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Sustainable Energy Research Network

Biomethane: an optimal transport fuel and a method of improving first generation biofuel systems

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UCC Biofuels Symposium
16th September, 2008

Ethanol in Northern Europe

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APPLIED ENERGY

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Ethanol production from energy crops and wastes for use as a transport fuel in Ireland

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RENEWABLE ENERGY
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What crop rotation will provide optimal first-generation ethanol production in Ireland, from technical and economic perspectives?

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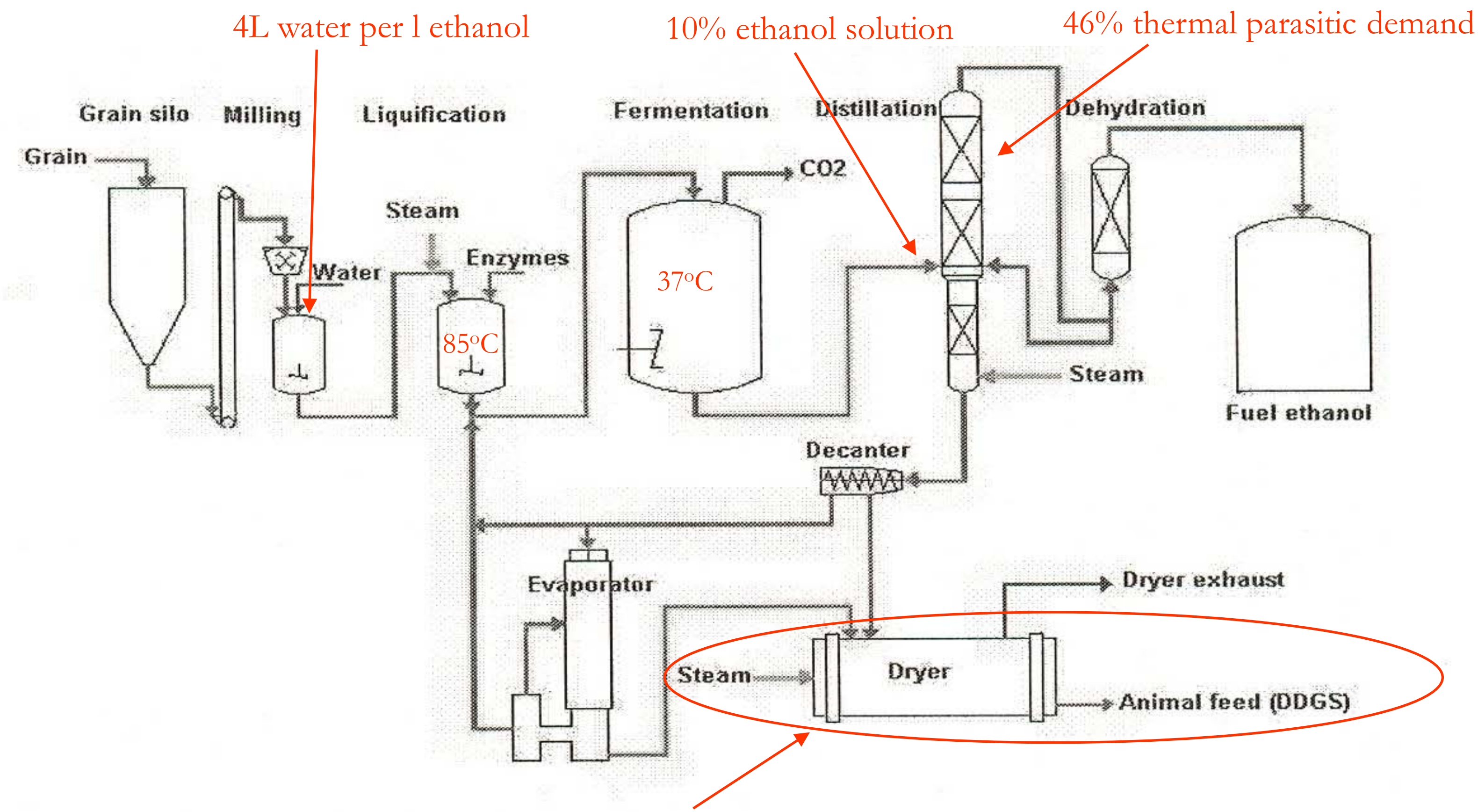
Ethanol from wheat and sugar beet in Ireland

Parameter	Wheat	Sugar beet
Ethanol yield (l/t)	374	100
Crop yield (t/ha/a)	8.4	55
Ethanol yield (l/ha/a)	3,141	5,500
Energy per hectare (GJ/ha/a)	66	116.6
Cost of feedstock €/t	200	50
Cost of feedstock €/l of ethanol	0.53	0.50

Cost of ethanol from wheat @ €200/t

- Production cost €0.34/l
- Feedstock cost €0.53/l
- Total cost €0.87/l
- With excise relief (VAT @ 21%) €1.05/l
- **Cost of petrol displaced**
- **With excise relief €1.50/l petrol equivalent**

Flow chart of ethanol facility based on grain



35% of thermal parasitic demand is used to dry the wet distillers grain and solubles (WDGS) to dry distillers grain and solubles (DDGS).

