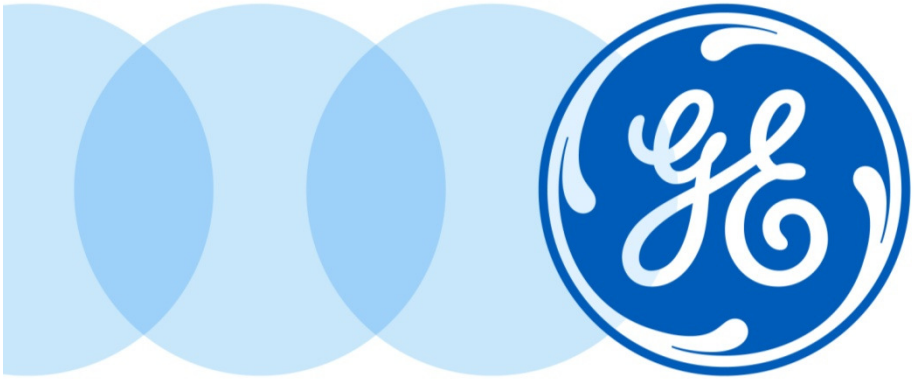


Renewable energy driven CO_2 utilization and decarbonization

M. Bialkowski, G. Guidati, G. L. Agostinelli

November 27, 2015

Imagination at work

Three key elements in the decarbonization strategy

- "Capture" and "bury" or "utilize"
- The multiple nature of the CO_2 sources
- The variable nature of the growing renewable generation

The old problem – CO_2 availability and New carbon feedstock

Too much CO_2 and not enough sufficient sinking capacity

- ~33.4 billion metric tones of CO_2 is emitted yearly
- Currently CO_2 price from power-CCS is 3-4x more expensive than the one in the CO_2 market

The industry can only access five carbon sources

- Natural gas, Crude oil, Coal, Biomass, CO_2.....
- … and carbon feedstock of today's production routes is cheap.

Some products from CO_2 – market and 'sinking capacity'

Chemical/ Product Application	Annual Market [mMt/yr]	Mt CO_2 used per Mt Product	CO_2 sinking capacity (based on the market size) [mMt/yr]	Comments
EOR	80	3	80	Exist. Non-captive CO_2.
Urea	100	70	73	Exists. Saturated market
Methanol	45	14	62	Exists. Competes with bio-methanol
Formates/formic acid	>1.5	1	2	Further growth by Fuel Cells
Inorganic carbonates	80	30	5-6	Exists. Needs "alkalinity" donor
Organic carbonates	2.6	0.2	1-2	Developing and promising market
Poly(urethanes	10	<10	10	Developing. Ply(carbs) not included.

Emerging market interest in CO_2-use

EOR is by far the highest CO_2 consumer: > 80 MT/yr

"Green plastics" demand grow by 13% and by 2019 will generate the market value of B$3.5

