CO_2 UTILIZATION BY ETHANOL PRODUCTION IN THE CEMENT INDUSTRY

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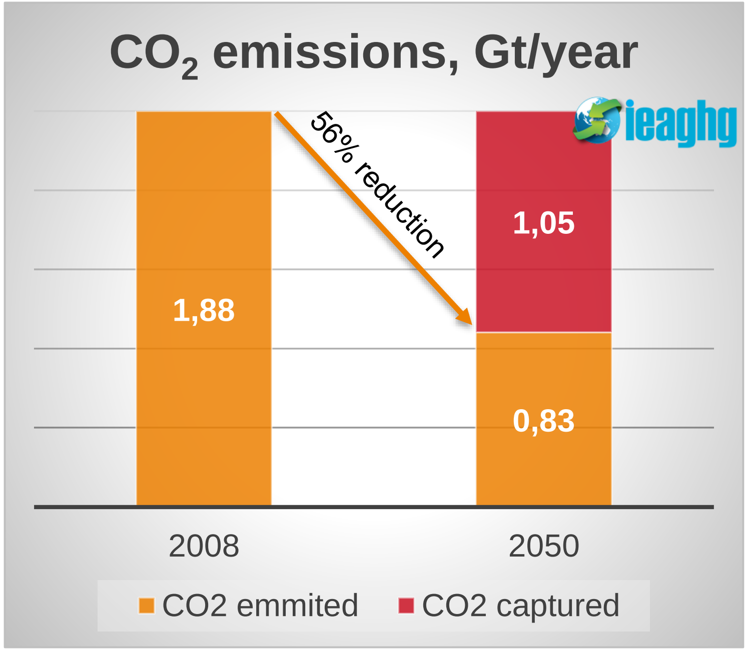
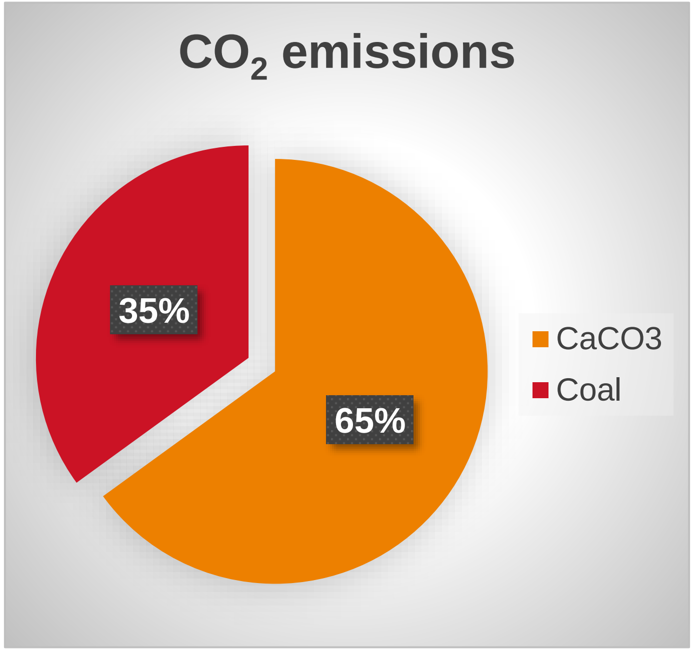
TNO innovation for life

Trondheim CCS Conference
CO_2 Capture, Transport and Storage

June 2017

THE CEMENT INDUSTRY





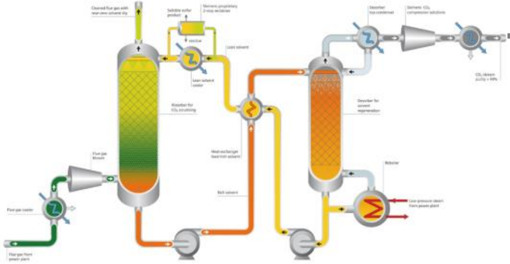
THE CEMCAP CONTEXT (1/3)

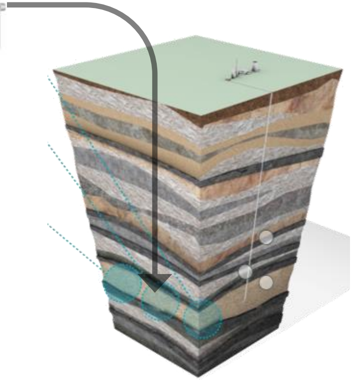
- WP3: CEMCAP Framework
  - Reference case: Best Available Technique (BAT) standard
  - Representative size for a European cement plant
  - Cement production of 1.36 Mt per year
  - Heat and mass balances available

THE CEMCAP CONTEXT (2/3)

- WP4: Comparative capture process analysis, D4.2
- Economic Key Performance Indicators

CO_2 compression to 110 bar





MEA 30wt%

THE CEMCAP CONTEXT (3/3)