50 million l/a ethanol production facility based on grain

Gross Energy of Ethanol from Wheat

Wheat	8.4 t/ha	375 l/t	3150 l/ha	**66.5 GJ/ha/a**

Net Energy of Ethanol from Wheat

Gross Energy	66.5GJ/ha/a
Energy used in process	41.5GJ/ha/a.
Energy in agriculture	21 GJ/ha/a.
Net energy	**4GJ/ha/a**

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Fuel 87 (2008) 1799–1806

FUEL

www.fuelfirst.com

How can we improve the energy balance of ethanol production from wheat?

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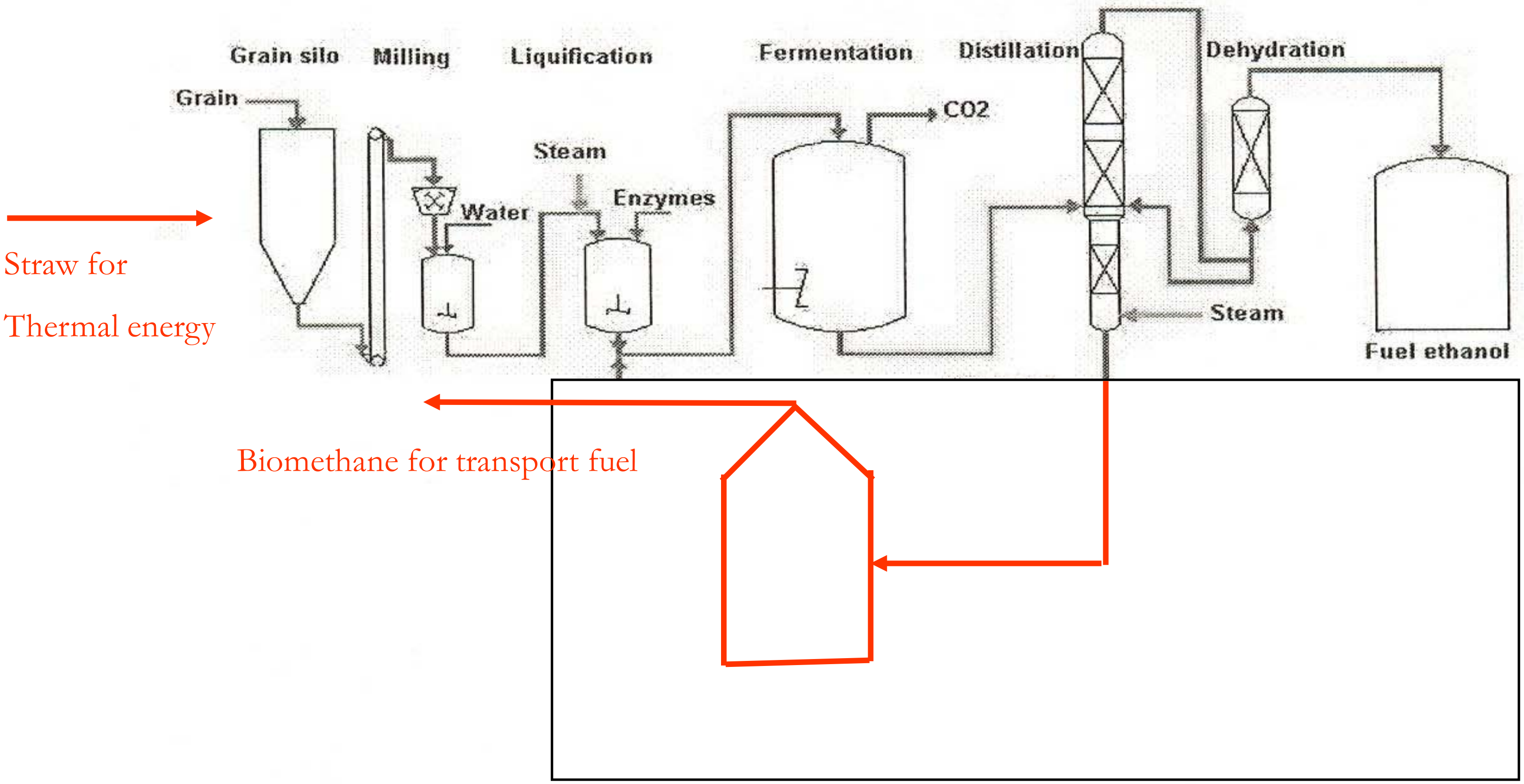
Methods of improving ethanol facility



Improved energy balance of process

Table 8
Improved energy balance from wheat through integration of technologies

Original ethanol from wheat grain system	
Gross energy in ethanol (21.1 MJ/l * 374 l/t * 8.4 t/ha/a)	66.3 GJ/ha/a
Primary parasitic energy demand associated with the ethanol process	41.3 GJ/ha/a
Net energy production in ethanol product	25.0 GJ/ha/a
Energy savings by not drying stillage	13.3 GJ/ha/a
Net energy production in ethanol product without drying stillage	38.3 GJ/ha/a
Energy saved by using 24.3% of straw as a source of thermal energy	20.9 GJ/ha/a
Net energy production with straw combustion and without drying stillage	59.2 GJ/ha/a
Energy in biomethane produced from DGS	
Gross energy in biomethane	17.8 GJ/ha/a
Primary parasitic energy demand associated with the biomethane process	4.7 GJ/ha/a
Net energy production in biomethane product	13.1 GJ/ha/a
Net energy produced in combined ethanol, biomethane product	72.3 GJ/ha/a

Net Energy of Ethanol from Wheat

Gross Energy	66.5GJ/ha/a
Energy used in process	41.5GJ/ha/a.
Energy in agriculture	21 GJ/ha/a.
Net energy	**4GJ/ha/a**

Net Energy of Ethanol from Wheat, Straw, DGS

Gross Energy (ethanol & biomethane)	84.1GJ/ha/a
Energy used in process	20.2GJ/ha/a.
Energy in agriculture	21 GJ/ha/a.
Net energy	**43GJ/ha/a**

Ability to compete with sugarcane ethanol?

