# BCSAF clinkers

# A credible low carbon alternative to Portland Cement

Laurent Barcelo, John Kline, Gunther Walenta, Bruce Blair and Ellis Gartner

**1**

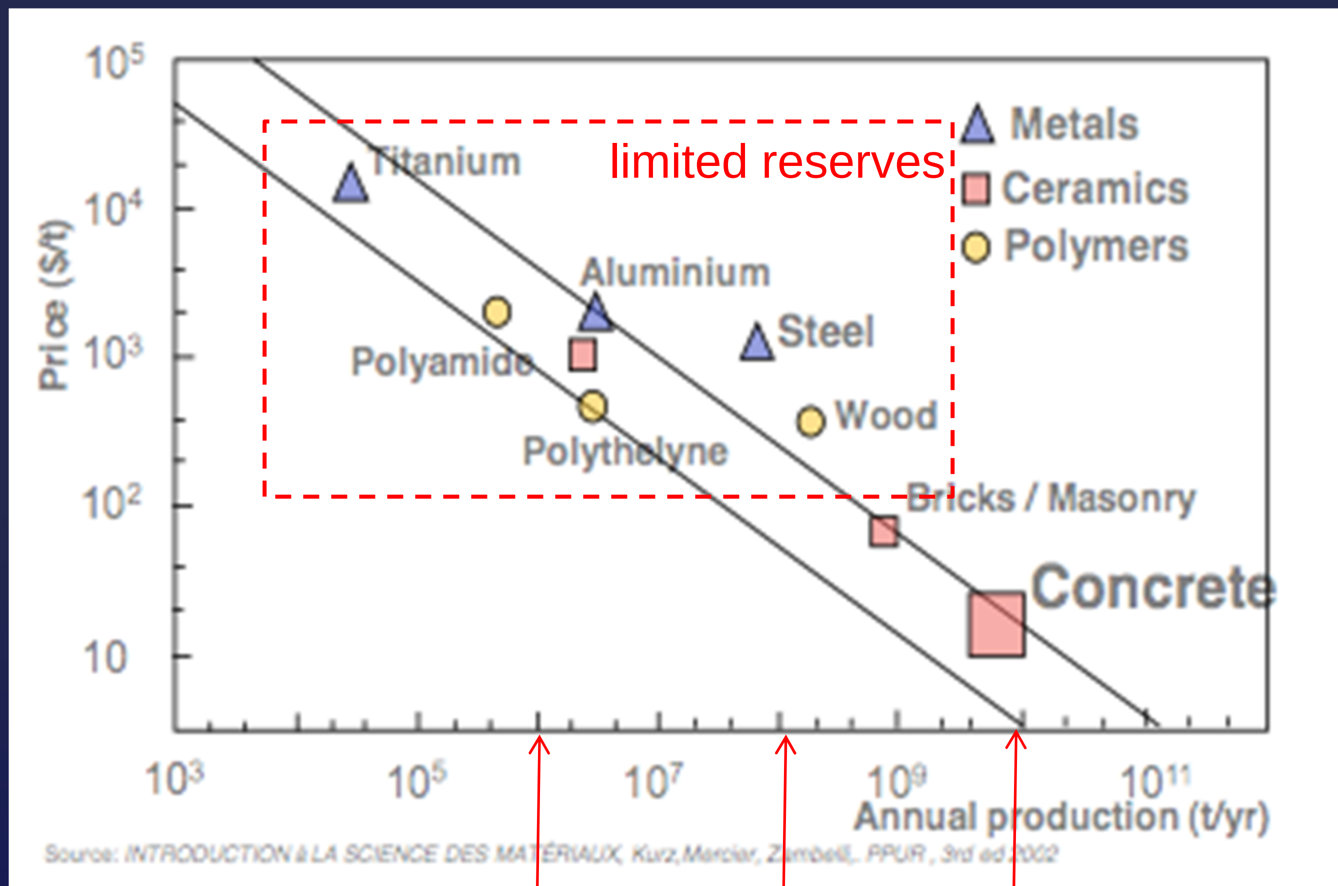
Cement and Concrete are not the “bad guys” we hear too often…

Conservative estimation of the amount of concrete produced every year on the planet:

# 15,000,000,000 t

# …over **2t/inhabitants**

# … and there are good reasons for this …




Orders of magnitude → 100g 10kg 1t

# … and there are good reasons for this …

Cost

Local availability in large quantities

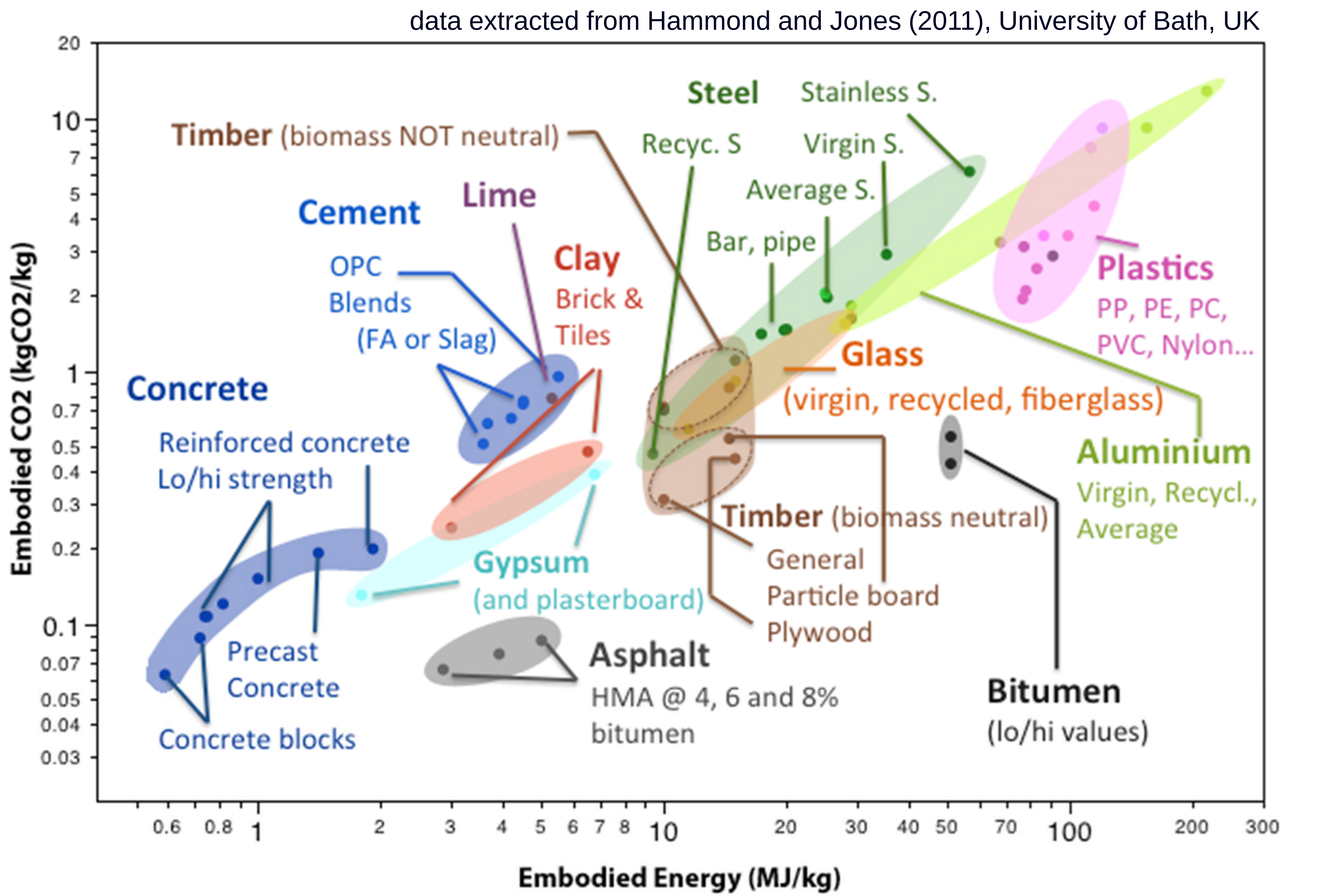
Ease of use

Relative robustness to misuse

Versatility

Durability

…


data extracted from Hammond and Jones (2011), University of Bath, UK
Embodied CO2 (kgCO2/kg)
Embodied Energy (MJ/kg)
Steel
Stainless S.
Recyc. S
Virgin S.
Average S.
Bar, pipe
Timber (biomass NOT neutral)
Lime
Cement
OPC
Blends
(FA or Slag)
Clay
Brick &
Tiles
Concrete
Reinforced concrete
Lo/hi strength
Precast
Concrete
Concrete blocks
Gypsum
(and plasterboard)
Asphalt
HMA @ 4, 6 and 8%
bitumen
Glass
(virgin, recycled, fiberglass)
Timber (biomass neutral)
General
Particle board
Plywood
Plastics
PP, PE, PC,
PVC, Nylon...
Aluminium
Virgin, Recycl.,
Average
Bitumen
(lo/hi values)

**2**

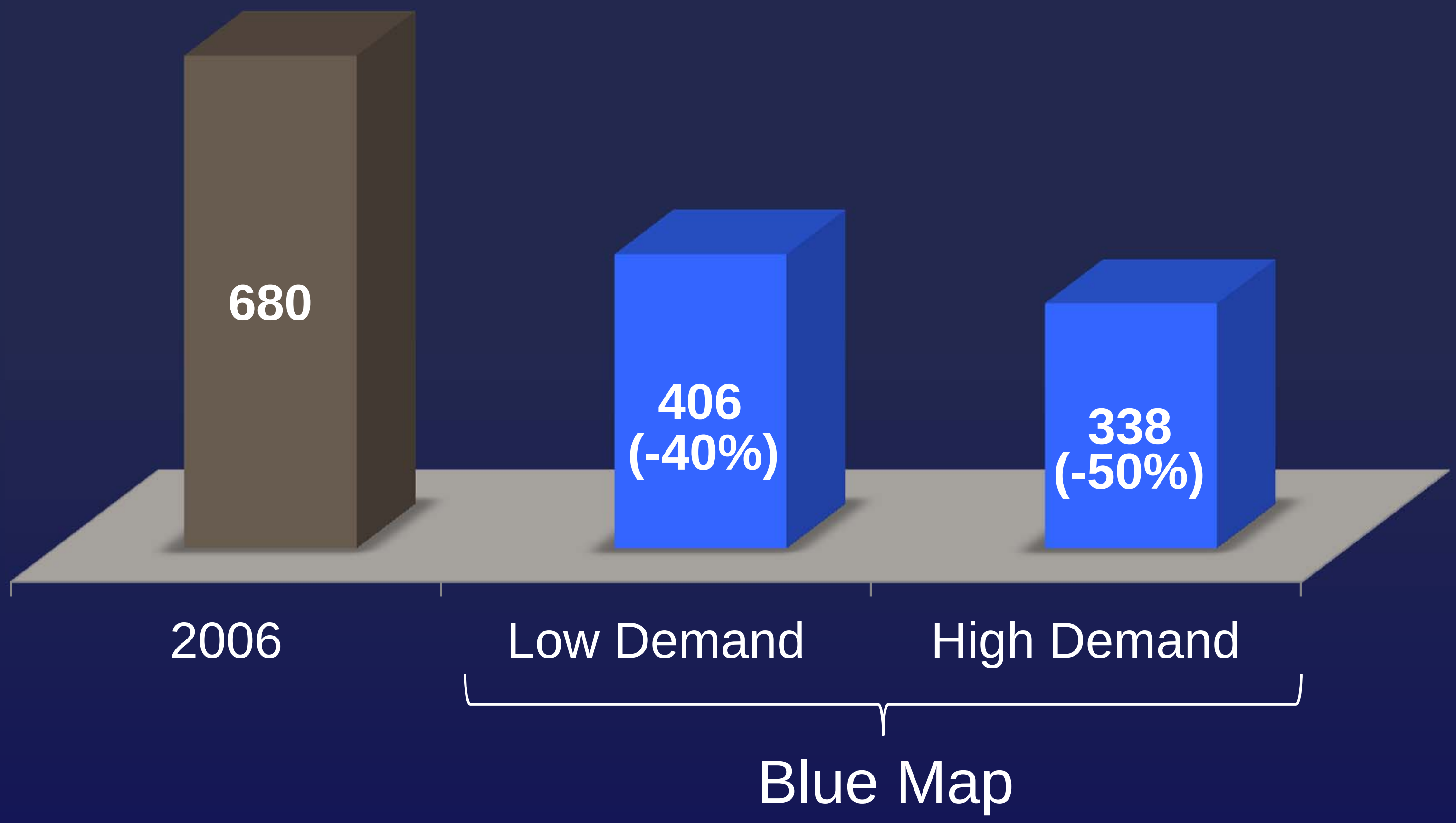
Of course, we need to develop “greener” cement and concrete…

# IEA Blue Map Scenarios

- Mandated by G20 to work on long-term **scenarios of carbon reductio**n (2050);
- 2012 update provides BAU scenario (eq. **+6° C**) as well as **+4° C** and **+2° C** scenarios by 2050
- Promote a **sectorial approach** as the least cost way to reduce carbon emissions
- Lead the development of **technology roadmaps** in key areas. One developed for the cement industry!

