The University of Texas at Austin
Civil, Architectural and Environmental Engineering
*Cockrell School of Engineering*

# *Energy and $CO_2$ Implications of the Global Cement Industry*

Maria Juenger
Professor

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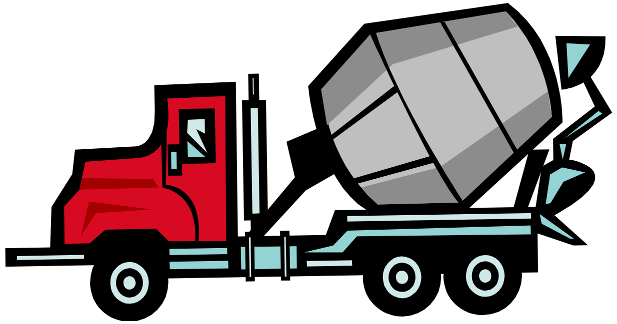
# Concrete is the world's most used material

- 17-20 billion metric tons of concrete per year globally



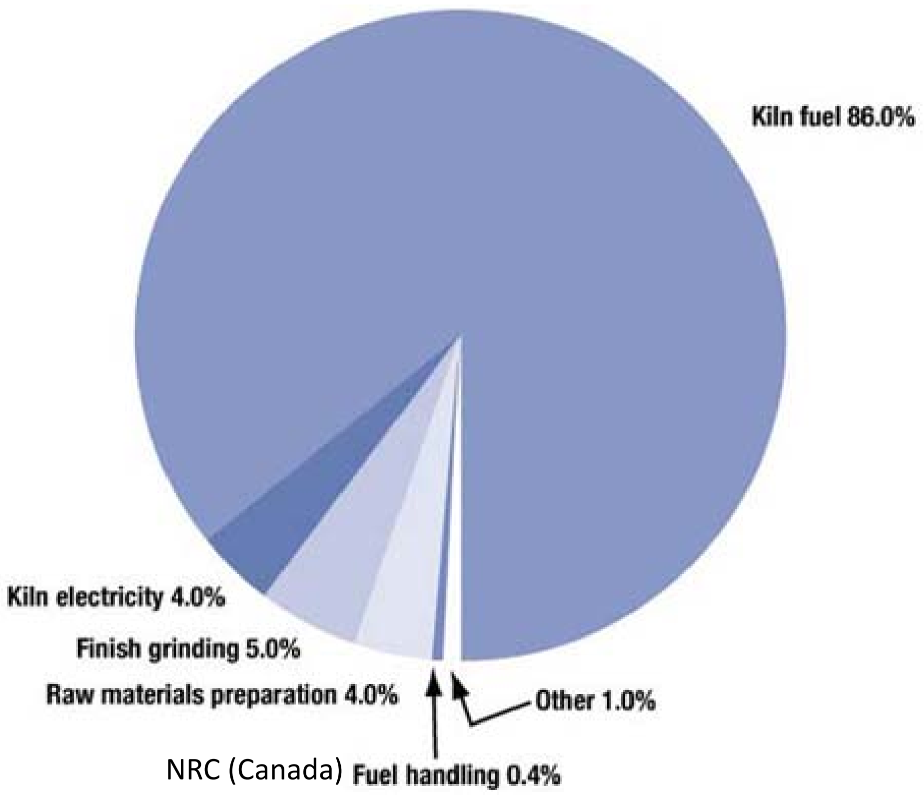
Concrete mixing truck holds 7-9 cubic yards of concrete with 5 to 8 sacks of cement (94 lb. each) per cubic yard


