Co-digestion: Some European Experiences
Co-digestión: Algunas experiencias Europea

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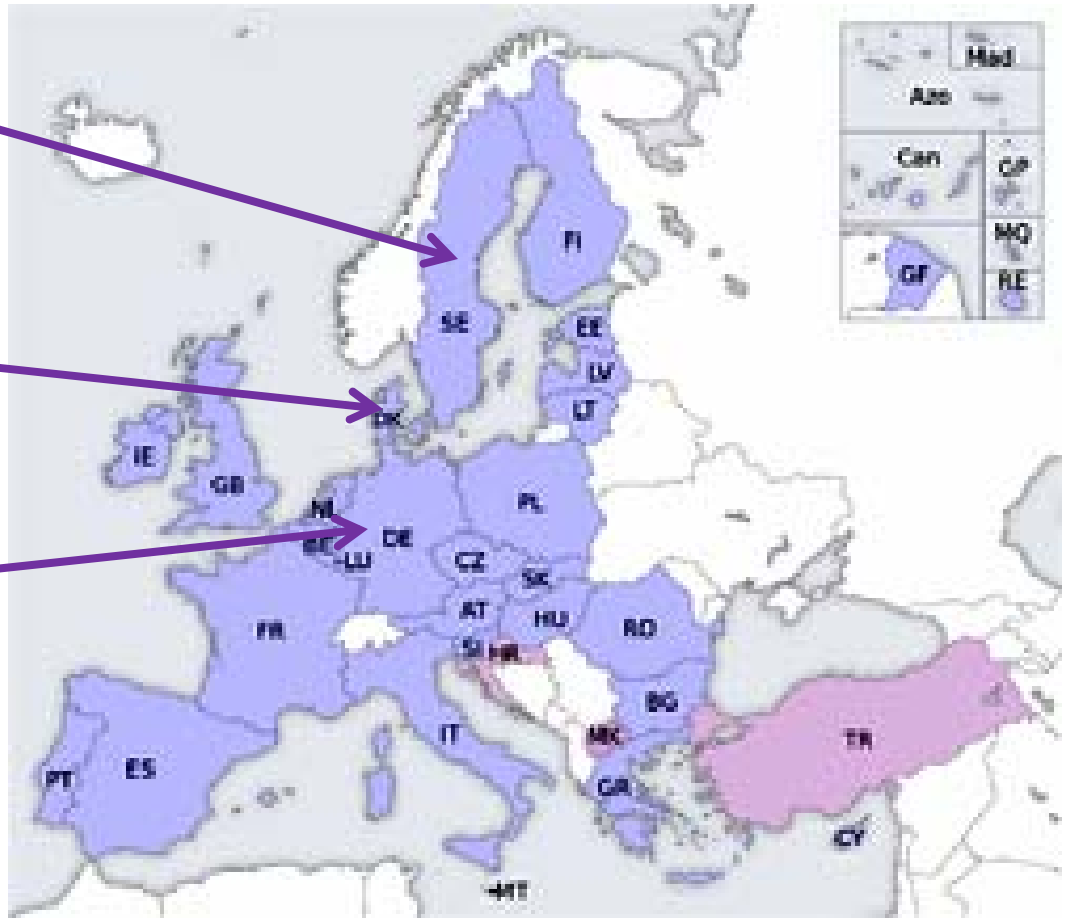
3 countries leading in co-fermentation

3 países líderes en co-fermentación

- Sweden
  - *Suecia*
- Denmark
  - *Dinamarca*
- Germany
  - *Alemania*



Co-Digestion
Co-fermentación

Anaerobic treatment of manure and sewage sludge

Tratamiento Anaeróbio de estiércol y de lodo de aguas residuales

- **long history in Germany**
- **today: preferred process for sludge stabilisation and for manure treatment**
- **use of biogas in block heat and power plant to generate electrical and thermal energy**
- **WWTPs: own requirement can be generated: 30 - 50 % of the electrical energy , nearly 100 % of the thermal energy**

Co-Fermentation of sewage sludge and biogenic waste

Co-fermentación de lodo de aguas residuales y de desechos orgánicos

- **relatively new process**
- **common treatment of sewage sludge or manure with bio-waste (co-substrates) in digesters of WWTPs, farms, or specialised centralised biogas plants**
- **digester gas production can be increased**
- **depending on the type and quantity of the co-substrates added gas generation can increase so strongly that a self-sufficient energy operation of the WWTP is possible, energy-farming will be promoted, and surplus energy will be sold.**

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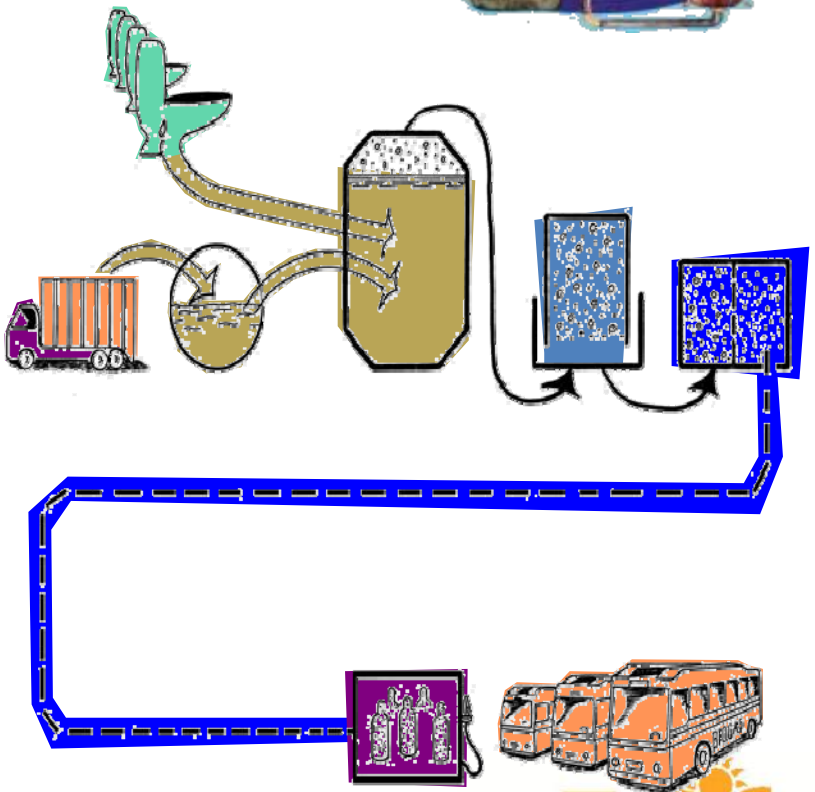
Closed loop economy

Economía de ciclo cerrado



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Co-Fermentation: the conflict behind

Co-fermentación -el conflicto detrás

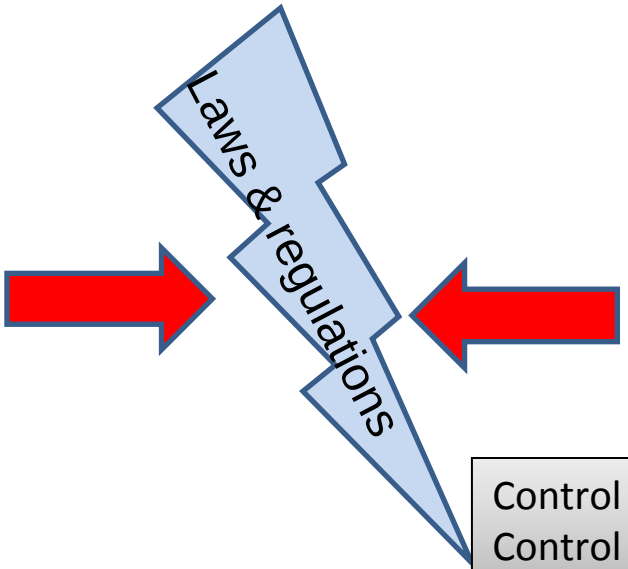
Promotion of Circular Economy / Promoción de la Economía Circular

Use organic products as much as possible for renewable energy generation and recycling on fields (fertilizer)

Do not contaminate soil, water, food with secondary products from energy carrier production

Farmers
Biogas operators

Health authorities
Environmental authorities



Sustainable Energy
Energía sustentable

Ground water and soil pollution
Contaminación de aquifero y tierra

Control of residues & pathogens
Control de patógenos y resíduos

European Fertilizer and Waste Management Regulation

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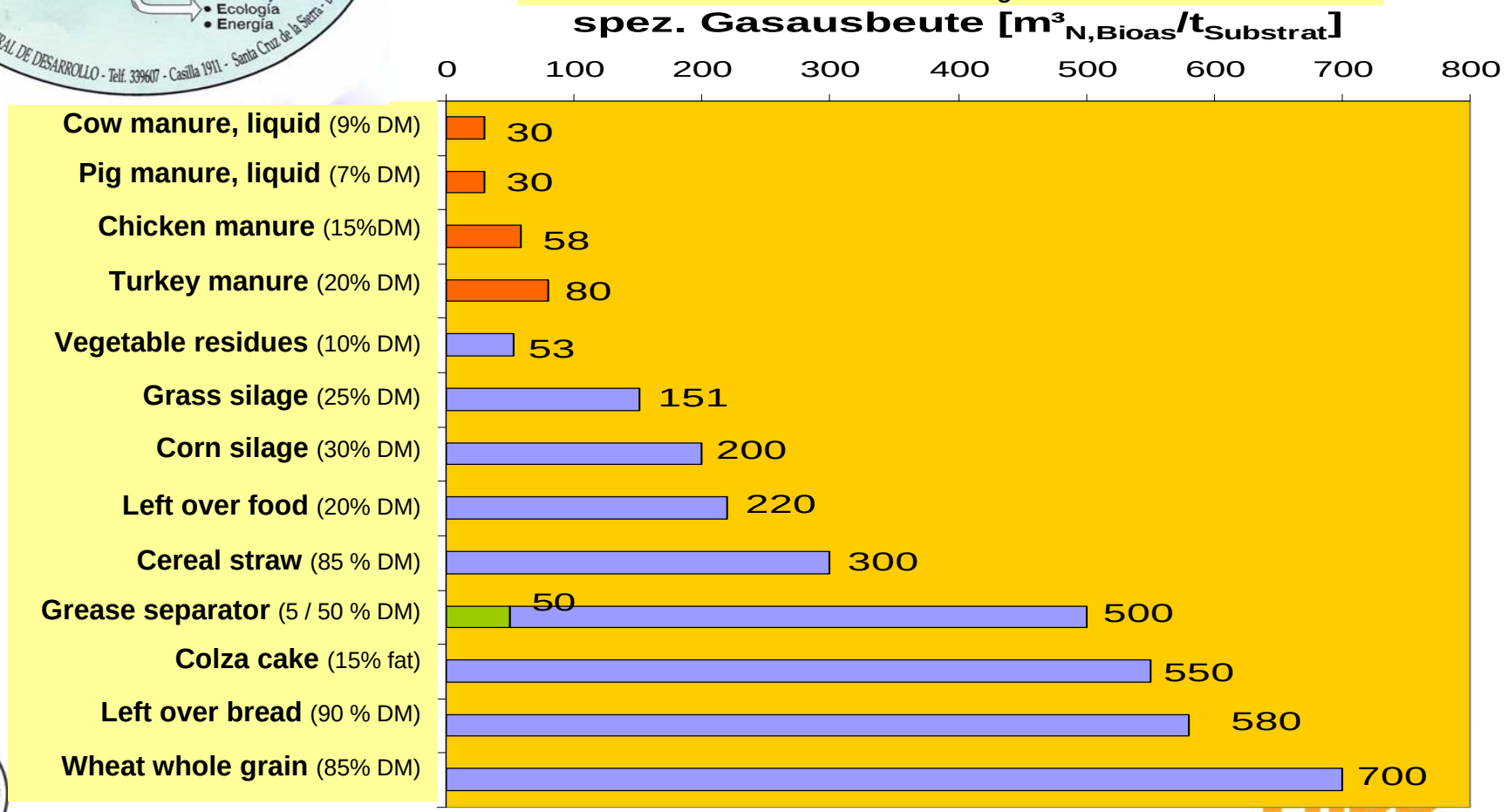
Energy from Co-Fermentation

Gas yields from different substrates

Rendimiento de gas en base de varios sustratos

spec. gas yield m^3 $_{N.Biogas}$/ t $_{substrate}$



Economy / economía

The operator of the **co-digestion biogas plant** increases his earnings in two ways:

Applicando la co-fermentación se aumenta las ganancias en dos maneras:

(1)just by taking the co-ferments from those who should/wants to dispose them

(1) Utilizando co-sustratos que deben ser descargados

(2) through higher energy production.

