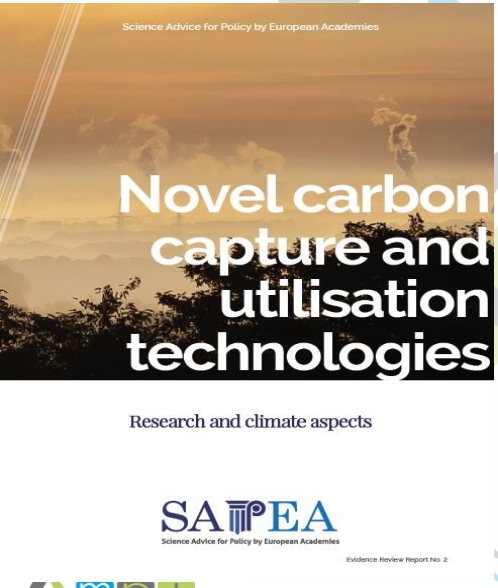
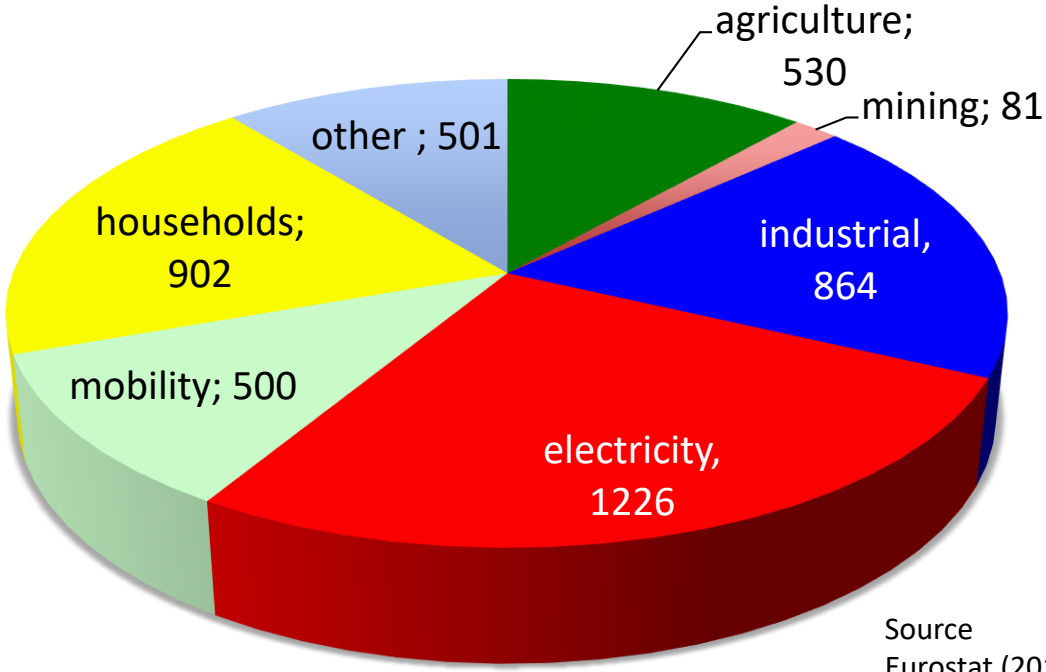
The circular economy of carbon: a critical element in sustainable energy systems



Robert Schlögl
Fritz-Haber-Institut, Berlin
MPI CEC, Mülheim,
www.solarify.de

CO_2 Emissions in Europe

- EU emits 3704×10^9 t CO_2 (energy, 2014)
- Its replacement by REL creates a huge volatility/storage challenge.
- Heat generation is the largest emitter followed by electricity.
- Impossible to address without CCU/CEC.
- Trans-EU distribution and long-term storage are critical for a deep penetration of REL into the supply structure.

