Biogas Resources, Technologies and Cost

Dr Jerry Murphy, BioEnergy and Biofuels Research, Environmental Research Institute, UCC

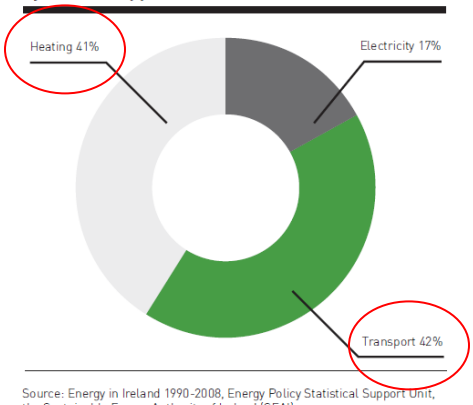
Energy Systems Modelling Addressing Energy Security and Climate Change
15th November 2010, University College Cork

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

Figure 2: Energy use in Ireland by mode of application 2008



Source: Energy in Ireland 1990-2008, Energy Policy Statistical Support Unit, the Sustainable Energy Authority of Ireland (SEAI).

Research Output

2004 -2010:

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

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

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Renewable and Sustainable Energy Reviews 13 (2009) 2349–2360

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Renewable and Sustainable Energy Reviews

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What is the energy balance of grass biomethane in Ireland and other temperate northern European climates?

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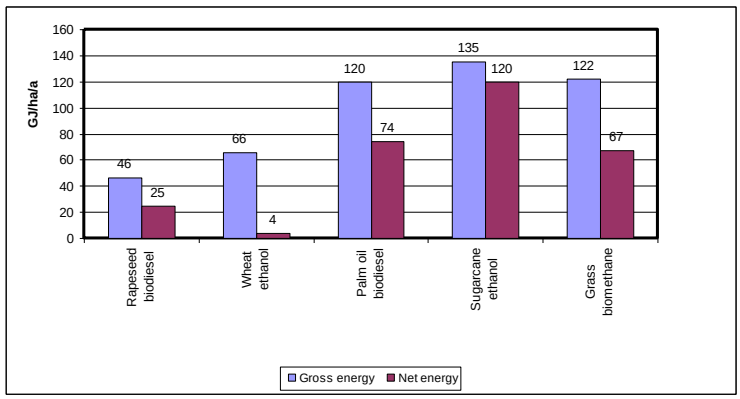
Relative Energy Balance of Grass Biomethane



Gross and net energy comparison of various crop systems

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).

	Crop t/ha[a]	Fuel/t	Fuel/ha/a	Gross[d] Energy GJ/ha/a	Land required ha/a	Rotation	Land to be contracted Ha
Biodiesel (rapeseed)	4	0.3 t	1.2 t oil	42	24	1 in 5	120
Ethanol (sugar beet)	50	100 l/t[b]	5000 l/ha	105	9.6	1 in 3	28.8
Ethanol (wheat)	8.4	375 l/t[b]	3150 l/ha	66	15.3	2 in 3	23
Biogas (sugar beet)	50	128 m^3/t[c]	6400 m^3[c]	134	7.5	1 in 3	22.4
Biogas (wheat)	8.4	420 m^3/t[c]	3528 m^3[c]	74	13.7	2 in 3	21
Biogas from silage	60	123 m^3/t[c]	7380 m^3[c]	155	6.5	3 in 3	6.5

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

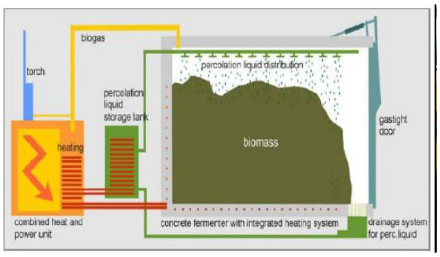
- Article 17 (2):
  - From Jan 1 2018 the greenhouse gas emissions of biofuels from new facilities are reduced by 60% compared to the alternative fossil fuel use;
- Article 17 (3):
  - No damage is done to sensitive or important ecosystems.
- Article 17 (4)
  - May not convert wetland, forestry or grassland 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