(2) a través del incremento de la producción energética

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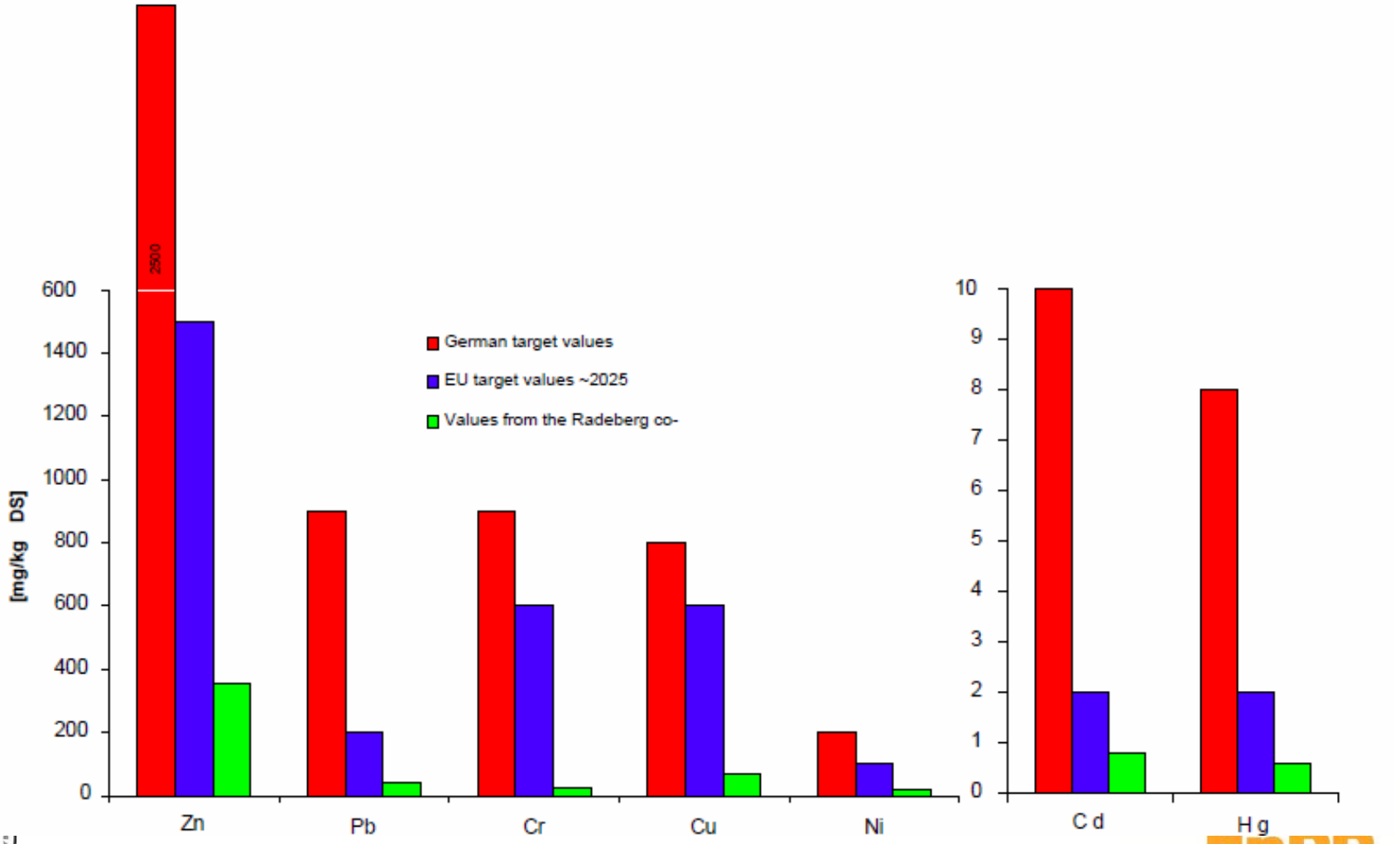
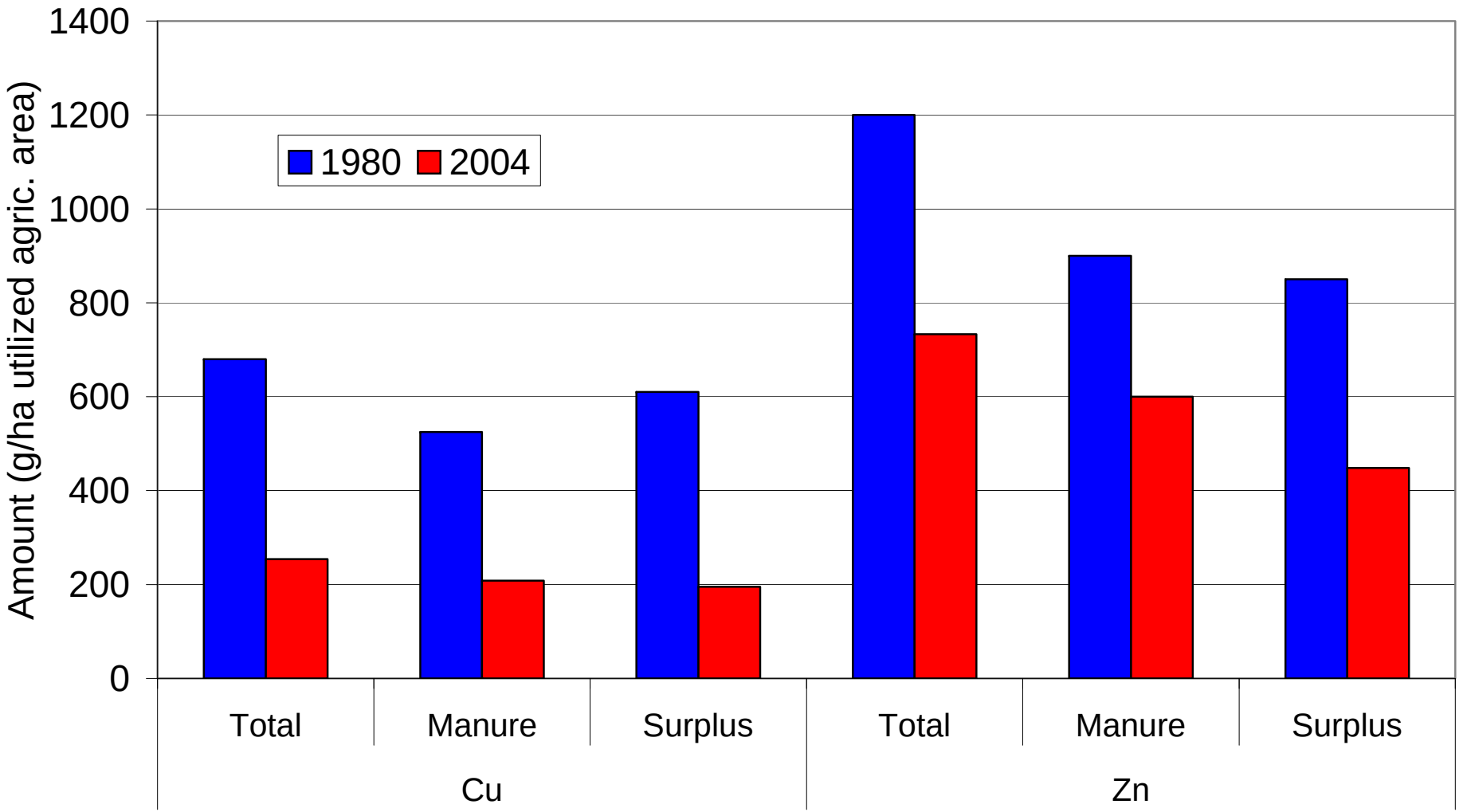
Comparison of target values for heavy metal content in treated sewage sludge used in agriculture with the values of sludge after treatment in a German co- fermentation plant

Valores metas y resultados de tratamiento de lodo de aguas residuales referente al contenido de metalos pesados



Cu and ZN Amount per hectare agricultural area in NL

cantidad aplicada / ha area agrícola



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Limited number of chicken/ha (exp. The Netherlands)
(max. 37.1 kg P, 150 g Cu and 600 g Zn per ha of arable land)
numero limite pollo/ha (ej. Los Países Bajos)

	Broilers	Layers
P	2680	245
Cu, EU < 2004	1300	110
Cu, EU ≥ 2004	1960	155
Cu, 15 mg/kg	3890	255
Zn, EU < 2004	740	60
Zn, EU ≥ 2004	1370	105
Zn, 100 mg/kg	2430	160

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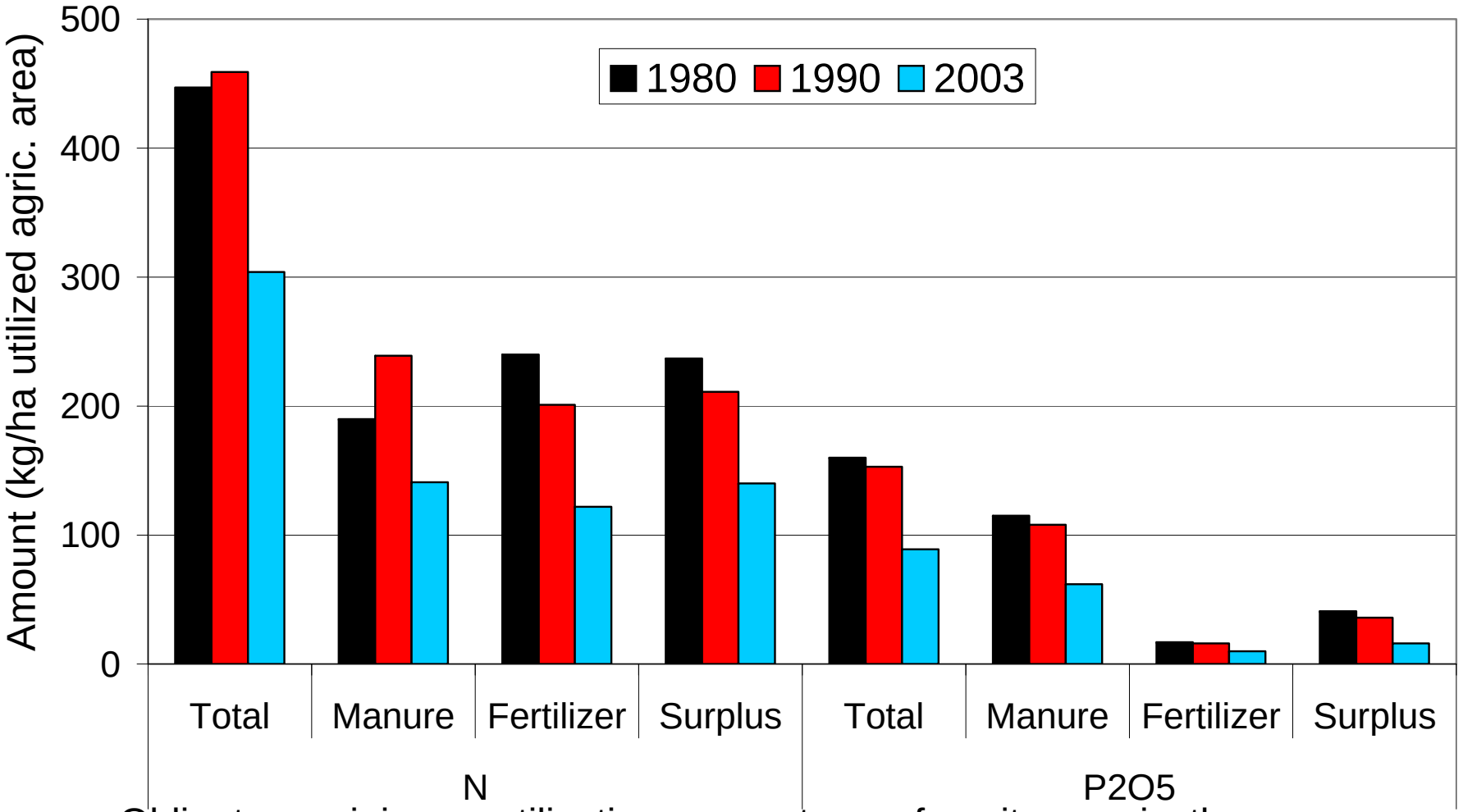
Amount / hectare utilized agricultural area in NL

