Group meeting

15.03.2022

Grégoire LEONARD

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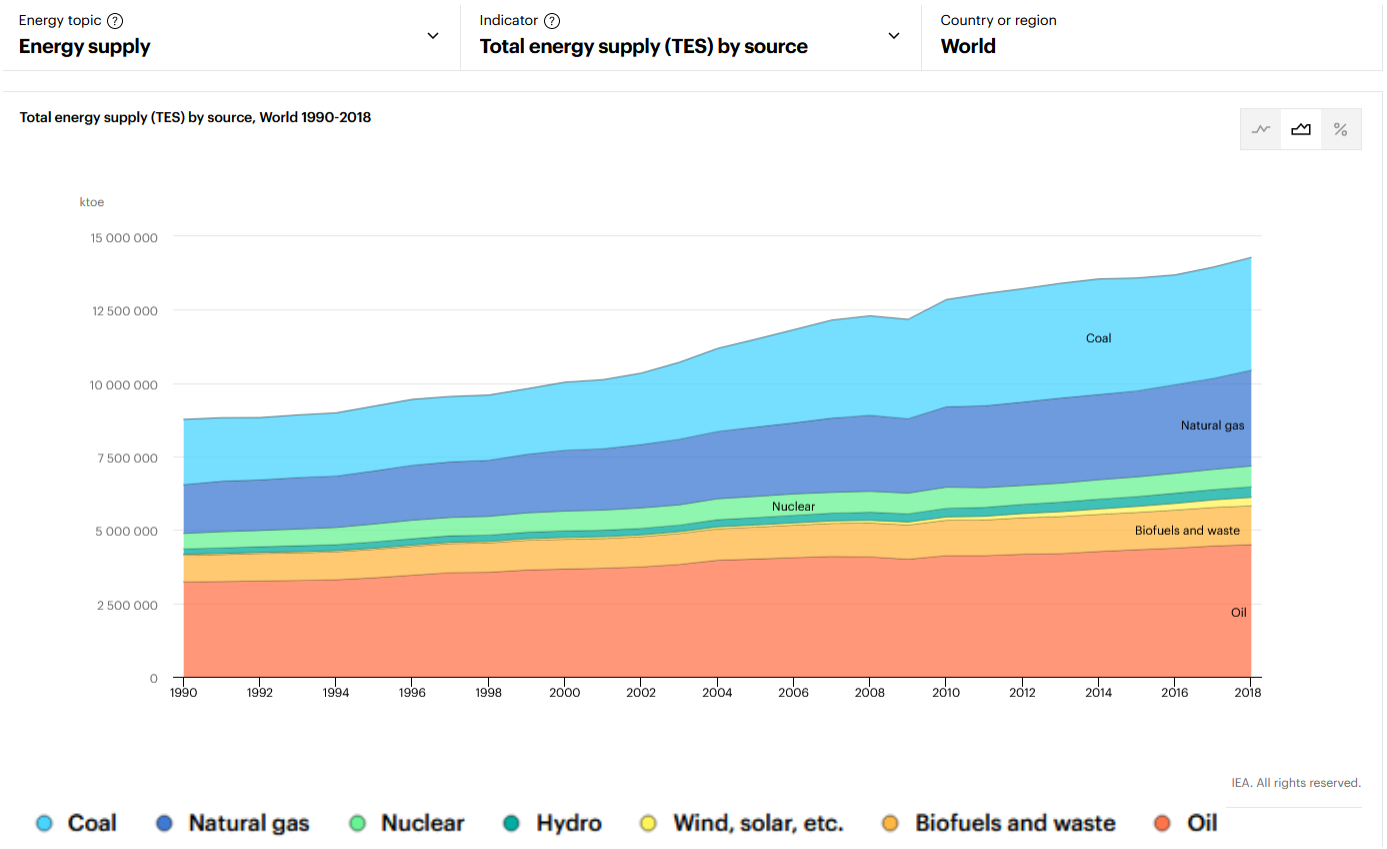
The Energy Transition has started…

Meeting the increasing demand is already a challenge in itself!

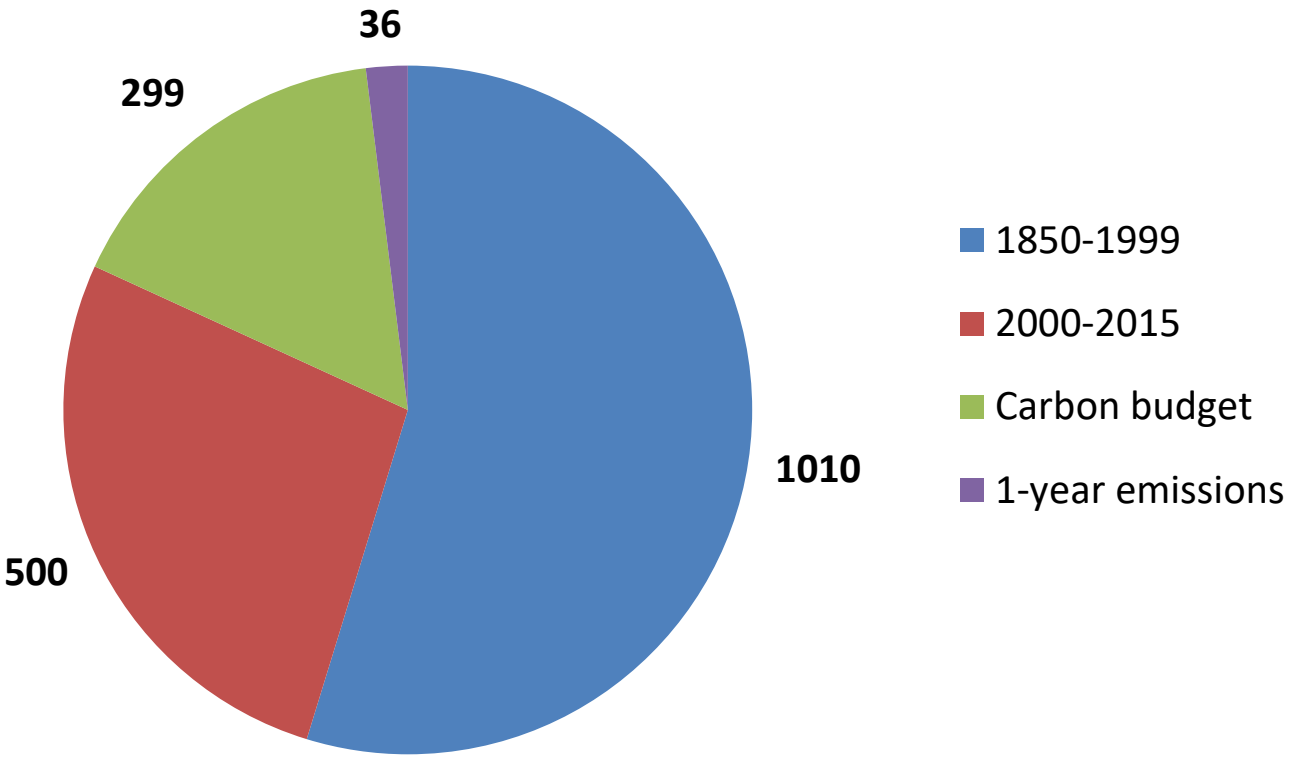
- And most of the energy is still fossil…



IEA 2021, https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20supply&indicator=TPESbySource