- 4.6 billion metric tons cement produced per year globally

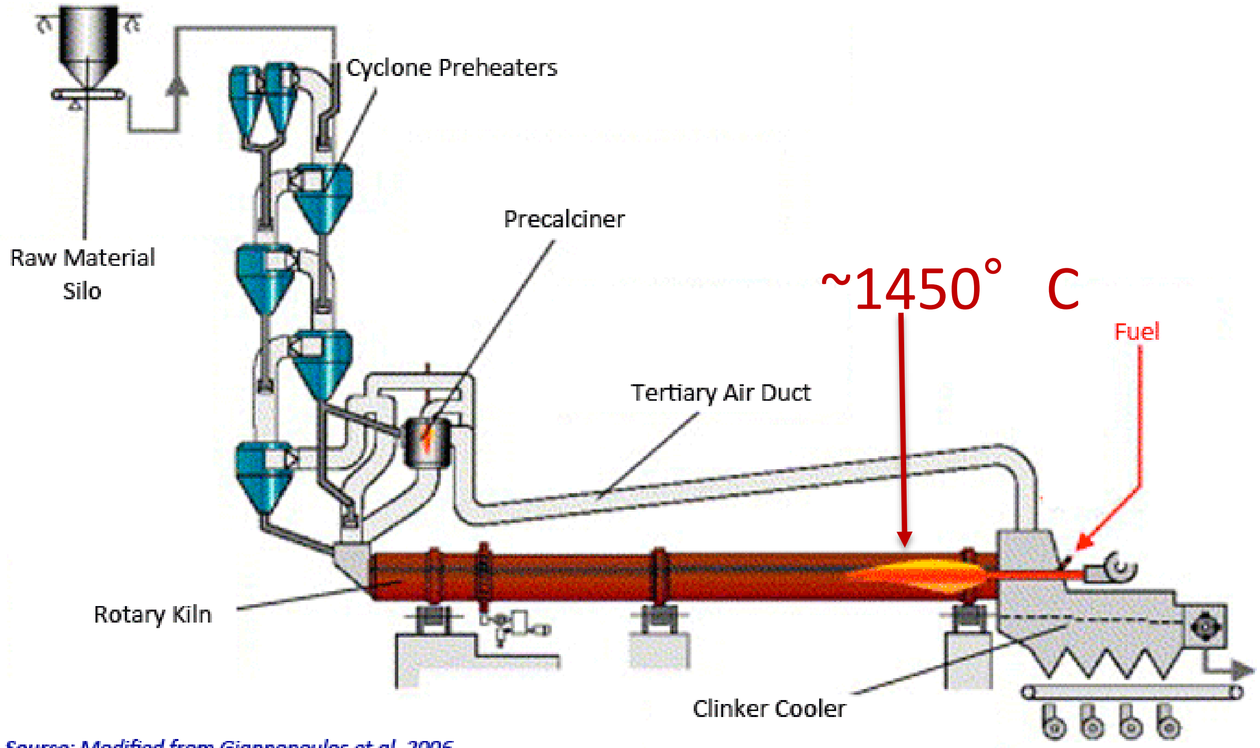
626 kg/per capita, higher than human food consumption

# Cement manufacturing is energy-intensive

- To produce 1 ton of portland cement requires up to 7000 MJ (2000kWh) of electrical power and fuel energy




NRC (Canada)



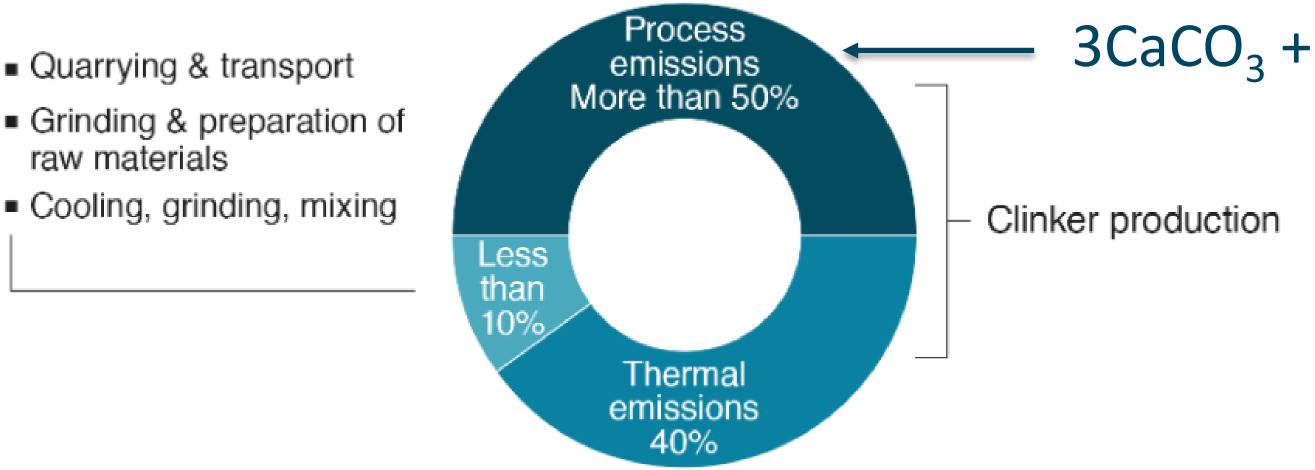

Source: Modified from Giannopoulos et al, 2006

www.iipinetwork.org/wp-content/letd/content/clinker-making.html

# Cement manufacturing produces $CO_2$

- "If the cement industry were a country, it would be the third largest emitter in the world - behind China and the US. It contributes more $CO_2$ than aviation fuel (2.5%) and is not far behind the global agriculture business (12%)." - BBC News, 17 December 2018