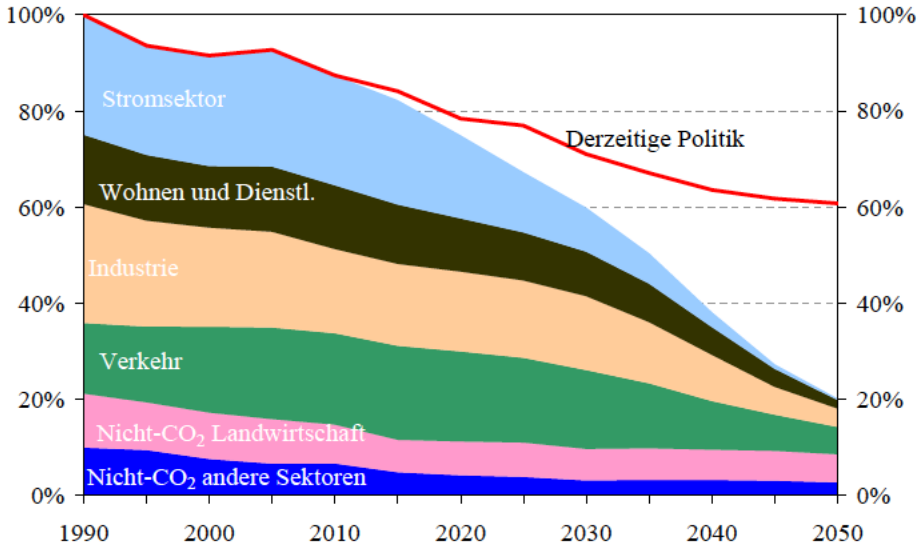


Source
Eurostat (2017)

EU targets and mobility

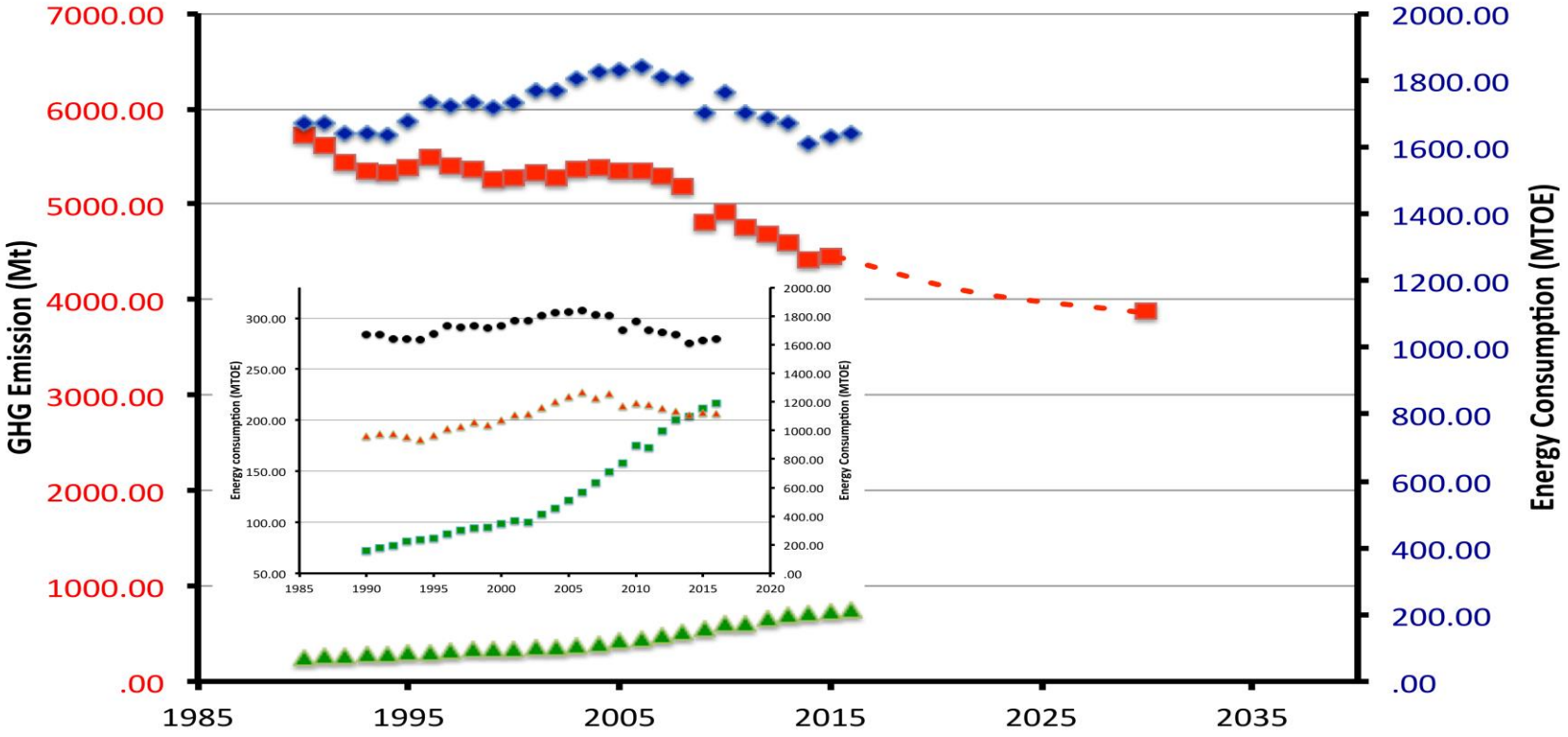
EU targets require strict reductions of CO_2 emissions.
Mobility is left with an only 50% reduction target due to its diffuse emission character.

