厌氧发酵技术概述

Overview of anaerobic digestion technology

中国城市生活垃圾处理领域国家适当减缓行动项目

China Integrated Waste Management NAMA Project

中华人民共和国住房和城乡建设部
Ministry of Housing and Urban-Rural Development (MoHURD)

NAMA Facility

On behalf of

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Department for Business, Energy & Industrial Strategy

Danish Ministry of Energy, Utilities and Climate

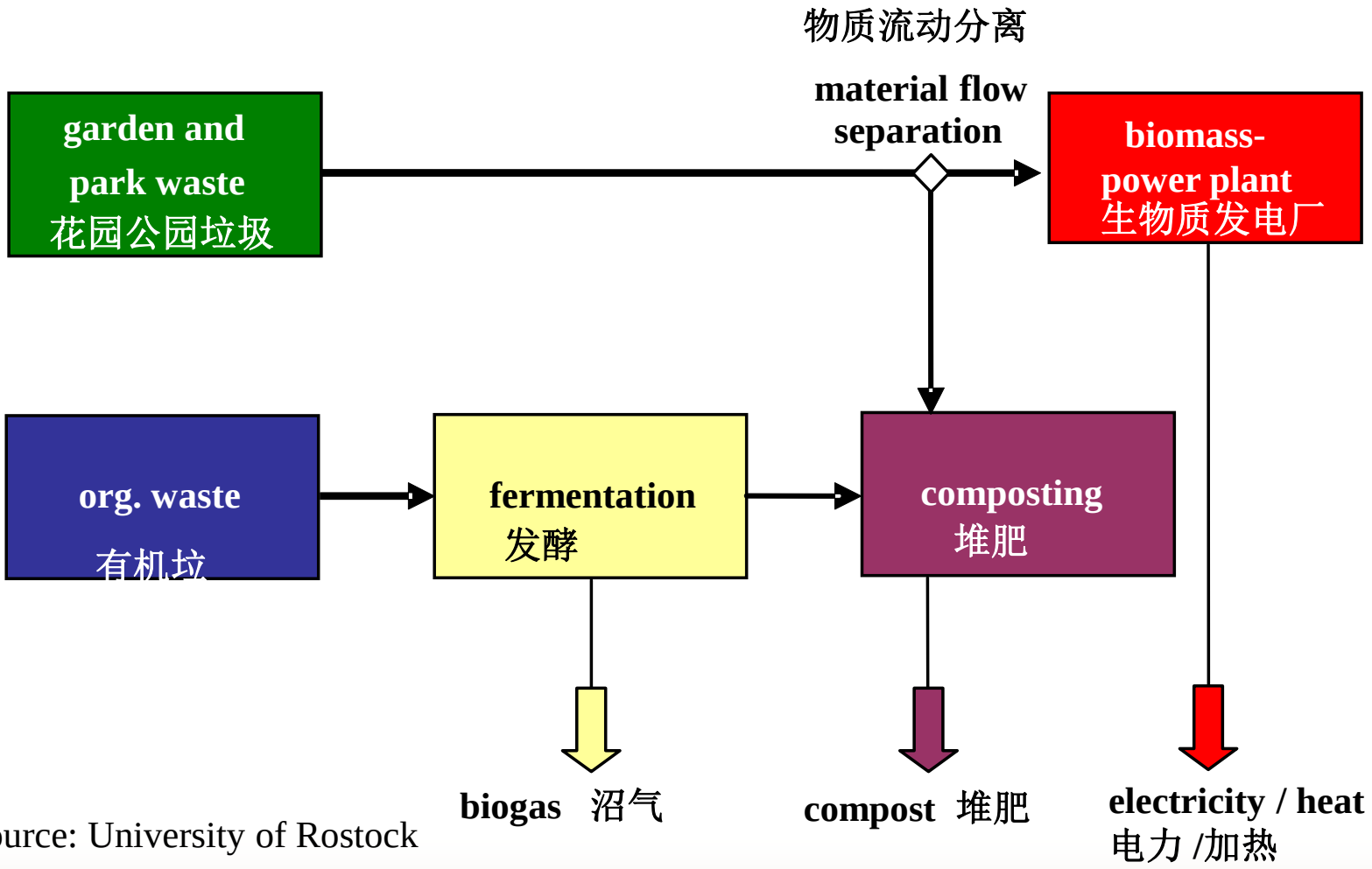
Implemented by

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

中国城市环境卫生协会
China Association of Urban Environmental Sanitation

China Integrated Waste Management NAMA

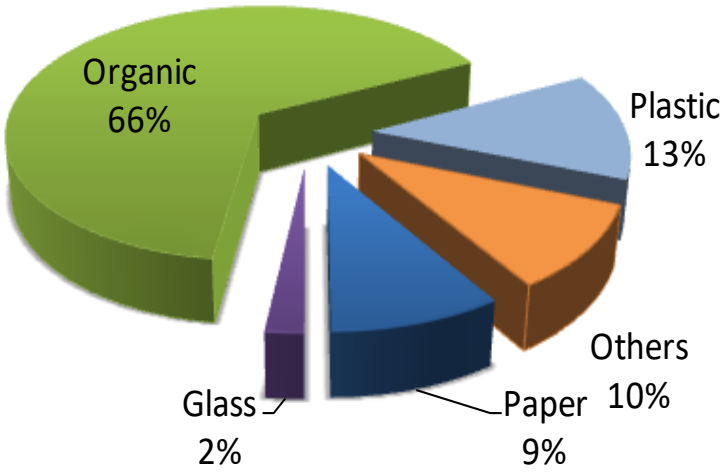
Integrated waste management concept
综合垃圾管理



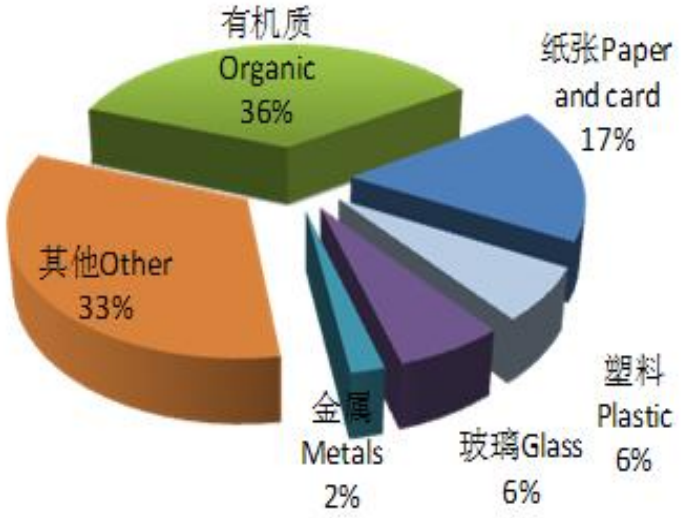
Source: University of Rostock

Comparison of the waste composition in China and Europe
中欧垃圾成分对比

MSW Property in China
中国市政垃圾特性



MSW Property in Europe
欧洲市政垃圾特性



Average BMW content of MSW
城市固体废弃物中的生活有机废弃物成分
China中国 = ± 66 % up to 80% (average from 27 cities in China
数据来源于中国27座城市)
Europe 欧洲 = ± 36 %

Comparison of Organic Matter Biodegradability of Chinese and European MSW
对中国和欧洲城市固体废物有机物质生物降解能力的对比