**The production of "clinker" accounts for most of the CO2 emissions of cement production**




$$3CaCO_3 + SiO_2 \leftrightarrow Ca_3SiO_5 + 3CO_2$$

Source: Chatham House

BBC

# Levers for change

1. Thermal and electric efficiency (equipment and process changes)
2. Alternative fuels (equipment and process)
3. Clinker substitution – supplementary cementitious materials and alternative cements (material changes)
4. Carbon capture and storage (equipment, process and material changes)
5. Efficiency of materials use (material changes)

International Energy Agency

World Business Council for Sustainable Development

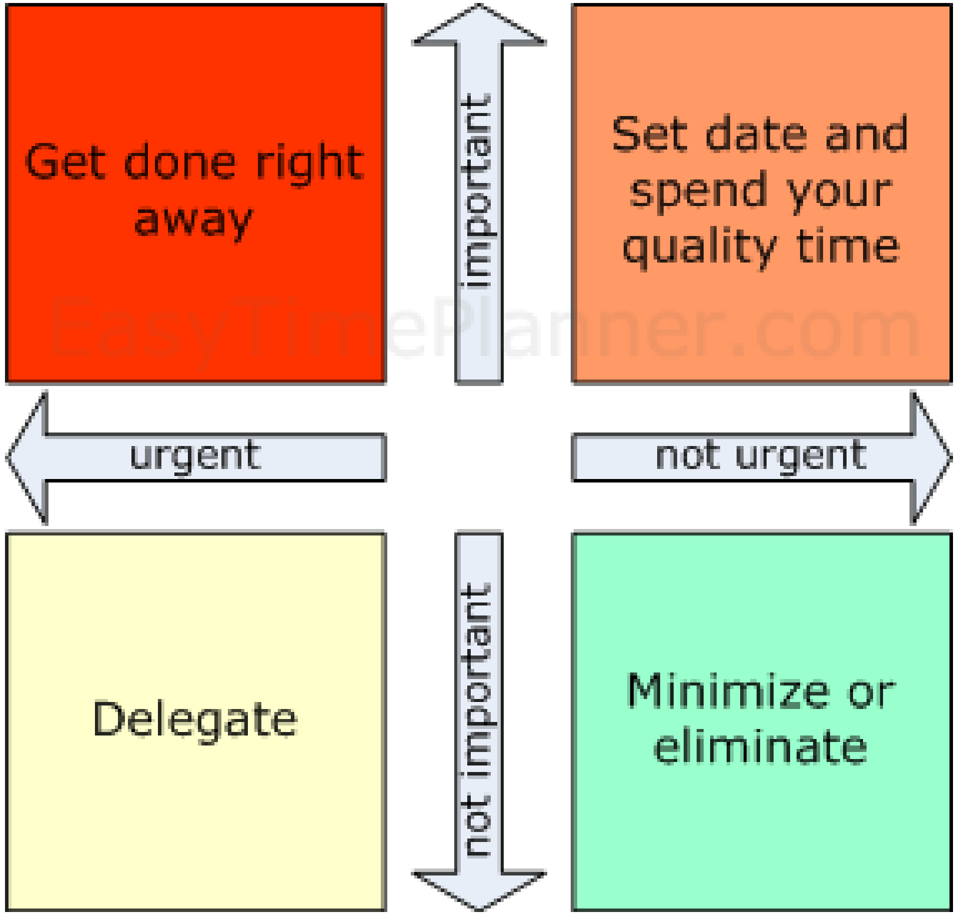
UNEP

# Planning strategies

## Eisenhower Decision Matrix

Ideas with rapid implementation potential

1. Thermal & electric efficiency
3. Clinker substitution

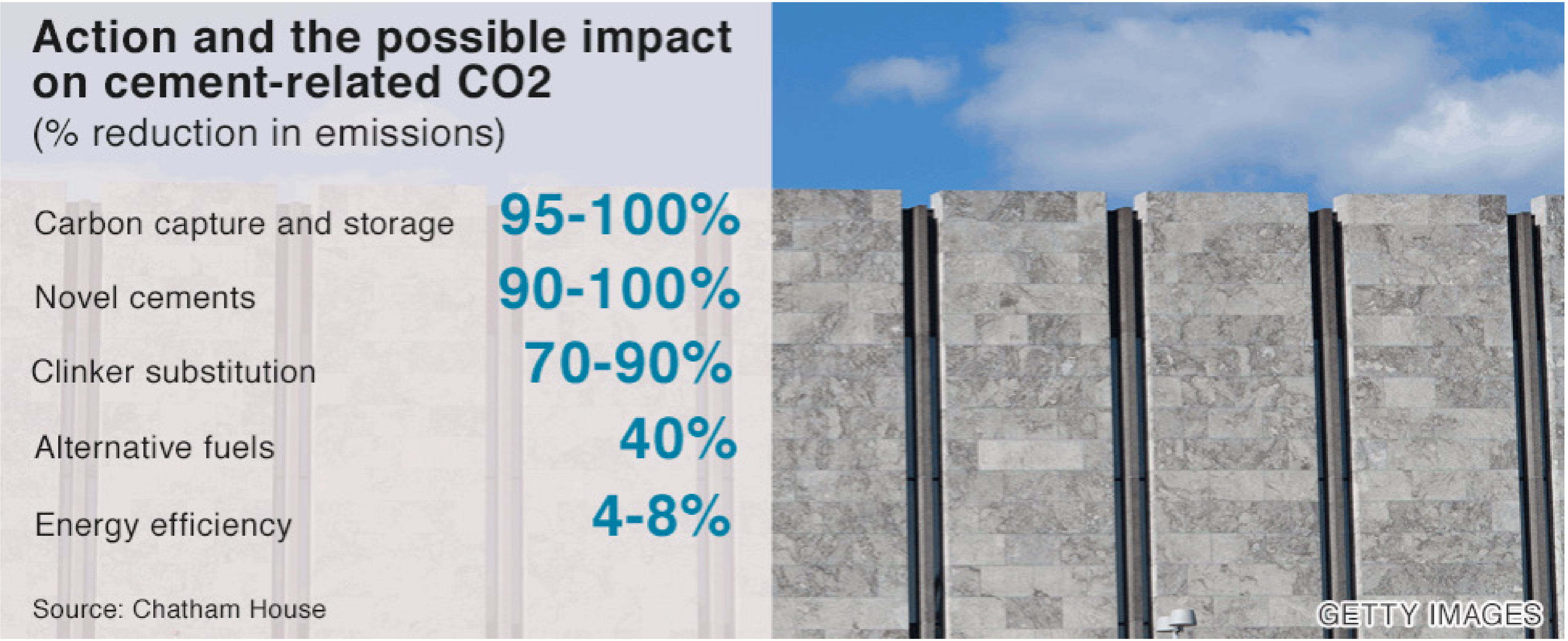



Ideas with long term potential

2. Alternative fuels
4. Carbon capture


Bad ideas!

