



Building a model of sustainable chemistry

Carbon Capture & Utilization
Tracks for CO₂ reuse

Advanced Innovation Office
March, 2015

Agenda

Solvay Group at a glance

Carbon Capture & Utilization (CCU)

CCU early demonstrators

CO₂ to methanol : one track for CO₂ reuse

Conclusions

Building a model of sustainable chemistry



10,213

million net sales



26,000

employees



119

sites



52

countries



15

major R&I centers

Building a strong leader, a player in the reshaping of the global chemical industry. **Asserting ourselves as a model** of sustainable chemistry, capable of attracting and developing talented people who conceive, design and produce solutions to meet the major challenges facing society today.

2014 figures

Our activities

Advanced Formulations



Performance Chemicals



Functional Polymers



Advanced Materials



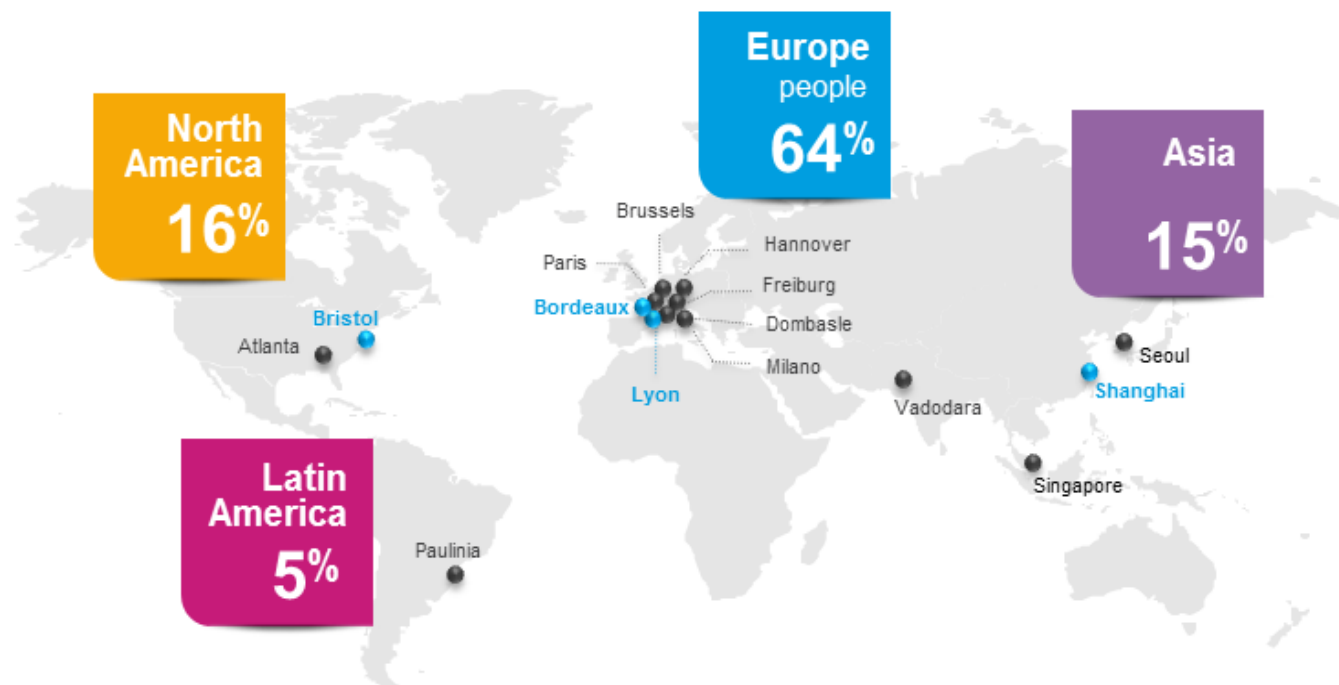
Corporate & Business Services



At the Heart of Global Innovation Ecosystems

Our R&I Network

Enhanced by Open Innovation



1950
Staff in R&I

€ 287 M/y
Efforts in R&I

82%
Of R&I resources managed by BUs

21%
New sales ratio

259
Patents filed in 2014



Target 2016:
30% of REBITDA growth generated by innovation

Open innovation

- 4 Joint labs with top research institutions of France, China and the USA & the French National Center for Scientific Research
- > 100 collaborative R&I Projects
- €55M invested in Venturing & Start-ups

6 R&I areas to meet **the challenges of the future**



Advanced materials

Expertise in polymers and formulations



Eco-designed processes

New processes offering diminished raw materials and energy consumption, and reduced emissions



Sustainable energy

Developing alternatives to fossil fuel consumption: new generation batteries, photovoltaics, bio-energy



