Virtual Biorefinery
Sustainability Assessment of New Technological Innovations

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Virtual Biorefinery

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General Overview - Concepts

Why Measuring and Evaluating the Success

- Aids in decisions about whether the project should be expanded, continued, improved or curtailed;
- Increase the effectiveness of project management;
- To satisfy calls for accountability;
- To measure the impact on the core problem.

Source: RTI International, 2004
General Overview - Concepts

Biorefinery

Oil and Biomass treatment and processing generate a large variety of products

Refinery

Fuels and Energy

Oil

Materials and Chemical Products

Biorefinery

Fuels and Energy
- Bioethanol
- Biodiesel
- Biogas
- Hydrogen

Materials and Chemical Products
- Conventional chemistry
- Fine chemistry
- Biopolymers
**General Overview - Concepts**

**Biorefinery – Life Cycle Assessment**

<table>
<thead>
<tr>
<th>Plant Raw-material</th>
<th>Pre-processing</th>
<th>Final Processing</th>
<th>Use</th>
<th>Recycle or Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grains</td>
<td>Carbohydrates</td>
<td>Fuels</td>
<td>Products to replace petroleum based or petroleum dependent products</td>
<td>Recycled within product system or to other product systems</td>
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<tr>
<td>Crop Residues</td>
<td>Protein</td>
<td>Chemicals</td>
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<td></td>
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<tr>
<td>Oilseeds</td>
<td>Oil</td>
<td>Polymers</td>
<td></td>
<td>Compost pile or landfill</td>
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<tr>
<td>Sugar Crops</td>
<td>Syngas</td>
<td>Feeds/Foods</td>
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<tr>
<td>Herbaceous/Woody Crops</td>
<td>Lignin</td>
<td>Monomers</td>
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<td></td>
<td>Ash</td>
<td>Lubricants</td>
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<td></td>
<td></td>
<td>Electricity steam</td>
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<td></td>
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<td>Fertilizer</td>
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</tbody>
</table>
General Overview - Concepts

Biorefinery focusing sugar-cane
Parallel with the development of the research agenda, in order to make the biorefinery technical-economic concept viable, different alternatives should be constructed, introducing all the routes/processes that are being studied and the results that are being achieved.

The whole process should be modeled, allowing its simulation, in order to evaluate the economic, social and environmental impacts that will be attained with the new technologies under development.
Virtual Biorefinery

Objectives

- Optimization of the biorefinery processes and concepts.
- Evaluation of different alternatives of biorefinery, referring to their sustainability indicators (economic, environmental and social).
- Evaluation of the level of success of the new developed (or being developed) technologies.
Virtual Biorefinery

- Simulation
- Process Optimization
- Impacts computation
- Comparison with Standard Biorefinery

Economical And Risk Assessment
Life Cycle Assessment (LCA)
Input - Output Assessment

Impacts:
- economical
- environmental
- social

LDP, PPDP, Others

Process Alternative

Mathematical Modeling Net
- Processes
- Unit Operations

Assessment of Success Level

New Approach (quantitative)
Virtual Biorefinery

Steps for the Development of the Virtual Biorefinery

- Definition of a standard biorefinery, including all the production and all the involved processes.

- Construction of the mathematical models of the different production units.

- Construction of the tools to be used for the economic and risk assessment, the life cycle assessment and the input-output assessment, which will allow to calculate the economic, environmental and social impacts, of each evaluated biorefinery alternative.

- Comparison of the calculated impacts with the ones obtained for the biorefinery defined as standard.
Virtual Biorefinery

Biorefinaria

Etanol – rota química e bioquímica
Simulation – Mathematical Modeling

- The simulation platform to be used, quantifies the process characteristics, the energy requirements and the project parameters for the major equipments for a particular operational alternative. Identifies, for each equipment, the volumes, the compositions and many other physical characteristics of the input and output fluxes. These information are the basis for the computation, for each equipment, of the utilities consumption and price.

- SuperPro Designer
- ASPEN Plus
- Hysys

The reason to use these simulation packages is to facilitate the modeling, the optimization and the technical-economic evaluation of the integrated processes, in a very wide spectrum of industries.
Simulation – Mathematical Modeling

Mathematical Models Construction

(1) Formulation of the Models

(2) Fitting the Models to experimental data

(3) Evaluation of the fitted Models

(4) Simulation of the process / operation using the Models.
Sustainability Methodologies

Economic and Risk Analysis

- Usage of Economic Engineering, in order to evaluate the obtained rentability and the required investments of a new technology.

- Risk analysis is a technique to identify and assess factors that may jeopardize the success of a project. This technique also helps to define preventive measures to reduce the probability of these factors from occurring and identify countermeasures to successfully deal with these constraints. Probabilistic risk assessment is a systematic methodology to evaluate risk associated with a complex engineered technology.
Sustainability Methodologies

Life Cycle Assessment (LCA)

- The LCA methodology evaluates and quantifies the environmental impacts, accounting for the total usage of natural resources and pollutant emissions.