# Impact of changes in processes and materials




BBC News, 2018

# Impact of changes in processes and materials

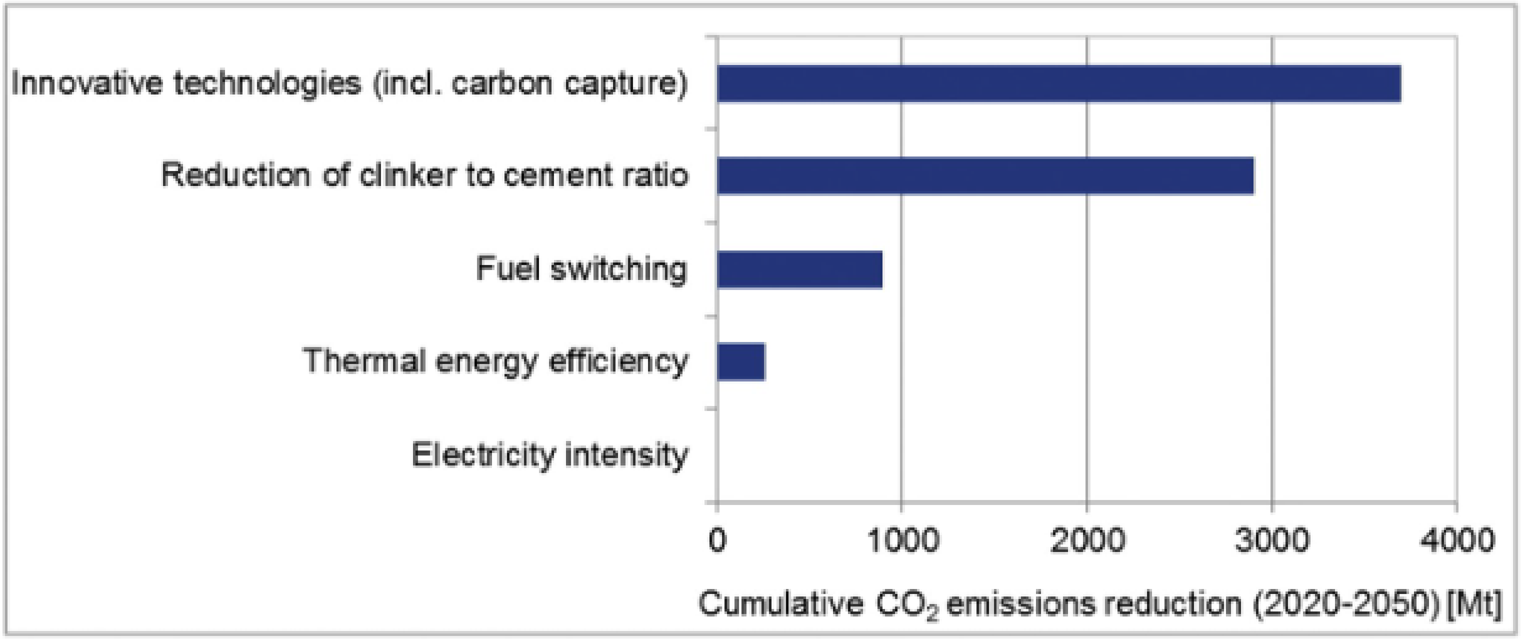



**Fig. 17.** Low-carbon roadmap cumulative $CO_2$ emissions reductions in the 2DS compared to the RTS from 2020 to 2050, as modified by VDZ, data from OECD/IEA/CSI [2].