MSW characterization 城市固体废物特点		China 中国 [m/m%]		EU 欧洲 [m/m%]	
Rapidly & moderately degrading 快速与中速分解	Bioorganic municipal waste BMW (food- and kitchen waste, green garden waste)	78		12	
Slowly degrading 低速分解	Organic matter with a higher semi- and lig-nocelluloses content (wood, yard waste, paper, textiles, composite material,)	10	∑88	47	∑59
Non degrading 不分解	Inert organic and inorganic matter (plastic, metal, glass, ash,)	12		41	
Total 总数		100		100	

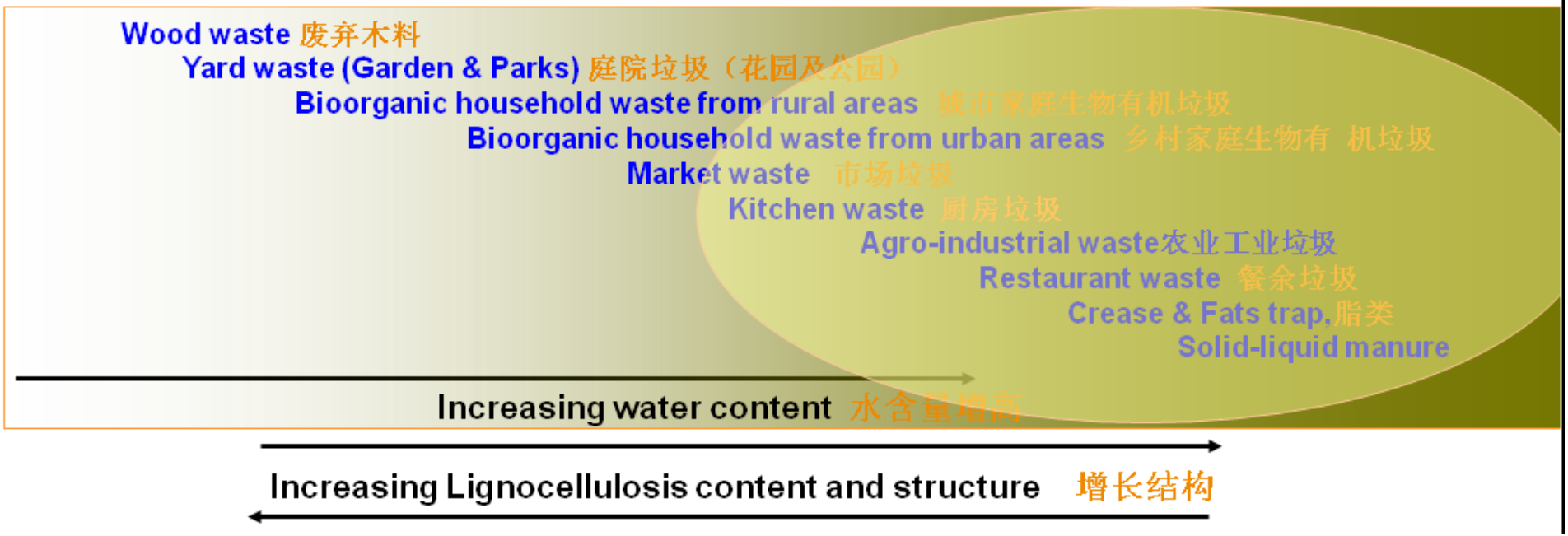
(Sino-German RRU-BMW project, Raninger & Li, 2008), (in m/m% FM)
(中德资源回收利用-城市生活有机垃圾项目2008年)

Suitability of BW for biotechnological treatment

生物有机垃圾对需氧和厌氧处理的不同使用性

Composting (aerobic)
堆肥（需氧）

Digestion (anaerobic)
消化（厌氧）



Overview – Evolution of the Amount of Biogas Plants in EU
概述 – 欧洲沼气工程数量

In 2016:

- Number of plants 工厂数量: 17,662
- Total annual production: 年产量总值 181,565 GWh (EU28)
- Installed Electric Capacity 安装电容： 9,985 MW
- Electricity generation 发电: 62,704 GWh

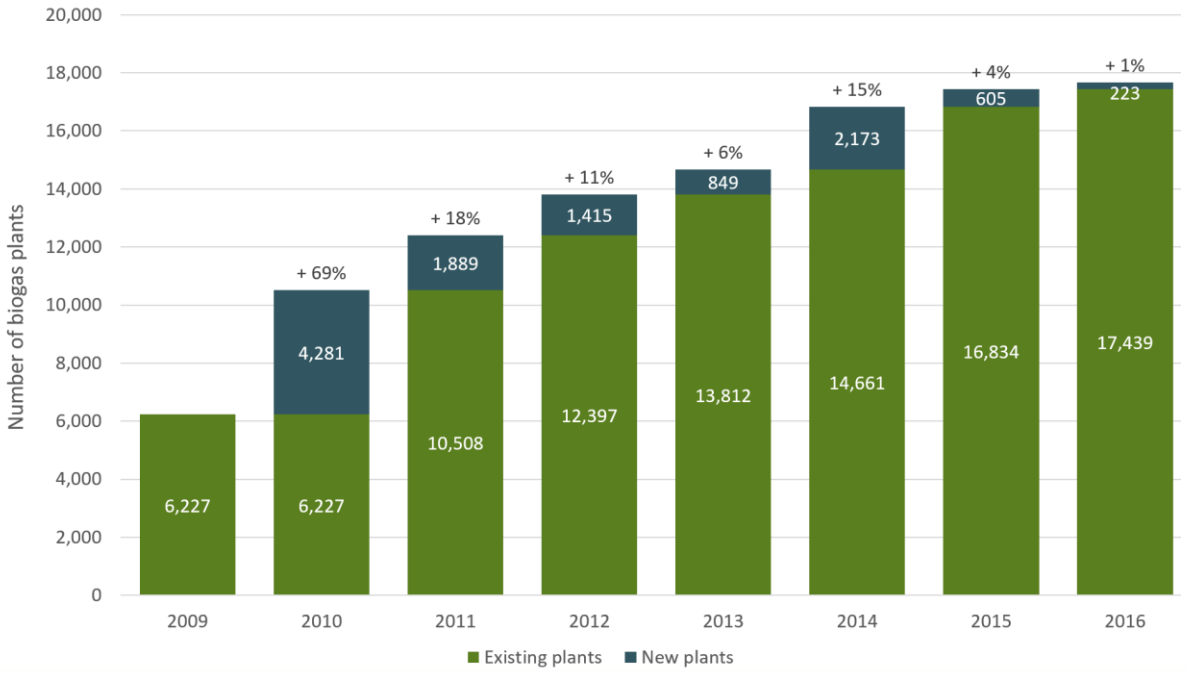


Figure 1: Evolution of the number of biogas plants in Europe, Source: EBA Statistical Report 2017