THG-Emissionsverringerung gegenüber 1990	2005	2030	2050
Insgesamt	-7 %	-40 bis 44 %	-79 bis 82 %
Sektoren			
Stromerzeugung (CO_2)	-7 %	-54 bis 68 %	-93 bis 99 %
Industrie (CO_2)	-20 %	-34 bis 40 %	-83 bis 87 %
Verkehr (einschl. CO_2 aus der Luftfahrt, ohne Seeverkehr)	+30 %	+20 bis 9 %	-54 bis 67 %
Wohnen und Dienstleistungen (CO_2)	-12 %	-37 bis 53 %	-88 bis 91 %
Landwirtschaft (Nicht-CO_2)	-20 %	-36 bis 37 %	-42 bis 49 %
Andere Nicht-CO_2-Emissionen	-30 %	-72 bis 73 %	-70 bis 78 %



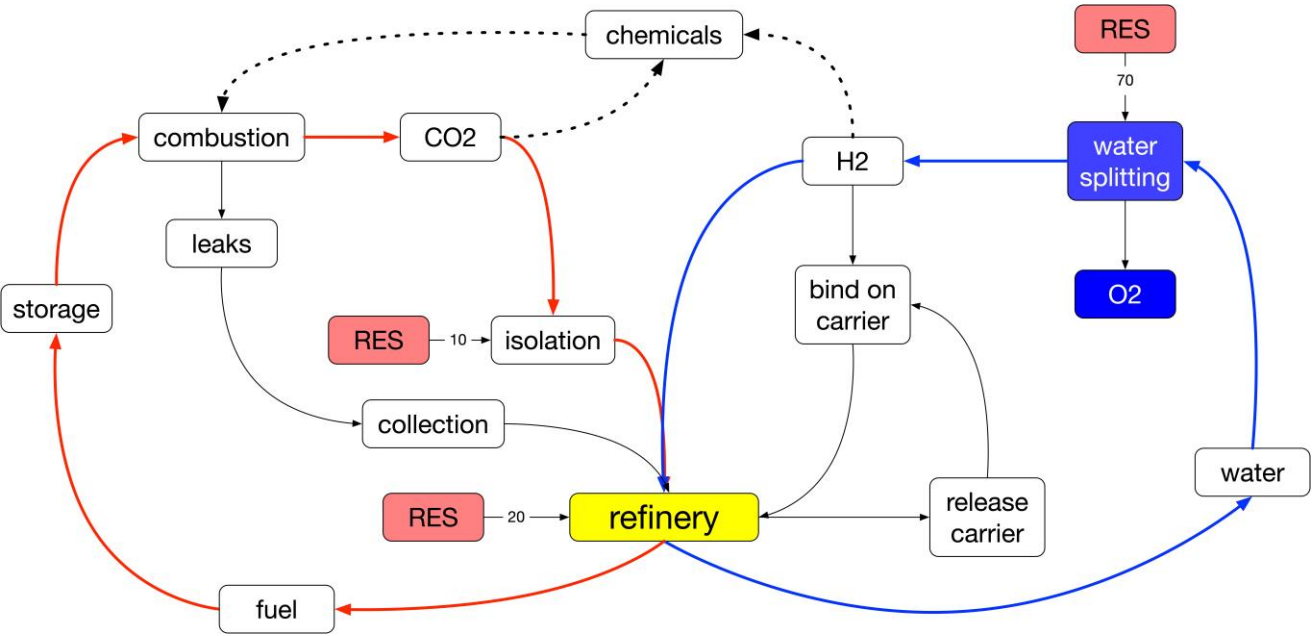
Regulations need to block double counting.
Reasonable emission reduction only when syn fuels reach closely 50% CO_2 reduction

What we have achieved



National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism provided by European Environment Agency (EEA)
Approximated greenhouse gas emissions provided by European Environment Agency (EEA)
Greenhouse gas projections provided by European Environment Agency (EEA)

