RESEARCH AND DIALOGUE FOR SUSTAINABLE SOCIETIES

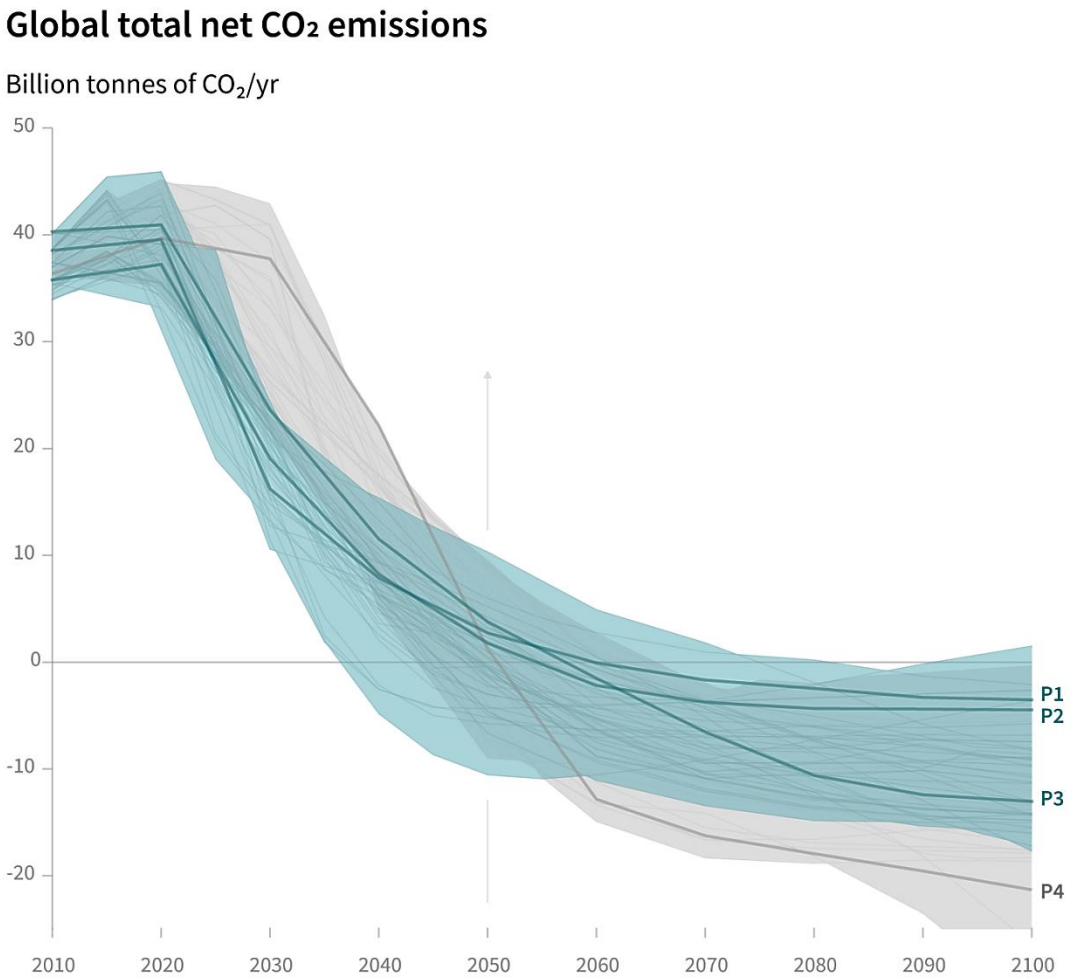
The economics of accelerated carbonation routes using captured CO_2

Till Strunge

Agenda

1. Introduction to CCU and cement industry
2. Calculating the costs of CO_2 carbonation
3. Revenue stream evaluation
4. Incentives and barriers for deployment

Introduction



P1: no fossil fuels with CCS or BECCS are used.

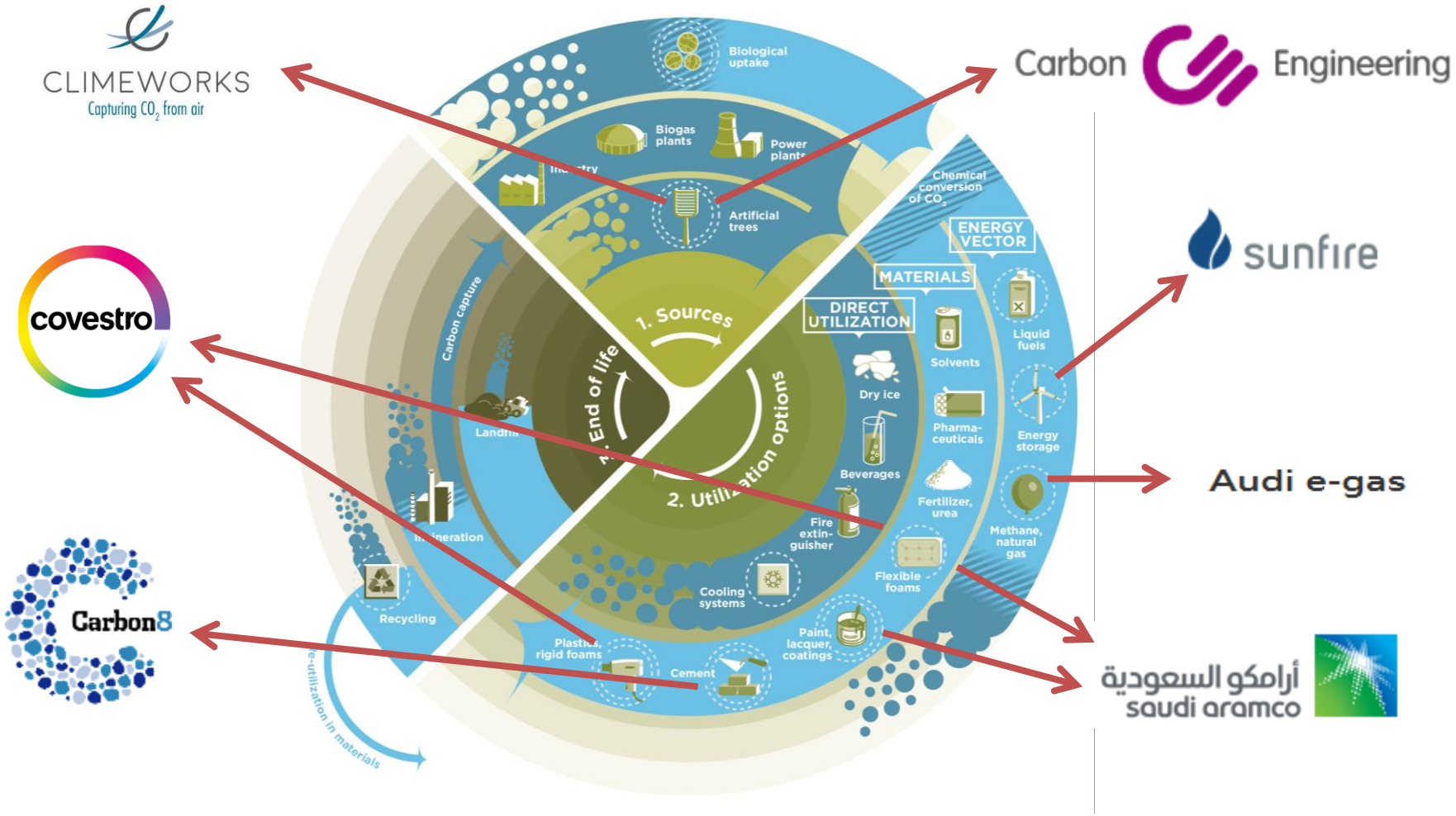
P2: Limited social acceptability for BECCS

