Guiding technology development using LCA
The case of bio-based adipic acid production

Matty Janssen & Anne-Marie Tillman

Division of Environmental Systems Analysis
Department of Energy & Environment
Chalmers University of Technology
Göteborg, Sweden

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Outline

1. Adipic acid and its conventional production
2. Description of the research project
3. Some preliminary results
4. Conclusions
Adipic acid

- Main application → Production of nylon-6,6
- Traditional production from fossil resources → KA oil

\[
\text{Cyclohexanone} + 1 \frac{1}{2} \text{HNO}_3 \xrightarrow{\text{Cu}^{2+}, \text{V}^{5+}} \text{HOOC-Adipic acid} + \frac{3}{4} \text{N}_2\text{O} + \frac{3}{4} \text{H}_2\text{O}
\]

\[
\text{Cyclohexanol} + 2 \text{HNO}_3 \xrightarrow{\text{Cu}^{2+}, \text{V}^{5+}} \text{HOOC-Adipic acid} + \text{N}_2\text{O} + 2 \text{H}_2\text{O}
\]

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BioBuF research project

- Biorefinery concept for the production of bulk and fine chemicals

- Bulk chemical → Adipic acid, lignin-derivative, e.g. terephthalic acid
- Fine chemical → Lutein
Information flow in the project

Knowledge about raw materials and processes

Literature data

Industrial biotechnology

Wood engineering

Process modeling

Process integration

Economic analysis

Environmental analysis

Background system

Results

1. Modelling based on experimental, lab-scale data
2. Process integration
3. Economic and environmental analysis
4. Feedback to development

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- IEST, ESA, SP

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Results
Process flow diagram of the biorefinery concept
Process flow diagram of the biorefinery concept

- Tool for (internal) cooperation and (external) communication
Some indicative calculations

- Theoretical emission factor of N\textsubscript{2}O is 300 kg per tonne of adipic acid produced\textsuperscript{2}
- ecoinvent process for adipic acid production\textsuperscript{3}
  - Uses KA oil for adipic acid production
  - 80\% of the N\textsubscript{2}O produced is removed by abatement technologies
  - Global warming $\approx$ 25 kg CO\textsubscript{2}-eq/kg adipic acid produced

\textsuperscript{2} L. Li et al. *Environmental Science and Technology* 48.9 (2014), pp. 5290–5297.
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- Switch from fossil to renewable resource and using a biochemical process
  - Elimination of N$_2$O emissions $\rightarrow$ 75% reduction of global warming
  - Switch to renewable resource $\rightarrow$ 10% reduction of global warming

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Further reduction of environmental impacts?

- Separation of adipic acid from the fermentation broth
  - Yield of adipic acid is 50%
  - Concentration of adipic acid in the broth is 18 g/l
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  - Yield of adipic acid is 50%
  - Concentration of adipic acid in the broth is 18 g/l

- Calculated energy need for separation $\approx 92$ MJ/kg adipic acid
- ecoinvent process $\rightarrow$ NREU $\approx 126$ MJ/kg adipic acid
- Careful screening of possible separation alternatives
Lessons learned so far

- Guiding technology development for adipic acid production using LCA
  - Reduction of N₂O emissions
  - Identify further opportunities to reduce environmental impact
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- Communication between project partners
  - Internal → Learning each other’s language
  - External → Tools to communicate with
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- LCA methodological issues
  - Data availability within the project (and external)
  - Uncertainties
  - What is most important to consider?
  - Communication of LCA results
THANK YOU

Any questions?