CO_2 Budget

Budget by 2050 for having 80% chances to stay below 2°C



Note: Values in Gt CO_2 eq

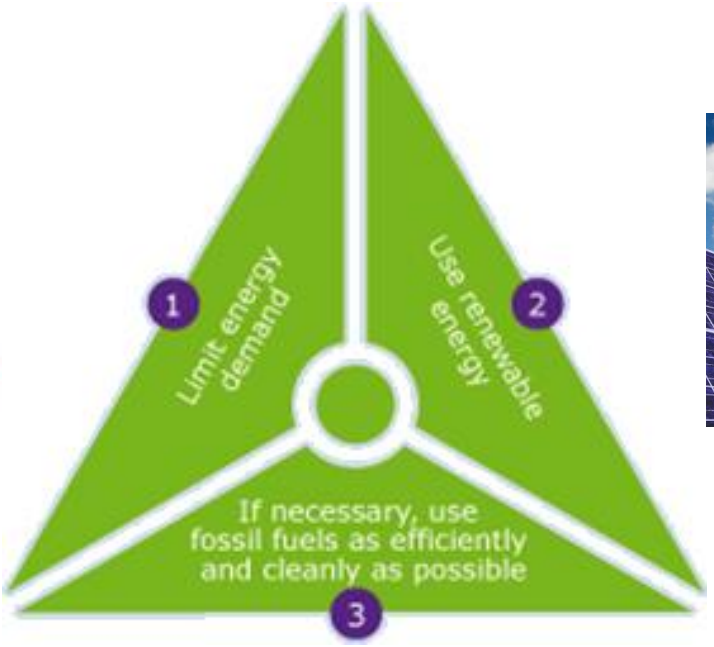
https://informationisbeautiful.net/visualizations/how-many-gigatons-of-co2/

Some interesting data…

- Belgium CO_2 emissions ~ 100 Mt/a
- This corresponds to ~ 8.6 t/hab.a
  - => 24 kg/day!!

- Source: Our world in data
  - Related reference: https://doi.org/10.5194/essd-12-3269-2020
  - https://ourworldindata.org/co2/country/belgium
  - https://ourworldindata.org/co2-emissions

Possible technological answers: Trias Energetica

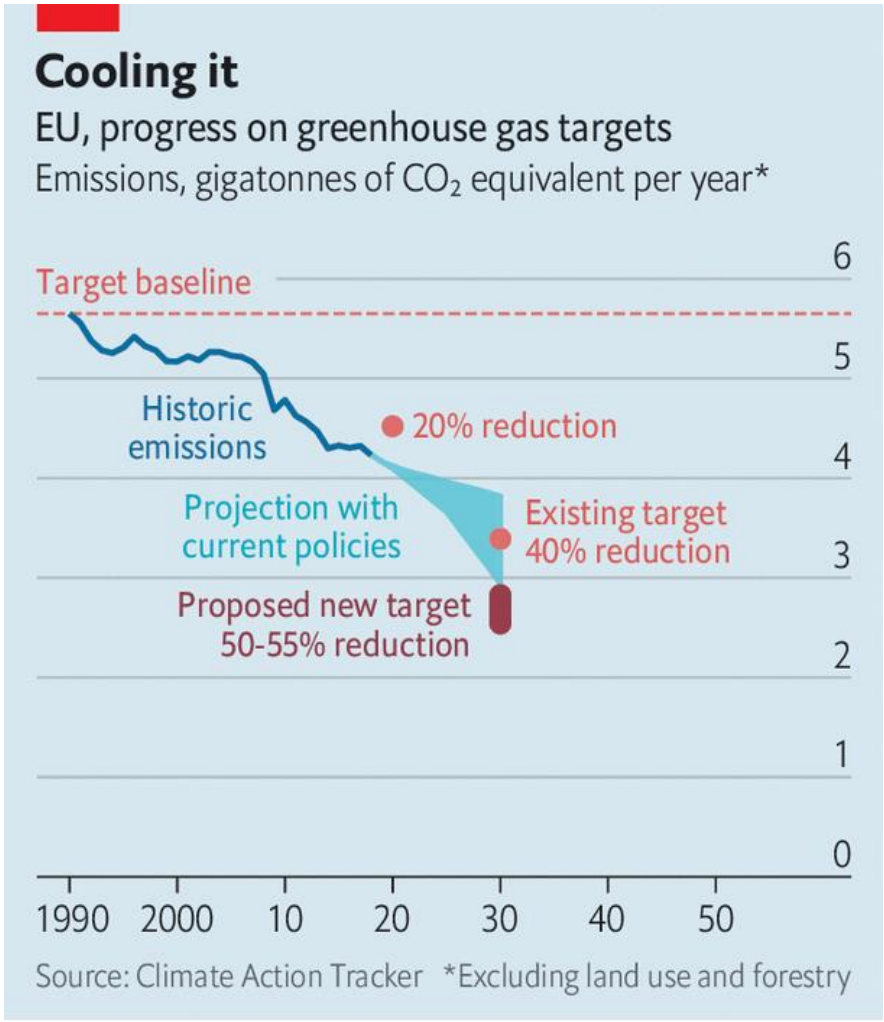


Lysen E., The Trias Energica, Eurosun Conference, Freiburg, 1996

At european level…

The green deal

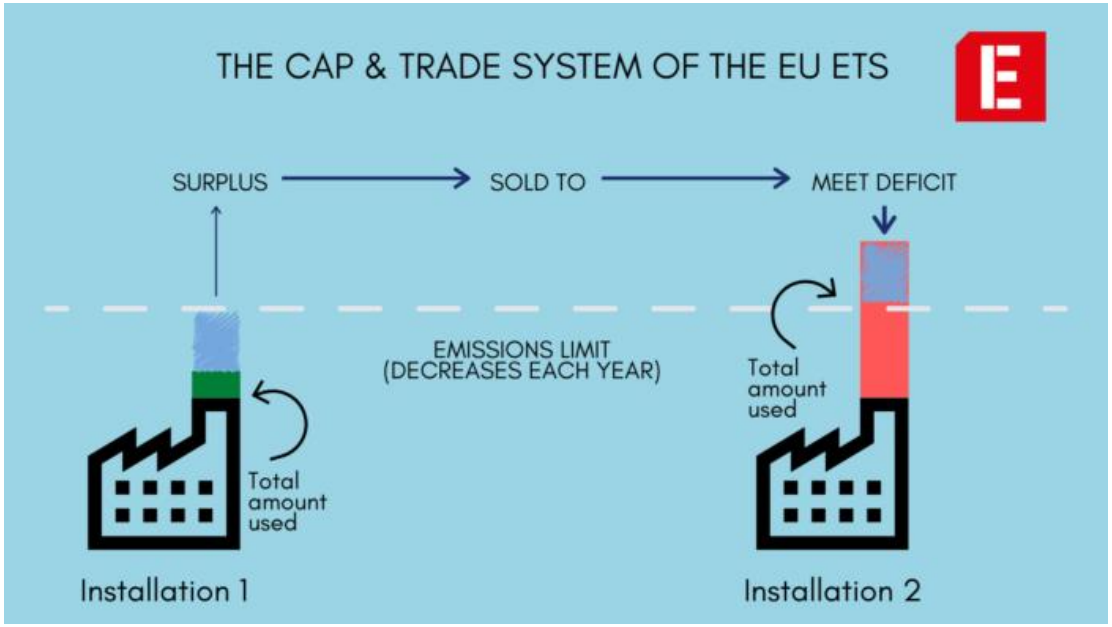
- Carbon neutrality by 2050
- - 55% CO_2 by 2030
- RED II: 32% Ren. En. 2030