P3: Emission reductions through changes of production pathways

P4: Strong use of CCS and BECCS

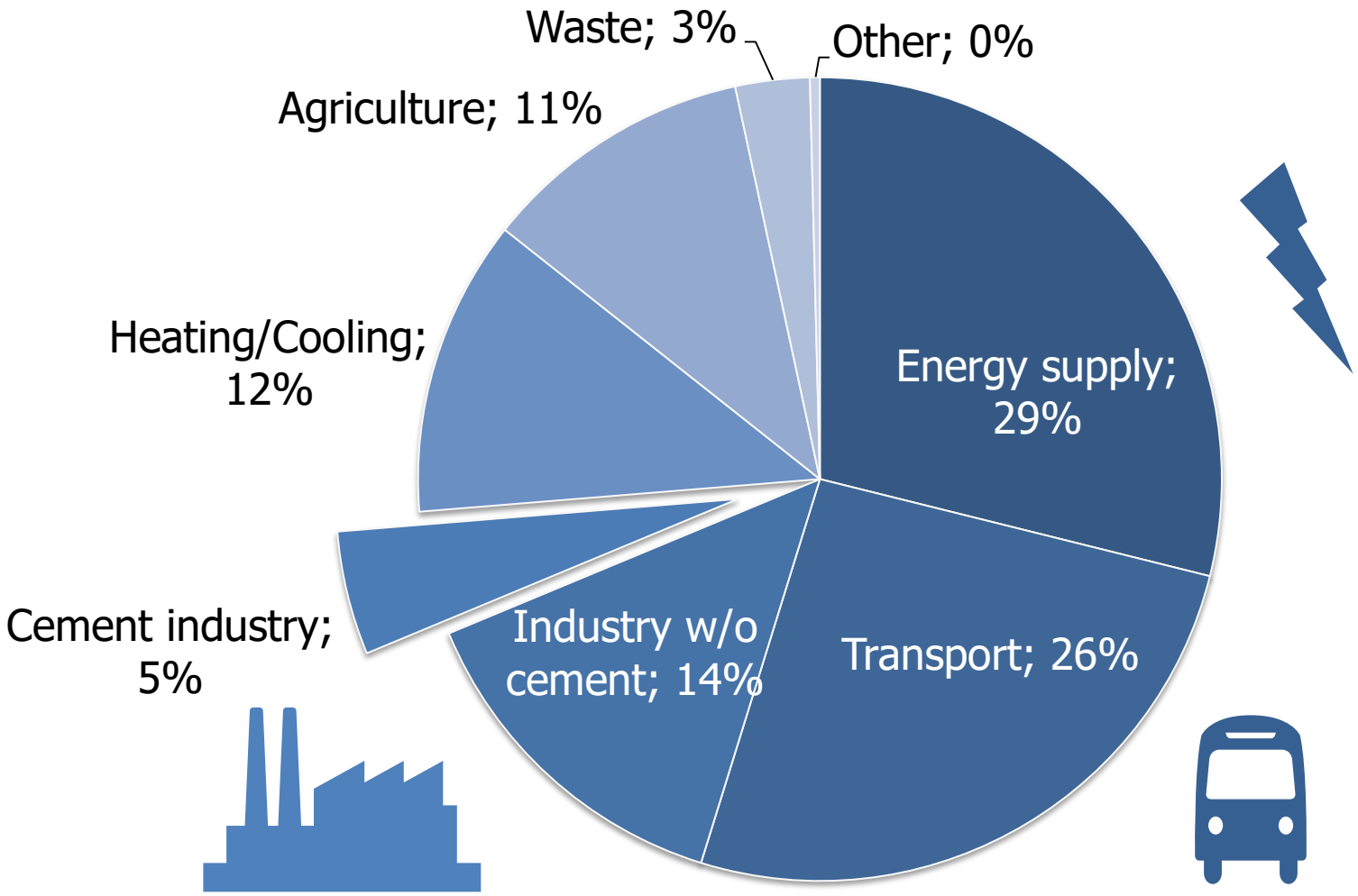
Reference: Masson-Delmotte, Valerie, et al. "IPCC, 2018: Summary for Policymakers." (2018).

CO_2 as a resource



References: Olfe-Kräutlein, B., Naims, H., Bruhn, T., Lorente Lafuente, A. M.: CO2 as an Asset: Challenges and potential for society, 2016.

CO_2 emissions of industry



Reference: IEA, Energy and CO_2 emissions in the OECD, 2017.

What is cement?

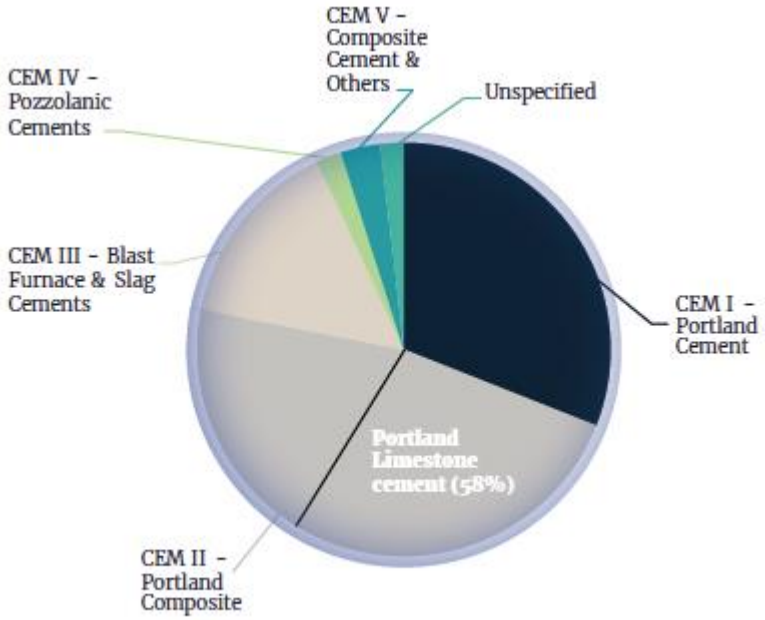
Source: © pixabay (free for commercial use)

What is cement?

Specification of cement:

Cement Type	Clinker Ratio
CEM I: Ordinary Portland Cement	95 %
CEM II: Portland Composite Cement	65-94 %
CEM III: Blast Furnace Cement	5-64 %
CEM IV: Pozzolanic Cement	45-89 %
CEM V: Composite Cement	20-64 %

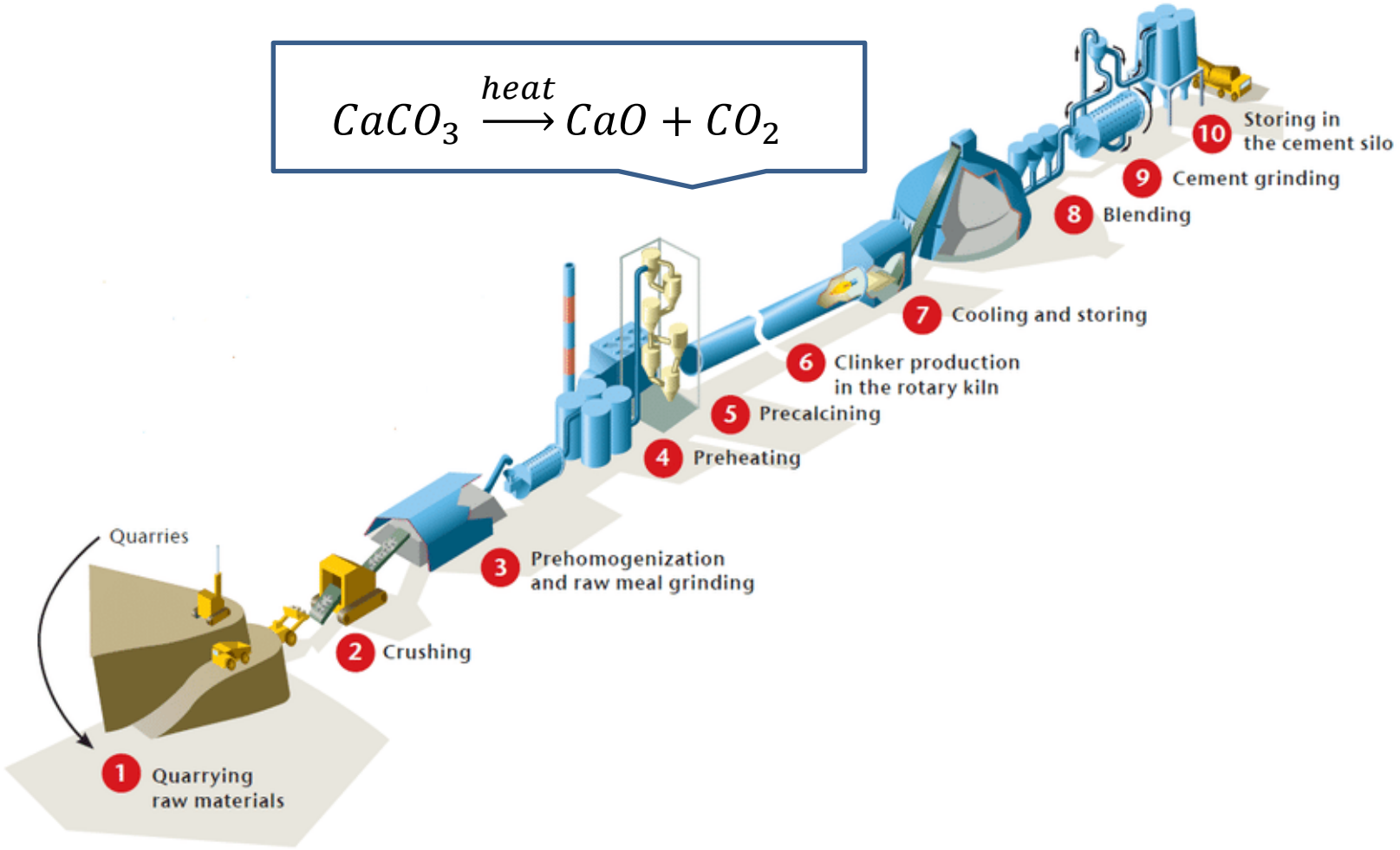
Market share of cement types in Europe:



