Potential of Co-digestion

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IEA Bioenergy

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Task 37 - Energy from Biogas and Landfill Gas

IEA Bioenergy aims to accelerate
the use of environmental sound
and cost-competitive bioenergy on
a sustainable basis, and thereby
achieve a substantial contribution
to future energy demands

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Content

What is Co-digestion?

Co–digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. The most common situation is when a major amount of a main basic substrate (e.g. manure or sewage sludge) is mixed and digested together with minor amounts of a single, or a variety of additional substrates. The expression co–digestion is applied independently to the ratio of the respective substrates used simultaneously.

Until quite recently anaerobic digestion (AD) was a single substrate, single purpose treatment. For example manure was digested to produce energy; sewage sludge was anaerobically stabilized and industrial waste water was pretreated before final treatment in a wastewater treatment plant. Today, the limits and the possibilities of AD are better known and co-digestion has therefore become a standard technology.

This report aims to highlight the advantages of co-digestion and to describe a number of successful case stories.

Since agriculture requires high quality fertilisers without pollutants, co-digestion lends itself towards blends of well controlled industrial wastes, grass clippings from parks, food industry wastes, dairy wastes etc. together with dilute substrates such as animal manures or sewage sludge.

There are two major drivers which helped to promote co-digestion:

1. 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. The extra electricity produced allows to cover the energy needs of waste water treatment at a reasonable cost.

2. Agricultural biogas production from manure alone (which has a relatively low gas yield) is economically not viable at current oil prices. Addition of co-substrates with a high methane potential not only increases gas yields but above all increases the income through tipping fees.

Fields of Application

Generally co-digestion is applied in wet single-step processes such as continuously stirred tank reactors (CSTR). The substrate is normally diluted with dry solid contents of around 8 to 15%. Wet systems are particularly useful when the digestate can be directly applied on fields and green lands without solid's separation.

More detailed information on co-digestion process technology can be found in the IEA Task 37 study "Potential of Co-digestion – Limits and Merits" (Source: http://www.novaenergie.ch/iea-bioenergy-task37/index.htm)

Large scale co-digestion plant, Holsworthy, UK
(Picture courtesy of Rudolf Braun, Austria)

Merits of Co-digestion

Co–digestion offers several ecological, technological and economical advantages:

Improved nutrient balance

The digestion of a variety of substrates instead of a single waste type improves the nutrient ratio of TOC[1]:N:P which optimally should be around 300:5:1. It also maintains a reasonable mix of minerals (Na, K, Mg, Mn, etc.) as well as a balanced composition of trace metals. Co-digestion therefore helps to maintain a stable and reliable digestion performance and a good fertilizer quality of the digestate.

Optimisation of rheological qualities

Wastes with poor fluid dynamics, aggregating wastes, particulate or bulking materials and floating wastes can be much easier digested after homogenisation with dilute substrate such as sewage sludge or liquid manure.

The mixing of different substrates allows some flexibility to be able to compensate for seasonal mass fluctuations of wastes. Underloading and overloading of digesters can be avoided and the digestion process can be maintained at a constant rate.

Gate fees and biogas recovery

In agricultural digesters the application of co-substrates can considerably improve the overall economics (payback time) of the plant. Gate fees create a win-win situation: The provider pays significantly lower prices at a farm-scale AD-plant than at an incineration or composting facility (usually a factor of 3 to 4). The farmer takes credit of the increased biogas production and the income from the gate fee.

The increased biogas productivity (m^3 gas per m^3 digester volume and day) compensates for the high investment and running costs of small or medium sized digesters. Provided there is sufficient farmland available, the digestate from co-digestion can be directly recycled as a fertilizer at reasonable cost.

In a country with abundant co-digestion like Denmark or Germany, the biogenic waste materials from industry often become limited. The demand out strips the waste available and gate fees start to drop.

Energy crops as co-substrate

In a limiting situation of industrial wastes, energy crops might become an interesting alternative, especially when the plants are grown on fallow or set-aside land which attracts subsidies.

A number of crops demonstrate good biogas potentials. Traditionally all C4-plants have very good growth yields. Corn for example has become a quite popular co-substrate in Germany. To make sure that the corn grown on set-aside land is taken out of the nutrition chain, it is treated after harvest with manure before it is ensiled.

