DEVELOPMENT OF ECO-EFFICIENCY INDICATORS FOR A BIOREFINERY

Celia Bee Hong Chua
Horst Steinmueller

Presentation on the 12th of February 2010
11th Symposium Energieinnovation

Energieinstitut an der
Johannes Kepler Universität Linz
Introduction

- “Biorefining: the sustainable processing of biomass into a spectrum of marketable products and energy.”
  
  Source: IEA Bioenergy Task 42

- Multiple biorefinery products
  → Which to produce?
  More fuel or more chemical?
  → Which configuration?
  feedstock-based or energy-driven biorefinery?
  → Which level of integration?
  fully-integrated = biorefinery plant + crop farm + livestock farm?

How to make the decision?

11th Symposium Energieinnovation | 11th February 2010
Introduction

**Eco-efficiency**

- **World Business Council for Sustainable Development**

  Definition: Creating more value with less environmental impact

- **Integration of environmental influence and economic value allows decision makers to weigh and compare products and technologies**

- **Helps to set measurable eco-efficiency targets and facilitate comparisons between companies and business sectors.**

  \[
  \text{Eco-efficiency indicator (EEI)} = \frac{\text{Production value}}{\text{Environmental influence}}
  \]

  Source: National Round Table on the Environment and the Economy (NRTEE)
Objectives

- Aids in decision-making process for stakeholders, biorefinery business owners, etc
- Understanding of eco-efficiency of biorefinery products
- Understanding of eco-efficiency of biorefinery type and integration level
- To achieve the above, We develop the eco-efficiency indicators specifically for biorefinery
Approach

- Physical flows of material and energy
  - Identification and definition of biorefinery integration levels
  - Selection of the system boundaries where inputs and outputs will be considered
  - Identification of the objective of the indicator and the information it conveys
  - Identification and quantification of all relevant inputs and outputs
  - Calculation of the indicators

- Includes only the biorefinery business/operations areas
Biorefinery Integration level

**INPUTS**

- Level II integration
  - Feedstock
    - If business includes crop farming
      - Crop Farm Boundaries
  - If business includes animal farming
    - Livestock Farm Boundaries

**OUTPUTS**

- Level I integration
  - Receiving & preparation of feedstock
    - Pre-treatment
      - Conversion to bioproduct
        - Waste water treatment system
          - Biorefinery Plant Boundaries

- Level III integration
  - Feedstock
    - Biofuels
    - Bioenergy
    - Biochemicals
    - Biomaterials
    - Air Emissions
    - Solid waste residue
    - Water Emissions

**Additional Elements**

- Raw materials
- Ingredients
- Process heat
- Electricity
- Water
- Waste water treatment system
- Process heat
- Electricity
- Water
Environmental Issues of biorefinery

- Energy analysis
- Global Warming potential resulted from Greenhouse Gas (GHG) emissions
- Eutrophication resulted from Nitrogen and Phosphorous-based compounds at the crop farm
- Acidification
ENVIRONMENTAL INFLUENCES

- Main environmental influences of a biorefinery:
  - Energy Consumption
  - Material Consumption
  - GHG emissions (kg CO2-equivalent)
  - Acidification (kg SO2-equivalent)
  - Eutrophication (kg PO4-equivalent)

Centrum voor Millieukunden Leiden (CML) 2001, impact assessment methodology
CHOOSING PRODUCTION VALUE

Generally Applicable Value Indicators (GAVIs):

- Quantity of product
- Net Sales
- Net Profit (PR) as defined in Generally Accepted Accounting principles (GAAP)
Eco-Efficiency indicator (EEI) example

**Product Energy consumption eco-efficiency indicator**

\[
EE_{TEC_{ij}}^{ij} = \frac{PR_{ij}}{\sum TEC_{ij}}
\]

**Biorefinery Energy consumption eco-efficiency indicator**

\[
(EE_{TEC_{i}}) = \frac{PR_{i}}{\sum TEC_{i}}
\]

*Notations: i refers to the level of integration of the biorefinery; j refers to the product*
Biorefinery case study

Set-up of Austrian Green Biorefinery Demo Plant

- Feedstock silage (Grass, Clover, Lucerne)
  - Mechanical Fractionation
    - Juice
      - Amino Acids Separation
        - Amino Acids mixtures
      - Lactic Acid Separation
        - Lactic Acid
      - Biogas digester
        - Electricity
          - Heat
          - Fertilizer
          - Fibre for different applications
- Press Cake Fibres
- Optional Fibre Processing
- Additional feed (manure, maize)

Source: National Round Table on the Environment and the Economy (NRTEE)
BIOREFINING PRODUCT ECO-EFFICIENCY COMPARISON

![Graph showing eco-efficiency comparison between amino acid mixtures and lactic acids.](chart.png)
Biorefinery Comparison

Biorefinery overall eco-efficiency score = €

• Energy consumption
• Material consumption
  • Acidification
  • Eutrophication
• Greenhouse gases

How much “weight” to each impact?
Biorefinery Comparison

Notations: $i$ refers to the level of integration of the biorefinery; $j$ refers to the product; $k$ refers to the feedstock
Conclusion

- The framework of the eco-efficiency indicators is developed for a biorefinery.
- Develop more and better indicators to reflect the eco-efficiency.
- "Give" the "weight" of each environmental impact for effective comparison of biorefinery.
- Hope to obtain actual data from a commercial biorefinery.
Danke für die Aufmerksamkeit!

Kontakt

Dr Horst Steinmüller
Energieinstitut an der Johannes Kepler Universität Linz
Altenberger Strasse 69
4040 Linz
Tel: +43 70 2468 5653
Fax: +43 70 2468 5651
e-mail: @energieinstitut-linz.at