References: PricewaterhouseCoopers, Significant. "Ecofys (2009)." *Collection of statistical in.*; The European Cement Association, The role of CEMENT in the 2050 Low Carbon Economy, 2013.

Cement production

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$



Reference: IEA 2009, 'Cement Technology Roadmap 2009, Carbon Emission Reductions up to 2050'.

Cement production

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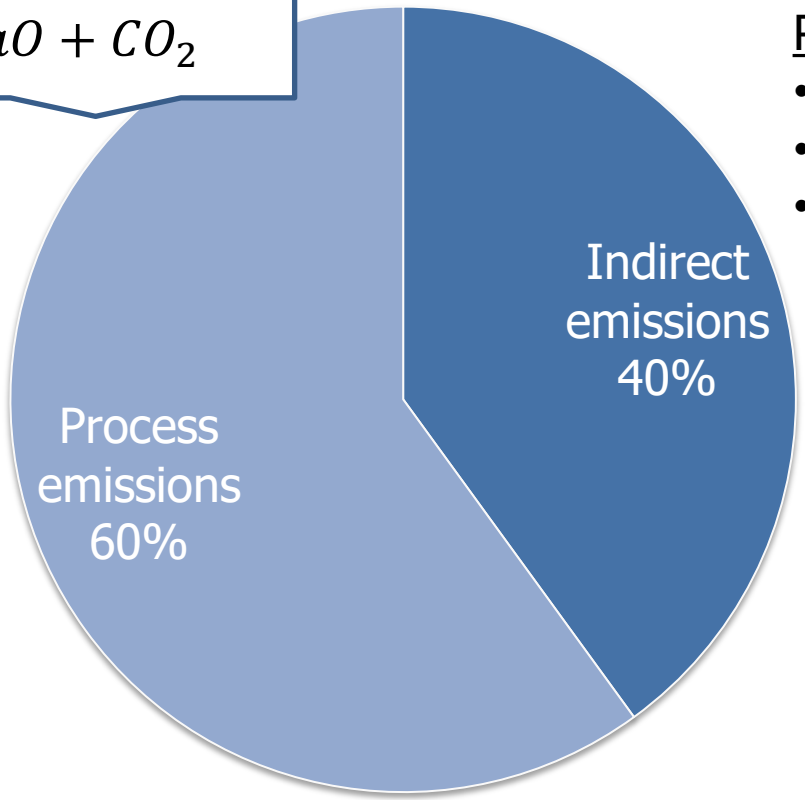
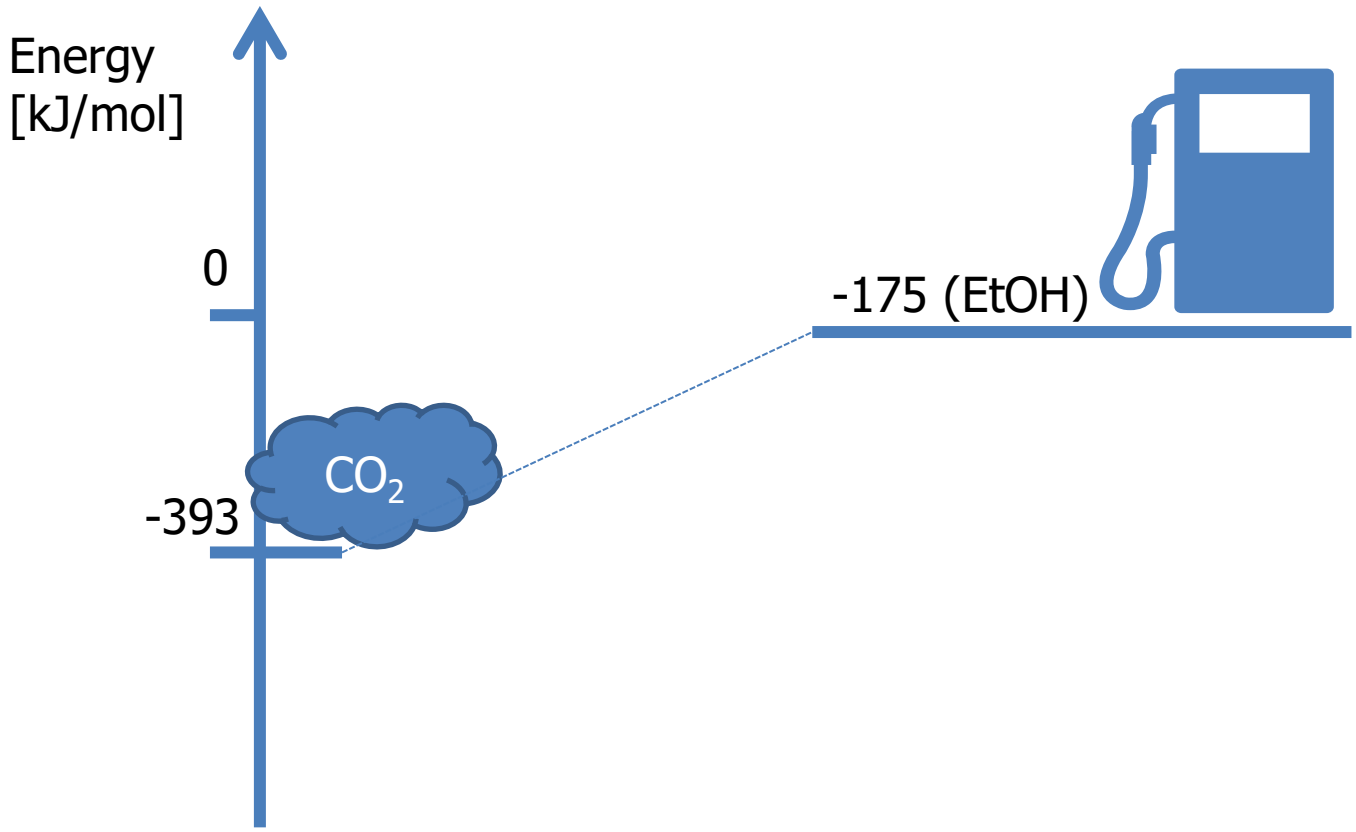


