Anaerobic digestion and biogas

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Composting Conference (Cré),

Heritage Hotel, Portlaoise, 5 May 2005

Outline of paper

- Waste to Energy Research Group CIT
- Biogas production from various wastes/fuels
- Economics of utilisation of biogas for CHP production
- Economics of utilisation of biogas as a transport fuel
- Case studies
- Composting versus digestion of OFMSW
- Application to Ireland

Waste to Energy Research Group: Research focus

- Investigate conversion of biomass to energy
- Produce decision support software, which allows the intelligent user to analyse various waste/biomass to energy systems
- Carry out technical/economic/environmental analysis of these systems
- Propose systems, which are best suited to each waste and biomass under Irish conditions

Waste to Energy Research Group- Publications

- JD Murphy, E McKeogh, G Kiely; "Technical/economic/environmental analysis of biogas utilisation," *Applied Energy*, Volume 77, Issue 4, pp. 407-427, April 2004, also in: *Current Readings in Transport Economics*, Volume 1, No.4, 2004.
- JD Murphy, E McKeogh; "Technical, economic and environmental analysis of energy production from municipal solid waste," *Renewable Energy*, Volume 9 pp. 1043-1057, 2004 also in: *Current Readings in Transport Economics*, Volume 2, No.1, 2004.
- JD Murphy, K McCarthy; "The potential ethanol production from energy crops and wastes for use as a transport fuel in Ireland," *Applied Energy*, in press.
- JD Murphy, E McKeogh; "The benefits of integrated treatment of wastes for the production of energy," *Energy*, in press.

Waste to Energy Research Group- Publications

JD Murphy, K McCarthy; “The optimal production of biogas for use as a transport fuel in Ireland,” *Renewable Energy*, in press.

JD Murphy, N Power; “The optimal method of energy production from newspaper in Ireland,” *Waste Management*, under review, submitted January 2005.

JD Murphy, N Power; “The optimal treatment of biodegradable municipal waste,” *Journal of Environmental Science and Health*, under review, submitted March 2005.

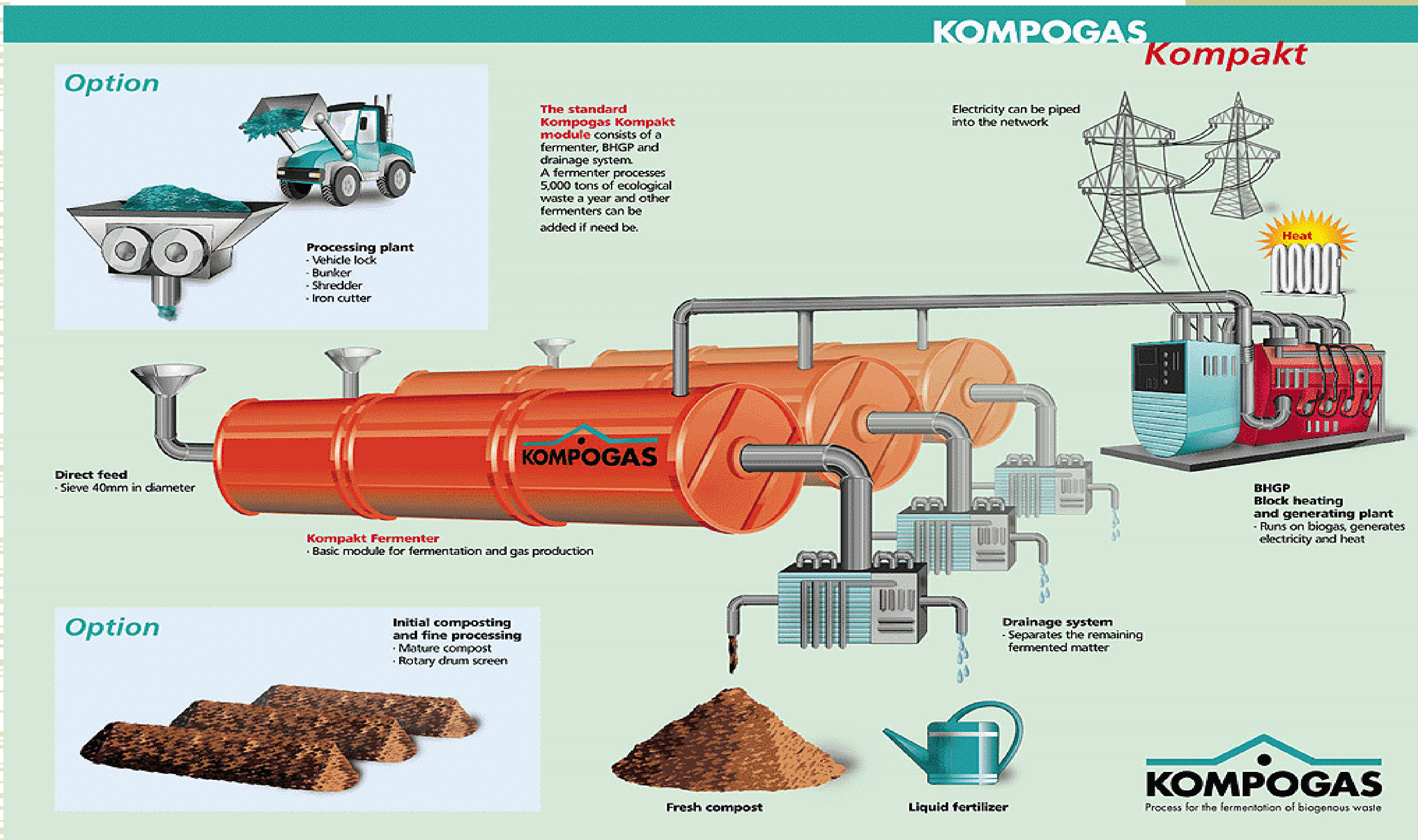
What is biogas?