Circular carbon economy



This system provides:
RES storage
Sector coupling

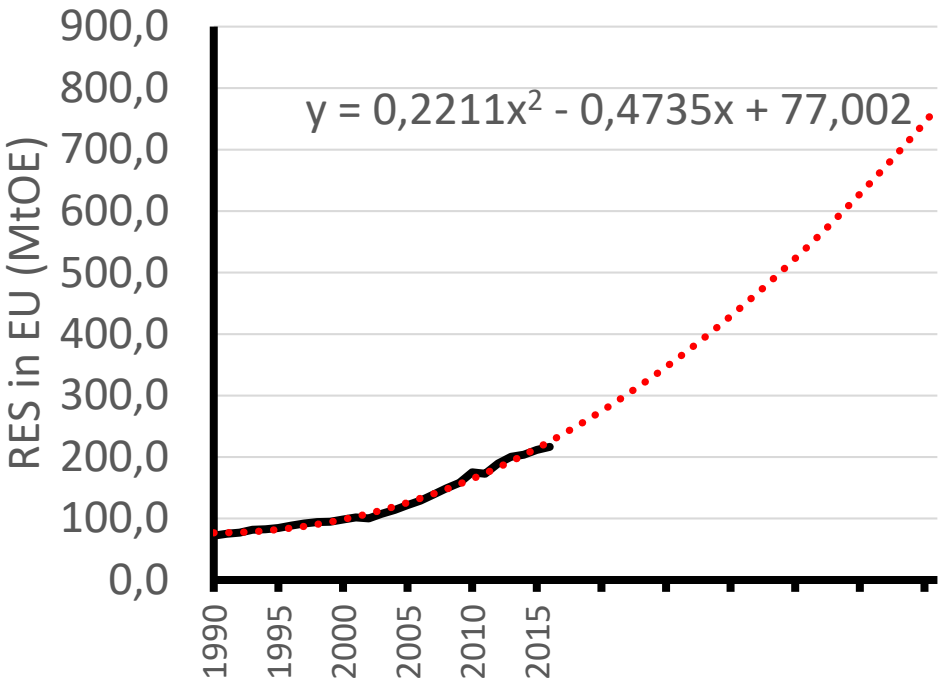
- A circle between fuel and CO_2 is driven by a second circle bring hydrogen to the "refinery".
- Transport of material interconnects the steps in the system.
- RES can be local or remote.
- The geography of the system is hierarchical (country, EU, global).

Energy import: today and in future

- EU imports most of its energy today.
- How should it be conceivable that this is complete omitted in future?
- Energy scarcity is no option.

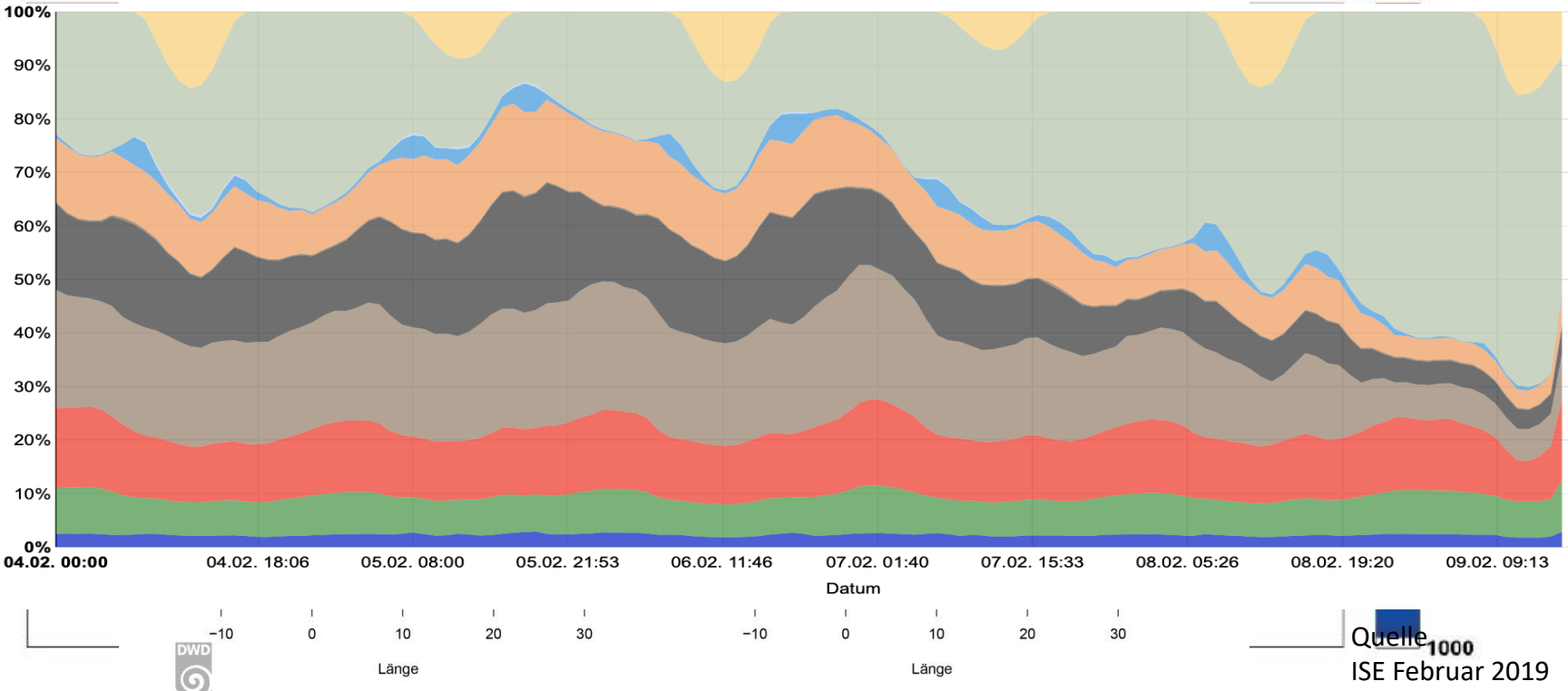
Values for 2016 from country data sheet (2018)	Energy in MtOE	RES in MtOE
Gross energy consumption	1641	
Extraction within EU	311	
Net import fossil	903	
nuclear	216	
Generation from renewables		211
RES generation to replace fossil		1214
Growth rate for RES generation in EU achieved (required)		4,7 (40)

