GEOPOLYMERCAMP 2015

Environmental implications and Life Cycle Assessment LCA of geopolymers

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Environmental implications of Geopolymers

29 June 2015 | Joseph Davidovits

How should we consider geopolymers? Many scientists and civil engineers are mistaking alkali-activation for geopolymers, fuelling confusion, using them as synonyms without understanding what they really are. We find in the literature either LCAs of geopolymer cements/concretes or LCA of alkali-activated-materials. The latter encompass the specific fields of alkali-activated slags, alkali-activated coal fly ashes, alkali-activated blended Portland cement.

A dedicated Geopolymer Institute video deals with the major differences prevailing between alkali-activated-materials and geopolymer cements: *Why Alkali-Activated Materials are NOT Geopolymers?* **http://www.geopolymer.org/faq/alkali-activated-materials-geopolymers**. First, we explain the main differences between alkali-activated-concrete, alkali-activated-slag, alkali-activated-fly ash on one hand and Slag-based Geopolymer cement on the other hand, in terms of chemistry, molecular structure, long-term durability. In a second part, we comment the industrialization of Slag/fly ash-based geopolymer cement/concrete by the company Wagners, Australia, and we focus on the results provided by the

Benefits

toxic fumes, toxic waste management, radioactive waste, etc…

Impacts (LCA)

acidification (water), eutrophication (water), Ozone layer depletion, Human toxic potential, Global Warming Potential

Split into two sub-themes

- Environmental implications of geopolymer resins/binders;

- Environmental implications of geopolymer cements/concretes.


1972


Plastics are dangerous !!
Are organic polymers heat resistant ??

- No ! NATURE states :
  - Only MINERALS provide fire and heat resistance
    - Target: Inorganic polymers

Environmental implications of geopolymer binders: benefits and impact (LCA)

The invention of geopolymer binders goes back to 1972, in the aftermath of various catastrophic fires in France causing hundreds of casualties in public buildings because organic plastic, toxic fumes.

LCA for organic polymers, with emphasis on the danger resulting from the emission of toxic fumes during fire did not exist at that time, and even today.

The Human Toxicity Potential values found in the LCA for organic products (resins or plastics) do not include any measurement of fire hazard and toxic fumes emission.

Geopolymers are used in foundries for the fabrication of sand cores for aluminium casting because geopolymer binders are emission free.

1994-2000 Aircraft cabin safety project

U.S.A.

Federal Aviation Administration, F.A.A.