Possible solutions:
- Reduce clinker content
- CCS
- CCU

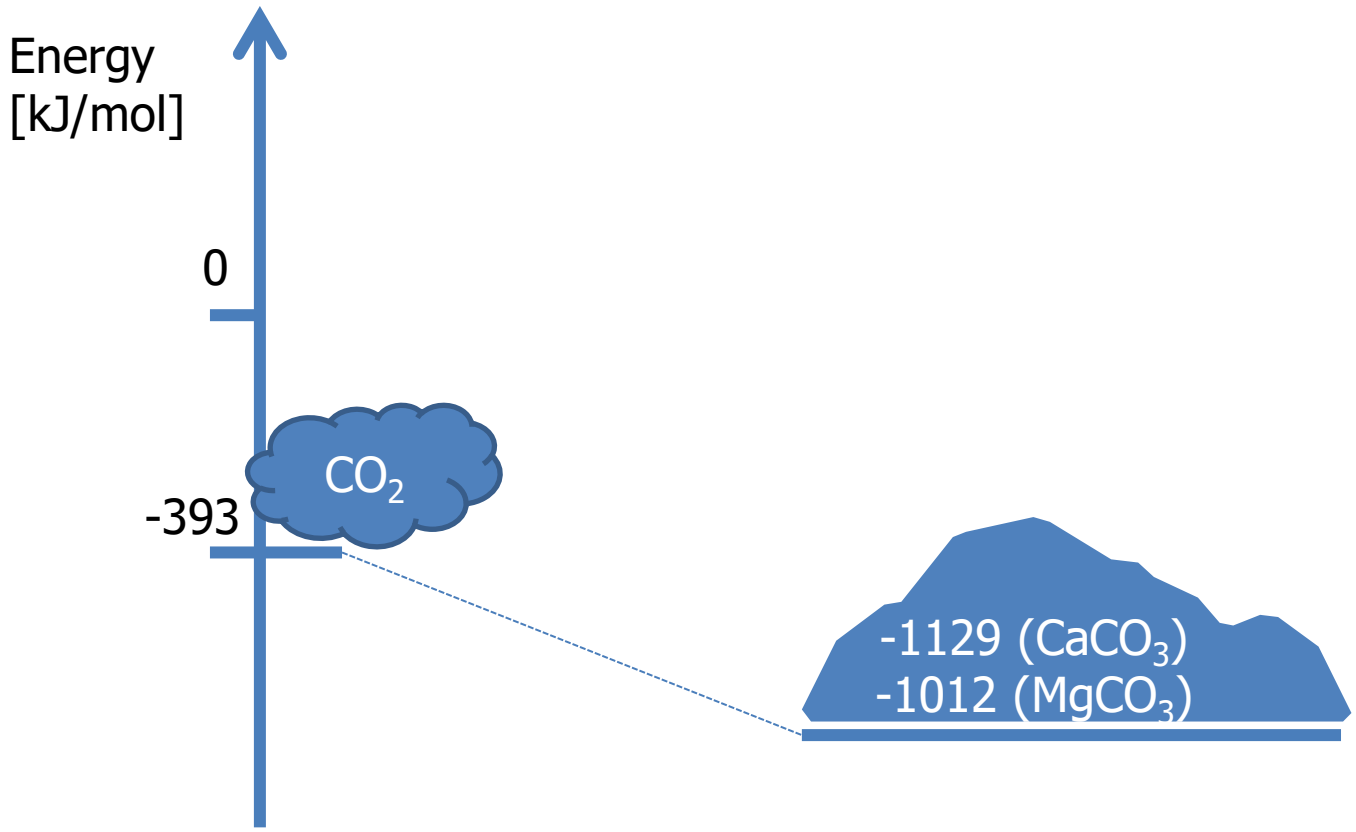
Possible solutions:
- Better heat integration
- Alternative fuels
- Electrification

References: Hoenig, V., and M. Schneider. "CO2 reduction in the cement industry." *VDZ Congress*. 2002.

CO_2 carbonation



CO_2 carbonation



CO_2 carbonation

Natural minerals (Mg- or Ca-rich siliciates):
- Olivine
- Serptentine
- Wollastonite

Industrial wastes:
- Steel slag
- Red mud

CO_2

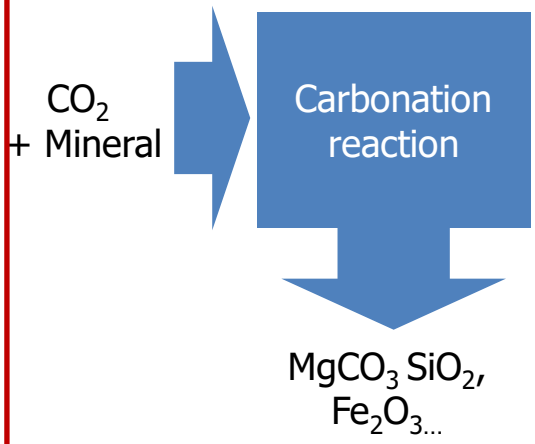
Point source:
- Cement plant

Carbonation reaction

Cementeous product

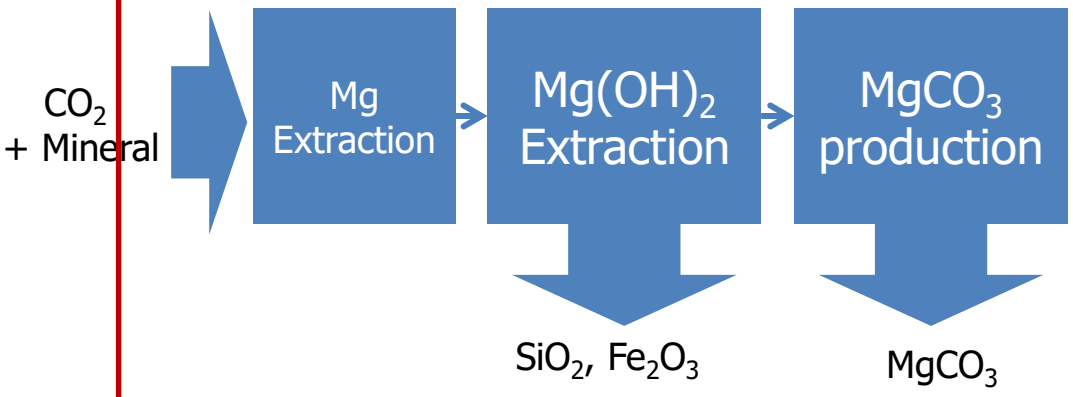
CO_2 carbonation

The **direct route** for carbonation:



- One step needed, easier reaction, not highly pure products
- Possible deployment: large volumes, low value products.

The **indirect route** for carbonation:

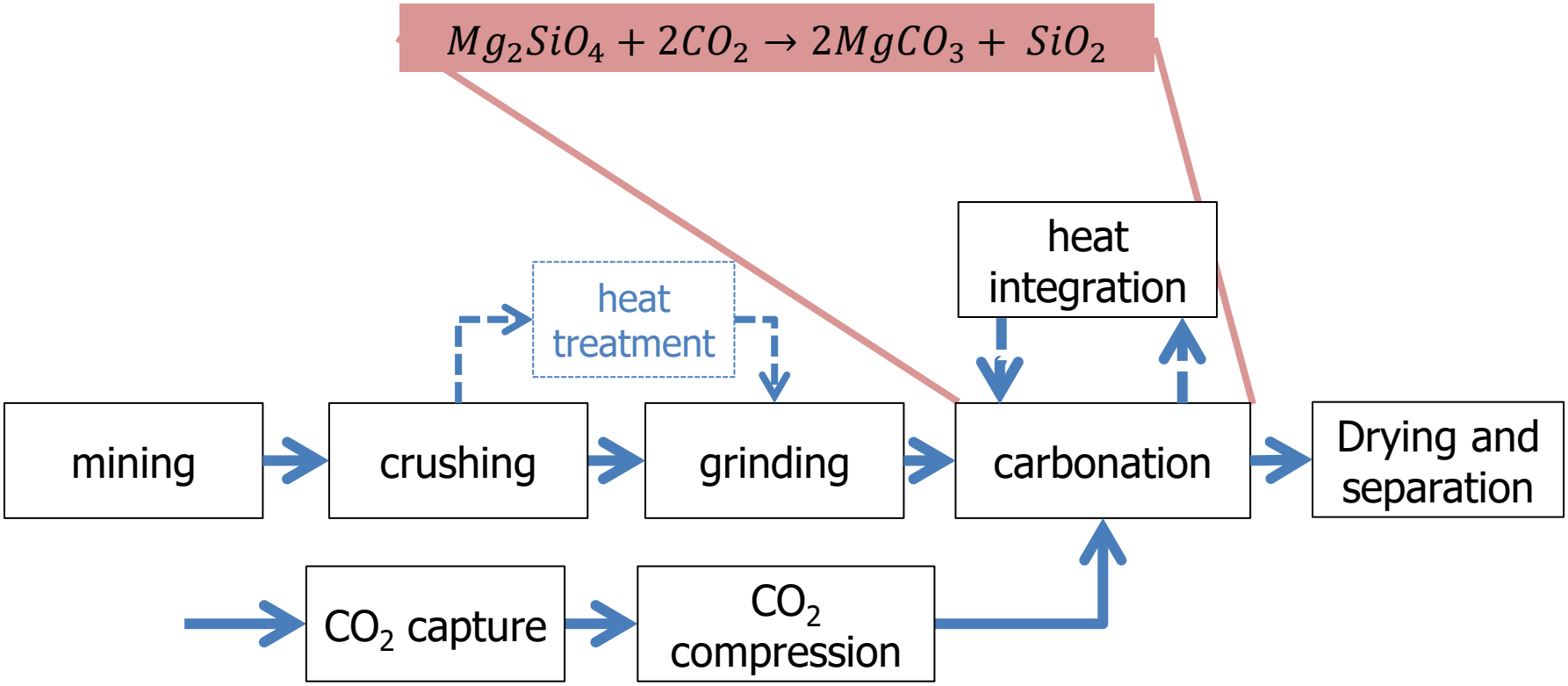


- Multiple steps lead to pure products.
- Possible implementation: Niche markets with high value of products.

Reference: Geerlings, H., and R. Zevenhoven. "Co2 Mineralization-Bridge between Storage and Utilization of Co2." *Annu Rev Chem Biomol Eng* 4 (2013)