Advanced formulations

Creating responsible products that provide solutions to global issues



Organic electronics

Materials to improve the sustainability of lighting devices and screens

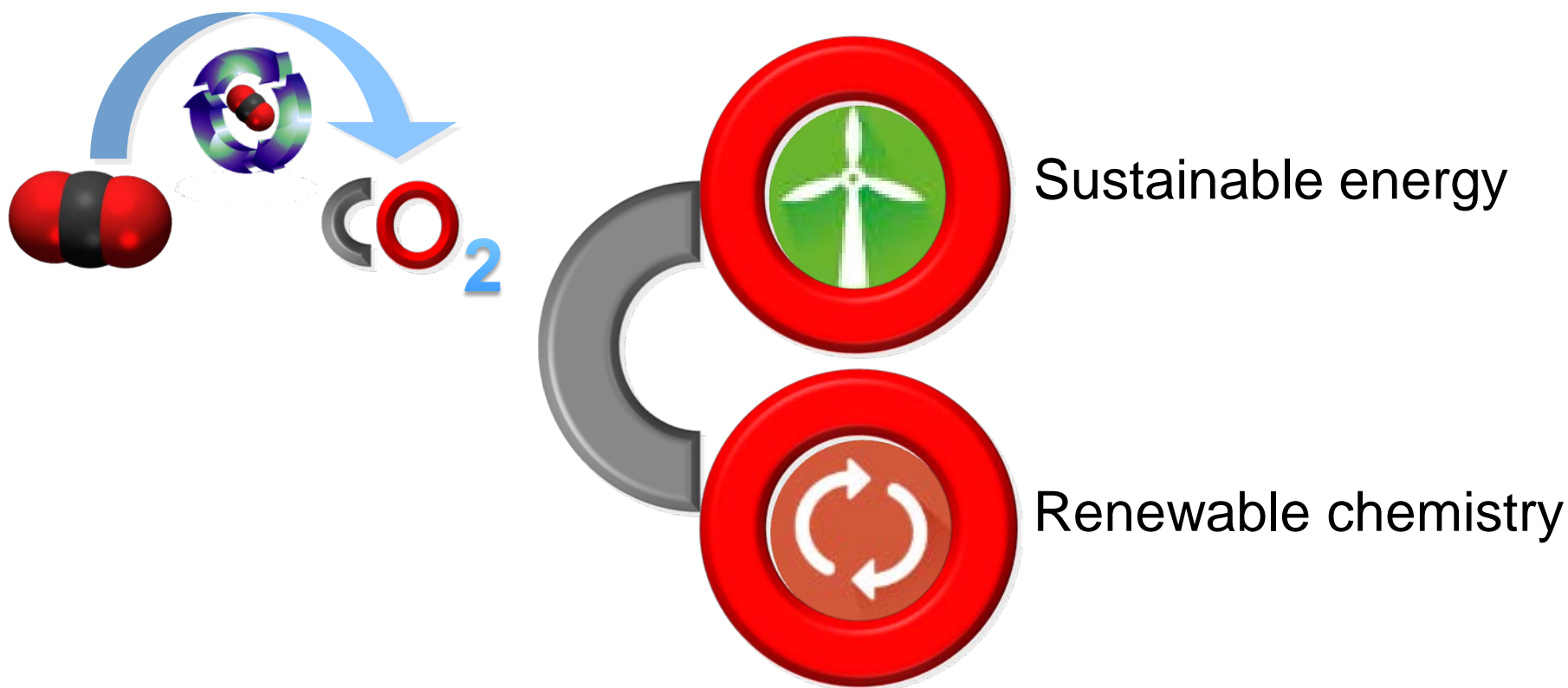


Renewable chemistry

Innovation in renewable or recycled raw materials

One molecule ... Several reuse

2 *Research & Innovation platforms*



Megatrends & definitions



Why carbon reuse is of interest ?

1. Net Reduction of carbon dioxide emissions released to the atmosphere;
2. Positive of other environmental impacts;
3. CO₂ reuse offers complement /alternatives for fossil resources to be used as fuels, chemicals and polymers;
4. Ability to reduce energy dependency by integrating local renewable energy.

*CO₂ reuse can be defined ...
as any process making use of carbon dioxide ???*

Several reuse ...

WITH / WITHOUT

CO2 modifications

Enhanced Oil recovery
~ 66 millions tons a year
USA use since 1973

Food & beverages
~ 15 millions tons a year

Urea : $2 \text{NH}_3 + \text{CO}_2 \rightarrow \text{NH}_2\text{-COO-NH}_4 \rightarrow (\text{NH}_2)_2\text{-CO} + \text{H}_2\text{O}$
~ 36 millions tons a year