In Austria, Sudan grass, another C4-plant, is grown as an energy crop for co-digestion. It demonstrated excellent growth yields even on the dry soils in the south-eastern parts of Austria.

MERITS of CO-DIGESTION

– Improved nutrient balance for an optimal digestion and a good fertilizer quality
– Homogenisation of particulate, floating, or settling wastes through mixing with animal manures or sewage sludge
– Increased, steady biogas production throughout the seasons
– Higher income thanks to gate fees for waste treatment
– Additional fertilizer (soil conditioner)
– Renewable biomass production for digestion (“Energy crop”) as a potential new income of agriculture

[1] TOC = Total Organic Carbon

Available Feedstocks

Worldwide, the anaerobic stabilization of sewage sludge is probably the most important AD process. Agricultural digesters are eventually more numerous however, the volumes treated are by far smaller than the ones of sewage sludge even though the potential is by a factor of 45 higher. The explanation is the economic background. AD of manure is primarily done for energy production. A digester on a farm is an extra piece of equipment which has to be financed by the energy produced whereas sewage sludge is a waste product of waste water treatment which has to be stabilized. e.g. by AD. The digester is therefore paid for by the polluter (or the local government body).

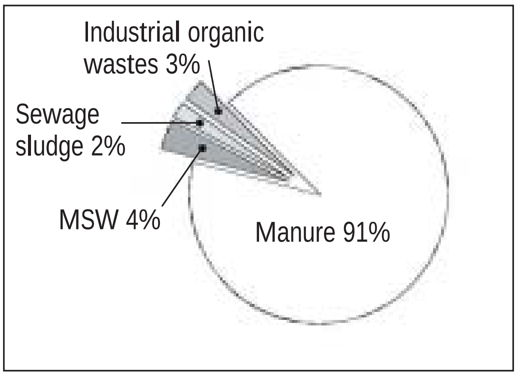
As explained above the addition of well defined industrial wastes might well improve the economic situation of on-farm digestion today. However, the limiting availability of substrates makes very clear, that co-digestion of industrial wastes is not the ultimate solution for increasing the biogas production. There is simply not enough material available. In future the digestion of manure together with energy crops will be the substrate of choice.

Today, the inclusion of a waste product for co-digeston is economically essential.

A number of organic substances which are anaerobically easily degradable without major pre-treatment. Among these are leachates, slops, sludges, oils, fats or whey. Some wastes (e.g. proteinacious wastes) can form inhibiting metabolites (e.g. NH_3) during anaerobic digestion which require higher dilutions with substrates like manure or sewage sludge. A number of other waste materials often require pre-treatment steps (e.g. source separated municipal bio-waste, food leftovers, expired food, market wastes, harvest residues). There is only a limited stock of organics which is poorly suitable for AD due to either high cost of pre-treatment, inhibiting components, poor biodegradability, hygienic risks or expensive transport (e.g. straw, lignin rich yard waste, category 1 slaughterhouse animal by-products).

Organic wastes and by-products for co-digestion with their approximate biogas yields in m³ per ton organic solids

MATERIALS	m³/t
HARVEST RESIDUES	
Straw, stems, sugar beet toppings, fibrous material	375
ANIMAL MANURES	200-500
Food industry waste	
Dough, confectionary waste, whey	400-600
YEAST AND YEAST LIKE PRODUCTS	
Yeast- and sludge from breweries, wine making, distilleries	400-800
RESIDUES FROM ANIMAL FEED PRODUCTION	
Expired feed	500-650
SLAUGHTERHOUSE WASTE	
Flotation sludge, animal fat, stomach- and gut- content, blood	550-1,000
WASTES FROM PLANT- AND ANIMAL FAT PRODUCTION	
plant oil, oil seed, fat, bleaching earth	1,000
PHARMACEUTICAL WASTES	
Proteinacious wastes, bacterial cells and fungal mycelium	1,000-1,300
WASTE FROM PULP- AND PAPER INDUSTRY	400-800
Other wastes	
Sludge from gelatine and starch production	700-900
BIOWASTES FROM SOURCE SEPARATED COLLECTION	400-500
MARKET WASTE	500-600
SEWAGE SLUDGE	250-350