Biofuel	Typical GHG savings	Default GHG savings
Wheat ethanol	32%	16%
Rape seed biodiesel	45%	38%
Sugar beet ethanol	61%	52%
Corn ethanol	56%	49%
Sugar cane ethanol	71%	71%
Waste oil biodiesel	88%	83%
OFMSW biomethane	80%	73%
Slurry biomethane	84%	81%

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

Blood and process water pumped in

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

harvest → weigh bridge → silage storage

Biogas service station ← anaerobic digester ← macerator

Source: energiewerkstatt, IEA and persona photos

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A biofuel strategy for Ireland with an emphasis on production of biomethane and minimization of land-take

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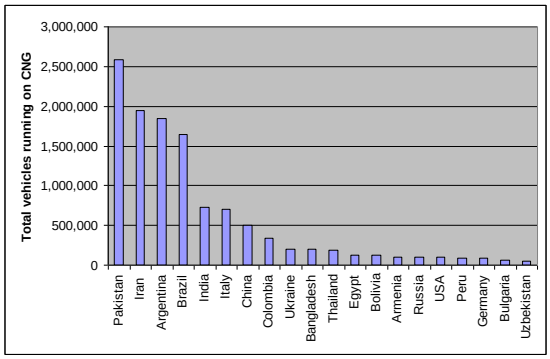
[b] Biofuels Research Group, Environmental Research Institute, University College Cork, Cork, Ireland

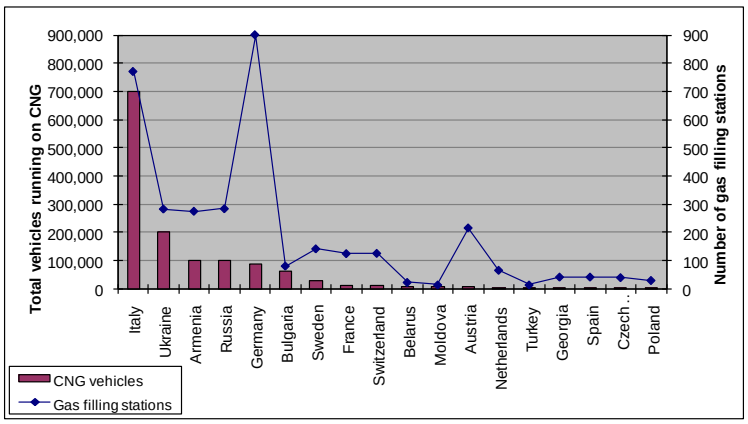
Biomethane: RES-T and RES-H

Feed stock	Potential 2020 (PJ)	Practical 2020 (PJ)	Factor for RES-T	Contribution to RES-T	% energy in transport 2020 (240 PJ)	% residential gas demand (34 PJ)
Slurry	15.53	1.88	X2	3.76	1.57	5.5
OFMSW	2.26	0.57	X2	1.14	0.48	1.7
Slaughter	1.37	0.68	X2	1.36	0.57	2.0
Grass	47.58	11.93	X2	23.86	9.94	35.1
Total	66.74	15.03		30.06	12.53	44.3

Number of vehicles running on GNG worldwide



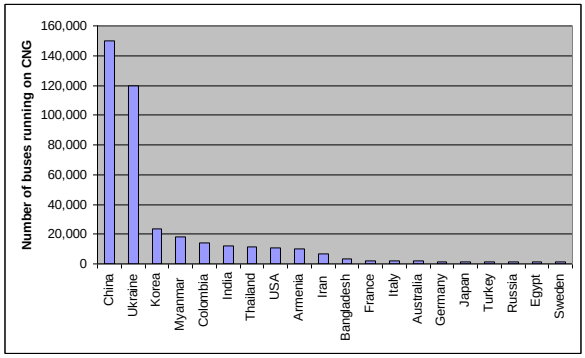
Ratio of GNG stations to CNG Vehicles in Europe