One grand challenge for the EU



- Without a strong additional growth of RES generation the targets will not be achievable.
- Most likely more energy will be needed in 2050 than today.
- Care with “efficiency gains” vs rebound effects.
- The missing RES means “50% stored” (additional RES required)!
- How to accelerate?
- Most likely only as global commodity.
- EU technologies ?

Overpowering is not sufficient to the volatility gap: Transport and storage essential

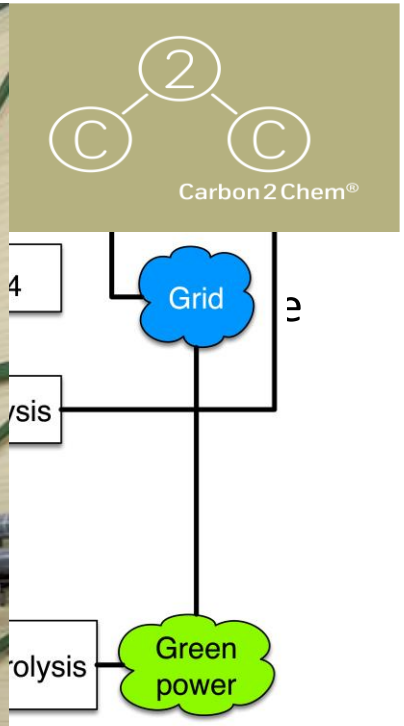


Quelle ISE Februar 2019

2017)