cantidad aplicada / ha area agrícola – ej PB



Obligatory minimum utilisation percentages for nitrogen in the manure and fixed maximum total application of nitrogen in manure and fertilisers for each crop.

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Characteristic values of substrates with different co-ferments

características de differentes sustratos para co-fermentación

Input	% of substrate	DM %	Total N (% of DM)	GVE/ha
Liquid pig manure	30	7.7	7.7	1.8
Grease trap content	30	20	1.1	0.7
Food leftovers	20	25	4.0	2.3
Floating fat	20	9.0	5.1	1.3
TOTAL	**100**	**15.11**	**4.46**	**1.47**

Restrictions on the livestock production in terms of maximum stock density per acreage where the manure is being spread: 1.4 livestock units (LU) for pigs and 1.7 LU for cattle (1 LU equals 100 kg of nitrogen in the manure)

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  - ***Produccion Biogás en Europa***
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  - *Promoción de Co-fermentación*
- Examples of co-fermentation substrates
  - *Ejemplos de sustratos para co-fermentación*
- European Co-fermentation examples
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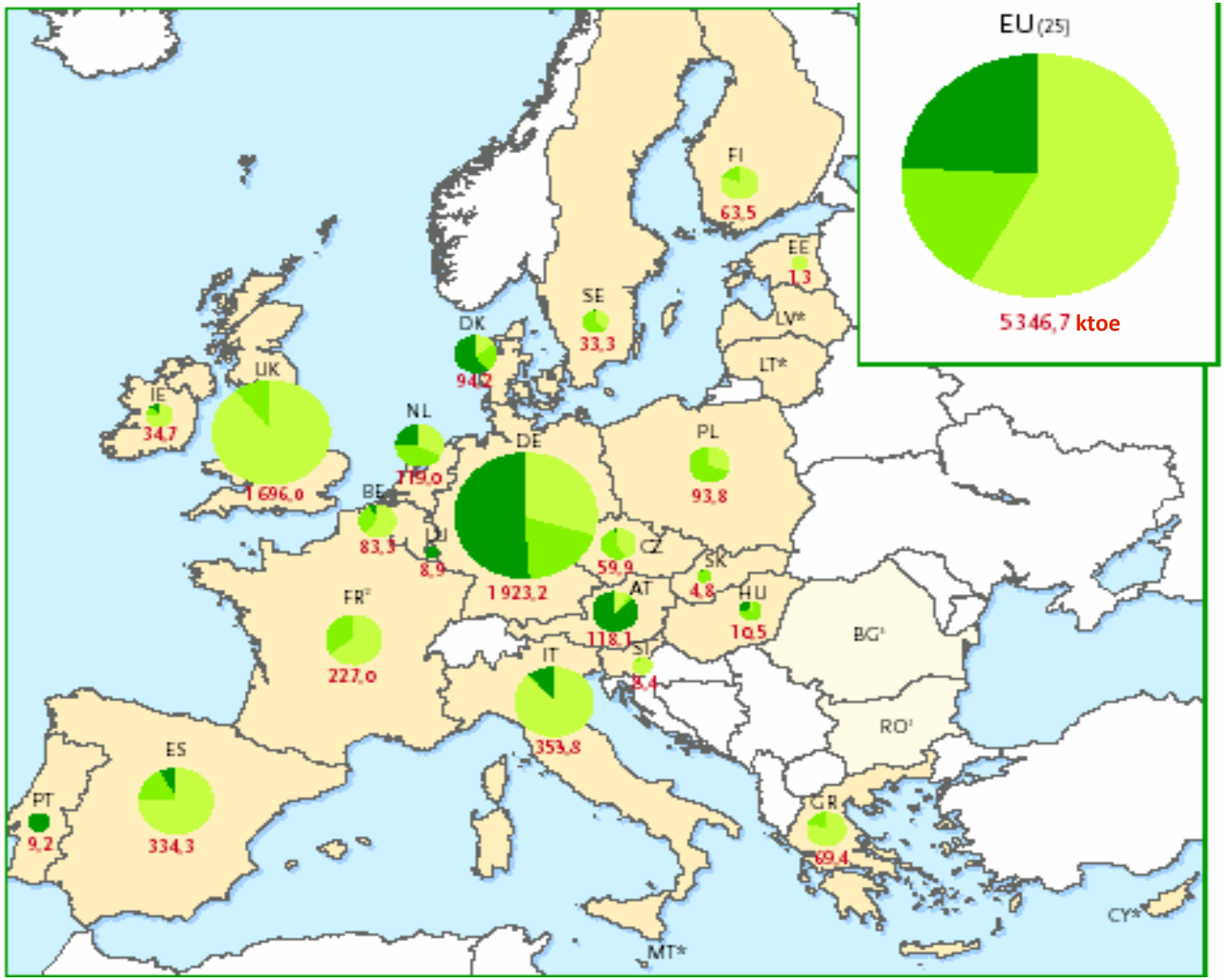
Biogas Production in Europe (2007) / Producción Biogás en Europa



- Landfill / Relleno sanitario
- Agriculture / Agricultura
- Sewage / Aguas residuales

Quelle: EurObserv'ER, May 2007

European electricity production from biogas in GWh

Generación de electricidad en base de biogás (GWh)

	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

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We act

- To promote and distribute a sustainable generation and utilisation of energy made from biomass
- To create sustainable , socially acceptable, ecologically sound and economically viable recycling systems from biomass production to its use and the re-use of residues and nutrients

Actuamos

- Para promover y distribuir una generación y uso sitenible de la energía proveniente de la biomasa
- Para cerrar de una manera sostenible, económica, ecológica y socialmente aceptable el ciclo de producción de biomasa y bioenergía a través de su uso y el aprovechamiento de sus residuos y nutrientes

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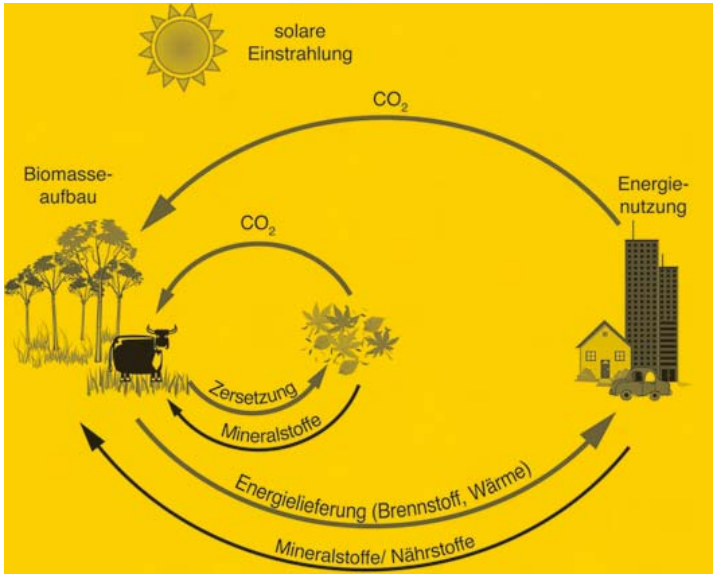
Main Focus – Punto de interés

Biogas

Wood Gas
Gasógeno

EcoSan
Saneamiento Ecológico

Plant Oil
Carburante de aceite vegetal



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FNBB – GERBIO

We reach our goals by offering

- Symposia and training courses for professionals
- Consultancy services
- Actively participating and constructing networks of experts and users of biomass and bioenergy

Alcanzamos nuestro objetivo ofreciendo

- Una educación continua, conferencias, simposios, capacitaciones a professionales y talleres
- Consultorías
- Y la formación de redes de expertos y usuarios de biomasa y bioenergías

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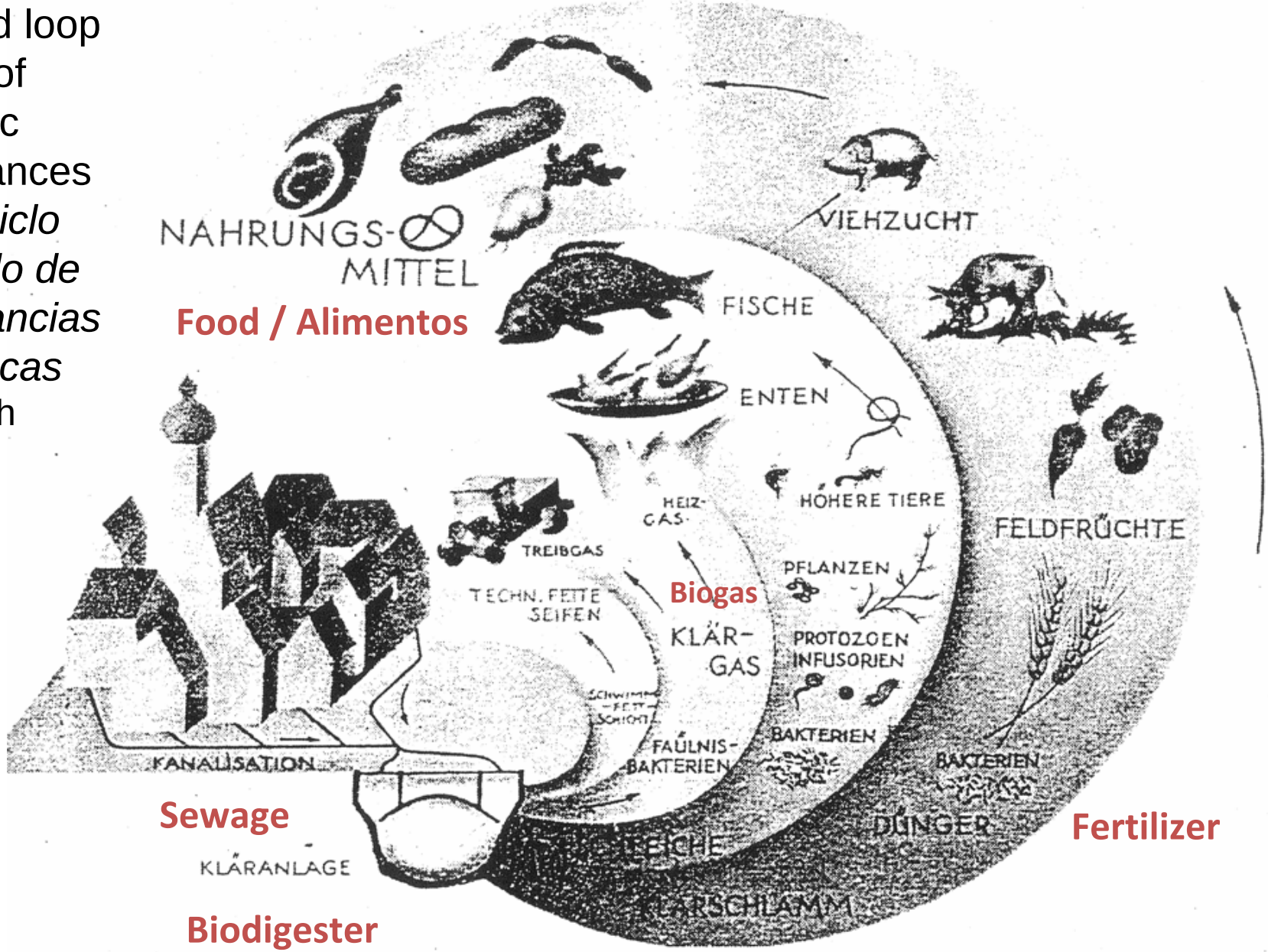
Closed loop circle of organic substances – *El ciclo cerrado de substancias orgánicas* (Munich 1929)



