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Life Cycle Analysis (LCA) of Multi-Crop Lignocellulosic Material for Bioethanol Production on western Canadian prospective: A Review

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Outline

- Introduction
- Lignocellulosic biomass potential
- LCA Methodologies
- Case studies-
    - Environmental
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- Discussion
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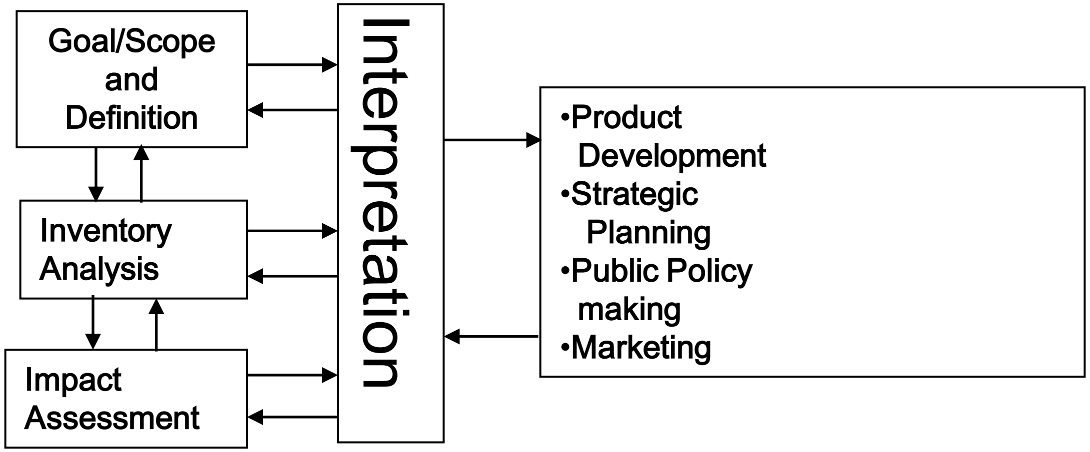
- Acknowledgements

Lignocellulosic biomass potential and need for doing LCA

- Cradle to grave analysis
- Environmental effects
- Economic issues
- Viability of lignocellulosic ethanol
- Possibility of using the co-product in a biorefinery concept

LCA Methodologies

1. Goal, definition and scope
2. Life cycle Inventory analysis
3. Impact assessment
4. Interpretation



Source:Blottnitz and Curran, 2006, ISO 14040-046, 048.-2006

Environmental issues (Case 1)

- Feedstock: cultivated and waste biomass (electric and biomass energy source)
- LCA:E10 with Gasoline
- FU: 1 km driven by car

Effect	E10 (bioethanol from Biomass with enzymatic hydrolysis)	Gasoline (unblended)
Energy	less	more
GHG	Less GHG when process steam derives from biomass (lignin)	More (all processes)
Summer fog, Ozone depleting substances, carcinogenic substance, heavy metals	Less	more
Solid waste, Eutrofication, Acidification, Winter smog	more	less

- Enzymatic production and feedstock cultivation has more environmental effects
- E10 will be more environmental friendly than gasoline if it consume energy from biomass itself (lignin) for processing

Source: Fu et al, 2003

Environmental issues (Case 2)

- Feedstock: Brassica Carinata
- LCA:E10 and E85 with Gasoline
- FU: 1 km driven by car, 1kg of ethanol

Effect	**E10**		**E85**	
FU	**(1km)**	**(1kg)**	**(1km)**	**(1kg)**
GWP, kg CO_2equiv	-31.0	-4.43	-372	-4.84
Acidification, g SO_2 equiv	0.095	13.59	0.202	2.63
Eutrophication, PO_4^{3-} equiv	0.027	3.86	0.069	0.897
Photochemical Oxidants, g C_2H_4 equiv	0.006	0.858	0.097	1.26

- E10- best on environment for driven distance whereas
  E85 – mass of ethanol
- Both contributed to Eutrophication and Photochemical oxidants

Source: Gonzalez-Garcia et al, 2009

Net Energy (Case 3)

- Feedstock: Switchgrass (multifarm trial)
- Renewable Energy- 540% more renewable than it consumed
- GHG – 94 % less than gasoline
- NEY-60GJ.ha^{-1}.yr^{-1} (93% more yield than human-made prairies)
- NEV -21.5 MJ/L
- PER (petroleum energy ratio)-13.1MJ for 1MJ of petroleum

*Compared with gasoline

Source: Schmer, et al.,2008

LCA-Net Energy Analysis

Feedstock	Energy value (MJ/L) EtOH	Reference
Energy value for ethanol	21.2	Prakash etal,1998
NEV (biomass)	17.65-18.93	Alzate & Toro,2006
NEV (corn)	5.57-6.99	Wang et al.,2006
NEV (switchgrass)	21.5	Schmer et al., 2008
NEV (sugarcane)	11.39	Prakash et al.,1998

Reference: Alzate & Toro, 2006

Energy efficiency

Fuel	Energy yield	Energy loss/gain
Gasoline	0.805	(19.5%)
Diesel	0.843	(15.7%)
Biodiesel	3.2	220%
Ethanol (corn)	1.34	34%
Bioethanol (switchgrass)	-	700%

* - Source: http://www.mda.state.mn.us/renewable/renewablefuels/balance.htm#yield accessed:14/08/09, Farrell et al., 2006; Schmer et al., 2008

Economical issues (Case 1)

- 4 feedstock-Aspen wood, hybrid poplar, switch grass, corn stover)
- More cellulose content -> more the ethanol
- More non-cellulose content ->more electricity
- Plant size increases -> electric generation also increases
- Production cost decreases-> from 1T/day to 2 Tonne/day, with plant size (2-4Tonne biomass /day)-decreases slowly

Reference: Huang et al, 2009

Economical issues (Case 2)

- Feedstock: Softwood, Hardwood, Cornstover
- Main process contributors: Pre-treatment, Steam generation, and SSF
- Co-product credit
- Raw material cost
- Enzyme cost
- Increasing DM content, higher WIS conc. In SSF- significant

Source: Sassner et al., 2008

WIS: water insoluble solids, DM-dry mass

Economical issues (Case 3)

- Cost of production is less SSF than SHF(0.57/0.63 USD/L)
- Recirculation of yeast (SSF)
- Value of co-product
- Enzymatic hydrolysis at higher conc. rate
- Recycle process steam
- 60% recycle stillage steam (14 % reduction prod. cost)
- SSF can yield 0.42 USD/L (26% reduction)

Source: Wingren et al, 2003

Discussion

Overall issues in lignocellulosic ethanol

- Enzyme cost -20% contribute to cost of fuel
- Large amount of waste water
- GHG lower
- Acidification, Eutrophication, Photochemical oxidants are higher

Source: Alzate & Toro, 2006

Use of Biomass for Bioethanol: Biomass ~ Grasses –western Canadian prospective

- Environmental effects
- Nutrients compensation
- Economical analysis
- Location specific
- Land type

Use of Biomass…

- The location should be carefully chosen where there is no shortage of water (northern SK, AB)
- Net energy value for specific feedstock should be determined
- Switch grass, alfalfa, and other perennial grasses can grow in marginal or pasture land

Conclusion

- Energy efficient
- Environmental effects

  (lower GHG but increase in acidification and eutrophication)
- Selection of feedstock and location of biorefinery is very important
- Process optimization should be done to make the process more energy efficent and economically viable
- Use of co-products will value-add to the process and can decrease the cost of production of ethanol

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