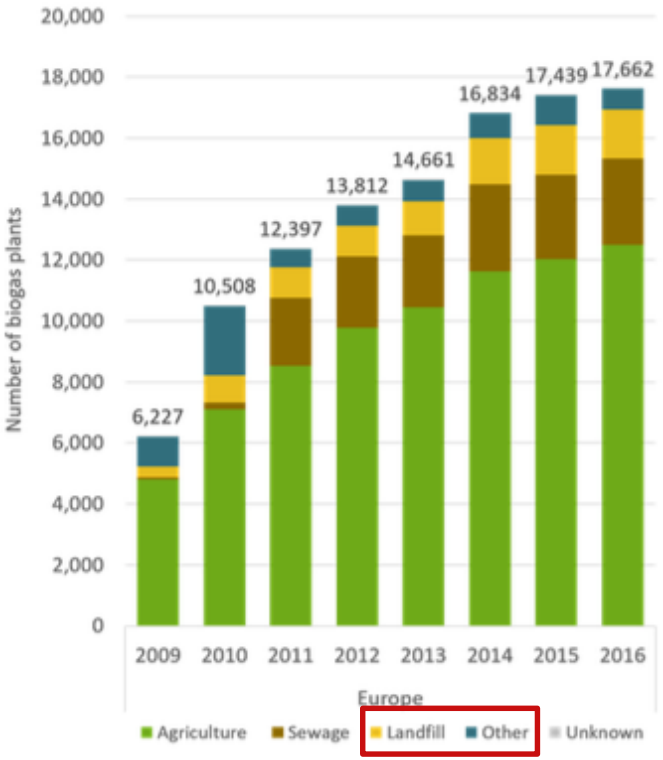


Figure 2: Evolution of the number of plants per feedstock, Source: EBA Statistical Report 2017

Overview - Evolution of Biomethane Production in the EU
概述 – 欧洲生物天然气工程数量

In 2016:

- Number of plants 工厂数量: 503
- Total annual production 年总产出: 17,264 GWh (EU28)

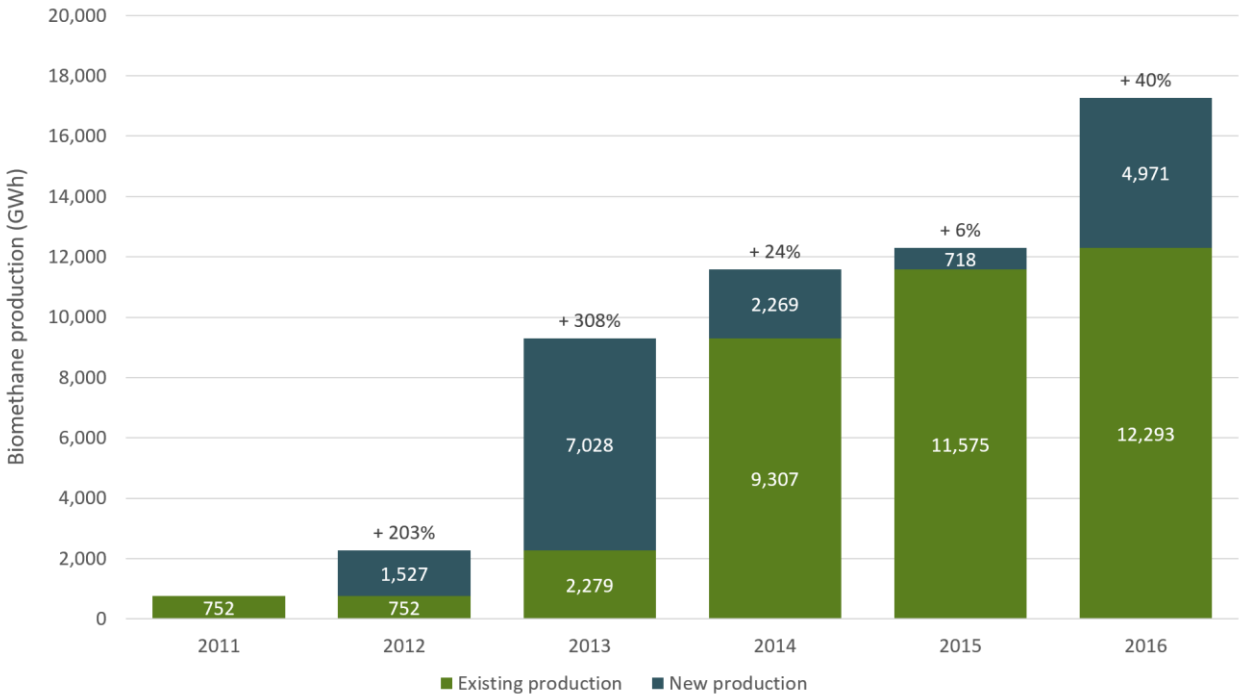


Figure 3: Evolution of biomethane production in Europe (GWh), Source: EBA Statistical Report 2017

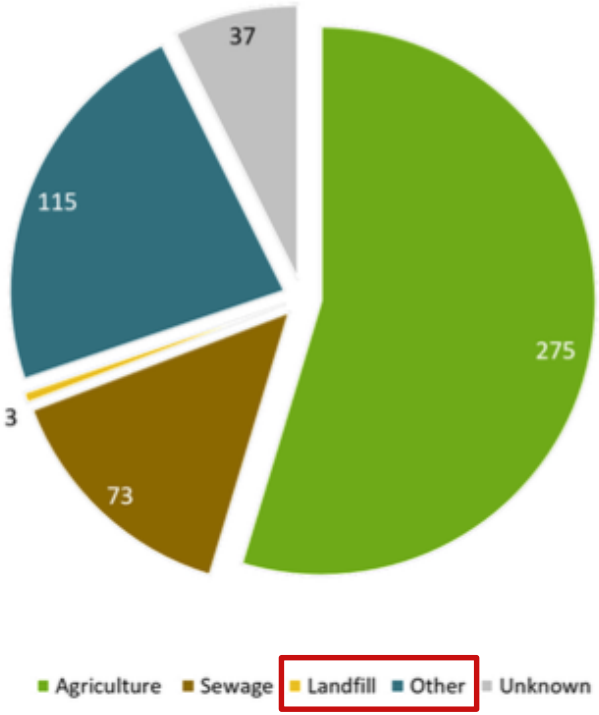
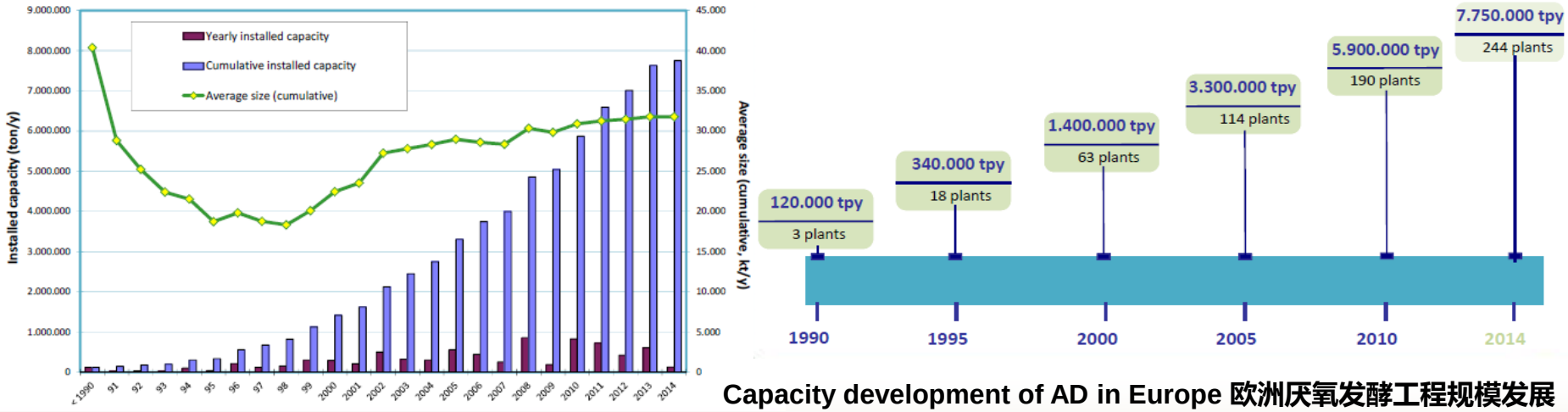


