SEMANA EUROPEA DE LA ENERGIA SOSTENIBLE EN ANDALUCIA:
“NUEVAS FUENTES SOSTENIBLES: BIOGAS”
Jueves, 31 de enero de 2008

Biogas Technology in Europe

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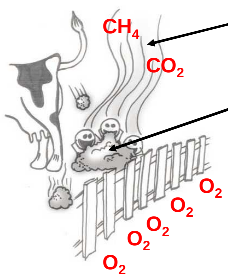
Outline of the presentation

1. **The basic principles of anaerobic digestion**
2. **Applications of biogas technology**
3. **Biogas utilisation**
4. **State-of-the-art of biogas technology in Europe**
5. **Concluding remarks**

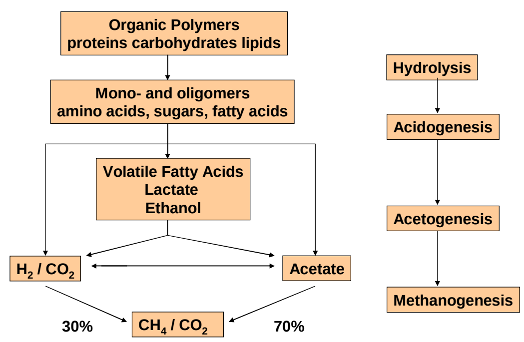
1. The basic principles of anaerobic digestion

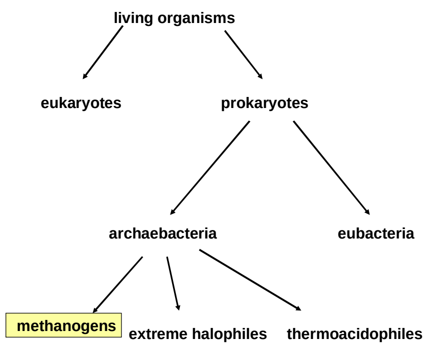
Biogas is formed through the activity of a variety of different bacteria in the absence of oxygen. The main products are:



1. **methane** which is an energy carrier
2. **digestate** which is an excellent fertiliser

Anaerobic Conversion of Organic Matter





Composition of biogas

- **methane** (CH_4): 50-75 vol.%
- **carbon dioxide** (CO_2): 30-60 vol.%
- **other gases**: 1-5 vol.%

→ hydrogen (H_2): 0-1 vol.%
→ hydrogen sulfide (H_2S): 0-3 vol.%

Methane production potential

The methane production potential depends on

- the biodegradability of the organic waste
- the particle size of the organic waste
- the temperature (mesophile / thermophile)
- the reactor pH
- the presence of toxic or inhibitory compounds
- the oxidation state of the carbon

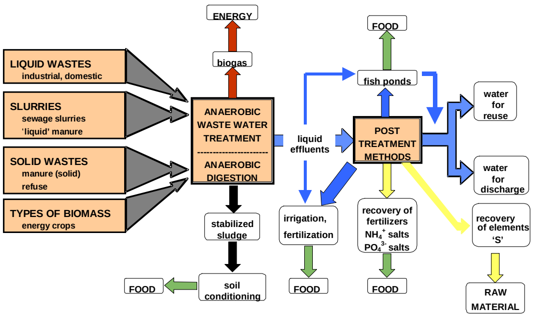
2. Applications of biogas technology

The 4 R's of sustainable waste management

1. **R**educe
2. **R**euse
3. **R**ecycle
4. **R**enewable energy

Anaerobic Digestion (AD) is a key method for waste reduction, reuse and recycle of valuable co-products and recovery of a renewable fuel as biogas.

AD as core technology in closing resource cycles



2. Applications of biogas technology

1. Wastewater treatment

a) (pre-) treatment step for industrial wastewater and liquid manure
b) (pre-) treatment step for domestic wastewater

2. Slurry digestion

a) sewage sludge stabilisation
b) manure digestion
c) co-digestion

3. Solid waste digestion

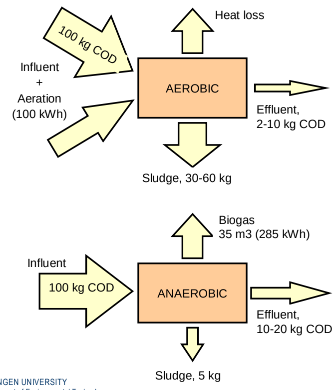
a) municipal solid waste (MSW) and organic industrial waste
b) biogas collection from landfill sites.
c) energy crops

1. Wastewater treatment
a) Anaerobic treatment of industrial wastewater

Standard technique
Anaerobic wastewater treatment (AWWT) of industrial wastewaters is a fully accepted reliable treatment technology.

Two step treatment.
If a high quality water discharge is required, AWWT is the first biological treatment step, normally followed by an aerobic post-treatment.

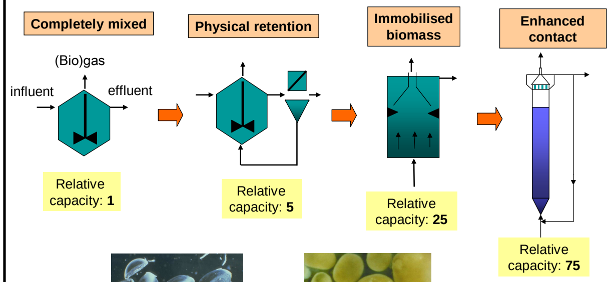
Why anaerobic treatment?

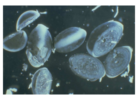


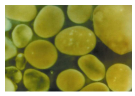
Comparison Aerobic - Anaerobic

Characteristic	Aerobic	Anaerobic
Reaction	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$
Energy release	$\Delta G° = -2840$ kJ/mol glucose	$\Delta G° = -393$ kJ/mol glucose
Carbon balance	50% → CO_2 50% → biomassa	95% → $CH_4 + CO_2$ (= biogas) 5% → biomassa
Energy balance	60% → biomassa 40% → heat production	90% retained in CH_4 5% → biomassa 5% → heat production
Biomass production	Fast growth of biomass, Resulting in a sewage sludge problem	Slow growth of biomass
Energy input for aeration	Yes	No

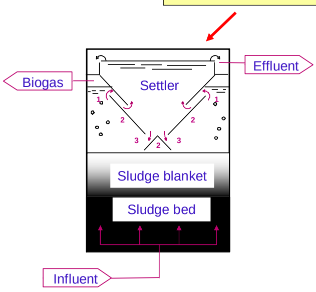
Development of "high-rate" anaerobic treatment systems



