Sustainable Energy Research Network

IEA Task 37, Istanbul, turkey, 13 April 2011

epa
Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

ucc
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

ERI
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Biogas Plant Inventory

- Summary of AD Plants:

- - 4 Agriculture facilities
- - 15 Industrial, Sewage sludge, Municipal (biowaste)
- - 7 Landfill Gas projects in Ireland

Farm slurries in Ireland

	Cattle[a]			Pig[a]			Sheep[a]			Poultry[b]			Total		
	2007	2010	2020	2007	2010	2020	2007	2010	2020	2007	2010	2020	2007	2010	2020
Number of heads (M)	6.00	5.89	5.5	1.62	1.6	1.49	3.83	3.45	3.28	12.95	12	12	24.40	22.94	22.27
Slurry quantity (Mt/a)	30.51	29.95	27.97	2.35	2.32	2.16	0.19	0.17	0.16	1.84	1.70	1.70	34.89	34.14	31.99
Biogas[c] (Mm_n^3/a)	671.22	658.90	615.27	51.70	51.02	47.52	10.34	9.15	8.70	81.88	75.81	75.81	815.14	794.88	747.30
CH_4 production[c] (Mm_n^3/a)	369.17	362.39	338.40	28.44	28.06	26.13	5.68	5.03	4.78	45.03	41.70	41.70	448.32	437.19	411.01
Total[d] energy (PJ/a)	13.95	13.69	12.78	1.07	1.06	0.99	0.21	0.19	0.18	1.70	1.58	1.58	16.94	16.52	15.53
Practical energy (PJ/a)	0.14	0.27	0.64	0.01	0.02	0.05	0.002	0.004	0.01	0.00	0.79	1.18	0.15	1.09	1.88

Slaughter waste in Ireland

	Cattle			Pig			Sheep			Poultry			Total		
	2007	2010	2020	2007	2010	2020	2007	2010	2020	2007	2010	2020	2007	2010	2020
Number of heads[a] (M)	1.78	1.67	1.59	2.62	2.60	2.47	3.26	2.74	2.85	12.95	12.00	12.00	20.61	19.01	18.91
Slaughter waste (Mt)	0.37	0.35	0.33	0.07	0.07	0.07	0.02	0.02	0.02	0.007	0.006	0.006	0.47	0.44	0.42
Biogas potential (Mm_n^3)	57.76	54.19	51.59	11.04	10.95	10.40	3.51	2.95	3.07	0.74	0.69	0.69	73.04	68.77	65.75
Methane potential (Mm_n^3)	31.77	29.80	28.38	6.07	6.02	5.72	1.93	1.62	1.69	0.41	0.38	0.38	40.17	37.83	36.16
Total energy potential (PJ)	1.20	1.13	1.07	0.23	0.23	0.22	0.07	0.06	0.06	0.02	0.01	0.01	1.52	1.43	1.37
Practical energy potential (PJ)	0.00	0.00	0.54	0.00	0.00	0.11	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.00	0.68

Farm Biogas Plants

- Three existing farm scale digesters in Ireland all in the South East:
  - Camphill (Mark Dwane)
  - Adamstown (Patrick Berridge)
  - Methanogen (Vicky Heslop)
- These facilities are continuously stirred tank reactors (CSTR) digesting predominately slurry with some food industry.
- Gate fees for off farm in the range €(40 – 120)t/a
- Patrick Berridge has received a grant for a new digester
- David Donnell in Limerick has recently constructed an anaerobic digester

David McDonnell's Farm, Limerick

12,000 t/a feedstock

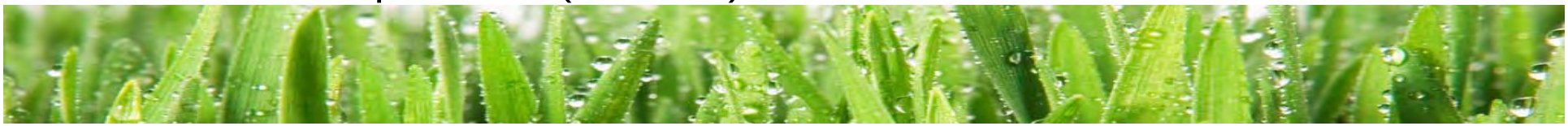
- 5,000 t/a cattle slurry
- 2,000 t/a poultry slurry
- 5,000 t/a off farm (Glycerol, dairy waste)

Off farm screened to 12mm, pasteurised at 70^{o}C

2 Digesters 1000 m^{3} each; HRT 35 days

460,000 m^{3}/a biogas; 110 kWe;
8% parasitic electrical demand
Heat from CHP fully employed in heating digesters & pasteurisation

€1.4 million capital cost (€116/t/a)



Completed tank wall.

Completed tanks and reception building preparation.