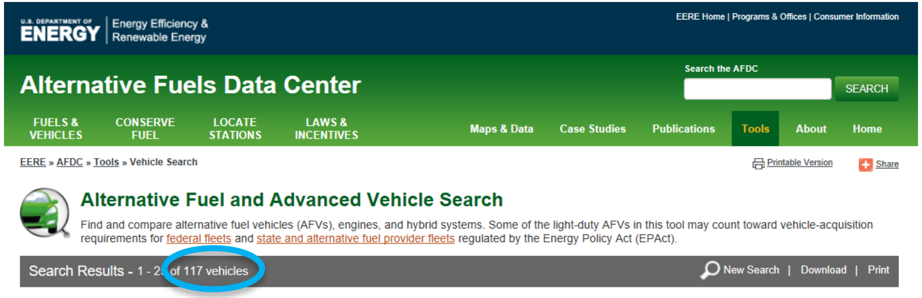
- WP5: Post-capture CO_2 management (CCUS)

  1. CCS: Geological sequestration: option to be defined (TNO)
  2. CCS: Mineralization to $MgCO_3$ (ETH Zurich)
  3. CCU: CO_2 hydrogenation to ethanol (TNO)
  4. CCU: CO_2 polymerization to Poly(propylene carbonate) (TNO)
  5. CCU: food-grade CO_2 (TNO)

ETHANOL

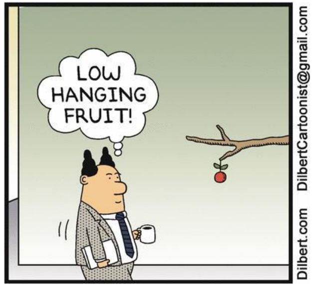
WHY ETHANOL?

- Fuel → large market 110 billion liters per year
- Potential for CO_2 utilization = 166 Mton CO_2 per year
- 195 BAT cement plants
- Market has potential to increase: drop-in fuel



WHY ETHANOL?

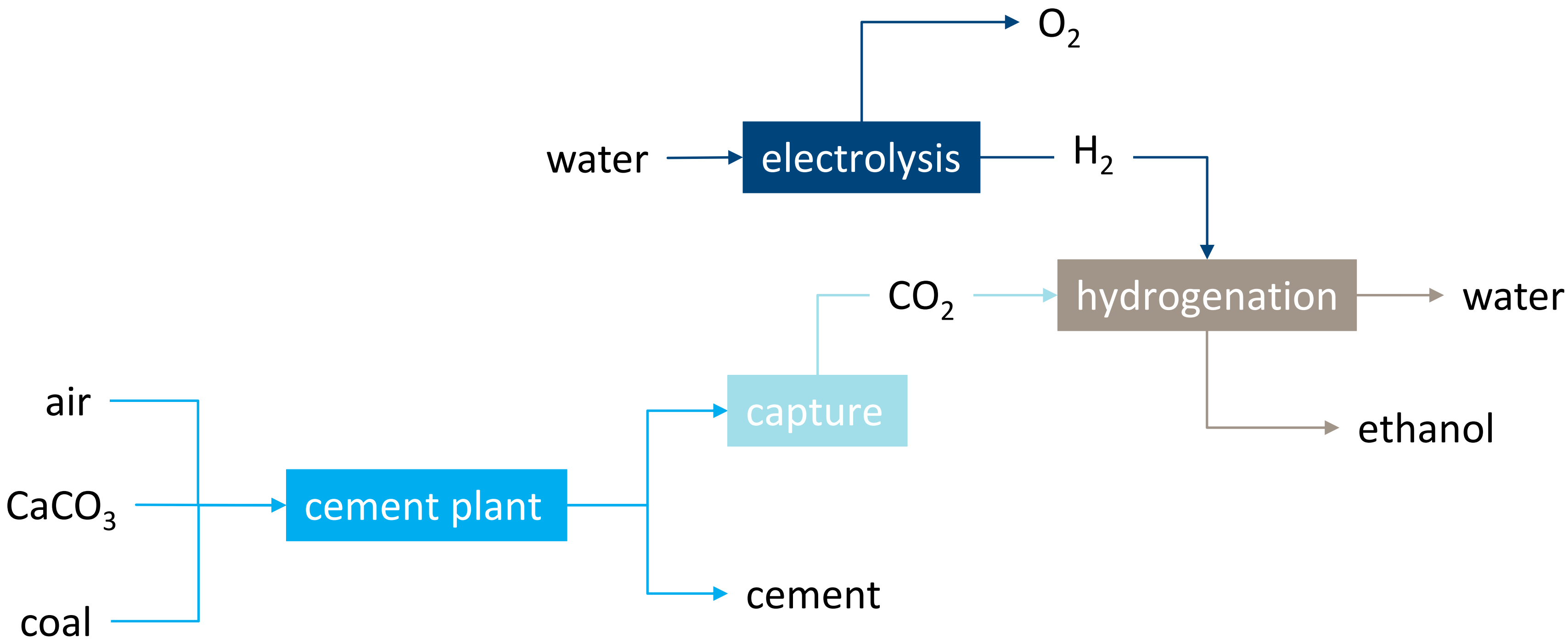
- Community already looking into methanol and methane