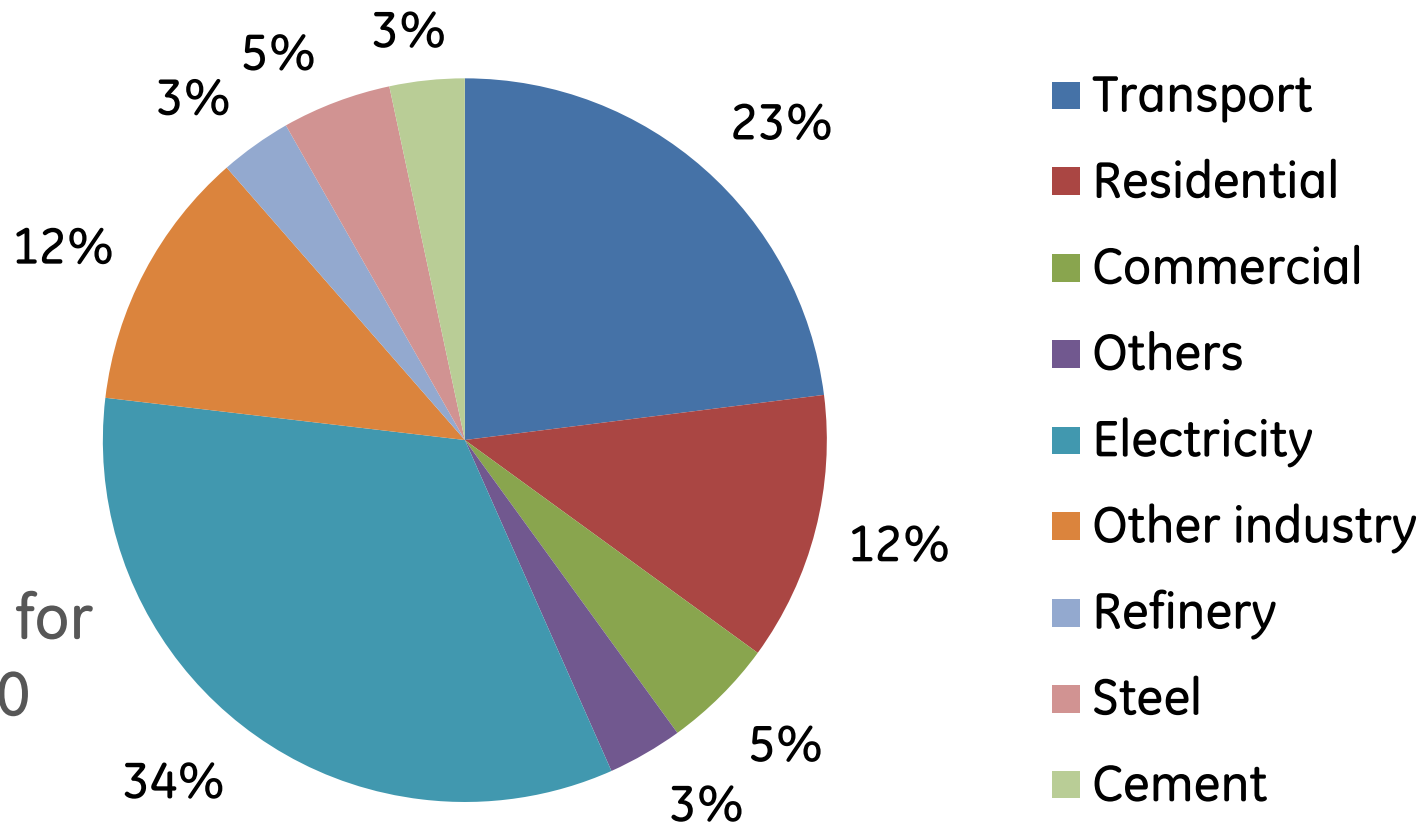
"Eco friendly materials" predicted growth is B$7 (2018)

Renewable alcohols will generate the market value of B$83.4 by 2018

Power-to-methane could absorb 20-40 TWh to store electricity (0.04 TWh stored today)

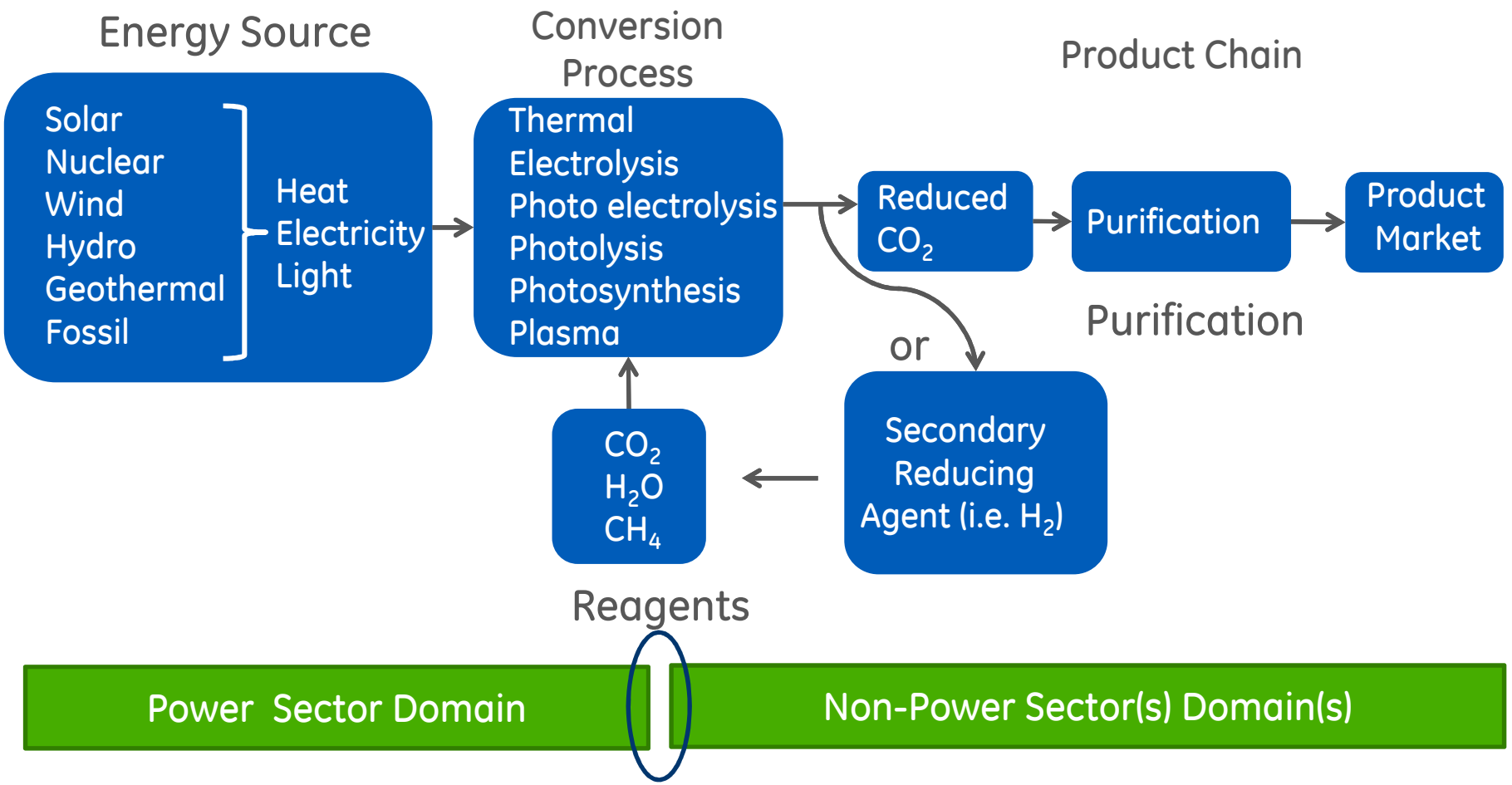
Two key elements - The multiple nature of the CO_2 sources