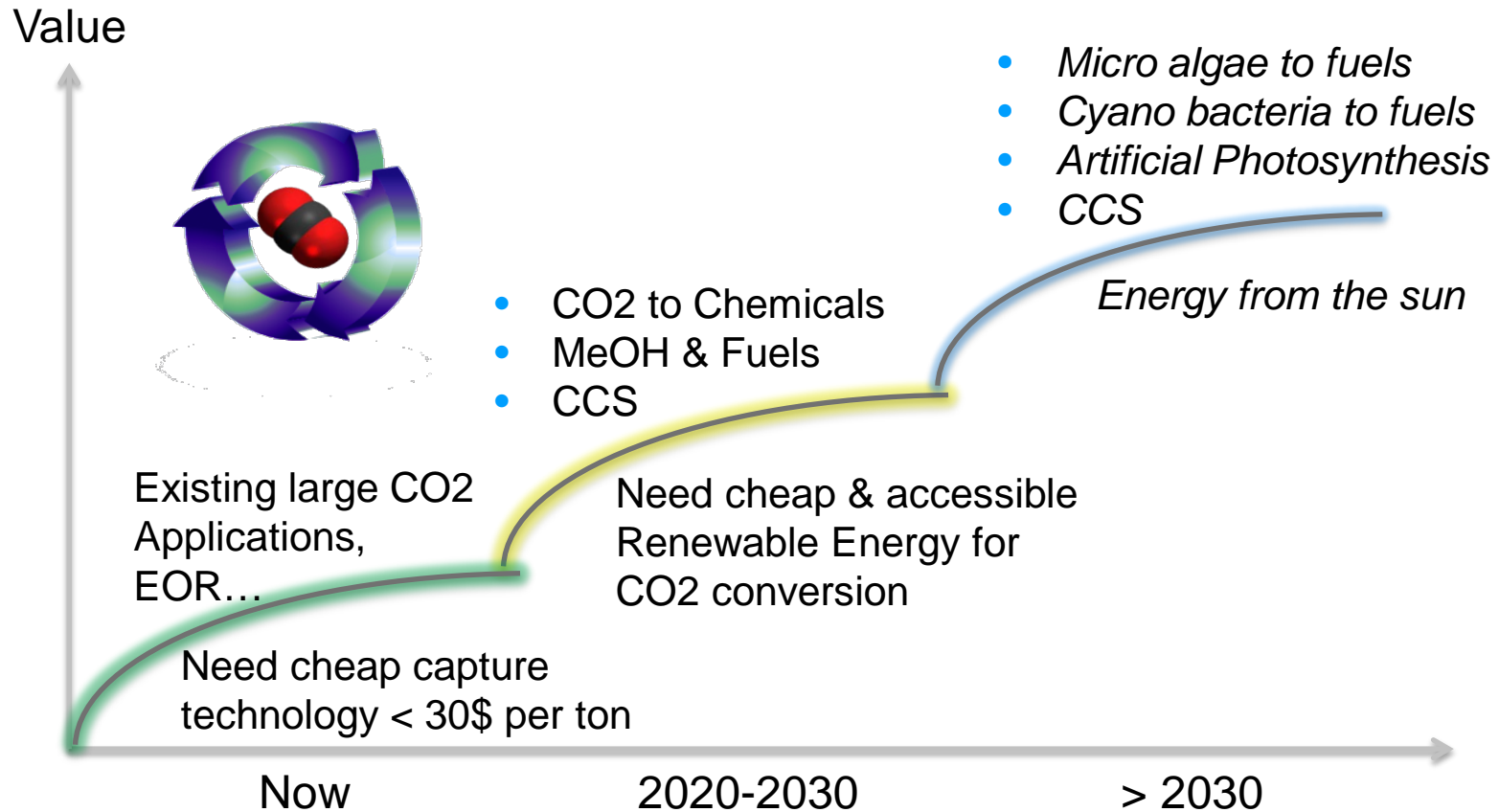
CO₂ reuse could be split in two groups:

1. CO₂ reuse without conversion of the carbon dioxide
2. CO₂ reuse with the conversion of carbon dioxide.

NEW CO2 reuse

CO2 reuse

Future steps & tracks



CO2 reuse Power to gas : methanation

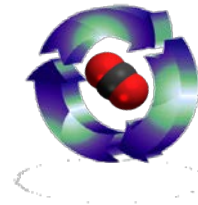
Power-to-Gas: Audi e-gas plant in Werlte (Northern Germany)



Quelle: EME Netz

Audi future lab: mobility

Wersprung durch Technik Audi

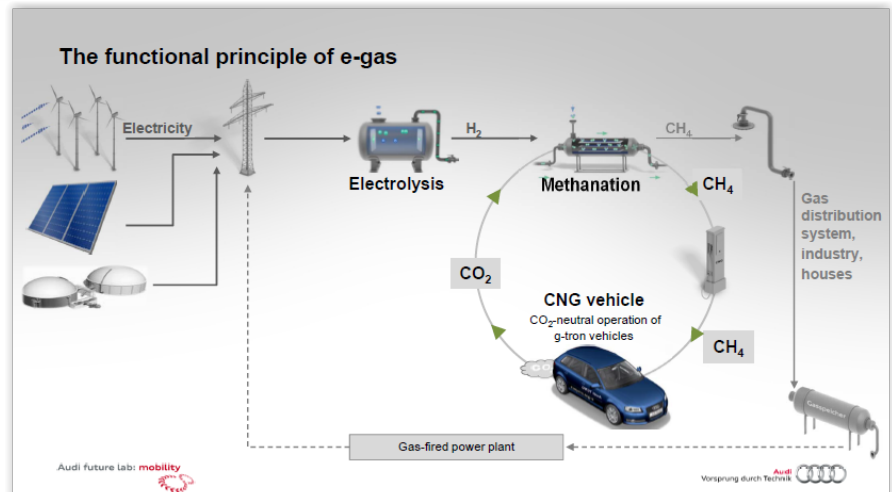


Source :

