An argument for using grass biomethane as RES-H & RES-T
Dr Jerry D Murphy, Bioenergy and Biofuels Research Group, ERI, UCC, Cork, Ireland

IEA Task 37
Copenhagen 26 May 2010
Research

Research areas
• Life cycle analysis of bioenergy systems
• Liquid and gaseous biofuels
• Basic research in biogas production

Research Team
• One PI, two Postdoc’s, three PhD’s, 4 Masters students.

Publications since 2004
• 30 peer review journal papers since 2004 (5 under review)
• 22 peer review conference papers
Backlash against biofuels

Biofuels Are Bad for Feeding People and Combating Climate Change
Scientific America, 7th February 2008

Biofuels worse than fossil fuels for environment, say activists
The Irish Independent, 15th April 2009

Ethanol Production Could Be Eco-Disaster, Brazil's Critics Say
National Geographic News, 8th February 2007

When Renewable Energy Is Bad For The Environment
Spiegel, 28th September 2006

Biofuels menace rainforests
The Guardian, 17th August 2007

Biofuels make climate change worse, scientific study concludes
The Independent, 8th February 2008
Rape seed biodiesel


Is it better to import palm oil from Thailand to produce biodiesel in Ireland than to produce biodiesel from indigenous Irish rape seed?

T. Thamsiriroj, J.D. Murphy *

Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
Environmental Research Institute, University College Cork, Cork, Ireland
Rape seed biodiesel

<table>
<thead>
<tr>
<th></th>
<th>Rapeseed biodiesel</th>
<th>Palm oil biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net energy</td>
<td>25.3 GJ/ha/a</td>
<td>74.2 GJ/ha/a</td>
</tr>
<tr>
<td>GHG emiss.</td>
<td>62.2 kg CO₂/GJ</td>
<td>39.2 kg CO₂/GJ</td>
</tr>
<tr>
<td>GHG saving</td>
<td>28.8%</td>
<td>55.1%</td>
</tr>
</tbody>
</table>
Can Rape Seed Biodiesel Meet the European Union Sustainability Criteria for Biofuels?

T. Thamsiriroj*†‡ and J. D. Murphy*†‡

*†Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland, and ‡Environmental Research Institute, University College Cork, Cork, Ireland

Received November 24, 2009. Revised Manuscript Received February 8, 2010
Rape seed biodiesel

Figure 3. Net energy result of different scenarios.
How can we improve the energy balance of ethanol production from wheat?

Jerry D. Murphy a,*, Niamh M. Power b

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b Department of Civil, Structural and Environmental Engineering, Cork Institute of Technology, Cork, Ireland

Received 28 September 2007; received in revised form 14 December 2007; accepted 19 December 2007
Available online 15 January 2008
Ethanol

Thermal parasitic demand is substantial: Cook at 85°C; triple distillation (78°C); Evaporate water off mash to produce dried distillers grains and solubles (DDGS).
Ethanol energy balance

<table>
<thead>
<tr>
<th>Wheat</th>
<th>8.4 t/ha</th>
<th>375 l/t</th>
<th>3150 l/ha</th>
<th>66.5 GJ/ha/a</th>
</tr>
</thead>
</table>

Less energy used in process 41.5 GJ/ha/a.
Less energy in agriculture 21 GJ/ha/a.
Net energy 4 GJ/ha/a
Methods of improving ethanol facility

Net Energy 54GJ/ha/a
Sustainable Biofuels

on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

- Article 17 (2):
  - From Jan 1 2018 the greenhouse gas emissions of new biofuel facilities are reduced by 60% compared to the alternative fossil fuel use;

- Article 17 (3):
  - No damage is done to sensitive or important ecosystems.

- Article 17 (4)
  - May not convert wetland, forestry or grassland to energy crop production

- Article 21 (2)
  - Biofuels from wastes, residues, non-food cellulosic material, and ligno-cellulosic material shall be considered to be twice that made by other biofuels
## Annex 5 of Renewable Directive

<table>
<thead>
<tr>
<th>Biofuel</th>
<th>Typical GHG savings</th>
<th>Default GHG savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat ethanol</td>
<td>32%</td>
<td>16%</td>
</tr>
<tr>
<td>Rape seed biodiesel</td>
<td>45%</td>
<td>38%</td>
</tr>
<tr>
<td>Sugar beet ethanol</td>
<td>61%</td>
<td>52%</td>
</tr>
<tr>
<td>Corn ethanol</td>
<td>56%</td>
<td>49%</td>
</tr>
<tr>
<td>Sugar cane ethanol</td>
<td>71%</td>
<td>71%</td>
</tr>
<tr>
<td>Waste oil biodiesel</td>
<td>88%</td>
<td>83%</td>
</tr>
<tr>
<td>OFMSW biomethane</td>
<td>80%</td>
<td>73%</td>
</tr>
<tr>
<td>Slurry biomethane</td>
<td>84%</td>
<td>81%</td>
</tr>
</tbody>
</table>
GNG Vehicles