CO_2 emissions for EU27 in 2010



SANDIA, US

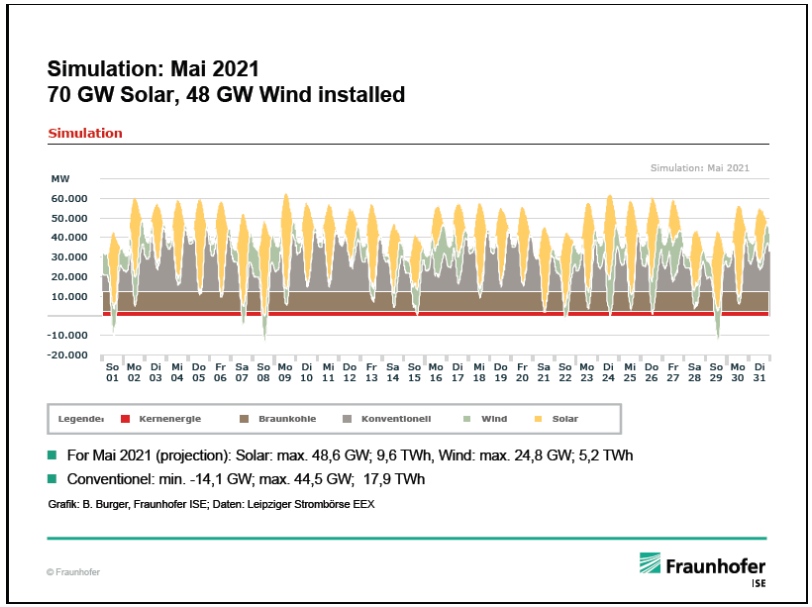
CO_2 Utilisation Pathway Map



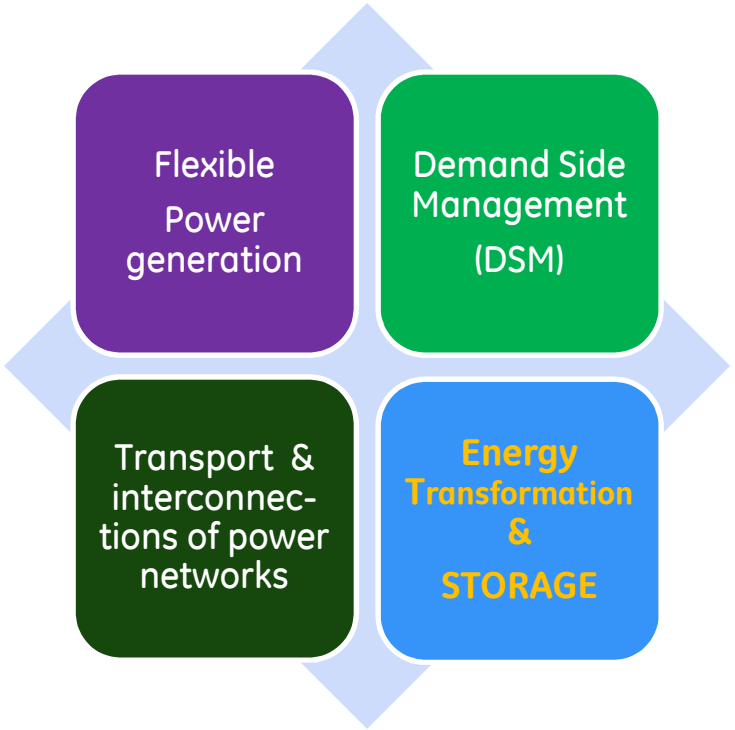
The variable nature of the growing renewable generation - How to integrate them?