Renewables

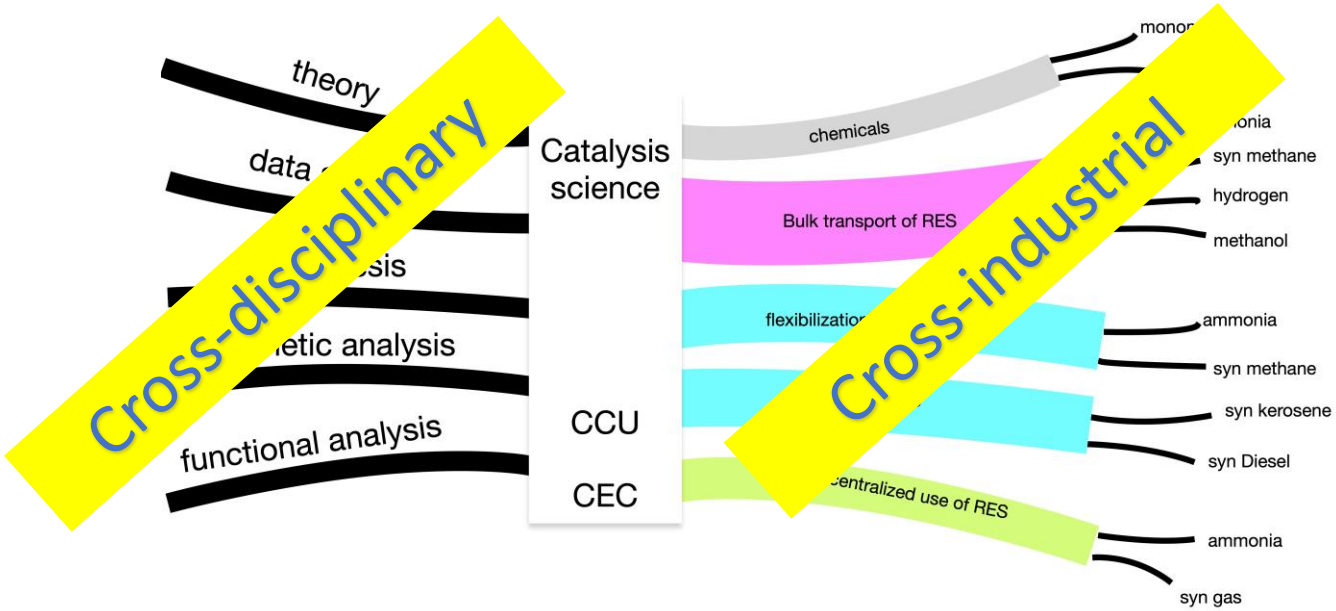
A pathfinder



Research: a challenge for Europe

- 2 lines of supra-national research:
  - deep fundamental insight into interfacial processes (theory, clean data)
  - Cross-disciplinary demonstrator realizations on grid scale (modern steelmaking).
- Critical timing: science today needs 30 years for grid scale technology.
- Large-scale, long-range focussed consortia of excellence are required now.
- Breakthroughs are to be delivered:
  - Novel processes and materials (all scalable!)
  - Novel industries and business models.
- Advantage Europe: strong connection between science and technology, capability of solving systemic challenges, excellent research infrastructure and scientist.
- Problem: regulatory boundaries for seamless collaborations between members and between industries and between industry and academia.