*M. Schneider Cement and Concrete Research 124 (2019) 105792*

# Alternative fuels

- Alternative fuels can play an important role
- Moisture content, burning rate, and contamination need consideration

M. Schneider / Cement and Concrete Research 78 (2015) 14–23

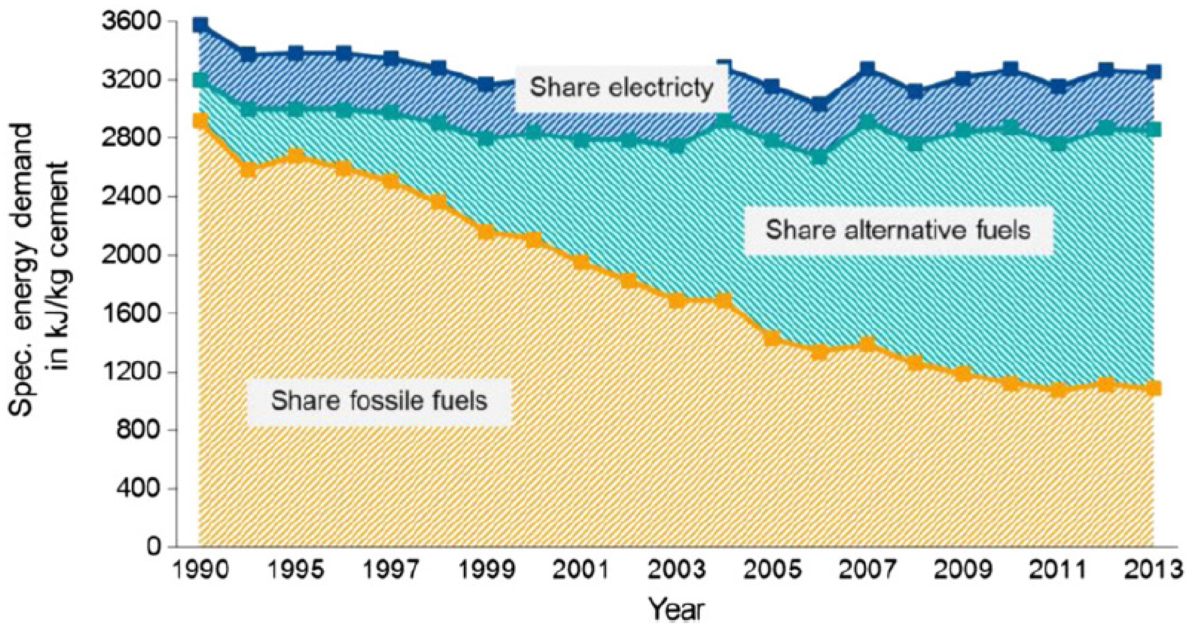
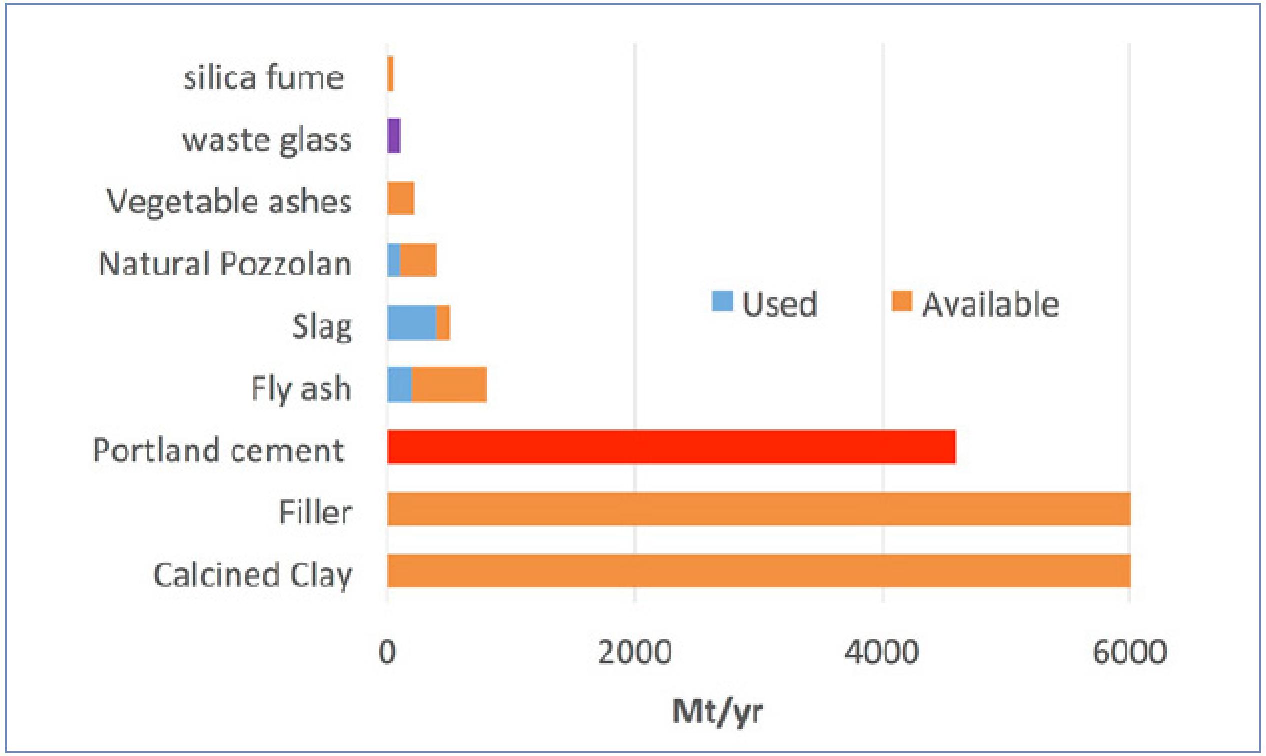



