Applications of Biogas in Chemical Energy Storage and Liquid Fuel Production

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1. Introduction

Various options for AD feedstock in NI are investigated as well as the possible routes from biogas to energy production. General Energy assessment is performed in each case which will set the basis for the extensive analysis of Liquid Fuel Production in future work.

Before choosing relevant feedstock, a quick environmental overview was conducted for N Ireland. The Green House Gas Emissions for the years 1990-2010 are presented in Table 1. Emissions presented in the year of 2010 show a total of 20,460 ktCO₂eq with 26% contribution from Agriculture, 21% from Transport, 19% from Energy Supply and 19% from Residential Sector.

Table 1: 1990-2010 Northern Ireland GHG Emission Inventory (ktCO₂eq)

<table>
<thead>
<tr>
<th>RC Format</th>
<th>1990</th>
<th>1995</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>5,548</td>
<td>5,548</td>
<td>6,532</td>
<td>7,760</td>
<td>7,760</td>
<td>21.7%</td>
</tr>
<tr>
<td>Fuels</td>
<td>2,734</td>
<td>2,738</td>
<td>2,485</td>
<td>2,205</td>
<td>2,205</td>
<td>6.2%</td>
</tr>
<tr>
<td>Energy Supply</td>
<td>5,315</td>
<td>5,316</td>
<td>6,541</td>
<td>6,341</td>
<td>6,305</td>
<td>19.3%</td>
</tr>
<tr>
<td>Industrial Process</td>
<td>761</td>
<td>711</td>
<td>795</td>
<td>652</td>
<td>419</td>
<td>1.1%</td>
</tr>
<tr>
<td>Land Use Change</td>
<td>56</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>0.1%</td>
</tr>
<tr>
<td>Public</td>
<td>461</td>
<td>461</td>
<td>500</td>
<td>515</td>
<td>515</td>
<td>1.4%</td>
</tr>
<tr>
<td>Residential</td>
<td>4,172</td>
<td>4,361</td>
<td>3,680</td>
<td>3,534</td>
<td>3,480</td>
<td>9.6%</td>
</tr>
<tr>
<td>Transport</td>
<td>3,321</td>
<td>3,321</td>
<td>3,321</td>
<td>3,321</td>
<td>4,241</td>
<td>11.6%</td>
</tr>
<tr>
<td>Waste Management</td>
<td>1,596</td>
<td>1,596</td>
<td>979</td>
<td>740</td>
<td>484</td>
<td>1.3%</td>
</tr>
<tr>
<td>Total</td>
<td>32,734</td>
<td>28,637</td>
<td>24,335</td>
<td>23,080</td>
<td>22,684</td>
<td>64.0%</td>
</tr>
</tbody>
</table>

2. Road-Map

Agricultural Feedstock can be classified into:

- Biochemical Processing
- Thermo-chemical Processing
- Wet Biomass
- Anaerobic Digestion
- Biogas
- Gasification
- Dry biomass
- Pyrolysis
- Syngas
- Liquid Fuel

3. Methodology and Results

Multi-criteria decision-making (MCDM) was used to assess the feedstock available in NI for AD. It is useful for ranking and selecting purposes among a larger number of alternatives when multiple criteria have to be considered simultaneously. An MCDM problem can be expressed in a matrix format with possible alternatives; the decision maker has to choose a criteria on which the assessment will be based. Weights corresponding to each criteria are generated according to a method known as the “Entropy Method”. Then, the ranking is done according to the “TOPSIS Method”.

Table 2: MCDM for feedstock selection in NI

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>CH4 yield (m³ VS)</th>
<th><strong>Availability (t/year)</strong></th>
<th><em>Opportunity cost (€/t)</em></th>
<th>Biogas production (m³/kg VS)</th>
<th>Calorific value (MJ/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>175.5</td>
<td>10,800,000</td>
<td>0</td>
<td>0.4</td>
<td>23.28</td>
</tr>
<tr>
<td>Food waste</td>
<td>415</td>
<td>188,000</td>
<td>45</td>
<td>0.55</td>
<td>25.1</td>
</tr>
<tr>
<td>Grass silage</td>
<td>412</td>
<td>1,901,250</td>
<td>25.87</td>
<td>0.56</td>
<td>20.7</td>
</tr>
<tr>
<td>Sewage</td>
<td>175</td>
<td>39,000</td>
<td>0</td>
<td>1</td>
<td>15</td>
</tr>
</tbody>
</table>

An Aerobic Digestion of single substrates known as mono digestion has some disadvantages that are linked to the substrate properties.

1. Animal manures have high N concentrations that can inhibit methanogens and also have low organic loads.
2. Sewage sludge also characterized with low organic loads.
3. Crops and agro-industrial wastes are seasonal and thus might lack N. These problems can be solved by the addition of a co-substrate.

4. Biogas to Energy Routes

Table 3: Feedstock Ranking based on TOPSIS

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure</td>
<td>1</td>
</tr>
<tr>
<td>Sewage Sludge</td>
<td>2</td>
</tr>
<tr>
<td>Grass Silage</td>
<td>3</td>
</tr>
<tr>
<td>Food Waste</td>
<td>4</td>
</tr>
</tbody>
</table>

5. Biogas to Energy Assessment

Table 4: Feedstock Ranking based on TOPSIS

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy Ratio E</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRI-R</td>
<td>0.82</td>
</tr>
<tr>
<td>SR(ATR)</td>
<td>0.77</td>
</tr>
<tr>
<td>TRI-(ATR)</td>
<td>0.77</td>
</tr>
<tr>
<td>SR</td>
<td>0.90</td>
</tr>
</tbody>
</table>

Table 5: Feedstock Ranking based on TOPSIS

<table>
<thead>
<tr>
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</table>

6. Future Work

The rig is currently under construction. It will be extensively used for Fischer-Tropsch experiments to be carried out on syngas/syngas to test the production of liquid fuel at different operating conditions.