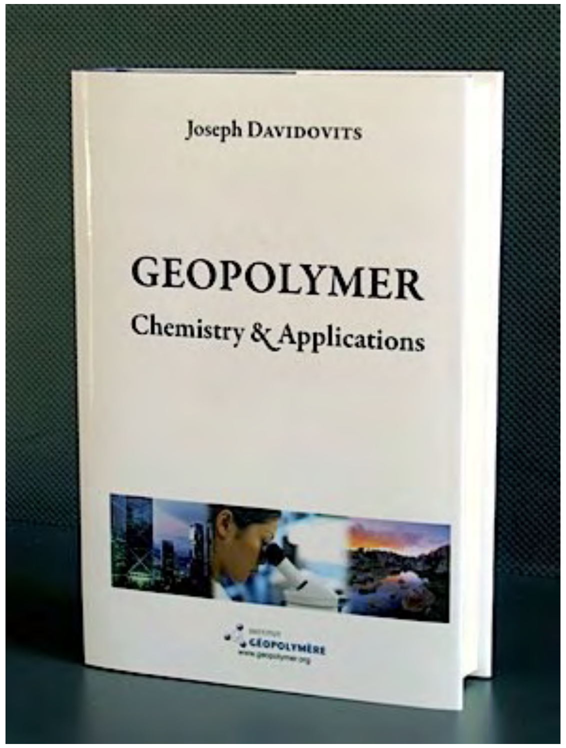
Rutgers

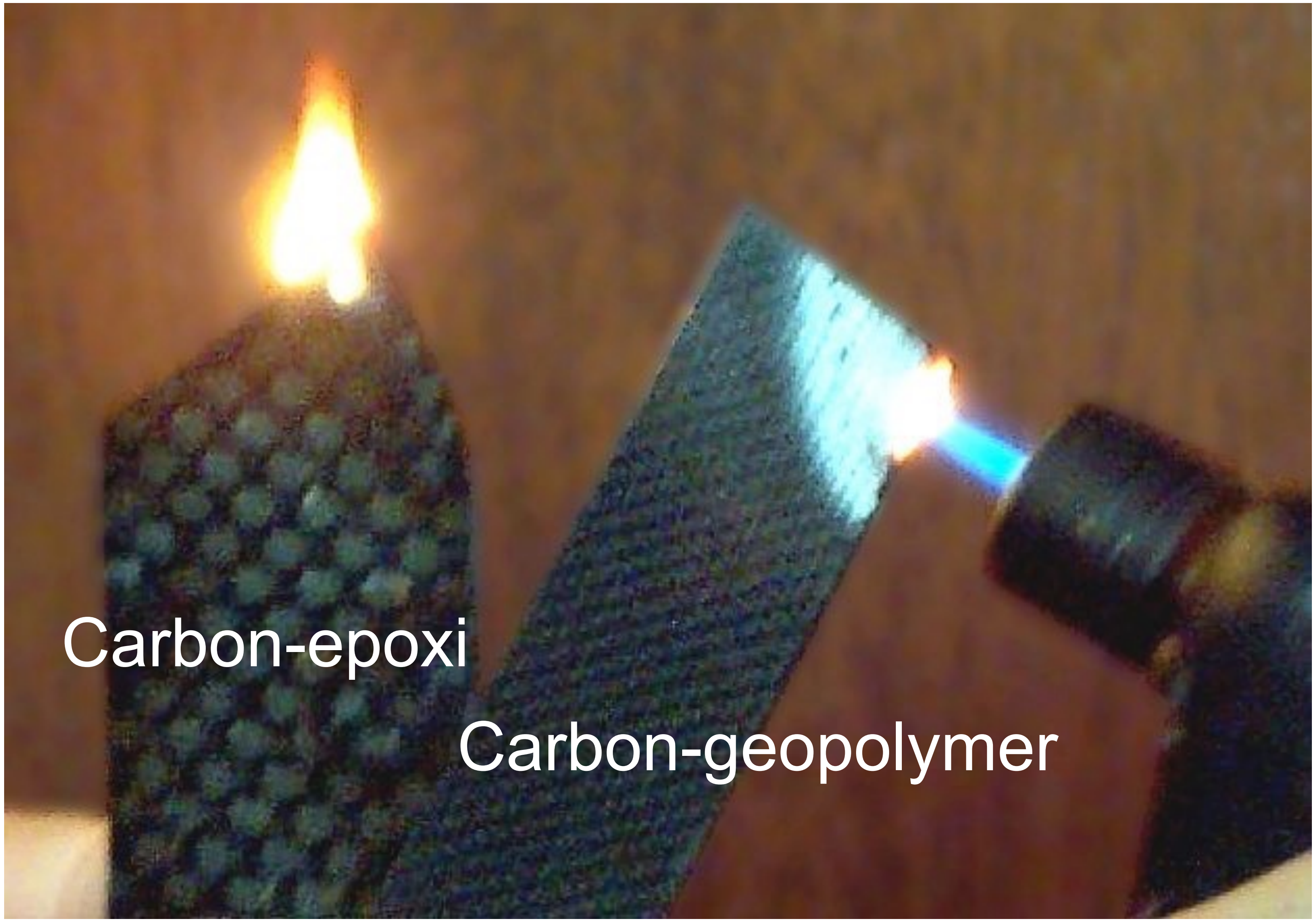
The State University of New Jersey

cordi-géopolymère Saint-Quentin, France

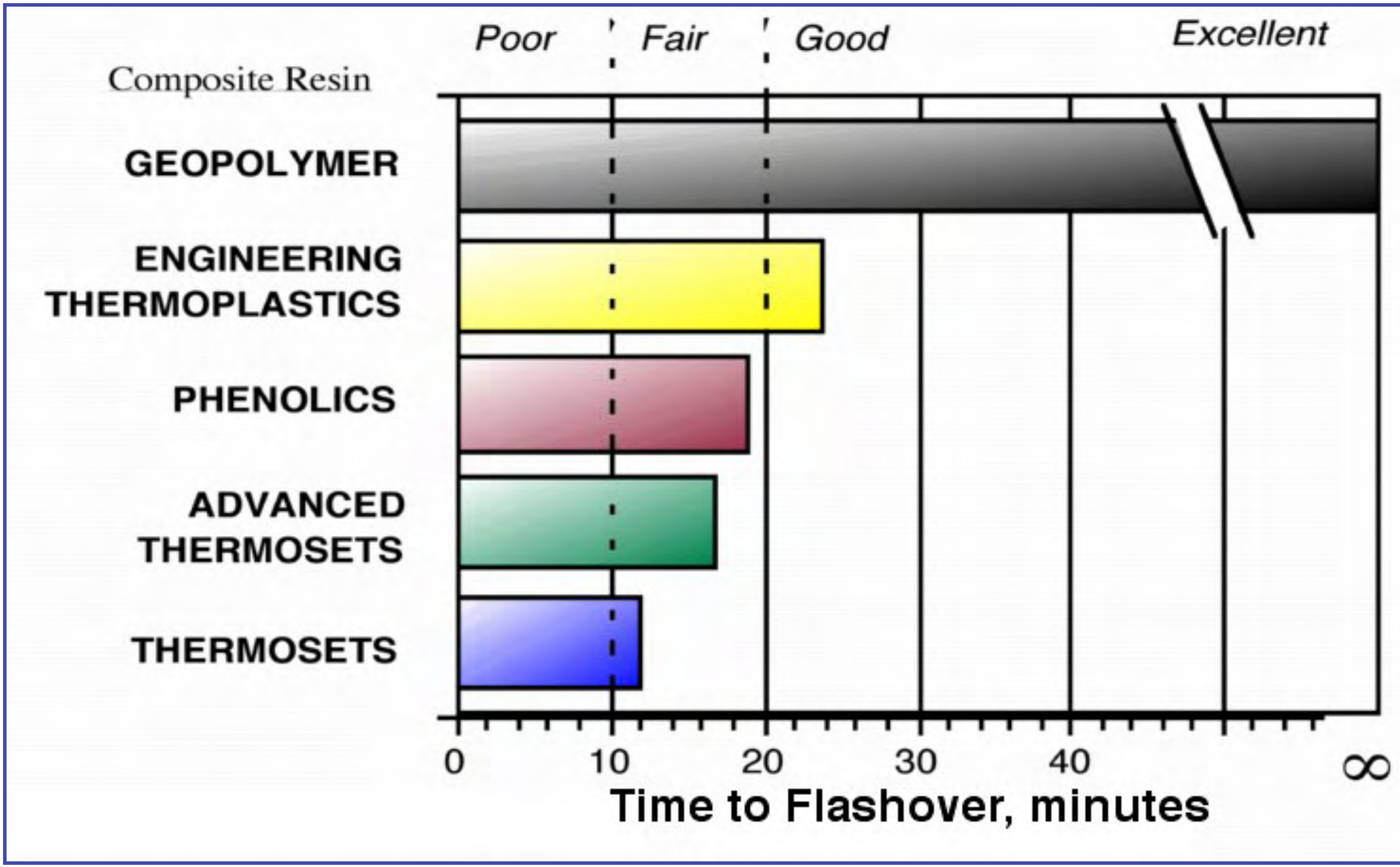
Heat- and fire-resistant carbon/geopolymer

Chapter 21





Giving Survivors more time to escape



Environmental impact of : epoxy resin / geopolymer resin Na-PSS, MK-750 = 35%, Na-Silicate 3.3 = 59%g and NaOH = 6%.

Impact category	Units	based-epoxy resin	NaOH powder	Na-silicate 3.3 37%% solid	Metakaolin MK-750	Geopolymer resin (Na-PSS)
Abiotic Depletion (ADP)	Kg Sb eq.	56.4	16.40	7.22	168	5.27
Acidification Potential (AP)	Kg SO2 eq.	40.3	10.7	5.22	0.32	3.81
Eutrophication Potencial (EP)	Kg PO4 eq.	6.6	810	495	49	0.35
Global Warming Potential (GWP)	Kg CO2 eq.	6,663	2,024	425	92.4	282.6
Ozone Layer Depletion Potential (ODP)	Kg CFC-11 eq.	1.26E-6	13.8E-5	8.82E-5	1.52E-6	6.05E-5
Human Toxicity Potential (HTP)	Kg 1.4-DB eq.	490.44	957	803	23	536.75
Freschwater Aquatic Ecotoxicity Potential (FAETP)	Kg 1.4-DB eq.	246.5	240	212	32	150.11
Territorial Ecotoxicity Potential (TETP)	Kg 1.4-DB eq.	29.1	46.6	8.96	323	8.13

The geopolymer binder outperforms the epoxy resin value with respect to Global Warming Potential by a factor of 23, as well as all others,

except for Human Toxicity Potential, which is a surprise. This is due to the high value given for this Na-silicate solution.