- Typically 55% methane (CH_4)
- 45% carbon dioxide (CO_2)
- H_2S and H_2O and trace gases
- Energy comes from methane only
- Energy value of methane 37.78MJ/Nm^3
- Energy value of biogas 21MJ/Nm^3

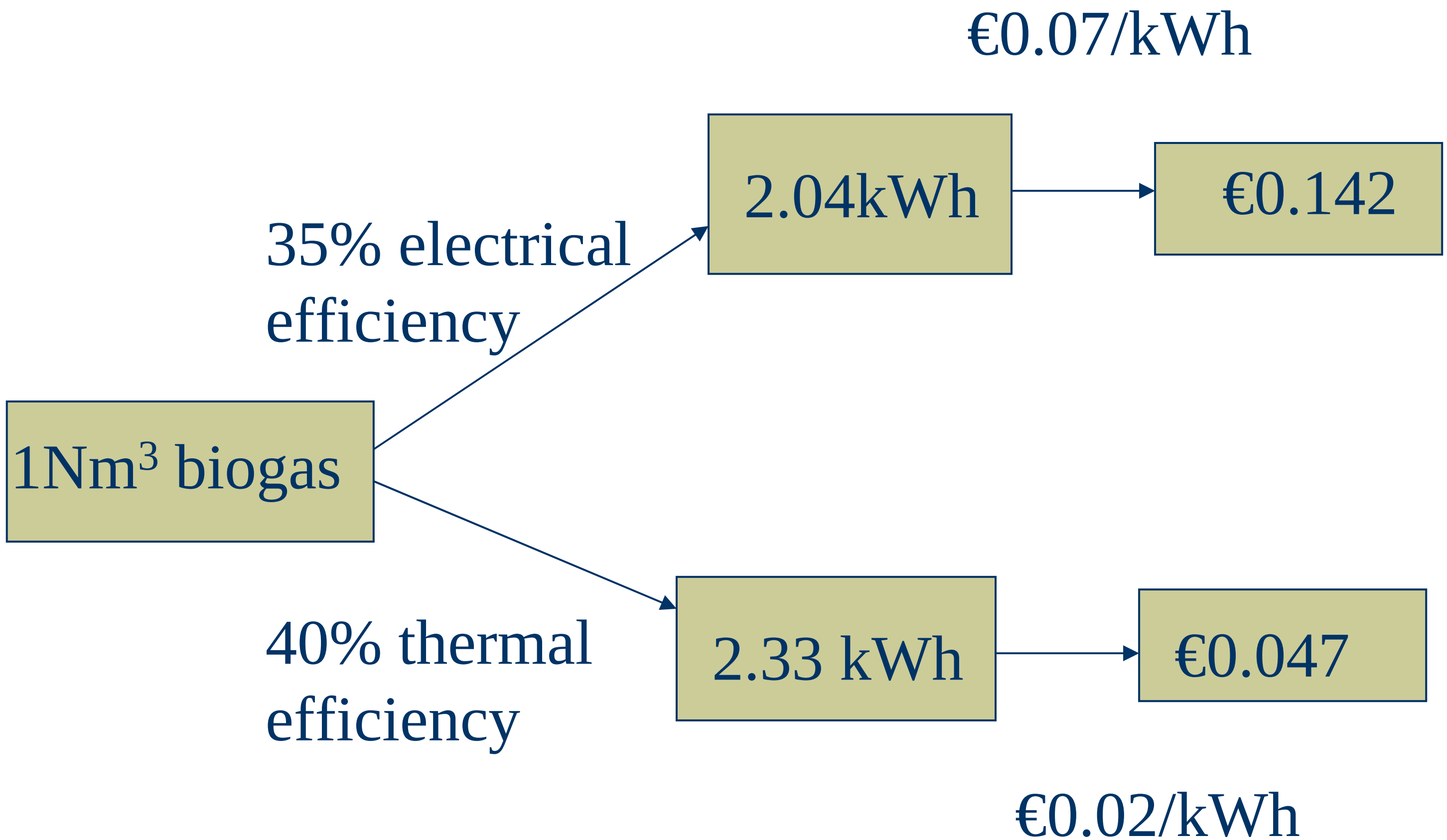
Biogas production from wastes

	Biogas Nm^3/t	Biogas $Nm^3/PE/y$	Biogas $Nm^3/pig/y$
Primary sludge (7%DS)	20	3.4	
WAS (3%DS)	8	2.6	
OFMSW (40%DS)	130	26	
Pig slurry (6%DS)	26		38
Total		32.7	38