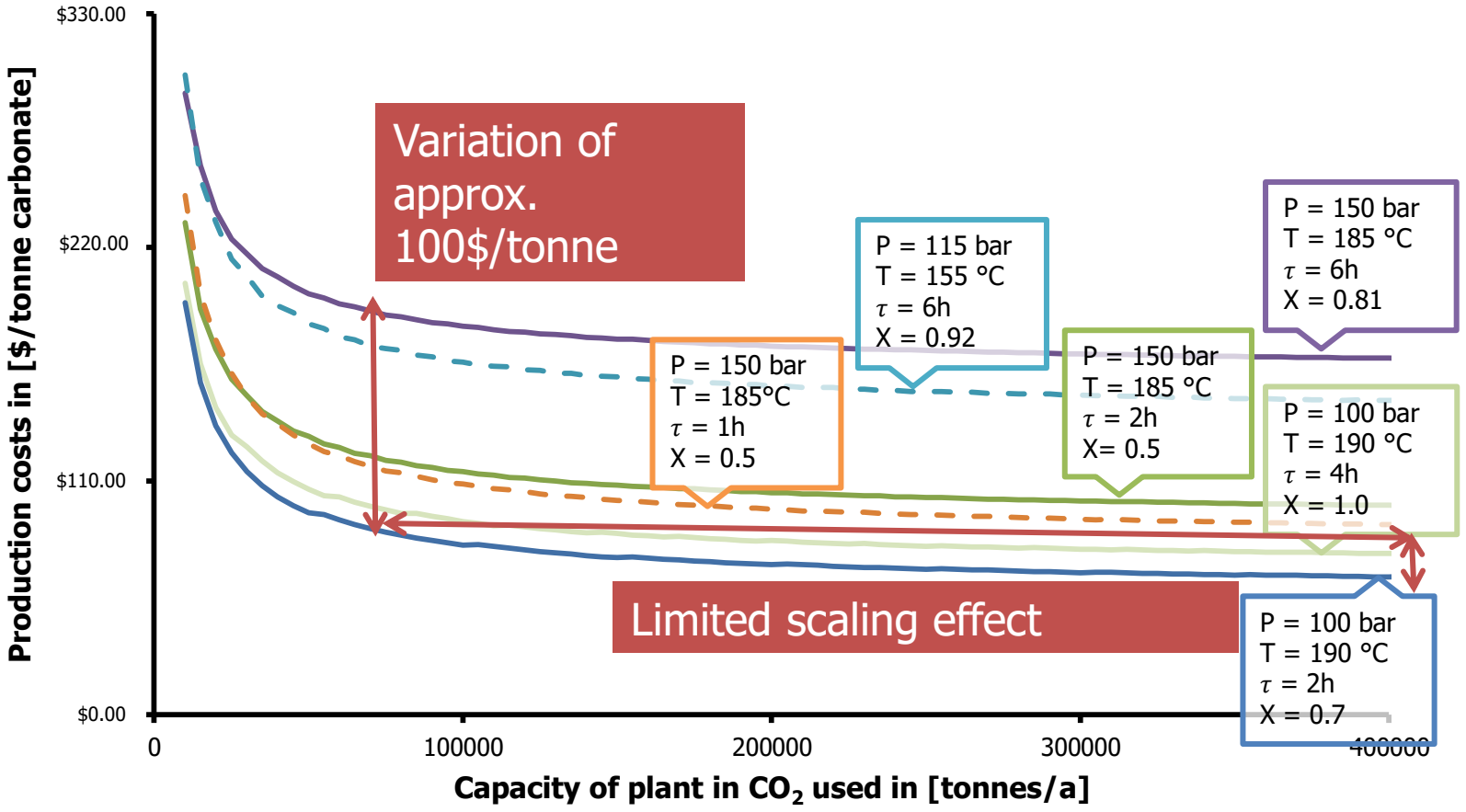
Developing an economic model

Integrated CO_2min process w/mining



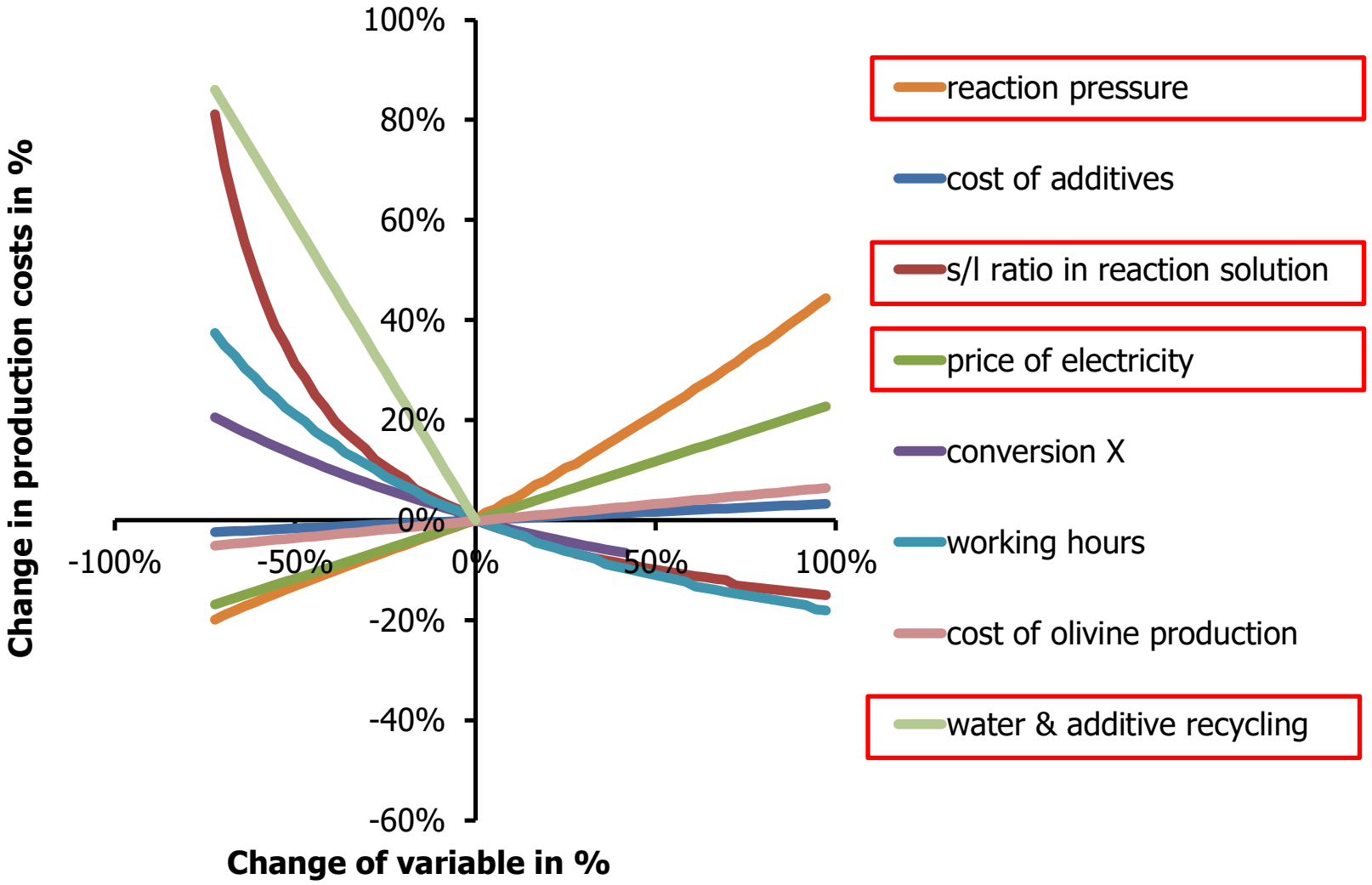
Preliminary results – cost evaluation*

*calculated for plant based in Germany



References: Eikeland, Espen, et al. "Optimized carbonation of magnesium silicate mineral for CO2 storage." *ACS applied materials & interfaces* 7.9 (2015): 5258-5264.
Gerdemann, Stephen J., et al. "Ex situ aqueous mineral carbonation." *Environmental science & technology* 41.7 (2007): 2587-2593.
O'Connor, W. K., et al. "Aqueous mineral carbonation." *Final Report–DOE/ARC-TR-04-002* (2005).

Preliminary results– Sensitivity analysis



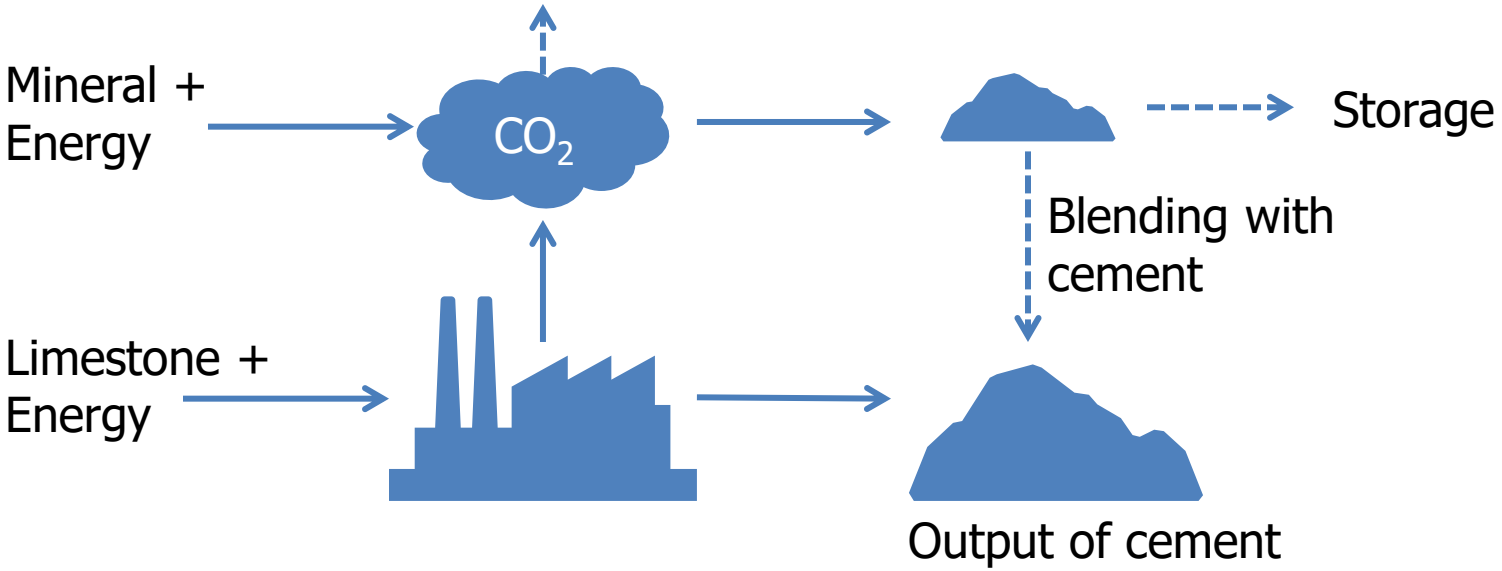
Learnings from sensitivity analysis

- Obtain a high recycling rate of solvent and additives
- Reduce the reaction pressure or possibly focusing on different reactor types
- Reduce the reaction volume
- Reduce the energy required for pre-treatment

Revenue model

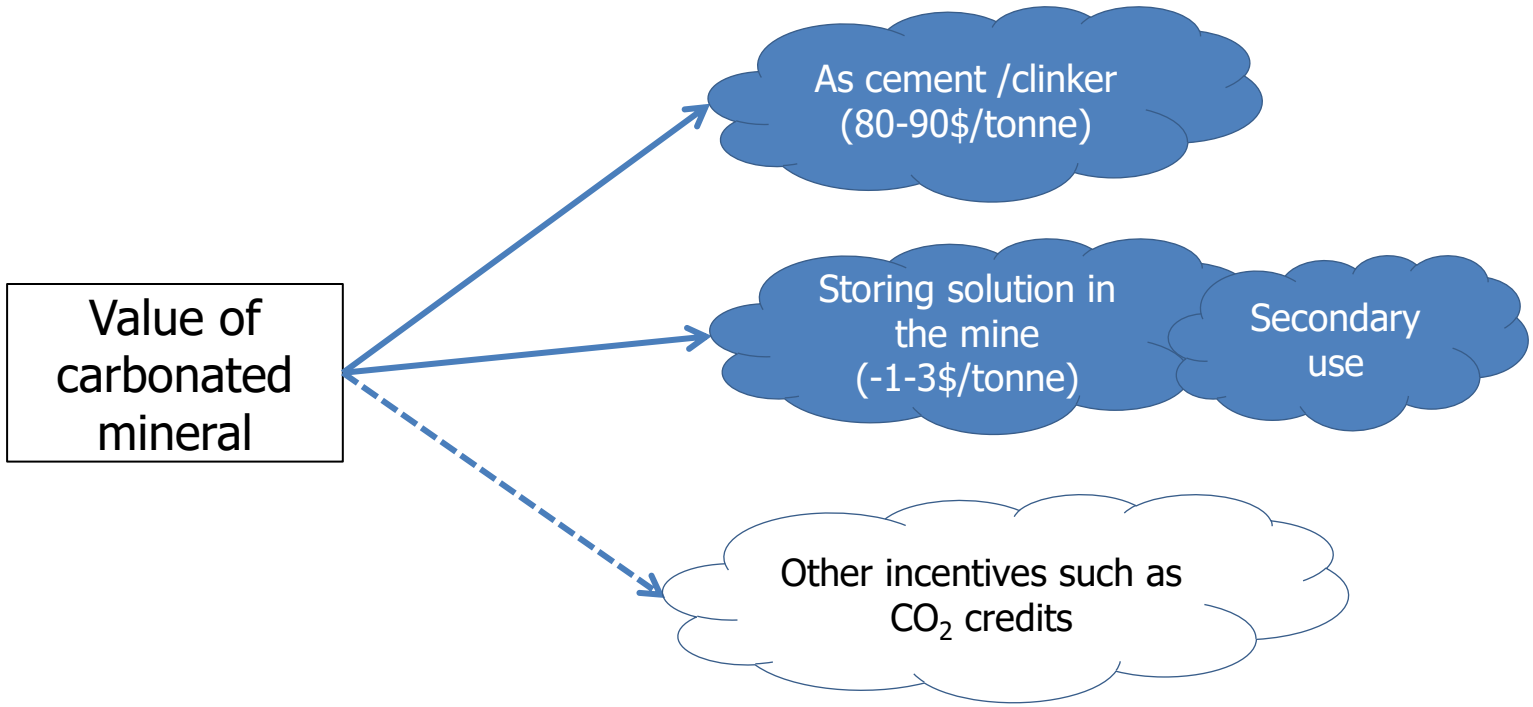
Developing a business case

$$Mg_2SiO_4 + 2CO_2 \rightarrow 2MgCO_3 + SiO_2$$



Issue: There is no market for carbonated/partially carbonated mineral.

