HTL OF COMMON POLYMERS IN PRESENCE OF ALKALINE CATALYST AND LIGNOCELLULOSIC MATERIALS

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PLASTIC WASTE

- Primary production: 8300
- In-use stocks: 2500 primary
- In-use stocks: 100 secondary
- Recycled: 600
- Discarded: 4900
- Incinerated: 800

Plastics – the Facts 2017. PlasticsEurope
PLASTIC WASTE

Primary production
8300

In-use stocks
2500 primary

30%

Discarded
4900

60%

Incinerated
800

10%

Recycled
600

Primary production
Primary waste

Polymers weight [Mton/year]

Others
PVC
PUR
PS
PET
HDPE
PP & A fibers
PP
LLD, LDPE

Plastics – the Facts 2017. PlasticsEurope
HYDROTHERMAL LIQUEFACTION (HTL)

Synthetic- and bio-polymers

+ $\text{H}_2\text{O}$

20 min @ 350 ºC (180 bar)

w/ wo/ KOH

HyFlexFuel
HYDROTHERMAL LIQUEFACTION (HTL)

Synthetic- and bio-polymers

\[ + \text{H}_2\text{O} \quad 20 \text{ min} \at 350 \degree \text{C} \at (180 \text{ bar}) \quad \text{w/ wo/ KOH} \]

Batch HTL

- Gas
- Aqueous Phase
- Oil
- Solids
POLYOLEFINS AND PS

Mass balance [%]

- LDPE
- LDPEcat
- HDPE
- HDPEcat
- PP
- PPcat
- PS
- PScat

AP (diff) Gas Oil Solids
POLYOLEFINS AND PS

- No reactive sites
- Depends on thermal cracking
- Onset decomposition > 350 ºC for all

PE ≈ 525 ºC
PP ≈ 400 ºC
PS ≈ 390 ºC

HyFlexFuel

HyFlexFuel
POLYOLEFINS

LDPE

[\begin{array}{c}
\text{Absorbance} \\
\text{Wave number [cm}^{-1}] \\
\end{array}]

HDPE

[\begin{array}{c}
\text{Absorbance} \\
\text{Wave number [cm}^{-1}] \\
\end{array}]

PP

[\begin{array}{c}
\text{Absorbance} \\
\text{Wave number [cm}^{-1}] \\
\end{array}]
ABS

Mass balance [%]

- AP (diff)
- Gas
- Oil
- Solids

Wave number [cm\(^{-1}\)]

Absorbance

Suggestion:
EPOXY AND PC

Mass balance [%]

- AP (diff)
- Gas
- Oil
- Solids

Epoxi
- Polymer: 68.5% C, 8.2% H, 3.2% N, 0.0% S, 20.1% O*
- Oil: 72.6% C, 8.0% H, 2.6% N, 0.1% S, 16.7% O*

PC
- Polymer: 75.7% C, 5.5% H, 0.0% N, 0.0% S, 18.8% O*
- Oil: 77.5% C, 6.9% H, 0.0% N, 0.0% S, 15.6% O*

*Oxygen by difference
Non-quantified, including: Dimers, trimers and oligomers of BPA; Variations of o,m,p ethyl phenols and cumenols; Non-identified compounds.
**PET**

\[
\begin{align*}
\text{O} & \quad \text{O} \\
\text{C} & \quad \text{C} \\
\text{C} & \quad \text{C} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\end{align*}
\]

**Catalytic**

\[
\begin{align*}
\text{O} & \quad \text{OH} \\
\text{O} & \quad \text{OH} \\
\text{O} & \quad \text{OH} \\
\text{O} & \quad \text{OH} \\
\end{align*}
\]

**Soluble salts**

**Mass balance [%]**

- Green: AP (diff)
- Blue: Gas
- Yellow: Oil
- Black: Solids

**Solid FTIR**

- PET
- PET HTL residue
- PET HTLcat residue
- TA reference
PA6 AND PA66

Mass balance [%]

AP (diff) Gas Oil Solids

PA6 PA6cat PA66 PA66cat

γ depolymerizes more than α
Mass balance [%]

**AP (diff)**

- Gas
- Oil
- Solids

% in Oil

- Non-quantified, including:
  - Aromatic compounds with 3 or more rings;
  - Non-identified heavy compounds (oligomers)
LIGNOCELLULOSIC WASTE FOR CO-LIQUEFACTION
## LIGNOCELLULOSIC WASTE FOR CO-LIQUEFACTION

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Potential (MtD/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereal (wheat) straw</td>
<td>241</td>
</tr>
<tr>
<td>Sugarbeet leaves</td>
<td>128</td>
</tr>
<tr>
<td>Final fellings from conifer trees</td>
<td>129</td>
</tr>
<tr>
<td>Final fellings from nonconifer trees</td>
<td>93</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>66</td>
</tr>
<tr>
<td>Thinnings from conifer trees</td>
<td>64</td>
</tr>
<tr>
<td>Maize stover</td>
<td>63</td>
</tr>
<tr>
<td>Miscanthus*</td>
<td>62</td>
</tr>
<tr>
<td>Unused grassland cuttings</td>
<td>58</td>
</tr>
<tr>
<td>Stumps from final fellings from conifer trees</td>
<td>51</td>
</tr>
<tr>
<td>Thinnings from nonconifer trees</td>
<td>47</td>
</tr>
<tr>
<td>Logging residues from final fellings from conifer trees</td>
<td>40</td>
</tr>
<tr>
<td>Sunflower straw</td>
<td>34</td>
</tr>
<tr>
<td>Cereal bran</td>
<td>34</td>
</tr>
<tr>
<td>Stumps from final fellings from nonconifer trees</td>
<td>30</td>
</tr>
<tr>
<td>Logging residues from thinnings from conifer trees</td>
<td>26</td>
</tr>
<tr>
<td>Non hazardous post consumer wood</td>
<td>25</td>
</tr>
<tr>
<td>Logging residues from final fellings from nonconifer trees</td>
<td>25</td>
</tr>
<tr>
<td>Other residues (conifers)</td>
<td>22</td>
</tr>
<tr>
<td>Oil seed rape straw</td>
<td>21</td>
</tr>
</tbody>
</table>

* - Potential according to area available
Synergy effect = \( \frac{\text{yield}_{\text{experiment}}}{\text{yield}_{\text{expected}}} \)

Synergy effect > 1 \( \rightarrow \) Positive

Synergy effect < 1 \( \rightarrow \) Negative

Synergy effect \( \approx \) 1 \( \rightarrow \) Neutral
**MISCANTHUS + POLYMERS**

**Synergy effect**

\[
\text{Synergy effect} = \frac{\text{yield}_{\text{experiment}}}{\text{yield}_{\text{expected}}}
\]

- **Synergy effect > 1** → **Positive**
- **Synergy effect < 1** → **Negative**
- **Synergy effect \approx 1** → **Neutral**
MISCANTHUS + POLYMERS

Synergy Effect

Synergy Effect

Oil

N [%]

0.0

0.2

0.4

0.6

0.8

1.0

1.2

1.4

1.6

1.8

2.0

PC  PP LDPE PVC HDPE PS Epoxi PET ABS PA6 PUR PA66

Solids Oil Gas AP

Synergy Effect

0.0

0.5

1.0

1.5

2.0

2.5

3.0

25/75 50/50 75/25

PUR/Miscanthus
NEXT STEPS

Polyolefins solutions?

Physico-chemical treatment

Plastic waste

HTL 350°C 180 bar

Hydrocarbons

$\text{HyFlexFuel}$

Upscaling and its consequences

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