LIFE CYCLE ASSESSMENT OF AGRICULTURAL RESIDUES UTILIZATION FOR BIOGAS DEPLOYMENT

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Outline

- Introduction
- Aims and Objectives
- Methodology
  - Life Cycle Assessment (LCA)
  - Gabi Software
- Results
- Conclusions
Introduction

- The massive use of fossil fuels on our daily life has led to an increase in the greenhouse gas GHG in the atmosphere and this subsequence affects global warming.
- Production of biogas from agricultural residues, energy craps and municipal waste is becoming increasingly important to reduce the GHG emissions.
First generation

- Corn
- Wheat
- Soybean

Second generation

- Agricultural residues (corn stover, wheat straw)
- Municipal Waste
Does the emission mitigation of biogas production from agricultural residues; digestate (by-product of a biogas production system) when substitutes the conventional mineral fertilizer is considered as a real environmental issue?

For this research, life cycle analysis, using Gabi software 4, is a tool have been used to quantify and evaluate the environmental impact of products through all stages in their life cycle.
Aims and Objectives

- To assess, quantify and model the impact that climate change will have on the production of biogas from agriculture residues.

- To undertake the a holistic life cycle environmental assessment of typical biogas production system from agricultural residues with comprehensive digestate utilization as an alternative to mineral fertilizer.
Methodology

Life Cycle Assessment (LCA): Analyses and comparisons of product, process and services according to the ISO standard covering the whole life cycle from the production of raw materials to end of life.

LCA can be used for:
- Carbon Footprint
- Water Footprint
- Critical Review
- Social LCA
- Life Cycle Costing (LCC)
LCA of a Product

INPUT
- Raw materials and energy
  - Raw material acquisition
  - Manufacturing, processing
  - Distribution, transportation
  - Use/reuse/maintenance
  - Recover, recycle
  - Waste management

OUTPUT
- Usable products
- Environmental impacts:
  - Airborne emissions
  - Water effluents
  - Solid wastes
  - Other environmental releases
LCA methodology: ISO 14044

1. Goal and scope definition
   - Purpose of the study
   - System boundaries
   - Functional unit

2. Inventory analysis
   - System definition
   - Data collection
   - Estimation of environmental burdens

3. Impact assessment
   - Selection of impact categories
   - Estimation of impacts

4. Interpretation
   - Identification of significant issues
   - Evaluation of results
   - Conclusions
Goal: To assess from “cradle-to-grave” the environmental performance of comprehensive production and utilization of biogas and digestate from agricultural residues

The scope of the assessment (Life Cycle Inventory – LCI) include impacts and credits occurring during residue collection, transportation of residue, conversion of residue to biogas in an anaerobic digestion plant, and the use of the biogas and digestate to substitute conventional natural gas and mineral (chemical) fertilizer, respectively.
**System Boundary:**
Covers all the phases from agricultural residue collection from the field to the final utilisation of biogas to produce energy.
Scheme of the system boundary for the collection of agricultural residues for the production of biogas for bioenergy.
The functional unit used for evaluating the environmental performance of the biogas production system is: 1 ton of dry residue input from common agricultural crops including maize, millet, sorghum, rice and wheat.

### Agricultural residues collection, at farm

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baling [work processes]</td>
<td>5.7143</td>
<td>pcs.</td>
</tr>
<tr>
<td>Loading bales [work processes]</td>
<td>5.7143</td>
<td>pcs.</td>
</tr>
<tr>
<td>Transport, lorry 20-28t, fleet average [Street]</td>
<td>0.7716</td>
<td>tkm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residue, at farm [plant production]</td>
<td>1000</td>
<td>kg</td>
</tr>
</tbody>
</table>
## Biogas anaerobic digestion process, at plant

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Amount</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic digestion plant covered, agriculture [fuels]</td>
<td>4.82E-04</td>
<td>pcs.</td>
</tr>
<tr>
<td>Electricity, low voltage, at grid [supply mix]</td>
<td>301.94398</td>
<td>MJ</td>
</tr>
<tr>
<td>Residue, at farm [plant production]</td>
<td>1000</td>
<td>kg</td>
</tr>
<tr>
<td>Transport, lorry 3.5-20t, fleet average [Street]</td>
<td>27.276</td>
<td>tkm</td>
</tr>
<tr>
<td>Treatment, sewage grass refinery, to wastewater treatment, class 3 [wastewater treatment]</td>
<td>6.0949</td>
<td>m³</td>
</tr>
<tr>
<td>Heat, natural gas, at boiler condensing modulating &gt;100kW [heating systems]</td>
<td>393.53</td>
<td>MJ</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas [Biomass fuels]</td>
<td>595.2</td>
<td>kg</td>
</tr>
<tr>
<td>Digested matter from agricultural anaerobic digestion [organic fertiliser]</td>
<td>989.0</td>
<td>kg</td>
</tr>
</tbody>
</table>
**What is Gabi Software?**

is an LCA creation tool, it automatically tracks all material, energy, and emissions flows, giving instant performance accounting in hundreds of environmental impact categories