Grid operators must offset power generation from wind and sun in a way that leads to the following, 4 pillars to integrate variable renewables

*Power **generation** = Power **consumption***

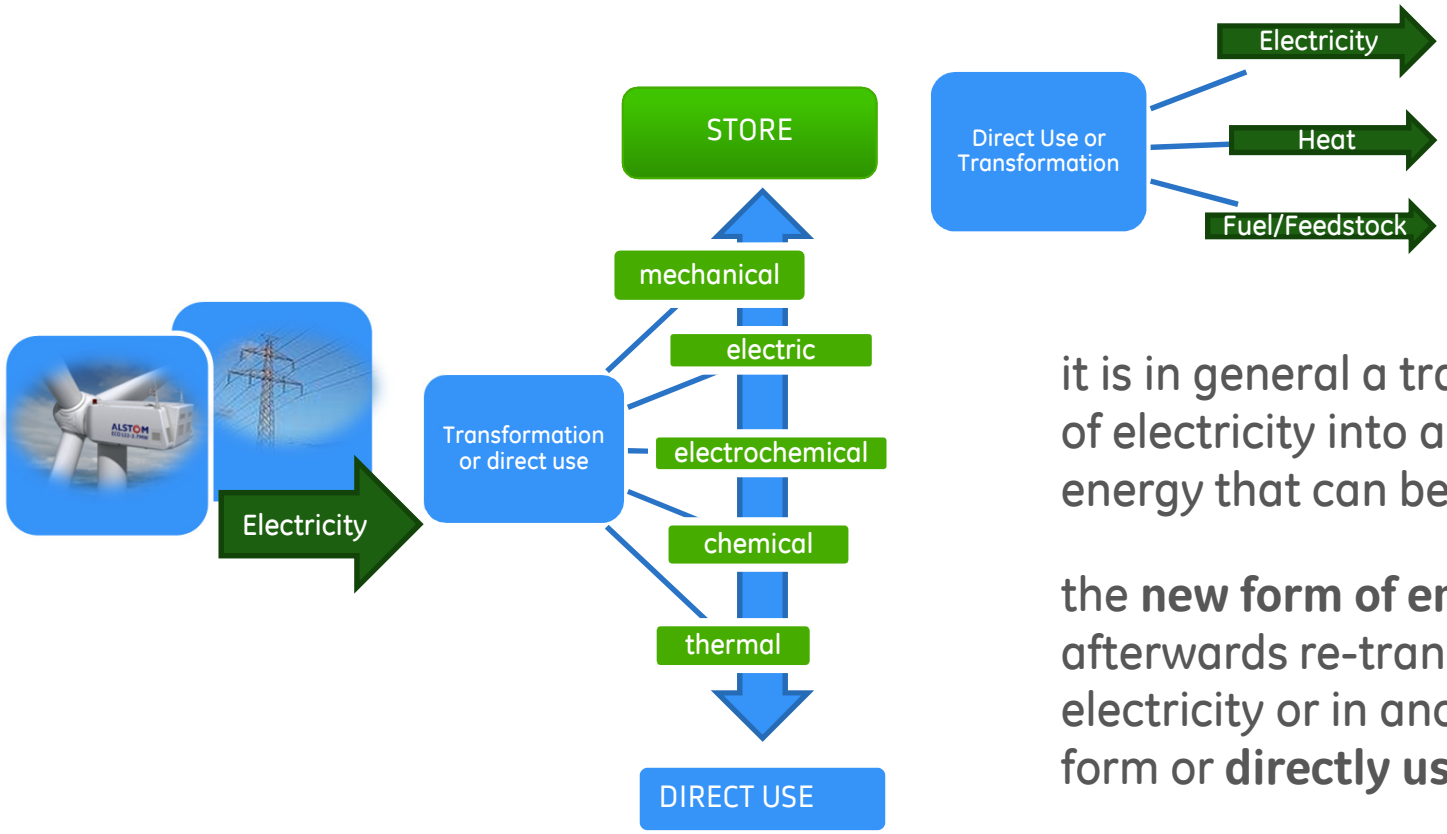


Variable .... Buffering ... Storing



Energy storage means transformation

Energy Storage is a temporary relocation of energy to help aligning generation and consumption, offer and demand.