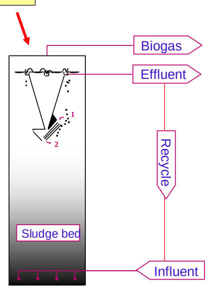




From UASB to EGSB



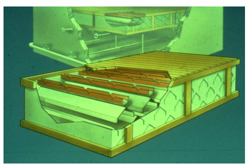
1. Sludge/biomass inlet
2. Gas baffle plates
3. Return settled sludge



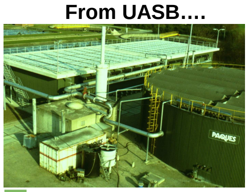
1. Sludge/water mixture
2. Settled sludge

BIOTHANE SYSTEMS INTERNATIONAL

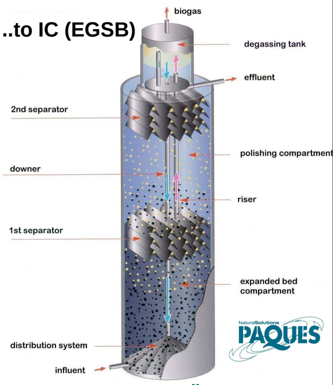
Application of Multi-layer settling system



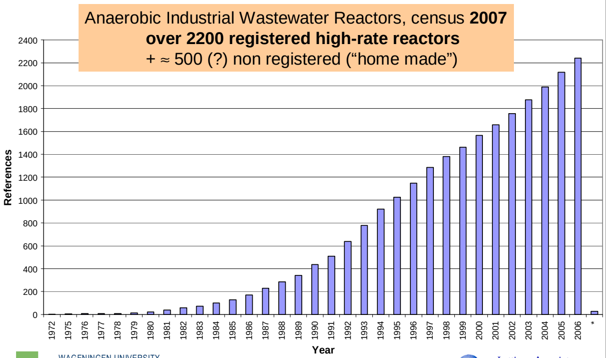
From UASB….



..to IC (EGSB)



Worldwide cumulative anaerobic references



Data collected by Yolanda Yspeert

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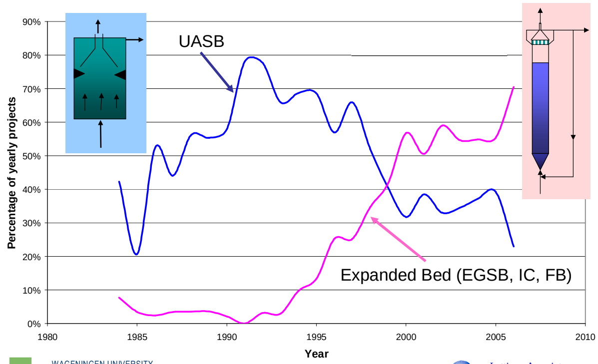
Full Scale Expanded Bed versus UASB Systems



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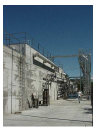
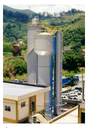
Benefits anaerobic wastewater treatment

- Reduction of excess sludge production by 90% !
- Up to 90% reduction in space requirements !
- High loading rates (up to 35 kg COD.m^{-3}.day^{-1}), smaller reactors
- No use of fossil fuels for treatment (saving 0.5-1 kWh / kg organic matter)
- Production of energy as CH_4 (3.5* kWh / kg COD matter converted or 1.4 kWh-electric / kg COD matter)
- Rapid start up (with granular sludge: 1 week)
- No or very little use of chemicals (e.g. nutrients)
- Excess sludge has a market value and can be stored unfed



Yeast



Beer

Distillery

Paper

Chemical

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Industries with wastewater suitable for anaerobic treatment

AGRO-FOOD INDUSTRY		BEVERAGE	ALCOHOL DISTILLERY	PULP & PAPER	MISCELLANEOUS
Sugar	Cannery	Beer	Sugar cane juice	Recycle paper	Chemical
Potato	Confectionery	Malting	Sugar cane molasses	Mechanical pulp	Pharmaceutical
Starch	Fruit	Soft drink	Sugar beet molasses	NSSC	Sludge liquor
Yeast	Vegetable	Fruit juice	Grape wine	Sulphite pulp	Municipal sewage
Pectin	Dairy	Wine	Grain	Straw	Landfill leachate
Citric acid	Bakery	Coffee	Fruit	Bagasse	Acid mine water

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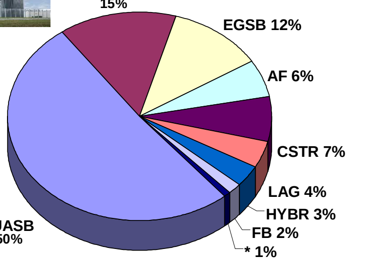
Installed anaerobic processes (1981 – 2007) (N= 2266)



(Granular) sludge bed based: 77%

* References with incomplete data (1%)
Source: Worldref. 04-2007

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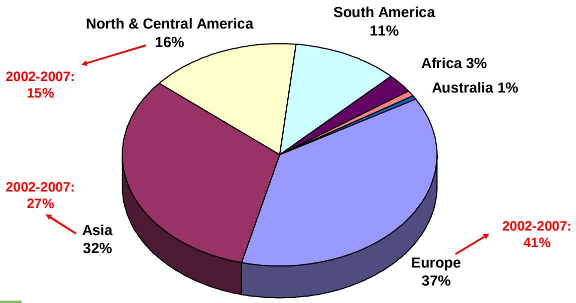
Geographic distribution of anaerobic plants (2007, N= 2266)



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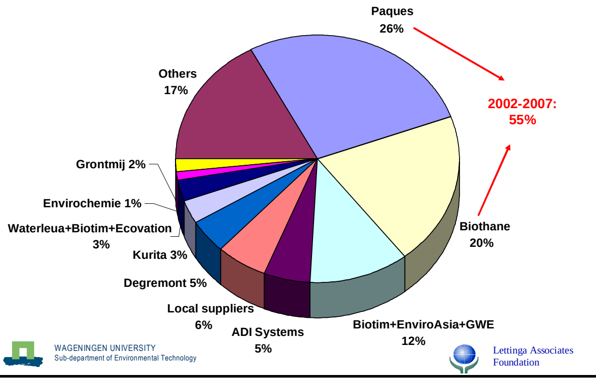
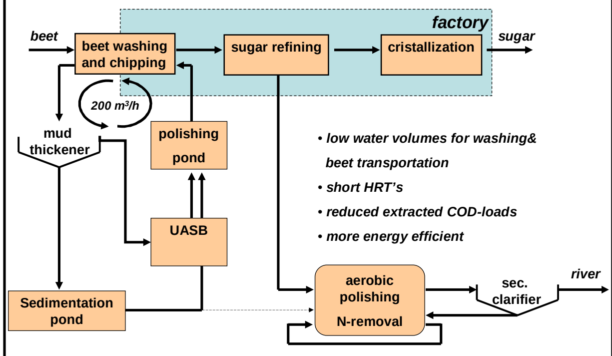
Major Anaerobic Technology Suppliers (2007, N= 2266)