Food / Alimentos

Biogas

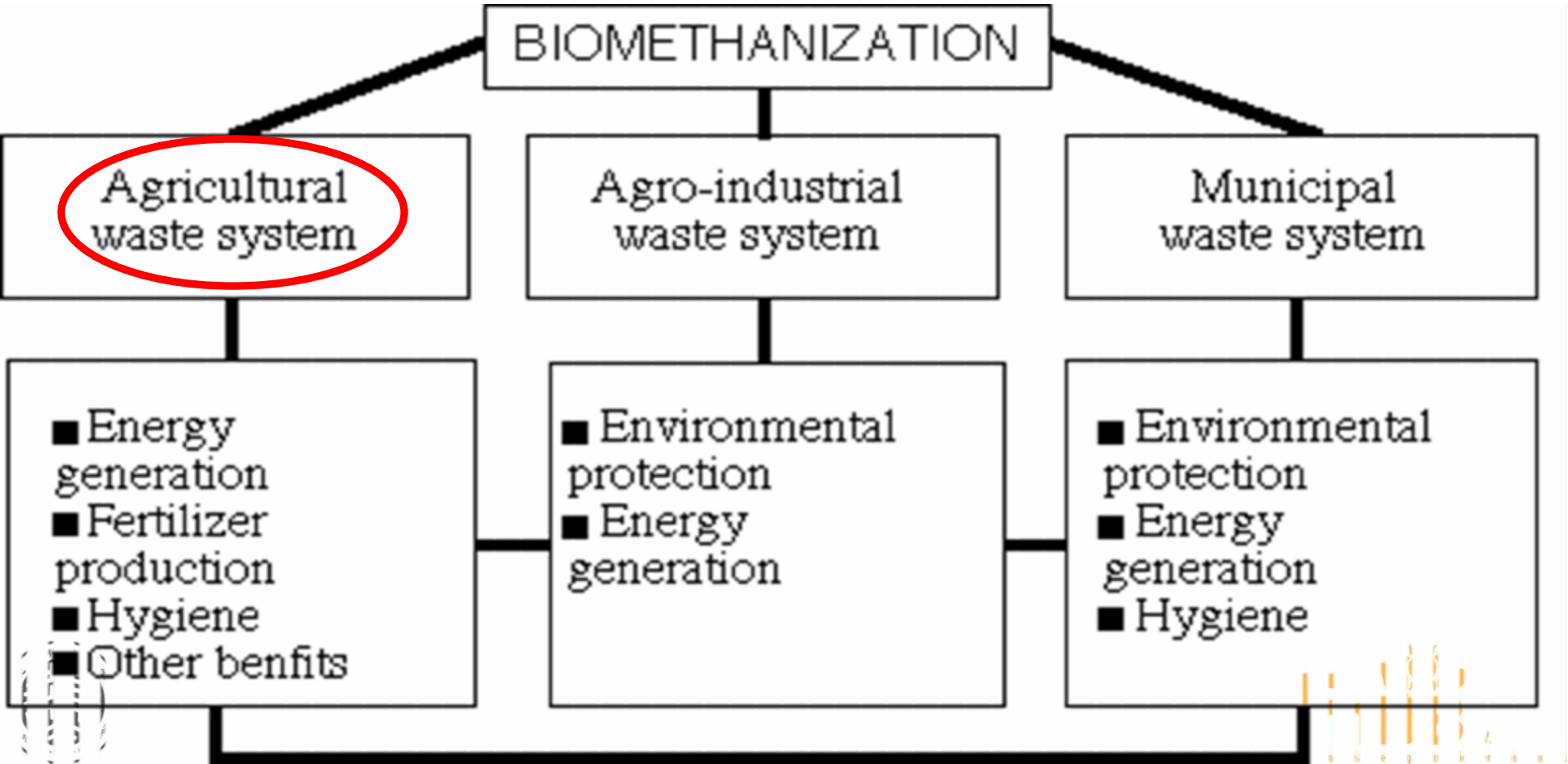
Sewage

Fertilizer

Biodigester

Biogas technology is suited to convert the organic waste from agriculture, livestock, industries, municipalities and other human activities

La tecnología de Biogás está apropiada para convertir los desechos orgánicos provenientes de la agricultura, animales, indústrias, municipalidades e otras actividades humanas



What are co-fermenting materials?

Qué se entiende como materiales de co-fermentación?

Co fermenting materials are generally all materials which are fermented additionally to the basic substrate.

Como materiales de co-fermentacion se llaman basicamente todos ellos que se fermentan addicionalmente con el sustrato principal

This could be agricultural residues but also any biologically degradable residues from outside of agriculture

Pueden ser desechos agrícolas, pero también todos los desechos biológicamente degradable

Why does it make sense to add co-fermenting materials?

Porqué lo hace sentido trabajar con sustratos de co-fermentación?

- Maintain closed natural cycles / *mantener los ciclos naturales*
- Increase gas yield / *aumentar los rendimientos en gas*
- Achieve income from waste treatment and disposal / *generar ingreso en base de tratamiento y descarga de desechos*

All types of biomass containing carbohydrates, proteins, fats, cellulose & hemicellulose

- Further criteria for substrate selection:
  - Appropriate for selected fermentation process
  - Nutritional value = potential for gas production as high as possible

Todo tipo de biomasa conteniendo carbón hidrático, proteínas, grasa, celulosa & hemicelulosa

- *Otro criteria de selección de sustrato*
  - *Apropiado para el proceso determinado de fermentación*
  - *Valor nutricional = un potencial de producción de gas más alto posible*

- *(Free of pathogens and other organisms which would need to be destroyed BEFORE fermentation process)*
- Low content of harmful substances and trash
- Composition of biogas appropriate for further application
- Fermentation residue appropriate as fertilizer

- *(Libre de patógenos y de otros organismos qui deben ser destruidos ANTES del proceso de fermentación)*
- *Bajo contenido de sustancias peligrosas y basura*
- *Composición de biogás apropiada para su uso futuro*
- *Lodo digerido apropiado como fertilizante*

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Improving biogas yield with co-substrates

Mejoramiento de los rendimientos por co-sustratos

- **Concentrated fat, fish silage etc.**
  200 - 1,000 m3/tonne

- **Fish waste, fat and flotation sludge, slaughterhouse waste, dairy waste, organic household waste etc.**
  50 - 200 m3/tonne

- **Fruit and vegetable waste, industrial wastewater, sewage sludge**
  10 - 50 m3/tonne

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Process chain for the digestion of added biowaste

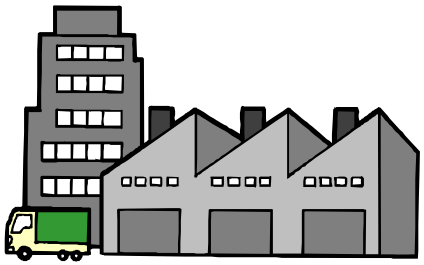
Cadena de proceso de co-fermentación con desechos orgánicos

Biogas

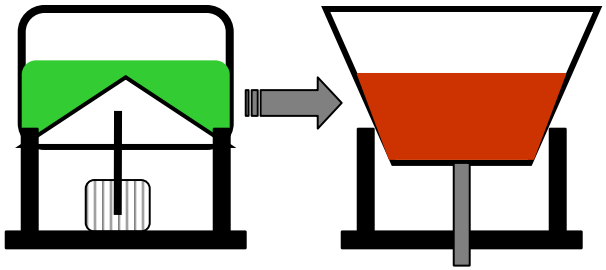
Reception of biowastes
=> closed chamber with odour treatment

Preparation
=>Chopping and sorting of disturbing materials

Co-Fermentation
with post treatment



Pulper



hygienising, separation

Compost (post composting)

liquid **Fertilizer**

15-20 per cent of the volume but containing more than 75 per cent of the phosphorous content and almost all the organic bound nitrogen

80-85 per cent of the volume containing 80 per cent of the nitrogen of which almost all is ammonium which can be utilised right away by the crops

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Waste grease or fat

Grasa residual

- Approx 150,000 – 280,000 Mg a^{-1} of dripping and chip fat can be collected in Germany - without waste oil from households
- Use as co-substrate would require high costs for maintenance and cleaning of co-fermentation plants, but :
  - Could be fermented in separate plants together with other biowaste or sewage sludge

Grass and green cuttings
hierbas y cortes verdes

- More and more towns and communities have to deal with landscape and road side maintenance residues. The grass and other organic cuttings have to be composted with considerable effort.
- If costs for composting raise over 100,- EUR/t, anaerobic digestion in many cases could be a better option.

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Straw

Paja

- Lignocellulose-containing biomasses
- Not fermentable in a biogas plant without special pretreatment:
  - Thermally
  - Chemically
- Energy efficient fermentation particularly of straw and leaves could make a substantial contribution to power supply.