The Economist

Possible answers: UE Example

- The EU carbon market ETS



- Monitoring of emissions out of ETS (Effort sharing)
- Legislations with set objectives (energy efficiency, cars and truck emissions, minimal share of renewables…)
- Support for CCUS technologies

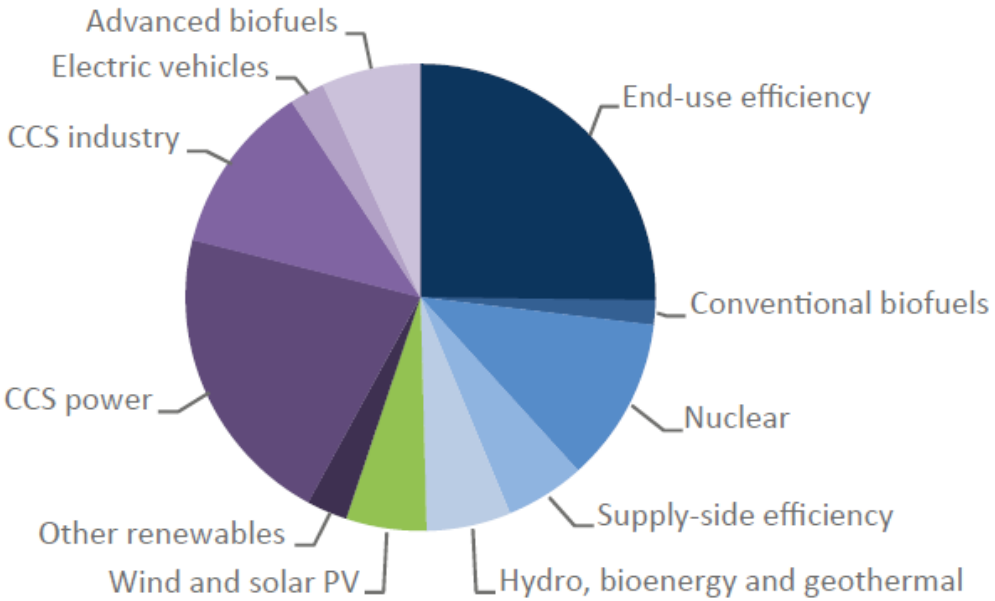
EU Climate action, 2021. https://ec.europa.eu/clima/policies/strategies/progress_en

Possible answers: UE Example

- Development of a EU carbon market ETS
- Monitoring of emissions out of ETS
- Objectives for increasing energy efficiency
- Objectives for CO_2 emissions of cars and trucks
- Legislation to reach 20% renewables by 2020
- Support to CO_2 capture technologies

Eurostat, 2017. Greenhouse gas emission statistics - emission inventories

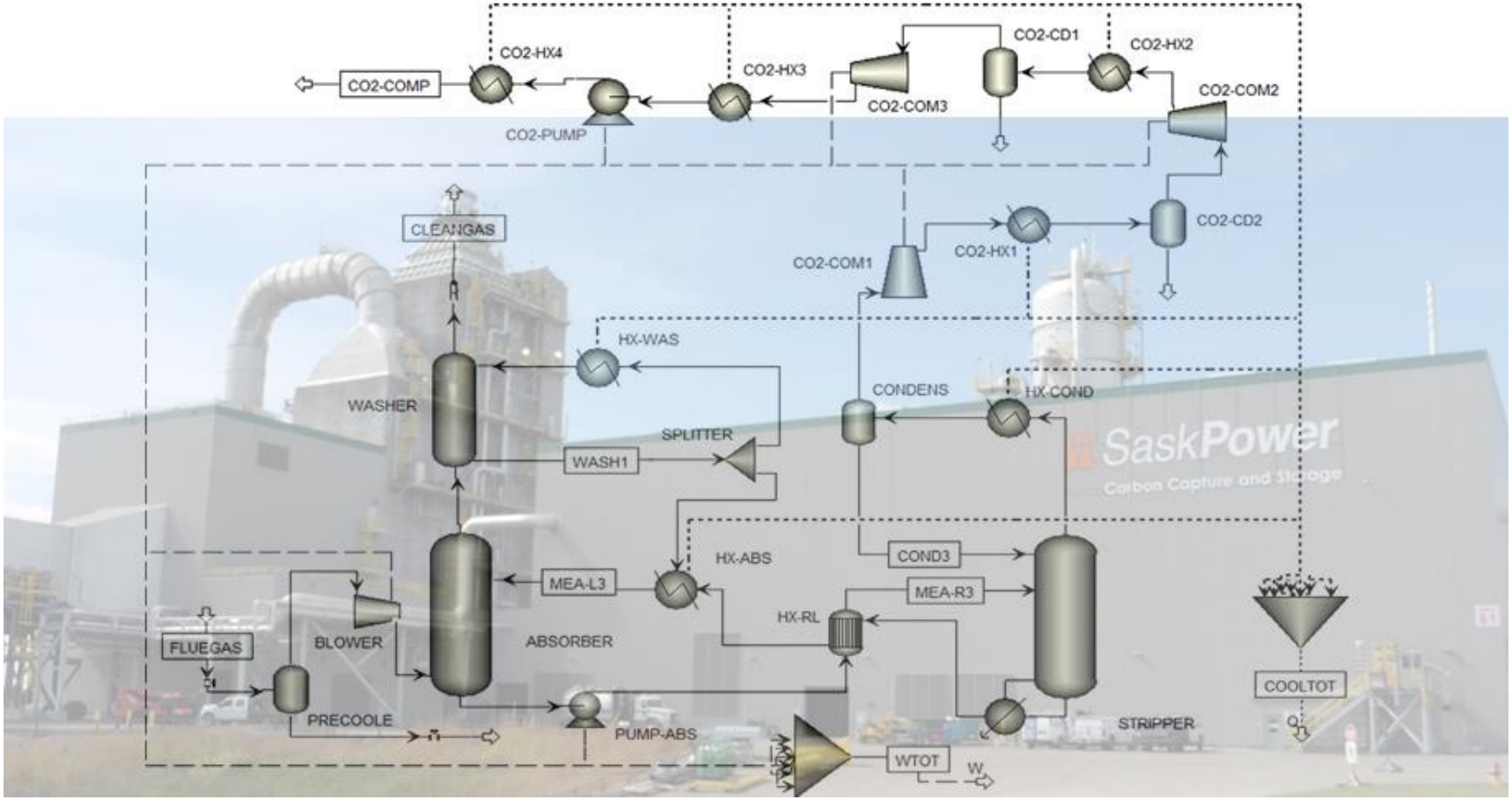
What efforts are needed?