Figure 4: Number of biomethane producing plants per feedstock in 2016, Source: EBA Statistical Report 2017

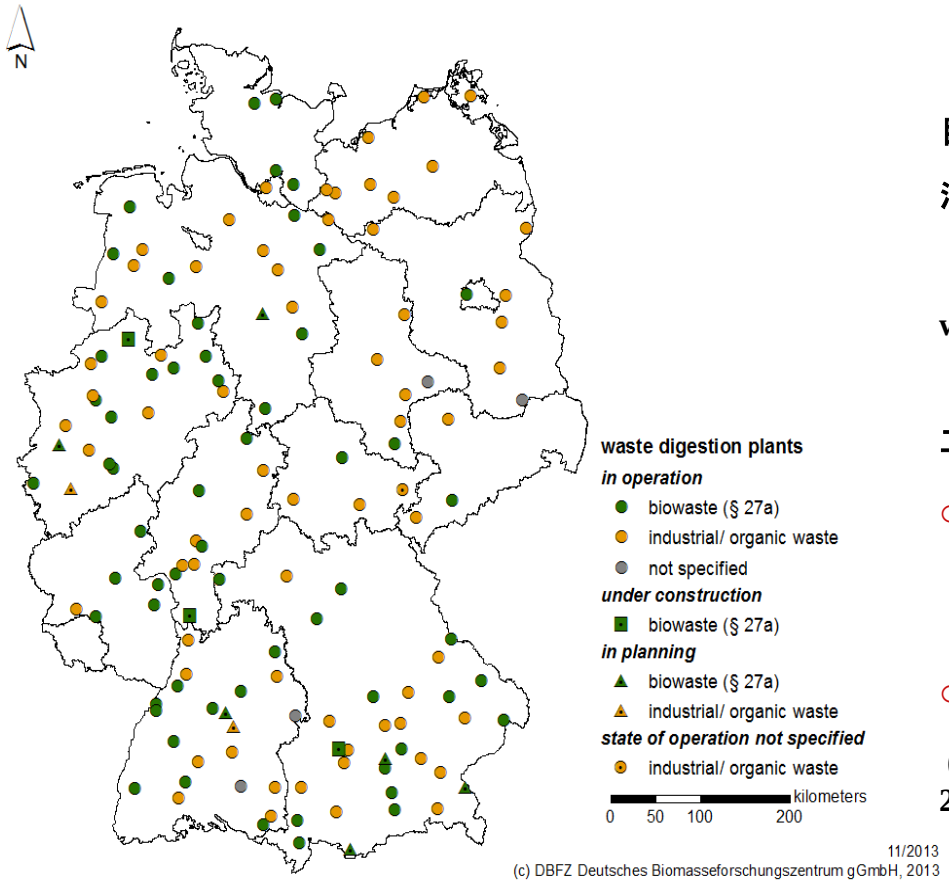
Waste – based AD capacity development in Europe
欧洲垃圾厌氧发酵工程容量发展

- Almost 8 million ton per year of digestion capacity in Europe by end 2014 in 244 plants
  2014年底244座工程处理能力可达800万吨每年。
- Equivalent to 5% of all household solid waste generated in Europe and equivalent to 25% of all biological treatment (incl. aerobic composting) for household solid waste 等同于欧洲家庭垃圾产生量的5%，等同于生物方法（含堆肥）处理能力的25%
- Steady increase in size since 1998; from 18.000 t/y to on average 32.000 t/y of digestion capacity (now 36.000 t/y on average in last 10 years = about 120,000 inhabitants) 自从1998年稳定增长，从平均规模1.8万吨/年到平均3.2万吨/年，过去10年平均为3.6万吨/年 = 一个工程平均覆盖12万人口



Capacity development of AD in Europe 欧洲厌氧发酵工程规模发展

Biogas Generation from Biowaste in Germany
德国利用有机垃圾的沼气生产



Waste digestion plants in Germany according to state of operation and substrate input (DBFZ database, 11/2013)

- about 130 plants generating biogas from organic waste digestion in operation (11/2013)

目前大约有130家运营工厂（11/2013）从有机垃圾消化中产生沼气

→ input: exclusively or predominantly bio-waste and green waste, organic waste and waste from the food industry

输入：专门或主要是生物垃圾和绿色垃圾，有机垃圾和食品工业垃圾

- 75 plants use municipal bio-waste from separate waste collection

75家工厂使用来自单独垃圾收集的市政生物垃圾

- 59 plants use exclusively or predominantly bio-waste

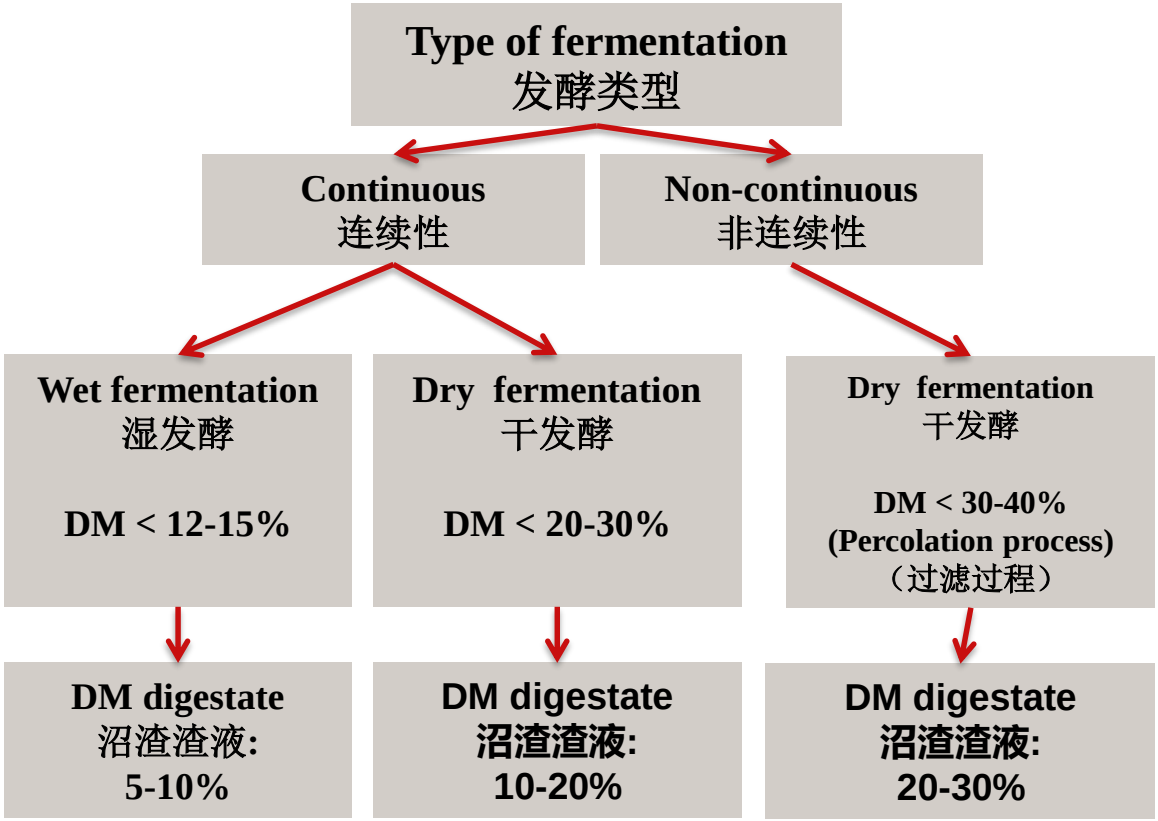
(under the terms of § 27a Renewable Energy Sources Act of 2012)