Organic waste to CHP



Asset value of biogas used in CHP production

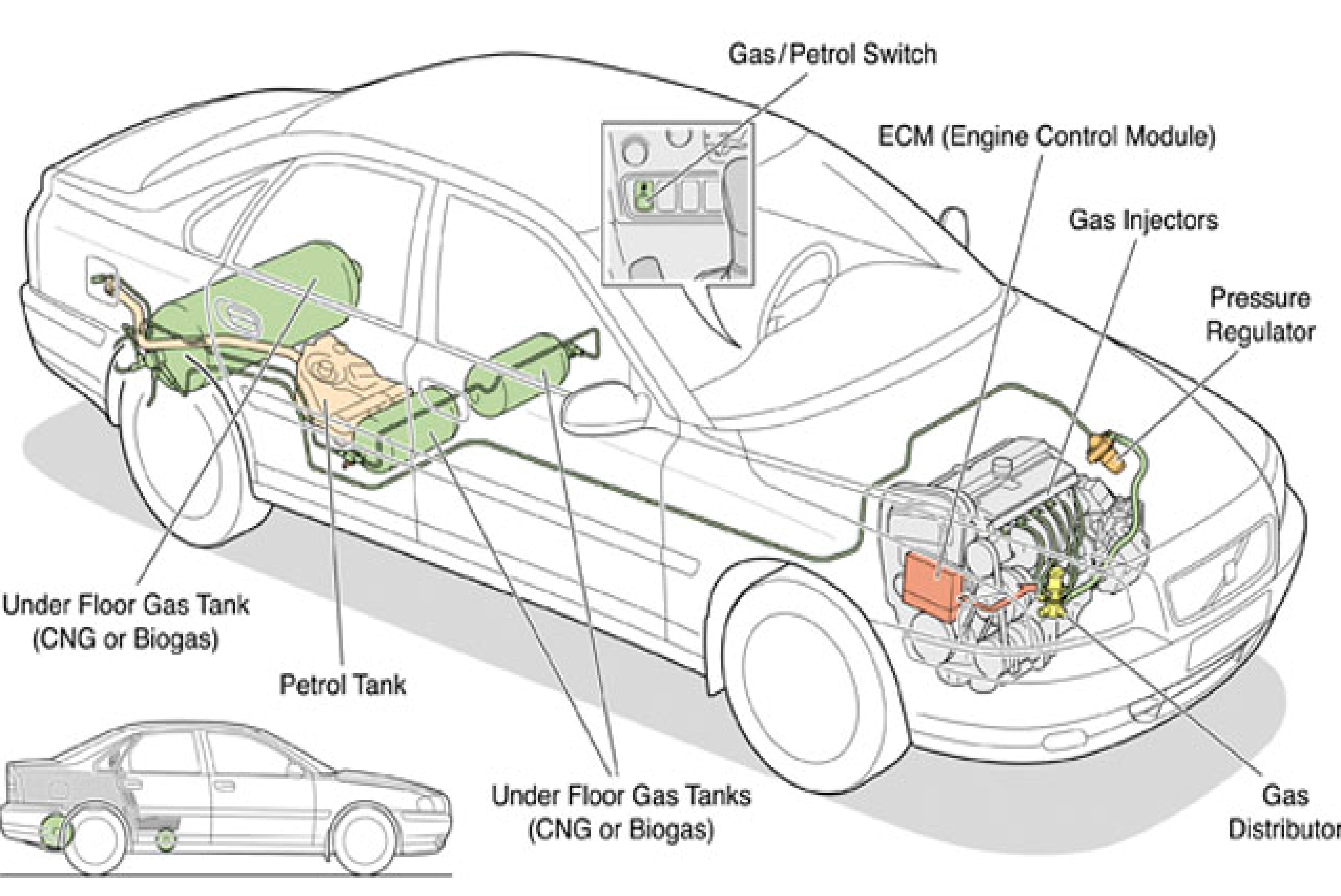


Organic waste to transport fuel

Biogas scrubber in Bromma, Sweden

148 biogas buses in Lille

Bi-Fuel System (CNG, Biogas)



Volvo S80

CH_4-enriched biogas: a transport fuel

- Biogas scrubbed to 97% CH_4 has as energy value of 36.6MJ/Nm^3
- 1Nm^3 of biogas produces 0.57 Nm^3 CH_4-enriched biogas
- 10km to 1Nm^3 of CH_4-enriched biogas, Volvo V70
- 1t of OFMSW = 130Nm^3 of biogas
- 1t of OFMSW = 74 Nm^3 CH_4-enriched biogas
- 1t of OFMSW = 740km in a Volvo V70

Asset value of biogas used as a transport fuel

- 1Nm^3 of CH_4-enriched biogas replaces 1L of petrol
- 1Nm^3 of biogas produces 0.57 Nm^3 CH_4-enriched biogas
- 1Nm^3 of biogas replaces 0.57L of petrol
- Unleaded petrol costs €1/L (April 2005)
- Assume excise duty relief (Biofuels Directive)
- Economic value of 1Nm^3 of biogas €0.47 (VAT at 21%)