Developing a business case



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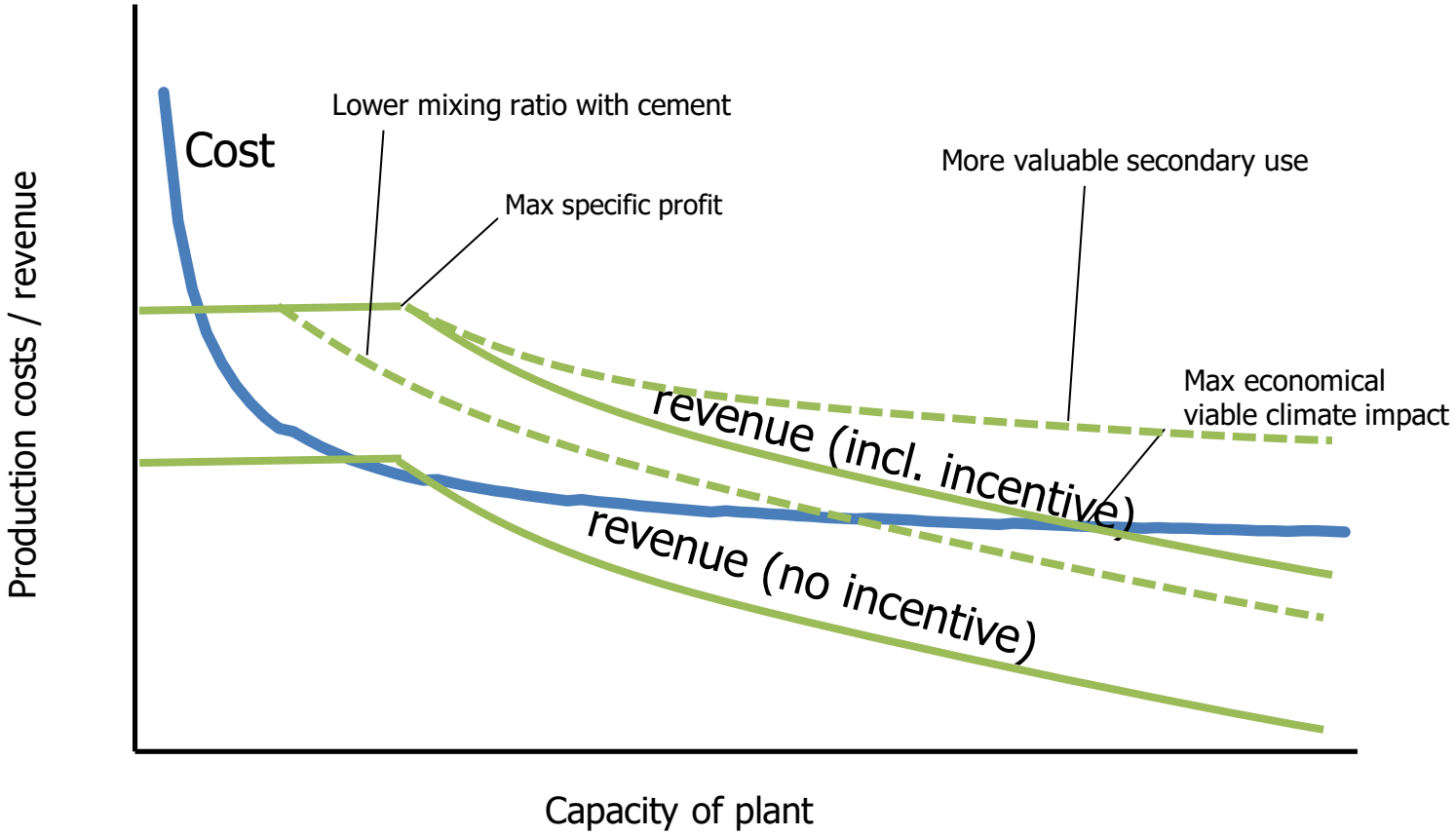
Idea for business case analysis