59家工厂专门或主要使用生物垃圾

（根据2012年可再生能源法案27a的条款）

Source: DBFZ, Projekt Stromerzeugung aus Biomasse, 2013

Bio-waste fermentation: overview technologies
有机垃圾发酵：技术概览



- A wide range fermentation types is available

有多种发酵类型可供选择

- Fermentation types are grouped according to (1) continuous or non-continuous processes and (2) dry or wet fermentation

发酵类型根据(1)连续或非连续过程和(2)干或湿发酵分组

- The choice of process depends on the dry matter content A wide range fermentation types is available

对于过程的选择取决于干物质含量。可提供广泛的发酵类型。

Source: BMU: Ökologisch sinnvolle

Pretreatment of wet fermentation
湿发酵预处理

Grinding by: screw-, knife- or hammer mills
螺旋切割

pre-disposal through squeezing
通过挤压的方式预处理

Hydro-pulper for liquid digestion technology

3 Fractions 3部分:

- **swim (Plastic, wood,..)**
- **飘浮 (塑料、木头）**
- **sink (stones, glass, sand for disposal)**
- **沉淀 (石头、玻璃、需处理的沙子)**
- **liquid suspension – for fermentation**
- **悬浮液 — 发酵**

Continuous stirred-tank reactor (CSTR)
全混工艺

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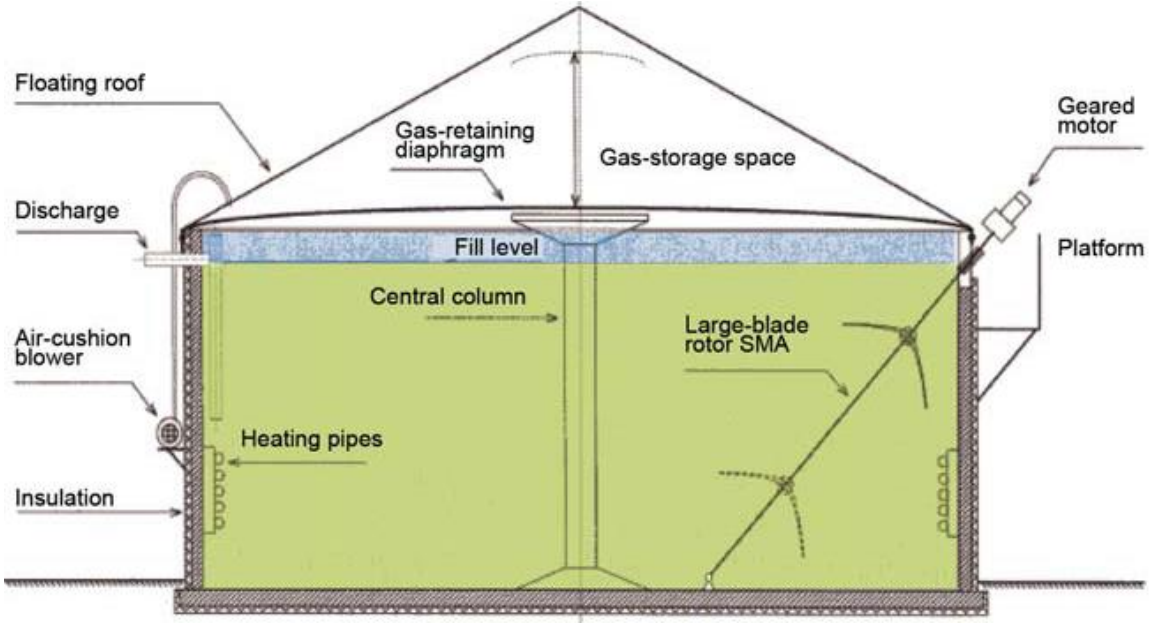
Suitable for livestock and poultry manure, energy crops (silage) kitchen waste, fruit and vegetable waste and other raw materials
适用于畜禽粪便、能源作物（青贮）餐厨垃圾、果蔬垃圾等原料






- **Wet fermentation process with stirring, continuous fermentation**

湿法发酵工艺，带搅拌，连续发酵

- **Reliable and flexible technology**

可且灵活的技术

- **靠Helps microbes in contact with raw materials**

有助于微生物与原料接触

- **Fully fermented raw materials**

可完全进行发酵的原料

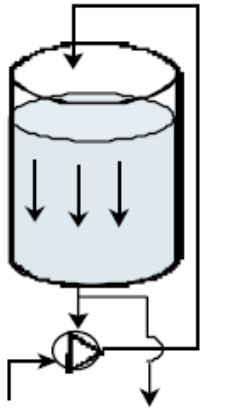
- **A large number of German companies use such processes， for Example： Envitec, MT, GICON, Weltec, Ökobit, BTA, AAT, Strabag, AAB, Arrowbio, Entec, Envirotec, Envitec, Schubio, AMB Haase, Biostab, Preseco**

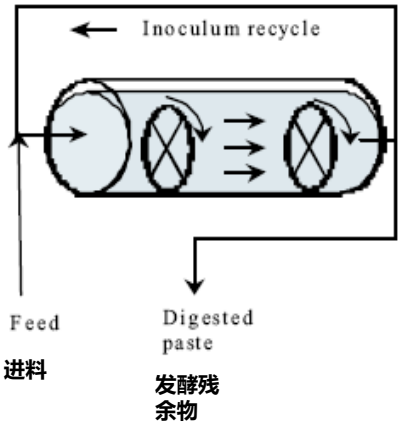
大量德国公司采用此类工艺

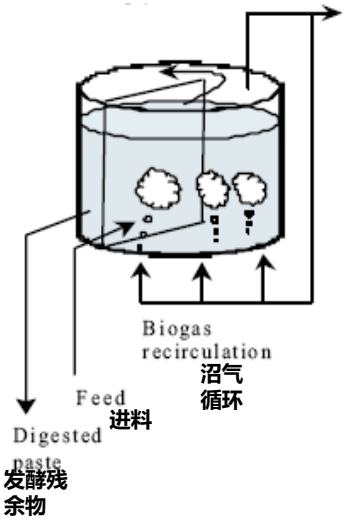
Anaerobic Digestion of high DM Feedstock
高浓度干物质含量原料的厌氧发酵

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Dranco **Kompogas** **Valorga** **BTA/LINDE** **Bekon GICON CARE, BAT**

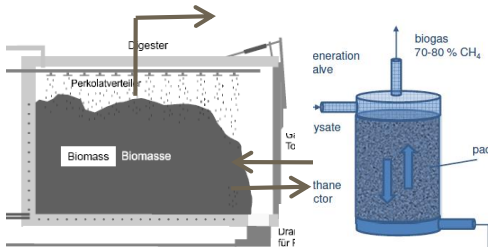






3 phases pulper

3相打浆机



Garage fermenter

2-step fixed bed reactor

车库式发酵间

2步固定床反应器

Anaerobic Digestion of Bio-Waste 生物垃圾的厌氧消化
Kompogas Technology (CH), Plugflow reactor (CSPFR)