David McDonnell, Developing an AD project on your farm Bioenergy News Issue 4, Sustainable Energy Ireland (SEI) Renewable Energy Information Office (REIO)

Ballytobin (Camphill) Digester

7,500 t/a feedstock

- 5,000 t/a slurry
- 2,500 t/a off farm (kitchen and food industry waste)

Off farm screened to 12mm, pasteurised at 70^{o}C

2 Digesters: 150 m^3 horizontal plugflow digester @ 55^{o}C; 450 m^3 CSTR digester @ 37^{o}C

HRT 55 days

219,000 m^3/a biogas; 85kW boiler to heat digester; 85 kW and 200 kW boiler for small district heating system; flare 100 m^3 /day surplus gas in summer (10% of energy in gas is flared)

Proposed farm digesters

Planning for at least two more facilities in Munster at a scale of 15,000 t/a and 30,000 t/a with grass as a significant feedstock

OFMSW biomethane

Details	2006	2010	2020
Population[a] (M)	4.23	4.38	4.74
OFMSW production[b] (Mt)	0.78	0.81	0.87
Biogas yield[c] (Mm_n^3)	97.38	100.84	108.93
Methane yield[c] (Mm_n^3)	53.56	55.46	59.91
Theoretical energy (37.78 MJ/m_n^3) (PJ)	2.02	2.10	2.26
Recoverable quantity to AD (%)	0	0	25
Practical energy (PJ)	0	0	0.57

Proposed MSW Digesters

- Potentially five facilities at planning or construction phase in size range 14,000 to 100,000 t/a.
- MBT model is proposed with 40% to digester and 60% to Refuse Derived Fuel line
- Biogas to CHP
- Electricity exported
- Heat to RDF line
- RDF to cement factory to replace coal

Landfill Gas

Dunsink Landfill, Dublin	5 MWe
Friarstown, Tallaght, Co. Dublin	1 MWe
Ballyogan, Leopardstown, Co.Dublin	2 MWe
Balleally, Lusk, Co.Dublin	5 MWe
Tramore Valley, Cork	2 MWe
Arthurstown, Kill, Co Kildare	4.2 MWe
Kilkullen, Co Kildare	1.2 MWe
Total	18.4 MWe

Maximum electrical potential 30 – 40 MWe

Commercial feasibility requires site of 50 – 100,000 t

From: Aine Car: “Landfill Gas resource 2010/2020 potential and scenario development” Sustainable Energy Authority Ireland (SEAI)

Supports for AD

- OFMSW
  - Landfill levy €20/t in Nov 2009 raising to €75/t in 2012
- Biogas to CHP
  - Was 7.2c/kW_eh in 2007; Raised to 12c/kW_eh in 2008

As of May 2010 tariffs are to be indexed and offered on a 15-year basis and include:

- AD CHP equal to or less than 500 kW: 15 c/kW_eh;
- AD CHP greater than 500 kW: 13 c/kW_eh
- AD (non CHP) equal to or less than 500 kW: 11 c/kW_eh;
- AD (non CHP) greater than 500 kW: 10 c/kW_eh

- Biomass CHP equal to or less than 1,500 kW: 14c/kW_eh;
- Biomass CHP greater than 1,500 kW: 12 c/kW_eh
- Biomass combustion using energy crops: 9.5 c/kW_eh; for all other biomass 8.5 c/kW_eh

Research Activities

- Higher Education Authority (HEA) Program Research Third Level Institutes (PRTLI), Cycle 4 ERI: "**Should we use indigenous biodiesel or grass biomethane as transport fuel in Ireland?"**
- Department of Agriculture Fisheries and Food (DAFF) Stimulus Fund **"GreenGrass": Developing grass for sustainable renewable energy and value added products.**
- Environmental Protection Agency: **"Grass biomethane"**
- Bord Gas Eireann (BGE): **Utilisation of compressed natural gas and biomethane as a transport fuel in Ireland**
- Irish Research Council Science Engineering and Technology (IRCSET) Enterprise Partnership with Bord Gais Eireann: **"Biomethane from residues"**

DAFF “GreenGas”

- Lead by Teagasc Grange
- Partners
  - Queens University Belfast
  - University College Cork

DAFF “BioGrass”

- Lead by UCD
  - This novel project investigates the suitability of Irish grassland, under a range of management intensities, for biofuel production. Factors that will be studied to include grass quality, biogas yield, the full greenhouse gas balance, soil C and N dynamics
  - http://www.ucd.ie/bioenergy/projects.html

- The Competence Centre for BioREFINING AND BIOenergy
  - Hosted by NUI Galway
  - Began 2009

Peer review Journal Papers Biomethane and Policy

Journal of Cleaner Production xxx (2010) 1–15

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Can we meet targets for biofuels and renewable energy in transport given the constraints imposed by policy in agriculture and energy?

B.M. Smyth [a,b], B.P. Ó Gallachóir [a,b,*], N.E. Korres [a,b], J.D. Murphy [a,b]

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Renewable and Sustainable Energy Reviews xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

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,*]

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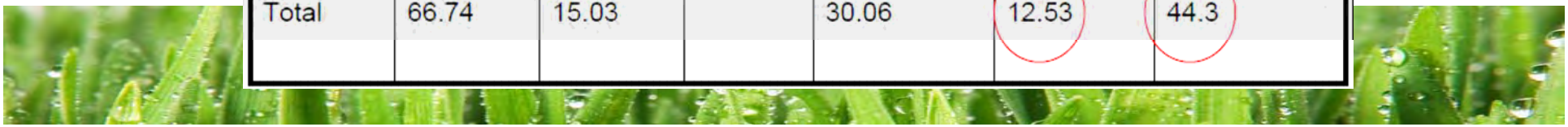
Feed stock	Potential 2020 (PJ)	Practical 2020 (PJ)	Factor for RES-T	Contribution to RES-T	% energy in transport 2020 (240 PJ)	% residential gas demand (34 PJ)
Slurry	15.53	1.88	X2	3.76	1.57	5.5
OFMSW	2.26	0.57	X2	1.14	0.48	1.7
Slaughter	1.37	0.68	X2	1.36	0.57	2.0
Grass	47.58	11.93	X2	23.86	9.94	35.1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