# The Cement Industry Technology Roadmap to Reduce Carbon Emissions

In terms of specific emissions (kg of $CO_2$ per ton of cement):



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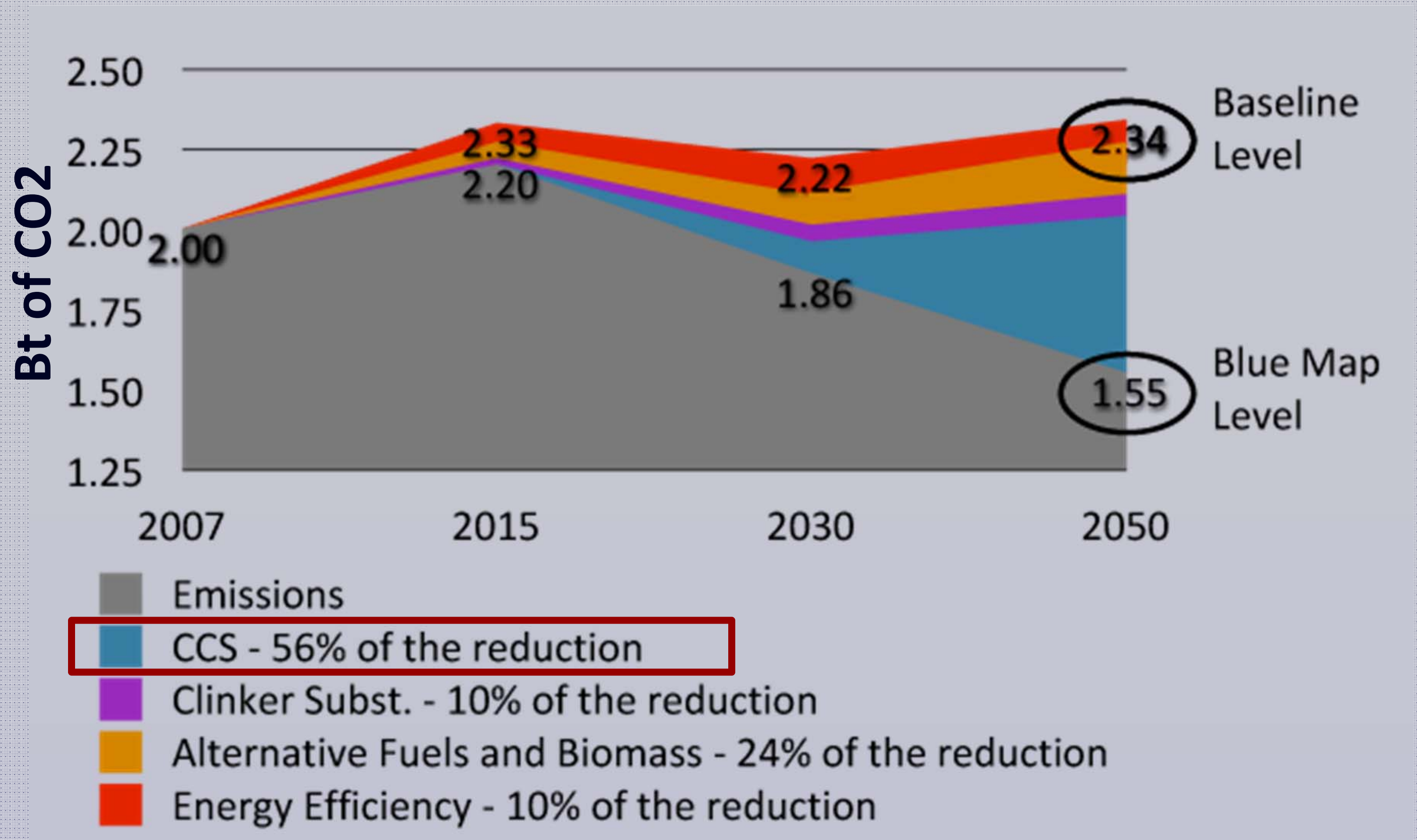
## We need to go beyond the traditional levers that the industry has been using

# The IEA & WBCSD cement technology Roadmap for carbon reduction



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We need to be creative for the use of cementitious additives

# Estimation of WW cementitious reserves made by IEA

**Table 3.5** ▶ **Availability of clinker substitutes in the BLUE scenario, 2005 and 2050**

| | 2005 (Mt) | 2050 (Mt) |
|---|---|---|
| Fly ash | 590 | 368 |
| Blast-furnace slag | 308 | 364 |
| Other clinker substitutes | 50 | 100 |
| Other additions, e.g. ground limestone | 267 | 500 |
| **Total** | **1 215** | **1 332** |

=> Fly-ash based geopolymers cannot be a global solution!
=> Fly-ash and slag may not be carbon neutral in the future