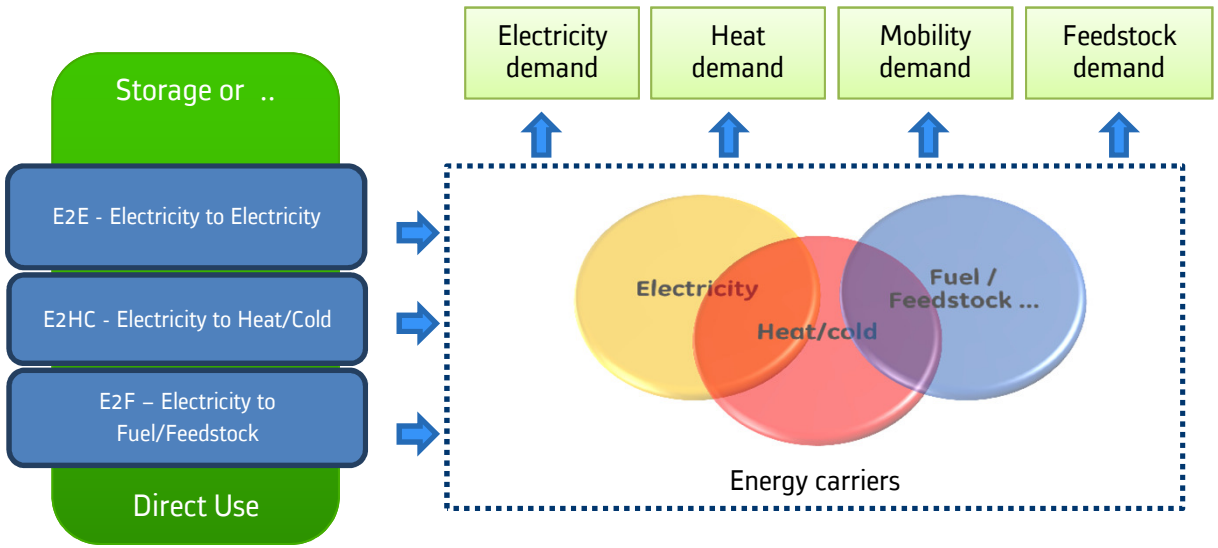


it is in general a transformation of electricity into a form of energy that can be stored

the **new form of energy** can be afterwards re-transformed in electricity or in another useful energy form or **directly used as it is**.

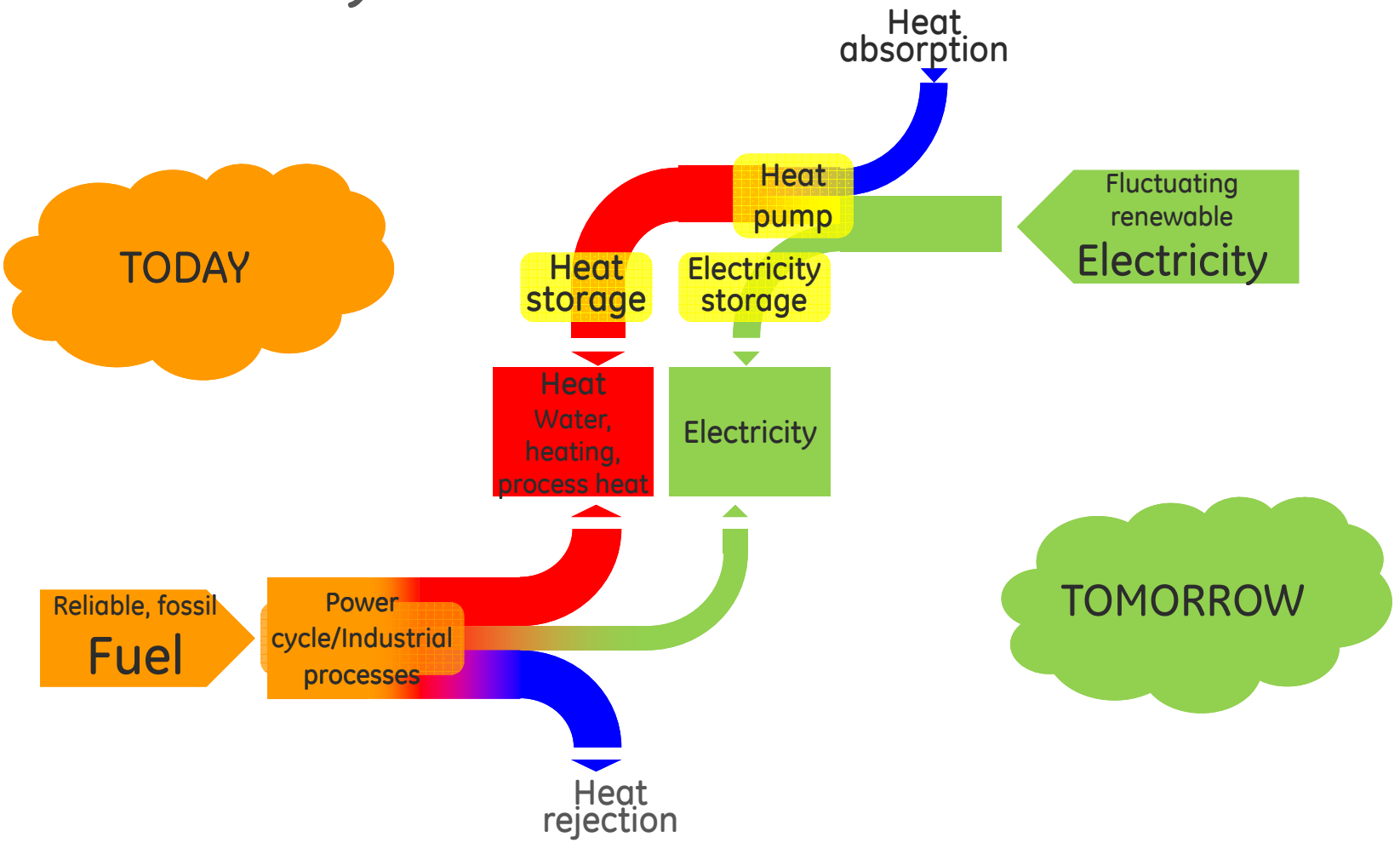
Energy Transformation and energy carriers Powering everyone , powering everything

