CEMENT AND CO2: WHAT'S HAPPENING

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The Cement Industry

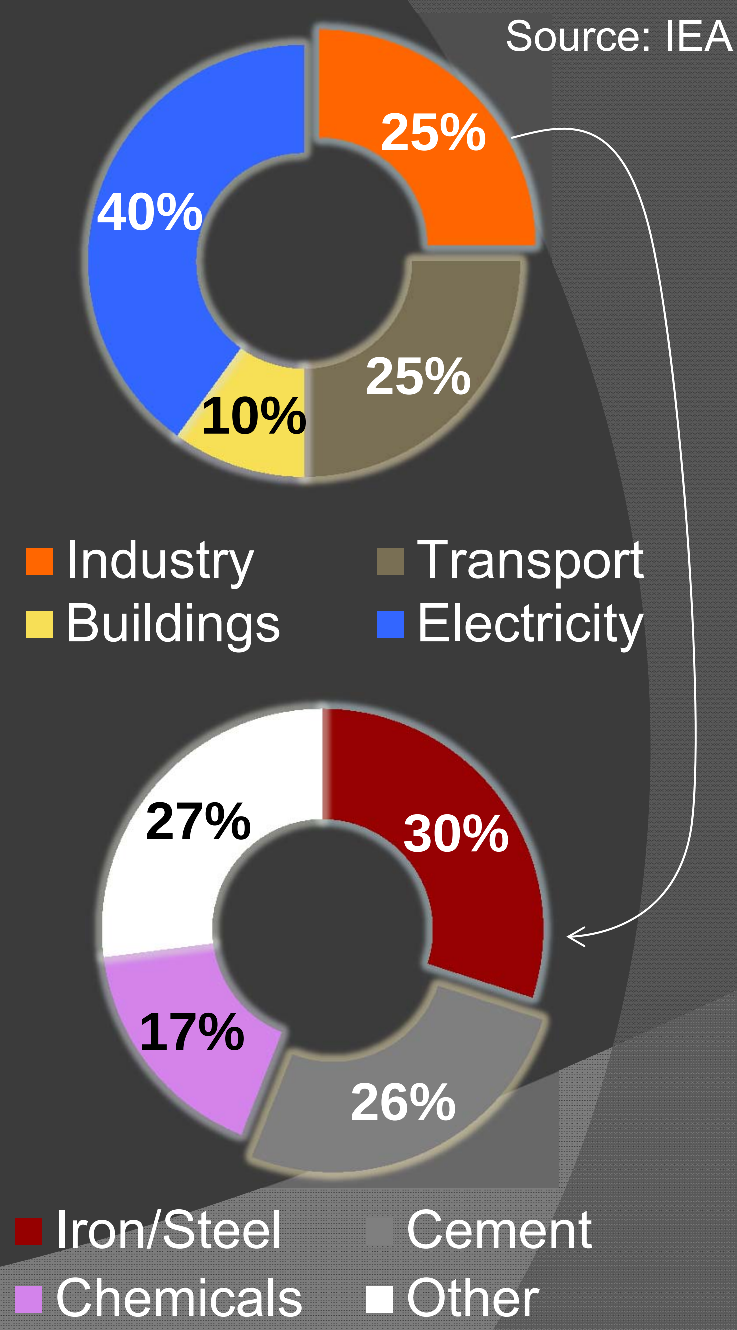
(approximate numbers)

- 4 billion tons of cement produced per year
- 16+ billion tons of concrete
- 400 million tons of process fuel consumed
- 400 gWhr process electricity consumed
- = 2.75 billion tons of $CO2$

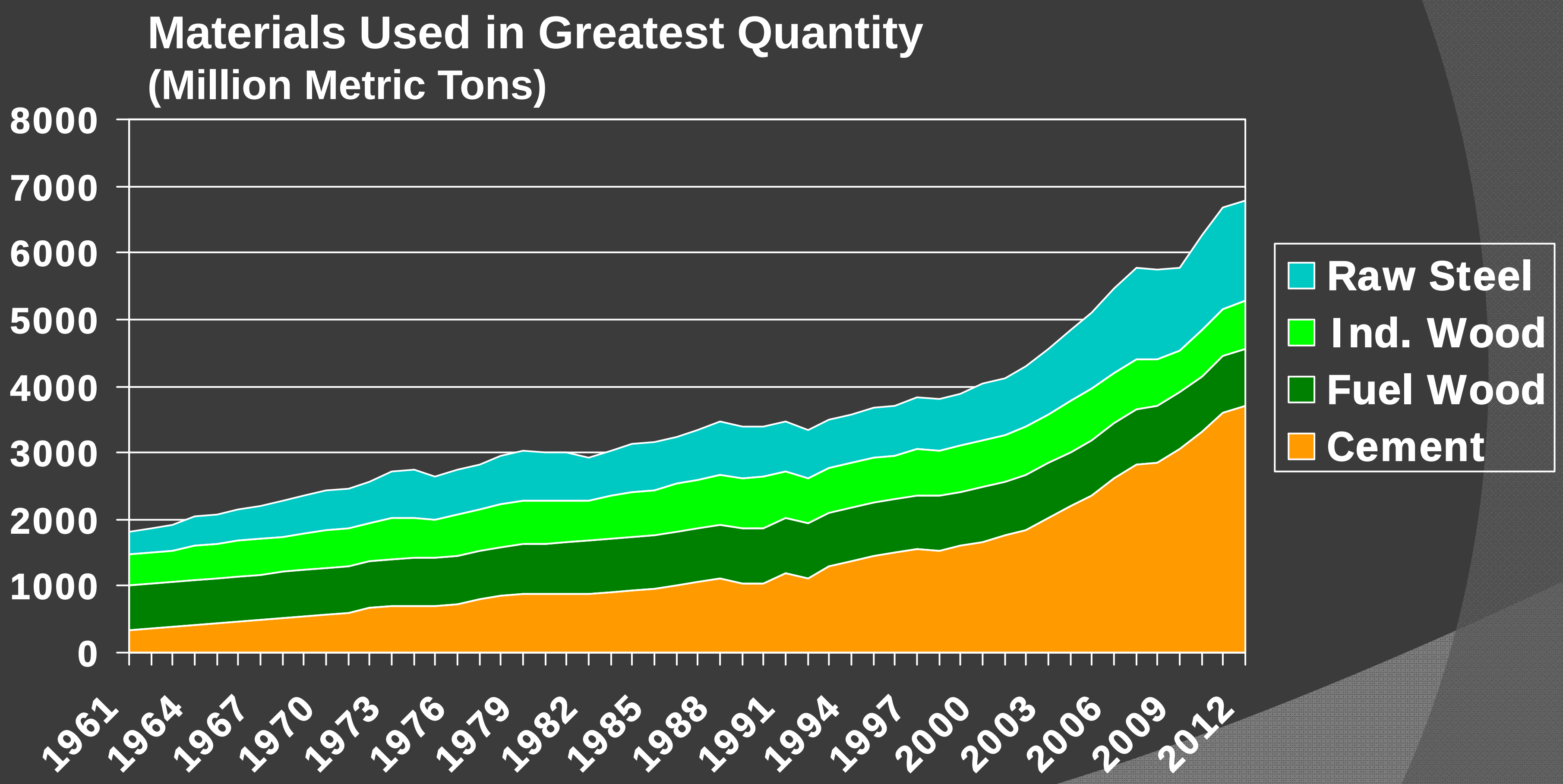
(Combustion & process only, excluding electricity)

Cement and CO_2

- World Resources Institute
  - 3.8% of worldwide GHG or
  - 5% of worldwide CO_2 emissions
- International Energy Agency
  - 7% of worldwide CO_2 emissions