Environmental implications of Geopolymer cements/concretes

The first LCA on « geopolymer cements/concretes was presented at the Geopolymer Camp 2010 by Habert et al. (2010) and it was a shock for the attendance. Published in 2011.

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An environmental evaluation of geopolymer based concrete production: reviewing current research trends

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They claimed that, in terms of CO_2 emission, geopolymer cement was not better than Portland cement, and worse for other parameters. One of their studies involved a mix design containing metakaolin MK-750 and Na-silicate and, because of the high amount of alkali silicate needed in the formulation, they claimed that geopolymer cement emitted twice the amount of Portland cement. This statement was taken for granted by other scientists without any further consideration.

(K-Ca) geopolymer cements

Evolution since 1983-85.

K-silicate % by weight of geopolymeric formulation

Pyrament (1985)	Geopolymite 50 (1987)	Rock-based (1997) 100 MPa	Rock-based (2002) 50 MPa	Fly Ash-based (2006) 100 MPa	Fly Ash-based (2006) 40 MPa
50 %	50 %	20 %	17 %	14 %	10 %

Actually, the most important document is the LCA paper by Fawer et al. (1999) *Life Cycle Inventories for the Production of Sodium Silicates*, Int. J. LCA 4 (4) 207-212 (1999). Life Cycle Inventories were compiled by EMPA St. Gallen / Switzerland from 12 West European silicate producers covering about 93% of the total alkaline silicate production in Western Europe.

The production routes for five typical commercial sodium silicate products were traced back to the extraction of the relevant raw materials from the earth.

Life Cycle Inventories for the Production of Sodium Silicates

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Table 3 *continued*

		LCI of various Sodium Silicates		
Weighted average		Na-silicate 3,3 (WR) furnace lumps, 100%	Na-silicate 3.3 (WR) furnace liquor, 37% solid	Na-silicate 2.0 (WR) hydrothermal liquor, 48% solid
Funktional unit		1,000 kg	1,000 kg	1,000 kg
Solid waste				
Mineral waste	kg	127	47.2	20.2
Filter residues	kg		0.9	1.2
Inert chemicals	kg	0.6	0.3	1.7
Slags & ash	kg			2.3
Regulated chemicals	kg			0.004
Air emissions				
Ammonia (NH3)	g	237	88.3	0.03
Carbon dioxide fossil (CO_2)	g	1,066,022	424,668	288,698
Carbon monoxide	g	3,748	1,406	218
Dust, particles	g	3,886	1,454	667

Although Habert et al. write " *data for sodium silicate solution come from Fawer et al. (1999)*", the value given in their Table 2 for the solution (37% solid)

Table 2
Environmental impact for 1 kg of var

CML 2001		Sodium silicate solution (37%)	CEMI
Abiotic depletion	kg Sb eq.	7.22×10^{-3}	1.59×10^{-3}
Global warming potential	kg CO_2 eq.	1.14	8.44×10^{-1}
Ozone layer depletion	kg CFC-11 eq.	8.82×10^{-8}	2.28×10^{-8}
Human toxicity	kg 1,4-DB eq.	8.03×10^{-1}	4.02×10^{-2}

1,14 kg CO2/kg

0,424 kg CO2/kg

This is a methodological flagrant error. We may therefore conclude that all the CO_2 emissions and environmental impacts calculated in Habert et al. paper are wrong and must be roughly divided by 2.

All LCAs published are also focusing on the amount of CO_2 that must be added to the original manufacture emissions in order to reflect the long distances that the raw ingredients and chemicals (metakaolin, slag, alkali-silicates) have to go all over before reaching their destinations. Sometimes, these distances are enormous: 6000 km for metakaolin or Na-silicate. This could contribute to a doubling of the Global Warming Potential numbers.

We feel, there is something unfair in these calculations. Local special environmental impact assessments are generalized to serve as references for the entire world.

But the most striking element is that each paper compares a well-established, 170 years old industry involving hundreds of cement plants and terminals, with a start-up situation. There is a lack in the methodology as well as in standard procedures.

For people involved in R&D and innovation, the logic would have been to consider the market forces. As a matter of fact, business will foster the manufacturing of the chemicals and ingredients to take place as close as possible to the market.

It is logical to understand why industry interested in developing geopolymer cements/concretes for the emerging countries, India, Africa, and others, will manage to establish alkali-silicates production sites located close to the market and to the geopolymer cement manufacturing sites.

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