5

We may need to develop alternative clinkers…

# 3 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)

**To what extent we can reduce this through clinker formulation?**

# Energy Required for $C_3S$ formation

1. Limestone Decarbonation

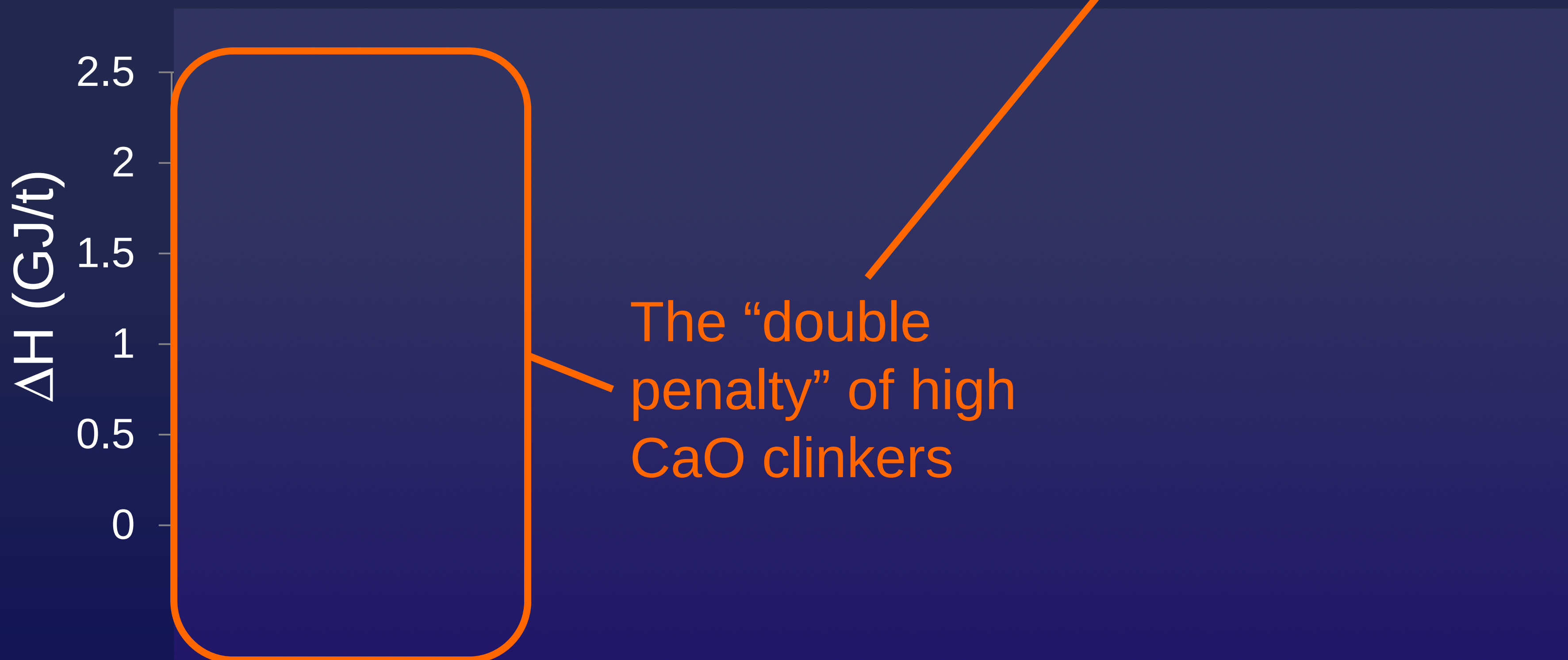
$$CaCO3 \longrightarrow CaO + CO_2$$

2. Formation of $C_2S$

$$2 \cdot CaO + SiO_2 \longrightarrow Ca_2SiO_4$$

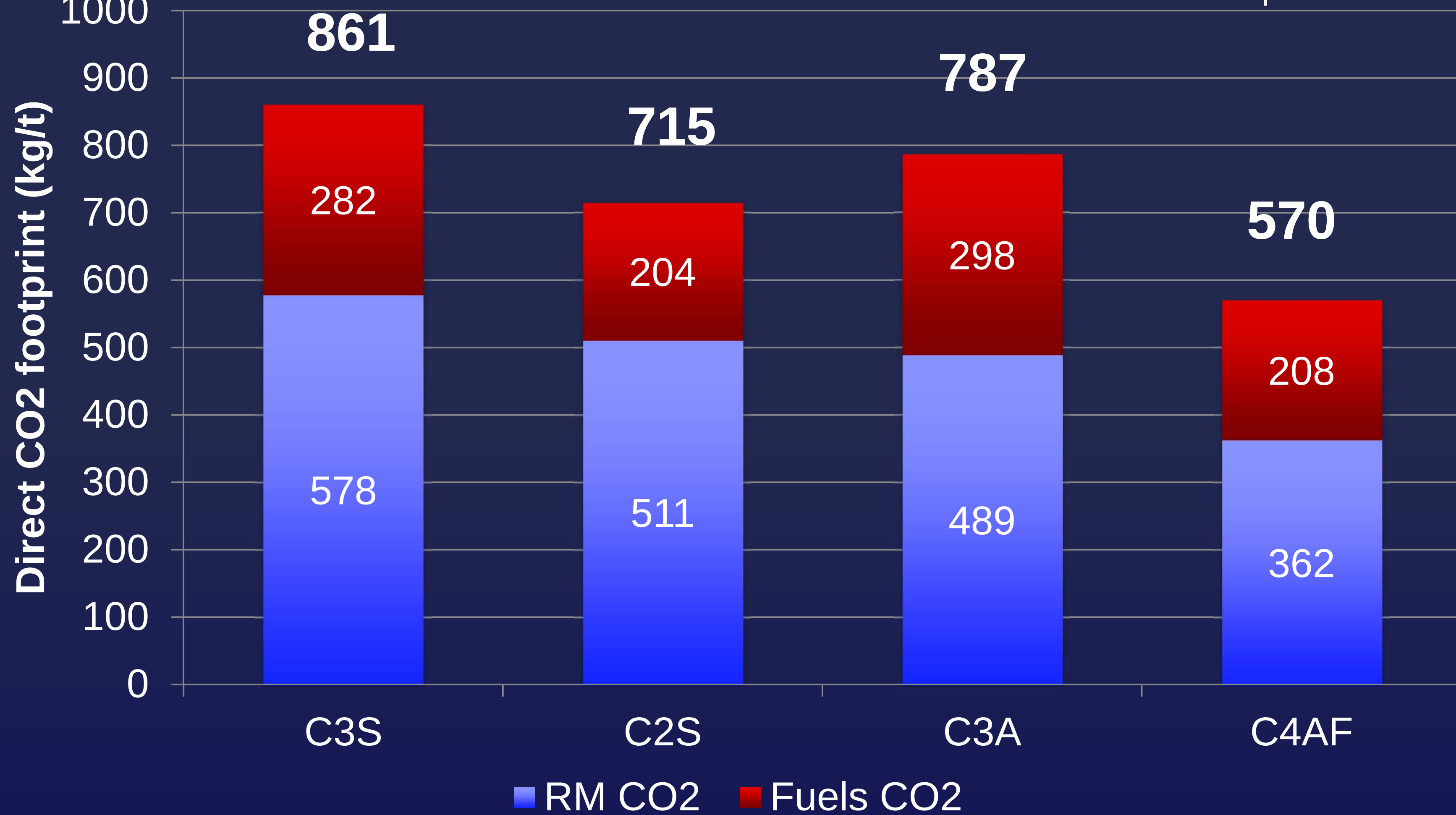
3. Formation of $C_3S$

$$Ca_2SiO_4 + CaO \longrightarrow Ca_3SiO_5$$

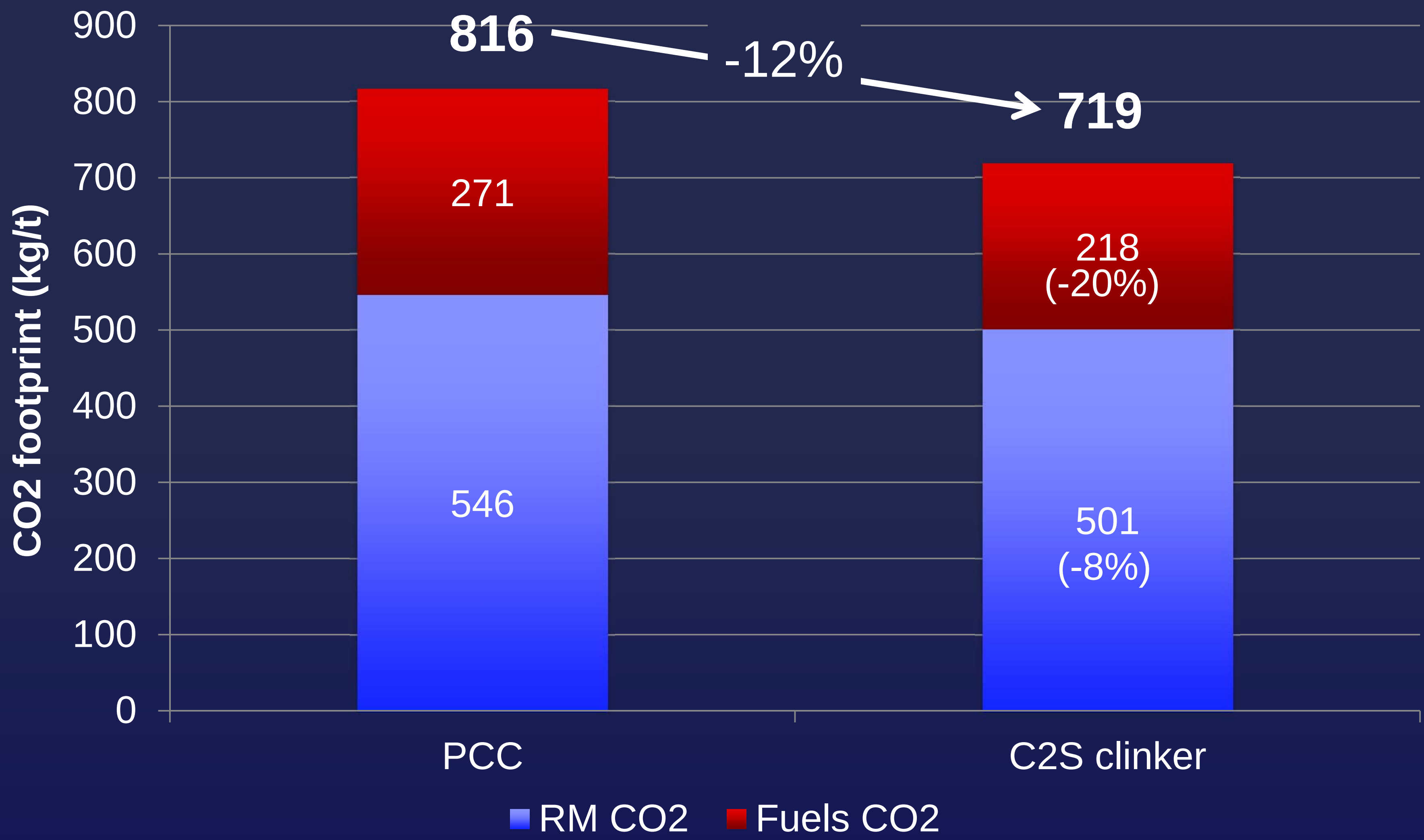


# Clinker formulation: Traditional PCC

Assumes all CaO from CaCO3;
Assumes bituminous Coal as fuel;
Assumes fuel consumption at BAT