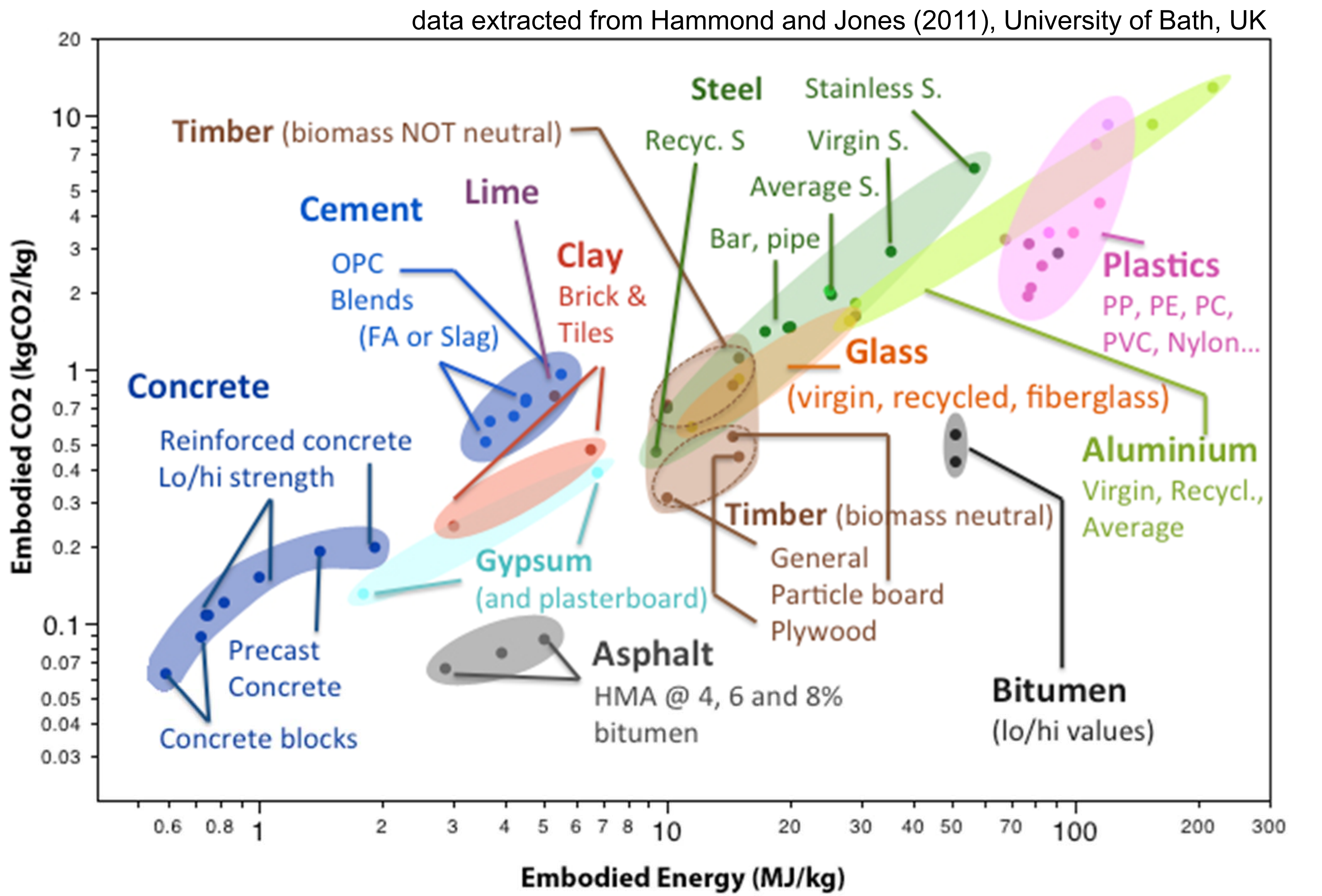


World Demand for Selected Raw Materials, 1961 – 2012

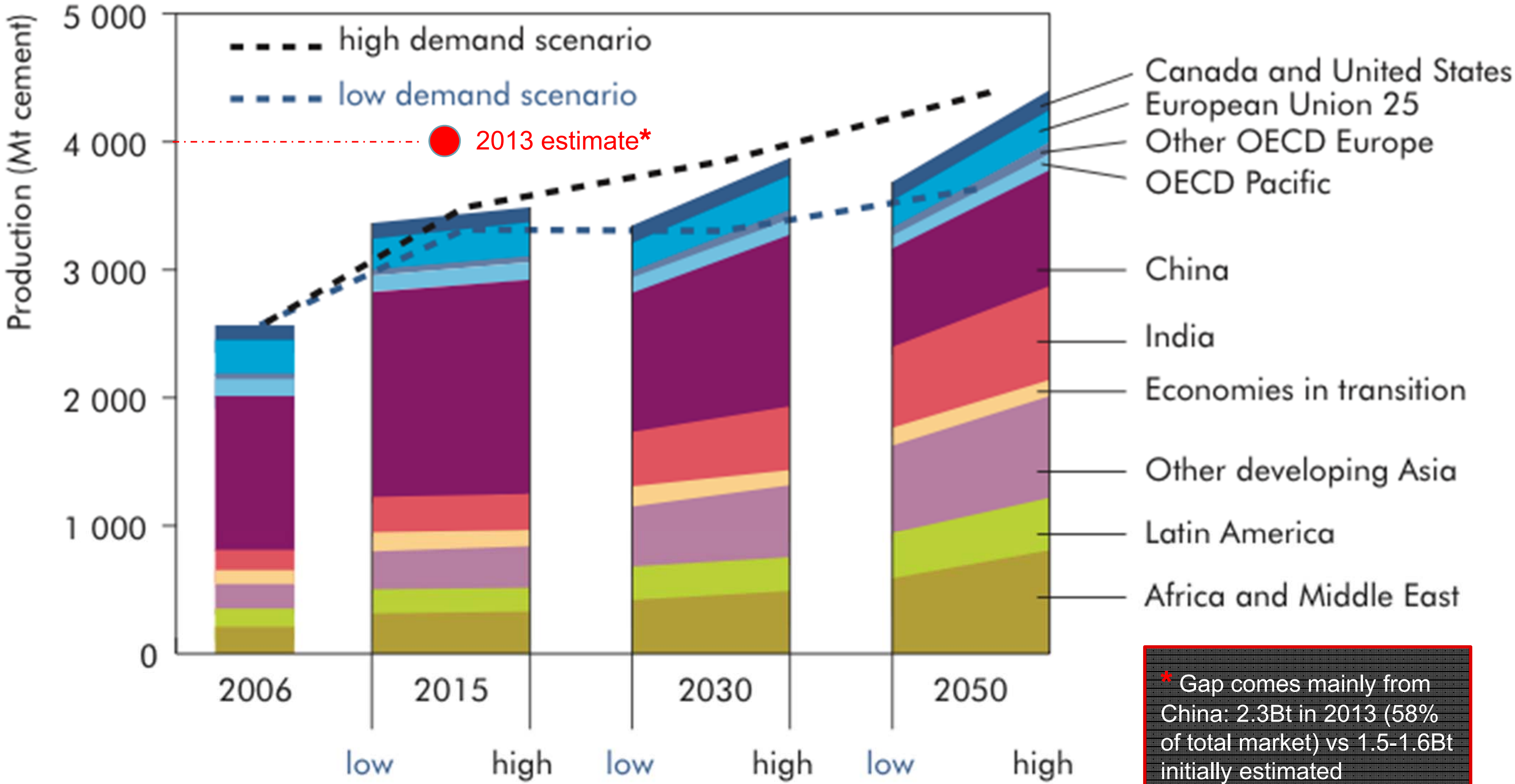


Source: U.S. Geological Survey, Commodity Summary Statistics (2013). Data for wood from UN, FAOStat Forestry (2013) compiled by forestinfo.org