Straw chopping and its influence on biogas production / *impacto de preparación de paja en la producción de biogás*

	10 days	20 days	30 days
	m³ / kg organic substance		
Wheat straw:			
chopped (3 cm)	0,11	0,17	0,23
milled (0,1 – 2,0 mm)	0,22	0,33	0,37

Reinhold und Noack, 1956

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Cereal straw, foliage and/or leaves
paja, follaje y hojas

- Fermentation is to be preferred to burning
  - Silage of straw (pretreatment for fermentation) takes 4 to 6 weeks → directly into the biogas plant
  - Preferred: co-fermentation of straw and liquid manure stabilizes fermentation process

Different efficient ways to produce energy from biomasses

Varios eficiente maneras para producir bioenergía

Process	Energy yield		Average	
rape to bio-diesel	45 GJ/ha	55 GJ/ha	50 GJ/ha	38%
starch to ethanol	50 GJ/ha	53 GJ/ha	52 GJ/ha	39%
lignocellulose to ethanol	35 GJ/ha	65 GJ/ha	50 GJ/ha	38%
lignicellulose to biogas	105 GJ/ha	160 GJ/ha	133 GJ/ha	100%

Source: Institute for Energy and Environment, Leipzig, 2007:

Kosten und Ökobilanzen von Biokraftstoffen

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Biogas potential in Denmark

Potencial biogás en Dinamarca

	Estimated Potential PJ	Production in 1999 PJ	Production in 2000 PJ	Danish energy plan 2030 PJ
Animal manure	24.0	0.50	0.56	14.0
Sewage sludge	4.0	0.79	0.86	1.5
Industrial waste, Danish	2.5	0.51	0.56	1.5
Industrial waste, imported		0.30	0.35	0.0
Organic household waste	2.5	0.01	0.01	2.0
Garden waste	1.0	0.00	0.00	0.8
Landfill gas	1.0	0.55	0.58	0.2
	35.0	2.67	2.91	20.0

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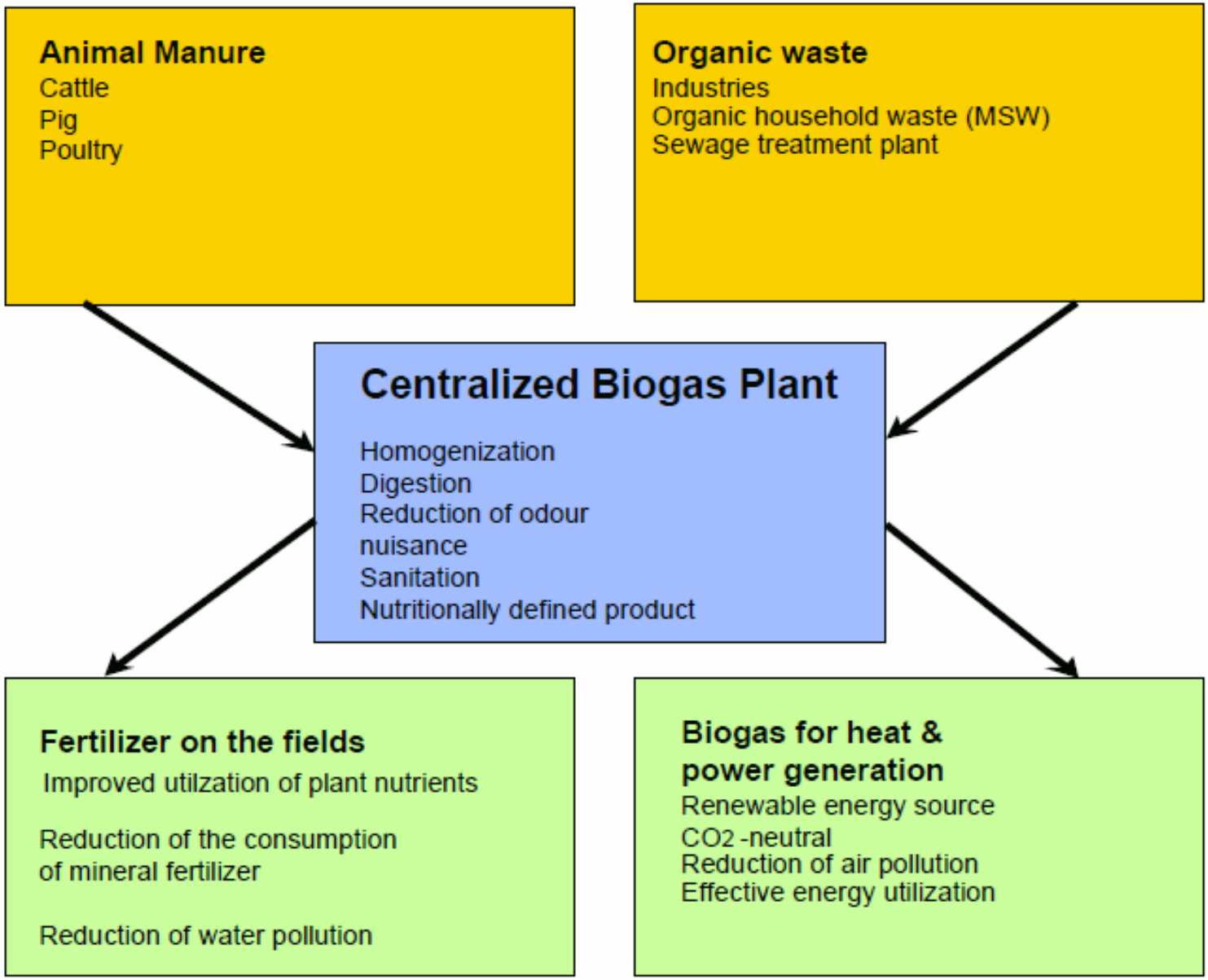
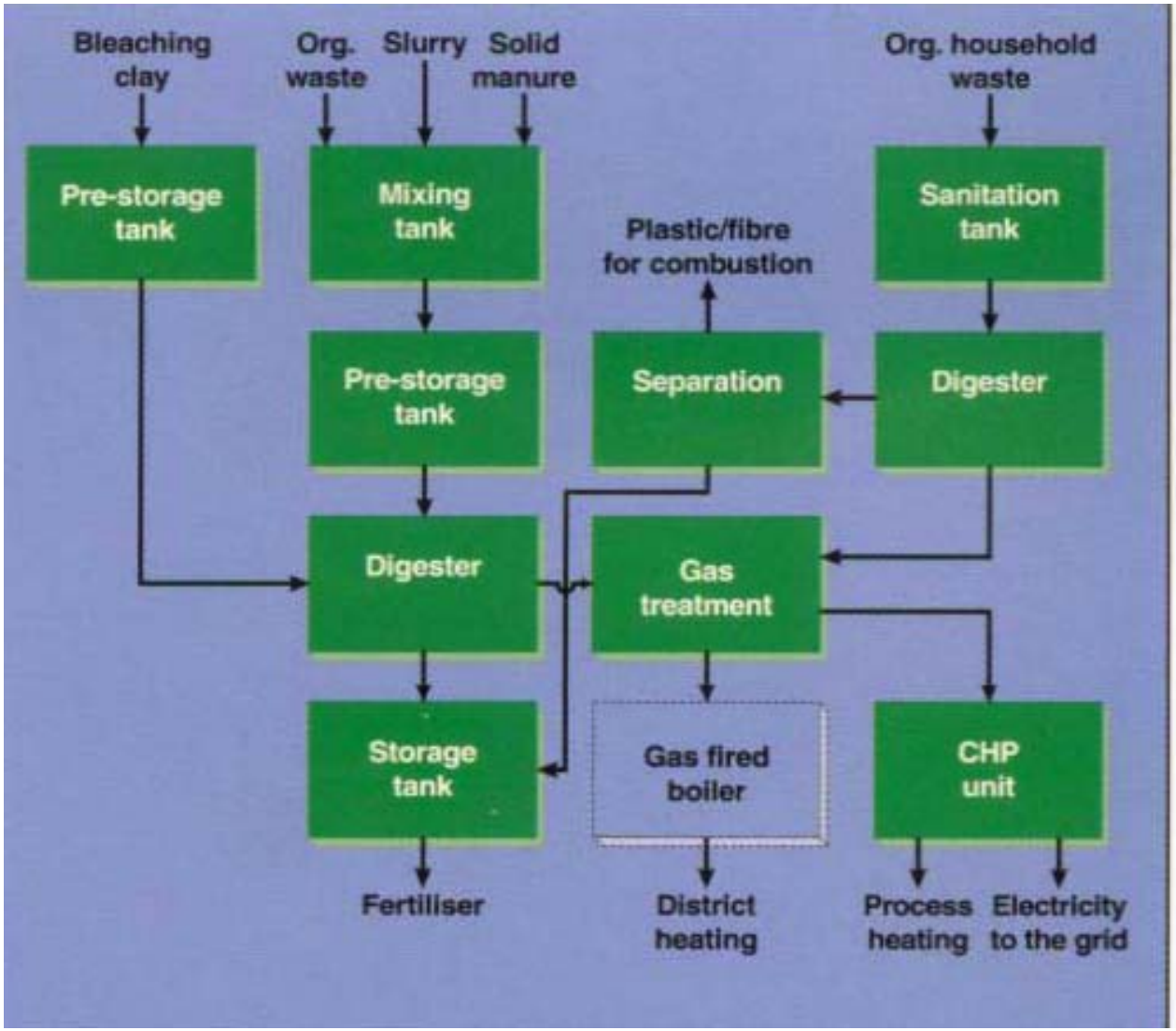


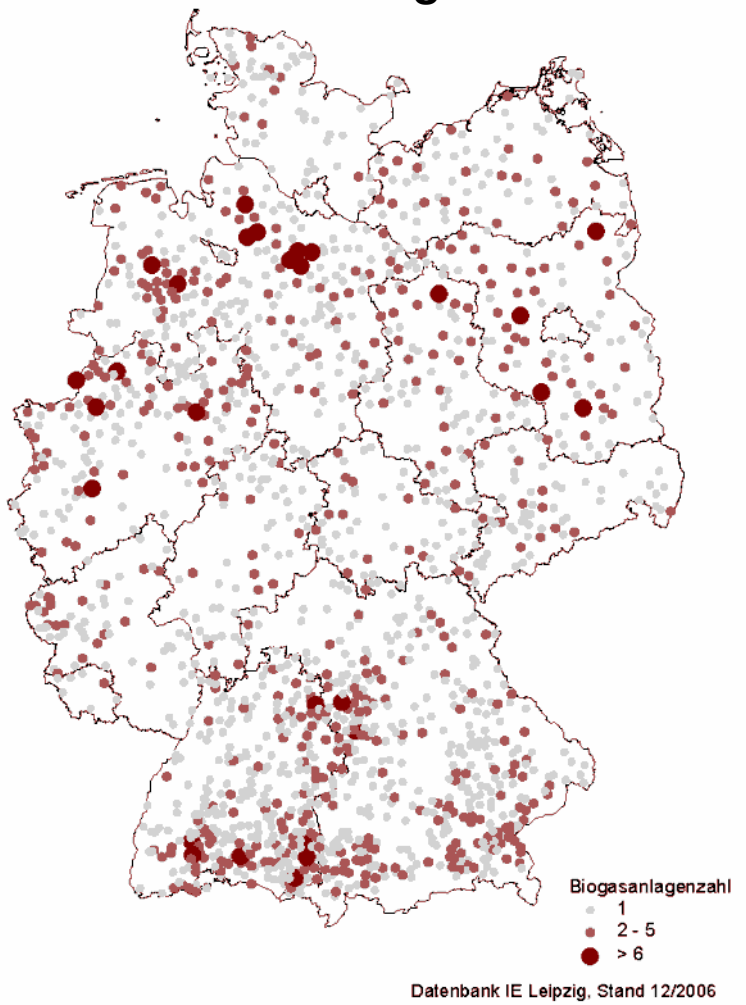
Danish co-digestion flow-chart

Proceso de co-fermentación en Dinamarca

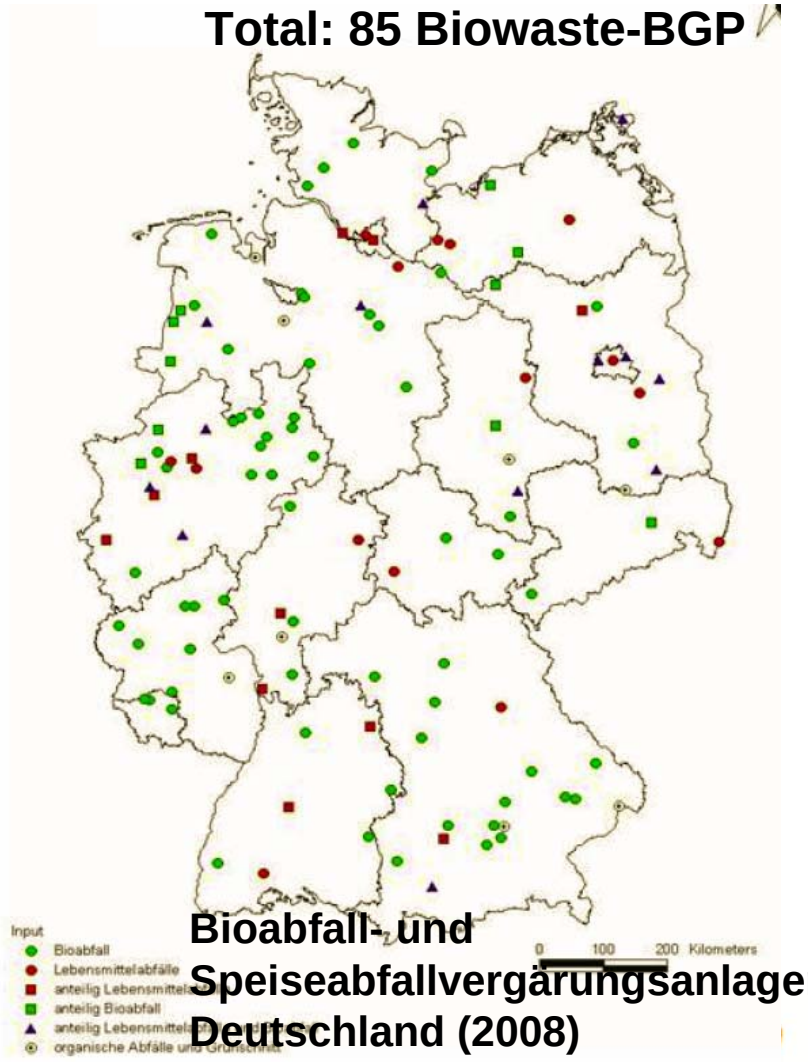


Biogas Plant Locations in Germany
Lugares en Alemania donde se operen instalaciones de biogás