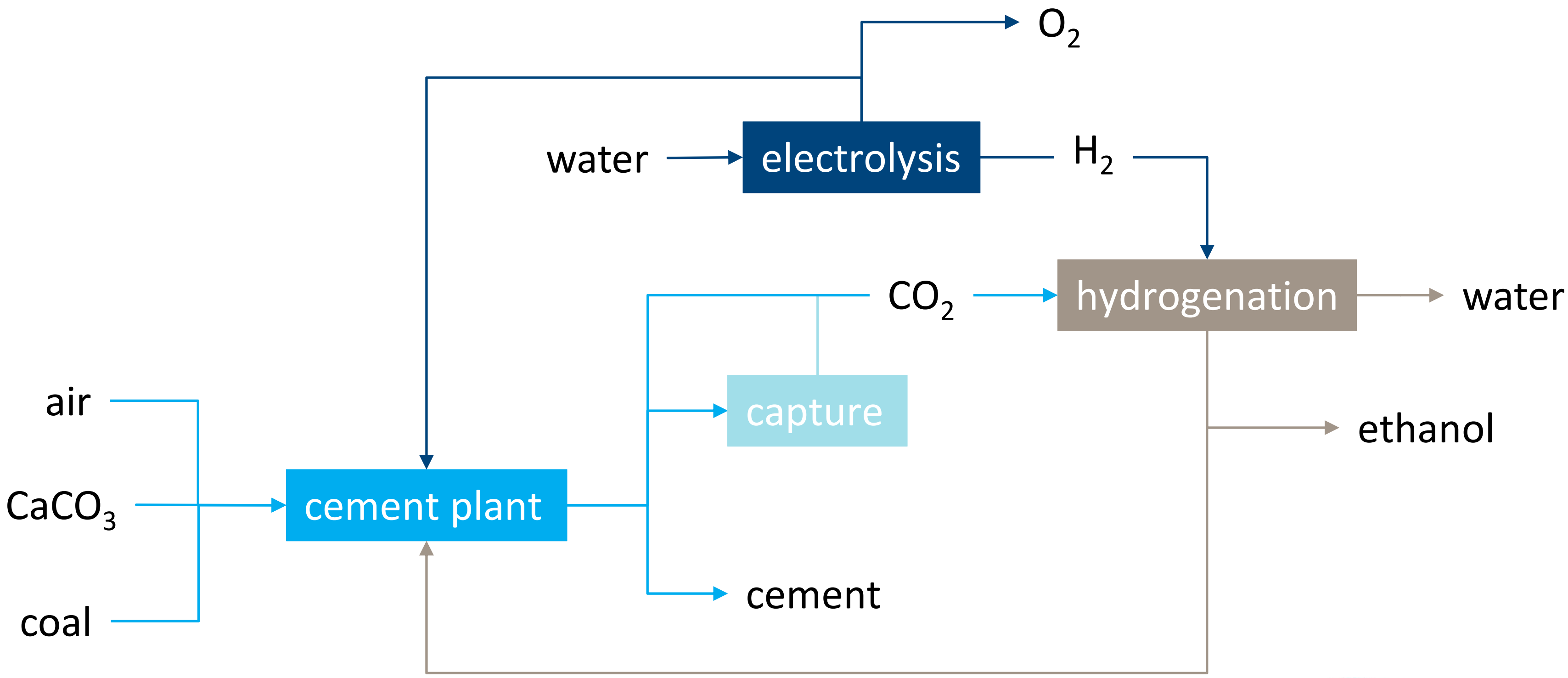
- Ethanol has a higher price

INTEGRATION

PROCESSES


O2
water
electrolysis
H2
CO2
hydrogenation
water
air
capture
ethanol
CaCO3
cement plant
coal
cement

INTEGRATED PROCESSES



COMPARING FUELS

	Coal	Ethanol
Calorific value, kJ/kg	27150	29700
C content, %wt	69	52
Calorific value, kJ/kgC	39450	59925

