Why?
Climate change - challenge and chance for the pre-fab industry!
**CO₂ emissions and building materials**

Concrete is a successful building material easy, available, cheap → high amounts

= 0,8-1 m³/year/person
Where comes the CO₂ from?

- Cement production
  - Raw materials
  - Fuels
- Steel (reinforced concrete)
- Concrete production itself
  - Electricity (production machines)
  - Heat (curing)
- Transport

GWP - example: pile

- cement: 33%
- steel: 7%
- other raw materials: 2%
- transport: 7%
- energie: 1%
Span of controle along the value chain

Structure

- <250 kg/m² <sub>structure</sub> (engineer)/ <500 kg/m² <sub>building</sub> (owner)
- Concrete
  - <3.5 kg<sub>Cl</sub>/m<sup>3</sup>/MPa (30-50 MPa)

Cement

- Filler

Clinker

- Filler

Demolition

- Reinforcement

- Cooperate along value chain
- Beyond the standards
- New constructions
- Resource efficiency and low climate impact
- Re-use of buildings & elements (long life time, modulair & demontable)
- Focus on the right KPIs
- Preferable pre-cast

GCCA net zero

PERCENTAGE CONTRIBUTION TO NET ZERO AND CO₂ EMISSION SAVINGS IN 2050

Savings in clinker production

11% 9% 36% 22%
410Mt CO₂ 350Mt CO₂ 1370Mt CO₂ 340Mt CO₂

Savings in cement and binders

Efficiency in design and construction

Decarbonisation of electricity

CO₂ sink: recarbonation

Carbon capture and utilisation/storage
Efficiency in design and construction/Examples

- **Organic forms**: Shel & net construction
- **Form follows force**: Less material is more strength
- **Material only where needed**: Space no more without
- **Lightweight constructions**: Combined functions, better recyclable
What about alternative binders?

INVIE cement

“I am not believing in alternative binders, and anyway it should come from the cement industry”

“Solutions has to be available at very large scale (general) same as portland-clinker”

“CCS needs large investment, infrastructuur, small (cement) companies will not survive”
Potential of saving CO$_2$ with alternative binder

PC = Portland cement, Belite = Belite
CSA = calcium sulfoaluminate, BCSA = belite calcium sulfoaluminate,
CACS = carbonation of calcium silicates (Wollastonite based),
MOMS = magnesium oxide derived from magnesium silicates.

Source: Technology Roadmap Low-Carbon Transition in the Cement Industry. IAE, CSI, wccsp
What are Geopolymers /alkali-activated binders?

1. Precursor (reactive powder)
   - Metakaolin
   - GGBS
   - Fly ash
   - Calcined clay
   - ... INVIE®glass

2. Alkaline activator
   - NaOH/KOH
   - Waterglas
   - Alkaliconbenaat/-sulfate
   - Portland clinker ...
   + Water

Binder

Successful if:
- Additional resources based on waste streams
- Reactive, high quality
- Production with green energy

Large possibility of combinations of
- precursors
- composition of activators
- combination precursor + activator

Will be influencing
- technical
- ecologic and
- economic KPIs

INVIE®glass
INVIE versus standard cement

Constructing a better world with a sustainable binder that makes powerful use of surplus industrial productions is powerfully utilized.

Photos taken from small scale production plant.
Reaction products

$\text{OH}^-$

Geopolymer

AA Metakaolin

$\text{C(A)SH}$

AA Fly ash + GGBS

AA GGBS

INVIE cement

$\text{ASN} \ \ [N(A)SH]$

$\text{CSH}$

Portland clinker + Pozzolan

Portland clinker + GGBS

Portland clinker
## INVIE & other geopolymers

<table>
<thead>
<tr>
<th></th>
<th>Geopolymer</th>
<th>INVIE® cement</th>
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<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Alkali-activated binder</td>
<td>Special Alkali-activated binder</td>
</tr>
<tr>
<td><strong>Reactive phase</strong></td>
<td>Depends on type precursor:</td>
<td>INVIE® glass, Melted from different secondary materials</td>
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<tr>
<td></td>
<td>• GGBS</td>
<td></td>
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<tr>
<td></td>
<td>• Fly ash</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Metakaolin(calcined clays)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Other pozzolanic raw materials</td>
<td></td>
</tr>
<tr>
<td><strong>Raw material quality</strong></td>
<td>differs</td>
<td>differs</td>
</tr>
<tr>
<td><strong>Quality precursor</strong></td>
<td>Depends on raw material (slow or quickly reacting), Can not be changed</td>
<td>constant at high quality as adjusted in production</td>
</tr>
<tr>
<td><strong>Need of alkaline activator (reactivity)</strong></td>
<td>Metakaolin &gt; Fly ash &gt;&gt; GGBS &gt; INVIE® glass</td>
<td></td>
</tr>
<tr>
<td><strong>Reaction velocity</strong></td>
<td>Fly ash &lt;&lt; metakaolin &lt; GGBS &lt; INVIE® glass</td>
<td></td>
</tr>
<tr>
<td><strong>Compensation of varying composition of raw materials</strong></td>
<td>Only by milling, mixing or type &amp; amount activator</td>
<td>Correction material during melting, milling and mixing</td>
</tr>
<tr>
<td><strong>Flexibility</strong></td>
<td>Low, Depending on raw materials and activator mix</td>
<td>Higher, not dependent on one raw material, different glass qualities possible</td>
</tr>
</tbody>
</table>
Status development

Cement production

- Pilot installation of glass production has been running since 2019, capacity 50 t/d
- Smelting campaigns took place 1-2 times per year
- Granulation with water
- Milling in ball mill
- Mixing with filler and (optional) activator in separate mixing plant

Financial support by RVO/DEI
Smelting campagne in pilot installatie
Status development

Concrete production & test projects

- Several production test and test applications were done since 2019 incl. type testing
- Product development and validation project are going on with focus on reinforced concrete elements and durability
- >2000t cements available for tests or production over the coming year
- Standardisation activities
- Monitoring of products in test projects

Financial support by RVO/DEI & LIFE21-ENV-NL-CIRRCON
Examples Testprojects

Retaining walls
- FBB/D 2012
- Testlocation Eastthüringia/G

Bycicle plates
- Meteoor 2021
- Leiderdorp/exchange

Retaining wall
- Kemper 2022
- ProRail, train station

Diver/ Plates
- Romein/2020
- for element tests
Examples Testprojects

- **Sewage pipes**
  - De Hamer 2020/2022
  - Testlocation Nijmegen

- **Levelbloks**
  - 2020
  - Afsluitdijk Ijsselmeer

- **Hollowcore slabs**
  - VBI/Consolis 2022/2023

- **Pavement stones**
  - De Hamer/2020
  - Ede/Wekerom
Beyond the standards

- How to speed up implementation of innovation?
- From descriptive to performance-based design and measurements
  - Design by testing
- Cooperation with engineers, scientists, owners, government and certification institutions
- ...its not all about technical aspects!
Thank you for your attention.

Questions?

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A WAY BETTER MATERIAL
FOR A WAY BETTER WORLD