LIFE CYCLE ANALYSIS (LCA)
Importance and Need in Biofuel Industry

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Why promote biofuels (in India)

- Part replacement of fossil fuels
- Sustainability
- Reduction of GHG emissions
- Regional (rural development)
- Social structure & agriculture

Indian biofuel Policy (2009) has a mandate of blending 5% (now 10%) and an ambitious plan of blending 20% biofuel in transport fuels by 2020.

CNG in Delhi because of Environmental concerns.
A myth

Biofuels Lifecycle Emissions
Biofuels are Carbon Neutral

CO2 Uptake (via Photosynthesis)
Feedstock Production
Feedstock Transportation
Biofuel Production
Biofuel Distribution
Combustion

The biofuels process recycles atmospheric carbon
Which is the best Alternate fuel?

- No straight answer
- Combination of factors decide
- Production cost, availability of raw material, technology, sustainable volumes
- Most important decision factor --- its capacity to reduce GHG load

Alternate fuels not only as replacement of fossil fuels but for their +ve environmental impact
Life cycle GHG emissions

Renewable Fuels
- Corn ethanol
- Sugarcane ethanol/Biodiesel
- Cellulosic ethanol

Advanced & Biodiesel Fuels
- Code D4 & D5

Cellulosic Fuels
- Code D3

EPA classification of biofuels & RIN/RFV
1 lit of D3 fuel = 3 lits of D6 fuel
What is LCA and NER?

- LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service.

- Net energy ratio (NER) is defined as the ratio of the energy output of the final biofuel product to the energy required to produce the biofuel.

  \[
  \text{NER} = \frac{\text{Energy input to produce biofuel}}{\text{Energy output from biofuel use}}
  \]

Why to do LCA/NER?

- Verify environmental impact of product or service & obtain concessions.
- Establish the benchmark against which improvements can be measured.
Importance of LCA

• To calculate environmental footprint and the future cost structure of a product

• Technology type affects LCA for a given biomass

• Each biofuel has different LCA & NER
<table>
<thead>
<tr>
<th>Transportation fuel</th>
<th>GHG emissions (g CO2 eq./km)</th>
<th>% reduction wrt gasoline</th>
<th>NER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioethanol, sugarcane molasses</td>
<td>50-75</td>
<td>65-70%</td>
<td>3.2-4.5</td>
</tr>
<tr>
<td>Bioethanol, corn</td>
<td>100-195</td>
<td>10-50%</td>
<td>0.9 -1.2</td>
</tr>
<tr>
<td>Cellulosic ethanol</td>
<td>25-50</td>
<td>70-92%</td>
<td>4.5 -6.0</td>
</tr>
<tr>
<td>Biogas</td>
<td>25-100</td>
<td>65-70%</td>
<td>4.3-5.0</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>80-140</td>
<td>45-50%</td>
<td>3.20</td>
</tr>
<tr>
<td>Gasoline</td>
<td>210-220</td>
<td>NA</td>
<td>0.80</td>
</tr>
<tr>
<td>Diesel</td>
<td>155-185</td>
<td>15-20%</td>
<td>0.74</td>
</tr>
</tbody>
</table>

Total Life Cycle emissions
## LCA framework and analysis parameters

<table>
<thead>
<tr>
<th>Environmental Impact Categories</th>
<th>Environmental Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global warming Potential</td>
<td>CO₂, NO₂, CH₄</td>
</tr>
<tr>
<td>Acidification Potential</td>
<td>SOₓ; NOₓ; NH₄</td>
</tr>
<tr>
<td>Eutrophication Potential</td>
<td>PO₄; NO; NO₂; NH₄</td>
</tr>
<tr>
<td>Photochemical Ozone creation potential</td>
<td>NOₓ, CO and hydrocarbons</td>
</tr>
</tbody>
</table>

Reference: ISO (14040-14044) Principles and guidelines, 2006
How LCA is done?

1. Goal and scope definition
2. Data collection
3. Validation of data
4. Relating data to unit process
5. Relating data to functional unit
6. Refining system boundaries
7. Complete life cycle inventory
8. Categorize environmental impacts
9. Interpretation
Example of system boundary: Ethanol from molasses

**Inputs**
- Land, water, fertilizers, herbicides
- diesel, electricity, labour
- Diesel
- Sugarcane juice, steam, chemicals, electricity
- Diesel
- Steam, urea, yeast, electricity, antifoam
- Diesel

**Processes**
- Sugarcane farming
- Sugarcane transport
- Sugar production
- Molasses transport
- Ethanol production
- Ethanol transport
- Blending

**Co-Products**
- Sugarcane trash
- Sugar, bagasse, filter mud
- Biogas
- Blended gasoline
- Combustion in automobiles
Data are available in public LCA databases can be purchased

Public Data

- U.S. LCI Database (fossil fuels, minerals, commodity plastics, crops)
- **GREET model** (transportation fuels, including bio-fuels)

Proprietary Data

- PE International (bundled with GaBi software)
- Eco Invent (thousands of European unit processes)

- A spreadsheet approach is an alternative to specialized LCA software
- **Spreadsheet LCAs offer transparency and flexibility, but require significant time for development and validation.**
- **Universal application capability on Indian conditions**
Allocation on the basis of mass (MA)

On a mass basis, product A is allocated 20% of the emissions.
GHG emission reduction using ethanol from sugarcane molasses in India

Mass and energy allocation approaches gives the real time analysis of situation and show GHG reduction from 63-76% wrt gasoline

Net energy ratio (NER) of fuel ethanol from sugarcane molasses in India

NER is positive in both regions of India with a score of 3.39 and 4.45 in NR & WR.