<http://www.cedec.com/en/events/sections/past-events/cedec-gas-day-27-may-2014-in-verona-italy>

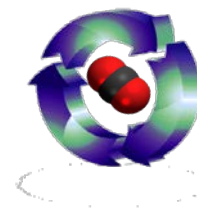
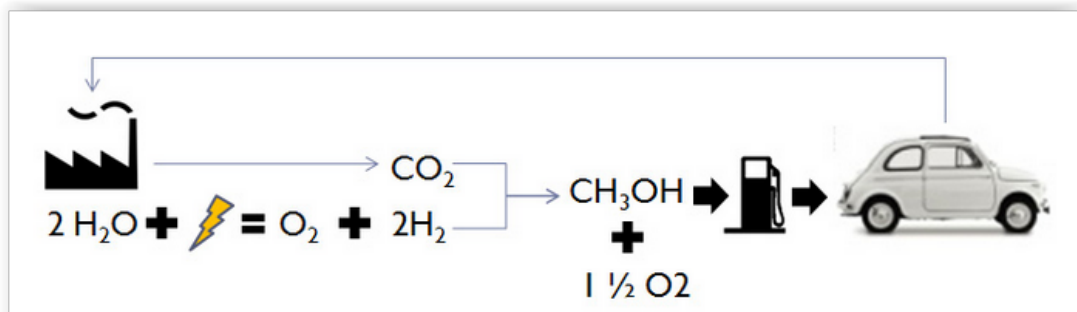
last access 16th March 2015

Methanation of carbon dioxide coming from bio-methane with renewable hydrogen (windfarm)



CO₂ reuse

Power to Liquid : methanolisation



Source : <http://www.carbonrecycling.is/>
last access 16th March 2015



Methanolisation of carbon dioxide coming from geothermal power plant with renewable hydrogen (geothermy)

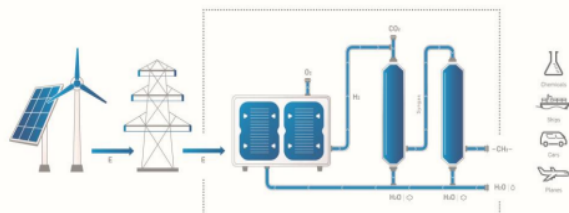


Power to Liquid : Fisher Tropsch

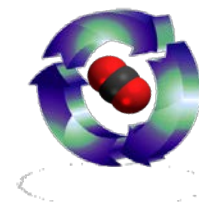
Sunfire

- Alliance of industry and academia
- **Production of liquid fuels from CO₂ and water using renewable energy – Power-to-Liquids**
- Core technologies: High Pressure Steam Electrolysis and Fischer-Tropsch-Process

POWER-TO-LIQUIDS



**Opening of worldwide first
PtL Pilot plant on 14th of
November in Dresden**



Source :

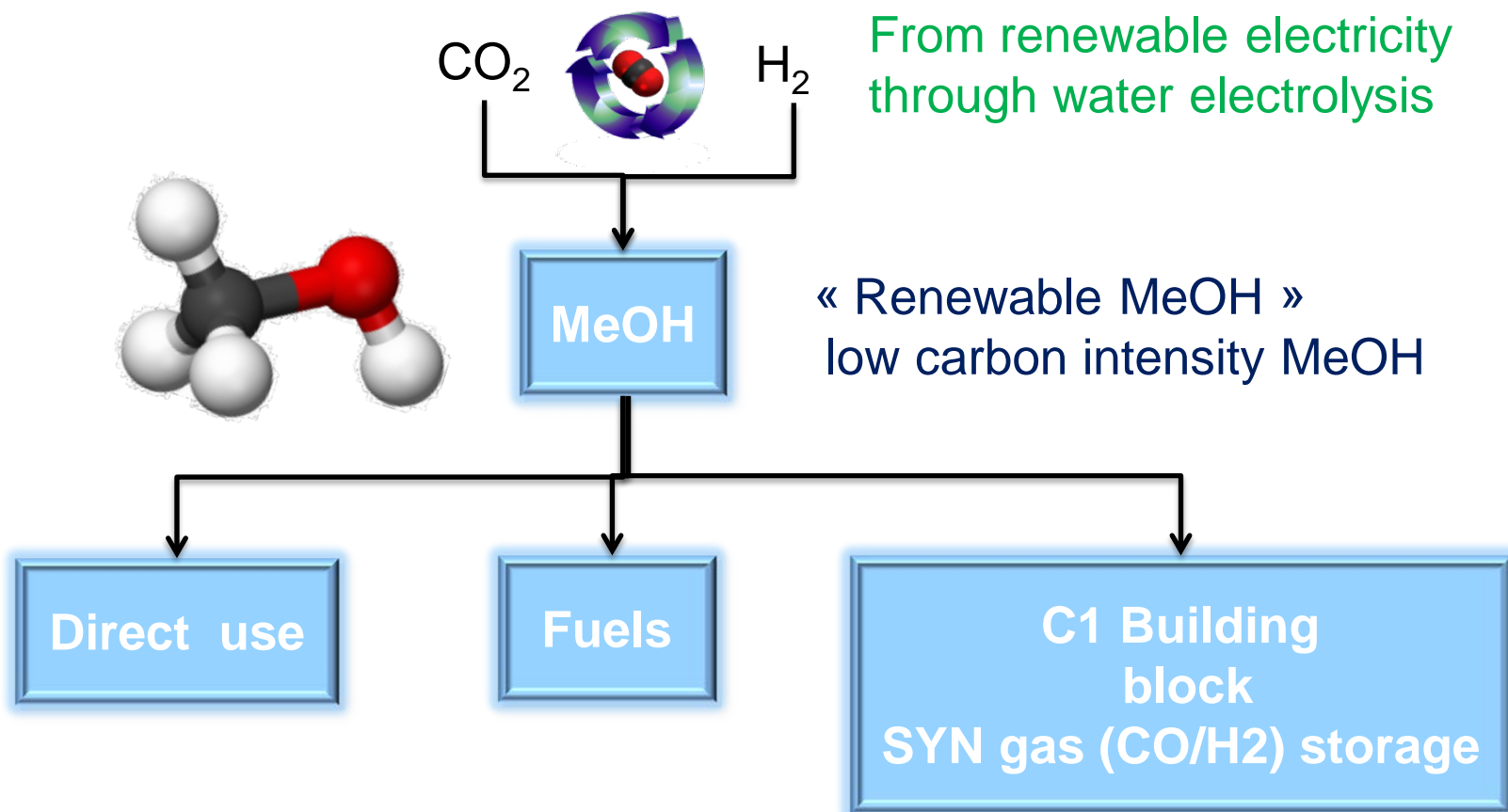
http://unfccc.int/files/bodies/awg/application/pdf/03_germany_angelina_prokofyeva.pdf

