LIFE CYCLE ASSESSMENT OF THE USE OF ALTERNATIVE FUELS IN CEMENT KILNS: A CASE STUDY

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Goal

• Evaluation of the environmental impacts of the use of alternative fuels (AFs) for 1 ton clinker production in the cement industry

• Selection of the most environmentally friendly fuel mixture using conventional fossil fuels (coal and petcoke) and different blends of alternative fuels (AFs)
In order to identify the best environmental option:

- Seven integrated scenarios for the production of 1 ton clinker were developed and compared.
- Scenarios include the use of fossil fuels and AFs.
- A spreadsheet model was constructed.
- Life Cycle Impact Assessment methodology was used, more specific: LCA software SimaPro 7.1 (CML 2 baseline 2000 and Eco-indicator 99 methodology).
Alternative Fuels (AFs)
- **RDF** (Refuse Derived Fuel)
- **TDF** (Tire Derived Fuel)
- **BS** (Biological Sludge)

Fossil Fuels
- Coal
- Petcoke
Alternative Scenaria

[Bar chart showing percentages for different scenarios]
System Boundary

Raw Materials

PRODUCTION/USE FUELS

PRODUCTION/USE ENERGY

PROCESS
Rotary Cement Kiln
PRODUCTION 1TON CLINKER

CLINKER

SOLID EMISSIONS

WATER EMISSIONS

AIR EMISSIONS

Functional unit: 1 ton clinker
Assumptions

- The choice of AFs was based on the adequate (net) calorific value and biodegradable fraction
- It is assumed that AFs have low volatile heavy metal concentration
- The production of clinker takes place in a rotary, dry process, kiln
- The thermal demand for the kiln is about 1,700 to 1,800 MJ/ton clinker
- All resources consumed during the operation phase and activities carried out are included.
- The construction phase is considered negligible
- The life span of equipment is about thirty years
Assumptions

- The life cycle impact assessment includes the quality and quantity of raw materials, fossil fuels, AFs and energy inputs during the operation phase.

- Extraction, production and transportation of raw materials, fossil fuels and electricity are included.

- The AFs replace 10% of the total calorific value needed for the function of the kiln.
### Inventory Data of Fossil and Alternative Fuels

<table>
<thead>
<tr>
<th></th>
<th>Conventional Fossil Fuels</th>
<th>Alternative Fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coal</td>
<td>Petroleum coke (petcoke)</td>
</tr>
<tr>
<td>NCV (kJ/kg dry fuel)</td>
<td>30000</td>
<td>33000</td>
</tr>
<tr>
<td><strong>Ultimate analysis mass % dry material</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>7.50E+01</td>
<td>9.00E+01</td>
</tr>
<tr>
<td>H</td>
<td>5.00E+00</td>
<td>3.74E-02</td>
</tr>
<tr>
<td>O</td>
<td>8.00E+00</td>
<td>7.60E-03</td>
</tr>
<tr>
<td>S</td>
<td>3.00E-01</td>
<td>4.34E-02</td>
</tr>
<tr>
<td>N</td>
<td>1.00E-02</td>
<td>2.37E-02</td>
</tr>
<tr>
<td>Cl</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>P</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>Slag</td>
<td>9.84E+00</td>
<td>5.80E-03</td>
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<tr>
<td><strong>Emission factors per ton of fuel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>2.76E+00</td>
<td>3.23E+00</td>
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<tr>
<td>H₂O</td>
<td>5.97E-01</td>
<td>5.01E-01</td>
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<tr>
<td>O₂</td>
<td>4.70E-01</td>
<td>5.37E-01</td>
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<tr>
<td>NOₓ</td>
<td>9.28E+00</td>
<td>1.06E+01</td>
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<tr>
<td>SO₂</td>
<td>9.05E-02</td>
<td>1.08E-01</td>
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<tr>
<td>HCl</td>
<td>3.20E-03</td>
<td>4.88E-02</td>
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<tr>
<td>P₂O₅</td>
<td>0.00E+00</td>
<td>0.00E+00</td>
</tr>
</tbody>
</table>
## Quantities of raw materials for the production 1 ton of clinker

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Quantity (ton)</th>
<th>Raw material</th>
<th>Quantity (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone</td>
<td>8.63E-01</td>
<td>Bauxide</td>
<td>2.30E-03</td>
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<tr>
<td>Slate</td>
<td>9.08E-02</td>
<td>Fly ash</td>
<td>1.80E-03</td>
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<tr>
<td>Flysch</td>
<td>5.00E-04</td>
<td>Fe source</td>
<td>1.82E-02</td>
</tr>
<tr>
<td>Sandstone</td>
<td>5.40E-03</td>
<td>Aggregates</td>
<td>2.00E-03</td>
</tr>
</tbody>
</table>
10% Substitution of Fossil Fuels by Alternative Fuels

Eco-indicator 99
GLOBAL WARMING

10% Substitution of Fossil Fuels by Alternative Fuels
*CML 2 baseline 2000*
Photochemical Oxidation

10% Substitution of Fossil Fuels by Alternative Fuels

\textit{CML 2 baseline 2000}
In the sequel, a 30% (instead of 10%) substitution of conventional fossil fuels by alternative fuels was examined.
30% substitution of Fossil Fuels by Alternative Fuels
Eco-indicator 99
Contribution of Scenarios 4, 5, 6 and 7 to the Impact Category Global Warming Potential (GWP) for 10% and 30% substitution of fossil fuels by alternative fuels.
Impact Percent reduction of scenarios 4, 5, 6 and 7 to the categories of CML baseline 2000 methodology when substitution is increased from 10 to 30%
Conclusions

- The use of **fossil fuels** results in environmental pollution in all impact categories.
- In addition, the use of petcoke results in harmful environmental impacts.
- The use of **AFs** *reduce the environmental impacts of all* impact categories.
- AFs are more environmentally friendly.

*BS* → *has the highest environmental impact in the life cycle of the process*

*RDF* → *is the most environmentally friendly prospect*
Thank you for your attention!