The Carbon Footprint of Cement and Concrete

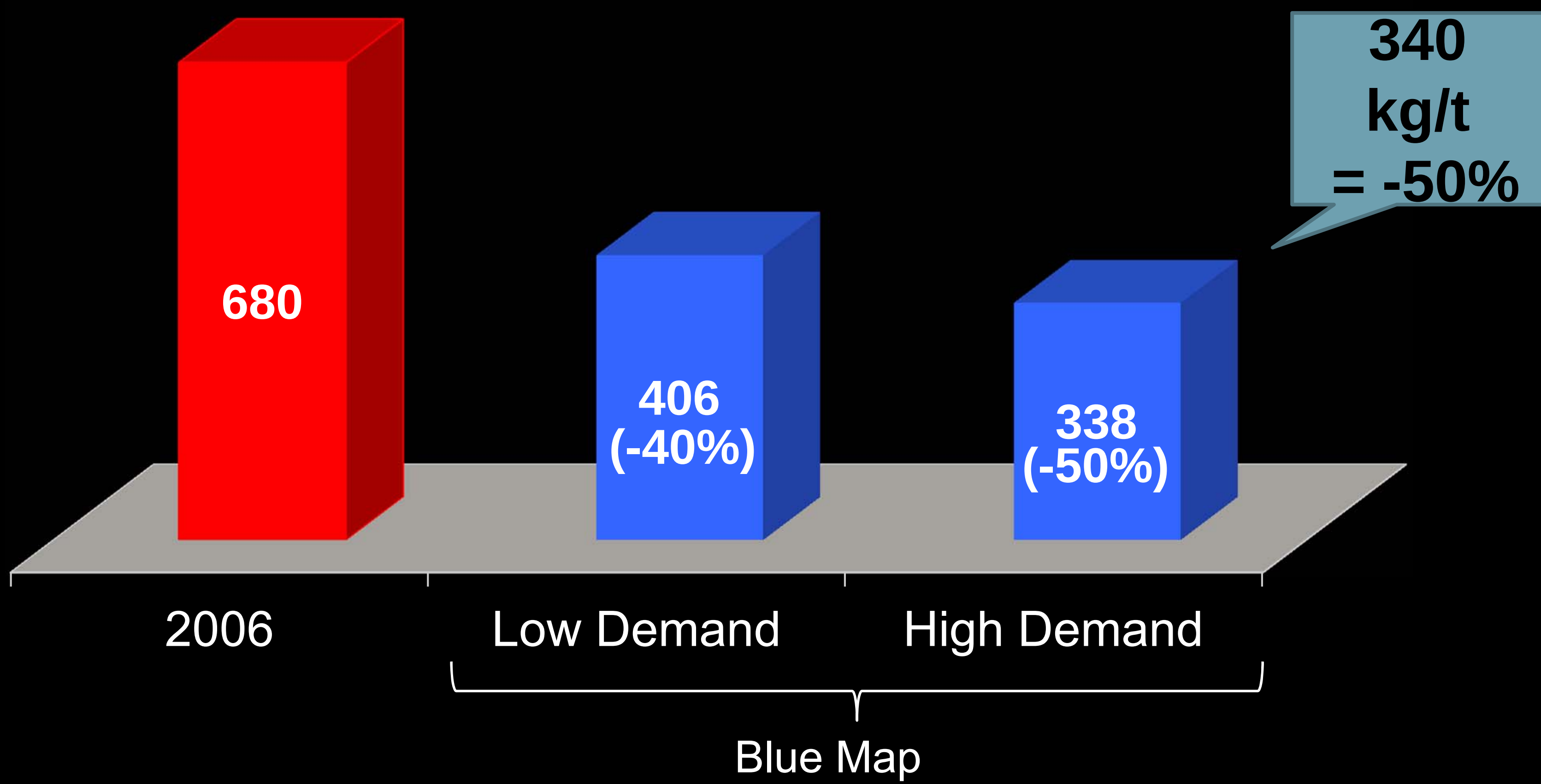


Cement demand from IEA projections



* Gap comes mainly from China: 2.3Bt in 2013 (58% of total market) vs 1.5-1.6Bt initially estimated

The Cement Industry Technology Roadmap to Reduce Carbon Emissions



Main levers to reduce CO2 emissions

Direct CO_2 emissions in Cement Manufacture

CO_2 from Limestone calcination *(fairly constant from plant to plant)*	⇨	**~535 kg/t clinker**
		+
CO_2 from fuels combustion *(larger variations from plant to plant)*	⇨	**~330 kg/t clinker**
		=
Direct CO_2 emissions for clinker	⇨	**~865 kg/t clinker**
		x
Average clinker content in cement *(2006 value from CSI)*	⇨	**78%**
		=
Direct CO_2 emissions for cement	⇨	**~680 kg/t cement**

Note: Excludes CO_2 from electricity (about 10% in the case of cement)

Plus a New Lever

Clinker Reformulation

Energy Efficiency

Biogenic Fuels

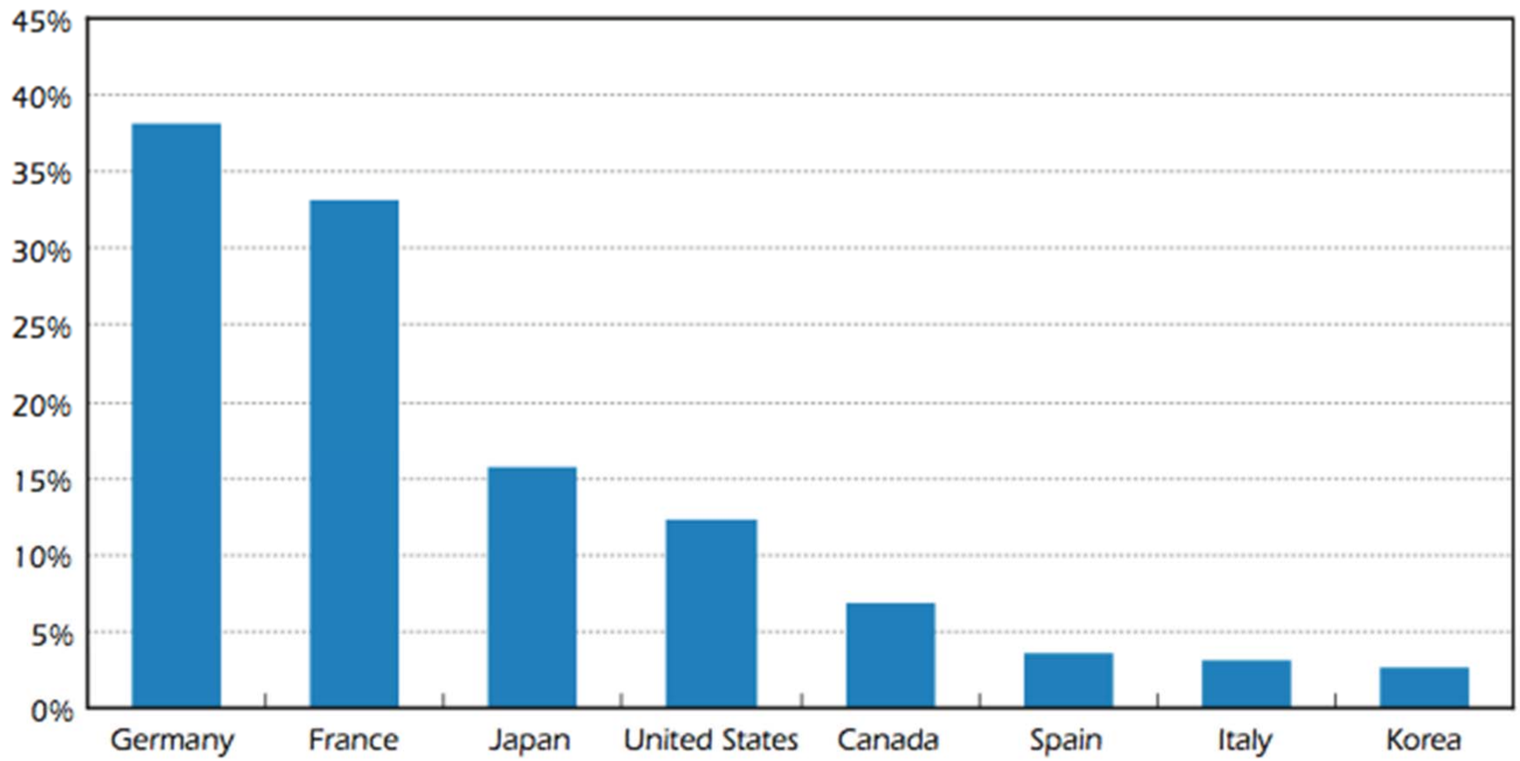
Clinker Substitution

1. Energy Efficiency

Process	Typical Fuel Consumption (GJ/t)	*Efficiency (%)*
Theoretical consumption	***1.75***	
Vertical Shaft Kilns	~5	*35%*
Wet Kilns	5.9 - 6.7	*25-30%*
Dry Kilns		
Long Dry Kilns	4.6	*38%*
2 Stages Pre-Heater (PH)	3.8	*46%*
4 Stages PH	3.3	*53%*
4 Stages PH + Pre-Calciner (PC)	3.1	*56%*
5 Stages PH+PC (BAT)*	**3**	***58%***