Origin of the of organic wastes collected in Europe (1,228 million tons per year).
MSW = **M**unicipal **S**olid **W**aste.
(Final Report EU Altener Waste for Energy Network, EU Contract Nr. 4.1030/D/95-006)

Waste Management Legislation

The possible use of wastes as co-substrates in anaerobic digestion is influenced and determined by EU legislation and/or National legislation and technical guidelines such as

– landfill
– soil protection
– groundwater protection
– waste collection and treatment
– human and animal health
– waste recovery
– legal definition of anaerobic digestion as a waste treatment or as a recovery process

Some of the legislation will promote co-digestion, some will reduce the potential of its application. Over the next years the waste material available for AD will increase substantially, mainly driven by waste legislation and the Kyoto protocol which introduces CO_2 trade. Land filling of untreated organic waste is gradually being reduced and in some of the European countries will soon be completely prohibited.

New regulations, favouring composting and anaerobic digestion, can be found in several IEA member countries. The EU has recently introduced a regulation (2nd draft) on "Biological Treatment of Bio-waste", favouring composting and anaerobic digestion and providing a positive list of suitable wastes.

By defining specific sterilization requirements, the EU regulation 1774/2002 will strongly influence the future use of huge organic mass streams like food leftovers and animal by-products not intended for human consumption.

Similarly national groundwater protection legislation aims for the prevention of groundwater and drinking water contamination.

An overview of the national legislation in the EU countries was made by Nordberg (ADNett Final Report 2000[2]) in the frame of the EU funded concerted action AD-Nett, a Network on Anaerobic Digestion.

Legislation on organic waste reduction in landfills in selected European countries

COUNTRY	BANNING YEAR	CRITERIA / REMARKS
EU		Reduction of untreated organic waste to 35% by 2014
Austria	2004	Waste >5% TOC or Upper heating value >6 MJ/kg TS
Denmark	1997	Ban for all wastes that can be incinerated
Finland	2002	All wastes shall be treated prior to landfill
Sweden	2005	All untreated organic wastes
Switzerland	2000	All organic waste
U.K.		Reduction targets for biodegradable wastes based on 1995 levels: Down to 75% by 2010; down to 50 % by 2013 and down to 35% by 2020. Since 2001 new landfills must only take pretreated waste

Pre-treatment Requirements of Co-substrates

Beside biogas as the energetic product of AD, the digestate is an important and valuable organic fertilizer. However, it only finds a market when the product is environmentally and hygienically safe and free of visible contaminants such as plastics, stones and metals.

The best and most economical way is to use clean (unpolluted) co-substrates with a high gas potential. If waste materials do contain undesired components they have to be taken out preferentially before digestion. This is often mandatory in order to avoid pipe blockage, scum formation, bottom layers, or damage of pumps and mixing devices. Such pre-treatment may require highly sophisticated machinery and may cause considerable operational costs.

The content of undesirables in the co-substrate is strongly influenced by the type of collection (bins, plastic bags, paper bags, etc.), the region of collection (sandy soils, etc.), the people's habits, the season and other factors.

In principle, two major AD techniques are applied for solid organic substrates (e.g. source separated organic household waste). These are dry,-respectively wet digestion processes. Dry AD

[2]) Brochure "Anaerobic Digestion": Making Energy and Solving Modern Waste Problems; Ortenblad, H. (Ed.) Herning Kommunale Vaerker, Postbox 1020, DK-7400 Herning, Denmark

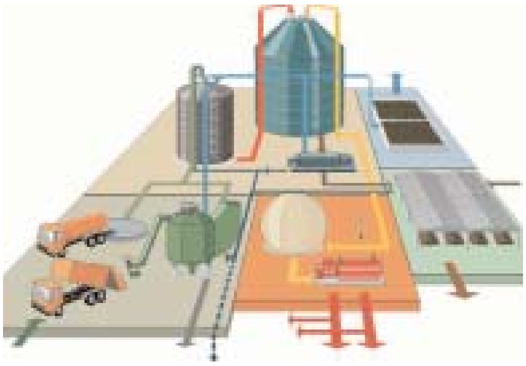
processes operate at TS concentrations of > 20% and require less pretreatment for contaminant removal. Wet AD processes are run with dilute substrates (< 10 % Total Solids) and demand for higher efforts in contaminant removal. Wet separation processes (i.e. pulper) are used for removal of light (e.g. plastics) and heavy fractions (e.g. gravel, sand) of contaminants.

