Decarbonisation of whiskey production using circular economy bioenergy systems

Dr Richard O’Shea, Prof Jerry D. Murphy
Bioenergy and Biofuels Research Group,
MaREI,
University College Cork
richard.oshea@ucc.ie, jerry.murphy@ucc.ie
RESEARCH AREAS

- Marine Renewable Energy Technologies
- Observation & Operations
- Bioenergy
- Materials & Structures
- Coastal & Marine Systems
- Energy Policy & Modelling
- Energy Management
Whiskey Production: Process and Energy Use

Cereal → Milling → Brewing/cooking → Fermentation → Distillation → Maturation → Whiskey

Thermal Energy Consumption (kWh/L) | Electrical Energy Consumption (kWh/L)
--- | ---
8.46 (Kang et al., 2020) | 0.37 (Kang et al., 2020)
2.0126 (Leinonen et al., 2018) | 0.273 (Leinonen et al., 2018)
1.673 (AMIENYO, 2012) | 0.273 (AMIENYO, 2012)
2.8-5 (German et al., 2019) | 

Feed Recovery → Animal Feed

Electricity

Pot ale, Thin stillage, Thick stillage

Steam

Gas

Fuel Oil
Whiskey Production: Bioenergy and the Circular Economy

Academic Literature
(Rutherford et al., 2003)
(Eriksson et al., 2016)
(Leinonen et al., 2018)
(Kang et al., 2020)
(O'Shea et al., 2020)

Example Plants
Balmenach, Scotland
Glendullan, Scotland
Bruichladdich, Scotland
Dalluaine, Scotland
Cameronbridge, Scotland
North British Distillery, Scotland
Slane Distillery, Ireland

Cereal

Milling
Brewing/cooking
Fermentation
Distillation
Maturation

Whiskey

Animal Feed

Draff

Feed Recovery

Electricity

Gas

Fuel Oil

Steam

Pot ale, Thin stillage, Thick stillage

Combustion

Anaerobic Digestion

Digestate
A perspective on decarbonizing whiskey using renewable gaseous biofuel in a circular bioeconomy process
(Kang et al., 2020)

**Scenario 1**
Biogas for heat. 46% of thermal demand. 42% CO$_2$ eq reduction.

**Scenario 2**
Hydrothermal pre-treatment. Biogas for heat. 50% of thermal demand. 46% CO$_2$ eq reduction.

**Scenario 3**
Biogas to CHP. 23% thermal demand, 408% electricity demand, export excess to grid. 56% CO$_2$ eq reduction.

**Scenario 4**
Biogas to CHP. 25% thermal demand, 446% electricity demand, export excess to grid. 61% CO$_2$ eq reduction.

---

Fig. 4. Reductions in CO$_2$ emissions for different scenarios. Scenario 1: biogas only used for heat; Scenario 2: improved biogas (incorporating pretreatment of draff) only used for heat; Scenario 3: biogas used for heat and electricity and Scenario 4: improved biogas (incorporating pretreatment of draff) used for heat and electricity.
Using biogas to reduce natural gas consumption and greenhouse gas emissions at a large distillery: Benefits

(O’Shea et al., 2020)

**Scope 1 GHG Emissions (Fuel combustion)**
- 154 GWh/a of biogas
- 61% of current natural gas consumption
- 64% of natural gas consumption without feed recovery
- 27,748 tCO₂eq Scope 1 GHG saving
- 3,973 tCO₂eq Scope 3 GHG saving

**Scope 3 GHG Emissions (Value Chain)**
- 597,545 twwt/a of digestate
- Replace 1,180 tCAN/a and 456 tPhosphorous/a
- 11,389 tCO₂eq/a Scope 3 saving
Using biogas to reduce natural gas consumption and greenhouse gas emissions at a large distillery: Drawbacks

(O’Shea et al., 2020)

**Digestate Logistics**
- Max transport distance 45-50km
- 50% of digestate to land within 25km
- Phosphorous limiting nutrient
- 541,884 m³ centralised storage. 249 trucks/hour (first application), 581 trucks/hour (second application)
- 126 decentralised tanks (500 m³ - 28,000 m³). 82 trucks/day throughout the year

**Animal Feed**
- Distillers grains (USA), 5% Irish imports in 2018: 32,646 tCO₂eq
- Soybean meal (Argentina), 2% Irish imports in 2018: 8,767 tCO₂eq
Using biogas to reduce natural gas consumption and greenhouse gas emissions at a large distillery: Balance? (O’Shea et al., 2020)

<table>
<thead>
<tr>
<th>Process</th>
<th>Scope 1 Emissions (kgCO₂)</th>
<th>Scope 3 Emissions (kgCO₂)</th>
<th>Other Emissions (kgCO₂)</th>
<th>Total Emissions (kgCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digestate to AD</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Draff to AD</td>
<td>-27,748,140.69</td>
<td></td>
<td></td>
<td>-495,288.48</td>
</tr>
<tr>
<td>Thick to AD</td>
<td></td>
<td>-11,388,776.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin to AD</td>
<td></td>
<td></td>
<td>38,641,628.75</td>
<td></td>
</tr>
<tr>
<td>Digestate Spreading</td>
<td></td>
<td></td>
<td></td>
<td>-495,288.48</td>
</tr>
<tr>
<td>Digestate Direct N₂O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestate Indirect N₂O</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided CAN Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided CAN Spreading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided CAN N₂O Direct</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided CAN N₂O Indirect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided Phos Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avoided Phos Spreading</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digestate Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distillers Grain Transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distillers Grain Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soymeal Production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soymeal Transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-495,288.48

Elec Saving (MWh): 8,514
Digestate (t ww): 597,545
Protein Loss (t): 13,554
UFL Loss (x10³): 42,802
Future Work: Achieving Balance?

\[ r(f(x_j); p, w) = \left[ \sum_{i=1}^{n} \left( w_i f(x_j) - w_i f(x_{UTOPIA}) \right)^p \right]^{\frac{1}{p}} \]
Thank you for your time