**Fig. 2.** Development of specific energy demand in the German cement industry [2].

# Clinker substitution: SCMs

- More than 60% of ready-mixed concrete in the US uses supplementary cementitious materials (SCMs) to replace a portion of cement in concrete




Eco-efficient cements: Potential, economically viable solutions for a low-$CO_2$, cement-based materials industry

Karen L. Scrivener, Vanderley M. John, Ellis M. Gartner

UNEP

# Clinker substitution: alternative cements

- Alkali-activated materials (“Geopolymers”)
- Calcium sulfoaluminate belite cements (CSAB)
- Magnesium-based cement


# Clinker substitution: alternative cements

TABLE 1

| Clinker compound | Chemical $CO_2$ emissions (kg/tonne) |
|---|---|
| Alite ($C_3S$) [typically, >60% of Portland cement clinker] | 579 |
| Belite ($C_2S$) | 512 |
| Tricalcium Aluminate ($C_3A$) | 489 |
| Tetracalcium Alumino-Ferrite ($C_4AF$, "Ferrite") | 362 |
| Quicklime (CaO) | 786 |
| Wollastonite (CS) [a major component in Solidia clinkers] | 379 |
| Ye'elimite ($C_4A_3\$$) [made with $CaSO_4$ as sulphur source] | 216 |
| Periclase (MgO) [made from magnesium carbonate] | 1100 |
| Periclase (MgO) [made from basic magnesium silicate rocks] | 0 |

Eco-efficient cements: Potential, economically viable solutions for a low-$CO_2$, cement-based materials industry