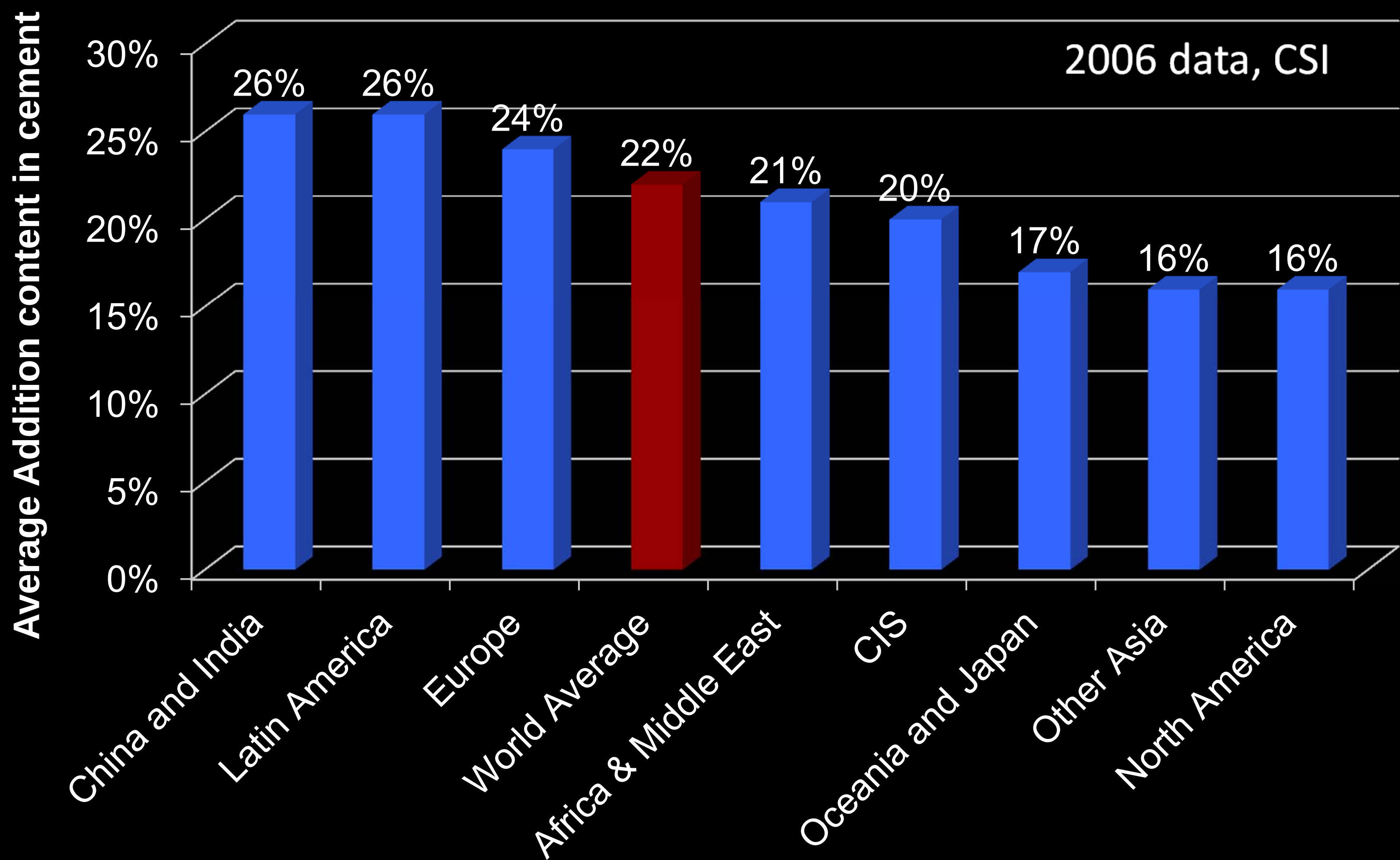
* Industry's Best Available Technology

2. Alternative Fuels and Biomass



Sources: VDZ, 2006; Japan Cement Association, 2006; USGS, 2006; NRCAN, 2006; AITEC, 2005; OFICEMEN, 2007; Observatoire de l'énergie, 2003; and Dong-Woon, 2006.

3. Clinker Substitution



How the Big Producers are Doing

Producers	Alternative Fuel %	Clinker in Cement %	Specific Heat Consumption Mj/t
Lafarge	13.9%	72.6%	3,653
Holcim	13.0%	70.3%	3,495
Heidelberg	21.7%	75.4%	3,342
Italcementi	6.5%	76.5%	3,820
Cemex	27.1%	81.8%	3,876
Best in Class	100%	<50%	<3,000
Limitation	Supply	Standards	Technology

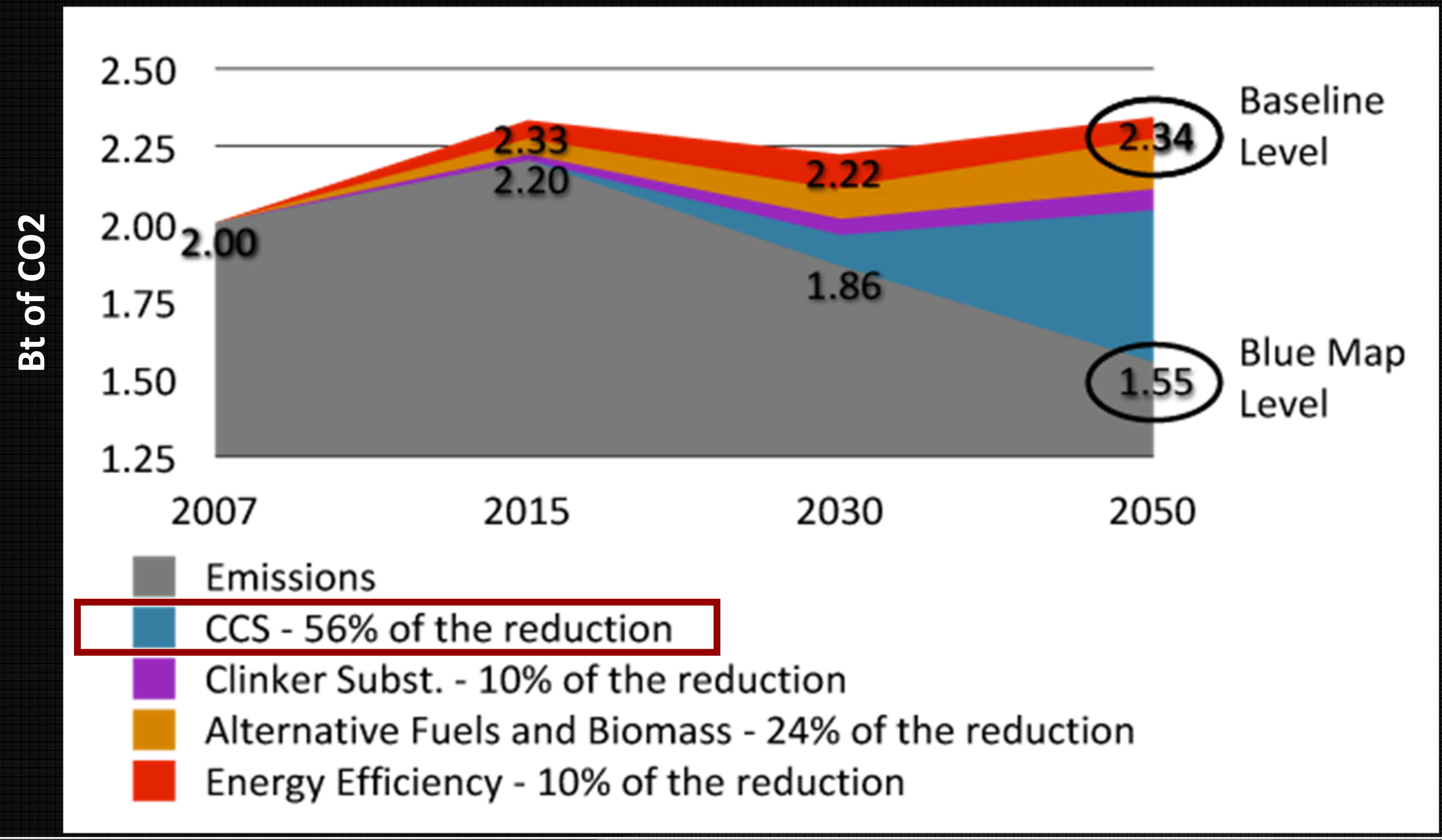
Source: 2012 Sustainability Reports

4. New Clinkers (New Lever)

Clinker Mineral	Normal Portland	Lafarge	Italcementi	Heidelberg	Buzzi	Vicat
CaO	43%	37%	31%	37%[1]	32%	↓
SiO_2	14%	12%	5%	17%	7%	N/A
Al_2O_3	4%	11%	28%	10%[2]	20%	↑
Fe_2O_3	2%	5%	1%	3%	2%	N/A
SO_3	1%	3%	11%	6%	9%	N/A
LOI	35%	29%	24%	24%	26%	↑