Total: 4000 Agro-BGP



Total: 85 Biowaste-BGP



Bioabfall- und Speiseabfallvergärungsanlagen in Deutschland (2008)
(1 Mio t/a capacity)

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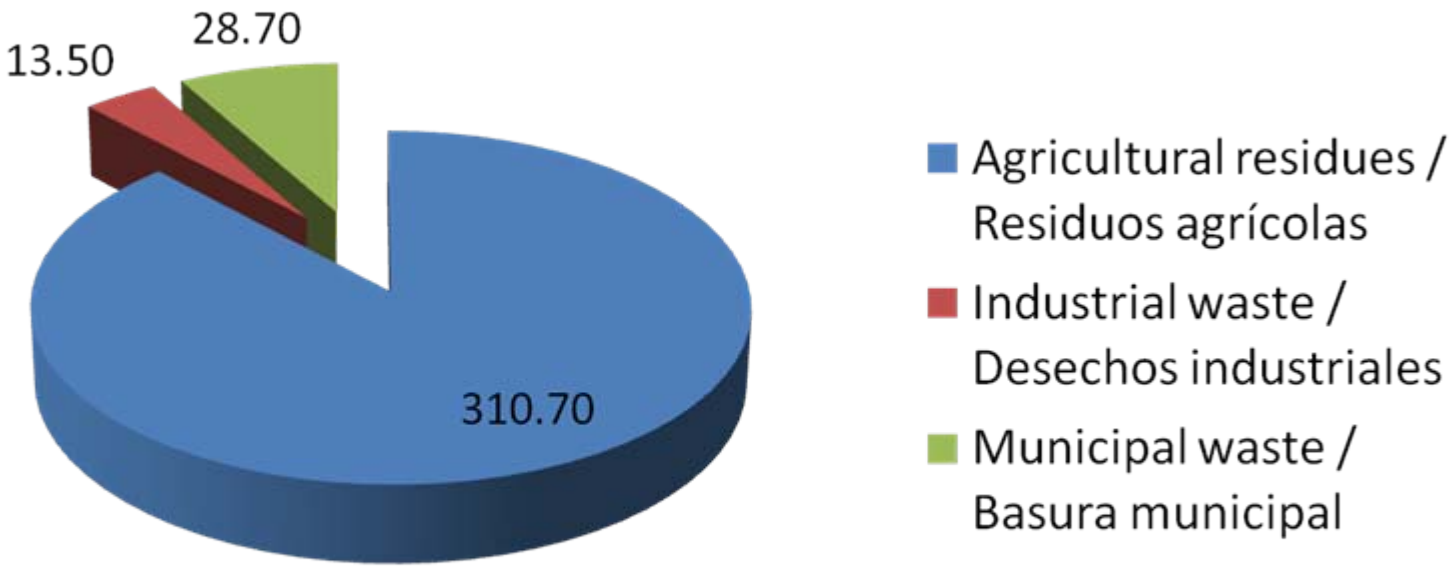
German Potential for Biogas production

Potencial de producción de biogás en Alemania

- PJ/a 2007 -



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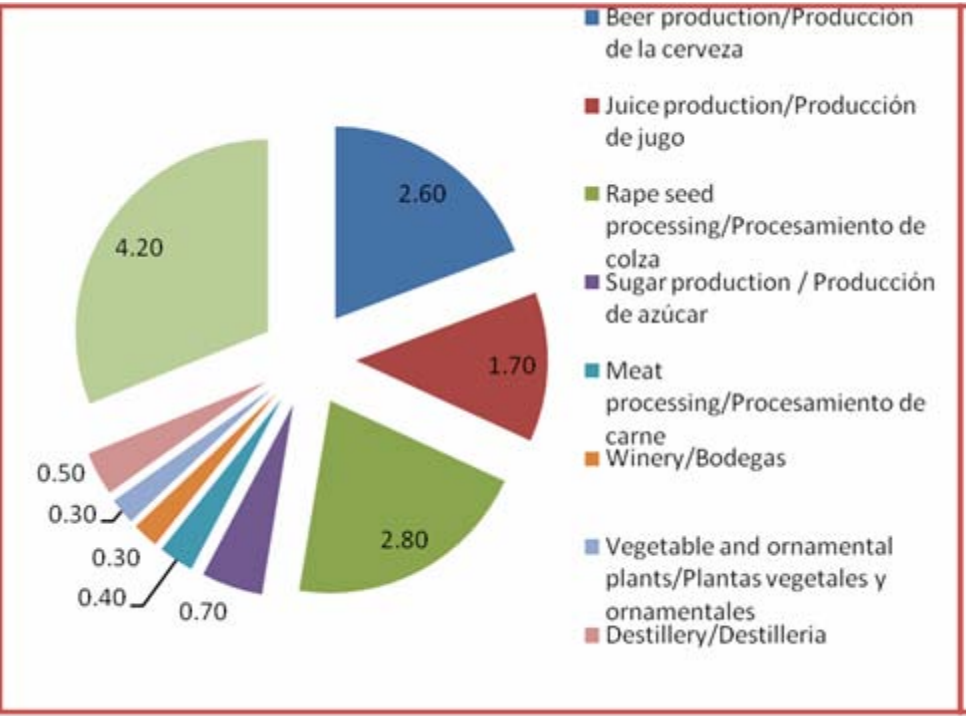
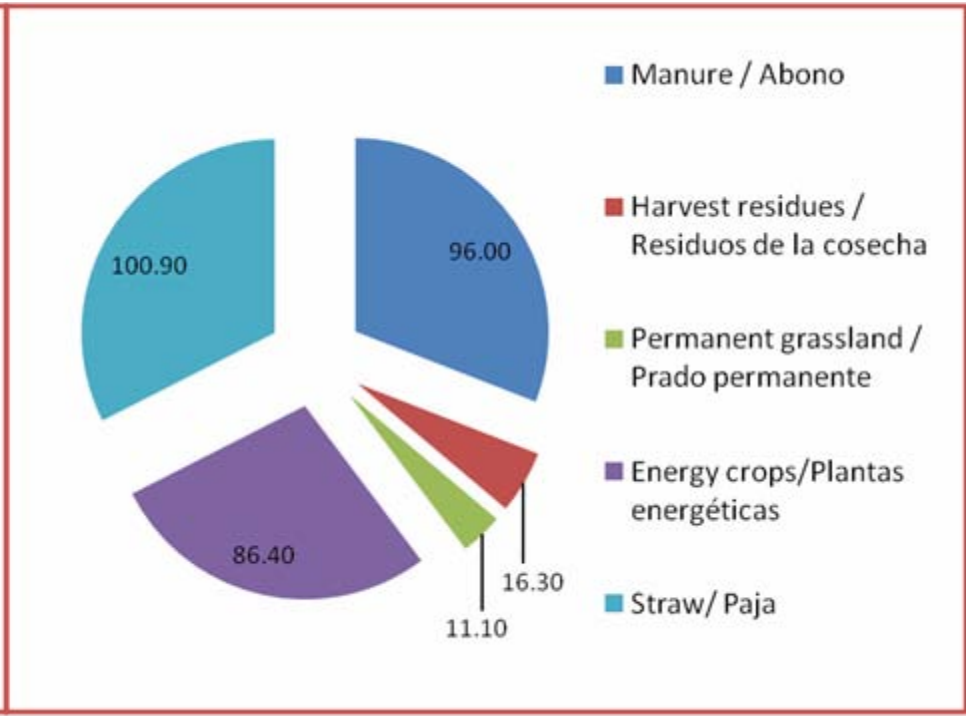
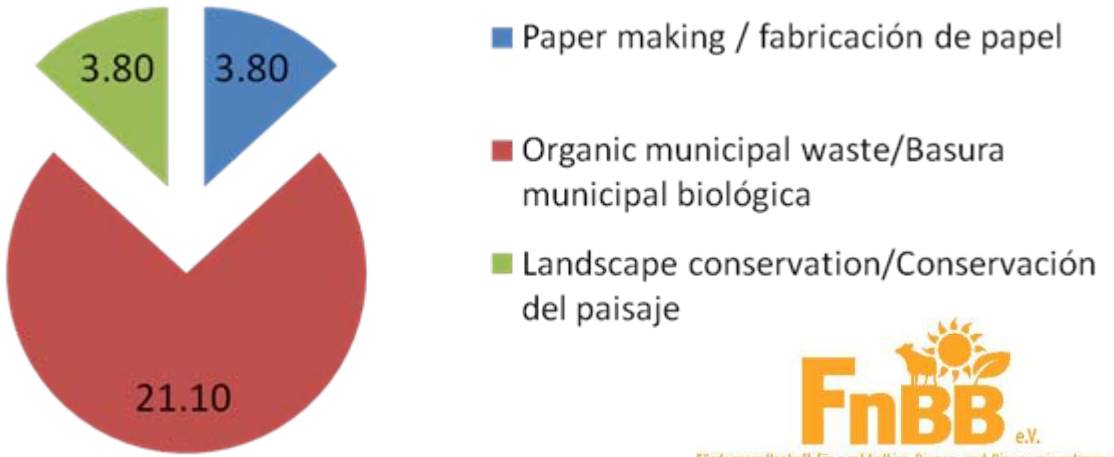
Industrial waste / Desechos industriales