Last access 16th March 2015

Fisher Tropsch technology with carbon dioxide coming from atmospheric capture with renewable hydrogen (windfarm)



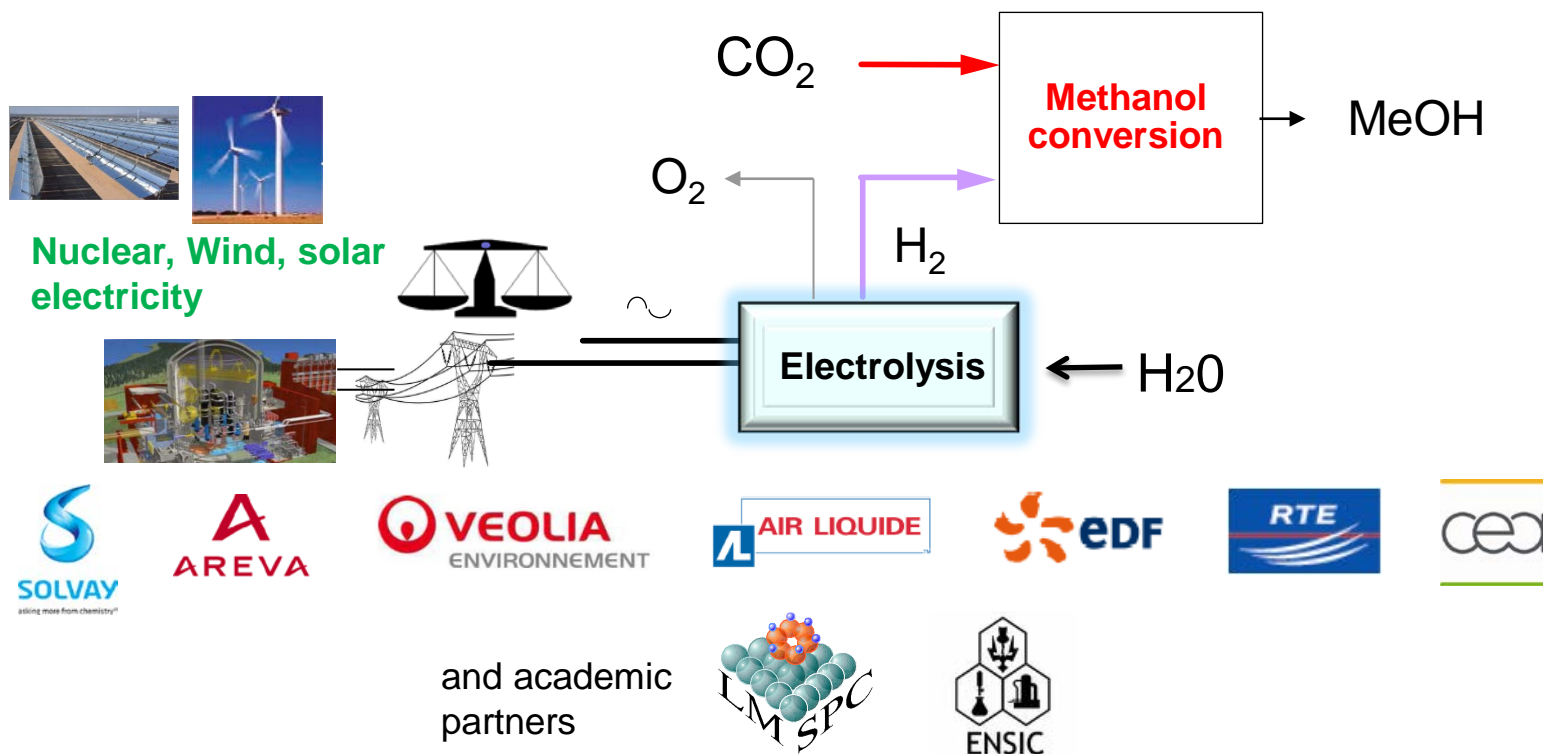