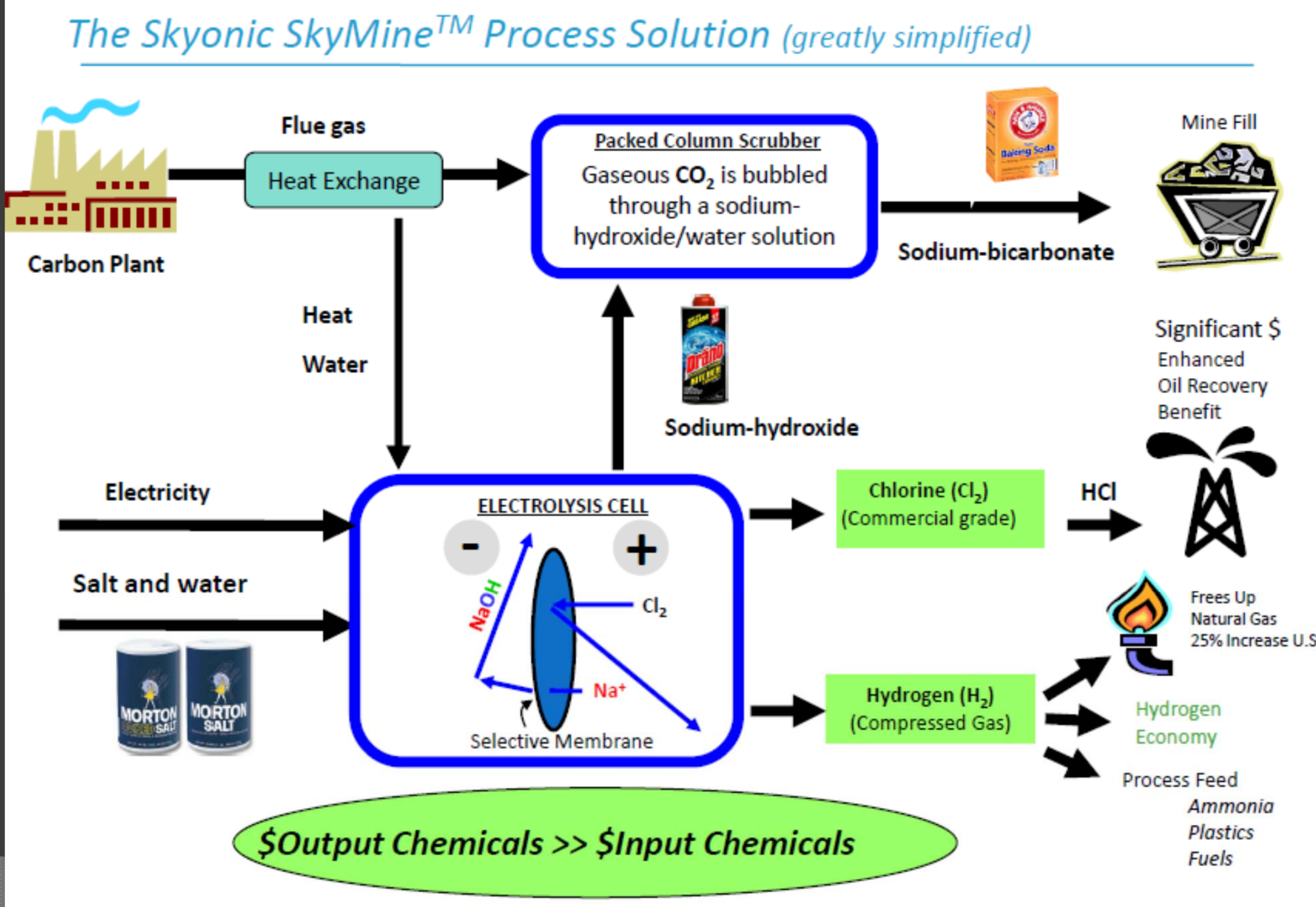
Potential for another 20% decrease ,,,

The Cement Technology Roadmap (CSI+IEA)

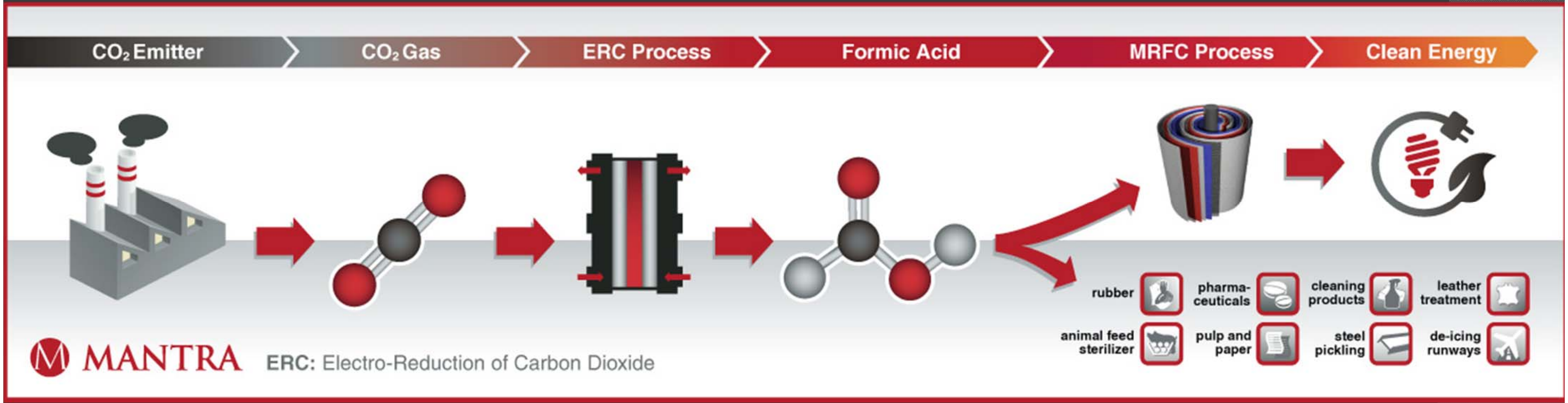


Carbon Utilization Projects In Cement

Capitol Aggregates – Cement Plant, San Antonio, Texas



Lafarge Cement – Vancouver, British Columbia, Canada



Cement - Algae / Microbe Projects

Company	Plant	Country	Partner	Comments
Holcim	Alicante	Spain	BFS	Now Cemex
Lafarge	Val d'Azergues	France	Salata	Closed
Heidelberg	Degerhamn	Sweden	Linnaeus Univ.	
Heidelberg	Cupertino	US	Oakbio	Microbes
Heidelberg	Buda	US	Sunrise Ridge Algae	Closed
Italcementi	Gargenville	France	GEPEA laboratories & Algosource Technologies	
Votorantim	St. Mary's	Canada	Pond Biofuels	
Argos		Columbia	Eafit Univ.	
Cemex		UK	Algaecat Consortium	
Holcim	Lanka	Sri Lanka	Algae-Tec	Not started
Secil	Cibra-Pataias	Portugal	A4F – Algafuel	
Intercement		Brazil	Various Univ.	
Taiwan Cement	Heping	Taiwan	Industrial Technology Research Institute	Using CO2 from capture

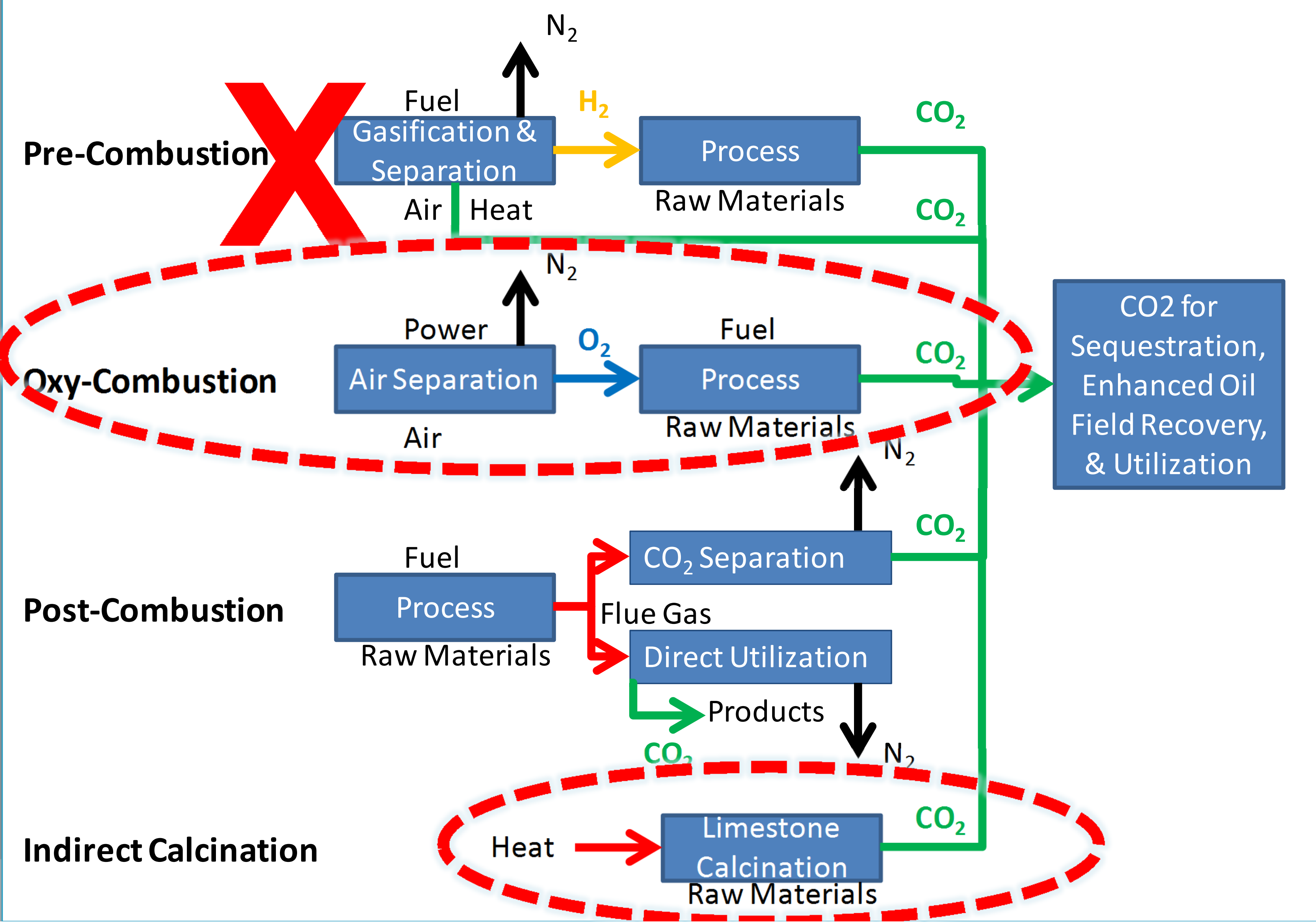
Carbonate Bonding

- Carbon Cure
- Injecting CO_2 into concrete while wet
- Pros – reduces CO_2 emissions
- Lower purity stream can be used
- Easy adoption
- Cons – only consumes 10% of cement CO_2 (Max)