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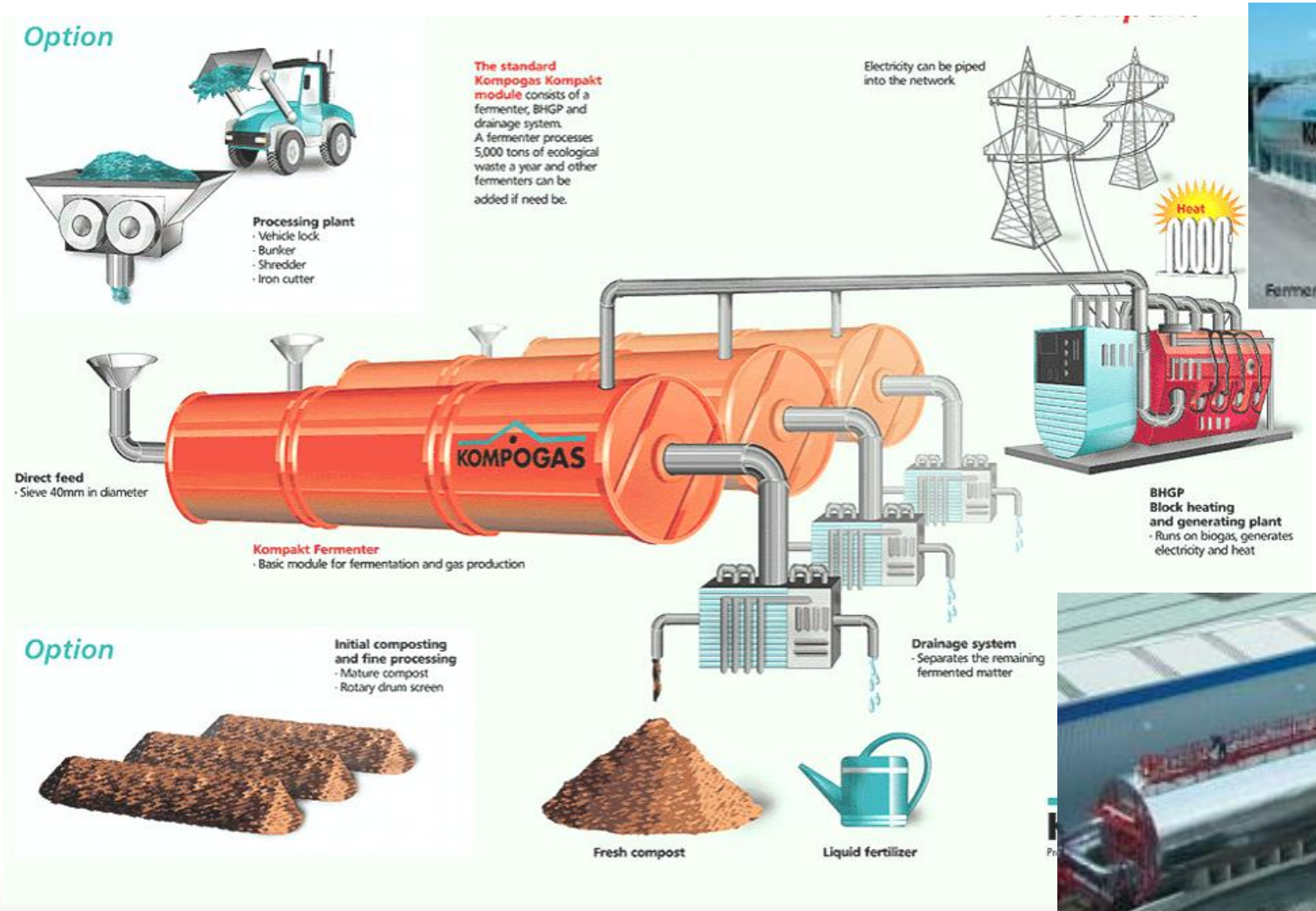
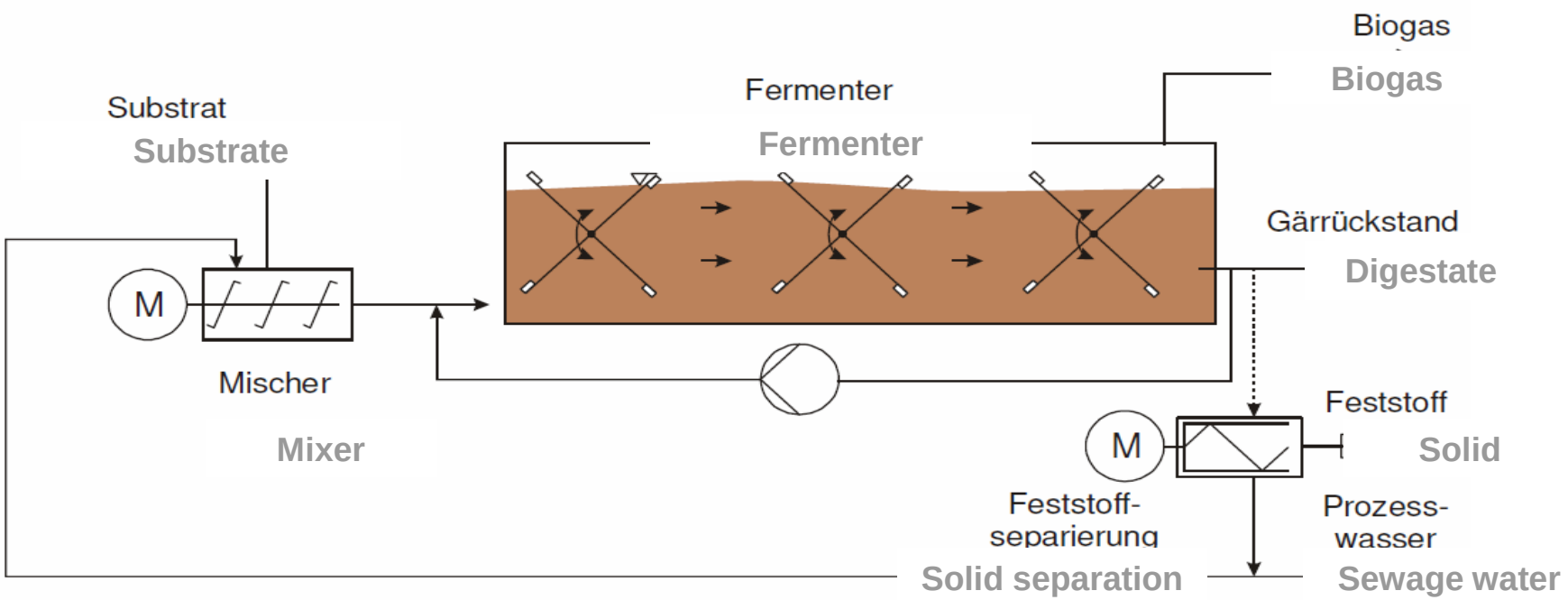
塞流式反应器



Plug flow fermentation – continuous operation
推流式反应器 – 连续发酵



- Cross-flow reactor with agitation, continuous fermentation, higher than the fermentation

横推流反应器，带搅拌，连续发酵，比CSTR技术的发酵浓度高

- Reliable and flexible technology

可靠且灵活的技术

- 有助于微生物与原料接触

Helps microbes in contact with raw materials

- Low operating energy consumption

运行能耗低

- Fully fermented raw materials

可完全对原料进行发酵

- A large number of German companies use such processes

大量德国公司采用此类工艺，比如：Axpo Kompogas, Archea, Dranco (vertikal), Valorga, Strabag u.a.