Catalysis science transforms in energy vectors

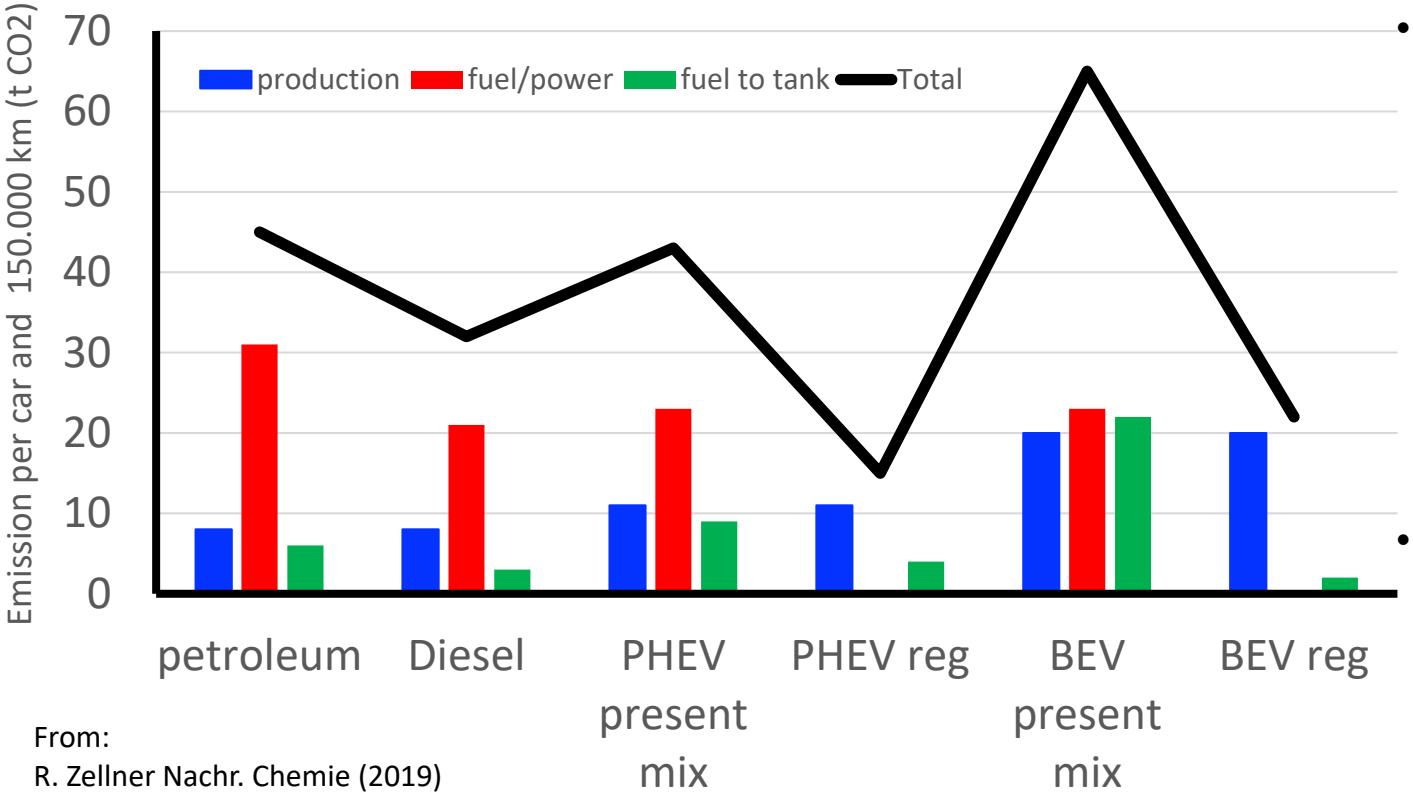


Europe can lead an initiative from innovative fundamental science to technology transfer and to roll out on global scale.
Europe combines a world-class science base and a powerful industrial network.
Time is critical calling for cross-sectoral integration.

Suitable target challenges

- Hydrogen at 2000 €/t with 30€/MWh.
- MeOH at 450 €/t with 1 tCO_2 saving per t MeOH.
- Ammonia reforming at 650 K without PM.
- Syn jet fuel at 1000 €/t.
- Syn fuels with zero regulated emissions at 800 €/ t.
- Digitized grid structures for electricity and molecules throughout Europe.

Power train options for cars

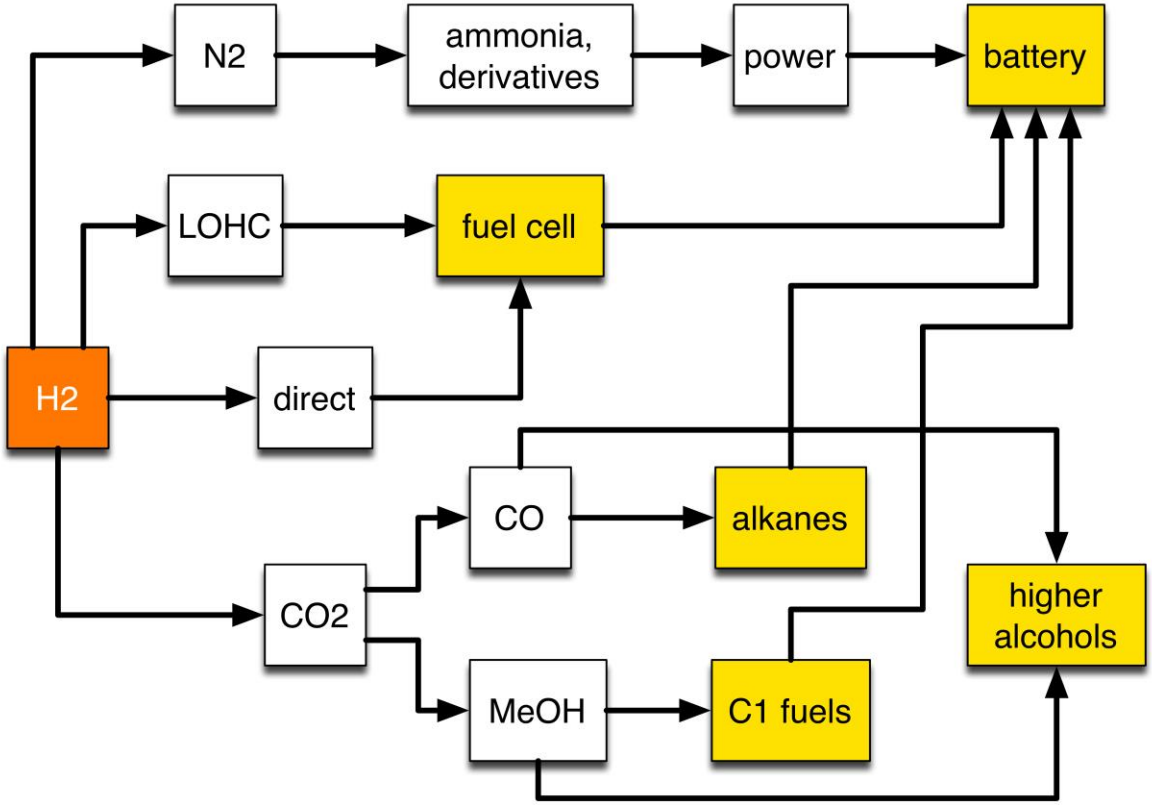


From:
R. Zellner Nachr. Chemie (2019)