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

Germany ca. 100:1

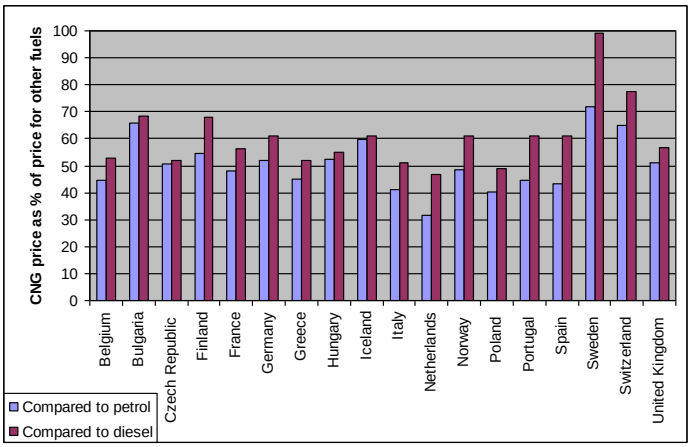
Biomethane Buses



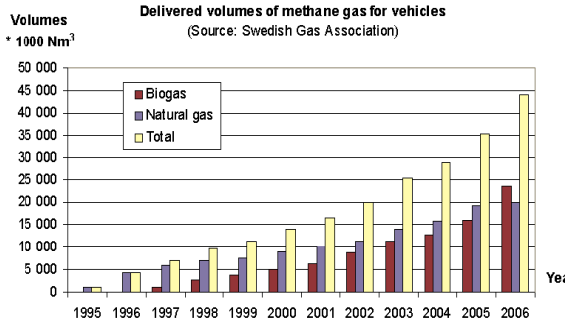
12m bus

18m bus

Cost of GNG as a percentage of petrol and diesel

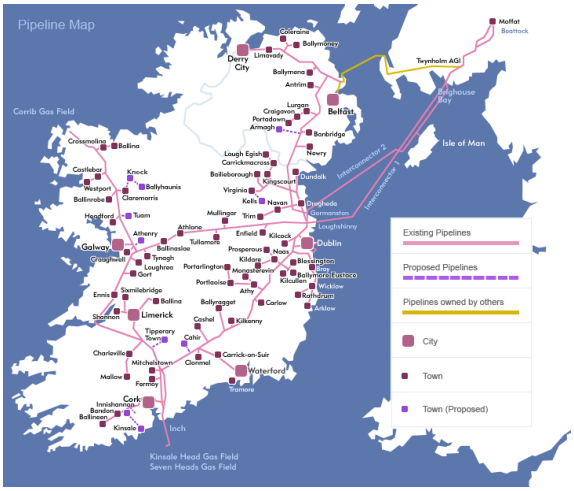


Swedish Example: First CNG then biomethane



Irish Gas Grid

Serves:
153 towns
19 counties
619,000 houses
24,000 industrial and commercial



Biomethane as a transport fuel

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

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

Biomethane as a transport fuel

Fuel	Unit cost	Energy value	**Cost per unit energy (€c MJ^{-1})**
Petrol	€1.224 L^{-1}	30 MJ L^{-1}	**4.08**
Diesel	€1.150 L^{-1}	37.4 MJ L^{-1}	**3.07**
Comp biomethane (Grass farmer)	€1.30 m^{-3}	37 MJ m^{-3}	**3.50**
CNG – Austria	€0.89 m^{-3}	37 MJ m^{-3}	**2.41**
CNG – UK	€0.71 m^{-3}	37 MJ m^{-3}	**1.92**
CNG – Germany	€0.70 m^{-3}	37 MJ m^{-3}	**1.89**
Bio-CNG (Grass farmer)	€0.76 m^{-3}	37 MJ m^{-3}	**2.05**