METHANOL as useful C1

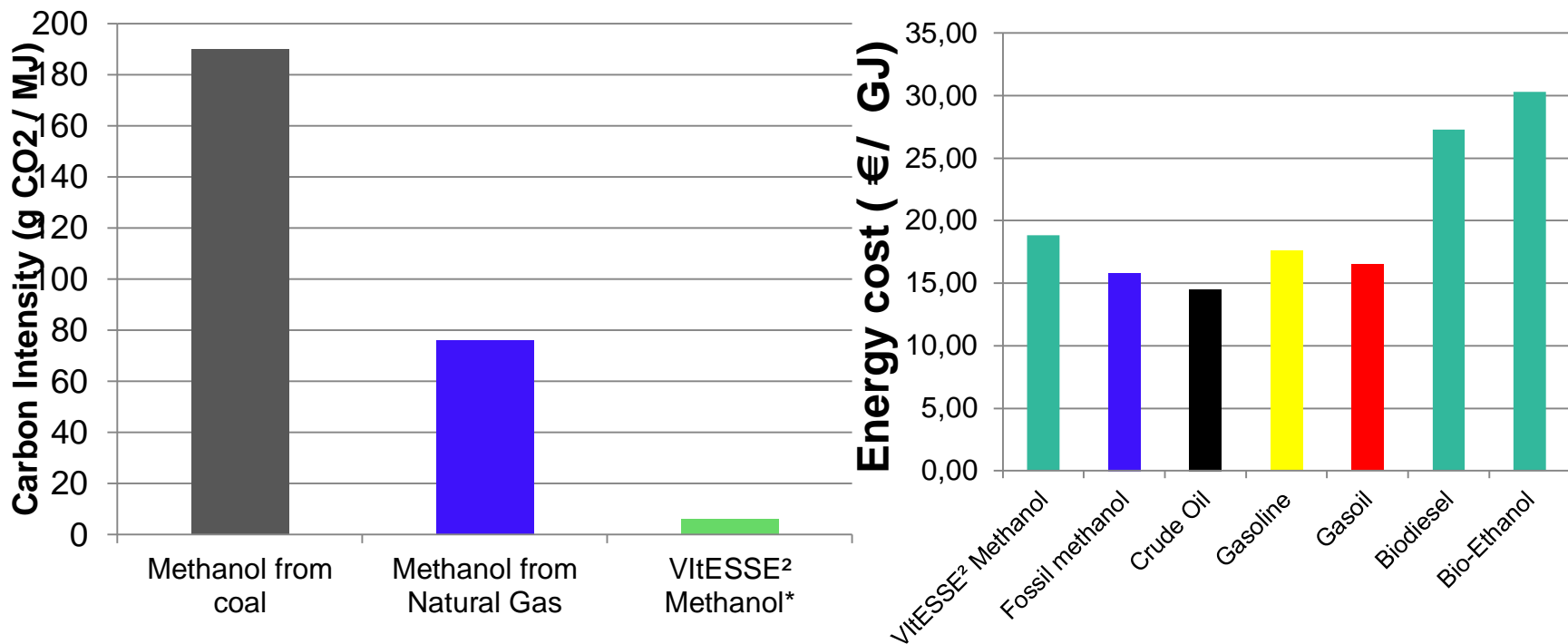


CO2 reuse

VITESSE² Consortium

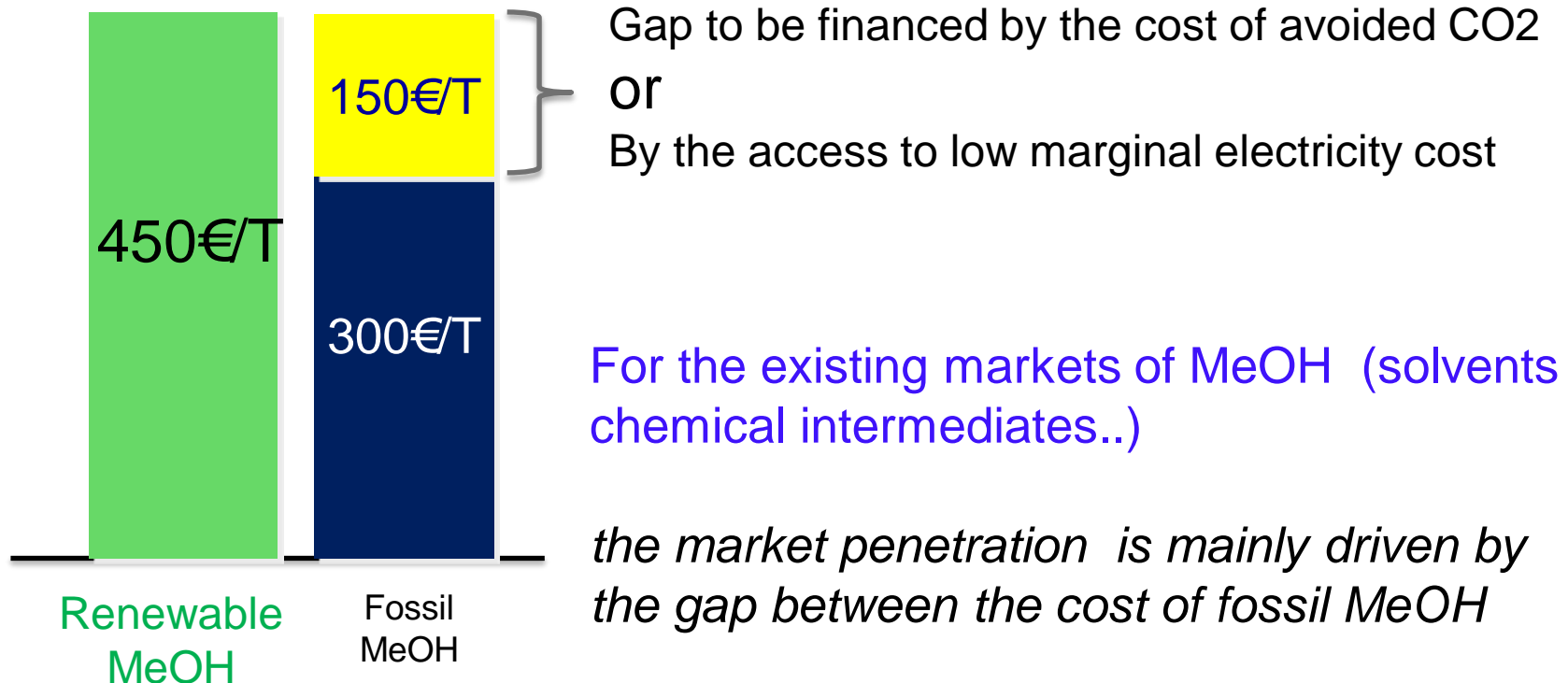
Conversion of CO₂ into MeOH and fuel, using