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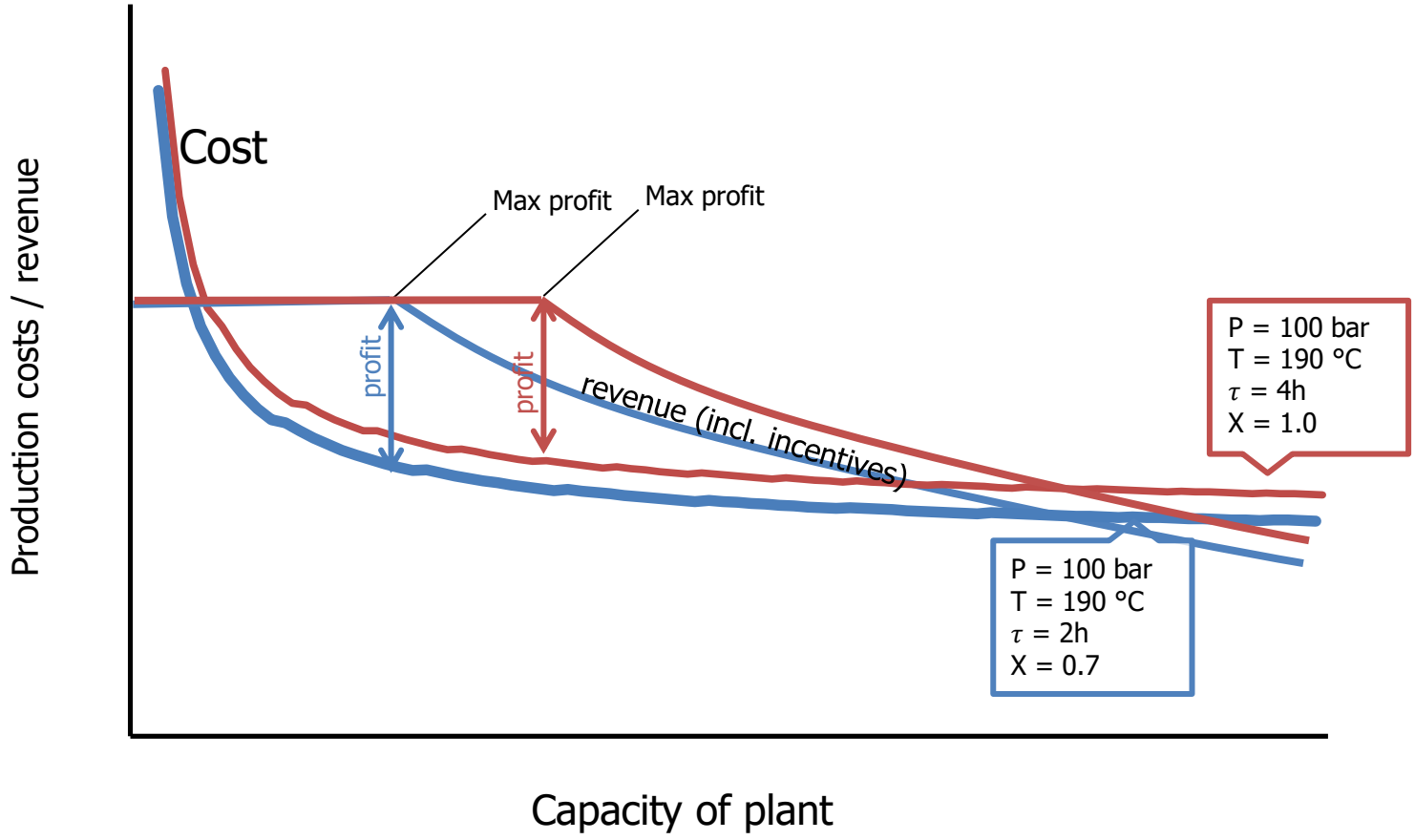
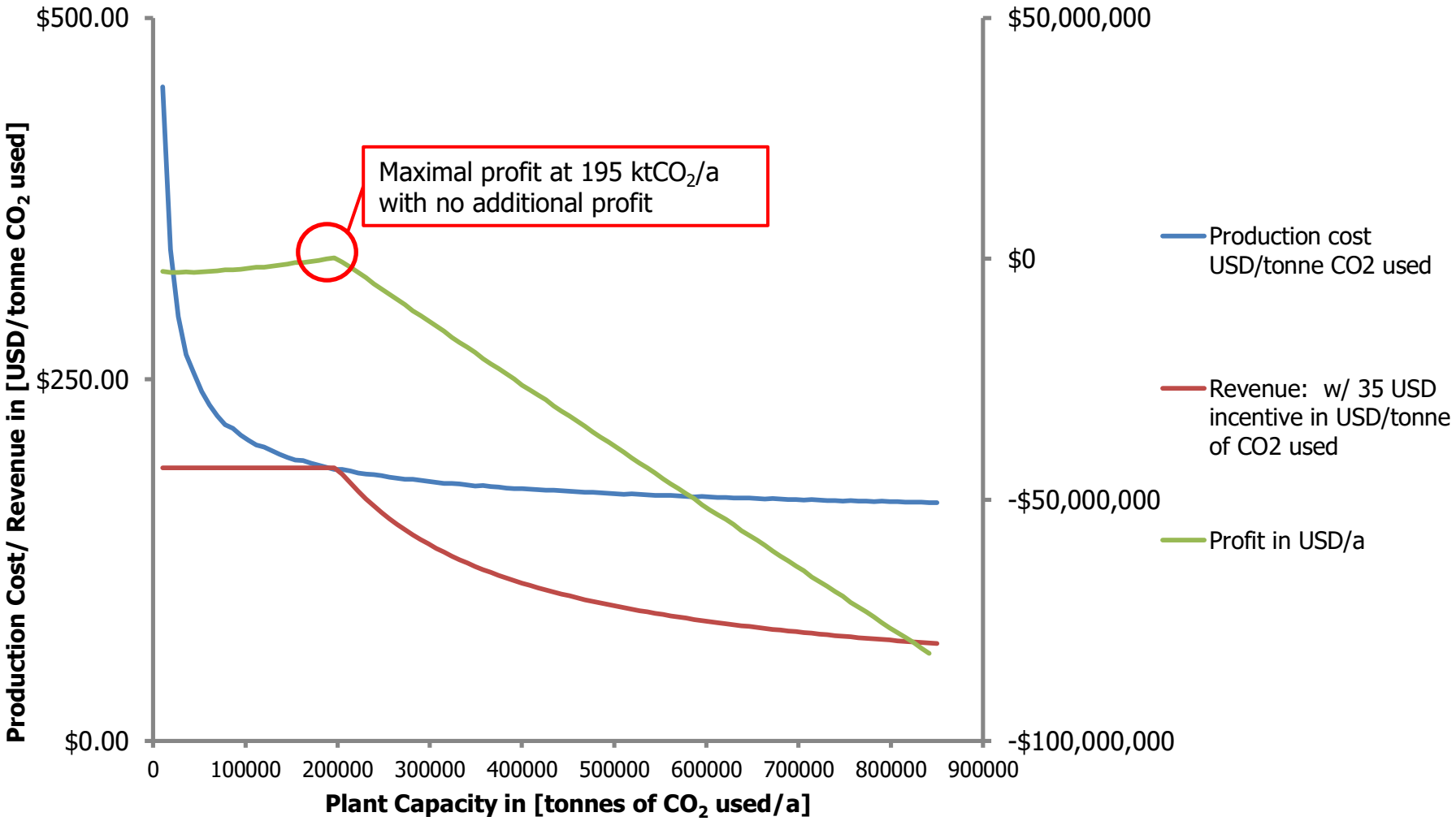
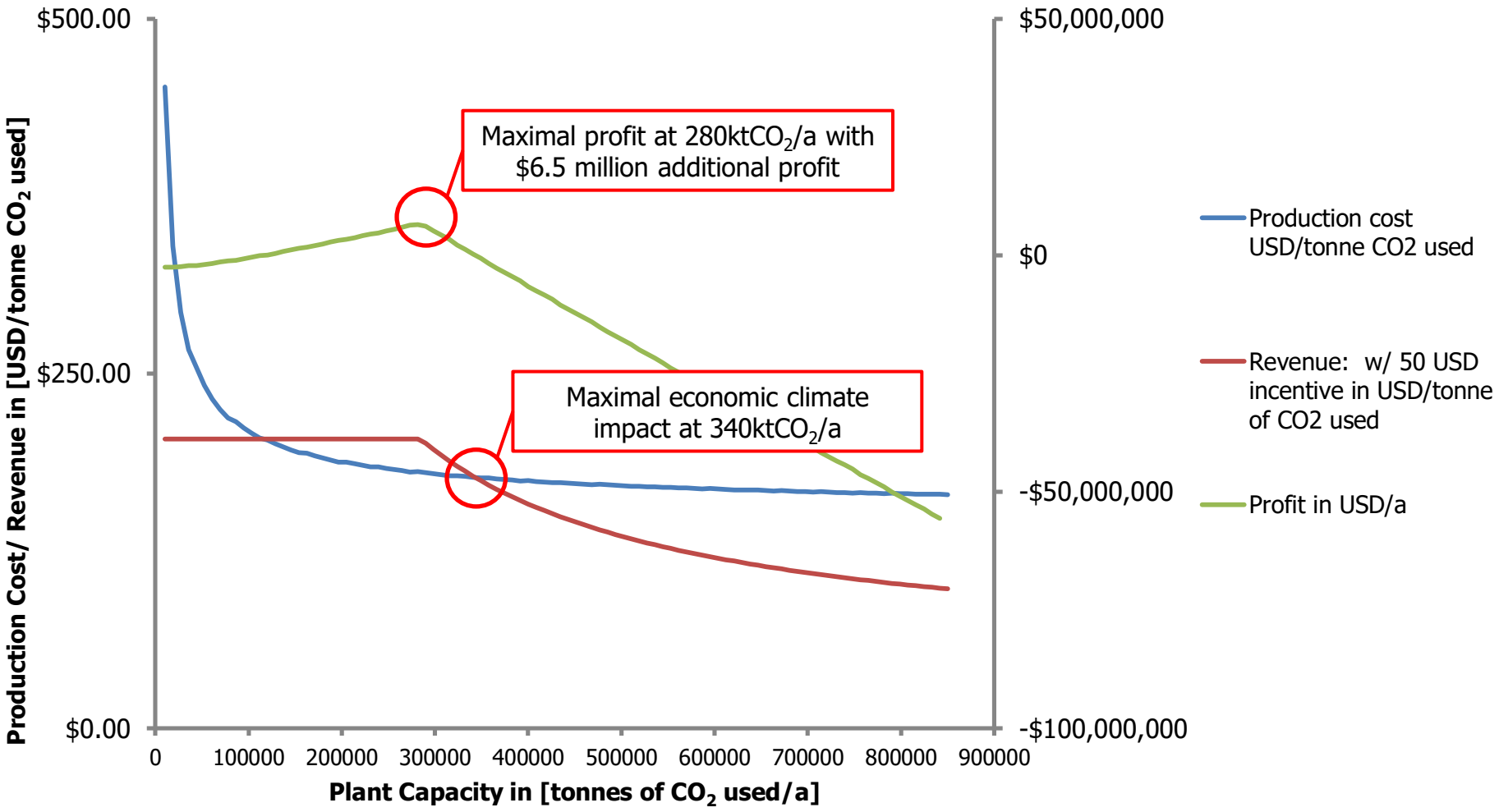


Preliminary results for revenue calculation – realistic case – $35 incentive, 17.5% share*



*assumed plant capacity of cement plant: 2 million tonnes of cement/ a, calculated for plant based in Germany

Preliminary results for revenue calculation – optimistic case – $50 incentive, 25% share*



*assumed plant capacity of cement plant: 2 million tonnes of cement/ a, calculated for plant based in Germany

Key take away messages

1. For a certain plant size, the carbonation technology can be profitable, even for moderate incentives (i.e. 45Q or ETS).

2. It appears that the technology will be limited in size, due to economics /missing markets.

3. Incentives are necessary to reach economic viability of these processes for larger scales.

Barriers and drivers of CO_2 carbonation

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Drivers for deployment:

- CO_2 Utilization credits (45Q (USA), ETS (EUROPE))
- Governmental Procurement (Buy Green California Act)
- Landfill tax credits
- Blending quota

Barriers

- Standardization of cement products (ASTM, EN, DIN)
- Waste shipment legislation

Thank you for the attention!

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