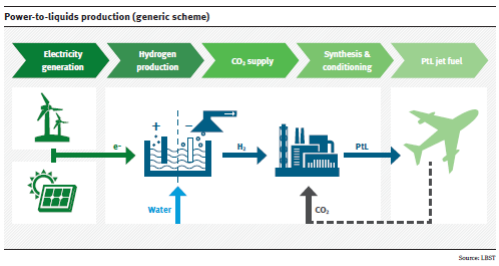
The Day After Tomorrow's Gas System Could Take Carbon From The Atmosphere And Put It Into Products or The Crust



Power – to – Gas : example of Methycentre

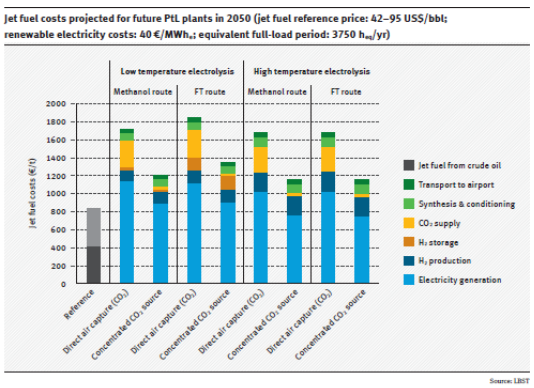


Real challenge for aviation is the 'queste' for 'sustainable' fuel…

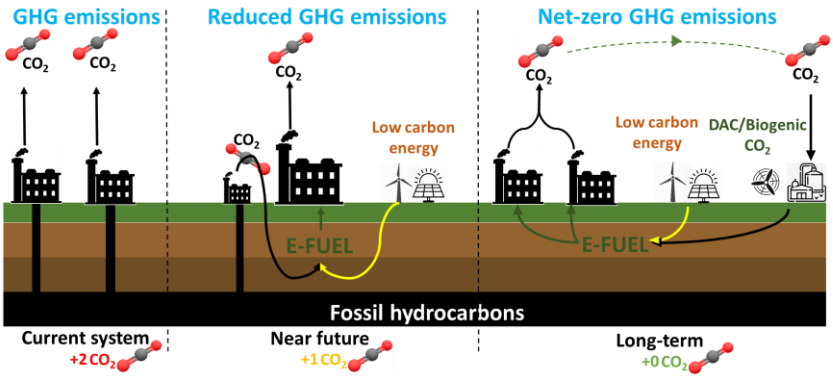


Too expensive **today** but highly dependent on electricity price for electrolysis…

Environmental and social impact better than most bio-fuels…



So we should love CO_2:



4

Conclusions

Take-aways

- In a first step, we must increase **energy efficiency** and think **circular**!
- **Electrification** of as much as possible is a good idea and for electricity, we have a good fossil free alternatives!
- **Molecules** will be needed for processes where energy density is crucial, e.g. in industry, aviation, storage of energy, transport of energy over long distances