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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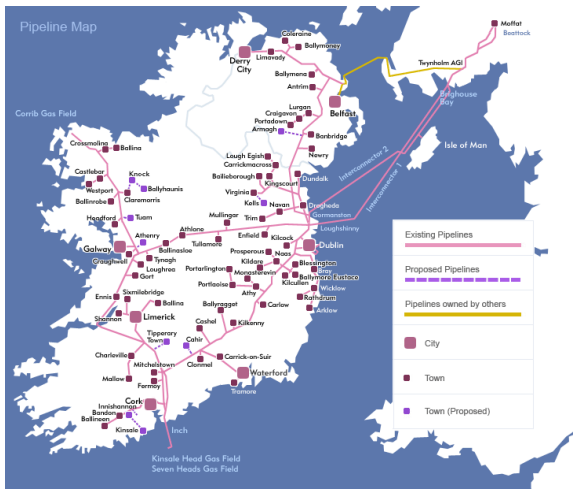

Basic Research in Reactor Design and Operation

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

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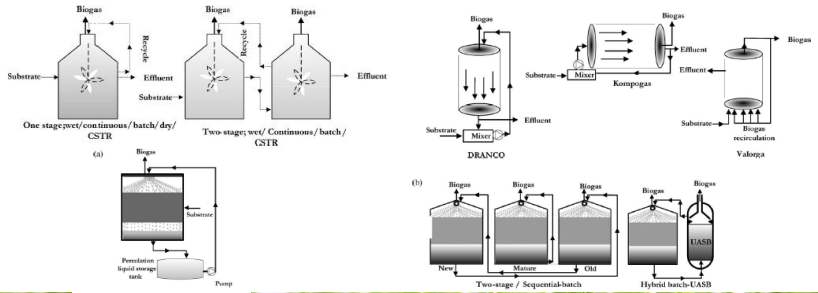

Energy Fuels XXXX, XXX, 000–000 · DOI:10.1021/ef1003039

energy&fuels
article

Difficulties Associated with Monodigestion of Grass as Exemplified by Commissioning a Pilot-Scale Digester

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

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[b] Environmental Research Institute, University College Cork, Cork, Ireland

Gas production from grass

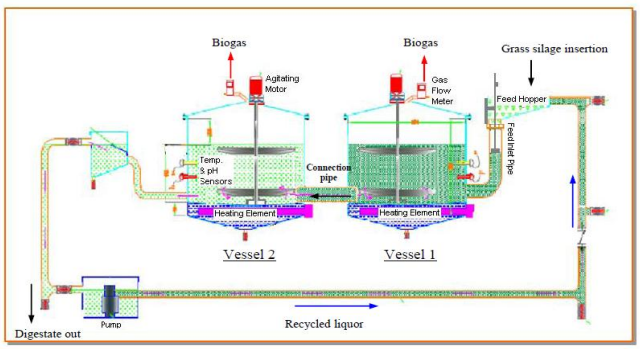
Energy content of grass ~ 19 MJ/kg Volatile Solid (VS)

Energy content of CH_4 ~ 38 MJ/m3

1 kg VS destroyed = 19MJ = 0.5 m^3 CH_4

Max production of gas is 500 L CH_4/kg VS added

Two stage wet continuous digestion



450 L CH4/kg VS added

91% destruction

@ 40 days retention time

@2 kg VS/m3/d

Energy Fuels **XXXX,** *XXX,* 000–000 · DOI:10.1021/ef100677s

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Role of Leaching and Hydrolysis in a Two-Phase Grass Digestion System

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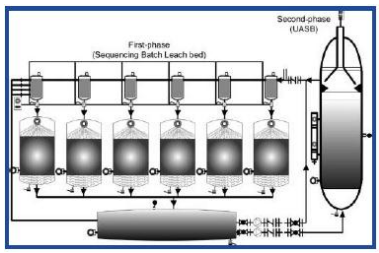

70% destruction of volatiles in sprinkling grass over 30 days

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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- DAFF