World CO_2 emissions abatement in the 450 Scenario (Bridge Scenario 2015-2040), IEA **2015**, WEO special report, Energy & Climate Change

- **Carbon capture and storage** mature technology, but cost only!
- **Re-use**: different maturity levels, depending on product

CO_2 capture


CO2-HX4
CO2-COMP
CO2-HX3
CO2-CD1
CO2-HX2
CO2-COM3
CO2-COM2
CO2-PUMP
CLEANGAS
CO2-COM1
CO2-HX1
CO2-CD2
HX-WAS
WASHER
CONDENS
HX-COND
SPLITTER
WASH1
HX-ABS
COND3
MEA-L3
MEA-R3
HX-RL
FLUEGAS
BLOWER
ABSORBER
COOLTOT
PRECOOLE
PUMP-ABS
STRIPPER
WTOT
W
SaskPower

CO_2 capture

Main focusses at ULiège

- Optimal operation of MEA-based CO_2 capture with process modeling
  - Mohamed Amine Berchiche
    - CO_2 capture for natural gas sweetening operations

- Experimental study of solvent degradation
  - Hana Benkoussas
    - Quantify the effect of O_2 mass transfer on the degradation of amine solvents
    - Kinetics of SO_x-induced degradation

CO_2 capture

Main focusses at ULiège

- Decision support tool (DST) for identifying the context-specific optimal CO_2 capture technology
  - So-mang Kim, PROCURA (Belgian ETF)
  - Link to the goals of Antoine Merlo: fair comparison of technologies

- Integration of CO_2 capture in industrial clusters
  - Muhammad Salman, TRILATE (Belgian ETF)

- Pilot-scale CO_2 capture unit on the Sart-Tilman Campus
  - RRF FWB
  - Feder

CO_2 capture

Guideline = contribute to:

- R&D about CO_2 capture technologies
  - Process modeling, solvent stability, process optimisation

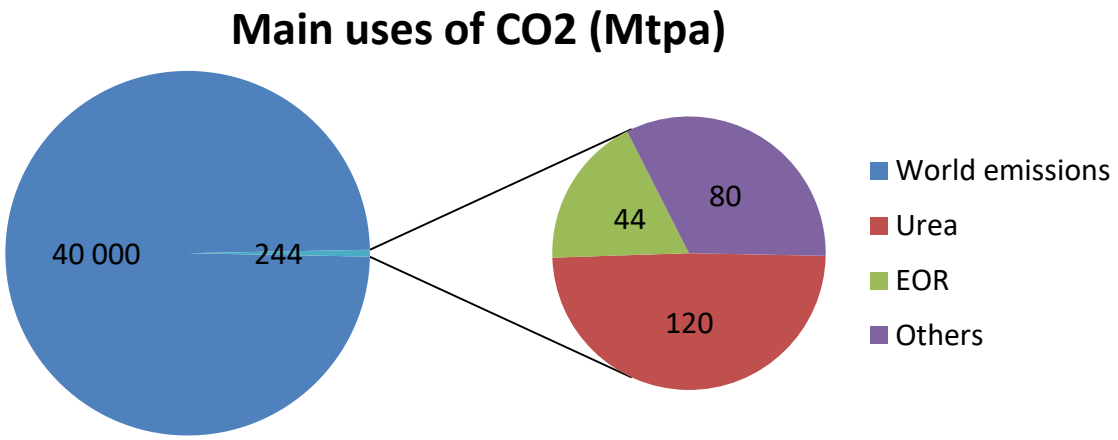
- Better understanding by the public
  - Conferences (local & international)
  - Technical as well as non-technical audience

- Local implementation
  - Support local industries
  - Identify case studies (e.g. Sart-Tilman) to demonstrate the feasibility

=> Make it happen!

CO_2, waste or feedstock?

- What to do with captured CO_2?
  - Consider CO_2 as a resource, not as waste

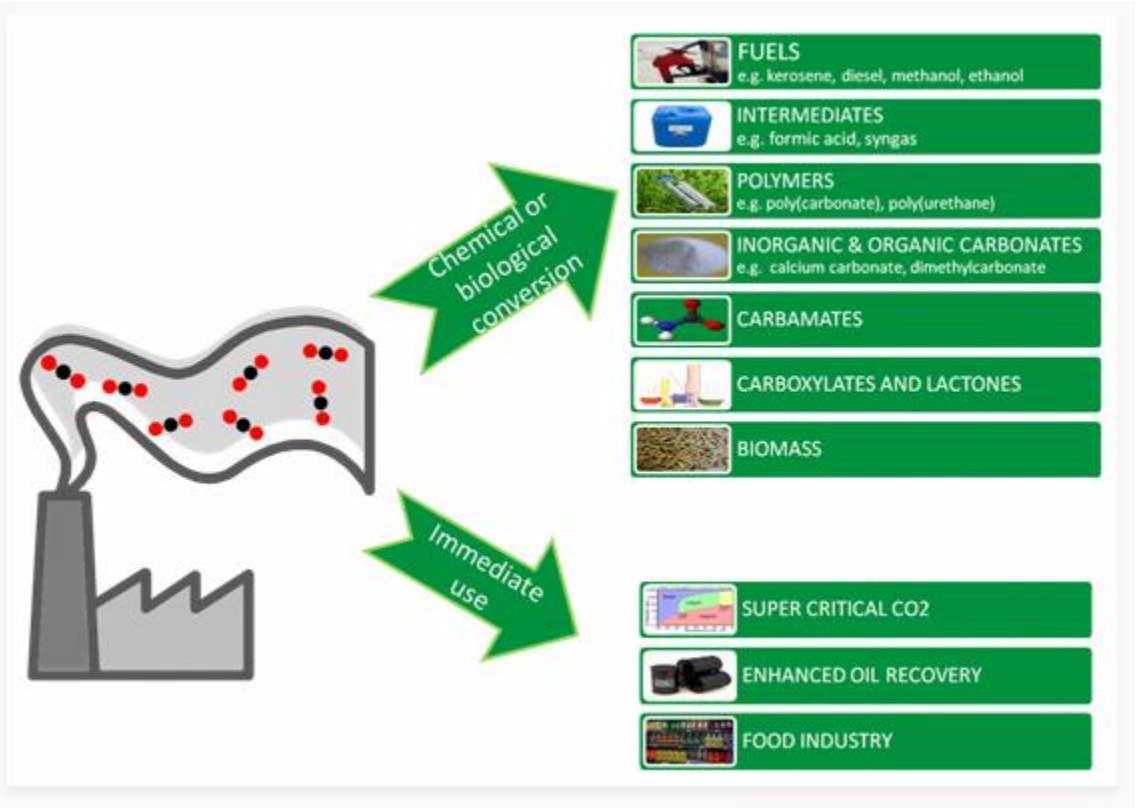


- So far, sources for CO_2 are high-purity ones
  - Industrial (Ethanol, Ammonia, Ethylene, Natural gas…)
  - Natural (Dome)
  - CO_2 from power plants (~2.4 Mtpa)

Global CCS Institute. Global Status of CCS 2016: Summary Report.
Koytsumpa et al, 2016. https://doi.org/10.1016/j.supflu.2017.07.029