	Production rate			
	Crop	Ethanol		Gross (Net) Energy
	t/ha			GJ/ha
Sugar cane	**80**	**80 l/t**	**6400 l/ha/a**	**135 (120)**

Use of bagasse to satisfy parasitic energy demands

Sugarcane ethanol = €0.55/l!!

Biodiesel in Northern Europe

Contents lists available at ScienceDirect

Applied Energy

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

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

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Biodiesel & Rape Seed

Poor Yield; Good Price(?)

High energy input crop, 4 year rotation

Cost of production of biodiesel = €0.87/l

Sale price (excise relief and VAT)= €1.05/l

Biodiesel & Palm Oil

Good yield, energy implications in transport to Northern Europe, ecosystem destruction?

Gross energy comparison of oils for biodiesel

	Rape Seed	**Palm Oil**
Yield of seed, fruits	4.11 t/ha/a	18.35 t/ha/a
Oil available from process	30%	17.7%
Yield of plant oil	1.23 t/ha/a (1355 l/ha/a)	3.25 t/ha/a (3569 l/ha/a)
Yield of biodiesel	1.19 t/ha/a (**1355 l/ha/a**)	3.07 t/ha/a (**3484 l/ha/a**)
Energy value of biodiesel	39 GJ/t	39 GJ/t
Gross energy of biodiesel	**46.5 GJ/ha/a**	**120 GJ/ha/a**

Net energy comparison of oils

(GJ/ha/a)	Rape Seed	Palm Oil
Gross energy of biodiesel	46.50	119.58
Parasitic energy		
Agriculture	14.15	9.12
Oil extraction	2.32	-
Transesterification	0.95	2.51
Methanol	3.49	11.31
NaoH catalyst	0.16	0.43
Transport	0.14	21.98
Total parasitic energy	21.21	45.35
% parasitic demand	46%	38%
Net energy of biodiesel	**25.29**	**74.23**

High energy input crop

Use of residues to satisfy parasitic demand in Thailand

More biodiesel/ha more energy/ha input

Transport distances

Methods of improving rape seed biodiesel facility

- Digestion of glycerol
- Digestion of rape cake
- Again a second biofuel…biomethane
- Funded research in UCC

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the promotion of the use of energy from renewable sources

(presented by the Commission)

{COM(2008) 30 final}
{SEC(2008) 57}
{SEC(2008) 85}

Article 15

- The greenhouse gas emissions of biofuels are reduced by 35% compared to the alternative fossil fuel use;
- No damage is done to sensitive or important ecosystems.

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on the promotion of the use of energy from renewable sources

A. Typical and default values for biofuels if produced with no net carbon emissions from land use change

biofuel production pathway	typical greenhouse gas emission saving	default greenhouse gas emission saving
sugar beet ethanol	48%	35%
wheat ethanol (process fuel not specified)	21%	0%
wheat ethanol (lignite as process fuel in CHP plant)	21%	0%
wheat ethanol (natural gas as process fuel in conventional boiler)	45%	33%
wheat ethanol (natural gas as process fuel in CHP plant)	54%	45%
wheat ethanol (straw as process fuel in CHP plant)	69%	67%
corn (maize) ethanol, Community produced (natural gas as process fuel in CHP plant)	56%	49%
sugar cane ethanol	74%	74%
the part from renewable sources of ETBE (ethyl-tertio-butyl-ether)	Equal to that of the ethanol production pathway used	
the part from renewable sources of TAEE (tertiary-amyl-ethyl-ether)	Equal to that of the ethanol production pathway used	
rape seed biodiesel	44%	36%
sunflower biodiesel	58%	51%
palm oil biodiesel (process not specified)	32%	16%
palm oil biodiesel (process with no methane emissions to air at oil mill)	57%	51%

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on the promotion of the use of energy from renewable sources

biofuel production pathway	typical greenhouse gas emission saving	default greenhouse gas emission saving
waste vegetable or animal oil biodiesel	83%	77%
Hydrotreated vegetable oil from rape seed	49%	45%
Hydrotreated vegetable oil from sunflower	65%	60%
Hydrotreated vegetable oil from palm oil (process not specified)	38%	24%
Hydrotreated vegetable oil from palm oil (process with no methane emissions to air at oil mill)	63%	60%
pure vegetable oil from rape seed	57%	55%
biogas from municipal organic waste as compressed natural gas	81%	75%
biogas from wet manure as compressed natural gas	86%	83%
biogas from dry manure as compressed natural gas	88%	85%

Carbon Neutrality in country of growth?