Energy carriers and interconnections of energy grids to feed energy demands

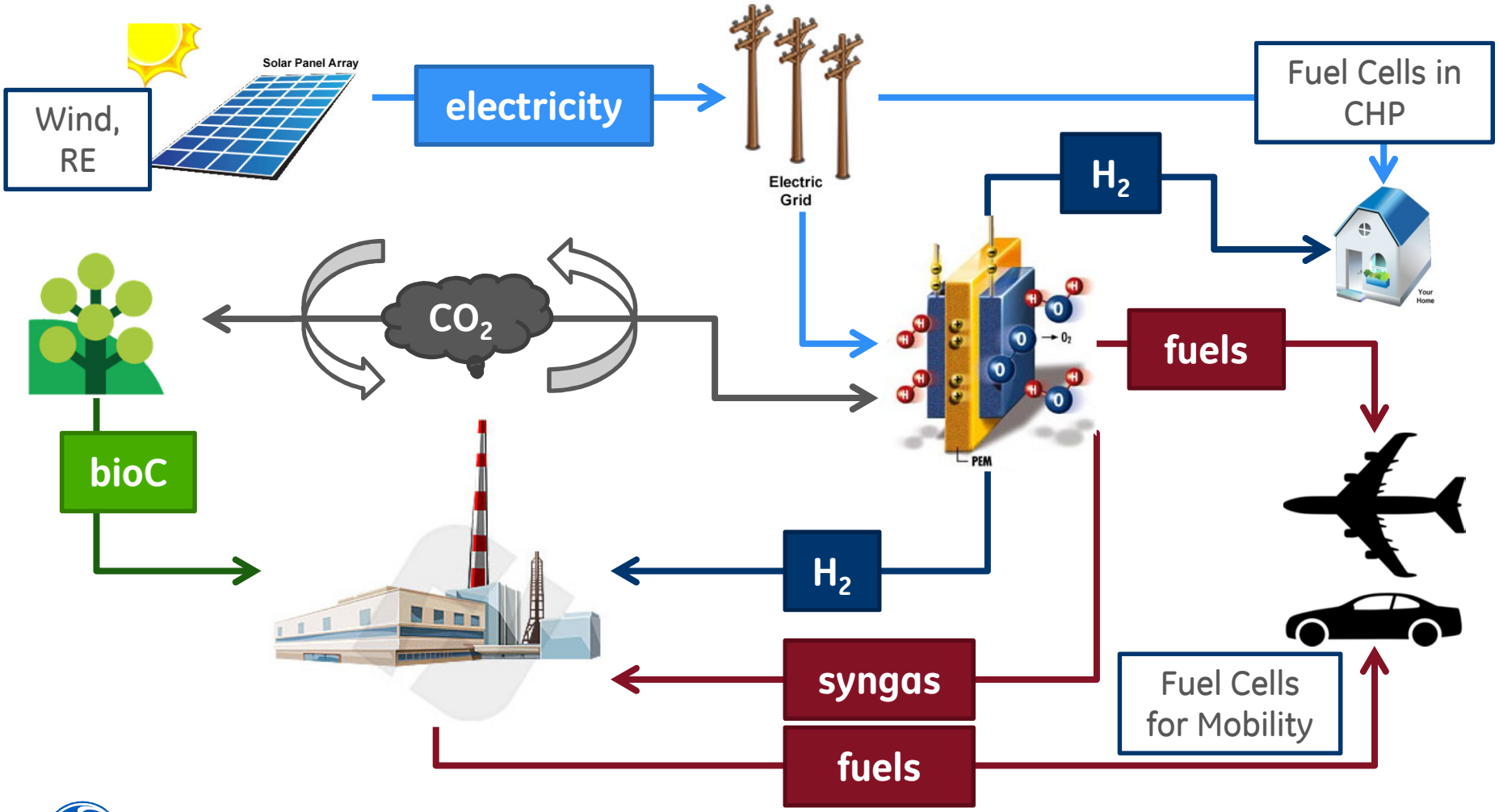


This means also industries will be more and more