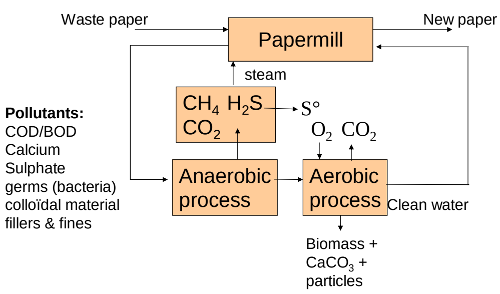


General scheme of a beet sugar mill water circuit



- *low water volumes for washing& beet transportation*
- *short HRT's*
- *reduced extracted COD-loads*
- *more energy efficient*

In-line treatment in zero discharge paper mills

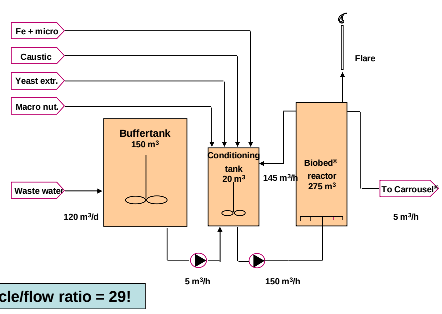


Pollutants:
COD/BOD
Calcium
Sulphate
germs (bacteria)
colloïdal material
fillers & fines

Caldic Europoort Wastewater characteristics

• Flow	m³/day	120
• Total COD	mg/l	40.000
• Total COD-load	kg/day	4800
• Formaldehyde	mg/l	10.000
• Methanol	mg/l	20.000
• pH		9
• Temperature	°C	35

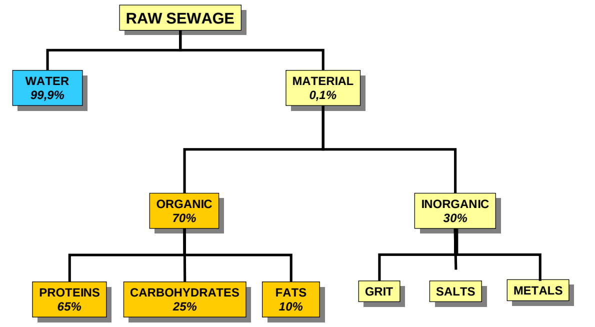
Caldic Europoort - Flow scheme anaerobic stage



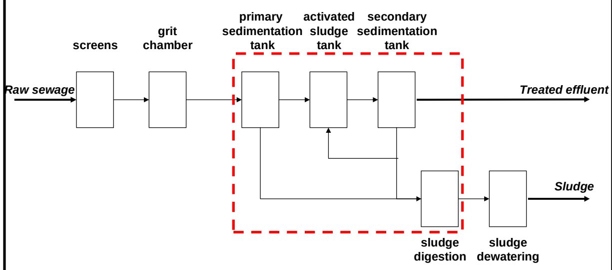
Recycle/flow ratio = 29!

1. Wastewater treatment b) Anaerobic treatment of domestic sewage

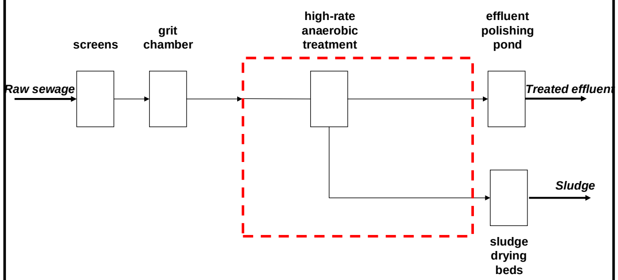
Sewage Composition



Basic setup of aerobic treatment

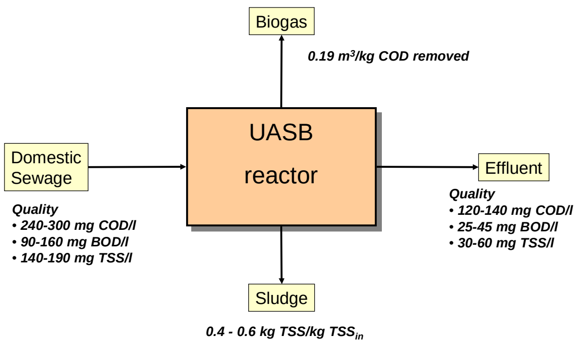


Basic setup of anaerobic treatment



AWWT plant Bucaramanga, Colombia

Overall COD / sludge balance 64 m³ pilot UASB Cali

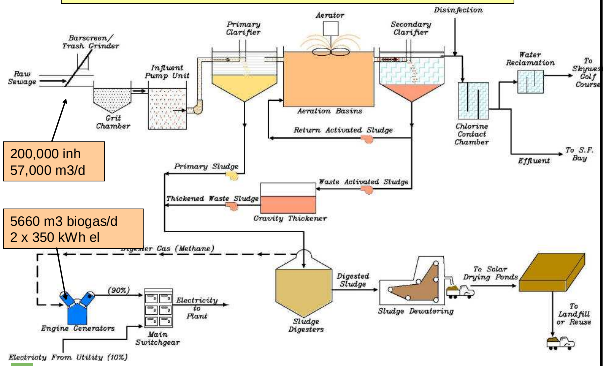


2. Slurry digestion
a) Sewage sludge digestion

Sewage sludge digestion is a well established technology
At around 50% of the sewage treatment plants the sludge is treated by AD depending on national legislation and priorities.

Benefits of sewage sludge digestion
- recycling of sludge back to land. (some countries limit the field application of sludge due to heavy metals).
- it sanitises and also reduces the odour potential from the sludge
- it produces biogas as renewable energy
- it improves the ability of the sludge to settle which makes it easier to dry.

Flow scheme of a wastewater treatment plant
Oro Loma Sanitary District, California, USA



2. Slurry digestion
b) Manure digestion

Digestion of **animal manure** is the most widespread AD application worldwide. It produces:
- a valuable fertiliser
- biogas.