# Clinker formulation : theoretical C2S clinker

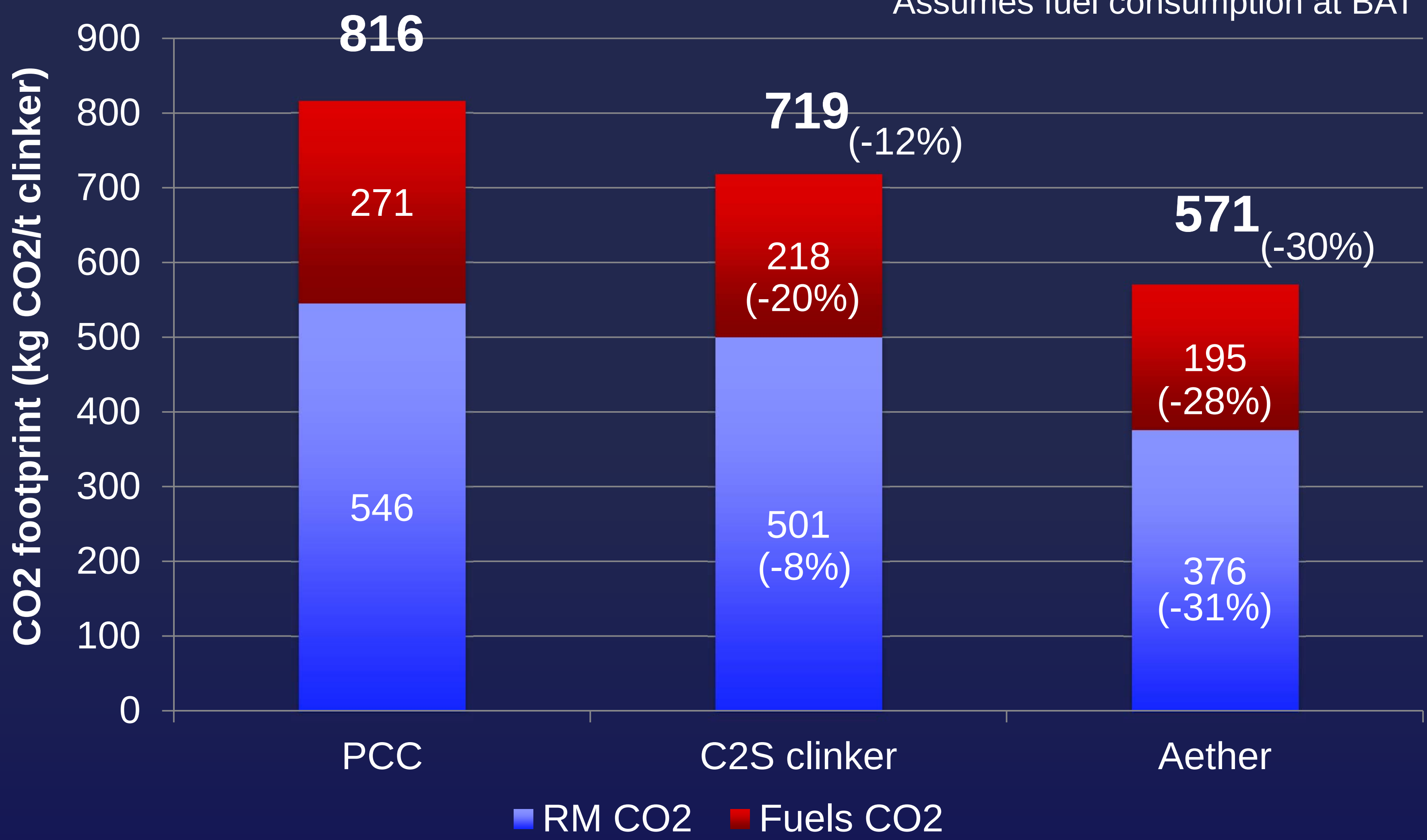


## What are the characteristics of the solution we're looking for?

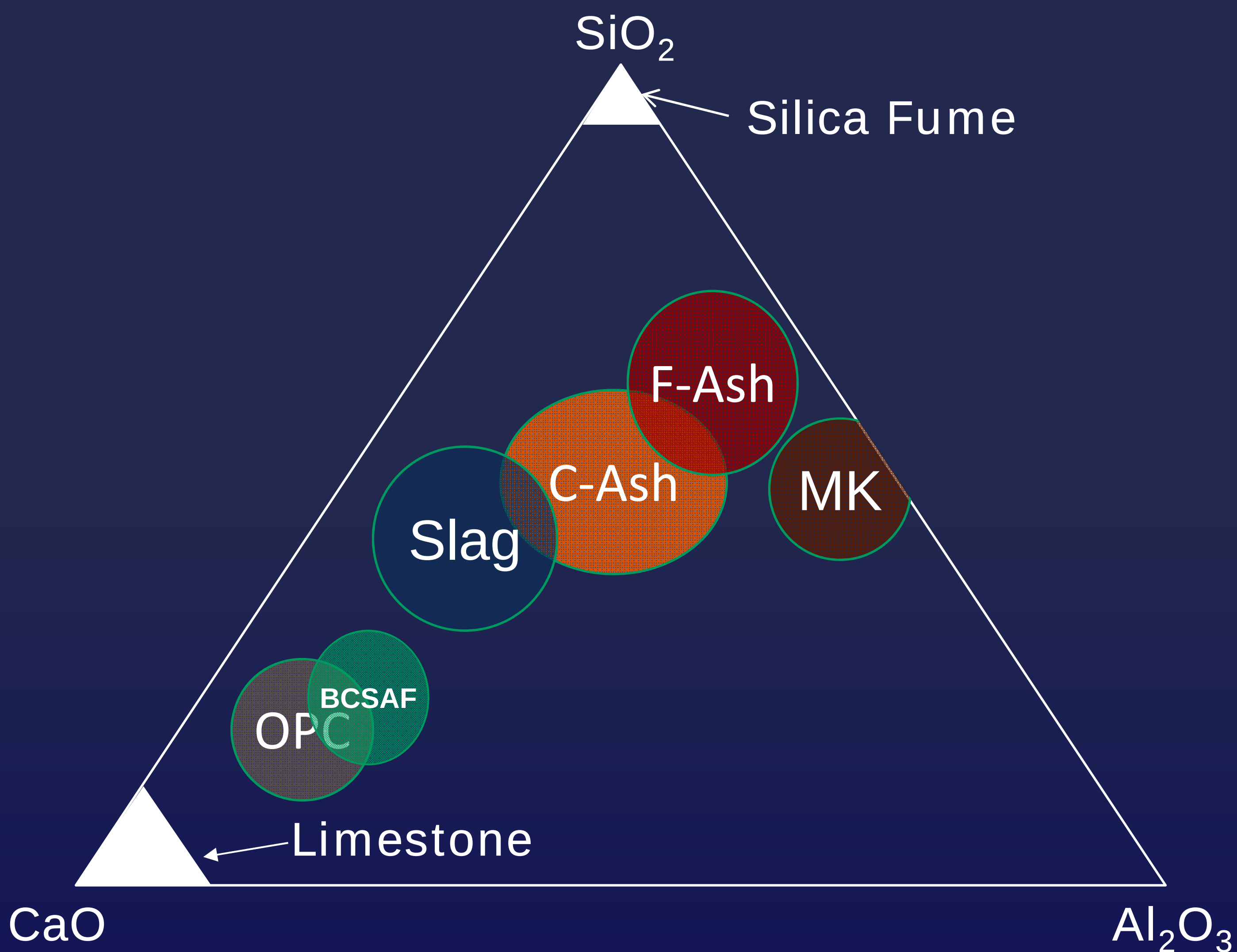
- A clinker that leverages all the current clinker advantages:
  - Made from raw materials locally available in large quantities
  - Cheap
  - A high level of early reactivity (similar to OPC) to work well with SCMs
  - Durable (including steel protection)
- And in addition:
  - A much lower CaO content to reduce significantly CO2 emissions;
  - Can be manufactured in existing plants

# A Carbon footprint reduced by 30%

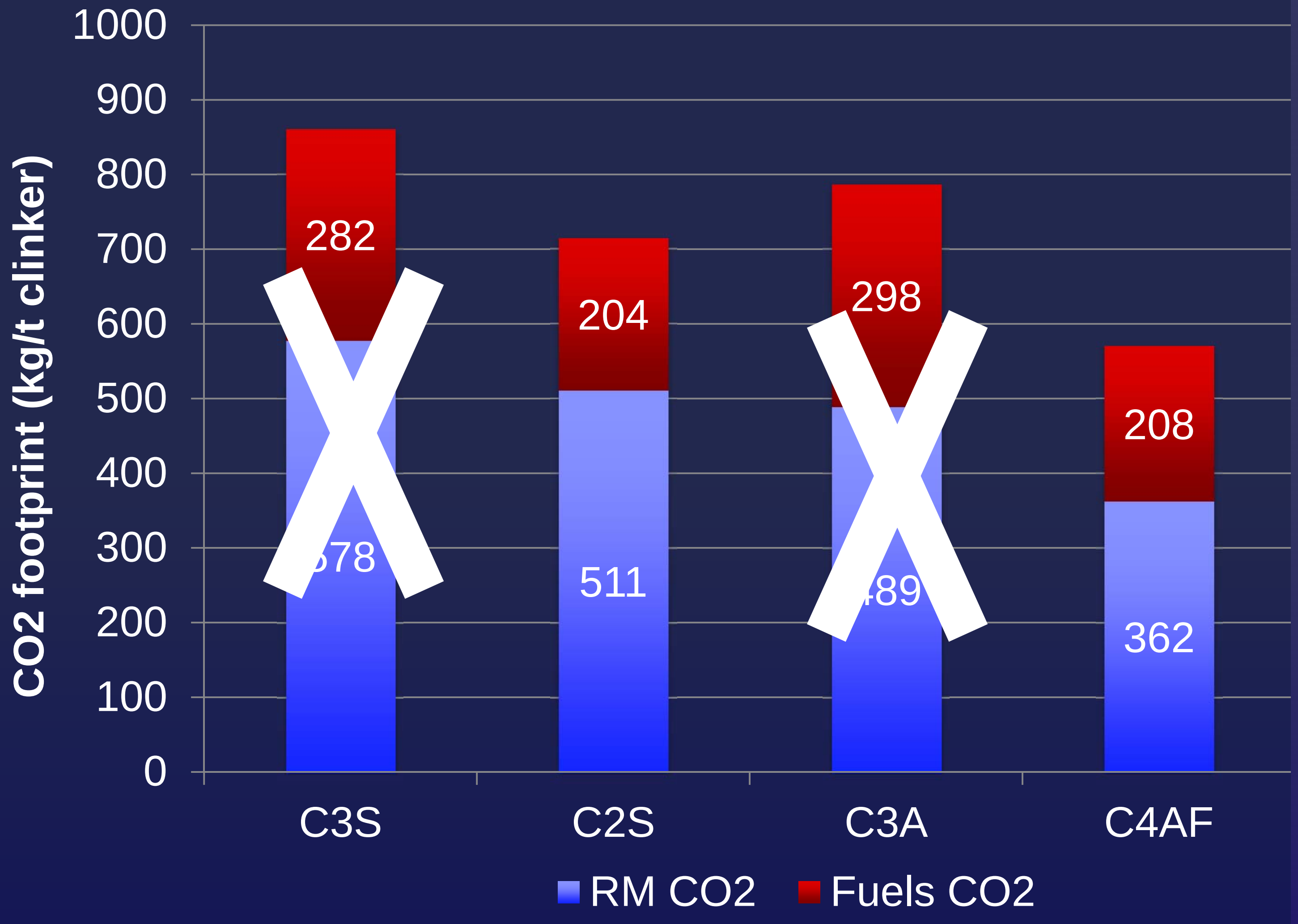
Assumes all CaO from CaCO3;
Assumes bituminous Coal as fuel;
Assumes fuel consumption at BAT



# BCSAF on C-A-S triangle:



# Components of the BCSAF clinkers



# Key benefits of BCSAF clinkers (Aether™)

- Reduction of up to **30% of the $CO_2$ footprint** of clinker manufacturing
- Potential **additional saving on indirect CO2** from electricity, as clinker is easier to grind
- Gives **high level of early** reactivity, allowing us to maintain **clinker substitution at the same level** as with OPC
- **Later strength development similar** to OPC
- Can be manufactured in **existing cement plants**: No need for heavy capital expenditure. Possibility of production rate increases.
- **Already demonstrated at industrial scale**, in a real clinker kiln.