Agricultural residues / Residuos agrícolas



Biodegradable Municipal waste / Basura municipal biodegradable



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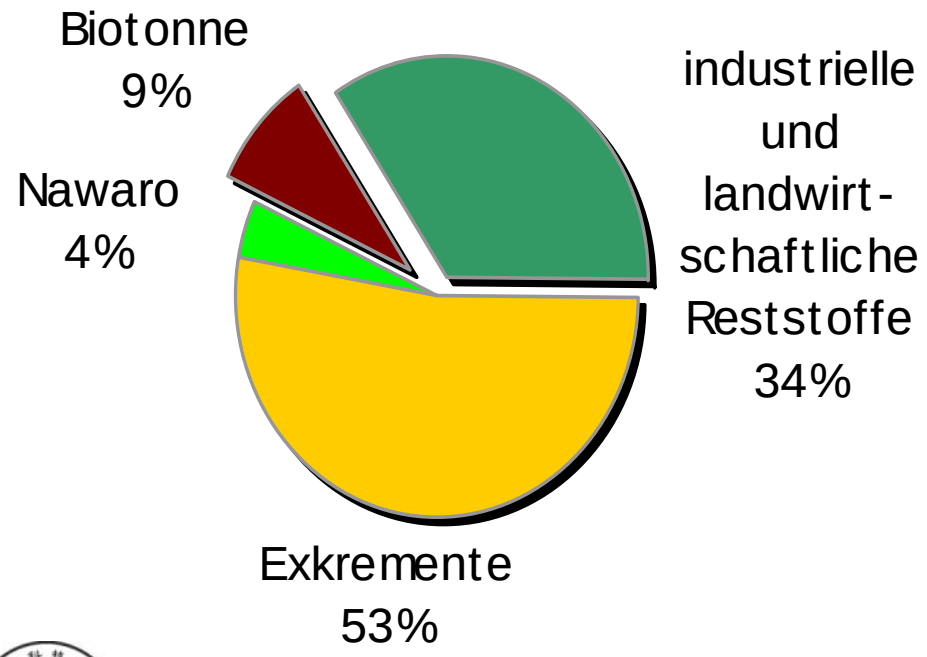
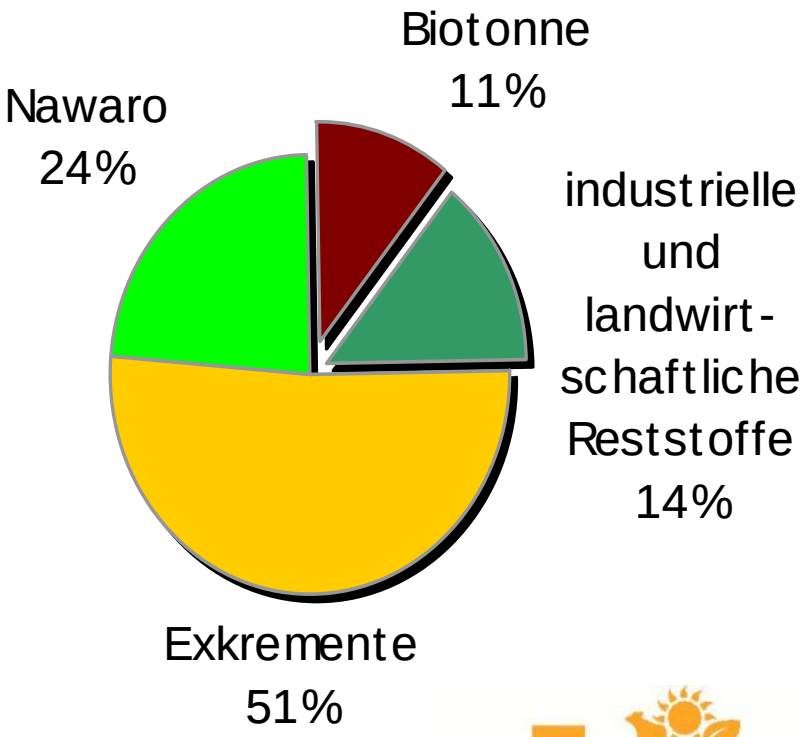
(Co-)Substrates fed in Biogas plants
co – sustratos utilizados en instalaciones de biogás

(Stand 6 / 2005)



(Stand 10 / 2006)



Quelle: IE, Leipzig 2006

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Biogas-co-substrates
Co-sustratos:

Organic waste
desechos orgánicos

Old bread
Apple marc
Brewers grains
Biowaste
Separation fat
Flotation fat
Greace
Vegetable waste
Grain cleanings
Destillery grains
Glycerin
Coffee draff
Cocoa shells
Potatoe greens
Potatoe peeling waste
Destilled potatoes
Leaves
Molasses
Wey
Fruit peelings
Rapeseed cake
Grass cuttings
Canteen waste
Onion peels
.....

Since EEG 2004 Trend

Tendencia desde EEG 2004

Energy crops
plantas energéticas

CCM
Fodder peas silage
Fodder beet silage
Grain destillery waste
Straw
Grassilage
Green rye silage
Green oat silage
Potatoes
Potatoe destillery waste
Clover grass silage
Lucerene silage
Maize
Maizesilage
Rape seeds
Rye
Clover silage
Fodder beet silage
Sunflower silage
Triticale
Grassilage
Wheat
Green wheat silage
Sugarbeet silage
.....

Germany : substrates for agricultural biogas (1/3)

Alemania: sustratos para agro-biogás

By law included Biomass ./. By law excluded Biomass

biomasa incluida por ley ./. biomasa excluida por ley

- Plants and parts of plants
  - *Plantas y parte de plantas*
- Waste and by-products of plant and animal origin from agriculture, forestry and commercial fish production.
  - *Desechos y productos de origen vegetal o animal, silvestre, de producción commercial de pescado*
- Mixed municipal solid waste from private households and similar waste from other source areas.
  - *Desechos municipales mezclados provenientes de domicilios y desechos similares*
- Paper, cardboard, pasteboard
  - *Papel etc.*
- Sewage sludge.
  - *Aguas residuales*
- Textiles.
  - *textiles*

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Germany : substrates for agricultural biogas (2/3)

Alemania: sustratos para agro-biogas

By law included Biomass ./. By law excluded Biomass

biomasa incluida por ley ./. biomasa excluida por ley

- Manure separated from the digestive tract; if there is no risk of dispersal of serious-infectious diseases, milk and colostrum.
  - *Contenido del tracto digestivo sin riesgo de infección a la leche etc.*
- Biowastes (any vegetable or animal waste destined for utilisation that can be degraded by microorganisms, soil organisms or enzymes), including kitchen and food waste, catering waste.
  - *Desechos orgánicos de origen vegetal, animal, cocina, alimentación, restaurantes*
- Animal carcasses or parts thereof and products within the meaning of the Animal Carcass Disposal Act .
  - *Animales muertos y partes de estos*
- Meat-containing wastes from the foodstuff industry, slaughterhouse wastes of animals fit for human consumption.
  - *Desechos provenientes de la indústria de procesamiento de carne, mataderos etc.*
- Domestic waste water
  - *Aguas residuales domésticos*

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Germany : substrates for agricultural biogas (3/3)

Alemania: sustratos para agro-biogas

By law included Biomass ./. By law excluded Biomass

biomasa incluida por ley ./. biomasa excluida por ley

- Supplementary energy crop bonus could only be applied if:

- Only plants and parts of plants origin from landscaping, agriculture, forestry or gardening are digested
- Manure as defined in the EU-Regulation Nr. 1774/2002 from Oktober 2002 respecting hygiene aspects for non-food classified animal by-products is added.
- Residues from own agricultural distilleries are used.

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Consequences for agro-biogas plants (1/2)

Consecuencias referido a construccion y operacion

1. **Mesophilic** digestion is accepted only together with a hygienisation (pasteurization) unit for biowaste (pre- or after heating at 70°C / 1h).
2. For **thermophilic** operated biogas-plants a **process-validation with indicator organisms** (Salmonella, Plasmodiophora brassicae, tomato seeds) is necessary in order to control the minimal retention time. The use of Bacillus globigii spore suspension as a 'biological tracer' has proven to be useful.
3. No more than 10 t of waste classified co-ferment per day added.

- ***Tipo Mesophilico:*** *acceptado solamente conjunto con unidad de higienisación: calentamiento antes o después por 70°C / 1h*
- ***Tipo Thermophilico:*** *validación del proceso mediante organismos indicadores*
- *No más que **10 t/d** de desechos clasificados como co-sustrato*

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Consequences for agro-biogas plants (2/2)

Consecuencias referido a construccion y operacion

4. For both processes **sterilisation for slaughterhouse waste** with steam pressure: at least 20 minutes without interruption at a core temperature of more than 133 °C and an absolute steam pressure of not less than 3 bar.
5. For hygienisation-units, a **process-validation with indicator-organisms** (Salmonella, Plasmodiophora brassicae, tomato seeds) is **not necessary**, only for thermophilic biogas-plants and composting-plants.
6. In **co-fermenting biogas-plants, the product quality is checked directly after the hygienisation unit** (without Salmonella spp. in 50 g; germable seeds and drive outable parts about 2 per litre).

- *En ambos sistemas: sterilisación al vapor de desechos de mataderos*
- *En unidades de higienisación no se requiere la validación del proceso mediante organismos indicadores*
- *Plantas de co-fermentación: Calidad del producto controlado directamente después de la unidad de higienisación*

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Energetic evaluation of decentralized household waste water treatment as co-ferment

Evaluación energética de las aguas residuales como sustrato de co-fermentación

- **Domestic wastewater with human excreta could be treated in biogas plant if total amount is less than 8 m^3a^{-1}**
- **Amount of waste water comes to 150 l per person and day**
- **Contents faeces, organic waste from food preparing and left overs**
- **Additional content of detergents, shampoos etc.**
- **Around 0,9 kWhel per person and day can be produced or 150 Euro/year**
- **Saving of waste water treatment fees up to 10 times as high.**
- **Saving of connecting fees to the public sewer**

Mass balance

		Manure (cow)	Domestic wastewater	Total
PE	number		5	
Wastewater amount	l/d/PE		150	
Wastewater amount	m^3/d		0,75	
Cows	number	100		
Manure amount	l/d/cow	50		
Manure amount	m3/d	5,0		
Influent	**m3/a**	**1.825**	**274**	**2.099**
Relation		**87 %**	**13 %**	
DM content	%	10 %	1,35 %	
DM content	**t/a**	**183**	**4**	**187**
Relation		**97 %**	**3 %**	
N-content		4,1 %	5,5 %	
N	kg/a	7.483	220 **(3%)**	**7.503**
Maximum N allowed under fertilizer/groundwater protection law	kg/ha	170	170	
Area needed	**ha**	**44**	**1,3 (3%)**	**45,3**

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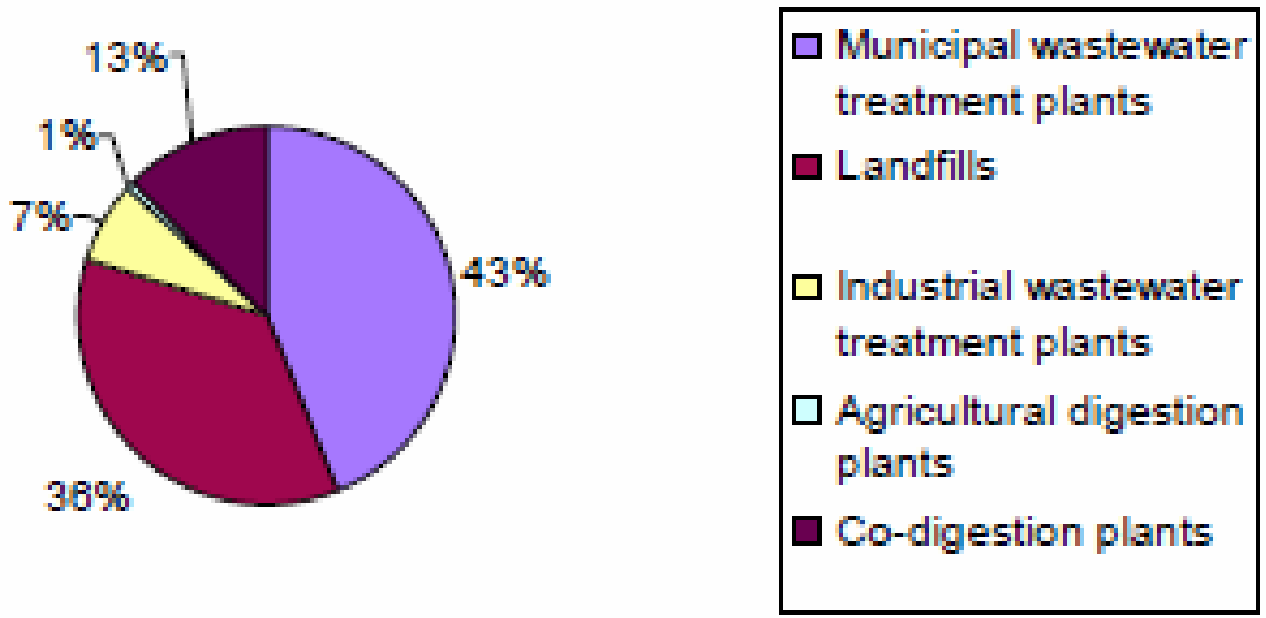
Sweden
Suecia