- 10 million vehicles worldwide
  - 1.75 million in Argentina
  - 580,000 in Italy
  - 70,000 in Germany

Sweden: biomethane/natural gas mix in vehicle fuel
An argument for using biomethane generated from grass as a biofuel in Ireland

Jerry D. Murphy\textsuperscript{a,b,*}, Niamh M. Power\textsuperscript{c}

\textsuperscript{a}Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\textsuperscript{b}Environmental Research Institute, University College Cork, Cork, Ireland
\textsuperscript{c}Department of Civil, Structural and Environmental Engineering, Cork Institute of Technology, Cork, Ireland
What is the energy balance of grass biomethane in Ireland and other temperate northern European climates?

Beatrice M. Smyth\textsuperscript{a,b}, Jerry D. Murphy\textsuperscript{a,b,*}, Catherine M. O’Brien\textsuperscript{a,b}

\textsuperscript{a} Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\textsuperscript{b} Environmental Research Institute, University College Cork, Cork, Ireland
Review of the Integrated Process for the Production of Grass Biomethane

ABDUL-SATTAR NIZAMI, NICHOLAS E. KORRES, AND JERRY D. MURPHY*

Department of Civil and Environmental Engineering, and Environmental Research Institute, University College Cork, Cork, Ireland

Received May 26, 2009. Revised manuscript received September 22, 2009. Accepted September 30, 2009.
Grass Biomethane Papers

Renewable and Sustainable Energy Reviews

What type of digester configurations should be employed to produce biomethane from grass silage?

Abdul-Sattar Nizami\textsuperscript{a,b}, Jerry D. Murphy\textsuperscript{a,b,*}

\textsuperscript{a}Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\textsuperscript{b}Environmental Research Institute, University College Cork, Ireland
Is grass biomethane a sustainable transport biofuel?

Nicholas E. Korres, Anoop Singh, Abdul-Sattar Nizami and Jerry D. Murphy, University College Cork, Ireland

Received December 15, 2009; revised version received February 8, 2010; accepted February 11, 2010
Published online in Wiley InterScience (www.interscience.wiley.com); DOI: 10.1002/bbb.228; Biofuels, Bioprod, Bioref. 4: xxx-xxx (2010)
Argument for using grass biomethane

**Regulations**
- Cross compliance regulations state that the ratio of permanent grass land to arable land may not change by more than 10% based on 2003.
- EU Renewable Energy Directive states that we may not convert wetland, forestry or grassland to energy crop production for biofuel production.

**Ireland**
- Ireland has 8% of EU cattle herd with less than 1% of EU human population.
- 91% of Irish agricultural land is under grass; 9% arable.
- Arable land fully employed..we import wheat.
- Sustainable indigenous employment in rural areas.

**Grass as a source of bioenergy**
- Grass is a perennial low energy input crop that does not require rotation.
- Digestion is a low energy input process.
Grass to biomethane process

harvest → silage storage → macerator

Service station ← Biomethane upgrading ← anaerobic digester
Relative Energy Balance of Grass Biomethane

Gross and net energy comparison of various crop systems
Land required to power one city bus

### Table 7 - Biofuels, and associated land area required, to substitute for fuel used by a typical Dublin bus (28,000 l of diesel/a, 1008 GJ/a).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Fuel/t</th>
<th>Fuel/ha/a</th>
<th>Gross Energy GJ/ha/a</th>
<th>Land Required ha/a</th>
<th>Rotation</th>
<th>Land to be contracted Ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel (rapeseed)</td>
<td>0.3 t</td>
<td>1.2 t oil</td>
<td>42</td>
<td>24</td>
<td>1 in 5</td>
<td>120</td>
</tr>
<tr>
<td>Ethanol (sugar beet)</td>
<td>100 l/t</td>
<td>5000 l/ha</td>
<td>105</td>
<td>9.6</td>
<td>1 in 3</td>
<td>28.8</td>
</tr>
<tr>
<td>Ethanol (wheat)</td>
<td>375 l/t</td>
<td>3150 l/ha</td>
<td>66</td>
<td>15.3</td>
<td>2 in 3</td>
<td>23</td>
</tr>
<tr>
<td>Biogas (sugar beet)</td>
<td>128 m³/t</td>
<td>6400 m³</td>
<td>134</td>
<td>7.5</td>
<td>1 in 3</td>
<td>22.4</td>
</tr>
<tr>
<td>Biogas (wheat)</td>
<td>420 m³/t</td>
<td>3528 m³</td>
<td>74</td>
<td>13.7</td>
<td>2 in 3</td>
<td>21</td>
</tr>
<tr>
<td>Biogas from silage</td>
<td>123 m³/t</td>
<td>7380 m³</td>
<td>155</td>
<td>6.5</td>
<td>3 in 3</td>
<td>6.5</td>
</tr>
</tbody>
</table>
A biofuel strategy for Ireland with an emphasis on production of biomethane and minimization of land-take