Greenhouse gas emissions from the production and use of transport fuels, biofuels and other bioliquids shall be calculated as:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{ccs} - e_{ccr} - e_{ee},$$

where

E = total emissions from the use of the fuel;

e_{ec} = emissions from the extraction or cultivation of raw materials;

e_l = annualised emissions from carbon stock changes caused by land use change;

e_p = emissions from processing;

e_{td} = emissions from transport and distribution;

e_u = emissions from the fuel in use;

e_{ccs} = emission savings from carbon capture and sequestration;

e_{ccr} = emission savings from carbon capture and replacement; and

e_{ee} = emission savings from excess electricity from cogeneration.

Summary of previous

- Tropical feed-stocks yield higher yields than Northern European crops
- Energy balance in tropical countries better as they use all of crop and use residues for parasitic demand
- Calculation of ghg reduction will have a big effect on life cycle analysis of imported feed-stocks for biofuel (carbon neutrality stays in tropical country, end of pipe emissions in country of combustion)
- Biogas from residues are one of the best biofuels (compressed biomethane).

Biogas, CH_4-enriched biogas, Biomethane

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APPLIED ENERGY

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Technical/economic/environmental analysis of biogas utilisation

J.D. Murphy[a,*], E. McKeogh[b], G. Kiely[b]

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RENEWABLE ENERGY
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The optimal production of biogas for use as a transport fuel in Ireland

J.D. Murphy*, K. McCarthy

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Taylor & Francis
Taylor & Francis Group

A Technical, Economic and Environmental Comparison of Composting and Anaerobic Digestion of Biodegradable Municipal Waste

Jerry D. Murphy and Niamh M. Power

Academic review

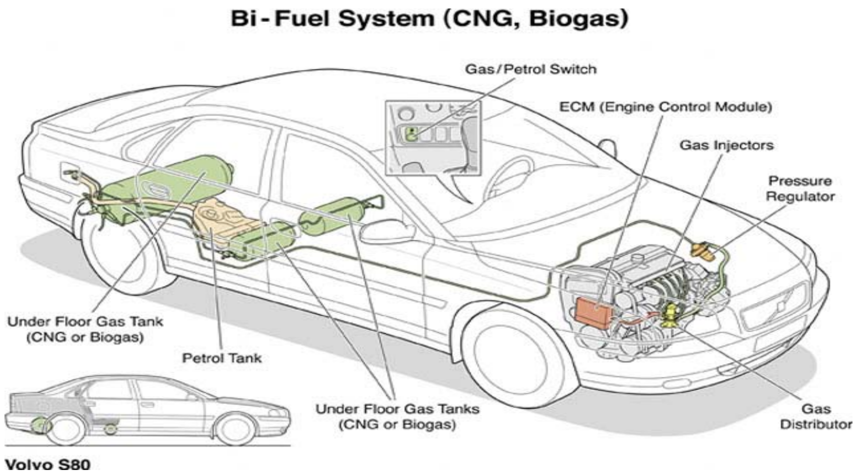
CH_4-enriched biogas utilised as a transport fuel

The case for the utilisation of biogas as a transport fuel

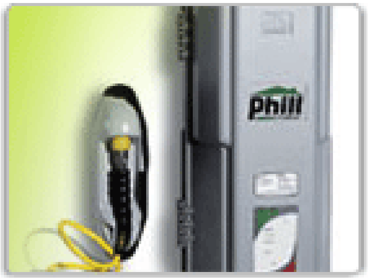
Murphy, J.D., BE MEngSC PhD MIEI CEng

Keywords:
Biogas,
Biofuels,
Gate fee.

CNG and compressed biomethane as a transport fuel



America's Greenest Car Award



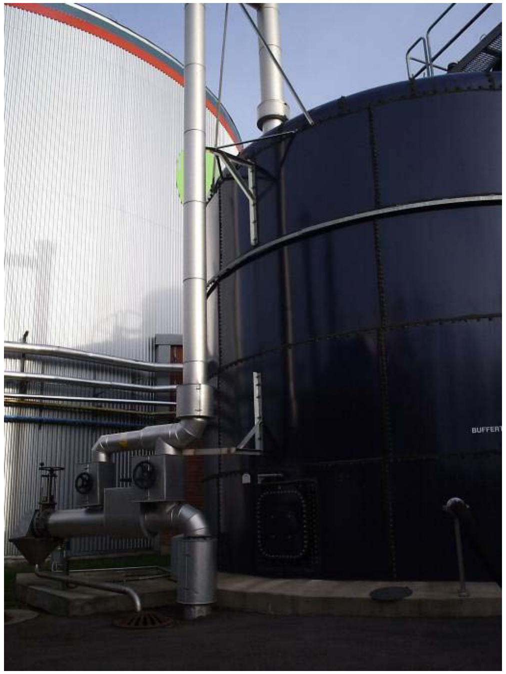
Lille Bus (148 buses)

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

Brecht II, Digestion of 50,000 t/a of OFMSW

High solid organic residues available for digestion in Ireland

Residues	Animals slaughtered	Total weight t/a	CH_4 production m_n^3/t	PJ/a
Pigs	2,872,800	77,544	70	0.205
Cattle	1,864,000	423,128	70	1.119
OFMSW		800,000	70	2.116
Total	4,736,000	1,300,672	70	3.440

1.8% of transport fuel = 9% if bioCNG (20% biomethane, 80% CNG) is used.