The biogas production system is modelled using LCI data from the ecoinvent database (Ecoinvent v2.0) (Ecoinvent 2007) in the commercial GaBi 4 LCA software (Eyerer 2006).
Key assumptions

- Baling operation with the bale size of about 1.4 m³, 700 kg on dry basis is assumed.
- A transportation distance of 100 km radius from farm to the processing plant is assumed in the assessment.
- The baled residue is loaded and transported (delivered) from the farm to the anaerobic digestion plant using 20-28 ton heavy-duty diesel vehicles.
- The LCA was done based on the guidelines for LCA according to ISO 14040:2006/14044:2006 (ISO 2006). The system boundary of this LCA is cradle-to-grave (residue collection, transportation, biogas production and distribution, and use).
- The CML method (Guinee et al., 2001) developed by the Centrum for Milieukunde in Leiden, Netherlands (CML) was chosen to assess inventory flows.
Results

The results of the analysis per functional unit (1 ton of agricultural residue processed) for ADP, AP, EP, GWP, ODP, HTP, POCP, FAETP and TETP are depicted in Table 1 (next slide).

- **ADP**: Abiotic Depletion Potential
- **AP**: Acidification Potential
- **EP**: Eutrophication Potential
- **FAETP**: Freshwater Aquatic Ecotoxicity Potential
- **GWP**: Global Warming Potential
- **HTP**: Human Toxicity Potential
- **ODP**: Ozone Layer Depletion Potential
- **POCP**: Photochemical Ozone Creation
- **TETP**: Terrestrial Ecotoxicity Potential
Environmental emissions saving for biogas production and utilization from 1 ton agriculture residues

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Unit</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADP</td>
<td>kg Sb-Equiv.</td>
<td>-44.9338</td>
</tr>
<tr>
<td>AP</td>
<td>kg SO₂-Equiv.</td>
<td>-16.9939</td>
</tr>
<tr>
<td>EP</td>
<td>kg Phosphate-Equiv.</td>
<td>-1.92822</td>
</tr>
<tr>
<td>GWP</td>
<td>kg CO₂-Equiv.</td>
<td>-10329.4</td>
</tr>
<tr>
<td>ODP</td>
<td>kg R11-Equiv.</td>
<td>-0.0007</td>
</tr>
<tr>
<td>HTP</td>
<td>kg DCB-Equiv.</td>
<td>-2695.38</td>
</tr>
<tr>
<td>POCP</td>
<td>kg Ethene-Equiv.</td>
<td>-1.43929</td>
</tr>
<tr>
<td>FAETP</td>
<td>kg DCB-Equiv.</td>
<td>-73.0778</td>
</tr>
<tr>
<td>TETP</td>
<td>kg DCB-Equiv.</td>
<td>-55.5836</td>
</tr>
</tbody>
</table>
The results revealed that there is a huge potential savings could be obtained per ton of dry agricultural residues. The result shows that per ton of dry agricultural residues, GWP yielded the highest reduction (i.e., 10329 kg CO$_2$-Eqiv.), followed by HTP (i.e., 2696 kg DCB-Equiv.).

Similarly, the results showed that agricultural residues based biogas resulted in substantial net reduction ADP, AP, EP FAETP, and TETP i.e., reducing around 44.93 kg Sb-Equiv., 17 kg SO2-Equiv., 1.9 kg Phosphate-Equiv., 73 kg DCB-Equiv., and 55.6 kg DCB-Equiv. per ton of dry agricultural residues, respectively.

If any government was to commit to a policy and incentive (for the domestic production of biogas), that would initiate and facilitate the development of biogas production from agricultural residues, and that would help substantially in climate change mitigation.
Conclusion

An LCA of agriculture residues utilization for biogas production revealed that agricultural residues utilization for biogas production would lead to high environmental benefits in terms of ADP, AP, GWP, EP, HTP, ODP, FAETP, and TETP.
Acknowledgment

- I would like to thank the Department of Engineering and Computing, Coventry University for providing Gabi software for research and education purposes.
- Thanks Dr Nasir Anka Garba and Mr Charles Kingdom for working as a team to achieve this work.
Thank you for listening!

Questions ???
References

- Dübendorf, Swiss Centre for Life Cycle Inventories, Ecoinvent Centre: Ecoinvent database (2007).