LCA of potential rice straw uses in India

- Incorporated in field
- Animal fodder
- Biogas
- Electricity
- Ethanol
System boundary of LCA rice straw utilization practices

1. Incorporated in field
   - Chopping
   - Ploughing in field
   - Biofertilizer
   - Substitute chemical fertilizer

2. Animal fodder
   - Collection
   - Transport
   - Chopping
   - Feed to animals
   - Substitute wheat straw

3. Electricity production
   - Collection & Bailing
   - Transport Field-collection centre-Power plant
   - Combustion In boiler
   - Electricity
   - Substitute grid based electricity

4. Biogas production
   - Collection & Bailing
   - Transport Field-biogas plant
   - Anaerobic digestion in plant
   - Biogas
   - Substitute LPG
Schematic of a Biochemical Cellulosic Ethanol Production Process

- Biomass Handling
- Enzyme Production
- Cellulose Hydrolysis
- Glucose Fermentation
- Pentose Fermentation
- Ethanol Recovery
- Lignin Utilization

Ethanol
Electricity production from rice straw gives highest GWP benefits (1471 kg CO\textsubscript{2} eq.) followed by use in biogas (730 kg CO\textsubscript{2} eq.) and ethanol (521 kg CO\textsubscript{2} eq.).

GHG emission benefits using second generation ethanol by two different technologies

Pure ethanol gives GHG reductions of 78% and 72% using Steam explosion and Dilute acid pretreatment method respectively are obtained.
Conclusions

• Bioenergy is an emerging field that would help in building the environment sustainability of country

• LCA is an important emerging tool in India for accessing environmental profile of products

• Indian Oil being largest oil producing company in country is gaining a lot after doing LCA of their new biofuels, being developed from rigorous research

• **LCA should be integral part of the technology selection process**
Biofuels LCA group

Dr. Ravindra Kumar. Sr Research Manger, IOCL
Biomass Pretreatment, Advanced characterization, LCA, Techno economic analysis.

Prof. Pal Borjesson
Lund University, Sweden
LCA of energy systems

Ms. Shveta Soam, PhD Scholar, IOCL
LCA of advanced biofuels
Thank you for your attention...
Allocation on the basis of economic value (EA)
In a multifunctional system, allocation is defined as partitioning the input or output flows of a process between the product and co-products/by-products based on mass, energy and economic price.

**MASS ALLOCATION**
Partitioning the emissions and energy input between product and co-products based on their mass.

**ENERGY ALLOCATION**
Partitioning the emissions and energy input between product and co-products based on their energy content.

**ECONOMIC ALLOCATION**
Partitioning the emissions and energy input between product and co-products based on their economic price.
Key issues affecting LCA results

✔ Type of biomass sources
✔ Conversion technologies
✔ System boundary
✔ Input data accuracy
✔ End-use technologies
✔ Allocation method
✔ Reference energy systems
Potential alternate fuel systems

Sugar Crops for EtOH
- Sugarcane
- Sweet sorghum
  - India / Brazil

Starch crops for EtOH
- Corn
- Wheat
  - US & Europe

Algae
- Oil
- Hydrogen

Oils for Biodiesel/ Renewable Biodiesel
- Soybean
- Rapeseed
- Palm Oil
- Jatropha
- Waste cooking fuel
- Animal fat

Cellulosic biomass for EtOH
- Corn stover, rice straw, wheat straw
- Forest residue
- Municipal solid waste
- Energy crops

Cellulosic biomass via Gasification / pyrolysis
- FT Diesel
- Methanol
- Hydrogen
Types of LCA

- **Cradle-to-grave**: LCA from resource extraction ('cradle') to use phase and disposal phase ('grave').

- **Cradle-to-gate**: Assessment of a *partial* product life cycle from resource extraction (*cradle*) to the factory gate (i.e., before it is transported to the consumer).
Concluding remarks from LCA study of fuel ethanol from sugarcane molasses

<table>
<thead>
<tr>
<th>Blends</th>
<th>E5</th>
<th>E10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allocation</td>
<td>WA</td>
<td>MA</td>
</tr>
<tr>
<td>% GHG reduction</td>
<td>6.5</td>
<td>-4.3</td>
</tr>
<tr>
<td>NER</td>
<td>0.78</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Significant environmental and energy benefits are obtained using ethanol blends in India and using mass and energy allocation approach.