The pre-treatment processes

Only few organic wastes, require extended preconditioning for wet co–digestion. Among these are bio-wastes from separate collection, garden and yard wastes, market wastes, expired food as well as some industrial wastes (e.g. leather industry waste). For most of the more problematic wastes cited, dry digestion offers the easier solution since the material doesn't separate much as long as the dry matter content remains above 25% total solids.

The pre-treatment steps might include three basic processes:

– Size reduction of the substrate
– Removal of indigestible components
– Hygienization

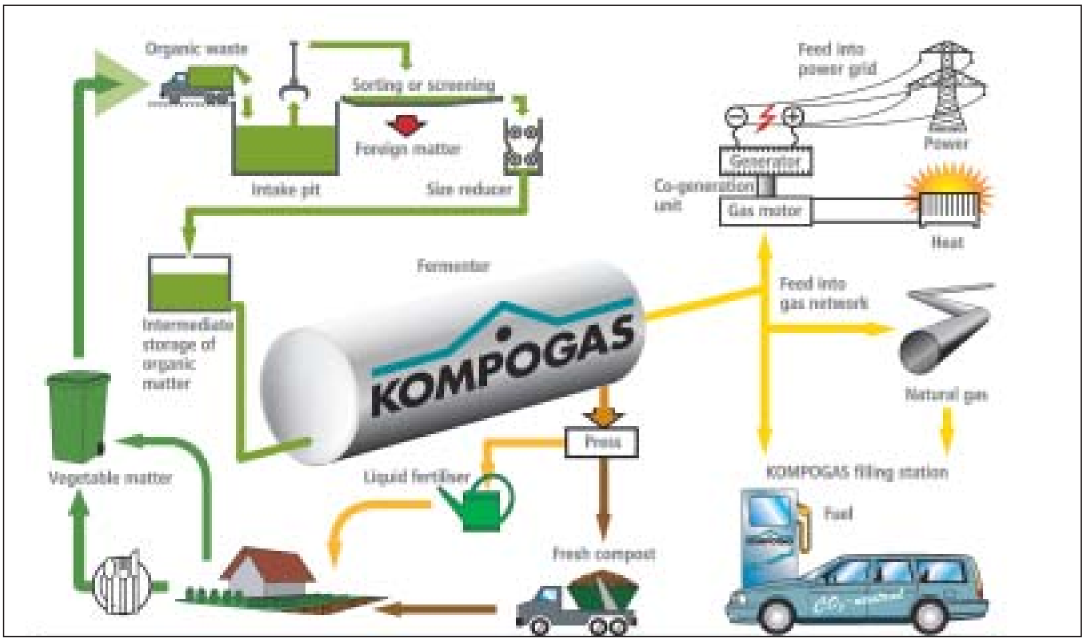


General scheme of a bio-waste wet anaerobic digestion process showing biowaste receiving area for slurries and solids, wet separation of contaminants (pulper), homogenisation and digestion tanks, dewatering of fermentation residues (centrifuge) followed by composting and finally gas storage and utilisation (Combined heat and power plant). Scheme courtesy of LINDE-KCA, Germany

Usually an extended pre-treatment requires:

– chopping,
– sieving,
– removal of metals,
– removal of glass, sand, stones, etc and
– homogenisation (mixing).

Wet separation processes remove settled out materials (glass, stones) and floating materials (plastics, wood, rubber) after the addition of recycled water. The technology is well established



General scheme of a bio-waste dry anaerobic digestion process (Scheme courtesy of Kompogas, Switzerland).