Potential revenues from biogas

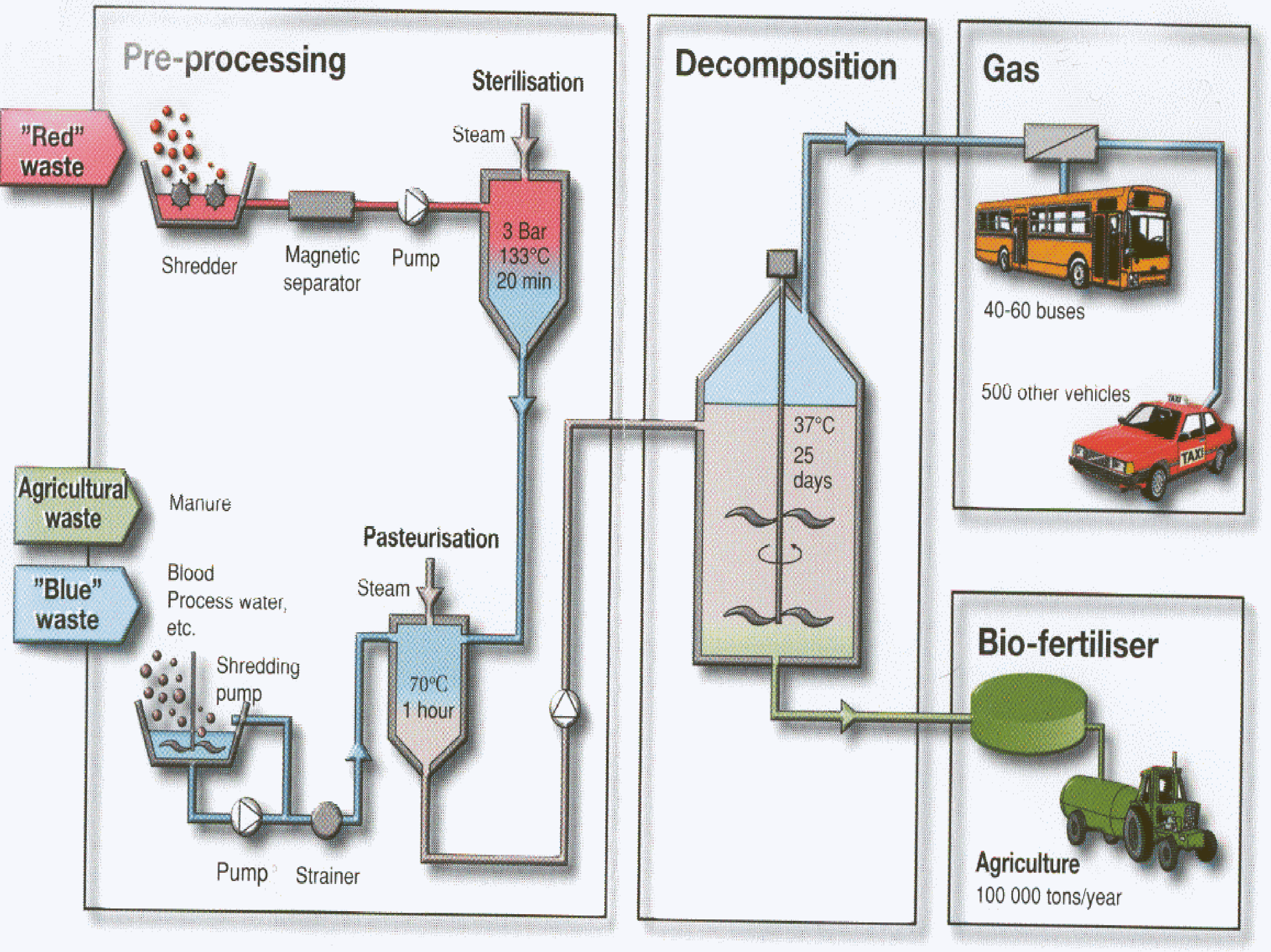
Utilisation of Biogas	€/m^3
Electricity	0.14
CHP	0.19
Transport	0.47

Studsgard biogas plant, Denmark

Biogas yield in Studsgard

Feed	Dry matter	Nm^3biogas/t
Cattle slurry	8.5	24
Pig slurry	6	26
OFMSW	35	150
Industrial sludge		178
80% pig slurry 15% industrial 5% OFMSW		0.8(26) + 0.15(178) + 0.5(150) = 55

Linkoping Biogas AB, Sweden



Pre-processing
Sterilisation
Steam
"Red" waste
Shredder
Magnetic separator
Pump
3 Bar
133°C
20 min
Agricultural waste
Manure
"Blue" waste
Blood
Process water,
etc.
Pasteurisation
Steam
Shredding pump
70°C
1 hour
Pump
Strainer
Decomposition
37°C
25 days
Gas
40-60 buses
500 other vehicles
TAXI
Bio-fertiliser
Agriculture
100 000 tons/year