Farm-scale digestion plants have seen widespread use throughout the world, with plants in developing and technically advanced countries

In rural communities **small-scale units** are typical;
Nepal has some 50,000 digesters and
China is estimated to have 8 million small-scale digesters.
These plants are generally used for providing gas for cooking and lighting for a single household.

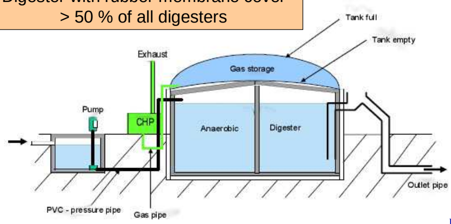
In western countries the digesters are normally **medium- to large-scale** Germany, Austria and Switzerland are leading countries. In Germany more than 2,000 farm-scale biogas digesters are in operation; Austria has approximately 120, and Switzerland over 70.

Two designs are prevailing throughout Europe:

- the so-called rubber top digester, and
- the concrete top digester usually built in the ground.

Both have a cylindrical form with a height to diameter ratio of 1:3 to 1:4.They are intermittently mixed tank reactors with hydraulic retention times (HRT) of the waste in the digester of 15 to 50 days.

Digester with rubber membrane cover
> 50 % of all digesters



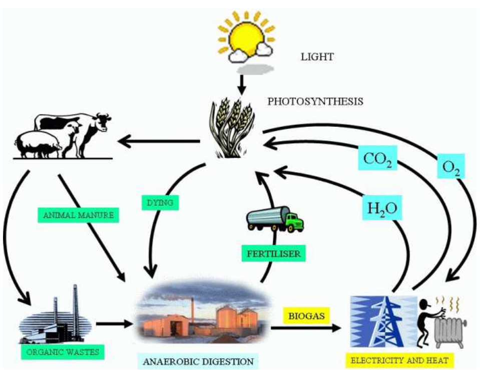
2. Slurry digestion
c) Co-digestion

Today, more and more organic (industrial) waste materials are added to the manure which brings:
- increased gas production and
- creates an additional income from the gate fee.

Manure + soluble organic waste materials
Quite commonly, the manure is collected in a feed tank where other soluble substrates can be added such as distillery, and potato slops, whey, etc.

Manure + solid organic waste materials
Provided the feed tank is equipped with a strong macerator, solid substrates can also be added. However, the limitation is the pumping capacity, which usually ends at a dry matter content of around 12%. In newer plants the solid material is added directly to the digester either with screw feeders from the top or by piston pumps below the liquid level in the digester.

Generally co-digestion is applied in **wet single-step processes** such as intermittently-stirred tank reactors.



Co-digestion with industrial organic solid wastes

Organic solid wastes from industry are increasingly treated in biogas plants.

- Even if some of the substances might be difficult to digest as a sole substrate, in mixture with manure (or sewage sludge) they generally don’t pose any problem.

- Especially waste products from the food industry have excellent gas potential and therefore are in demand by plant operators.

Benefits of co-digestion

1. **Sewage sludge digesters:** Digesters in waste water treatment plants are usually oversized. Addition of co-substrates helps to produce more gas and consequently more electricity at only marginal additional cost.
2. **Manure digesters**: Agricultural biogas production from manure alone (which has a relatively low gas yield) is economically not viable at current oil prices.
3. Addition of co-substrates increases the income through **tipping fees**.
4. Until recently the industry paid the operators reasonably high gate fees (up to 35 Euro per ton) to accept the waste products. Now, the operators are starting to pay for the waste materials with the highest gas potential like fat and vegetable oil. With **high feed-in tariffs** they can easily recover the cost of these wastes.

New development in co-digestion: Centralised Anaerobic Digestion (CAD)

CAD
A large digestion plant is fed with agricultural manures from many farms, biodegradable waste materials from industry and in some cases small amounts of municipal wastes. Large-scale industrial plants (V = 4,000 to 6,000 m3) are more economic and therefore have shorter payback times (3 to 10 years).

CAD was first applied in Denmark where there are now 20 plants in operation, all with manure as the major substrate.

CAD is now used in many European countries as well as in Asia and the USA. In Sweden, wastewater treatment plants started to use co-substrates in their sludge digesters.

Centralised Anaerobic Digestion (CAD) has been developed in Denmark and is spreading into a number of European countries like U.K. This Holsworthy plant started operation in 2002.
(Courtesy Nova Energie)

Benefits of CAD

Improved nutrient balance for optimal digestion

Homogenisation of particulate, floating, or settling wastes through mixing with animal manures or sewage sludge

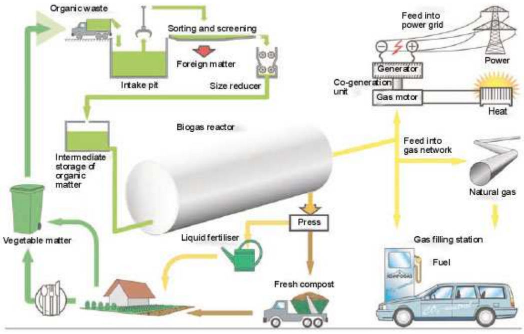
Increased, steady, biogas production throughout the seasons

good fertiliser quality

Higher income from gate fees for waste treatment

Renewable biomass production for digestion ('energy crop') as a potential new income for agriculture

3. Solid waste digestion
a) municipal solid waste (MSW) or organic industrial waste



Application of AD for MSW

Worldwide, there are now approximately 150 AD plants in operation and a further 35 under construction using MSW or organic industrial waste as their principal feedstock.

The total annual installed capacity is more than five million tonnes, which has the potential to generate 600 MW of electricity.

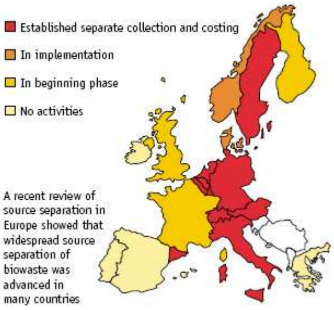
The benefit of source separation of MSW

In most of the participating countries, the **source separation** of MSW is actively encouraged. This includes separation of the biodegradable organic fraction, also known as **'green waste' or 'biowaste'.**

Experience has shown that source separation provides the best quality feedstock for AD. The digested material is a valuable fertiliser and soil improver, especially after aerobic post-treatment.

Where source separation has been widely introduced, the results are encouraging.

Odour free storage and efficient collection of source separated waste are the key components for a successful introduction of an MSW system.