# Thank you for your attention !!

www.lafarge.com
www.aether-cement.eu

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# Direct $CO_2$ emissions in Cement Manufacture

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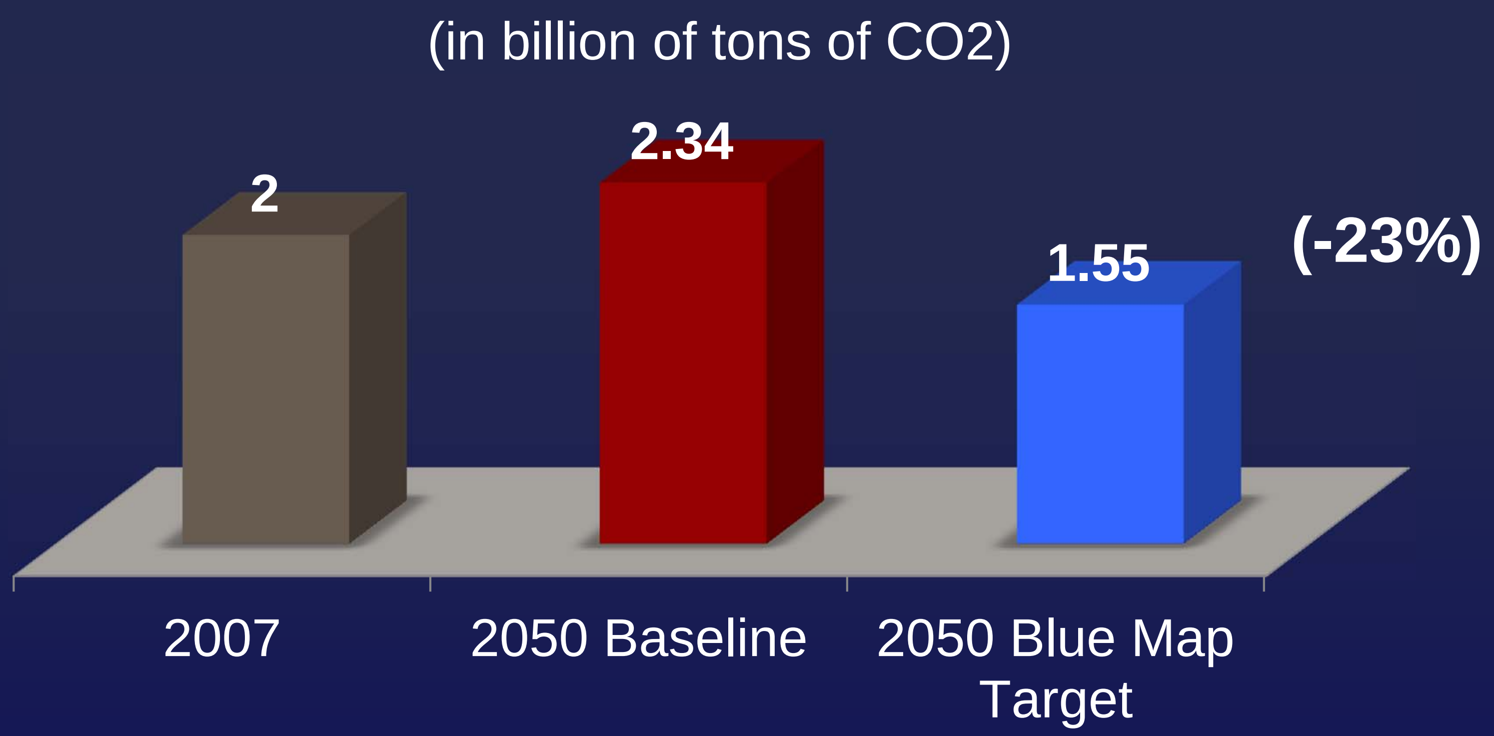
# Appendix

# The Cement Industry Technology Roadmap to Reduce Carbon Emissions

Cement Sustainability Initiative (CSI) and IEA partnered to establish a roadmap for the cement industry:



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1 Energy Efficiency

2 Alternative Fuels and Biomass

(Levers 1 and 2 → ~330 kg/t clinker)

3 Clinker Substitution

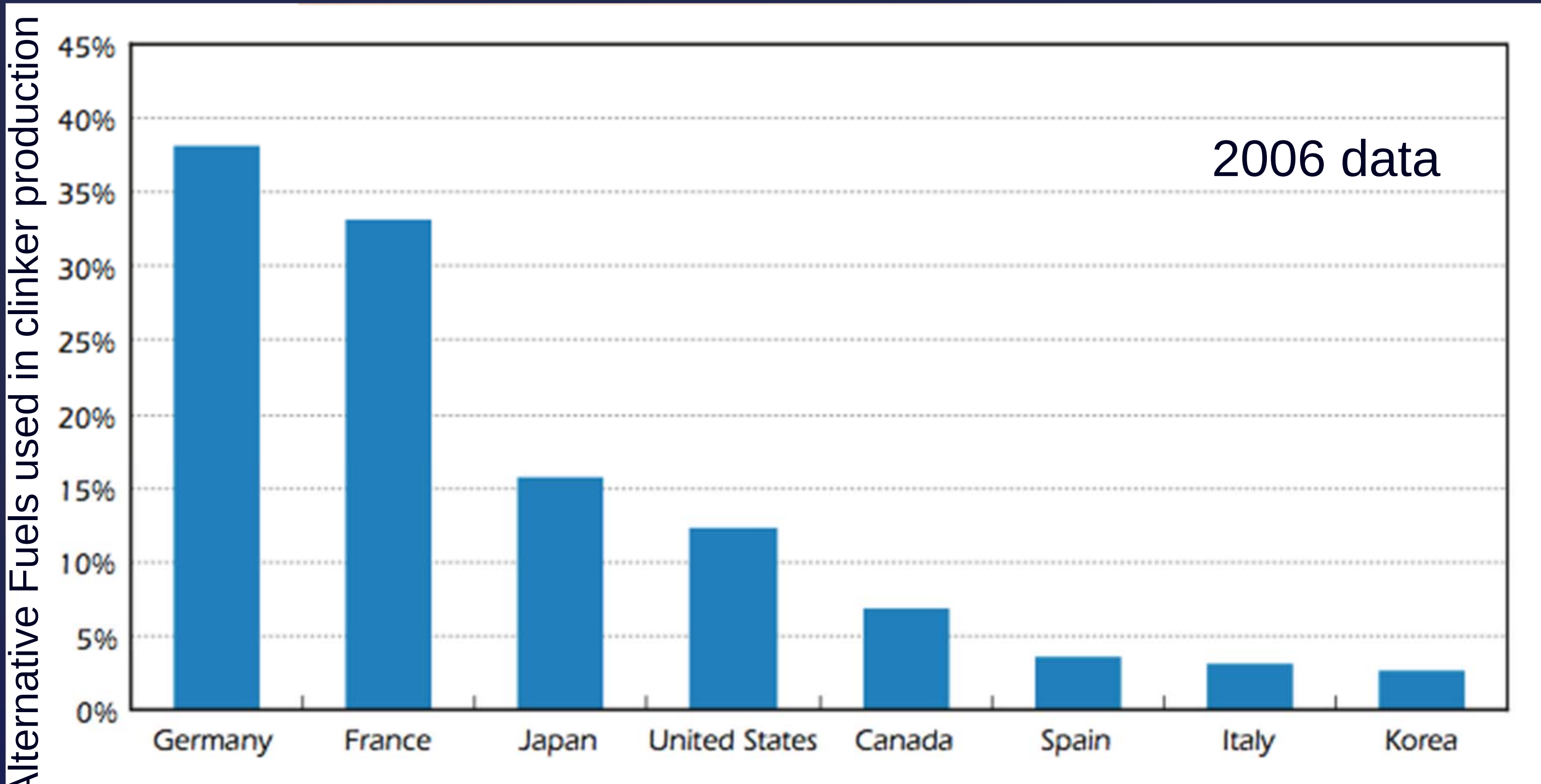
(Lever 3 → 78%)