Studsgard & Linkoping: Outputs

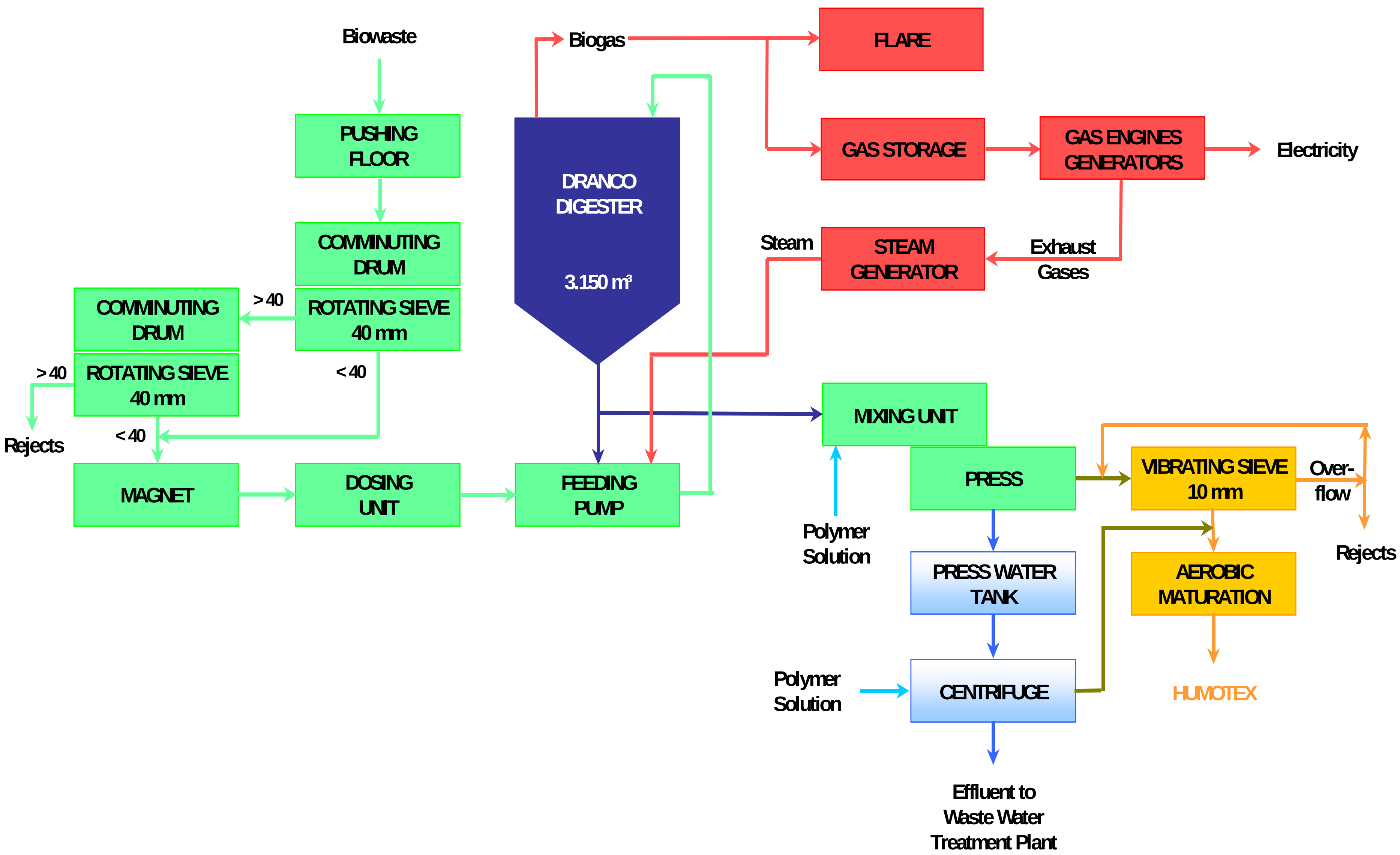
	Studsgard	Linkoping
Biomass tpa	111 000	99 000
Biogas Nm^3pa	5 840 000	5 780 000
Biogas Nm^3/t	52.6	58.4
Output	1.4MWe 1.6MWt	3 330 000 Nm^3pa CH_4-enriched biogas

