Meeting the need for product-specific LCAs for composites – the lessons learnt from the DACOMAT project

Callum Hill JCH Industrial Ecology
Sustainable Composites: The Future - Virtual Conference, Cabot Institute, Bristol
29/06/2020 – 3/07/2020
Partners from the whole value chain

Duration: January 2018 - December 2021
Budget: 5.9 M€
Contact: jens.k.jorgensen@sintef.no
Twitter: @DACOMAT_EU
WEB: www.dacomat.eu
The targeted effect

Nature has demonstrated this already!

Nature has demonstrated this already!
WORKPACKAGE 6

• LCA/LCCA background data to support decision-making processes regarding formulation

• LCA/LCCA of the whole value chain – e.g., new formulation may have higher impact, but reduce downtimes, or inspections of wind turbines – what are the benefits and what are the burdens?
POTENTIAL FORMULATION OF COMPOSITE

• Vinyl ester resin
• Glass fibre
• Carbon fibre
• Sizing agent
• Gel coat
• Fillers
The DACOMAT project has received funding from the European Union’s Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
The DACOMAT project has received funding from the European Union's Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
Polyester and vinyl ester resin

Unsaturated polyester resin

Vinyl ester resin based upon bis-phenol A epoxy
Polyester and vinyl ester resin

Unsaturated polyester resin

Vinyl ester resin based upon bis-phenol A epoxy
LCA of new VER compared with state of the art
The DACOMAT project has received funding from the European Union’s Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

**OIL REFINING**

- **NATURAL GAS**
  - 58.3 MJ/kg
  - 0.52 kg CO₂e/kg
- **CRUDE OIL**
  - 47.4 MJ/kg
  - 0.18 kg CO₂e/kg
- **NAPTHA**
  - 50.3 MJ/kg
  - 0.34 kg CO₂e/kg
- **PYROLYSIS GAS**
  - 65.2 MJ/kg
  - 1.02 kg CO₂e/kg

**CRACKING**

- **ETHYLENE**
  - 72.5 MJ/kg
  - 1.44 kg CO₂e/kg
  - 72.5 MJ/kg
  - 1.44 kg CO₂e/kg
- **BENZENE**
  - 80.2 MJ/kg
  - 1.86 kg CO₂e/kg

**CATALYTIC REFORMING**

**CUMENE PRODUCTION**

- **CUMENE**
- **Catalytic Rearrangement**
  - **ACETONE**
    - 61.9 MJ/kg
    - 1.64 kg CO₂e/kg
  - **PHENOL**
    - 67.8 MJ/kg
    - 1.79 kg CO₂e/kg

**BISPHENOL A PRODUCTION**

- **BISPHENOL-A**
  - 80.1 MJ/kg
  - 2.54 kg CO₂e/kg

**BISPHENOL PRODUCTION**

- **EPOXY RESIN**
  - 137.1 MJ/kg
  - 8.1 kg CO₂e/kg
- **EPOXY RESIN PRODUCTION**
- **EPICHLOROHYDRIN**
- **EPICHLOROHYDRIN PRODUCTION**
- **ALLYL CHLORIDE**
  - 19.9 MJ/kg
  - 0.90 kg CO₂e/kg
- **ALLYL CHLORIDE PRODUCTION**
- **PROPYLENE**
  - 72.5 MJ/kg
  - 1.44 kg CO₂e/kg

**CHLORINE**

- **NaOH**
  - 17.1 MJ/kg
  - 0.86 kg CO₂e/kg

**ELECTROLYSIS**

**BRINE/ROCK SALT**

Source: Plastics Europe
The DACOMAT project has received funding from the European Union's Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Source: Plastics Europe
VER in Ecoinvent

Diluent is styrene, or methacrylic acid, or mixture of the two
The DACOMAT project has received funding from the European Union’s Horizon 2020 research and innovation programme under GA No. 761072. The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
Initiator