Karen L. Scrivener, Vanderley M. John, Ellis M. Gartner

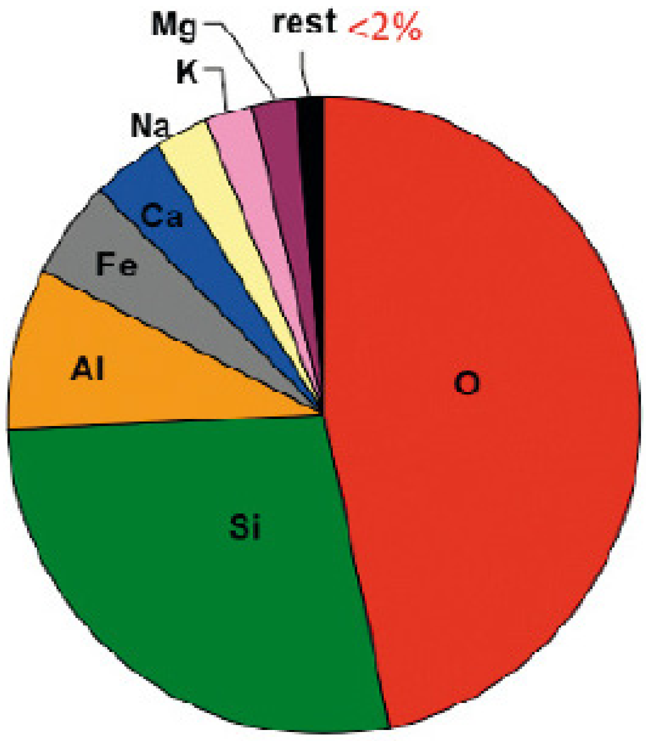



**Figure 10.** The abundance of elements in the earth's crust [Source: Wikipedia].

# Carbon capture technologies

- Amine Scrubbing
  - Norcem Brevik, Norway
- Calcium Looping
  - Heping Cement Plant, Taiwan
- Oxyfuel Combustion
  - CEMCAP in EU

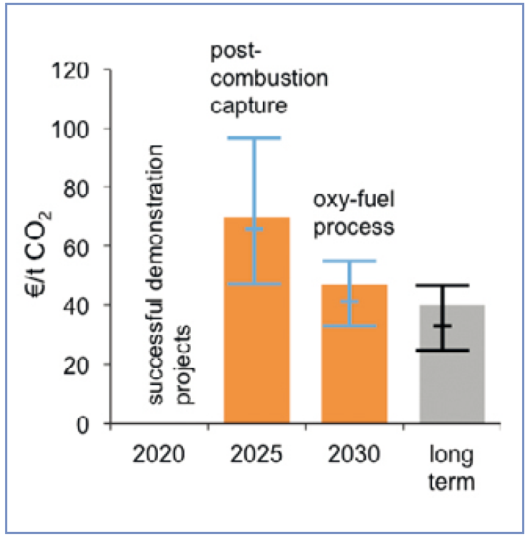
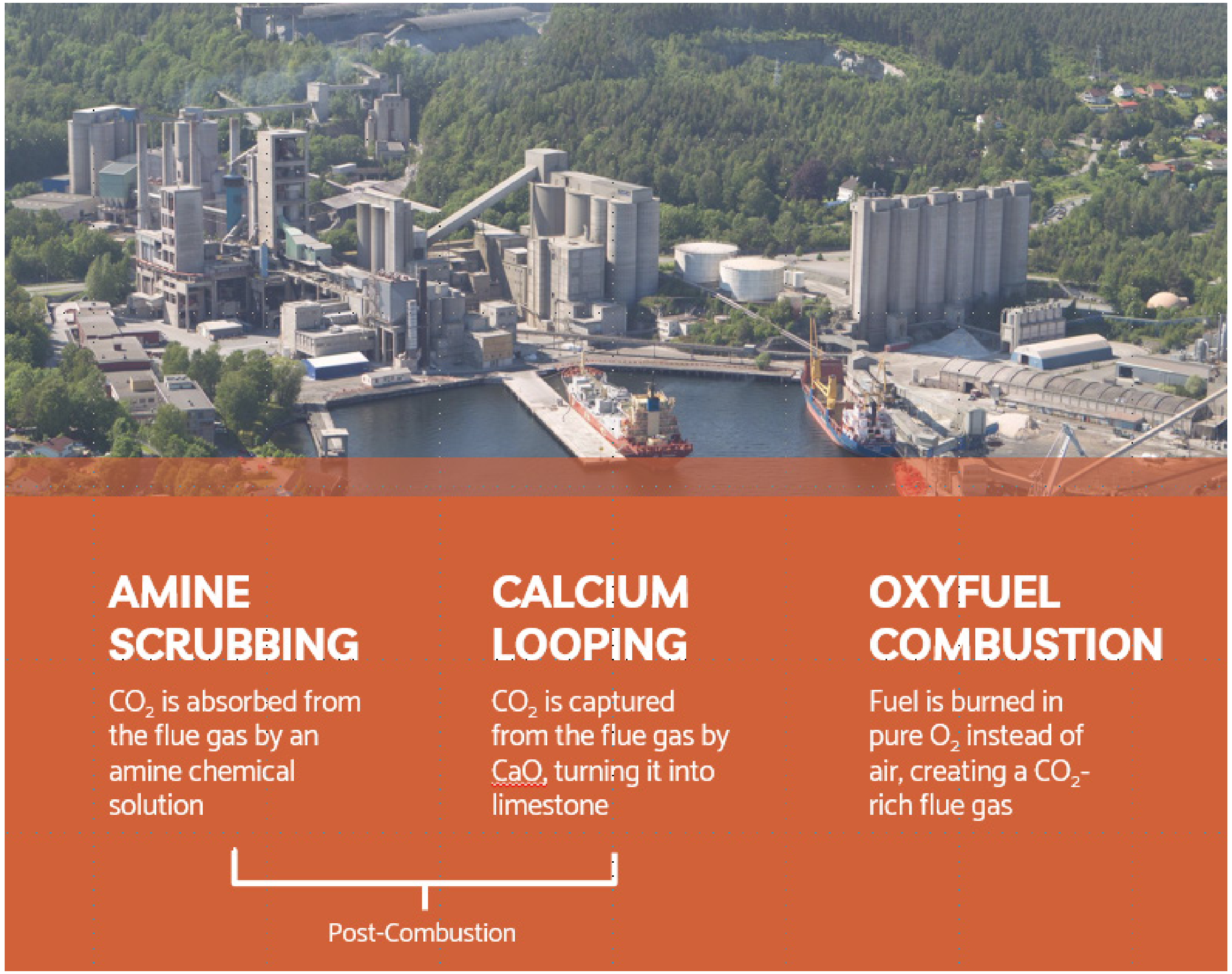