Peer review journal papers
Life Cycle Analysis of Biomethane

BIOMASS AND BIOENERGY 33 (2009) 504–512

Available at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

ELSEVIER

BIOMASS & BIOENERGY

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

Jerry D. Murphy[a,b,*], *Niamh M. Power*[c]

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[b]*Environmental Research Institute, University College Cork, Cork, Ireland*
[c]*Department of Civil, Structural and Environmental Engineering, Cork Institute of Technology, Cork, Ireland*

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

Environ. Sci. Technol. **2009**, *43*, 8496–8508

Review of the Integrated Process for the Production of Grass Biomethane

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

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

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

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

Beatrice M. Smyth [a,b], Jerry D. Murphy [a,b,*], Catherine M. O'Brien [a,b]

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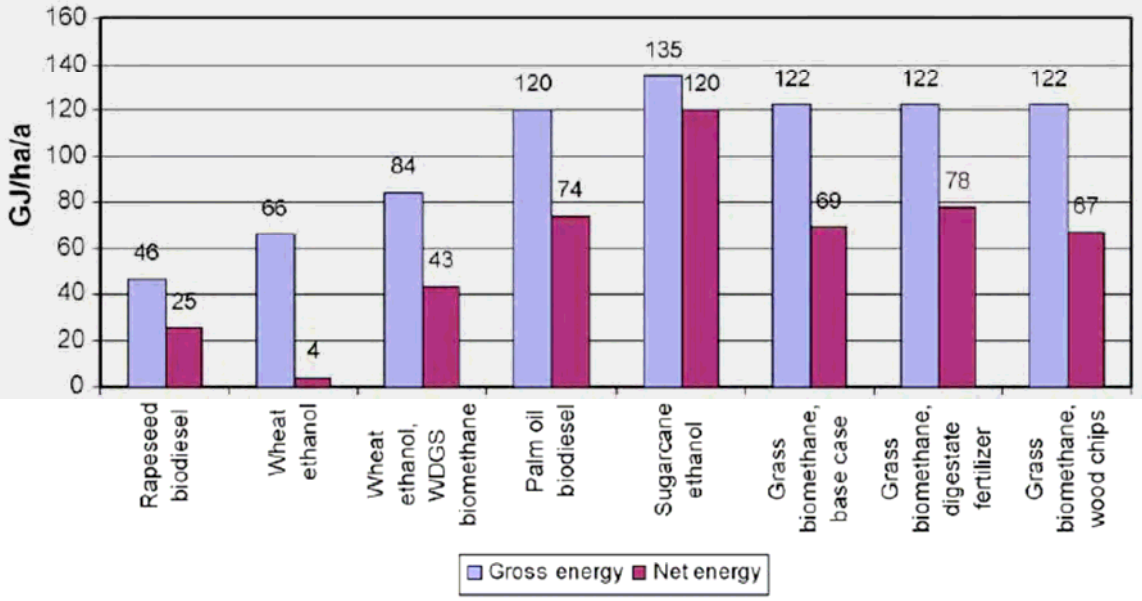


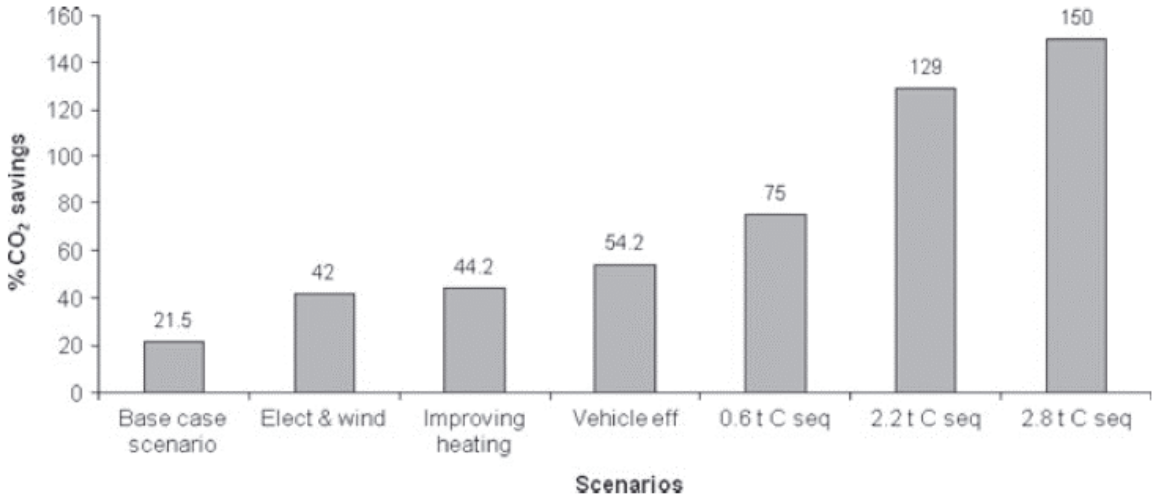
Modeling and Analysis

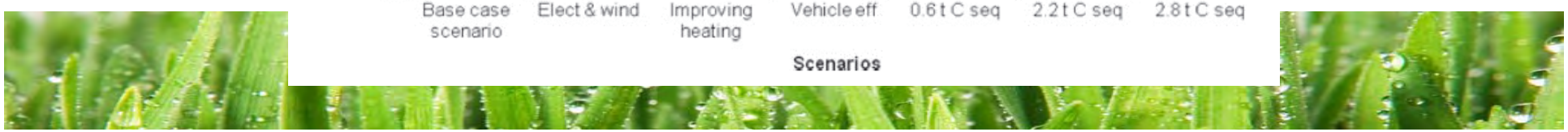
Biofpr
Biofuels Bioproducts & Biorefining