H₂ produced with the excess of decarbonated electricity (Nuclear, Renewables) vs grid consumption

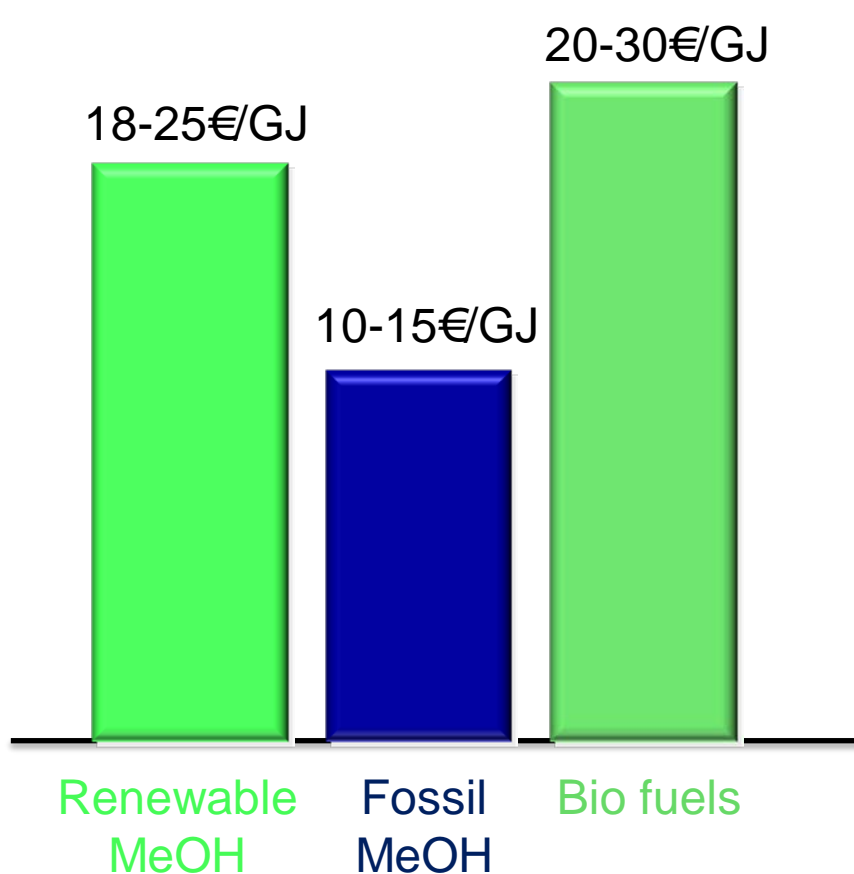


ECONOMICS

Lowest Carbon Intensity but...