Main CO_2 re-use pathways

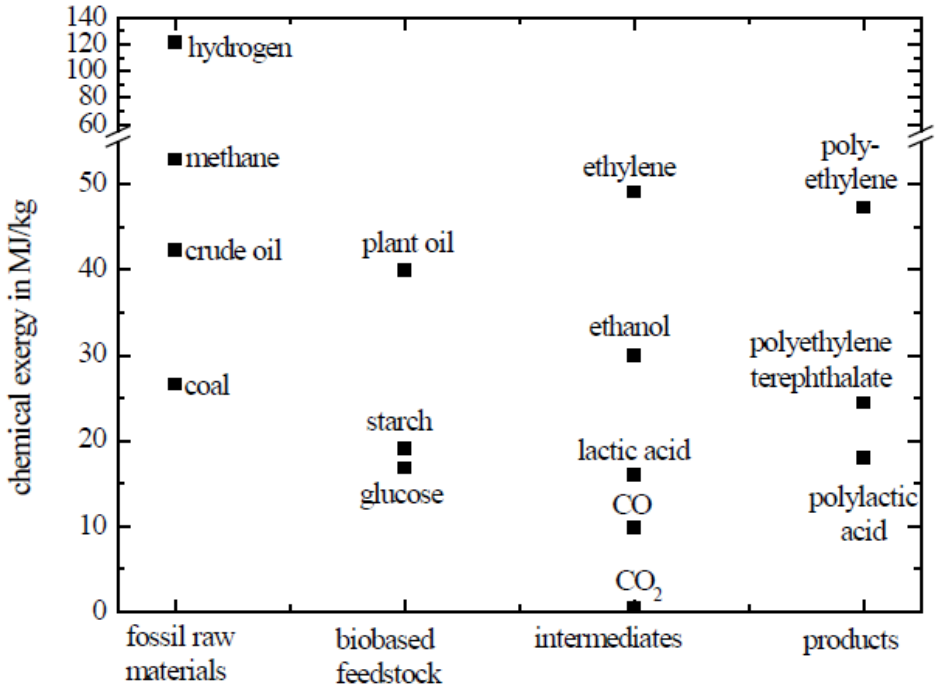
Many different products, as CO_2 can be seen as a carbon source => leads to almost all petrochemical products!



Source: CO2Chem

Main CO_2 re-use pathways

- Direct use, no transformation
- Biological transformation
- Chemical transformation
  - To lower energy state
    - Carbonatation
  - To higher energy state

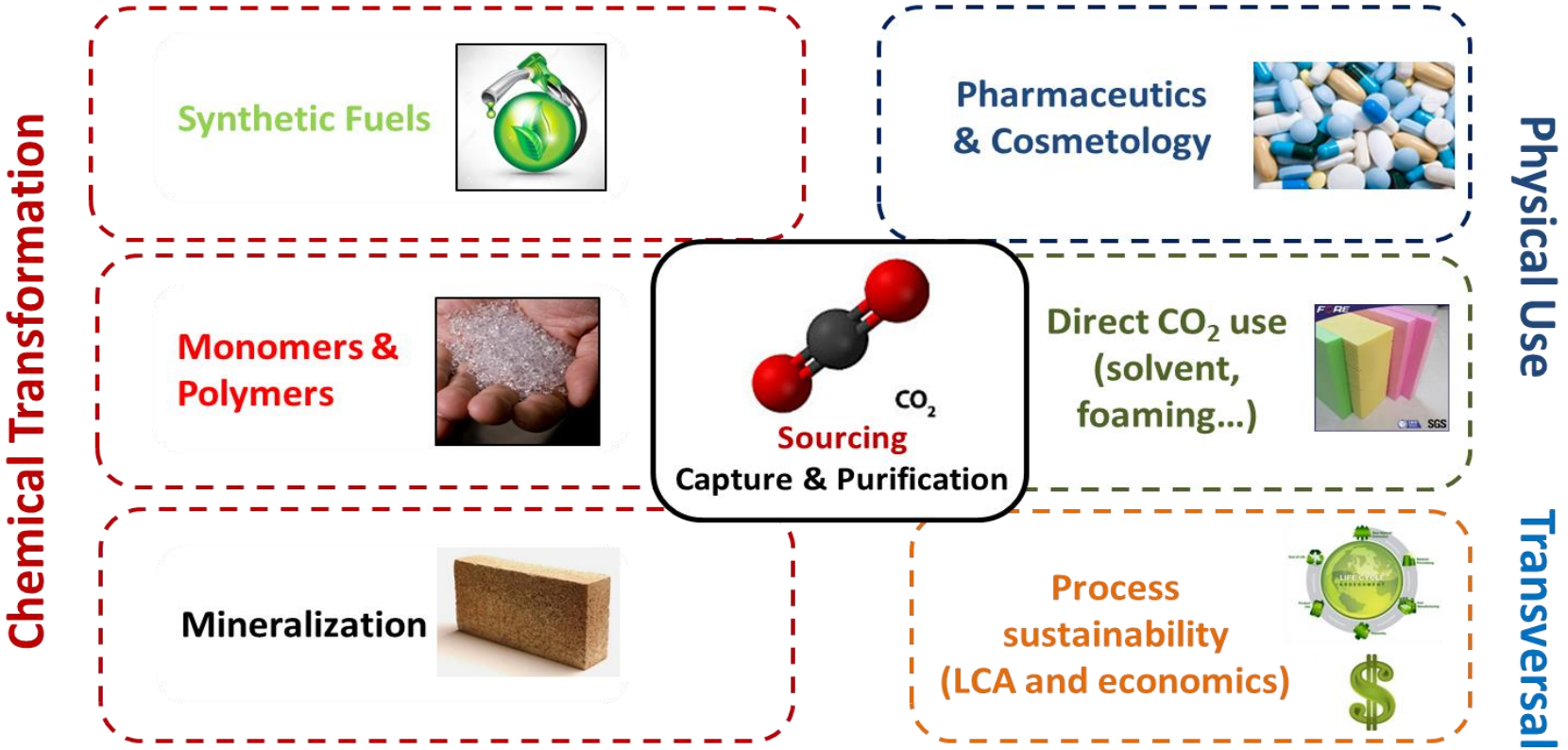


=> At large scale, need to make sure that energy comes from renewables!

Frenzel et al, 2014. Doi:10.3390/polym6020327

Perspective ULiège: FRITCO$_2$T platform

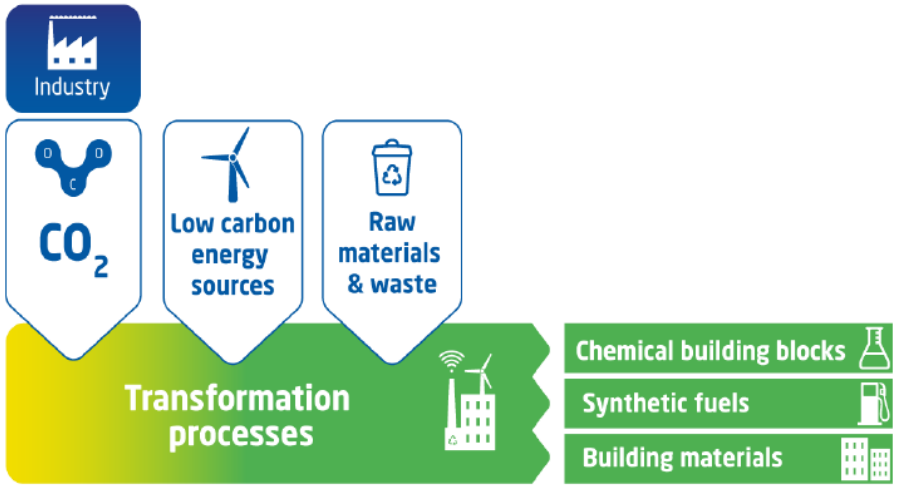
Federation of Researchers in Innovative Technologies for CO_2 Transformation



CO_2 Value Europe

- 30.11.2017: Creation of CO_2 Value Europe, an Association for promoting:

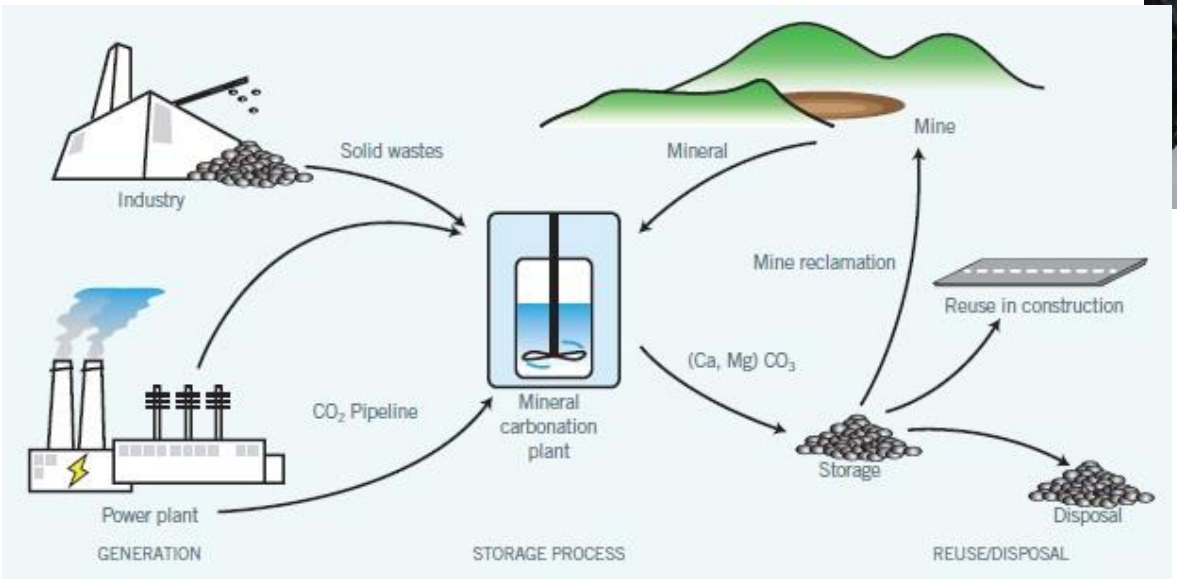
"the development and market deployment of sustainable industrial solutions that convert CO_2 into valuable products, in order to contribute to the net reduction of global CO_2 emissions and to the diversification of the feedstock base."



CO_2 re-use

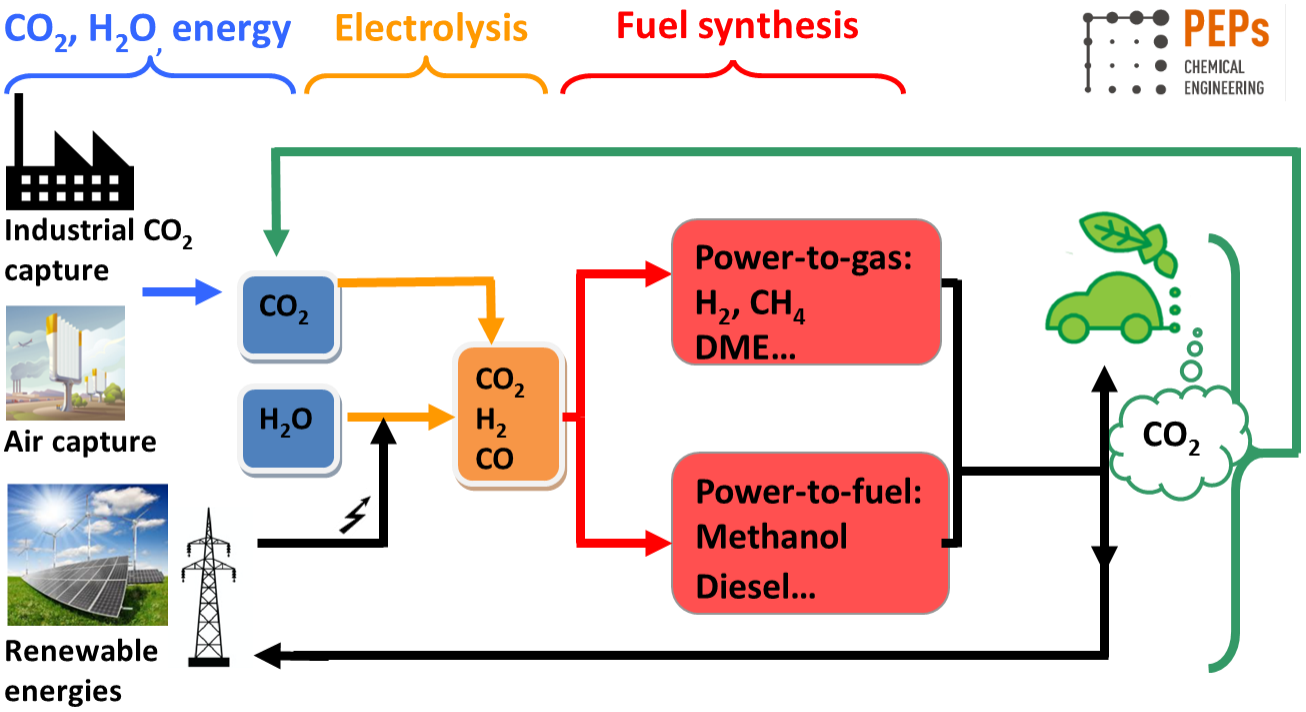
- Mineral Loop project
  - Carbonation of construction wastes
  - Greenwin project (WR)
  - Natalia Vidal

Carbstone, ORBIX, 2019



CO_2 to fuels

- Decisive advantage: a fantastic energy density!
- => Power-to-liquid, power-to-gas



=> Sustainability is possible with carbonated fuels!

Energy storage

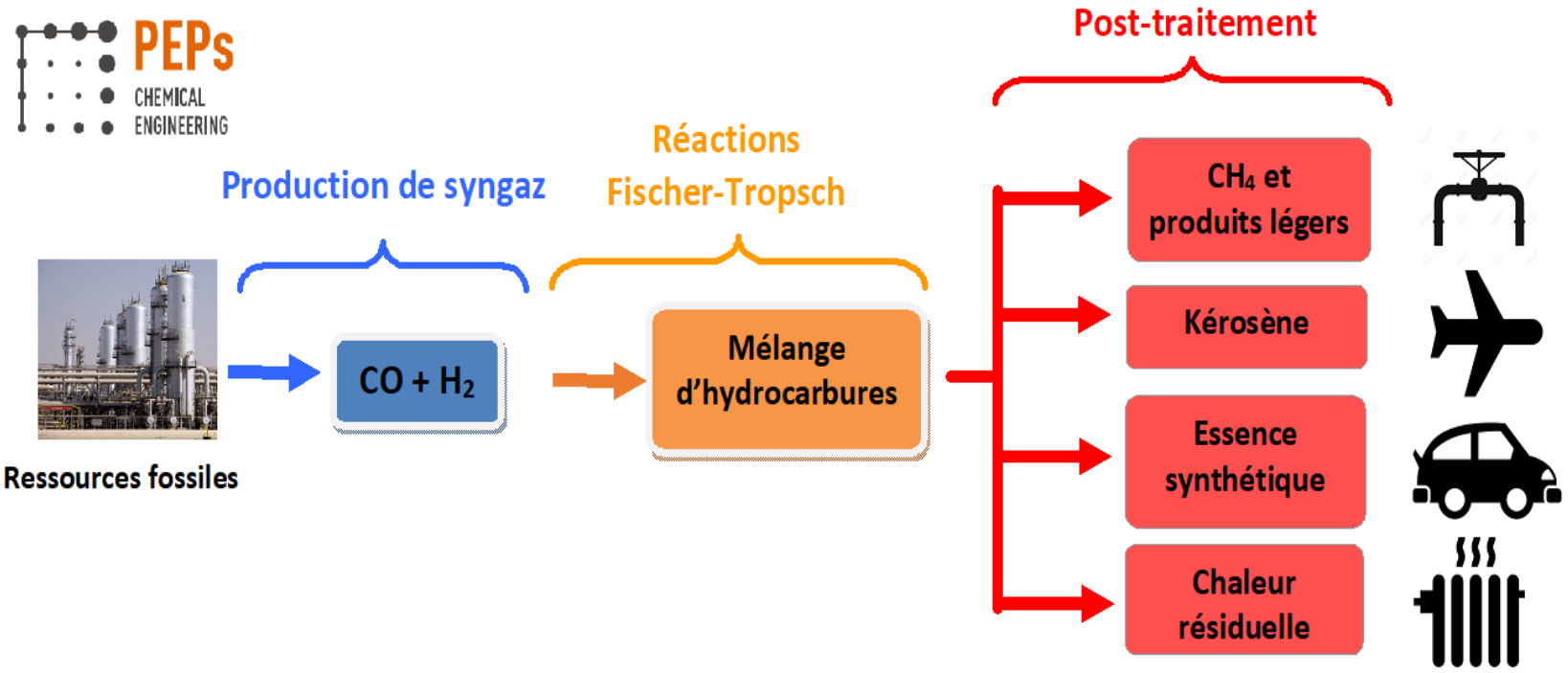
- Quick calculations
  - How many cars tanking at the same time are needed to develop a power of 1 GW?
    - 1 L/s gasoline transfer
    - Gasoline ~ 35 MJ/L
    - => 1 car = 35 MW_{th}
    - 1 GW_{el} ~ 3 GW_{th} ~ 85 cars