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Technical and economic analysis of biogas production in Ireland utilising three different crop rotations

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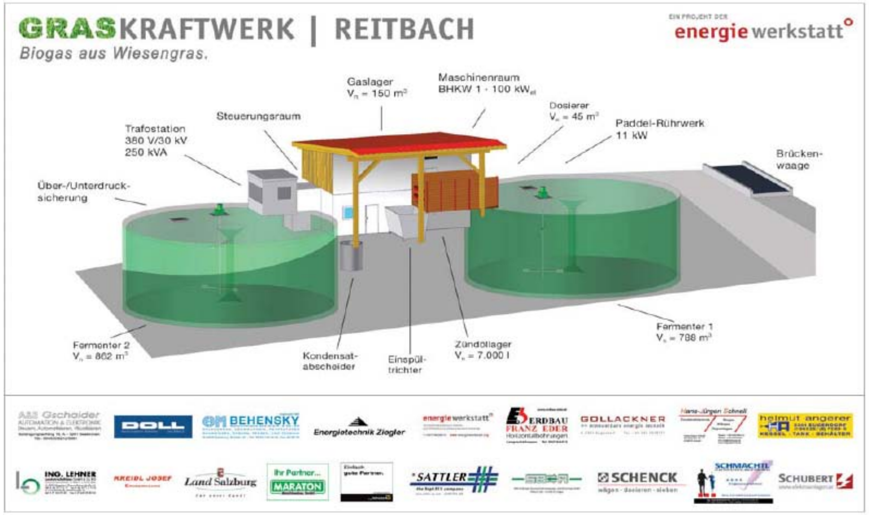
What is the best energy crop in Ireland?

Low energy input crop,
sequesters carbon into soil,
grows every year,
easy technology,
low energy input digestion process

65t grass silage/hectare/annum @ 113m^3/biogas/t @ 55%CH_4
= 4039m^3CH_4/ha/a @ 37.7MJ/mn^3 CH_4
= 153 GJ/ha/a
= 5,100 l of petrol/ha/a
= 4,100 l of diesel/ha/a

Salzburg AG Eugendorf

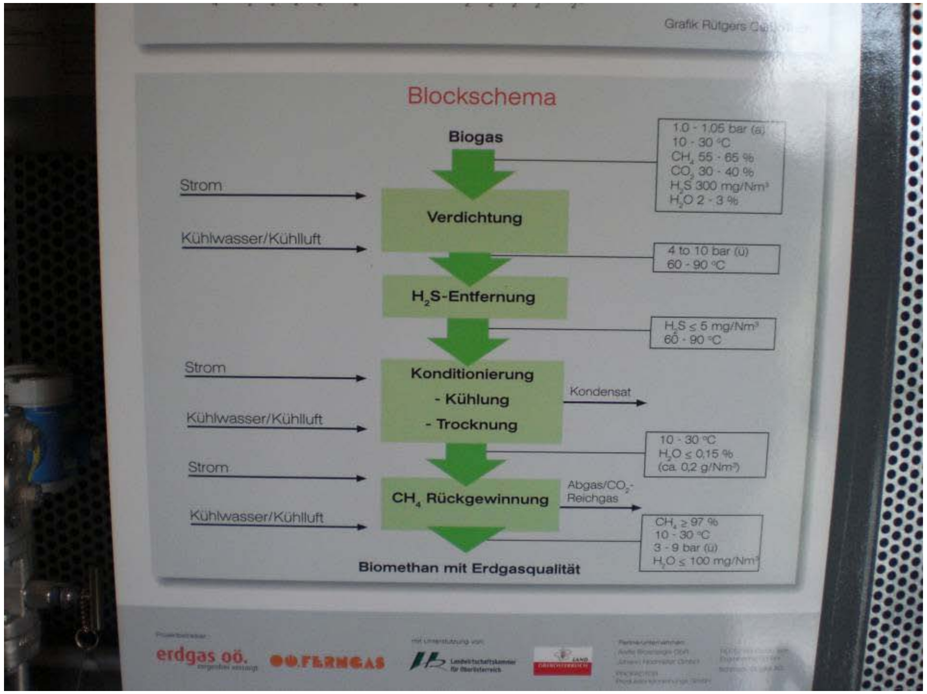


CNG Service Station

- Stand alone system including for compressors, fuel dispenser, credit card system.
- Cost in the region of €350,000 - €450,000
- Obviously need throughput

