Renewable Targets 2020

- **RES** 16% – EU Target
- **RES-E** 40% – Irish Target
  - Equates to 7% RES
- **RES-H** 12% – Irish Target
- **RES-T** 10% – EU & Irish Target
Focus of Research

2004 - 2010:
• 32 peer review journal papers
• 18 peer reviewed conference papers
• 22 invited lectures
• 3 post doctorates
• 5 PhD students
• 14 masters students

Research Output

Source: Energy in Ireland 1990-2000, Energy Policy Statistical Support Unit, the Sustainable Energy Authority of Ireland (SEAI)

An argument for using biomethane generated from grass as a biofuel in Ireland

Jerry D. Murphy$, Niamh M. Power$

\*Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\$Environmental Research Institute, University College Cork, Cork, Ireland
\$Department of Civil, Structural and Environmental Engineering, Cork Institute of Technology, Cork, Ireland
Relative Energy Balance of Grass Biomethane

Gross and net energy comparison of various crop systems
Sustainable Biofuels

DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 23 April 2009
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 biofuels from new 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>

Energy from rubbish
Brecht II, 50,000 t/a of OFMSW to gas
Munich Waste Treatment: Dry batch digesters

Linkoping Sweden
Feed stock for Linkoping

- 7,000t/a of pig slurry
- 47,000t/a of slaughter waste

Biogas treatment

- Collection over digester
- Scrubbing
- Compression and storage
65 buses, 10 waste collection lorries, 600 cars...

And a train
Brook an der Leitha: 60,000 t/a of out of date food with grid injection of biomethane

Biogas from grass as transport fuel in Salzburg

Source: energiewerkstatt, IEA and persona photos
A biofuel strategy for Ireland with an emphasis on production of biomethane and minimization of land-take

Anoop Singh a,b, Beatrice M. Smyth a,b, Jerry D. Murphy a,b,c

a Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
b Biofuels Research Group, Environmental Research Institute, University College Cork, Cork, Ireland
c Biofuels Research Group, Environmental Research Institute, University College Cork, Cork, Ireland

Biomethane: RES-T and RES-H

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Potential 2020 (PJ)</th>
<th>Practical 2020 (PJ)</th>
<th>Factor for RES-T</th>
<th>Contribution to RES-T</th>
<th>% energy in transport 2020 (240 PJ)</th>
<th>% residential gas demand (34 PJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slurry</td>
<td>15.53</td>
<td>1.88</td>
<td>X2</td>
<td>3.76</td>
<td>1.57</td>
<td>5.5</td>
</tr>
<tr>
<td>OFMSW</td>
<td>2.26</td>
<td>0.57</td>
<td>X2</td>
<td>1.14</td>
<td>0.48</td>
<td>1.7</td>
</tr>
<tr>
<td>Slaughter</td>
<td>1.37</td>
<td>0.68</td>
<td>X2</td>
<td>1.36</td>
<td>0.57</td>
<td>2.0</td>
</tr>
<tr>
<td>Grass</td>
<td>47.58</td>
<td>11.93</td>
<td>X2</td>
<td>23.86</td>
<td>9.94</td>
<td>35.1</td>
</tr>
<tr>
<td>Total</td>
<td>66.74</td>
<td>15.03</td>
<td></td>
<td>30.06</td>
<td>12.53</td>
<td>44.3</td>
</tr>
</tbody>
</table>
Number of vehicles running on GNG worldwide

Ratio of GNG stations to CNG Vehicles in Europe

Italy: ratio of CNG cars to CNG service stations ca. 933:1

Germany ca. 100:1
Biomethane Buses

Cost of GNG as a percentage of petrol and diesel
Swedish Example: First CNG then biomethane

Delivered volumes of methane gas for vehicles
(Source: Swedish Gas Association)

Irish Gas Grid

Serves:
153 towns
19 counties
619,000 houses
24,000 industrial and commercial
Biomethane as a transport fuel

<table>
<thead>
<tr>
<th></th>
<th>OFMSW</th>
<th>Slaughter waste</th>
<th>Grass (Farm)</th>
<th>Grass (Developer)</th>
<th>Co-digest Grass &amp; slurry</th>
<th>Slurry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inject to gas grid</td>
<td>0.14</td>
<td>0.73</td>
<td>0.97</td>
<td>1.1</td>
<td>1.23</td>
<td>1.83</td>
</tr>
<tr>
<td>Compression + service station</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
<td>0.11</td>
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<td>0.11</td>
</tr>
<tr>
<td>Compressed biomethane</td>
<td>0.25</td>
<td>0.84</td>
<td>1.08</td>
<td>1.21</td>
<td>1.34</td>
<td>1.94</td>
</tr>
<tr>
<td>Inc. VAT @ 21%</td>
<td>0.30</td>
<td>1.02</td>
<td>1.30</td>
<td>1.46</td>
<td>1.62</td>
<td>2.34</td>
</tr>
</tbody>
</table>