Overview on legislation and guidelines influencing organic waste recovery through anaerobic digestion

DESIGNATION	SOURCE	REMARKS
Council directive 1999/31/EC on the landfill of waste	Official Journal of the European Communities L 182/P.1-19 (16.7.1999) http://www.deponie-stief.de/recht/eg/texte/deponierili/egrili_en.pdf	Reduction of organic waste in landfills of untreated organic wastes from 2004 onwards up to 65% in 2014.
EU guideline "Biological treatment of bio-waste"	European Commission (2001) http://www.compost.it/biod.pdf or http://europa.eu.int/comm/environment/waste/facts_en.htm	List of organic wastes and by-products, allowable for composting and/or anaerobic digestion; limiting values for contaminants; Guideline is in preparation; 3rd draft appears 2003
Regulation (EC) no 1774/2002 of the European Parliament and of the Council laying down health rules concerning animal by-products not intended for human consumption	Official Journal of the European Commission L273/2 http://europa.eu.int/servlet/portail/RenderServlet?search=DocNumber&lg=en&nb_docs=25&domain=Legislation&coll=&in_force=NO&an_doc=2002&nu_doc=1774&type_doc=Regulation	Definition of 3 main groups of animal by-products (including manure, food leftovers, stomach contents), with specific thermal sterilization and biogas plant equipment requirements
Regulation EC No 2150/2002 of the European Parliament and of the Council on Waste Statistics	Official Journal of the European Communities L332/1P.1-36 (9.12.2002) http://europa.eu.int/servlet/portail/RenderServlet?search=DocNumber&lg=en&nb_docs=25&domain=Legislation&coll=&in_force=NO&an_doc=2002&nu_doc=2150&type_doc=Regulation	Establishment of waste statistics including nomenclature and classification

for the pre-treatment of bio-waste in large-scale bio-waste digestion plants and can be principally applied for the extraction of a digestible waste fraction for co–digestion.

It is generally accepted that wet separation processes achieve higher impurities removal compared to dry separation. However, the processes are more laborious and therefore expensive. Dry separation processes leave higher concentrations of sand, glass splinters, plastic particles and other impurities in the final product. The selection of a proper pre-treatment process must always be waste specific, in accordance with the digestion process applied and adjusted to the product quality required.

Hygienization

Potentially infectious material must be hygienized by law. There are country specific regulations but in general we can distinguish between three degrees of pathogen control:

– Sterilization (20 minutes at 2 bars, 121°C)
– Pasteurisation (Between 70° and 90°C for 15 to 60 minutes)
– Sanitation (heat treatment at lower temperatures over an extended time period)

Pulper unit for removal of settlable and floating impurities from biowaste in wet fermentation processes (Picture courtesy of LINDE KCA, Germany)

Hygienization unit (70°C, 60 Min) using exhaust waste heat, in a small scale agricultural biogas-plant (picture courtesy of Rudolf Braun, Austria)

For most bio-wastes thermophilic operation of digesters is considered as sufficient for a reliable hygienization. National guidelines sometimes require treatment at elevated temperatures between 70-100°C for at least 30 to 60 minutes. The forthcoming European guideline "Biological treatment of bio-waste" (2nd draft available) allows either

– thermophilic digester operation (i.e. 55°C guaranteed for 24 hours at minimum residence times of at least 20 days), or
– in case of mesophilic digestion pre-treatment of substrates at 70°C for 60 minutes, or
– post–treatment of the digestate at 70°C for 60 minutes, or
– composting of the digestate.

Accordingly, various specified animal by-products and wastes have to undergo sterilization before anaerobic digestion. The hygienization guideline (EC) 1774/2002 defines 3 categories of animal by-products and, dependent on the intended application, specifically assigns 6 different thermal pre-treatment procedures to category 2 and 3 materials.

Category 1 materials (i.e. specified TSE risk materials, catering wastes from international transportation) may not be used for anaerobic digestion.

Exceptions are defined for manure, stomach- and gut contents (Category 2 materials), or food leftovers (Category 3 materials), which under specified conditions must not undergo hygienisation prior to anaerobic digestion.

Additional Technical Equipment Requirements for Co-digestion

Technical equipment

Depending on the quality and nature of the waste to be used for co-digestion and the size of the operation, some additional digester equipment may be required for achieving a reliable digestion. Basically, additional equipment or precautions may be required for

– delivery of the waste,
– homogenisation and mixing of co-substrates,
– prevention of excessive foaming and scum layer formation,
– removal of sediments from the digester.