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)





Modeling and Analysis

Biofpr
Biofuels Bioproducts & Biorefining

Can grass biomethane be an economically viable biofuel for the farmer and the consumer?

Beatrice M. Smyth, Environmental Research Institute (ERI), University College Cork (UCC), Ireland
Henry Smyth, Bord Gáis Éireann, Cork, Ireland
Jerry D. Murphy, ERI, UCC, Ireland

Received April 16, 2010; revised version received May 24, 2010; accepted May 28, 2010
Published online in Wiley InterScience (www.interscience.wiley.com); DOI: 10.1002/bbb.238;
Biofuels, Bioprod. Bioref. **(2010)**

Table 8. Comparison of vevhicle fuel costs.

Fuel	Unit cost	Energy value	Cost per unit energy (€c MJ^{-1})
Petrol[a]	€1.224 L^{-1}	30 MJ L^{-1}	4.08
Diesel[a]	€1.150 L^{-1}	37.4 MJ L^{-1}	3.07
Compressed biomethane (high)[b]	€1.63 m^{-3}	37 MJ m^{-3}	4.41
Compressed biomethane (low)[b]	€0.96 m^{-3}	37 MJ m^{-3}	2.59
CNG – Austria[c]	€0.89 m^{-3}	37 MJ m^{-3}	2.41
CNG – UK[c]	€0.71 m^{-3}	37 MJ m^{-3}	1.92
CNG – Germany[c]	€0.70 m^{-3}	37 MJ m^{-3}	1.89
BioCNG (high)[d]	€0.80 m^{-3}	37 MJ m^{-3}	2.17
BioCNG (low)[d]	€0.74 m^{-3}	37 MJ m^{-3}	1.99

[a]Price of petrol and diesel is the price at the pumps.[73]
[b]Price of compressed biomethane is the minimum selling price of grass biomethane. The highest and lowest prices from Table 7 are used.
[c]In the absence of Irish CNG prices, the prices in Austria, Germany and the UK[67] are shown for comparison.
[d]BioCNG price calculated using UK CNG prices and a blend of 10% biomethane, 90% CNG.

Peer review journal papers
Reactor Design and Operation

Renewable and Sustainable Energy Reviews 14 (2010) 1558–1568

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

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

Abdul-Sattar Nizami [a,b], Jerry D. Murphy [a,b,*]

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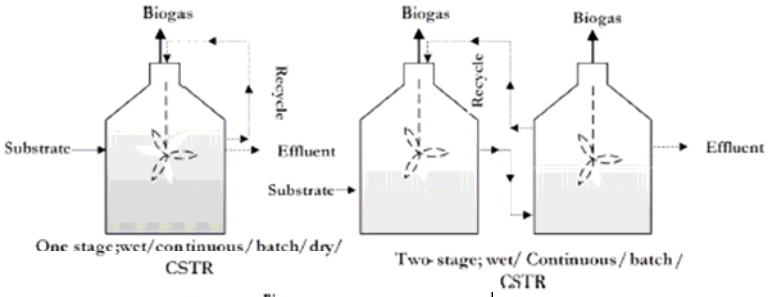
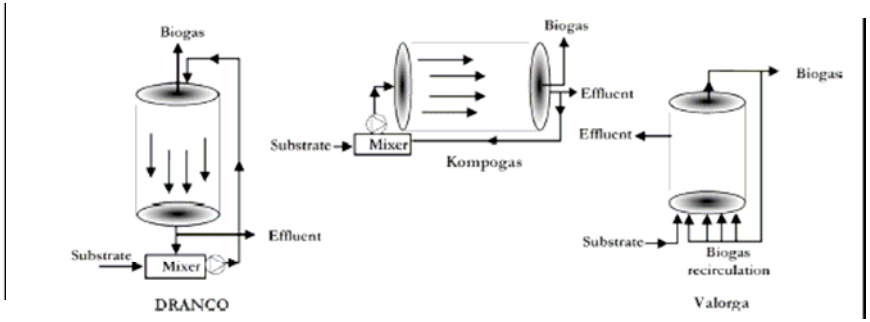
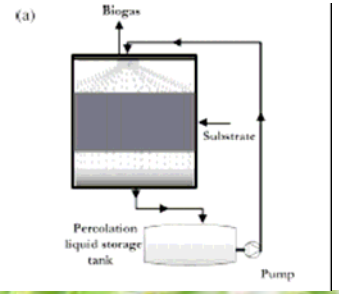
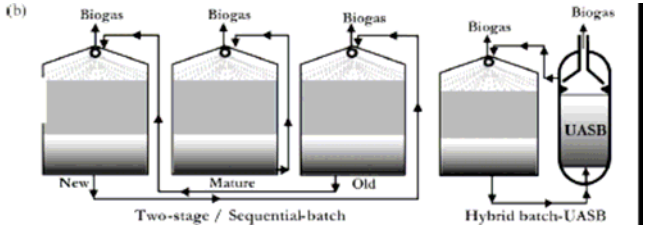
[b] Environmental Research Institute, University College Cork, Ireland