- Solidia
- Creating a new formulation that only bonds with CO_2
- Pros – lower carbon footprint to manufacture
- Consumes CO_2 for bonding
- Cons – adoption time

Oxy-Combustion
& Indirect Calcination
In Cement (and Lime)

CO2 Capture Technologies



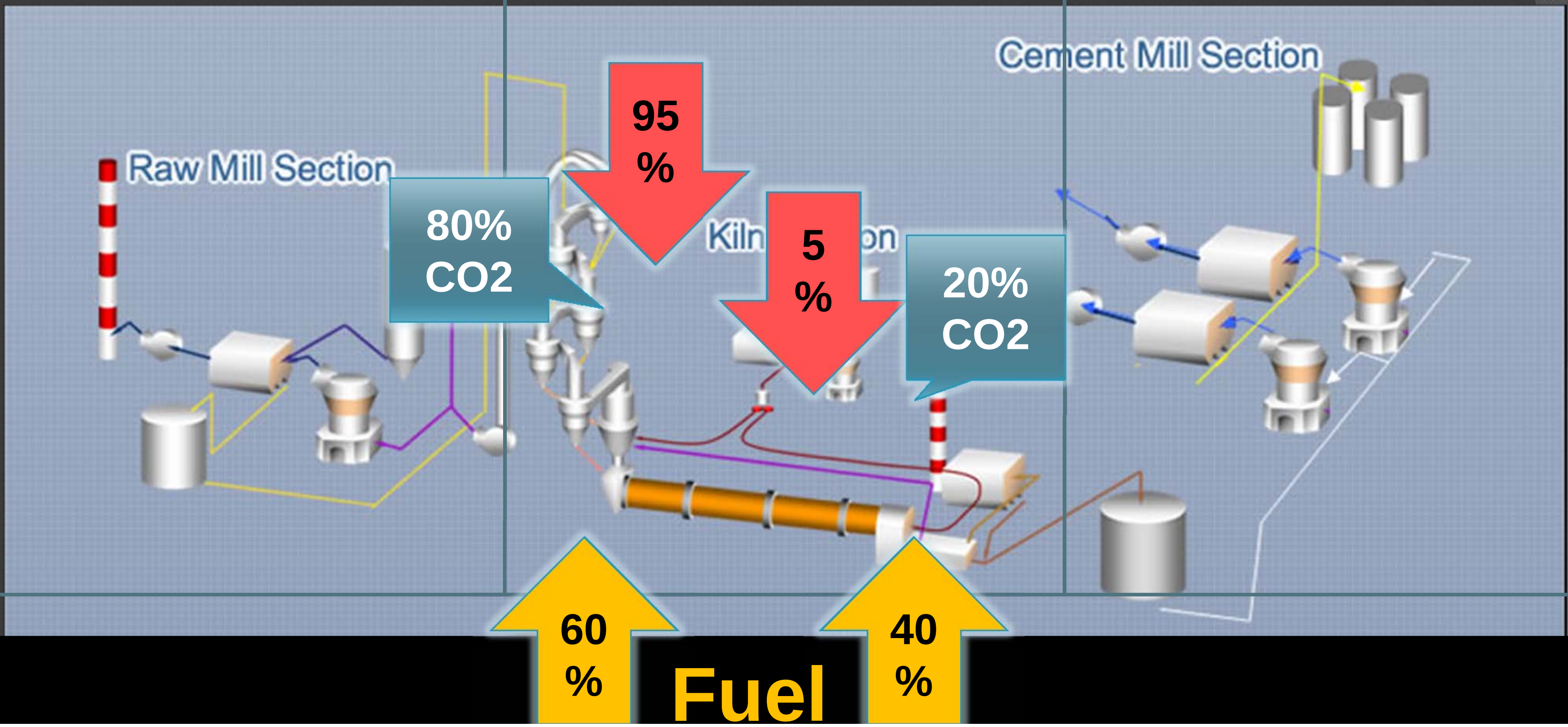
ECRA – European Cement Research Academy

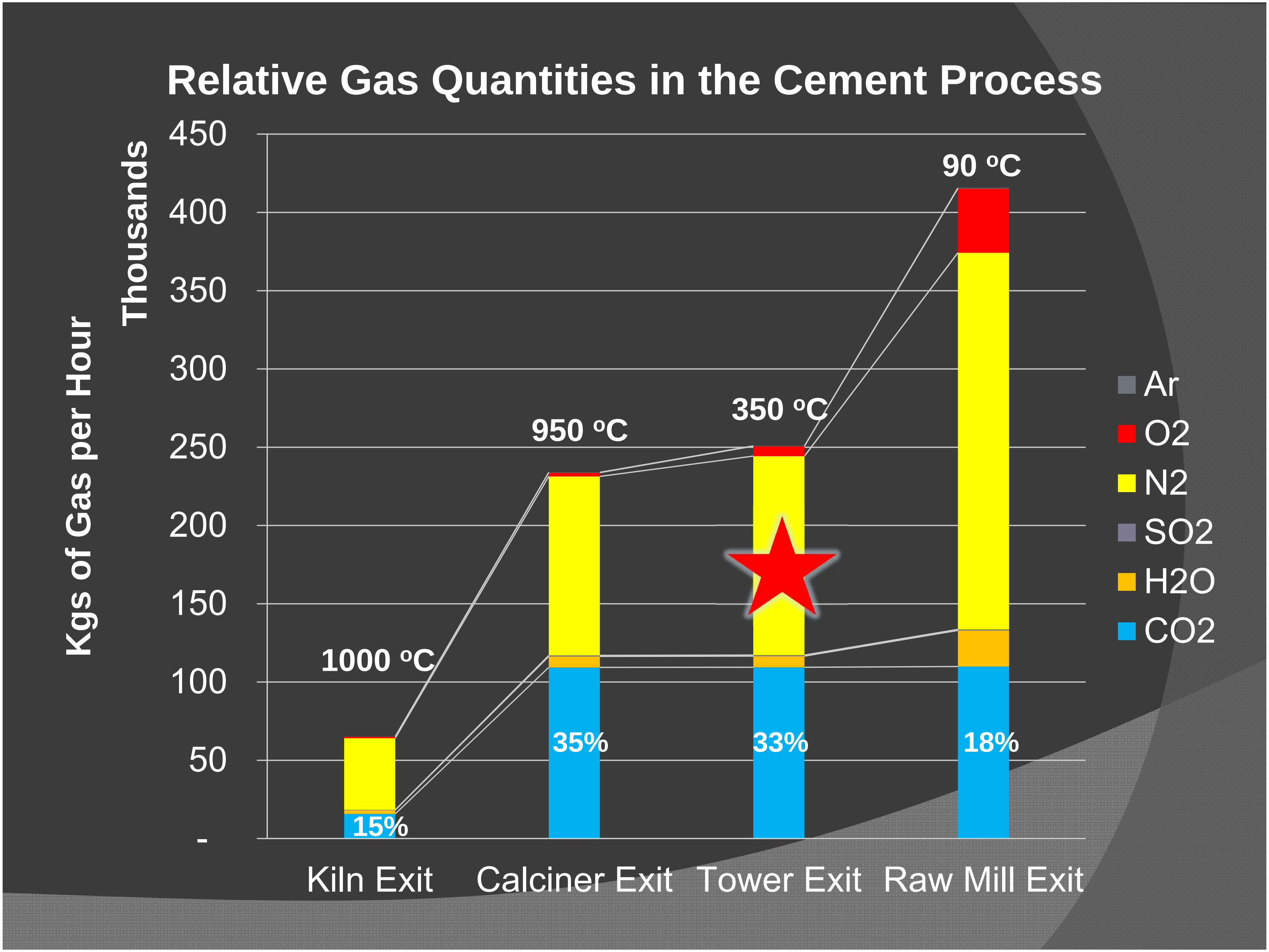
- Phase I: Literature and scoping study (January - June 2007) - finalized
- Phase II: Study about technical and financial aspects of CCS projects, concentrating on oxyfuel and post-combustion (amine sorbent) technology (summer 2007 – summer 2009)
- Phase III: Laboratory-scale / small-scale research activities (autumn 2009 – summer 2011)
- Phase IV: Pilot-scale research activities (time-frame: 2-3 years)
- Phase V: Demonstration plant (time-frame: 3-5 years)