Excise duty is not charged on gas used as a propellant, but VAT at 21% has to be added. Cost €/m$^3$ biomethane = cost per litre diesel equivalent

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Biomethane as a transport fuel

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Unit cost</th>
<th>Energy value</th>
<th>Cost per unit energy (€c MJ$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol</td>
<td>€1.224 L$^{-1}$</td>
<td>30 MJ L$^{-1}$</td>
<td>4.08</td>
</tr>
<tr>
<td>Diesel</td>
<td>€1.150 L$^{-1}$</td>
<td>37.4 MJ L$^{-1}$</td>
<td>3.07</td>
</tr>
<tr>
<td>Comp biomethane (Grass farmer)</td>
<td>€1.30 m$^3$</td>
<td>37 MJ m$^3$</td>
<td>3.50</td>
</tr>
<tr>
<td>CNG – Austria</td>
<td>€0.89 m$^3$</td>
<td>37 MJ m$^3$</td>
<td>2.41</td>
</tr>
<tr>
<td>CNG – UK</td>
<td>€0.71 m$^3$</td>
<td>37 MJ m$^3$</td>
<td>1.92</td>
</tr>
<tr>
<td>CNG – Germany</td>
<td>€0.70 m$^3$</td>
<td>37 MJ m$^3$</td>
<td>1.89</td>
</tr>
<tr>
<td>Bio-CNG (Grass farmer)</td>
<td>€0.76 m$^3$</td>
<td>37 MJ m$^3$</td>
<td>2.05</td>
</tr>
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BioCNG is 10% biomethane and 90% CNG; blend allows compliance with RES-T of 10%
Bus Rapid Transport powered by Biomethane?

Cork Bus (89 buses): 600 ha of grass biomethane

Biomethane as a source of Renewable Heat
## Biomethane: RES-T and RES-H

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### Irish Gas Grid

Serves:
- 153 towns
- 19 counties
- 619,000 houses
- 24,000 industrial and commercial
Basic Research in Reactor Design and Operation

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

Abdul-Sattar Nizami, Jerry D. Murphy

* Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
* Environmental Research Institute, University College Cork, Ireland
Difficulties Associated with Monodigestion of Grass as Exemplified by Commissioning a Pilot-Scale Digester

T. Thamsiriroj\textsuperscript{1,2} and J. D. Murphy\textsuperscript{3,4,5,6}

\textsuperscript{1Department of Civil and Environmental Engineering and \textsuperscript{2}Environmental Research Institute, University College Cork, Cork, Ireland}

Received March 15, 2010. Revised Manuscript Received July 13, 2010

Modelling mono-digestion of grass silage in a 2-stage CSTR anaerobic digester using ADM1

T. Thamsiriroj\textsuperscript{a,b} and J.D. Murphy\textsuperscript{a,b,c}

\textsuperscript{a} Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
\textsuperscript{b} Environmental Research Institute, University College Cork, Cork, Ireland
Gas production from grass

Energy content of grass ~ 19 MJ/kg Volatile Solid (VS)

Energy content of CH\textsubscript{4} ~ 38 MJ/m\textsuperscript{3}

1 kg VS destroyed = 19MJ = 0.5 m\textsuperscript{3} CH\textsubscript{4}

Max production of gas is 500 L CH\textsubscript{4}/kg VS added

Two stage wet continuous digestion

450 L CH\textsubscript{4}/kg VS added
91\% destruction
@ 40 days retention time
@2 kg VS/m\textsuperscript{3}/d
Role of Leaching and Hydrolysis in a Two-Phase Grass Digestion System

A. S. Nizami,*,++, T. Thamsiriroj,*,++, A. Singh,*,++ and J. D. Murphy*,++

*Department of Civil and Environmental Engineering and ++Environmental Research Institute, University College Cork, Cork, Ireland *These authors contributed equally to this work.

Received June 1, 2010. Revised Manuscript Received July 16, 2010

70% destruction of volatiles in sprinkling grass over 30 days

350 L CH4/kg VS added

Would suggest a regime of feeding of subsequent digesters every 5 days; yielding an overall 30 day cycle time

Biofuel and Bioenergy Research Group
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- EPA
- SEAI
- HEA PRTLI
- IRCSET
- DAFF