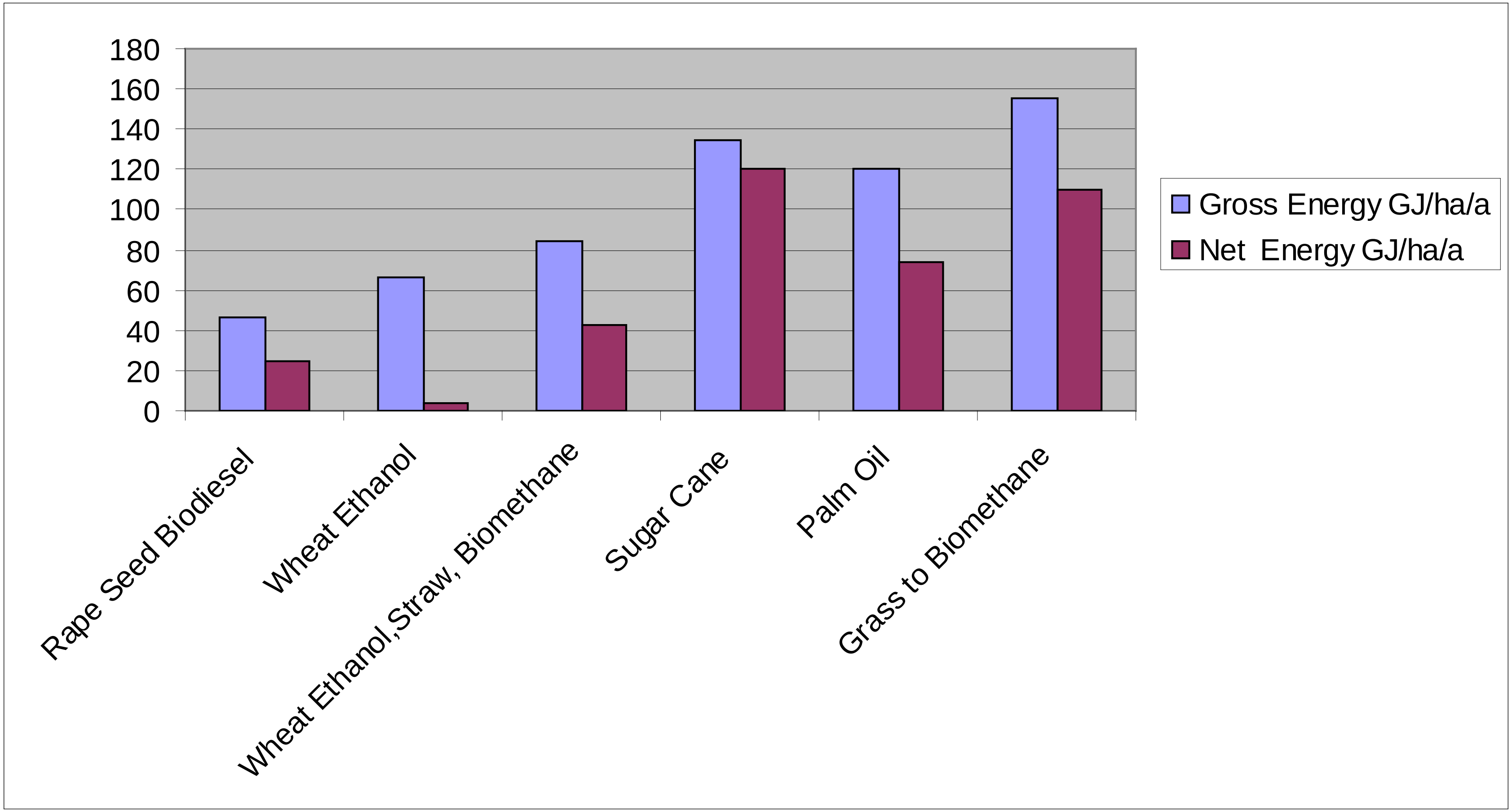
Upgrading of Gas

Gas Specifications

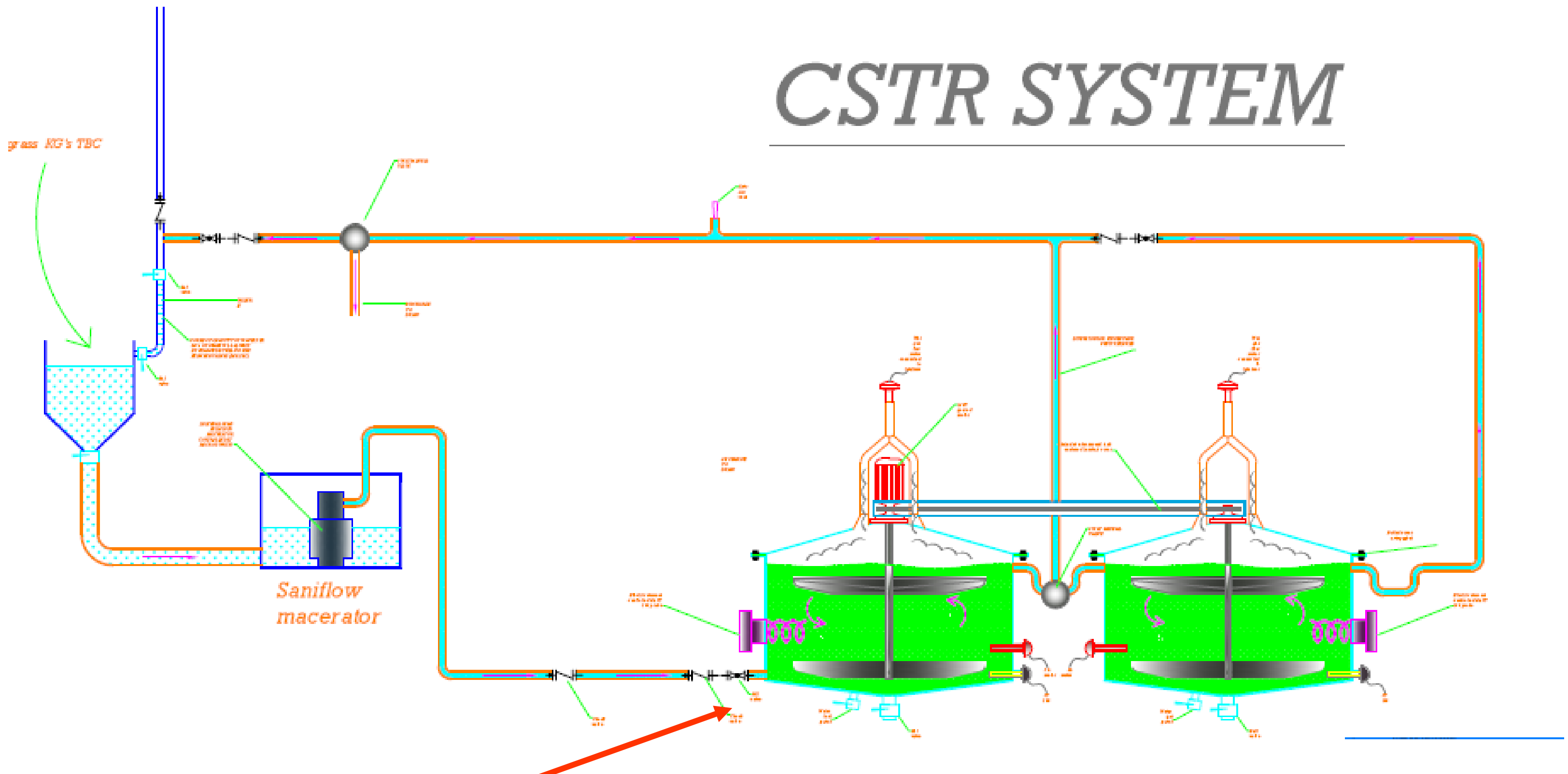


- OVGW G31
  - CH4 > 97%; CO2 <2%; H2S < 5mg/mn3; H2O < 100mg/mn3,
  - density 0.74kg/mn3; energy value > 10kWh/mn3; Wobbe Index 14.75 kWh/m3