Burning ethanol generates 40% less CO_2

INTEGRATION

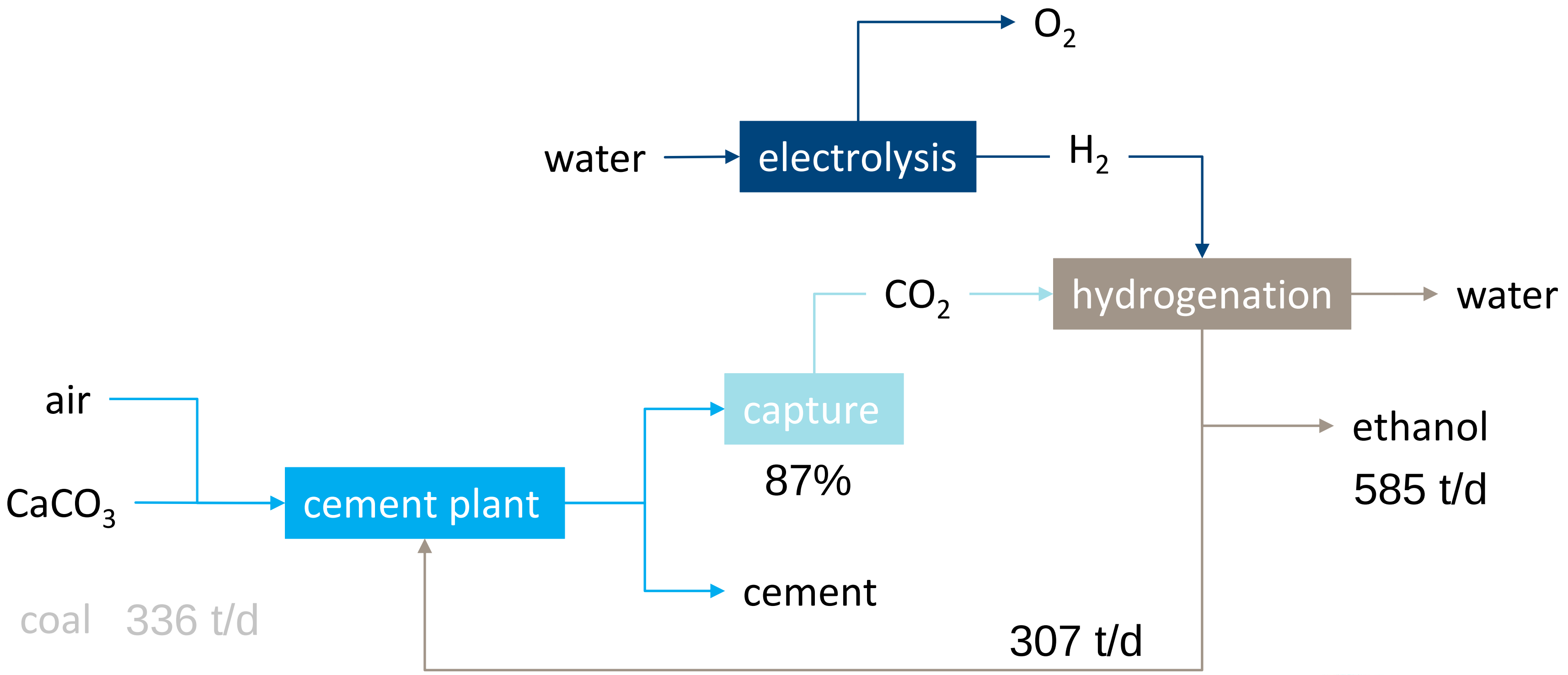
- Various possibilities

- What about feasibility?