Dry continuous digestion of source separated MSW

Dry digestion involves a continuously-fed digestion vessel with material with a dry matter content of 20-40%. There are two basic designs:

Completely-mixed system
Mixing is achieved by the introduction of compressed biogas through jets at the bottom of the digester.

Plug-flow systems.
Plug flow systems rely on external recycling of a proportion of the outgoing digestate to inoculate the incoming raw feedstock. There are systems with vertical plug-flow and horizontal plug-flow.
One of the successful processes of solid waste digestion is the horizontal plug-flow digestion at thermophilic temperatures (55℃).

Dry continuous digestion of source separated MSW

Horizontal plug-flow digester

Dry continuous digestion of source separated MSW

Most of the dry systems are operated at thermophilic temperatures between 52 and 57℃. The benefits are:

Optimal degradation rate at a reasonably short retention time of 15 to 21 days.

Sanitation of the digestate.

Low demand for process energy. The horizontal plugflow system requires only 20% of the electricity produced from biogas to operate the plant, including the pre-treatment process of material size reduction and sorting out undesirables.

Treatment of unsegregated MSW

Unsegregated MSW or the ‘grey waste’ after separation of the ‘biowaste’ can be treated as well in order to

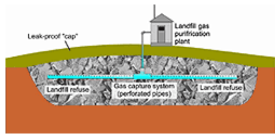
- gain the biogas from the waste
- stabilise it to prevent further problems in landfill.

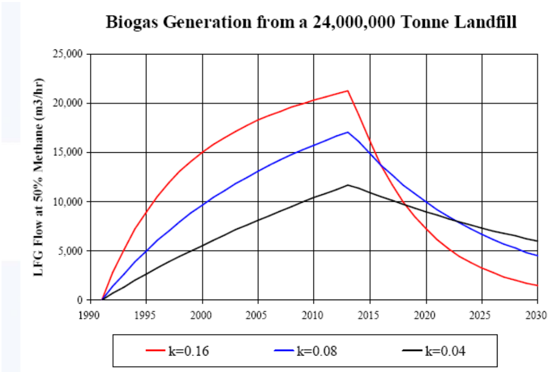
Treatment of unsegragated MSW require technologies based on mechanical and biological treatment (MBT) steps.

3. Solid waste digestion
b) biogas collection from landfill sites.

Factors affecting amount of landfill biogas production:

– amount of waste
– type of waste
– age of waste
– moisture content
– temperature
– pH
– site conditions





Landfill gas recovery

Landfill biogas recovery = landfill biogas generation x collection efficiency

Collection efficiency = amount of landfill biogas collected / amount of landfill biogas generated

Collection efficiency based on:
– Type of facility (landfill vs. dump)
– Type/design of collection system
– Extent collection system covers waste volume
– Waste characteristics – permeability
– Collection system operation

Achievable collection efficiencies at disposal sites:
– Engineered and sanitary landfills: ~60-90%
– Open and controlled dump sites: ~30-60%

The EU has set the goal of reducing the amount of organic waste to landfill by 65% by 2014.

3. Solid waste digestion
c) energy crops

Energy crops as co-substrate

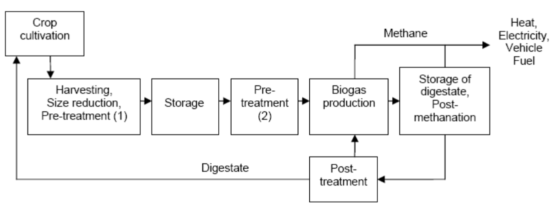
In countries like Denmark, Austria and Germany the easily degradable wastes are becoming scarce and farmers are looking for alternative substrates. Energy crops such as corn, barley, rye or grass can be interesting alternative substrates.

Energy crops as sole substrate

Many crops can be used for direct methanisation. Up to 3 000–5 000 m3 of methane and 30–50 MWh of gross energy can potentially be obtained from one hectare of energy crops cultivated for biogas production.

In Germany the income from electricity produced from biogas made from corn is higher than using the same crop to feed fattening beef because of the higher feed-in tariffs

Flowsheet for direct biomethanisation of energy crops



Methane potential of various energy crops
(source A. Lethomäki, 2006)

Substrate	Methane potential (m^3 CH_4 kg^{-1} VS_{added})	Methane potential (m^3 CH_4 kg^{-1} TS_{added})	Methane potential (m^3 CH_4 t^{-1} ww)	Methane potential (m^3 CH_4 ha^{-1} a^{-1})	Gross energy potential (MWh ha^{-1} a^{-1})	Ref.
Forage beet	0.46	n.r.	n.r.	5 800 [a]	56 [ac]	1
"	0.36	0.32 [c]	55 [c]	3 240 [b]	34 [b]	2
Alfalfa	0.41	n.r.	n.r.	3 965 [a]	38 [ac]	1
"	0.32	0.28 [c]	56 [c]	2 304 [b]	24 [b]	2
Potato	0.28	n.r.	n.r.	2 280 [a]	22 [ac]	1
Maize	0.41	n.r.	n.r.	5 780 [a]	56 [ac]	1
Wheat	0.39	n.r.	n.r.	2 960 [a]	28 [ac]	1
Barley	0.36	n.r.	n.r.	2 030 [a]	20 [ac]	1
Rape	0.34	n.r.	n.r.	1 190 [a]	12 [ac]	1
Grass	0.41	n.r.	n.r.	4 060 [a]	39 [ac]	1
"	0.27	0.24 [c]	46 [c]	1 908 [b]	20 [b]	2
"	0.27–0.35	0.25–0.32	64–83	n.r.	n.r.	3
Clover	0.35	n.r.	n.r.	2 530 [a]	25 [ac]	1
"	0.14–0.21	0.12–0.19	24–36	n.r.	n.r.	3
Marrow kale	0.26	n.r.	n.r.	1 680 [a]	16 [ac]	1
kale	0.32	0.28 [c]	42 [c]	2 304 [b]	24 [b]	2
Jerusalem artichoke	0.27	0.24 [c]	49 [c]	2 862 [b]	30 [b]	2
Sugar beet	0.23	0.19 [c]	n.r.	n.r.	n.r.	4
tops	0.36–0.38	0.29–0.31 [c]	36–38 [c]	n.r.	n.r.	5
Straw	0.25–0.26	0.23–0.24	139–145	n.r.	n.r.	3
"	0.30 [c]	0.25 [c]	n.r.	n.r.	n.r.	6

[a] in Germany, [b] in Sweden, [c] Values calculated from the data reported, VS = volatile solids, TS = total solids, t ww = tons of wet weight, a = year, MWh = megawatt-hour, n.r. = not reported. 1: Weiland 2003, 2: Brolin et al. 1988, 3: Kaparaju et al. 2002, 4: Gunaseelan 2004, 5: Zubr 1986, 6: Badger et al. 1979.