- Valve diverts gas from grid if specification not met as measured by Gas chromatograph.

Comparison of biofuel systems

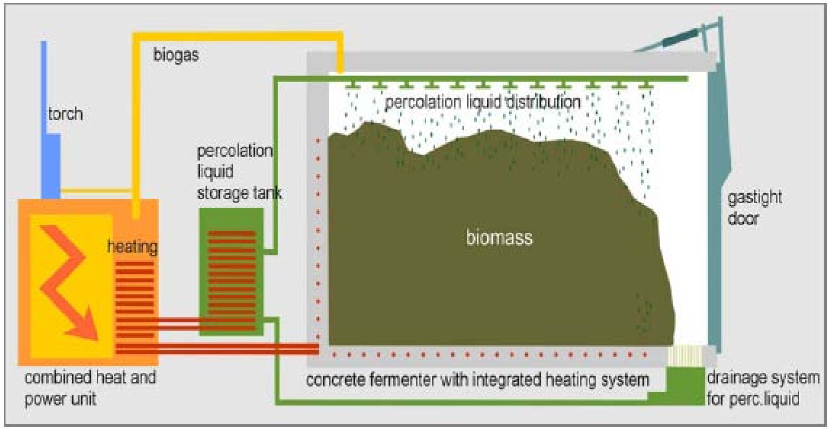


Digesters for digesting grass: CSTR



1 kg VDS/m3 reactor/day

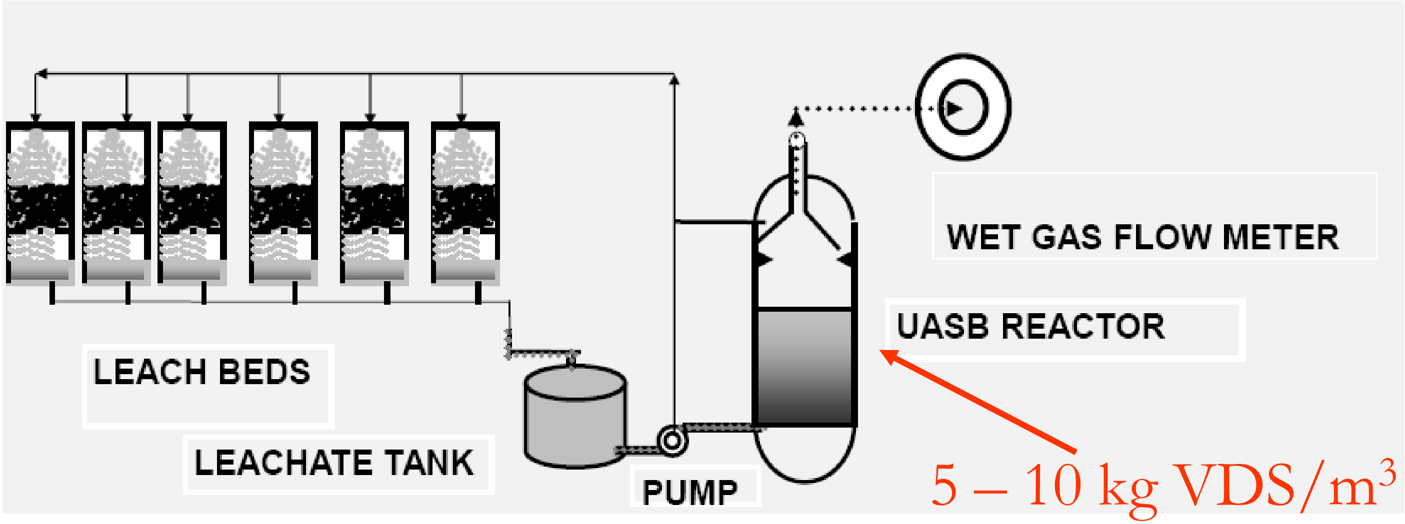
Digesters for digesting grass: Bekon Process