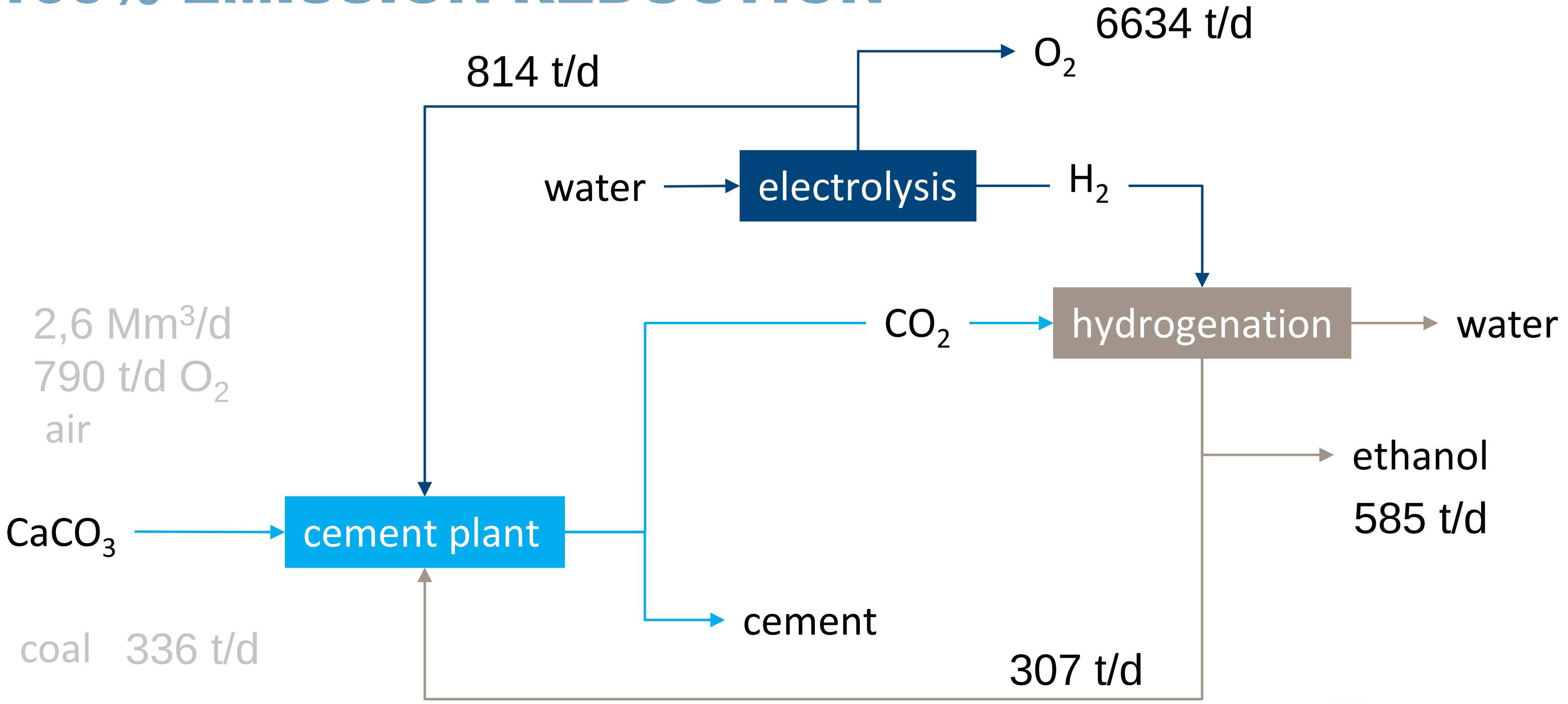
HEAT AND MASS BALANCES

innovation for life

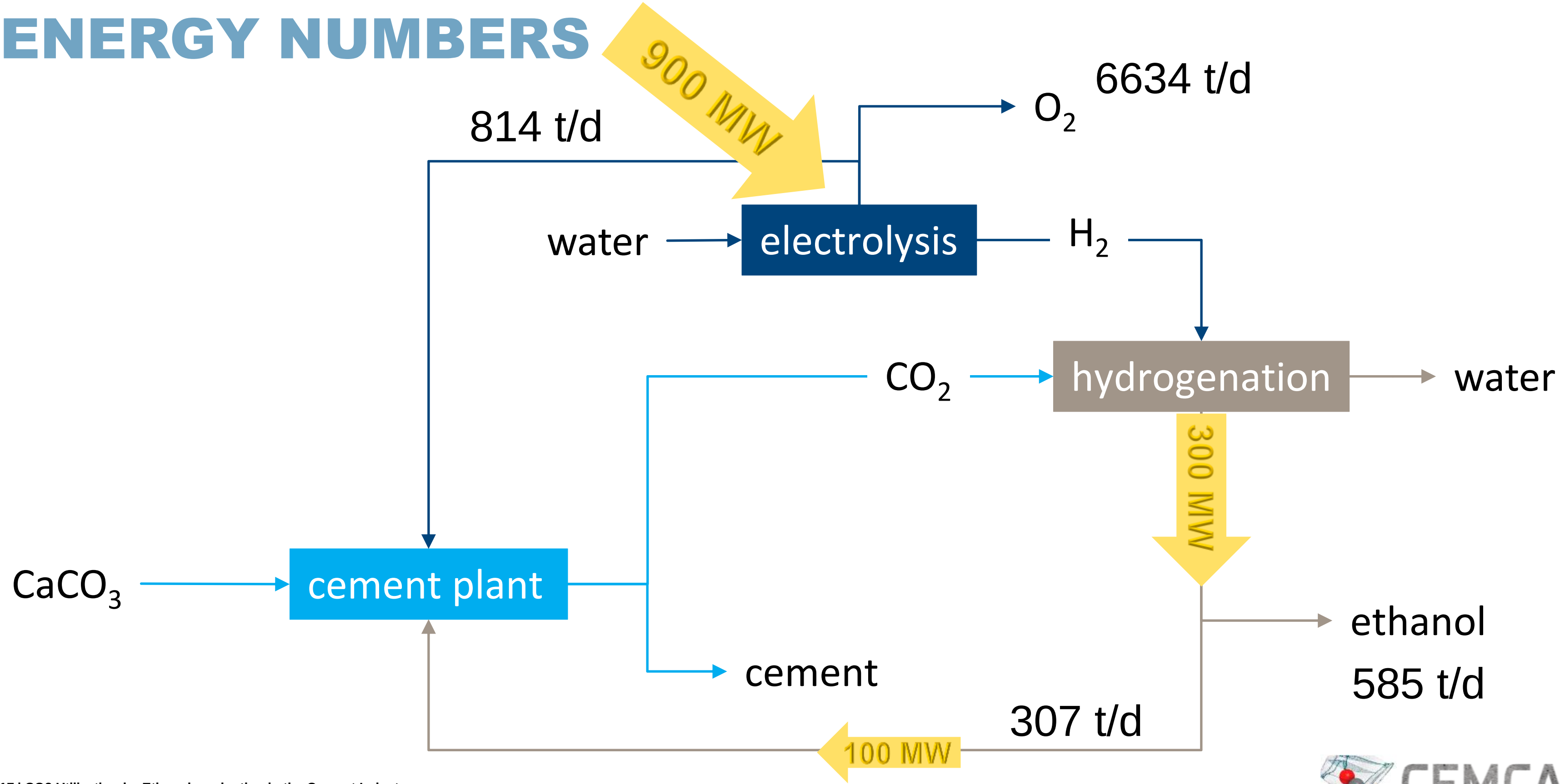
90% EMISSION REDUCTION



100% EMISSION REDUCTION



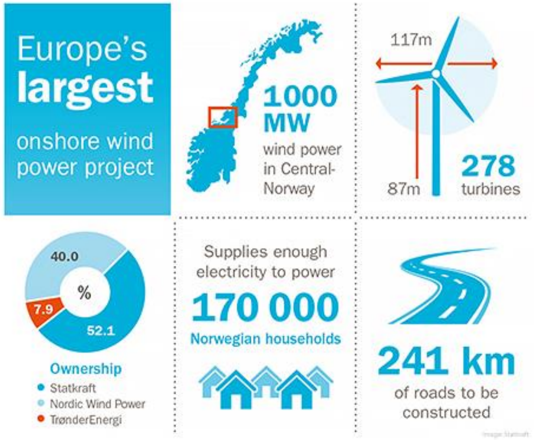
ENERGY NUMBERS



WIND FARM SCALE

Fosen Vind = 3,4 TWh/year

900 MW → electrolysis = 7,22 TWh/year = 2 x



http://www.fosenvind.no/om-fosen-vind/

3 x Manhattan

½ Trondheim

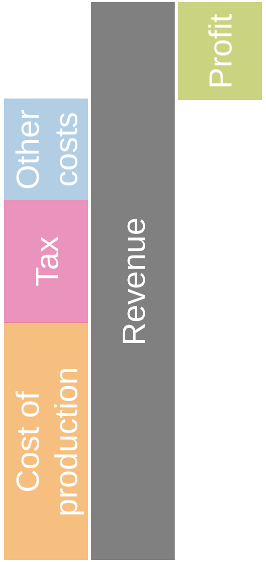