Cement Manufacture - Precalciner

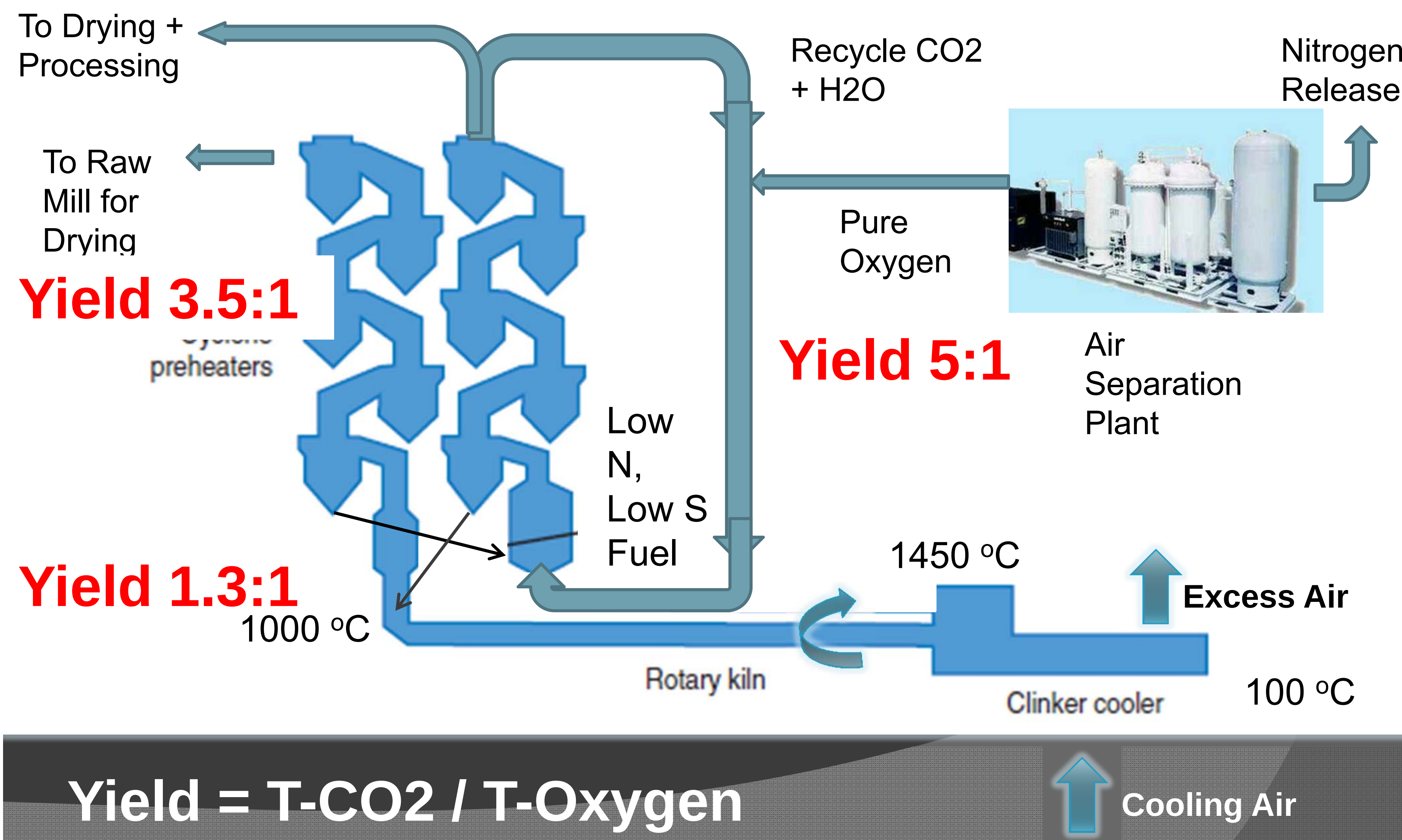
Material Preparation	Thermal Processing	Finishing

Calcination



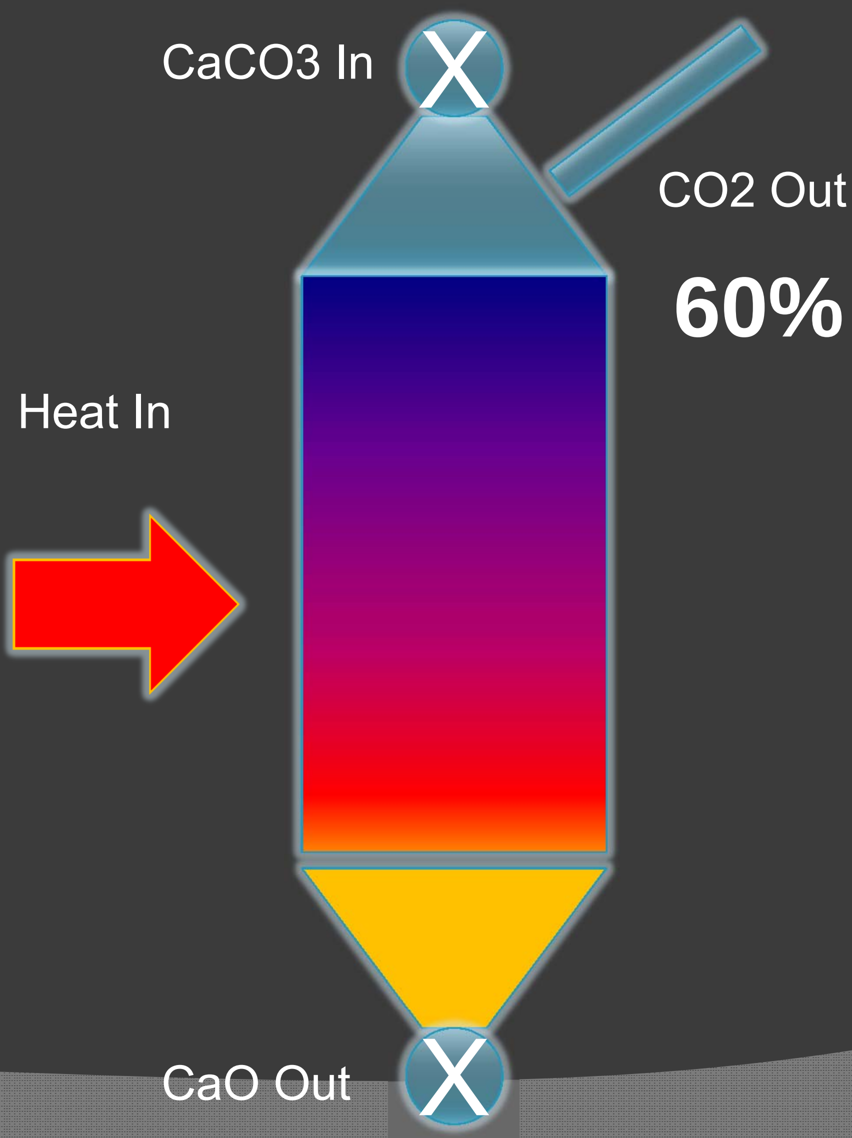

Relative Gas Quantities in the Cement Process
Kgs of Gas per Hour
Thousands
450
400
350
300
250
200
150
100
50
-
1000 ºC
950 ºC
350 ºC
90 ºC
15%
35%
33%
18%
Kiln Exit
Calciner Exit
Tower Exit
Raw Mill Exit
Ar
O2
N2
SO2
H2O
CO2

Potential Oxy-Calcination (80%)