# 1. Energy Efficiency

| **Process** | **Typical Fuel Consumtion (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%*** |

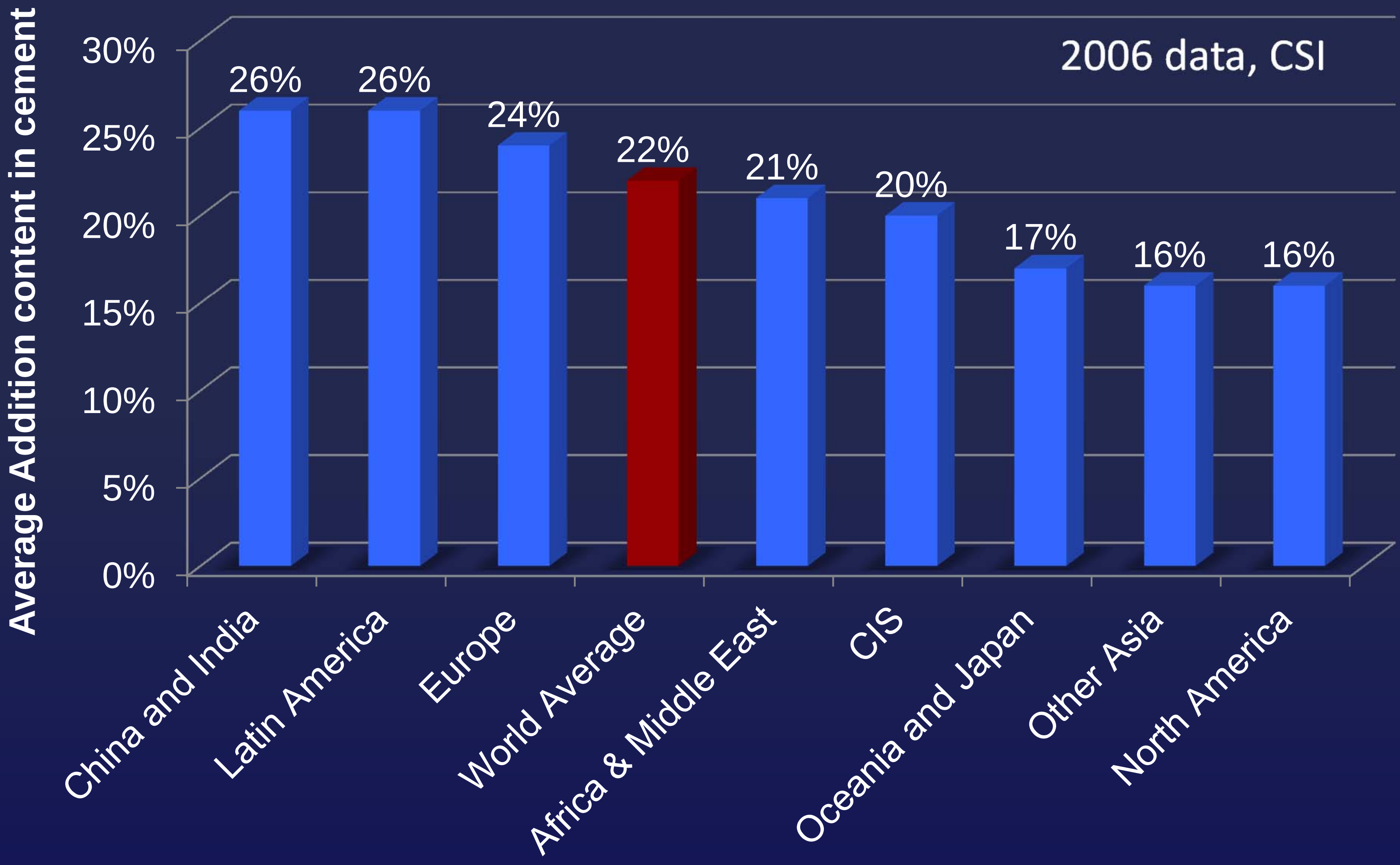
* Industry's Best Available Technology

# 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



# Clinker formulation: Traditional PCC

| | CaO content (%) | $\Delta H$ (Gj/t) |
|---|---|---|
| C3S | 74% | 1.85 |
| C2S | 65% | 1.34 |
| C3A | 62% | 1.95 |
| C4AF | 46% | 1.36 |
| Free lime | 100% | 3.18 |

# Challenges

- **Cost of raw-materials can be a little bit higher**.
  - Some level of taxation of $CO_2$ needs to happen to make Aether™ commercially viable at large scale.
  - Additional cost compared to PCC is nevertheless about **one order of magnitude lower than CCS**
- Cement and Concrete science has **100+ years of R&D** and still many aspects are not fully mastered. **We have just scratched the surface!**
- Specifications, acceptance, etc..

The IEA predicts that $CO_2$ emissions need to be **cut in half** to maintain temperature rise to +3° C (+5° F)

IEA proposes a **sectorial approach** as the **least cost way** to reduce emissions


The cement industry is a **large contributor** to CO2 emissions, more because of production **volumes** than intrinsic performance

The cement industry and IEA partnered to build a **technology roadmap** for $CO_2$ reduction

The roadmap calls for **23%** reduction of **absolute** $CO_2$ emissions and **40 to 50%** of **specific** emissions.

Existing levers (energy eff., clinker subst.) should lead us **half-way**. **High costs** forecast for CCS

Lafarge is proposing **one novel approach** to help reduce carbon emissions through **clinker reformulation**. **BCSAF clinkers** (Aether™) have the opportunity to **reduce by up to 30%** the $CO_2$ footprint of clinker manufacturing