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Dry fermentation – continuous operation
干式发酵 – 连续发酵

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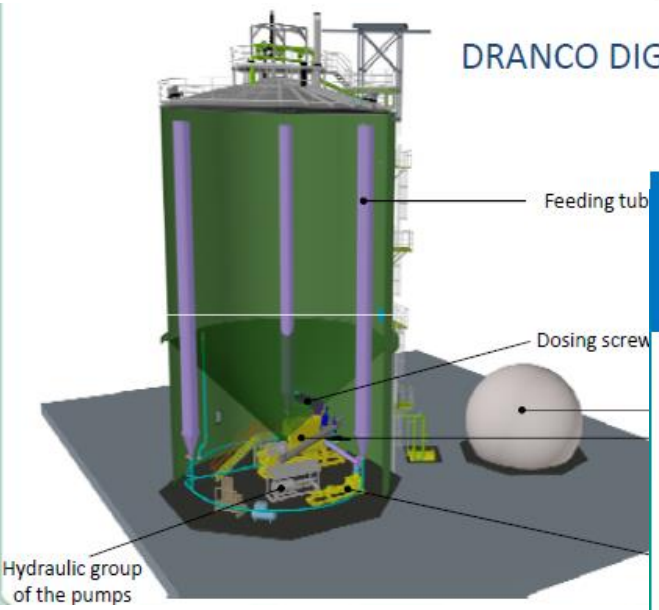
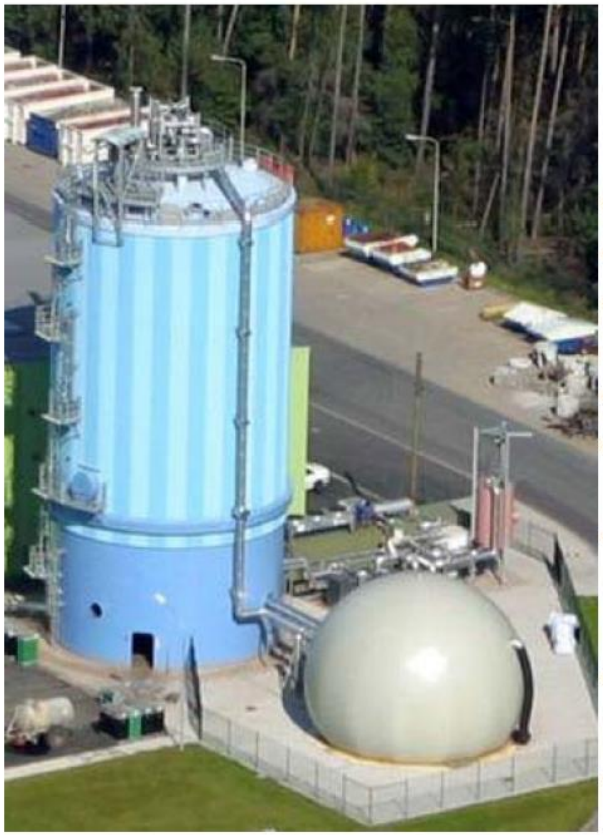




Biogas Plant

Digester:

- 26 m high, 2.500 m³ total volume
- System: Dry Fermentation, 55° C
- Input: Organic material with 45 % DS
  approx. 35.000 tons / a
- Output: ~ 600 m³ Biogas / hour
- Retention Time: 21 days
  10 circles
- Gas-Elements: CH_4 50 – 60 %
  CO_2 40 – 50 %

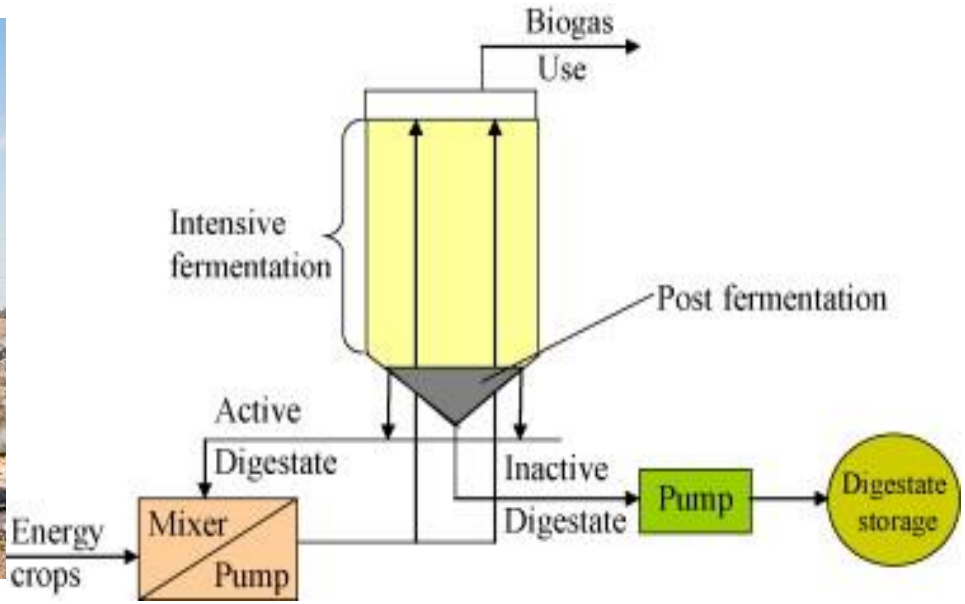
CHP unit:

- 460 kW el. 520 kW th. Energy

Gas Storage:

- Volume 600 m³

Dry fermentation – continuous operation
干式发酵 – 连续发酵

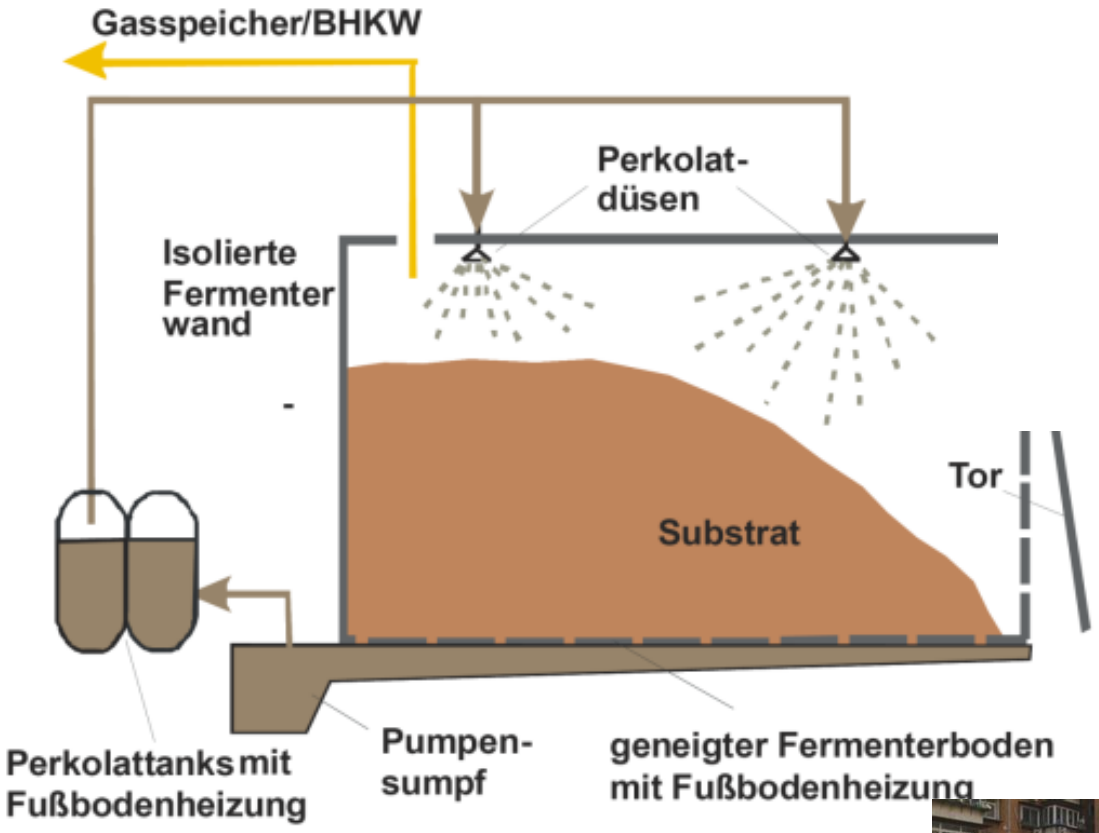


- No moving parts in the digester
- 发酵罐内不存在活动部件
- Piston pump moves the digestate and mixes fresh substrate in
- 利用活塞泵将原料和沼渣混合后入罐