Energy storage

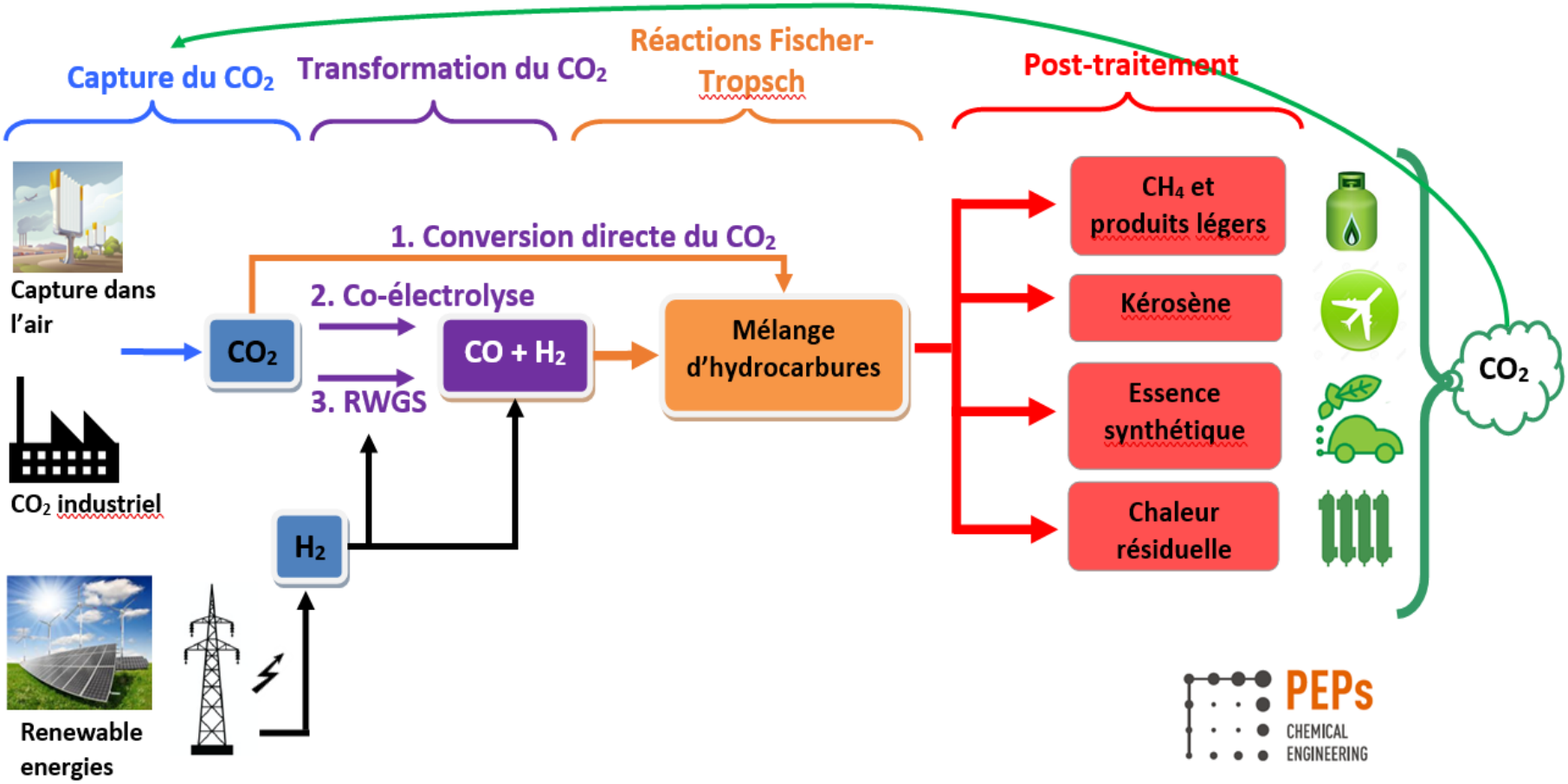
- Quick calculations
  - What would be the hourly gage for one worker based on fossil fuel cost?
    - Physical activity ~300 W
    - 1 h = 300 Wh = 0.3 kWh = 1.08 MJ
    - Cost of one barrel (159 L oil) ~50 USD
    - 159 L oil @ 40 MJ/L = 6360 MJ
    - => 1 hour of human work at standard fossil energy prices

    = 1.08 MJ * 50 USD/6360 MJ = 0.0085 USD

CO_2 to fuels


PEPs
CHEMICAL ENGINEERING
Post-traitement
Production de syngaz
Réactions Fischer-Tropsch
CO + H2
Mélange d'hydrocarbures
CH4 et produits légers
Kérosène
Essence synthétique
Chaleur résiduelle
Ressources fossiles

CO_2 to fuels


Capture du CO_2
Transformation du CO_2
Réactions Fischer-Tropsch
Post-traitement
Capture dans l'air
CO_2 industriel
Renewable energies
1. Conversion directe du CO_2
2. Co-électrolyse
3. RWGS
CO_2
$CO + H_2$
H_2
Mélange d'hydrocarbures
CH_4 et produits légers
Kérosène
Essence synthétique
Chaleur résiduelle
CO_2
PEPs
CHEMICAL ENGINEERING