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

T. Thamsiriroj[†,‡] and J. D. Murphy*[,†,‡]

Bioresource Technology xxx (2010) xxx–xxx

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

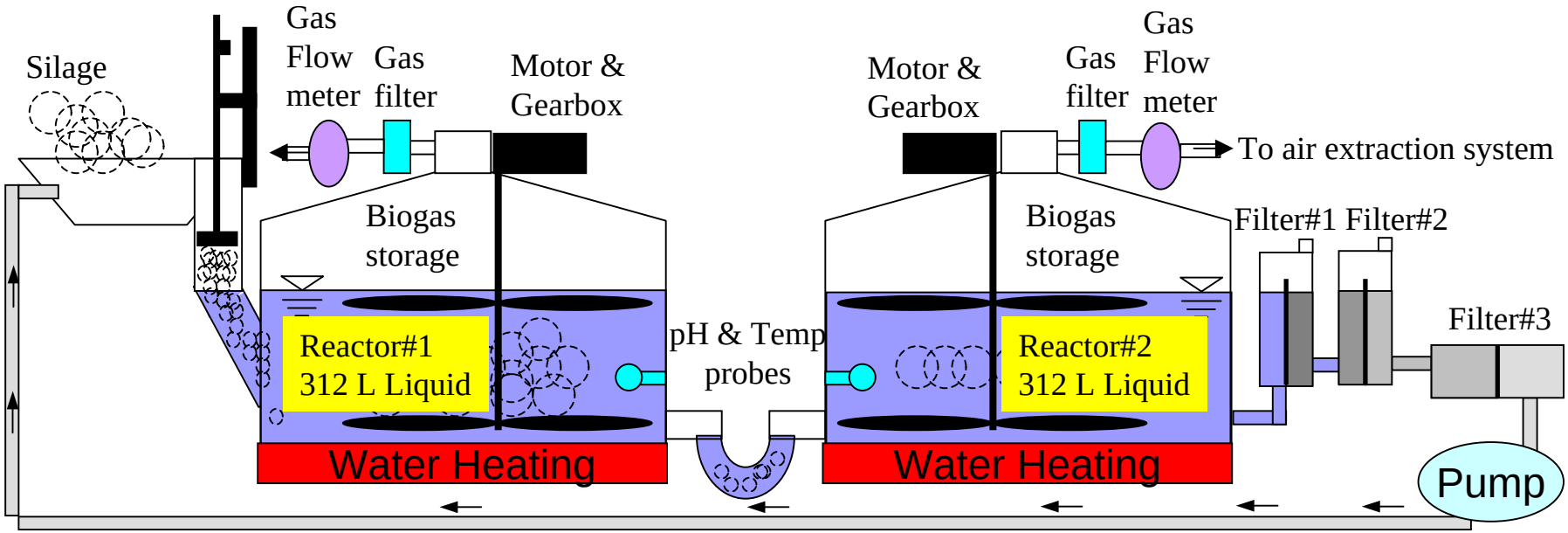
Modelling mono-digestion of grass silage in a 2-stage CSTR anaerobic digester using ADM1

T. Thamsiriroj [a,b], J.D. Murphy [a,b,*]

[a] Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland
[b] Environmental Research Institute, University College Cork, Cork, Ireland