Anoop Singh\textsuperscript{a,b}, Beatrice M. Smyth\textsuperscript{a,b}, Jerry D. Murphy\textsuperscript{a,b,*}

\textsuperscript{a} Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\textsuperscript{b} Biofuels Research Group, Environmental Research Institute, University College Cork, Cork, Ireland

7.5 – 33% substitution of natural gas

Table 9

<table>
<thead>
<tr>
<th>Digester type</th>
<th>Number</th>
<th>Feedstock treated</th>
<th>Total feedstock</th>
<th>Capital Investment (M€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>183</td>
<td>50,000 t/a; 29,000 t/a grass (530 ha); 21,000 t/a slurry</td>
<td>9.15 Mt/a; 5.3 Mt/a grass (97 ha); 3.87 Mt/a slurry</td>
<td>183 × €7 = €1281</td>
</tr>
<tr>
<td>Slaughter</td>
<td>4</td>
<td>52,000 t/a</td>
<td>208,000 t/a</td>
<td>4 × €15 = €60</td>
</tr>
<tr>
<td>Municipal</td>
<td>4</td>
<td>54,500 t/a</td>
<td>218,000 t/a</td>
<td>4 × €20 = €80</td>
</tr>
</tbody>
</table>

\textsuperscript{*} Capital costs from Murphy and Power [41], case study of Linkoping Digester, Murphy and McCarthy [73].
Swedish use of biomethane as a transport fuel

**Biomethane as vehicle fuel in Sweden**
30 June 2007

~ 13,500 gas-powered vehicles (39% increase)

~ 109 fuelling stations for CBG/CNG

~ 14 mNm³ biogas (38% increase)

~ 12.7 mNm³ naturgas (31% increase)

*(1st half year)*
Extensive Gas Grid Infrastructure in Ireland
Renewable Energy Targets

- RES 16% – EU Target
- RES-E 40% – Irish Target (Equates to 7% RES)
- RES-H 12% – Irish Target
- RES-T 10% – EU & Irish Target
Biomethane for RES-H

- RES-H 12%
- How do we convert existing city houses to RES-H???
- How will Government Buildings meet targets???

- Sell blend of natural gas and biomethane
  - Natural gas ca. 6 c/kWh
  - Grass biomethane 11 c/kWh
  - 0.88(6) + 0.12(11) 6.6 c/kWh

- Wood chips (inc annualised capital costs) 8-10 c/kWh
Basic research on grass digestion

Two stage wet continuous system (Continually Stirred Tank Reactors) with recirculation of leachate;

Sequencing fed Leach Bed Reactors coupled with Upflow Anaerobic Sludge Blanket, (SLBR-UASB);
Papers on grass digesters

- T Thamsiriroj, JD Murphy; “The difficulties associated with mono-digestion of grass as exemplified by commissioning a pilot scale digester” submitted to *Energy and Fuels*, March 2010.
  - Functional specific gravity of grass very different to maize: grass wants to float
  - 455 L CH4/kg VS added @ 1 kg VS/m3 reactor/day for 1st cut perennial ryegrass

- Nizami AS, T Thamsiriroj, JD Murphy: “The role of leaching and hydrolysis in a two phase grass digestion system” submitted to *Environmental Science and Technology*, May 2010.
  - 70% destruction of volatile solids in 30 days sprinkling leachate onto bale silage (30% dry solids)
  - 61% destruction of volatile solids in 30 days sprinkling leachate onto pit silage (19% dry solids)
ERI@2GTi: Research informed Green Industry for Ireland

• €8.9 million proposed RD&D facility:
  – Injection to gas grid plus use as vehicular fuel
  – City Centre Site adjacent to P&R plus 300 Local Authority Vehicles
  – €4 million from Bord Gais Eireann
  – Dry and wet digestion facilities @ a scale of ca. 12000 t/a

• Build on existing expertise in Ireland in:
  – IT
  – Biotechnology

• Develop Green Industry in SMART Digesters, employing:
  – Wireless adaptive technology
  – Enzymatic pre-treatments
  – Process Engineering
Biofuels Research Group funded by:

• Environmental Protection Agency (EPA)
• Bord Gais Eireann (BGE)
• Higher Education Authority (HEA)
• Irish Research Council for Science Engineering and Technology (IRCSET)
• Sustainable Energy Authority Ireland (SEAI)
• Department Agriculture Food and Fisheries (DAFF)