3. Biogas utilisation

The following compounds might be present in biogas:
- **Methane**
- **Carbon dioxide**
- **Hydrogen sulphide**
- **Siloxane**
- **Aromatic compounds**
- **Air (oxygen, nitrogen)**
- **Halogenic compounds (chlorides, fluorides)**

Biogas Upgrading
There are a number of compounds which have to be removed from biogas where they are present. Often only **water vapour** and **hydrogen sulphide** are to be removed
When gas is compressed as vehicle fuel or when gas is fed to the grid (to meet energy standards 97% methane is usually required) **carbon dioxide** is to be removed.

Upgrading of biogas is an important cost factor in the production of fuel gas. Typical costs for an upgrading plant treating 200m3 per hour of raw gas is in the order of 1.5 Euro cents per kWh

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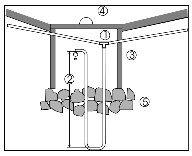
Gas purification

Before the biogas can be used it has to be treated and upgraded (dependent on the use). The most important required treatment steps are:

Handling of condense water

Simple method for the collection of condense water in gas pipes



Desulphurisation
Removal of hydrogen sulphide (H2S) recommended because of the very corrosive effect. In principle, there are two basic procedures:
• Physical-chemical treatment Absorption of hydrogen sulphide by ferric oxide or scrubbing
• Microbial treatment. Microbial desulphurisation by the addition of air.

CO2 removal
For upgrading CO2 removal is required This is in principle done in a scrubber with a neutral or alkaline solution

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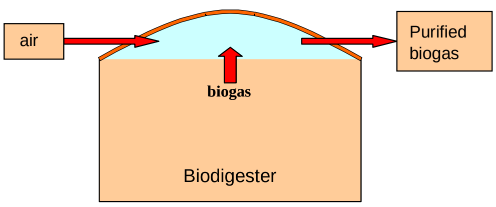
Hydrogen sulphide removal

Air injection in a floating gas storage



Precaution addition of oxygen can give an explosive mixture in the ratio of 1:15 to 1:20

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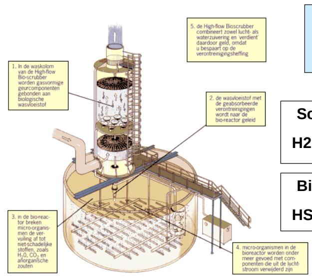
Hydrogen sulphide removal



Bioscrubber:
Regeneration of alkalinity

Scrubber
H2Sgas + OH- → HS-liquid + H2O

Bioreactor
HS- + ½ O2 → S + OH-

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Biogas utilisation

Possible utilisation of biogas:

- (Co-)generation units for **electricity** and **heat** production;
- Industrial steam burners, often to provide **mechanical energy**
- **Steam** production to provide thermal energy (i.e. for slaughter houses, distilleries)
- for **hygienisation** or **cooking** of i.e. restaurant food wastes, biowaste, hospital wastes or animal feed
- **Ignition** and base energy for incineration plants
- **Cooling** and **refrigeration** in store and warehouses (i.e. milk-producing plants, cheese factories, slaughterhouses or meat processing plants, drink factories ...) or for the cooling of medicine in hospitals and health stations
- Energy for heating systems of the anaerobic municipal, industrial or agricultural treatment plants (mainly by means of **hot water**)
- **Fuelling** urban gas or heating **pipe networks**
- **Transport** uses for buses (sometimes even in bags without compression), trucks, cars, taxis and motorcycles
- **Drying** purposes, i.e. of grain, food, wood or compost
- **Ice making**

Co-generation

Co-generation or Combined Heat and Power Plants (CHP)
Virtually all of the plants use the biogas for electricity production in combined heat and power plants (CHP). Most of them use at least part of the heat for the digester, as well as for hot water for the stables and the farm dwelling.

Two types of engines are often used.

Thousands of **internal combustion engines** (gas engines) are operated on sewage works, landfill sites and biogas installations. The engine sizes range from approximately 12 kWe on small farms up to several MWe on large-scale landfill sites.

A diesel engine can be rebuilt into a **spark-ignited gas engine** or a **dual fuel engine** where approximately 8-10% diesel is injected for ignition.

Newest designs show electric efficiencies up to 41%.

New engine types

In recent years new engine types have been developed such as

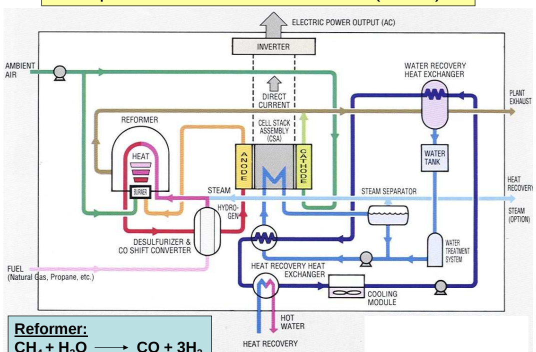
- **hot fuel cells**

Hot fuel cells have the potential to reach electric efficiencies of close to 50%. Molten carbonate (MCFC) or solid oxide fuel cells (SOFC) do not require CO2 to be removed from the raw gas

- **micro turbines.**

Micro turbines have far lower electrical efficiencies of 26 to 28% but they produce steam instead of hot water, which might be used for industrial purposes.

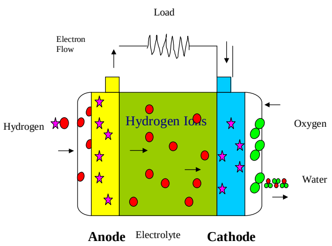
Principle of a Fuel Cell Power Plant (FCPP)



Reformer:
$CH_4 + H_2O \longrightarrow CO + 3H_2$

CO Shift Converter:
CO + H2O ⟶ CO2 + H2

Proton Exchange Membrane (PEM) fuel cell



Anode	$H_2 \longrightarrow 2H^+ + 2e^-$
Cathode	$\frac{1}{2} O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

Biogas as vehicle fuel

Biogas Fuel
The utilisation of biogas as vehicle fuel uses the same engine and vehicle configuration as natural gas.
Worldwide there are more than 3 million natural gas vehicles and about 10,000 biogas driven cars and buses, demonstrating that the vehicle configuration is not a problem for use of biogas as vehicle fuel. However, the gas quality demands are strict so the raw biogas from a digester or a landfill has to be upgraded.