Most of the biowaste is delivered in special containers or trucks. Unloading of the material should be done in an enclosed building with under pressure to avoid odour emissions. Normally, the viscous air is treated in a bio-filter. After unloading the truck should be cleaned and sanitized on the inside to prevent transfer of pathogens and washed on the outside to make sure that the roads don't become dirty. An excellent standard of unloading stations has been set by the Danish Biogas companies.

Since many co-substrates cannot be fed directly into the digester, a premixing and homogenizing tank has to be provided. Often, the homogenisation tank can be combined with a pasteurisation step.

The high efforts required for pre-treatment of some co-substrates can often not be met by small scale biogas plants. Such plants are more or less restricted to co-substrates requiring no, or only minor pre-treatment. If extensive waste pre-treatment is required, usually only large-scale centralized farm digesters, industrial applications or municipal sewage sludge co-fermentation plants can meet the requirements.

Analysis, monitoring and documentation

Minimum requirements for regular waste documentation are the recording of

– type (composition) and amount of input waste materials (and unwanted contaminants),
– origin of waste materials,
– results of visual input waste control and
– amount of digestate leaving the plant.

This information must be collected in the plant operation diary together with the date and signature of the operator.

It is strongly recommended that wastes which are used for the first time are analysed regarding composition and potential inhibitors.

Process control

Depending on the size of the operation the monitoring of the process can be kept at low level. The most important control parameters are the overall daily substrate flow (m^3/d, tonnes/d) and the quantity of biogas produced daily (m^3/d). For proper control the determination of the CH_4 – concentration is highly advisable. In case of co-digestion, additionally type and amount of separated impurities must be registered. A periodic calculation of the resulting biogas yield (daily biogas amount divided by daily substrate flow) can give a clear picture of the efficiency of the digestion process. In large scale operations the analysis of the volatile fatty acids and the ammonia concentration is recommended.

Possible influences of co-substrates on the digester behaviour should be recorded. Especially the frequently occurring formation of scum layers and formation of bottom sediments must be observed carefully.

In case of sterilization, the type and amount of wastes and the treatment conditions (time and temperature) have to be monitored and documented additionally.

The forthcoming European guideline "Biological treatment of bio-waste" (2nd draft available) comprehensively defines for plants over 500 t/a of biowaste and for plants over 250 t/a digesting other wastes (e.g. food waste), the sampling frequency and methods for analysis required for quality assurance of the end product digestate or compost.

Utilisation of digestate

The digestate contains non-digestible and residual particulates, and liquid organic and inorganic waste constituents, as well as bacterial biomass.

Farm scale and even large-scale co-operative agricultural (liquid) digesters, use the digested slurry without further treatment as a fertilizer on farm land. Sufficient slurry storage capacity is required (national legislation usually defines storage capacities in function of climate and altitude from 3 to 8 months). For ecological reasons storage in covered, gastight tanks is required. Depending on local regulations, spreading is often allowed exclusively on the proper farmland. Typically dragging hose quipment should be used for the environmentally friendly spreading of manure. The amount of co–substrate permitted in manure digestion can also be limited. Strict limits also exist for the total yearly amount of nitrogen introduced into the soil and for the possible entry of heavy metals. An overview on limiting values for heavy metals as well as the maximum yearly nutrient load from digestate has been collected by Nordberg (ADNett Final Report 2000).

Environmentally friendly dragging hose spreading of manure (Picture courtesy of Teodorita Al Seadi; Denmark)

Large-scale commercial agro-based bio-waste digesters are generally bound by law to further process the digested slurry. After dewatering, the particulate fraction is usually composted. Surplus wastewater is used on the fields or treated aerobically in activated sludge type plants according to local demands. For commercial plants, national limits must be met for the quality of compost, as well as for the quality of wastewater effluent and for biogas combustion emissions.

The forthcoming EU guideline "Biological treatment of bio-waste" defines two classes of quality for compost and digestate, as well as the amount of compost or digestate allowable for soils. The classification is based on: the heavy metal content; the PCB and PAH content; the content of impurities > 2 mm; and the content of gravel and stones > 5 mm.

Selected Examples of Co-digestion Plants

Basically the main treatment and recovery alternatives for organic wastes and by-products are
- direct use as soil conditioner or fertilizer (e.g. manure, crop residues, sewage sludge),
- direct use as animal feed or feed supplement (e.g. yeast sludge, whey, crop pulp, husks and stalks),
- upgrading to compost,
- upgrading to biogas and compost, or
- incineration.