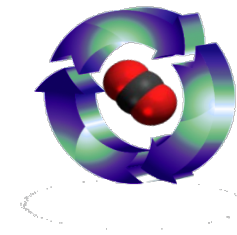
...More expensive than fossil MeOH while could be competitive with other renewable Fuels

Chemical MARKETS

Fuel MARKETS

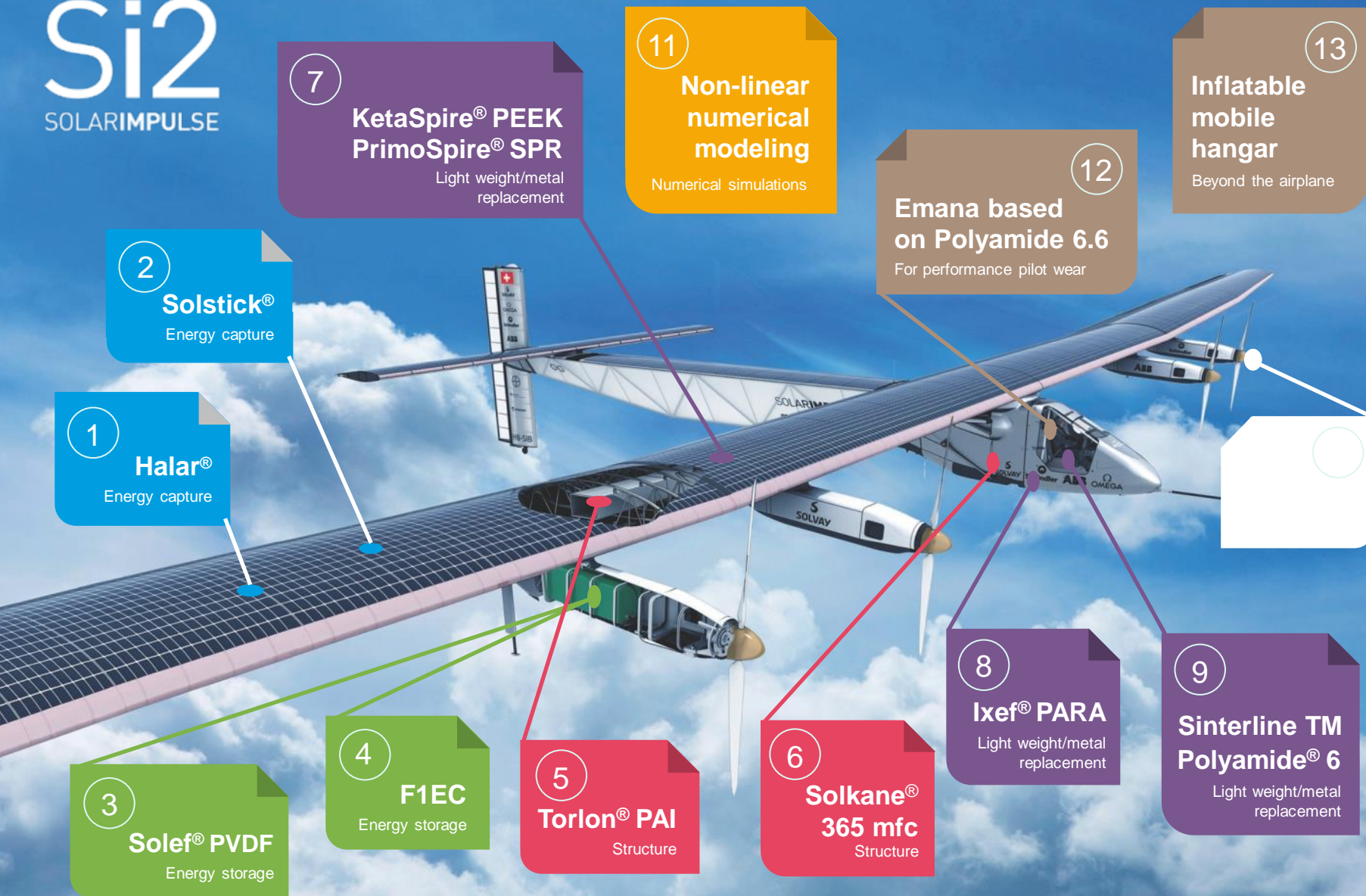
Challenges :

- ✓ incorporation into the gasoline: Direct Blending MTBE, Transesterification
- ✓ Regulatory scheme to compete vs biofuels (EU transport directive)
- ✓ Drop in existing fuel from Renewable MeOH (MTG)
- ✓ Development of new fuels (ex DME) need adaptation of the transport industry



Promising tracks for CCU carbon dioxide reuse

- CCU Industry already exist mainly in current applications of CO₂ and can be boosted by cheap CO₂ capture technologies
- The next development horizon will be triggered by CO₂ transformation, already emerging, but limited by the energy required. MeOH to fuels being the largest pathway
- Possible competitiveness vs Biofuels but require solutions ... for the incorporation and the compatibility with fuels (Drop in to new fuels)



Thank you for your attention



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