Continuously Stirred Tank Reactor

Continuously Stirred Tank Reactor



451 L CH4/kg VS added; 88% destruction

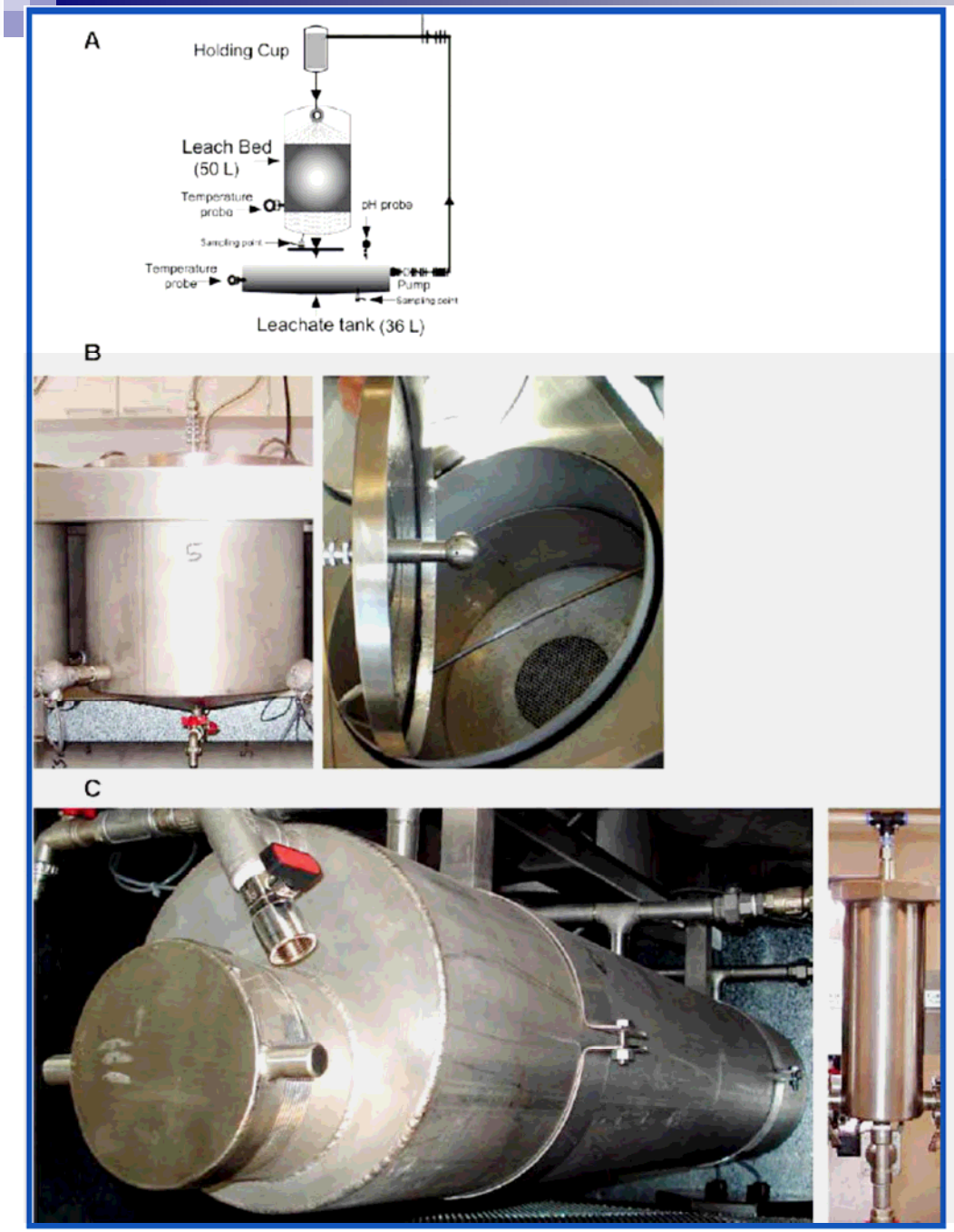
@ 50 days retention time @2 kg VS/m3/d

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

energy&fuels
article

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

A. S. Nizami,[†,‡,§] T. Thamsiriroj,[†,‡,§] A. Singh,[‡,§] and J. D. Murphy*[,‡,§]



70% destruction of volatiles in 30 days when sprinkling 100 L/d over bale silage

Should be equivalent to 350 L CH_4/kg VSadded in 30 days

Energy & Fuels | 3b2 | ver.9 | 10/1/011 | 15:7 | Msc: ef-2010-01739d | TEID: ccd00 | BATID: 00000 | Pages: 11.26

Energy Fuels **XXXX**, *XXX*, 000–000 · DOI:10.1021/ef101739d

energy&fuels
article

Design, Commissioning, and Start-Up of a Sequentially Fed Leach Bed Reactor Complete with an Upflow Anaerobic Sludge Blanket Digesting Grass Silage

Abdul-Sattar Nizami,[†,‡] Anoop Singh,[†,‡] and Jerry D. Murphy*[,†,‡]

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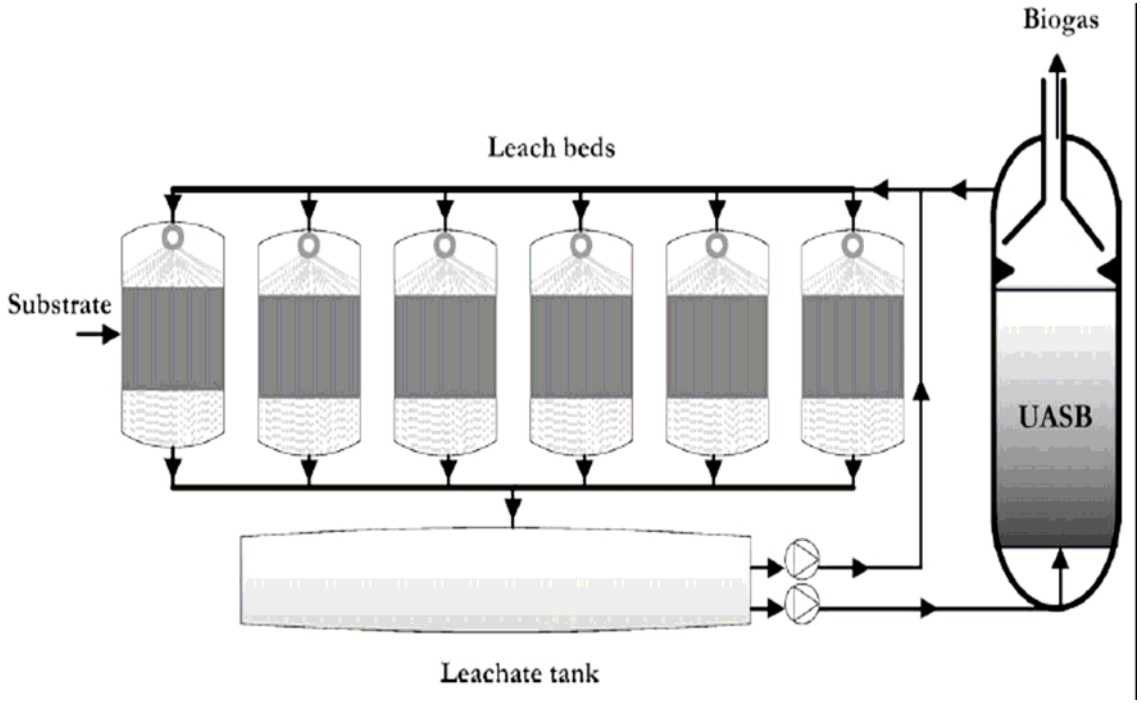
Received December 22, 2010