The percentage of anaerobic digestion plants in waste treatment processes is steadily increasing in particular the number of co-digestion plants.

In fact, a number of existing municipal sewage sludge digesters are already using co-substrates. New sewage treatment plants or plant extensions increasingly implement co-substrates such as source separated bio-waste, food leftovers, fat wastes, flotation sludges and various other materials.

The addition of co-substrates yields an improvement of the energy balance. As an average the self-sufficiency of electricity is around or even below 50% when using sewage sludge as the only substrate. With co-substrates the coverage can be as high as 80% or in a few cases a WWTP can even become a net energy producer. As a further advantage, a controlled organic waste disposal (e.g. fat trap contents, food leftovers etc.) can be achieved in the communities concerned.

In agriculture co-digestion has become a standard technology. Many small and medium sized farm scale digesters use considerably high amounts of single or mixed co-substrates together with manure. In 2002 about 2,000 agricultural plants were in operation in Germany, most of them using co-substrates. Considerably less were in function in Austria (110), Switzerland (71), Italy (> 100), Denmark (>30), Portugal (>25), Sweden, France, Spain, England and some other countries.

In Denmark and to a smaller extent in Sweden and Italy, several farmer co-operatives or companies successfully operate large-scale farm digesters. The digester residues are recycled to farm land, while biogas is used for electricity production or in some cases is upgraded as a fuel.

More examples can be found on the IEA Task 37 "Biogas and Landfill Gas" – webpage: <www.novaenergie.ch/iea-bioenergy-task37>

Co–digestion of energy crops

Energy crops like maize, sunflower, grass, beets etc., are increasingly added to agricultural digesters, either as co-substrates or as the main or in some cases as a single substrate. The cultivation of energy crops on fallow- or set-aside land can reduce agricultural surpluses and provide a new income for agriculture. Biogas produced from energy crops therefore helps to achieve the "EU White Paper" target of substituting up to 12 % of the overall energy demand through renewable energy sources by 2010.

Energy yield

The most popular crop today is maize. Depending on the climate the crop yield achieves values up to 20 tonnes dry matter per ha.

From one ton of maize (dry matter) approx. 400-600 m^3 biogas is produced. As a rule of thumb we can say that
1 ha of maize (silage) yields:
8.000-12.000 m^3 biogas (50 % CH_4-content) or
13.200-19.800 kWh electricity

Large Scale Centralised Co-digestion Plant Lemvik, Denmark (Picture courtesy of Teodorita Al Seadi, Denmark)

Successful Case Studies

Farm scale energy crop co-digestion

Energy crop digestion is critically dependent on electricity prices obtainable per kWh. The capital payback time of evaluated farm scale biogas plants lies between 9–13 years which is high, but still reasonable for agricultural machinery. Provided low crop production costs at high yields per hectare and a high biogas yield during fermentation can be achieved, energy crop digestion can become economically viable without subsidies.

Large scale centralized co–digestion

Large-scale industrial plants usually have more favourable economics. The plant shown is one of the large scale centralised Danish co-digestion plants. Typical examples (e.g. digester volumes 4,650 – 6,000 m^3) have payback times between 3 and 10 years. However, pre-condition for economic success still is a careful design, layout and operation as was shown by a recent survey on 17 large-scale Danish centralized agricultural biogas plants[3].

Unfavourable economics can be caused by reduced or missing gate fees obtainable for the wastes treated.

Future deployment of co-digestion can also be adversely influenced by the currently increasingly restrictive legislation on allowable wastes and the more restricted reuse of digestate.

Agricultural Co-digestion Plant in Austria (Picture courtesy of Rudolf Braun, Austria)

[3] Brochure "Centralized Biogas Plants"; Christensen, J. (Ed.), Danish Institute of Agricultural and Fisheries Economics, Univ. Southern Denmark, DK-6700 Esbjerg

Large Scale Centralised Co-digestion Plant Grindsted, Denmark
(Picture courtesy of Rudolf Braun, Austria)

Municipal sewage sludge co–digestion

Due to increased biogas yields, the co-digestion of bio-wastes together with municipal sewage sludge in existing municipal sewage digesters can considerably reduce wastewater treatment costs. Therefore, in many municipal sewage sludge digesters, organic wastes are co-digested on an occasional basis. Some successful examples from sewage treatment plants have been reported in Denmark, Germany and Switzerland. Several new co-digestion plants have been built recently, dedicated for combined sewage sludge and bio-waste treatment.