Yield = T-CO2 / T-Oxygen

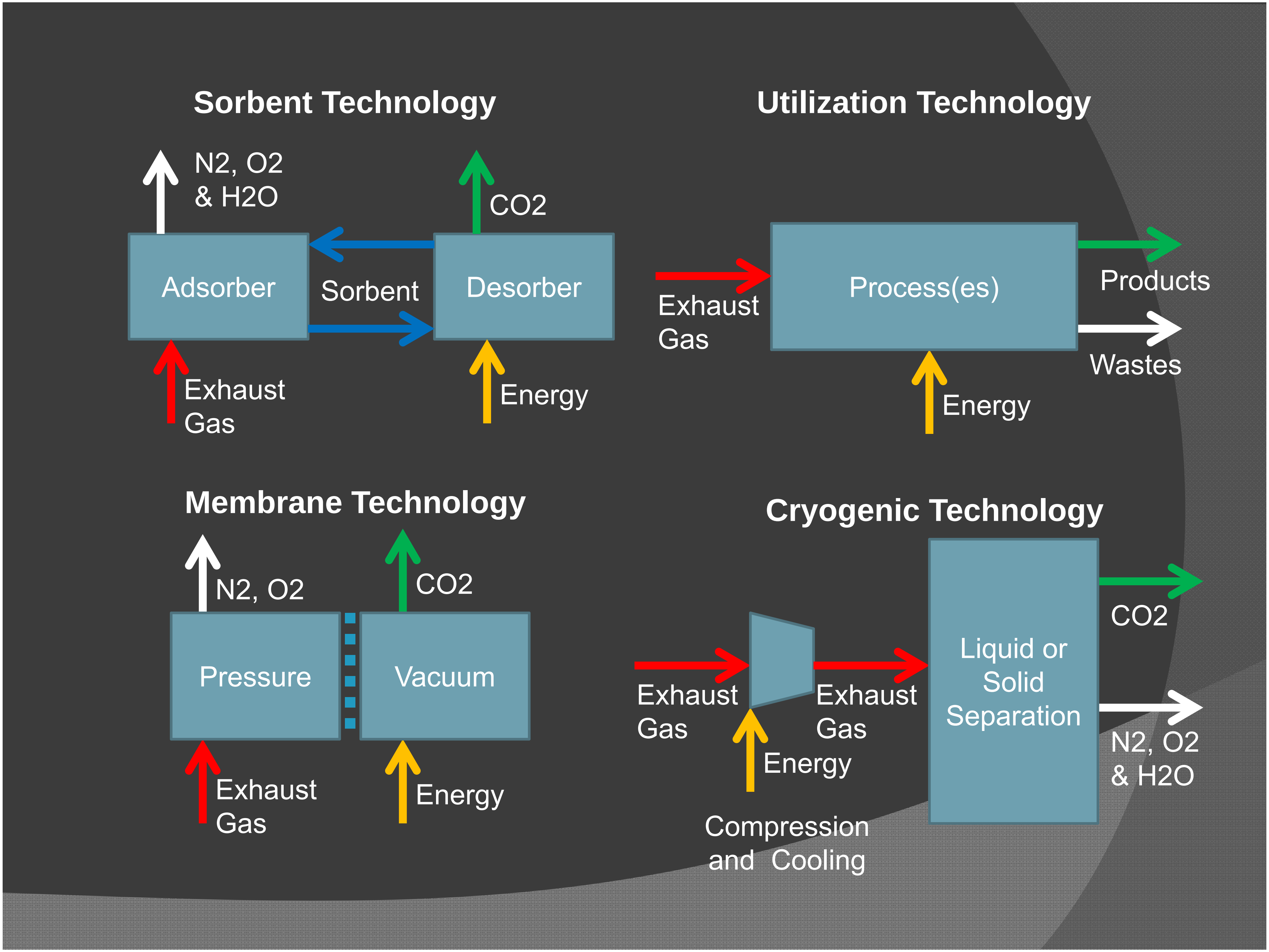
Indirect Calcination



Potential Indirect Heat Sources:

Electric Induction
Heat Transfer Oils
Hot Gases
Metal Balls
Clinker
Ceramic Media
Etc.

Post Combustion Projects In Cement



Sorbent Technology
N2, O2
& H2O
CO2
Adsorber
Sorbent
Desorber
Exhaust
Gas
Energy
Utilization Technology
Exhaust
Gas
Process(es)
Products
Wastes
Energy
Membrane Technology
N2, O2
CO2
Pressure
Vacuum
Exhaust
Gas
Energy
Cryogenic Technology
Exhaust
Gas
Exhaust
Gas
Energy
Compression
and Cooling
Liquid or
Solid
Separation
CO2
N2, O2
& H2O

Cansolv – Amines Pilot

- CalPortland, Mojave, CA 2008
- 45 – 90% Capture
- Limited information available

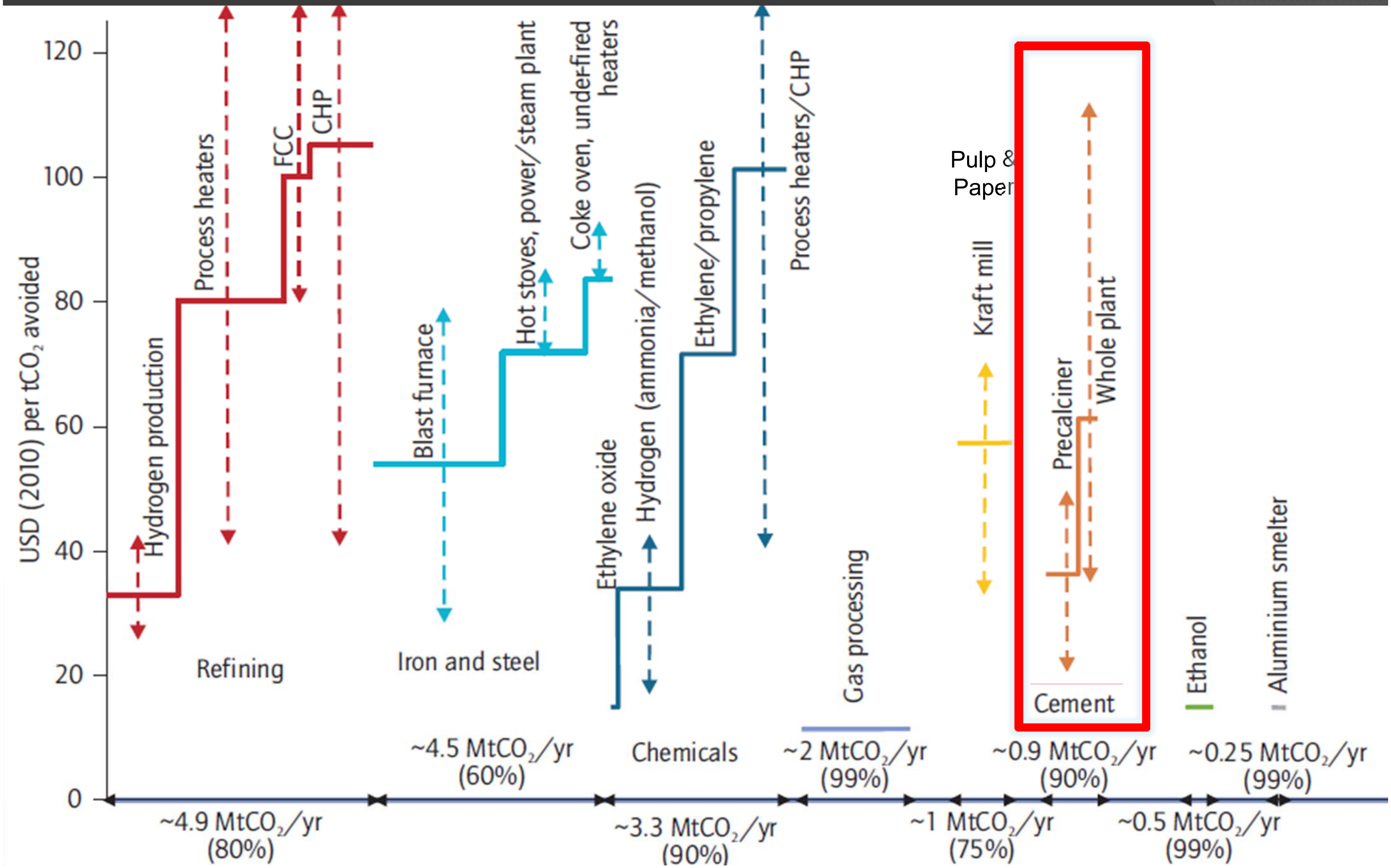
Cement Specific Projects

- Norcem (Heidelberg) pilot projects at their Brevik, Norway cement works.
  - Four different post-combustion capture technologies will be studied in Test Step 1:
    - KEMA GL/ NTNU & Yodfat Engineers – **Membrane Technology** (MC) – 2014 - Jan
    - RTI - **Solid Sorbent Technology** – 2014 - Feb
    - Aker Solutions - **Amine Technology** – 2014 - Apr
    - Alstom Power - **Regenerative Calcium Cycle** – 2014 – Mar (phase I – off site)

Taiwan Cement
Heping Plant
Taiwan

1 tph CO_2
Carbonate
looping project
\$26 - \$40 / t-CO_2

Costs of CO2 Avoidance (IEA 2013)



Conclusions

- The cement industry is serious about the challenge
- Significant progress has been made through traditional means
- Cement and Concrete are still the most sustainable building materials
- Carbon utilization shows promise, but not there yet
- Carbon capture and sequestration remains expensive and should be the last option
- However, Cement manufacture represents a better source for CO2 capture

Get some CO2 from a Cement Plant Near you !

Legalize Coal