interconnected into a energy ecosystem

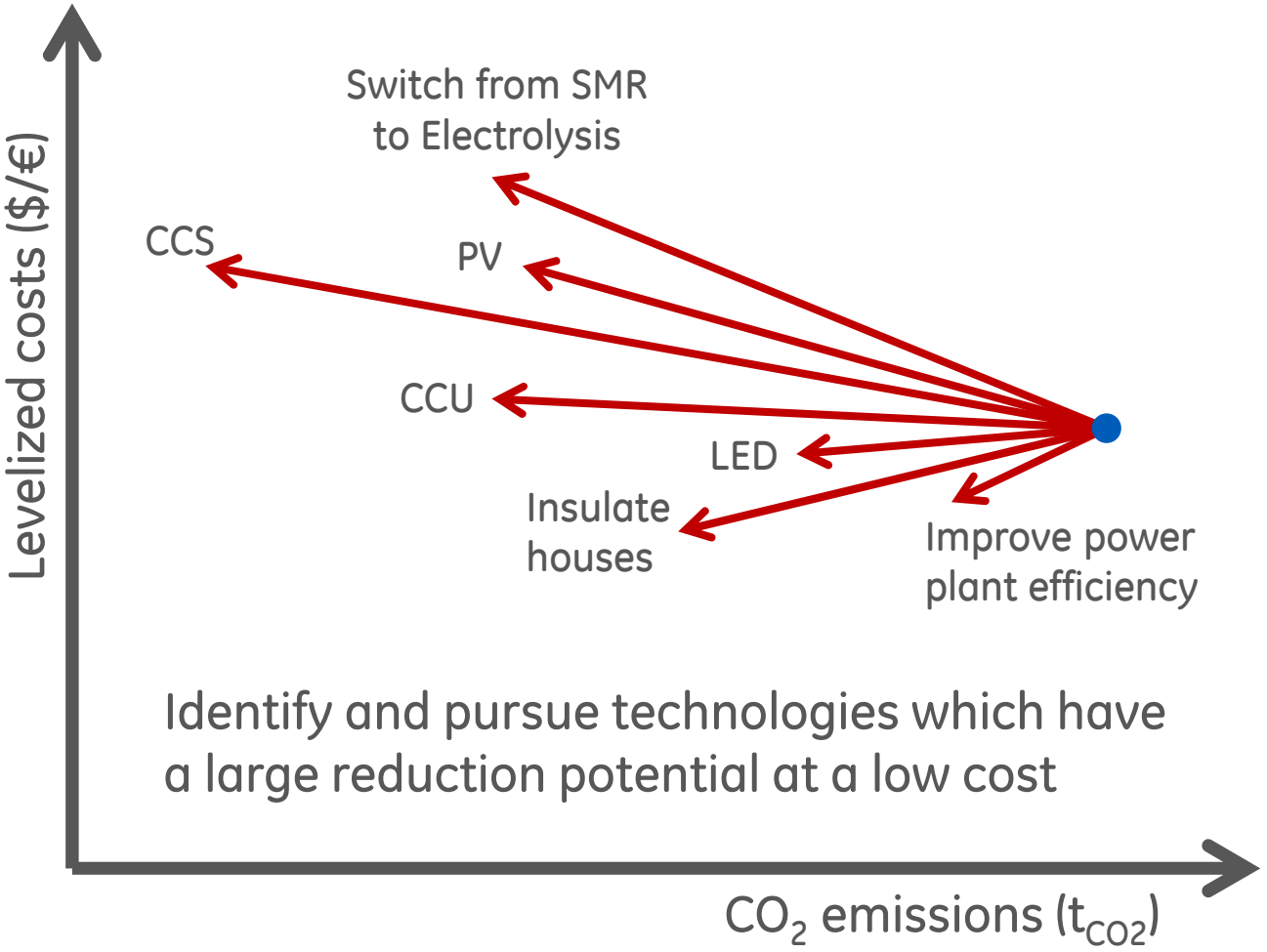
“Today’s” thermally driven processes harvest little electricity but “Tomorrow” will be different