- LCA methodology accounts the major fluxes of mass and energy, computing the environmental impacts of the whole production chain, including the stages from nature extraction of raw-materials to final disposal of products and co-products.
Sustainability Methodologies

Life Cycle Assessment (LCA)

- The major environmental impacts calculated in the LCA are:
  - depletion of biotic and abiotic resources;
  - climate changes;
  - stratospheric ozone depletion;
  - human toxicity;
  - ecotoxicity;
  - photo-oxidation formation;
  - acidification;
  - eutrophication;
  - others.
Input-Output Analysis (IO)

- A basic model is generally constructed from observed economic data for a specific geographic region (for example, a country). One is concerned about the activity of a group of industries that both produce goods (outputs) and consume goods from other industries (inputs) in the process of producing each industry’s own output.

- In CTBE “sustainability program”, an IO model will be developed and integrated with the virtual biorefinery, in order to evaluate social-economic and environmental impacts from new technologies to produce ethanol as well as new products.

- The model is able to compute both direct and indirect effects involved in the whole production chain to offer the amount required by final demand.
Sustainability Methodologies

Social Indicators - Examples

Improve citizens’ quality of life by:
– creating and retaining high quality jobs;
– creating and retaining high quality companies (generally in technology-based industries);
– improving the stability and/or competitiveness of local and regional economy through the innovation.
Preliminary Evaluation

Alternatives for Evaluation

(1) Conventional plant (producing sugar and ethanol and exporting the surplus of co-generated electric energy).

(2) Distillery dedicated to the production of ethanol, using the surplus bagasse and the straw for the production of ethanol through hydrolysis (acid and enzymatic).

(3) Distillery dedicated to the production of ethanol, using the surplus bagasse and the straw for the production of liquid fuels (BTL process).

(4) Biorefinery producing different products, besides ethanol and sugar.

(5) Other alternatives / technologies developed in CTBE’s LDP and PPDP or in any other partner Institution.
Preliminary Evaluation
- Present Context
Preliminary Evaluation
- Present Context
Preliminary Evaluation
- Energy Optimization

1 ton. cana

85 L etanol
0.044 TEP
R$ 85,00

140 kg bagaço e palha seca
0.06 TEP
R$ 4,20

ou

210 KWh
0.01 TEP
R$ 20,00

1 m³ de vinhaça

10 m³ de biogás

6 m³ de G.N.
0.0053 TEP
R$ 4,20

Matéria-Prima:
0.16 TEP
R$ 30,00

Produtos:
0.11 TEP (89%)
R$ 110,00 (3.7 x)
Preliminary Evaluation
- Radical Innovation
Preliminary Evaluation
- Enzymatic Hydrolysis

Matéria-Prima:
0,16 TEP
R$ 30,00

Produto:
0,09 TEP (56%)  
R$ 163,00 (5.4 x)
Preliminary Evaluation
- New Chain - Biorefinery

Cana-de-açúcar

- vinhaça
  - levedura
  - cachaca

- açúcar
  - bagaço e palha
    - gaseificação

- etanol
  - biodiesel
  - hidrogênio
  - alcoolquímica

- biogás
  - gás natural

- fertilizantes

Créditos de carbono

Avaliação Ambiental Estratégica

- diesel
- NH₃
- metanol
Preliminary Evaluation - Methanol from Bagasse and Straw

1 ton. cana

- 85 L etanol
- 140 Kg bagaço e palha seca
- 1,0 m³ de vinhaça
- 175 Kg gás
- 10 m³ biogás
- 6 m³ gás natural

Productos:
- 0,044 TEP R$ 85,00
- 0,034 TEP R$ 66,00
- 0,0053 TEP R$ 4,20

Matéria-Prima:
- 0,16 TEP
- R$ 30,00

0,08 TEP (50%)
R$ 155,00 (5,2 x)
Preliminary Evaluation
- PHAs from Bagasse Hydrolysate

Matéria-Prima:
R$ 30,00

Produtos:
R$ 313,00\(^{(1)}\) \((10,4 \times)\)
R$ 2,330,00\(^{(2)}\) \((77,7 \times)\)

(1) Embalagem
(2) Saúde
Preliminary Evaluation
- Technology Comparison
Preliminary Evaluation
- Technology Comparison

![Bar Chart]

- Valor Agregado

- R$ / ton de Cana

- Cana
- Cadeia Atual
- Otimização Energética
- Hidrólise Enzimática
- BTI (Metanol)
- Plástico Biodegradável

- 30
- 86.5
- 110
- 163
- 155
- 343
- 2,330
Final Remarks

- For each evaluated technology, the Virtual Biorefinery will generate a set of indicators.

- Composite indicators should be used with caution, mainly if weightings are applied to the individual indicators.

- No single composite indicator will ever be able to capture entirely the results of a new developed technology, risking to generate an unwarranted impression of accuracy and reliability.

- The measure of success of a new technology will take into account the set of resulting individual indicators and, through a strategic analysis, will reach a final conclusion.
THANK YOU !!!