Sweden and Switzerland are the only countries where pure biogas is available as transport fuel. In Sweden a **biogas train** is in operation.

4. State-of-the-art of biogas technology in Europe

EC activities

Biomass Action Plan

At the end of 2005, the EU's Biomass Action Plan redefined an objective for all of the 25 member States:

Increased use of biomass (solid biomass, biogas, biofuels, renewable municipal waste) that should reach approx. 150 Mtoe in 2010
- **> 55 Mtoe intended for electricity production,**
- **> 75 Mtoe intended for production of heat and**
- **> 19 Mtoe intended for transport**

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EC activities

Biomass Action Plan

This should lead to:

1. **12% share in total energy consumption**
2. **21% share in gross electricity consumption**
3. **5.75% share in vehicle fuel consumption.**

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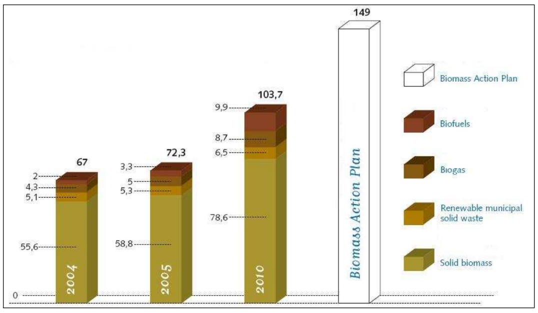
Comparison between the current trend and the EU Biomass Action Plan scenario (in Mtoe)
EurObserv'ER 2006



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Primary production of biogas (in ktoe)
Top 10 countries in the European Union in 2005
(Source: EurObserv'ER 2006)

Country	Landfill gas	Sewage sludge gas	Other biogas	Total
United Kingdom	1,421.0	179.0		1,600.0
Germany	573.2	369.8	651.4	1,594.4
Italy	334.1	0.4	42.0	376.5
Spain	236.5	56.8	23.6	316.9
France	129.0	77.0	3.0	209.0
Netherlands	59.8	50.7	29.6	140.1
Denmark	14.3	20.5	57.5	92.3
Belgium	56.3	9.7	7.8	73.8
Czech Republic	21.5	31.4	2.8	55.8
Poland	25.1	25.3	0.3	50.7

Total EU: 4,715.0 ktoe

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ENERGY	TJ	Ktoe	Ktce	Gwh
Terajoule (TJ)	1	0.024	0.034	0.28
Kiloton oil equivalent (Ktoe)	41.868	1	1.428	11.63
Kiloton coal equivalent (Ktce)	29.308	0.700	1	8.14
Gigawatt-hour (Gwh)	3.6	0.086	0.123	1

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Relative share of biogas production (in %) other than landfill sites and sewage sludge digestion in different EC countries

1. Denmark	62.3
2. Austria	31.9
3. Germany	27,2
4. The Netherlands	19.3
5. Ireland	17.1
6. Italy	11.2
7. Belgium	10.6
8. Spain	8.0
9. Czech republic	5.6
10. France	1.4

Electricity production from biogas (in GWh) Top 10 countries in the European Union in 2004 and 2005

(Source: EurObserv'ER 2006)

Country	2004	2005	Increase (%)
Germany	4,414.0	5.564.0	26.1
United Kingdom	4,383.0	4,690.0	7.0
Italy	1,170.3	1,313.1	12.2
Spain	824.7	879.4	6.6
France	444.0	460.0	3.6
Netherlands	282.0	286.0	1.4
Denmark	265.0	274.0	3.4
Greece	179.0	179.0	0
Poland	155.0	175.1	13.0
Czech Republic	138.8	160.9	15.9
EU total	12,819.9	14.593.8	13.8

1000 GWh (or 1 TWh) is the approximate annual amount of electricity consumed by 45000 households

Governmental incentives in UK and Germany

UK

The **Renewable Obligation Certificate System** of 2002 . This system imposes that electricity suppliers annually increase the renewable electricity share of their electricity production. This obligation was of 3% in 2002- 2003 ; 4.3% in 2003-2004 ; 4.9% in 2004-2005 ; 5.5% in 2005-2006, and should reach 15.4% in 2026-2027.

Germany

The success of biogas origin electricity production in Germany can be explained by

➢ the **Renewable Energy Law** of March 2004. The electricity purchase prices (feed-in tariffs) are especially attractive for electricity production from biomass. Germany has tariffs of up to 21.5 ct/kWh (Fixed feed-in tariffs typically range from 5 to 8 € ct/kWh)

➢ the availability of subsidies in the form of **soft loans** for construction of new biogas plants

Intelligent Energy Europe

EC activities

PROBIOGAS

Promotion of Biogas for Electricity and Heat Production in EU Countries

Economic and Environmental Benefits of Biogas from Centralised Co-digestion, aiming to transfer and apply the results of 20 years of R&D in the field of biogas from centralised co-digestion in Denmark, to six selected case studies in Europe: France, Greece, The Netherlands, Spain, Ireland and Belgium

Project supported by the "Intelligent Energy-Europe" Programme of the European Community

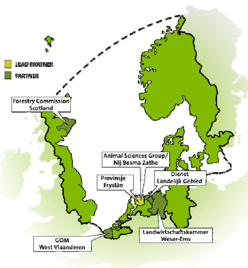
Intelligent Energy Europe

EC activities

PROBIOGAS - Spanish case study: Pla d'Urgell area in Catalonia (by Juan Mata Alvarez, University of Barcelona),

- The region has a high concentration of pig farms. 26% of the overall pig slurry is produced in Catalonia and biodegradable wastes are largely available.
- The energy potential of animal slurry and the available biodegradable wastes in Pla d'Urgell is estimated at 10 to 15 ktoe per year.
- The region is facing great environmental challenges due to the animal breeding and food industries activities,
- there were so far little incentives to recover energy from slurry and organic wastes due to low electricity prices and limited interest for heat utilization.

EC activities



North Sea Bio Energy (NSBE) project

Digital library BioEnergy-Info!