22000+ soccer fields

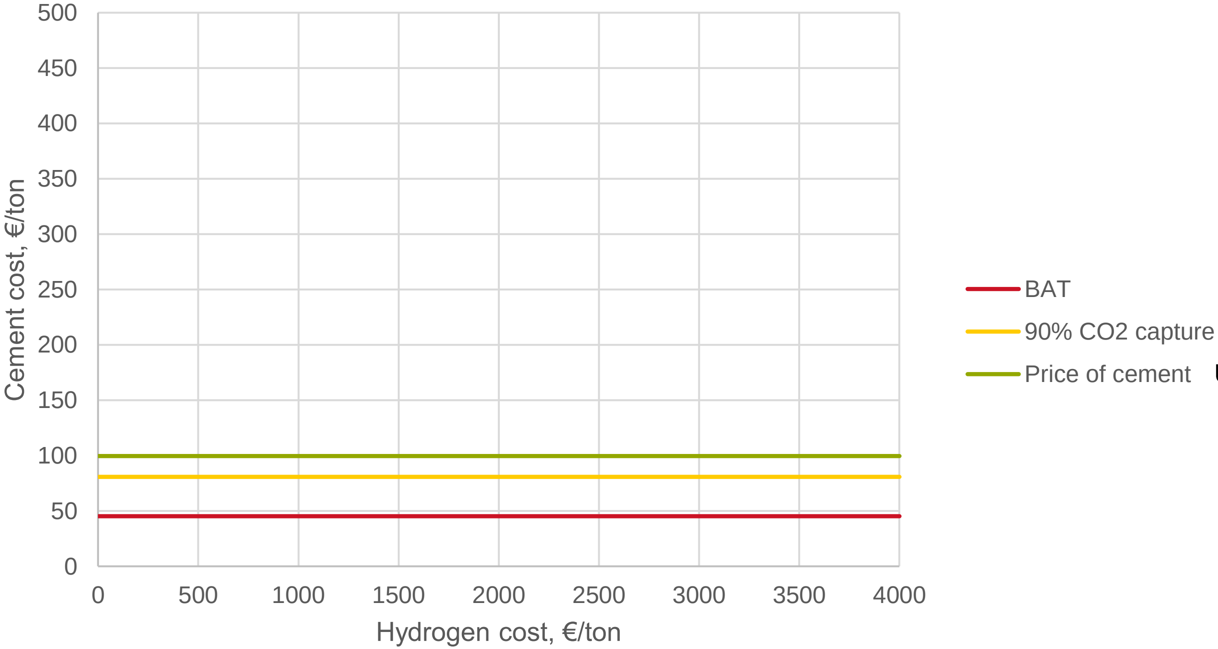
ECONOMICS

Cement €/ton	No capture	90% CCS	90% CCU
Raw meal	3,68	3,68	3,68
Fuel	6,92	6,92	0,00
Electricity	5,64	9,69	*7,00*
Steam	0,00	14,19	*16,00*
Cooling water	0,00	0,65	*1,00*
Hydrogen	0,00	0,00	457,46
Other	0,80	2,32	3,00
Variable OPEX	17,04	37,45	488,14
Fixed OPEX	13,33	19,64	*25,00*
CAPEX	14,99	23,60	*50,00*
Ethanol revenue	0,00	0,00	91,00
Cost of cement	**45,36**	**80,69**	**472,14**