SLBR-UASB

Sequencing fed Leach Bed Reactors coupled with Upflow Anaerobic Sludge Blanket, (SLBR-UASB)



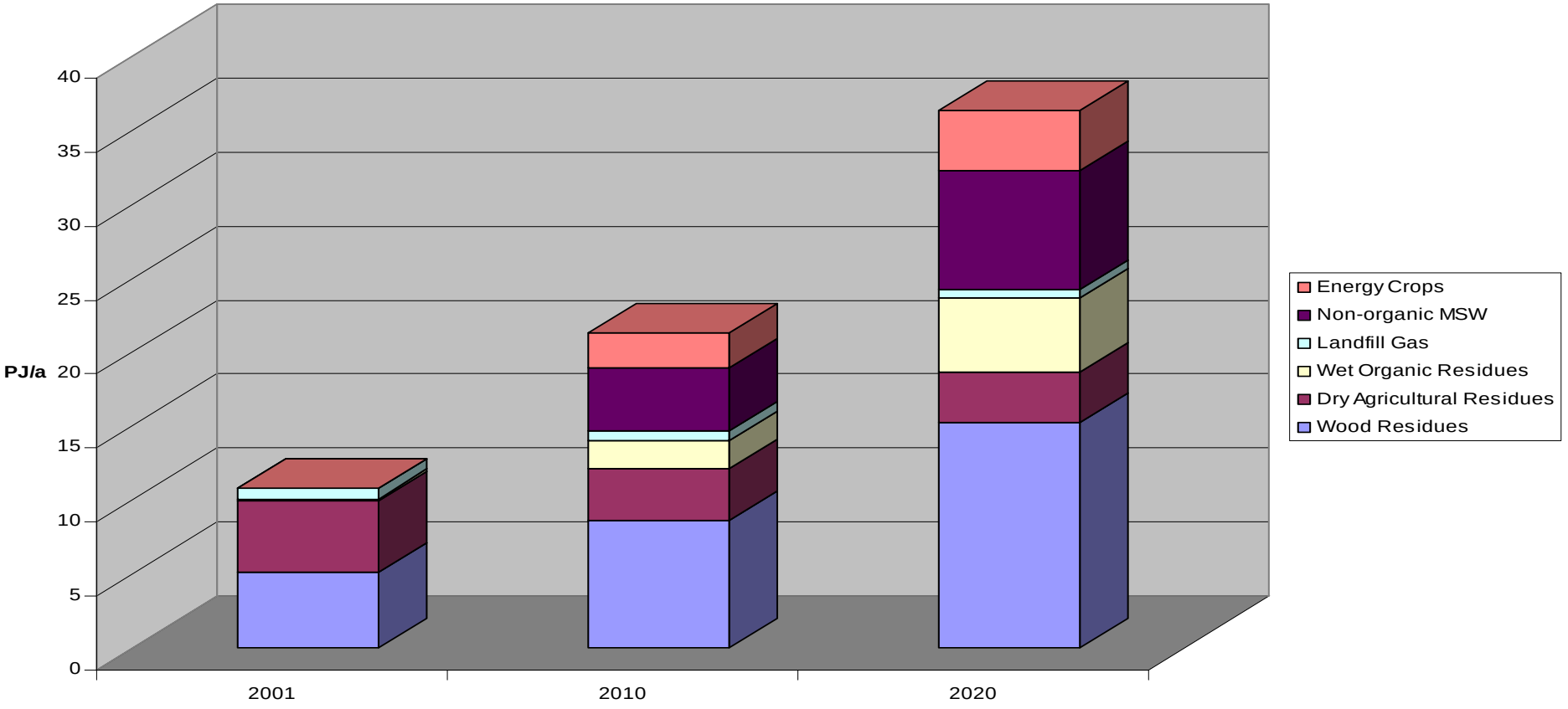
2 pumps; one at 17 L/d for UASB; the second at 600 L/d (100 l/d over each batch): **341 L CH4/kg VS added: 68% destruction @ 30 days retention time**

Methane from bale silage

	SLBR-UASB	**CSTR**	**Micro BMP**	**Small BMP**	**Large BMP**
HRT (Days)	30	50	35	22	26
CH_4 content (% CH_4 in Biogas)	71	52	51	54	70
CH_4 production (L CH_4 kg^{-1} VS added)	341	451	350	355-419	483-493