The digital library aims to provide an overview of information resources on bioenergy. The emphasis is on the production of biogas from the (co-)digestion of manure with energy crops (such as energy maize) and the combustion of wood on a small scale.

http://www.bioenergy-info.com/enindex.php

AD-Nett

EC activities

European Anaerobic Digestion Network

information dissemination and a means to put people in touch with each other. It includes news on developments in the network, information about technical developments on anaerobic digestion (AD) of agro-industrial waste and will include reports from databases of plant and contacts

http://www.ad-nett.net/

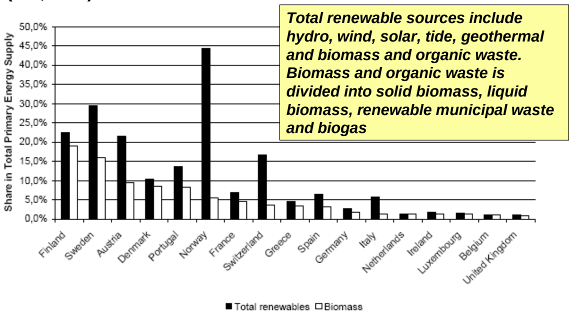
International Energy Agency
Agence Internationale de l'Energie

Member States

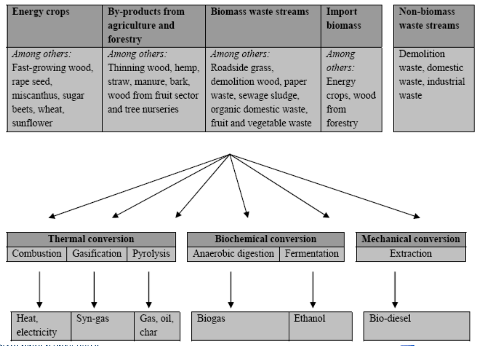
Australia	Greece	Norway
Austria	Hungary	Portugal
Belgium	Ireland	Slovak Republic
Canada	Italy	Spain
Czech Republic	Japan	Sweden
Denmark	Korea	Switzerland
Finland	Luxembourg	Turkey
France	The Netherlands	United Kingdom
Germany	New Zealand	United States

Share of total renewable sources and of biomass and organic waste in primary energy supply in several European countries in 2001. (IEA, 2003).

Total renewable sources include hydro, wind, solar, tide, geothermal and biomass and organic waste. Biomass and organic waste is divided into solid biomass, liquid biomass, renewable municipal waste and biogas



Objective IEA Bioenergy Programme: Improving cooperation and information exchange between countries that have national programs in bioenergy research, development and deployment.



IEA Bioenergy Programme

Task 37: Energy from Biogas and Landfill Gas

Task 37 is a working group which covers

1. **the biological treatment of the organic fraction of municipal solid waste (OFMSW) as well as**
2. **the anaerobic treatment of organic rich industrial waste water.**

- **The main interests are the production of biogas and a digestate of a high quality.**
- **Collection, sorting, gas upgrading and gas utilization are accompanying technologies.**

Members:
Austria, Canada, Denmark, Finland, France, Germany, Sweden, Switzerland, The Netherlands, United Kingdom

5. Concluding remarks

AD has also been shown to be an economically viable sustainable technology for both small-scale rural applications in developing countries and for a range of scales in the developed world.

Biogas is a flexible form of renewable energy that can produce heat, electricity and serve as a vehicle fuel.

AD processes yield valuable fertiliser and reduce emissions and odour nuisances

Thanks to its simple, reliable and proven technology, AD has all the advantages to increasingly become one of the most efficient and economical sources of renewable fuel.

It will become an important component of the available renewable energy technologies and fuels that will be required to substitute for diminishing oil supplies.

Primary production of biogas in the European Union in 2004 and 2005 (in ktoe)

	2004				2005			
	Décharges Landfill Gas	Station d'épuration Sewage sludge gas	Autres biogaz Other biogas	Total	Décharges Landfill gas	Station d'épuration Sewage sludge gas	Autres biogaz Other biogas	Total
United Kingdom	1 327,0	177,0		1 504,0	1 421,0	179,0		1 600,0
Germany	573.2	369.8	351.7	1 294.7	573.2	369.8	651.4	1 594.4
Italy	297.7	0,3	37.5	335.5	334.1	0,4	42,0	376.5
Spain	219,1	52,4	23,6	295,1	236,5	56,8	23,6	316,9
France	127,0	77,0	3,0	207,0	129,0	77,0	3,0	209,0
Netherlands	67,1	53.8	28,9	149.8	59.8	50,7	29,6	140,1
Denmark	13,8	19,8	55,6	89.3	14.3	20,5	57.5	92,3
Belgium	56,3	9.7	7,8	73.8	56,3	9.7	7,8	73.8
Czech Republic	18,6	28,7	2,9	50,2	21,5	31,4	2,8	55,8
Poland	21,5	23.9		45.4	25,1	25.3	0,3	50,7
Austria	11,8	19,1	14,5	45.4	11,8	19,1	14,5	45.4
Greece	20,5	15,5		36,0	20,5	15,5		36,0
Ireland	19,9	4,8	5,1	29,9	24,9	4,8	5,1	34,8
Sweden	12,0	22,1	1,2	35.3	10,1	18,7	0,9	29,8
Finland	16,6	9,9		26,5	16,6	9,9		26,5
Portugal			4.5	4.5			10,0	10,0
Slovenia	5,8	0,9		6,6	6,0	0,7		6,8
Luxembourg			5,00	5,0			6,7	6,7
Slovakia		5.7	0,2	5.9		5.7	0,2	5.9
Hungary	0,7	2,6	0,2	3.5	0,8	2,9	0,2	3,8
Total EU	**2 808,6**	**893,1**	**541,7**	**4 243,3**	**2 961,4**	**898,0**	**855,6**	**4 715,0**

Source: EurObserv'ER 2006

	2004	2005
Germany	4 414,0	5 564,0
United Kingdom	4 383,0	4 690,0
Italy	1 170,3	1 313,1
Spain	824,7	879,4
France	444,0	460,0
Netherlands	282,0	286,0
Denmark	265,0	274,0
Belgium	231,9	236,9
Greece	179,0	179,0
Poland	155,0	175,1
Czech Republic	138,8	160,9
Ireland	101,0	122,0
Austria	57.7	57.7
Portugal	14,6	34.4
Slovenia	30,3	32,2
Sweden	61,6	53.4
Luxembourg	20,3	27,1
Hungary	23,0	25,0
Finland	21,7	21,7
Slovakia	2,0	2,0
Total EU	**12 819,9**	**14 593,8**

Source: EurObserv'ER 2006

Electricity production from biogas in the European Union in 2004 and 2005 (in GWh)

1000 GWh (or 1 TWh) is the approximate annual amount of electricity consumed by 45000 households

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