Typical co-substrate addition rates in sewage sludge digesters are between 5-20 %. Addition of flotation sludge, fat trap–contents, food leftovers, proteinacious wastes etc. considerably raises the biogas productivity of sewage sludge digesters by 40-200 %. Nevertheless, if co-digestion is to be implemented into existing sewage treatment plants, depending on the bio-waste concentration and rheology, additional pre- and post-treatment equipment has to be installed.

Economic evaluation of a typical farm scale energy crop co-digestion plant

PARAMETER	
DIGESTER VOLUME (m^3)	700
MAIN SUBSTRATE	Corn silage
CO-SUBSTRATE	manure
INVESTMENT COSTS (Euro)	**250,000**
SUBSIDIES (Euro)	**50,000**
NET ENERGY (kWh/a)	750,000
ELECTRICITY RATES (Euro cents/kWh)	10,23
RUNNING COSTS (Euro/a) Labour Maintenance Various	**58,200** 9,000 750 48,450
INCOME (Energy, Euro/a)	78,225
INCOME (Co - substrates)	0
TOTAL INCOME (Euro/a)	**78,225**
NET MARGIN (Euro/a)	**20,025**

Economic evaluation of a large scale, centralised co-digestion plant

PARAMETER	
DIGESTER VOLUME (m^3)	6,600
MAIN SUBSTRATE	Piggery manure
CO-SUBSTRATE	Industrial waste (20%)
INVESTMENT COSTS (Euro)	**5,493,300**
SUBSIDIES (Euro)	**0**
NET ENERGY (kWh/a)	23,203,000
ELECTRICITY RATES (Euro cents/kWh)	8 – 8,7
RUNNING COSTS (Euro/a) Labour Maintenance Various	**452,132** 164,666 124,000 163,466
INCOME (Energy, Euro/a)	905,200
INCOME (Co - substrates)	146,000
TOTAL INCOME (Euro/a)	**1,051,200**
NET MARGIN (Euro/a)	**599,068**

Lessons Learned

Co-digestion can offer several benefits. Most important are:

– Digester operational advantages, e.g. better nutrient balance, improved co-substrate handling, improved fluid dynamics;
– Improved overall process economics, e.g. higher biogas yields and additional income from gate fees paid for the waste materials digested,
– Most of the chemical energy of the substrates is turned into biogas, less spent solids are to be processed and applied as fertilizer or soil conditioner,

Landfill bans for organic wastes bring numerous questionable substrates to the market and special care has to be taken for proper selection and analysis of waste materials to be used in co-digestion.

The application of co-substrates causes additional efforts due to

– legal requirements, e.g. contaminant analysis, hygienisation and
– necessary technical equipment, e.g. contaminant removal, heat treatment, homogenisation, additional mixing requirements;

Care has to be taken for sustainable operation. Only high quality digester residues will be allowed for composting and land application in the future.

High quality industrial co-substrates are limited. In the future much more co-substrates must be derived from "Energy Crop" production, e.g. maize, fodder beets, grass.

Recommended Further Reading

BRAUN, R. (2001): *Stand der Technik der Bioabfallvergärung.* Study on behalf of the Environmental Legal Agency of Vienna, A-1190 Wien, Muthgasse 62

IEA (2001): *Biogas and More – Systems and Markets Overview of Anaerobic Digestion.* IEA Bioenergy Task 37, c/o Nova Energy, email: <office@novaenergie.ch>.

LUA (2000): LUA Draft Guideline "*Mitbehandlung von biogenen Abfällen in Faulbehältern*". Landesumweltamt (LUA) Nordrhein – Westfalen, Germany

VDMA (1997): VDMA Einheitsblatt 24435 "*Anlagen und Komponenten zur anaeroben Abfallbehandlung*", VDMA Verband Deutscher Maschinen- und Anlagenbau e.V., Frankfurt / Main