Impact of Research

SEI Future Practical Resource 2004

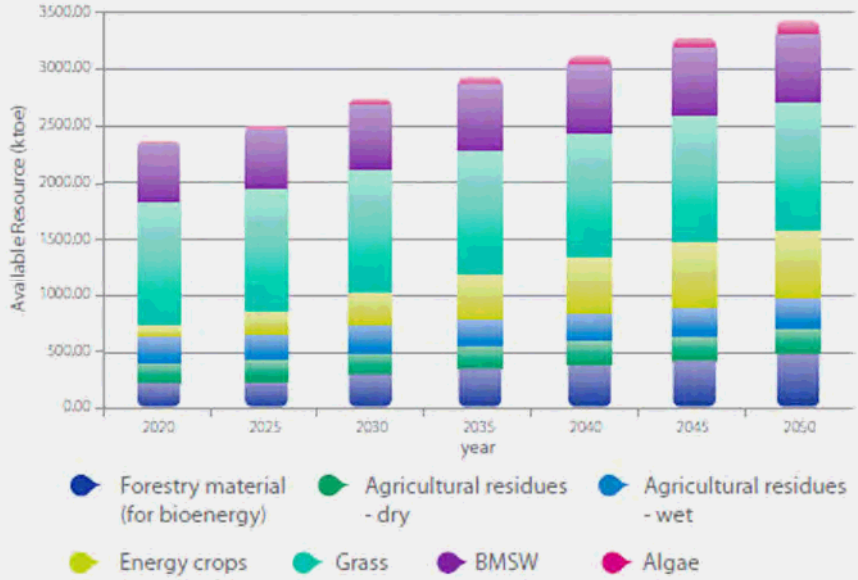


seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

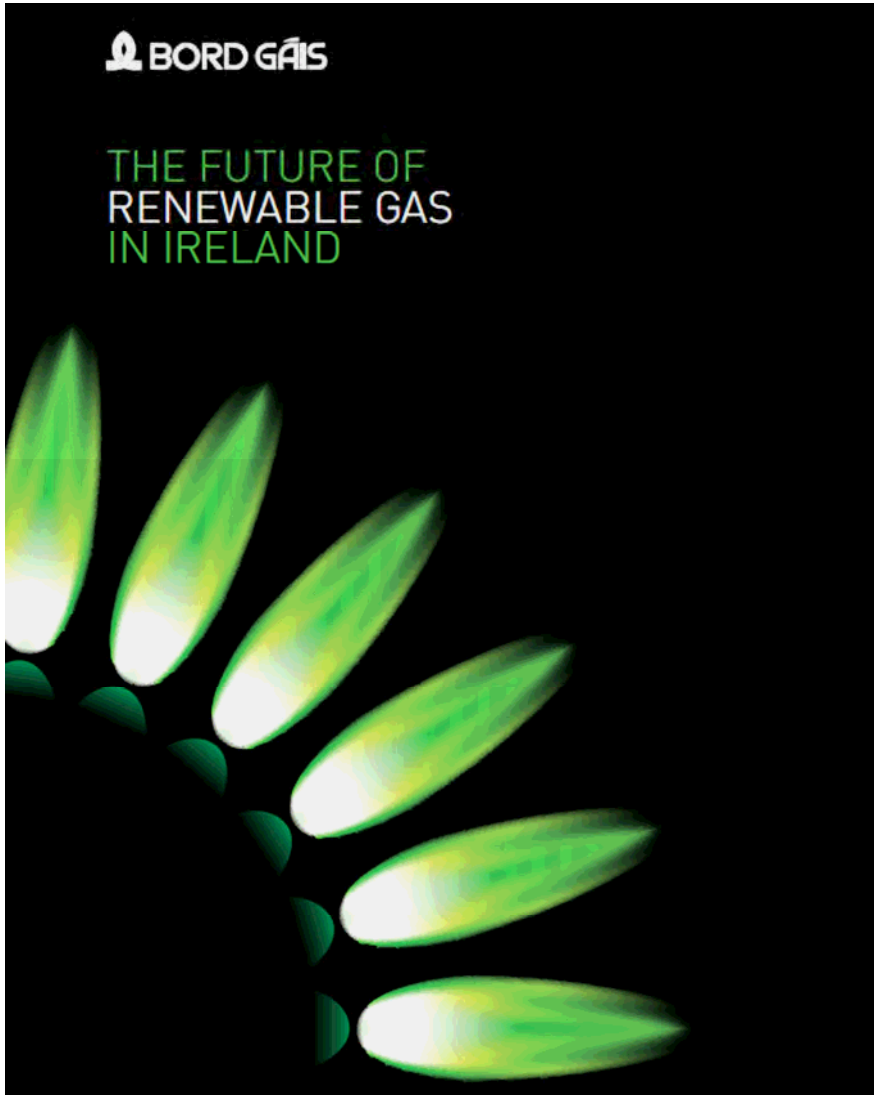
BIOENERGY
Roadmap

Bioenergy to 2050

Total biomass resource for bioenergy to 2050



Key Point: Grass & wastes can be significant energy resources in the coming decades



AN SEACHTÚ TUARASCÁIL DEN COMHCHOISTE UM ATHRÚ AERÁIDE AGUS ÁIRITHIÚ FUINNIMH

TUARASCÁIL MAIDIR LE FUINNEAMH BITHGHÁS IN ÉIRINN

SEVENTH REPORT OF THE JOINT COMMITTEE ON CLIMATE CHANGE AND ENERGY SECURITY

REPORT ON BIOGAS ENERGY IN IRELAND

EANÁIR 2011

JANUARY 2011

Grass and biomethane funded by:

- Bord Gais Eireann
- EPA
- SEAI
- HEA PRTLI
- IRCSET
- DAFF
- SFI