Accompanying innovation process of lignin based products

Life Cycle Assessment in line with technology readiness levels

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SmartLi – Project overview

*Smart Technologies for the Conversion of Industrial Lignins into Sustainable Materials*

**Lignin**
- **Pretreatments**
- **Degradation & Fractionation**
- **pulp & paper**

**Processes:**
- Epoxy resins
- PU resins
- PF resins
- Composites

- Creating **new value chains** for the by-product lignin
- Develop **sustainable bio-based products**
- Reducing GHG emissions by **20%**
SmartLi activities span from TRL 2 (concept) to TRL 5 (prototypes)
Modular Life Cycle Assessment

- System boundaries:
  - newly developed products (S4) and technologies (S3)
  - Biorefinery (S2) and Forestry (S1)

![Diagram showing system boundaries from S1 Forestry to S4 Products with S2 Biorefinery and S3 Valorisation in the middle. The diagram is labeled 'Cradle to gate' and is covered by SmartLi.]
Modular Life Cycle Assessment

- System boundaries:
  - newly developed products (S4) and technologies (S3)
  - Biorefinery (S2) and Forestry (S1)
Modular Life Cycle Assessment

- **System boundaries:**
  - newly developed products (S4) and technologies (S3)
  - Biorefinery (S2) and Forestry (S1)

This modular approach provides the opportunity to:
- Assess each system (e.g. hot-spot analysis within one system)
- Easily add new information (e.g. up-scaling of developed technologies)
- Develop the LCA in parallel to the technological advancements
S1: cultivation & harvesting of pulpwood
S2: production of pulp & lignin as by-product
S3: various pretreatment technologies to improve lignin quality
S4: various lignin-based products (resins & composites)
TRL 2 Identification of process pathways

**TRY 2** concept

- Gain knowledge on potential process pathways
- Identify uncertainties along the process pathways
- Demonstrate linkages to different stakeholder/project partners
TRL 3 Specification of process pathways

- Increased knowledge/TRL reduce possible process pathways
- (Primary) data availability as bottleneck
- Feedback after initial assessment

**Composites Degradation & Fractionation**

**Pretreatment 1**

**Pretreatment 2**

**Degradation & Fractionation**

**Process a**

**Process b**

**PF resins**

**PU resins & epoxy resins**

**Kraft Lignin**

**Pretreatment 3**

**Pretreatment 4**
Feedback: From LCA to R&D at low TRL

Knowledge development | Technology development | Business development

TRL2 | TRL3 | TRL4 | TRL5

Basic technology research | Research to prove feasibility | Technology demonstration | Technology development and prototypes

Feedback from LCA to R&D

Continuous Feedback to R&D

Life Cycle Assessment
Exemplary results SmartLi

- **Aim:** 20% reduction of GHG compared to fossil based resins
  - Streamlined LCA & Hot-Spot Analysis for two lignin epoxy resins recipes (L.-epox. R1 & R2)

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Can we increase the bio-based content?
Exemplary results SmartLi

- Aim: 20% reduction of GHG compared to fossil based resins
- Streamlined LCA & Hot-Spot Analysis for two lignin epoxy resins recipes (L.-epox. R1 & R2)

- Additional use of further bio-based inputs

![Bar chart showing GHG reduction comparison between L-epox. R1, L-epox. R2, and fossil epox. R]
Feedback: From R&D to LCA at low TRL

Knowledge development  Technology development  Business development

TRL2  TRL3  TRL4  TRL5

Basic technology research  Research to prove feasibility  Technology demonstration  Technology development and prototypes

Feedback from R&D to LCA

Continuous Feedback to R&D

Life Cycle Assessment
Exemplary results SmartLi

- Scenario: 50% reduction of GHG compared to fossil based resins

- Performance and technical feasibility?

- Need for market orientation as additional supportive iterative process

- LCA & market orientation as part of sustainable product development
Accompanying innovations processes along TRL

Knowledge development → Technology development → Business development

TRL1 → TRL2 → TRL3 → TRL4 → TRL5 → TRL6 → TRL7 → TRL8 → TRL9

R&D Feedback → R&D Feedback → R&D Feedback

Market orientation

Technological & economic aspects

Life Cycle Assessment

Environmental aspects
Integrated market orientation in technical R&D processes

Public SmartLi project report Oct. 2017  Identifying barriers and incentives for the market diffusion of lignin-based products. Comparative case studies for lignin-based composite materials and resins
Thank you!

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