Future systems with CO_2 valorized by green electricity as carbon feedstock

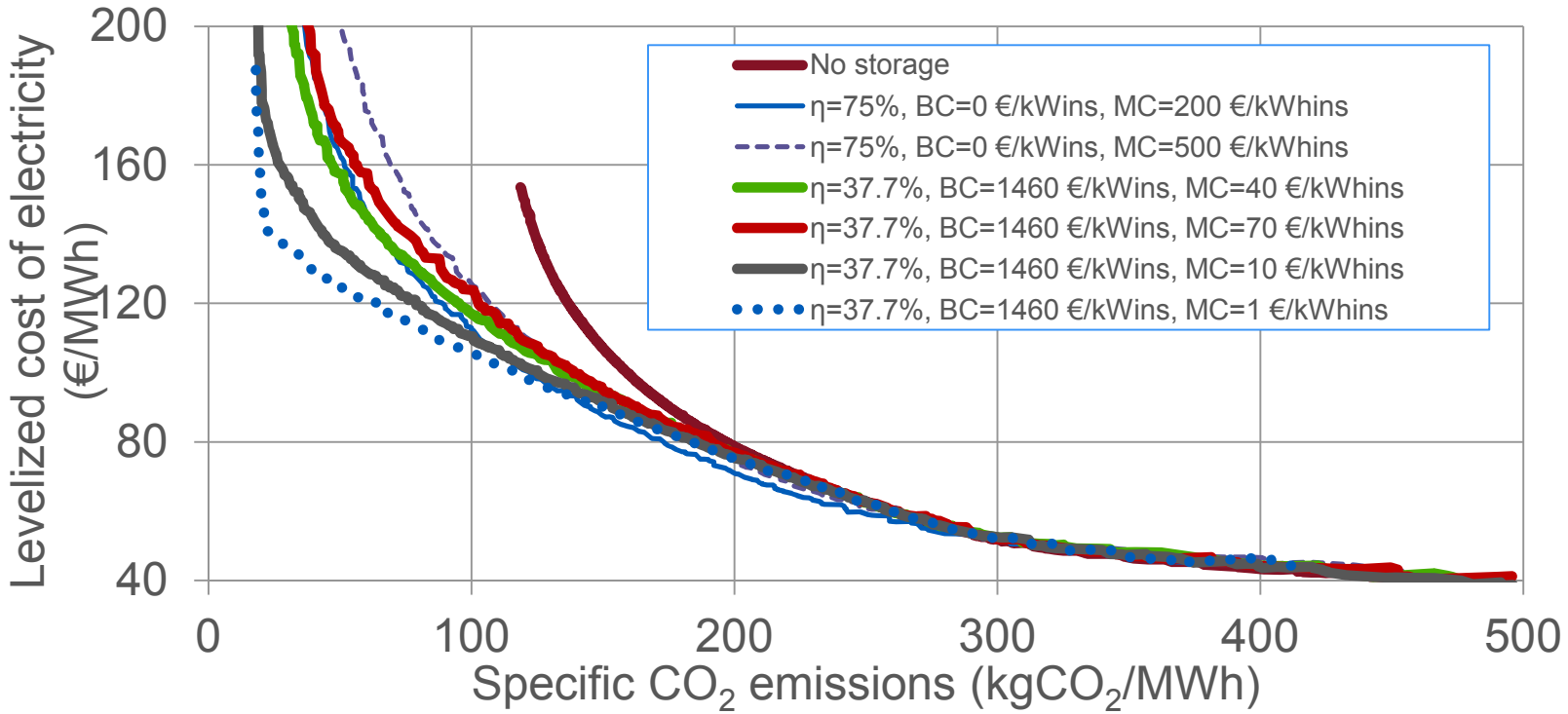


How to measure cost effective decarbonization?



Importance of storage when renewables increase their share

Impact of base cost and marginal cost on LCE



Carbon as vector

- Carbon is everywhere
- CO_2 is part of many processes
- Integration of Electricity to displace/reutilize CO_2 will be more and more a reality
- Many opportunities by using H_2 , CO_2 , syngas → Powering everything

Summary

Variable nature of the growing renewable generation is seen as a main driver for decarbonisation

- “Storage” capability of CCU is limited by the market and carbon lifetime of the products.
- Industries need to take advantage of energy ecosystem interconnection .
- Energy storage and electrochemical CCU as solutions to lower carbon footprint.