- Benzoyl peroxide (BPO) (CAS: 94-36-0)
- Cobalt naphthenate (CAS: 61789-51-3)
- Cumene hydroperoxide (CAS: 80-15-9)
- Methyl ethyl ketone peroxide (MEKP) (1338-23-4)
- Tertiary butyl peroxybenzoate (CAS: 614-45-9)

- Addition at about 3 phr
## Ecoinvent entries for initiators (per kg)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>GWP (kg CO₂e)</th>
<th>EE (MJ)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzoyl peroxide</td>
<td>3.6</td>
<td>93</td>
<td>DACOMAT (calculated)</td>
</tr>
<tr>
<td>Cobalt naphthanoate</td>
<td>10.6</td>
<td>131</td>
<td>Ecoinvent (cobalt)</td>
</tr>
<tr>
<td>Cumene hydroperoxide</td>
<td>2.5</td>
<td>80</td>
<td>Ecoinvent (cumene)</td>
</tr>
<tr>
<td>Methyl ethyl ketone peroxide</td>
<td>1.8</td>
<td>60</td>
<td>Ecoinvent (methyl ethyl ketone)</td>
</tr>
<tr>
<td>t-butyl peroxy benzoate</td>
<td>1.5</td>
<td>42</td>
<td>Ecoinvent (benzoic acid)</td>
</tr>
</tbody>
</table>
Sizing agent

- typically added at 0.5-0.6% by fibre weight
- often tri-alkoxy silane-based with pendant organic moiety, for glass fibre
- one entry in the Ecoinvent database for an alkoxy silane (TEOS, tetraethyl ortho silicate) – used as a proxy
The composite
The DACOMAT project has received funding from the European Union’s Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

The bar chart shows the Global Warming Potential (GWP) in kg CO$_2$e for different materials:
- **Fibre**: 1.26 kg CO$_2$e
- **Resin**: 2.08 kg CO$_2$e
- **Sizing**: 0.018 kg CO$_2$e
- **Initiator**: 0.02 kg CO$_2$e
The DACOMAT project has received funding from the European Union's Horizon 2020 research and innovation programme under GA No. 761072.

The information on this presentation reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
Blade/Bridge element LCA/LCCA

• Materials (glass fibre, resin)
• Energy (cure, lay-up)
• Service life (life expectancy, maintenance, inspections)
• End of life (disposal, recycling, re-use)
• Compare DACOMAT system with the state-of-the-art
Questions

• What size rotor?
• What wind turbine power output?
• Offshore/onshore?
• Composition of rotor – how does this compare?
• Sensors included?
<table>
<thead>
<tr>
<th>Class</th>
<th>Unit blade mass (t/MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1 MW</td>
<td>8.43</td>
</tr>
<tr>
<td>1-1.5MW</td>
<td>12.37</td>
</tr>
<tr>
<td>1.5-2.0 MW</td>
<td>13.34</td>
</tr>
<tr>
<td>2.0-5.0 MW</td>
<td>13.41</td>
</tr>
<tr>
<td>&gt;5.0 MW</td>
<td>12.58</td>
</tr>
</tbody>
</table>

Inspections/Maintenance

• Downtime
• Time between inspections
• Rules for interventions/limit states (e.g. crack length)
• Repairs/replacement
• Distance travelled
How to account for down-time? What size turbine?

Greenhouse gas performances [g CO₂ e /kWh]

- Vestas V80-2MW
- Vestas V90-2MW
- Gamesa G87 -2.0MW
- Gamesa G83 -2.0MW
- Gamesa G80 -2.0MW

A Simplified Life Cycle Approach for Assessing Greenhouse Gas Emissions of Wind Electricity

Pierrepont Pades, Isabelle Blanc, Denis Le Boëch, and Xiaohua Zhao

Journal of Industrial Ecology Volume 16, Number S1
Lifetime of turbine – versus blade life

Questions?

https://www.sintef.no/projectweb/dacomat/