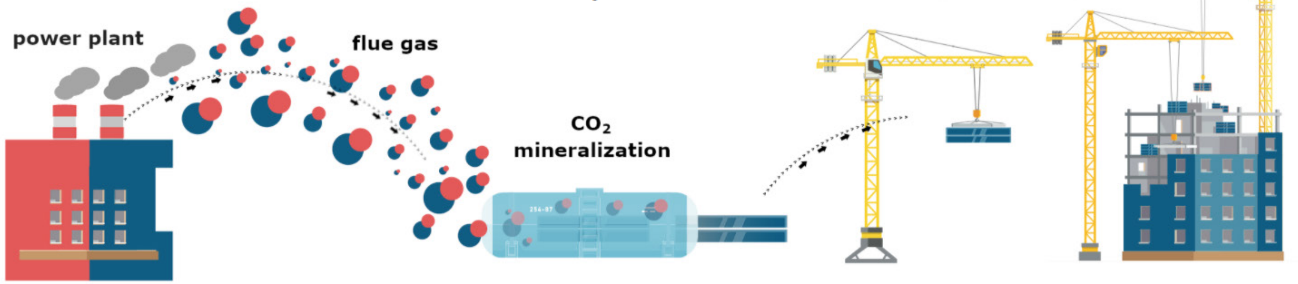

**Figure 6.** Estimated cost of carbon capture and Storage (CCS) source ECRA



# Carbon capture + alternative cements

## $CO_2$Concrete, LLC

The $CO_2$Concrete technology turns carbon dioxide emissions into $CO_2$Concrete™ products that can replace traditional concrete, with a much lower $CO_2$ footprint. The technology is based on the concept of "$CO_2$ mineralization" – the conversion of gaseous $CO_2$ into solid mineral carbonates (e.g., CaCO3) within the $CO_2$Concrete™ products.

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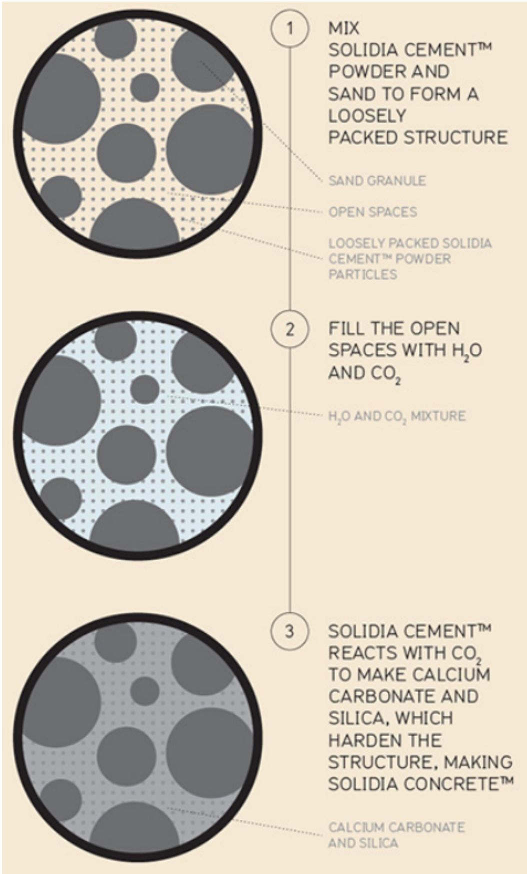

# Conclusions

- Cement and concrete are the most important materials for development of infrastructure globally
- The $CO_2$ and energy footprints of the cement and concrete industries are large, but there are several strategies being used to reduce emissions:
  - Use more alternative fuels
  - Reduce clinker/cement content in concrete
  - Implement technologies for $CO_2$ capture and reuse
- The need for change is urgent, and we need to explore short-term and long-term solutions simultaneously