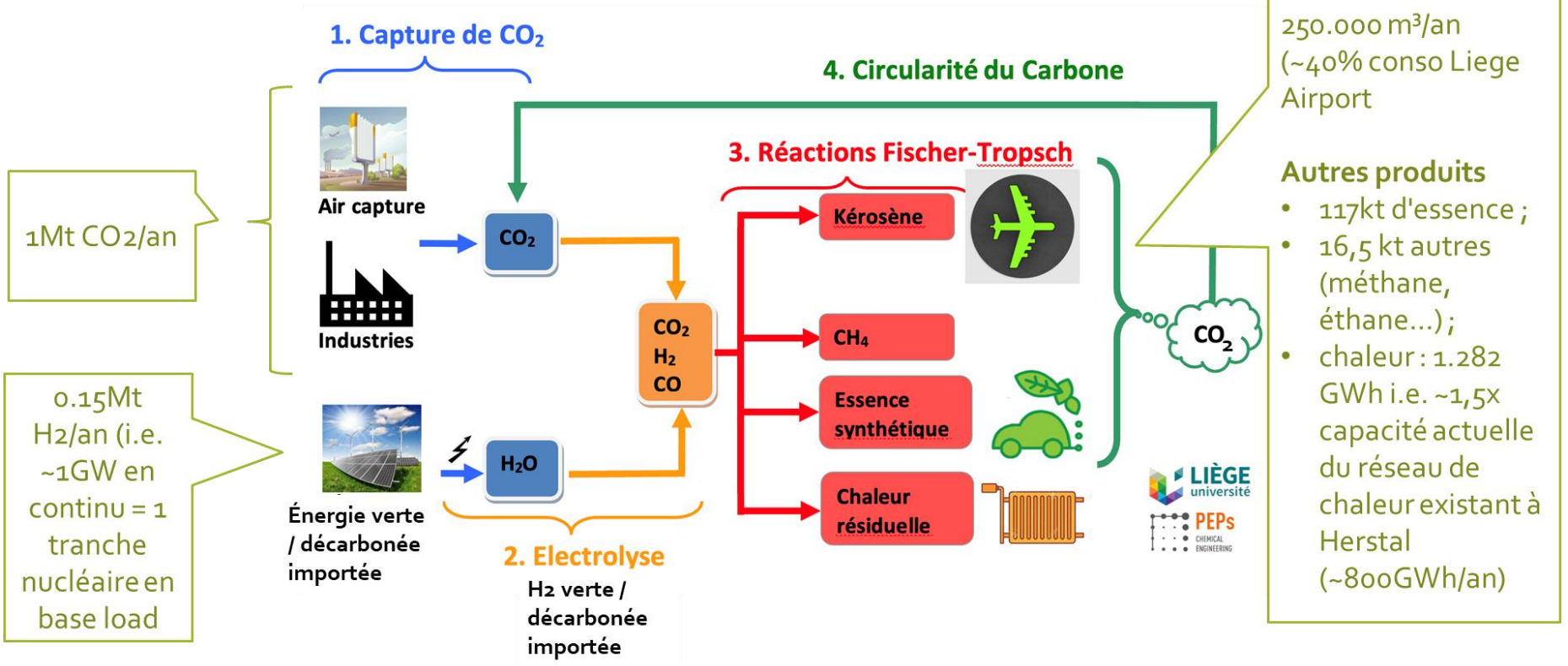
Recent announcement

- Carbon neutral kerosene!

https://trends.levif.be/economie/entreprises/du-kerosene-wallon-neutre-en-carbone/article-normal-1466097.html?cookie_check=1637791560

Recent announcement

Capture de CO_2 + électrolyse + synthèse Fischer-Tropsch



https://trends.levif.be/economie/entreprises/du-kerosene-wallon-neutre-en-carbone/article-normal-1466097.html?cookie_check=1637791560

CO_2 to fuels

- Experimental development of a Fischer-Tropsch reactor for CO_2 to fuel
  - Alejandro Morales
  - Electrolysis capacity of 6.6 kW (1.5 Nm^3/h)
  - Reactor design and dynamic study

- Alternative to the RWGS – FT pathway
  - Foteini Lappa
  - Collaboration with KU Leuven, catalyst development

- PhD in industry
  - Hamon, RIGAE

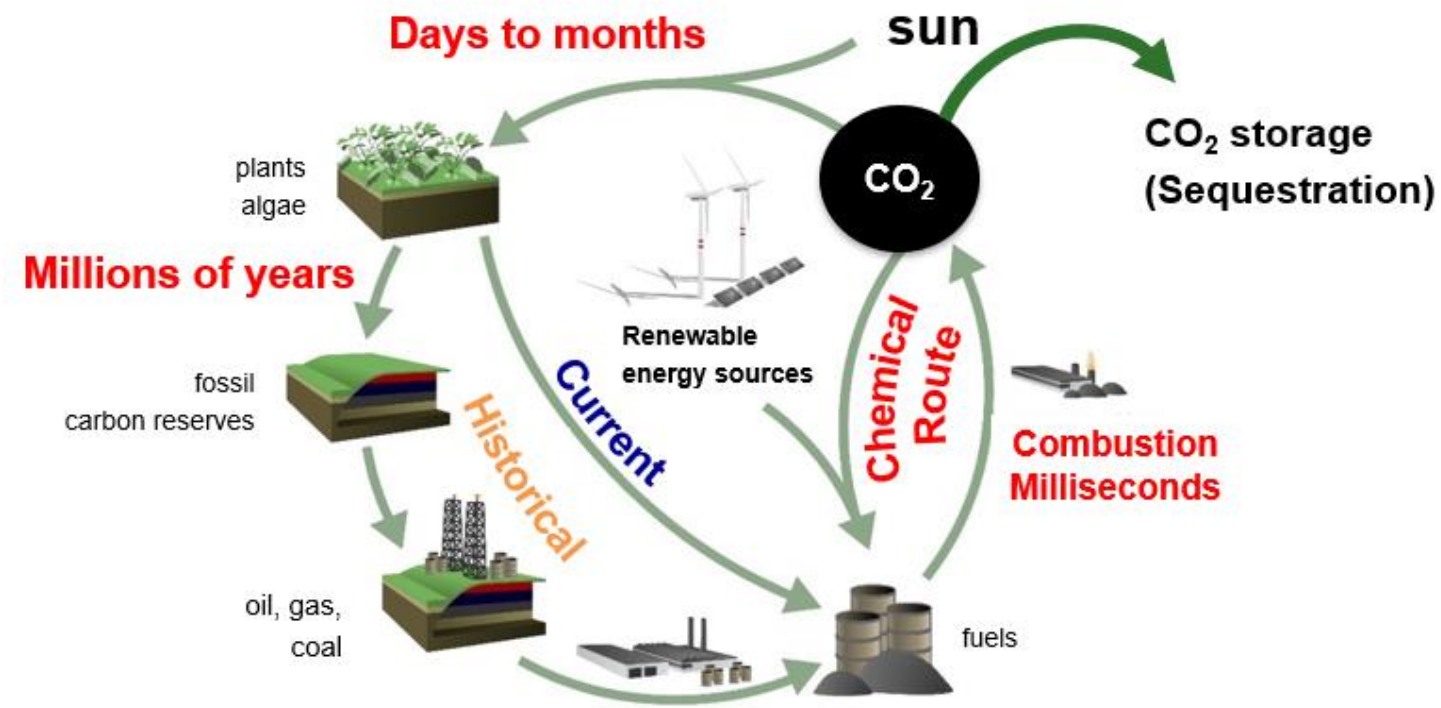
CCUS

- CO_2 capture is not cheap ~ 40 €/t
- ETS market has dramatically increased recently !

https://ember-climate.org/data/carbon-price-viewer/

Perspective

- We live in a carbon-based society, with very good reasons for that !
- A CO_2 neutral future is in sight with passionating (and huge) challenges for engineers!



Saeys et al., KVAB, Green Chem

Thank you for your attention!

Questions?

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