hydrogen
4000 €/ton

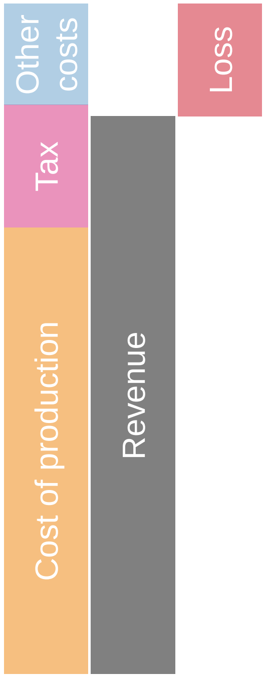
ECONOMIC SCENARIOS

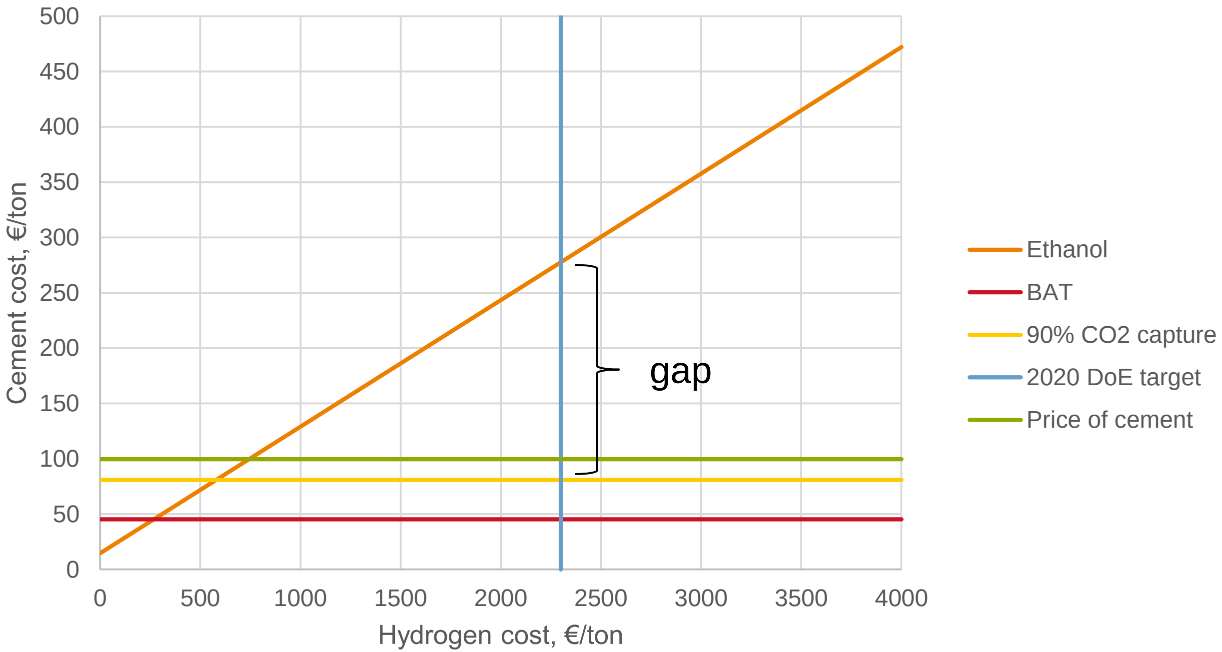




US 2016, Portland

ECONOMIC SCENARIOS

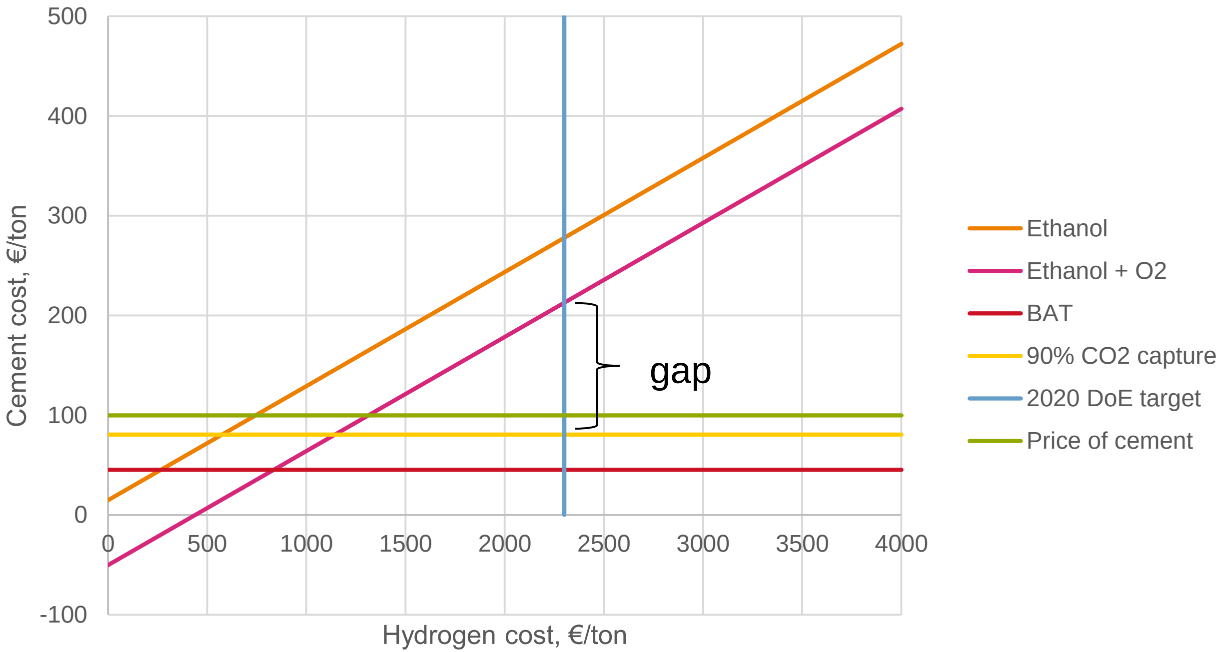




#1 INCREASE REVENUE – SELLING OXYGEN

- 6634 ton/day = 0,55% of global market
- Hydrogen future (2050?) → oxygen may have little to no value
- Oxygen price = €40/ton → cost of on-site production

ECONOMIC SCENARIOS

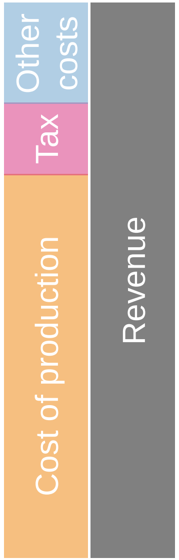


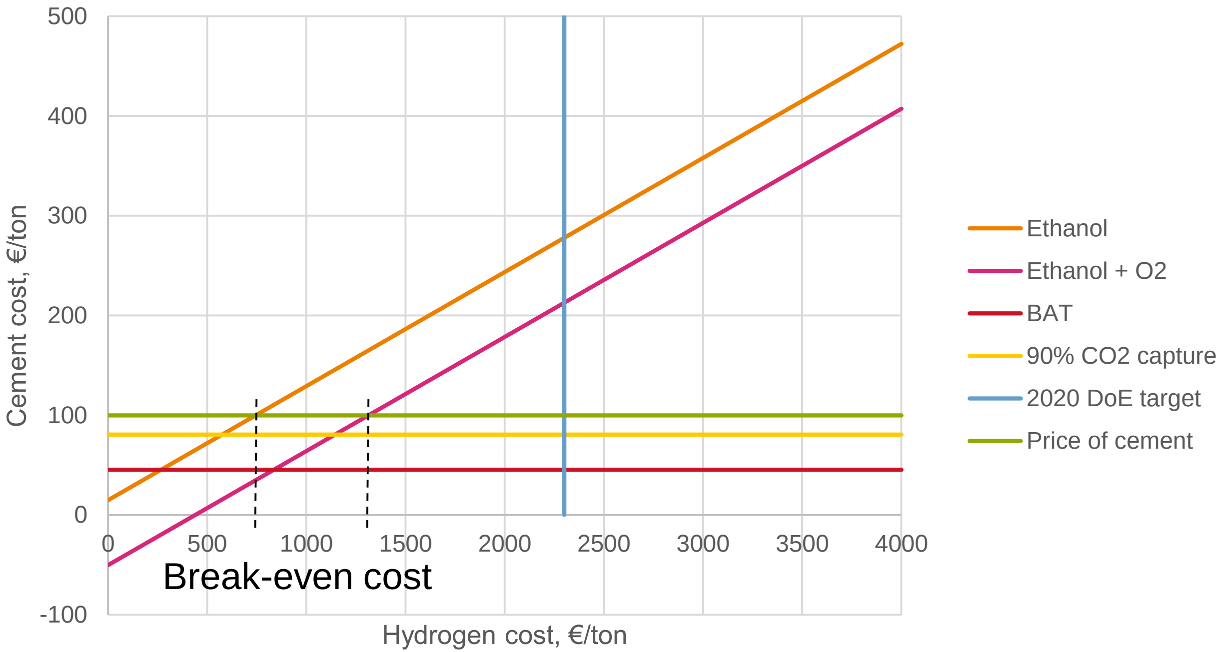
#2 DECREASE COSTS

- Lower or no **tax** on “green” cement
- Lower **hydrogen cost**
  - Cheaper electricity
  - Improvements on hydrolysis
  - Alternative technologies, e.g., photocatalytic: 1600 – 10400 USD/ton

Pinaud, B. A., Benck, J. D., Seitz, L. C., Forman, A. J., Chen, Z., Deutsch, T. G., … Jaramillo, T. F. (2013). Technical and economic feasibility of centralized facilities for solar hydrogen production via photocatalysis and photoelectrochemistry. *Energy & Environmental Science*, *6*(7), 1983–2002. https://doi.org/10.1039/C3EE40831K

ECONOMIC SCENARIOS





Acknowledgement

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www.sintef.no/cemcap

Twitter: @CEMCAP_CO2

THANK YOU FOR YOUR ATTENTION

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