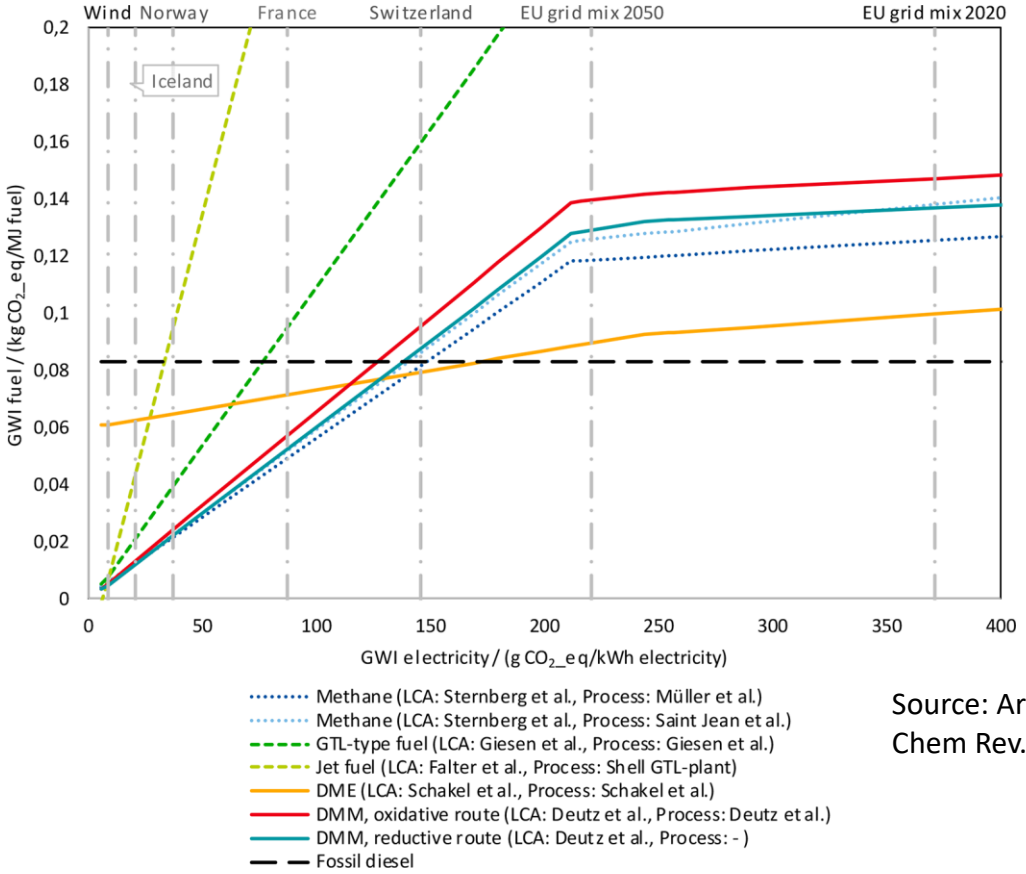
- The current debate about power trains is good illustration for the non-systemic approach in the energy debate: each sector optimizes its tasks independent from the total system.
- Here the energy cost of providing the traction energy as well as the emissions from technology-specific manufacture were disregarded.

“Solar” or syn fuels: a toolbox

- Based upon hydrogen as primary chemical energy conversion product storing RES.
- Several options with specific advantages (efficiency) and disadvantages (complex novel technologies and infrastructures).
- Different application profiles for different mobility applications (light duty, heavy duty).
- Optimized combustion developments for syn fuels are required to avoid the emission of novel toxic substances.



The consequence of electricity use



Source: Artz et al ; Chem Rev. (2018)

Grid mix D

Making syn fuels with German or European grid mixes generates more CO_2 than it absorbs!

- The synthesis technology is of little influence!
- To reach useful CO_2 reduction factors exclusively RES must be used: in Europe intermittent flexibility operation for ca. 2500 FLH is possible: import!

Take home

- Stable European sustainable energy systems will need a carbon circular economy .
- For bulk heat and electricity applications the circle is closed. Leaks occur for diffuse sources.
- Its operation requires about twice the RES than a hypothetical immediate use of the same RES.
- Only after breakthrough process implementations at grid scales.
- The circular economy is hierarchical in geography and technology-open in carrier technologies.
- Europe faces the dual challenge of speeding up its RES infrastructures and in demonstrating the integration of the circular carbon economy for stabilizing the energy supply in all sectors.

There is no fundamental law requiring simplicity in natural processes

Mache die Dinge so einfach wie möglich aber nicht einfacher

Albert Einstein

Thank You