Studsgard & Linkoping: Revenues

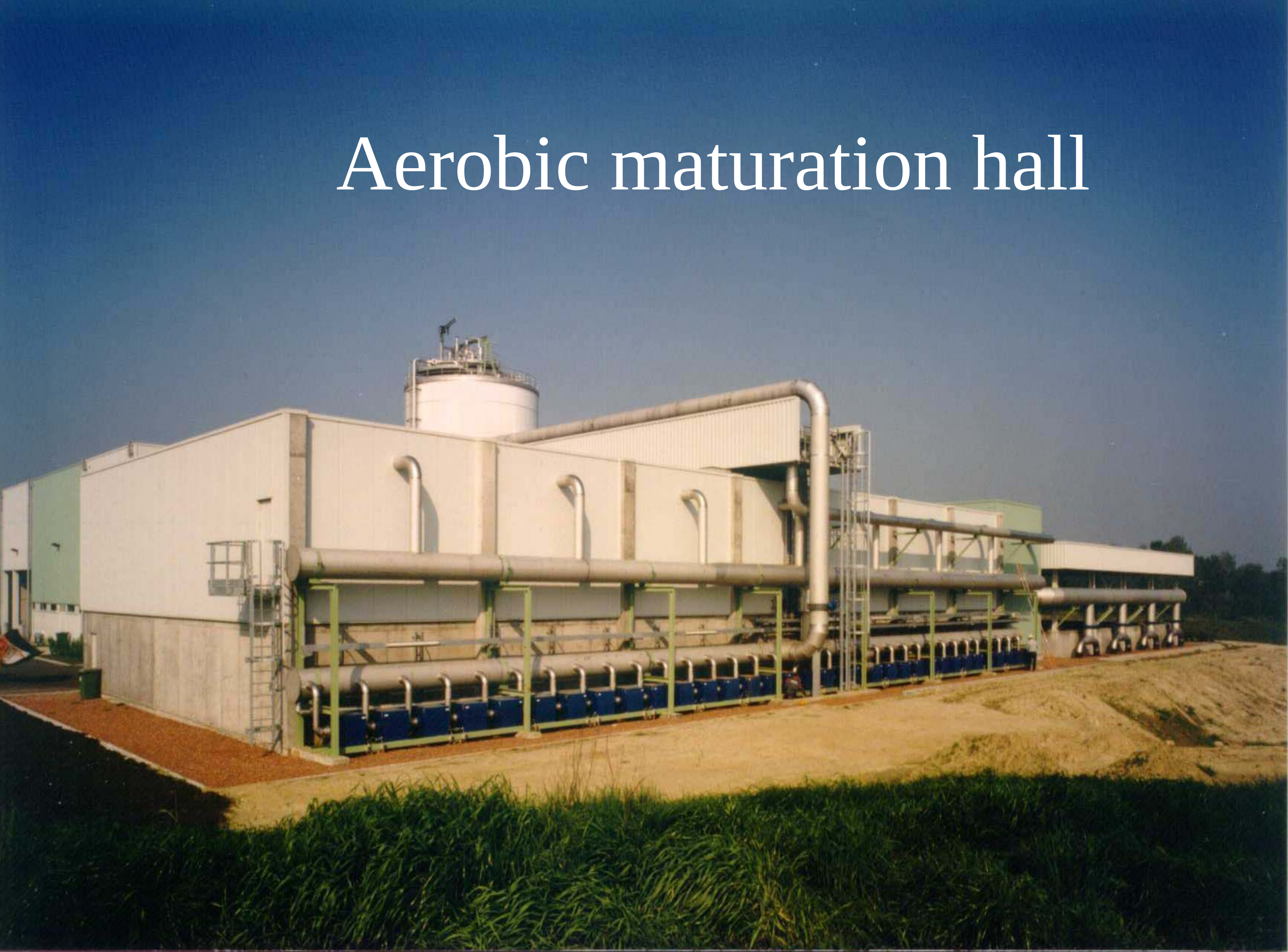
	Studsgard	Linkoping
Output	10,424MW$_e$hpa 14,016MW$_t$hpa	3,330,000 Nm^{3}pa CH_4-enriched biogas
Revenue/unit	€0.07/kW$_e$h €0.02/kW$_t$h	€0.83/Nm^3
Revenue	€1,101,000pa	€2,764,000pa