Biogasproduction from different sources in Sweden, 2005
Totally 1,28 MWh/year



Content / *Contenido*

- European Biogas Production
  - *Produccion Biogás en Europa*
- Promotion of Co-fermentation
  - *Promoción de Co-fermentación*
- Examples of co-fermentation substrates
  - *Ejemplos de sustratos para co-fermentación*
- European Co-fermentation – examples
  - *co-fermentación en Europa - ejemplos*
- **Summary / *Resumen***

Advantages and Disadvantages of co-fermentation (1/3)
ventajas y desventajas

- Co-substrates increase organic content of substrate → the yield of biogas increases
  - Only profitable if co-substrates are sourced within a economic distance
  - *Incremiento de producción de gas en base de co-sustratos disponibles dentro de una distancia economicamente viable*
- Content of DM should be 2 – 12% to ensure functionality of standard pumps and proper mixing
  - *Contenido de materia solida entre 2 – 12 %*

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Advantages and Disadvantages of co-fermentation (2/3)
ventajas y desventajas

- Co-substrates pose higher hygienic risk
  - *Riesgo higiénico debido a co-sustratos*
- Co-substrates like residue fat contain nitrogen-rich nutrients
  - When used as fertilizer, the fermentation residue must meet national limits for nitrogen exposure *(water protection; additional costs for transport to cattle-less areas)*
  - *Co-sustratos ricos en nitrógeno causan costos addicionales*

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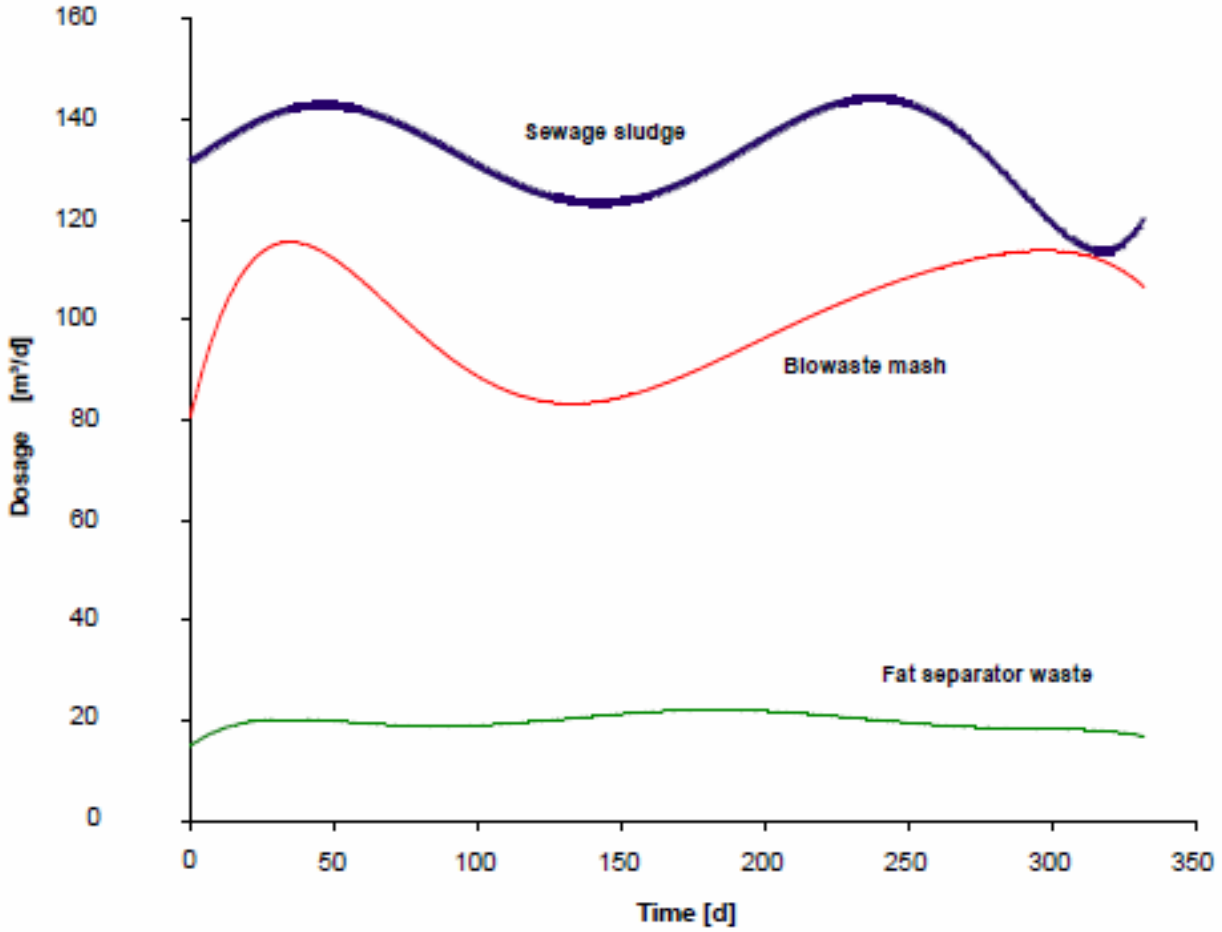
Example: daily feed of bio-waste mash, fat separator waste and sewage sludge processed

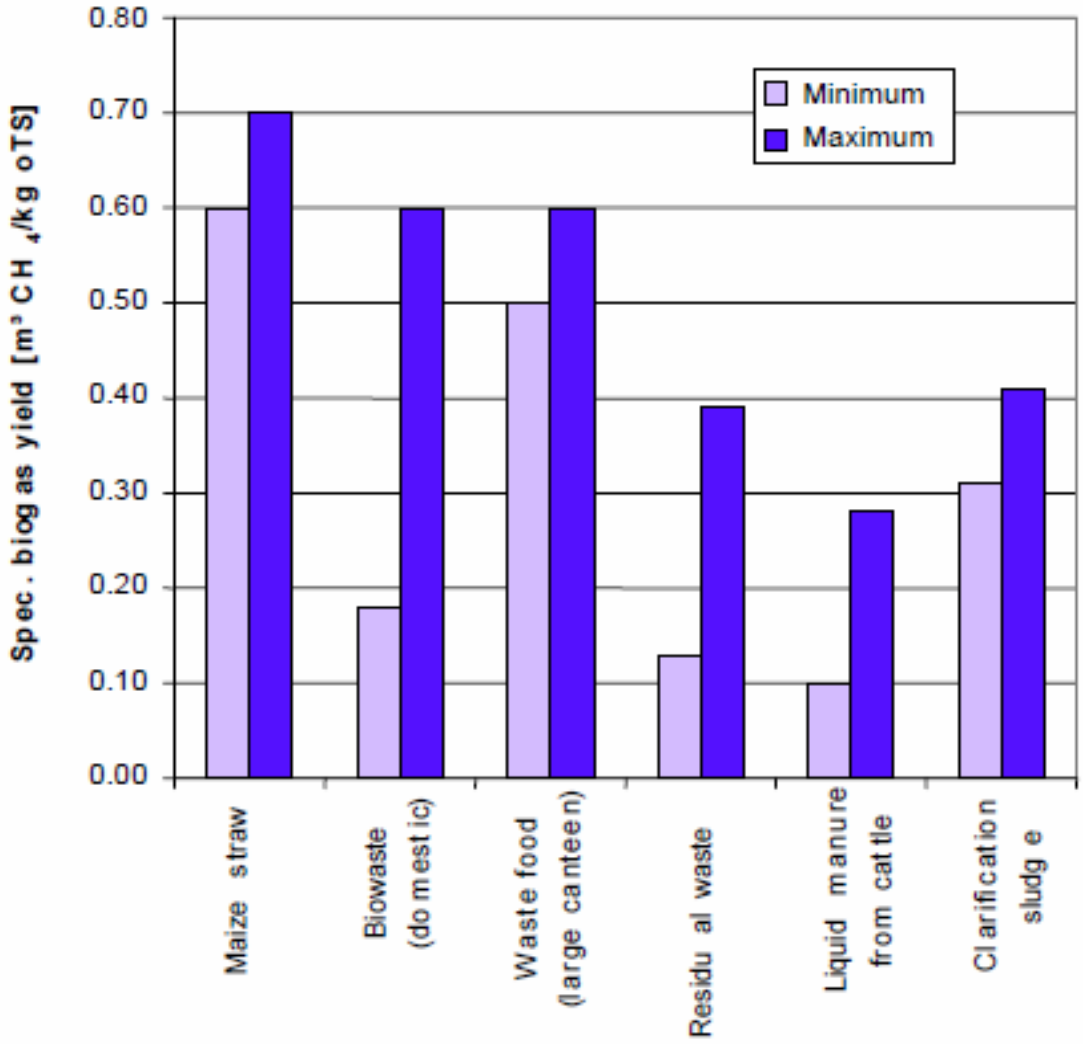
Ejemplo: bio digestores alimentados diariamente con desechos orgánicos, grasa residual y lodo de aguas residuales



Specific yields of biogas from various substrates fluctuate strongly

co-sustratos: fluctuaciones en la producción de biogás

- For example, from maize straw up to 400 m³ CH4/Mg original substance can be won, while liquid manure from cattle with 8% solids will yield a mere 10 - 15 m³ CH4/m³.



Factors influencing co-digestion overall economy

Factor	Impacts
EU- and national waste management legislation	Allowable waste type and share; Quality requirements; Hygienisation requirements
EU- and national environmental legislation	Waste air treatment; Plant operational requirements; Heavy metal limits etc.
Waste collection and waste composition	Impurities ; Contaminants ; Recyclable contents
General waste treatment costs and gate fees for co–substrates	Availability and gate fees (costs) of wastes for co–digestion; Transportation costs
Waste pre-treatment and sterilization requirements	Content of impurities and contaminants; Hygienic status
Additional digester equipment requirements for co–substrate receiving digesters	Sorting; Sieving; Filtration; Homogenisation; Storage capacity; Mixing; Post treatment; Hygienisation; Dewatering equipment
Volumetric limits of co-substrate addition	Legislation; Maximum volumetric loading
Substrate degradation efficiency and biogas yield	Organic content; Degradeability; C:N:P - proportion
Degree of use and cost efficiency of using the end products biogas and digestate	Obtainable prices for biogas, electricity, heat and compost
End product upgrading costs	Biogas purification requirements; Digestate handling requirements (direct land application possible?); Composting required?
Effluent treatment costs	Wastewater; Waste gas (biofilter)

Factores impactantes en la economía de la Co-fermentación

- By producing energy from renewable resources, biogas plants make an active contribution to combating climate change.
  - *Por la producción de energía en base de recursos renovables instalaciones de biogás contribuen a la protección de clima*
- In view of shrinking reserves of mineral phosphate, the use of fertilizer from secondary raw materials is also a very positive development.
  - *En vista a la reducción de las reservas de fósforo mineral, la utilización de fertilizante producido en base de matéria prima secondaria parece un buen desarrollo*

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www.biogas-zentrum.de

For (future) plant operators and for Networking / *para operadores de plantas y para la red de contactos:*

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