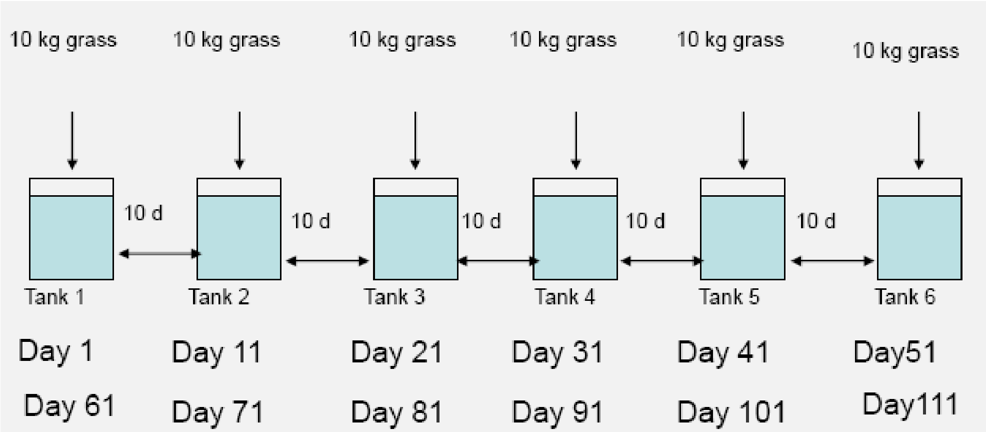
Fill day 1, empty day 60

Biogas production over 60 days, relatively consistent, peaks about day 20

Optimal Digester for Grass?



5 – 10 kg VDS/m^3 reactor/day



Accelerate biogas production using leach beds coupled with UASB

Maximise area under graph,
reduce time to peak, push to left

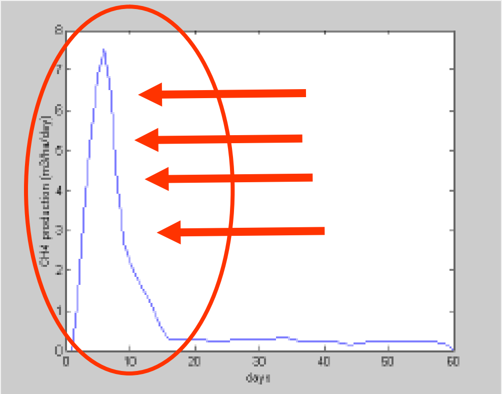


Figure 1: Biogas produced from 1 leach bed and UASB system

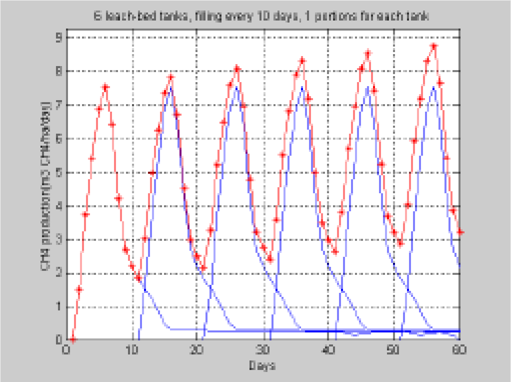


Figure 2: Biogas produced from 6 leach beds and UASB system filling a leach bed every 10 days

Numerous leach beds for consistent gas production

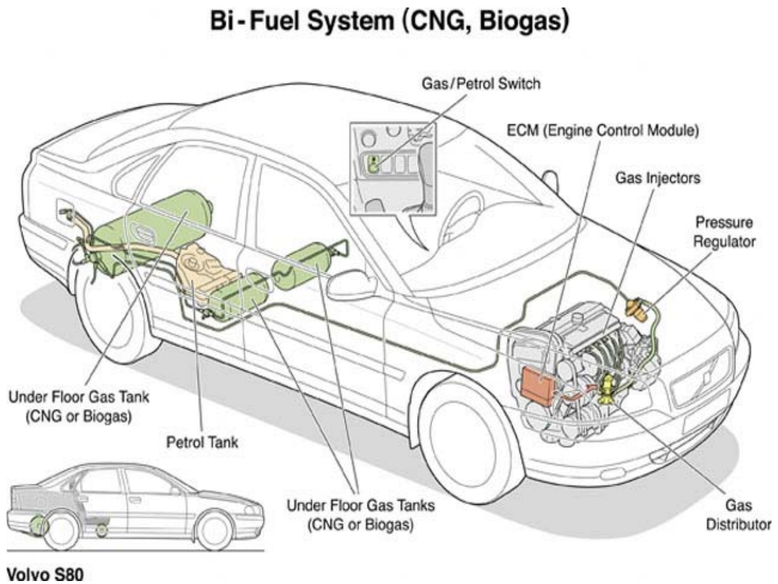
Figure 6: Leach bed system with UASB at pilot scale

Figure 7: UASB reactor with digital display for pH, temperature and gas flow and pump

Figure 8: System for sprinkling water and leachate

Figure 9: Common leachate tank

Irish Gas and Irish Grass for Irish Fuel



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