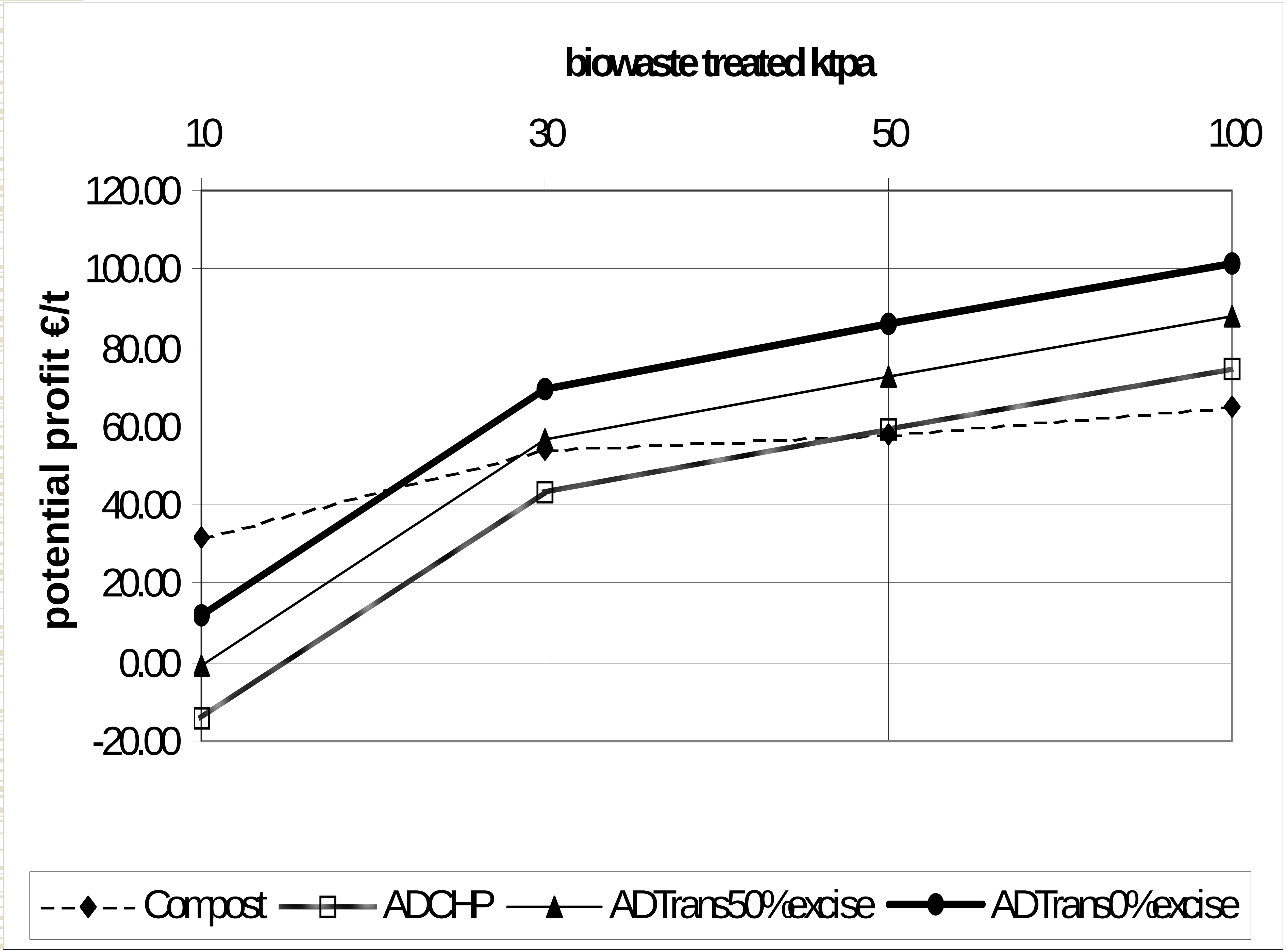
Brecht II, digestion of 50,000tpa of OFMSW

Flow sheet of the DRANCO Plant Brecht II (Belgium)



Aerobic maturation hall




biowaste treated ktpa
10
30
50
100
120.00
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
potential profit €/t
Compost
ADCHP
ADTrans50%excise
ADTrans0%excise

Digestion of OFMSW

- If treating in excess of 20,000tpa of biowaste anaerobic digestion may be economically cheaper than composting
- Typically 0.2t OFMSW/person
- Areas with populations in excess of 100,000 people should consider digestion of OFMSW

Application to Cork Waste Strategy

- Population 447,829 (2002 census)
- OFMSW 90,000tpa (0.2tOFMSW/person)
- Net biogas production 11.2 million Nm^3pa ($130Nm^3$/t OFMSW, 4% thermal demand)
- 6.4 million Nm^3pa CH_4-enriched biogas production
- 6.4 million L of petrol pa or 4.5 million Lpa diesel
- Cork bus (89 buses) utilised 4.5 million L of diesel in 2003

Output from Cork example

- Fuel 89 buses
- 6.4 million Nm^3pa CH_4-enriched biogas
- = 64,000,000 km in a Volvo V70
- = 3,200 cars travelling 20,000kmpa
- Revenue from OFMSW €13.5 million (based on a gate fee of €150/t)
- Revenue from biofuel €5.3 million (based on €0.47/Nm^3 of biogas)

Conclusions

- Biogas is generated from organic material
- OFMSW is a rich source of biogas
- Economics are optimised by digesting OFMSW and producing a transport fuel
- Composting is cheaper than digestion at scales less than 50,000tpa if CHP is produced from biogas
- Composting is cheaper than digestion at scales less than 20,000tpa if transport fuel is produced and excise duty is removed from digestion
- Digestion of OFMSW from a city will fuel the bus fleet.