Dry fermentation – batch operation
干式发酵 – 批式发酵

Suitable for household waste, kitchen waste, straw, and other organic wastes with more impurities

适用于家庭垃圾、厨余垃圾、秸秆、以及其他杂质较多的有机废弃物



- Non-continuous (batch) technology for solid dry materials

非连续性（批式）技术，适用于固体干原料

- Reliable and flexible technology

可靠且灵活的技术

- Suitable for raw materials with high impurities, low pretreatment requirements

适用于杂质较多的原料，对预处理要求低

- Low construction and operating costs

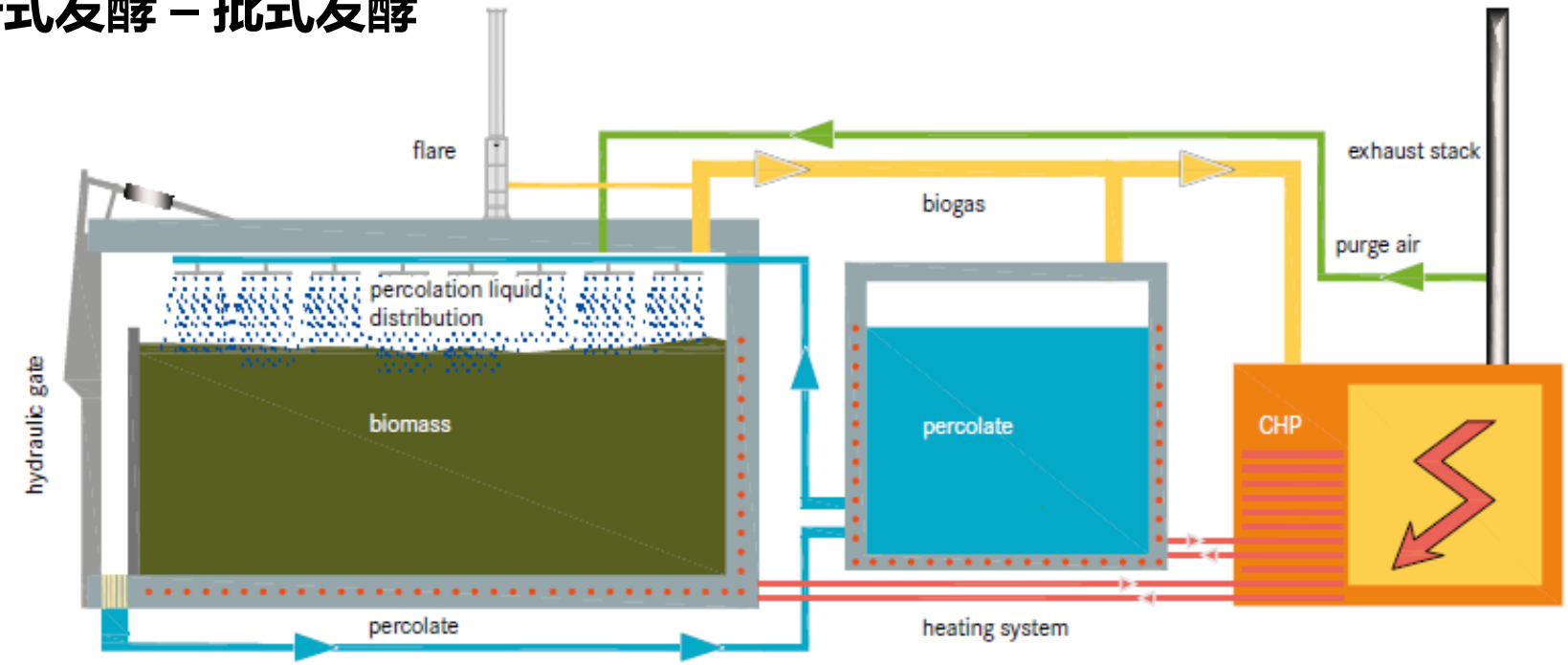
建造成本和运行成本低

- Easy to appear dead ends, unable to fully ferment raw materials

易出现死角，无法完全发酵原料

- A large number of German companies use such processes, for example：BEKON, Bioferm, Loock TNS, Biocel, Biopercolat, GICON, Kompoferm
- 大量德国公司采用此类工艺，

Dry fermentation – batch operation
干式发酵 – 批式发酵

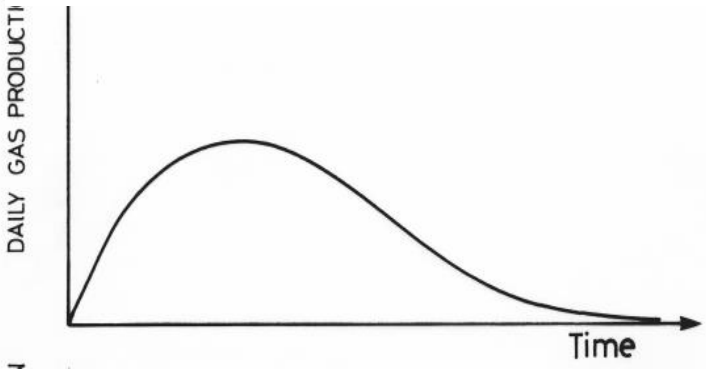


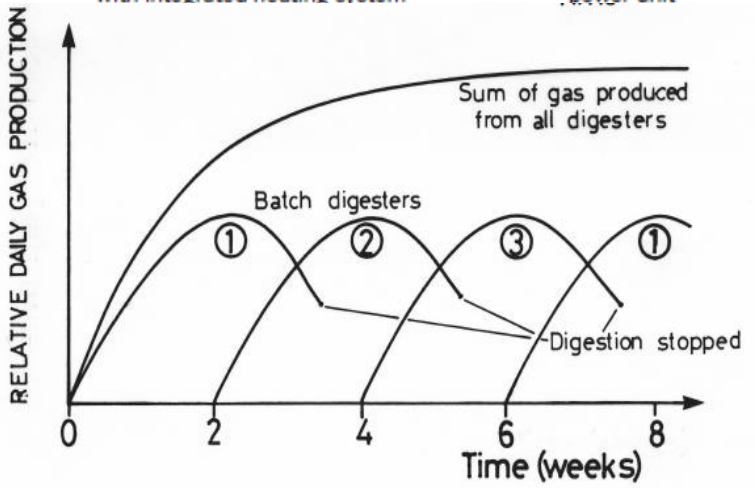
drainage system for percolation liquid

concrete digester with integrated heating system

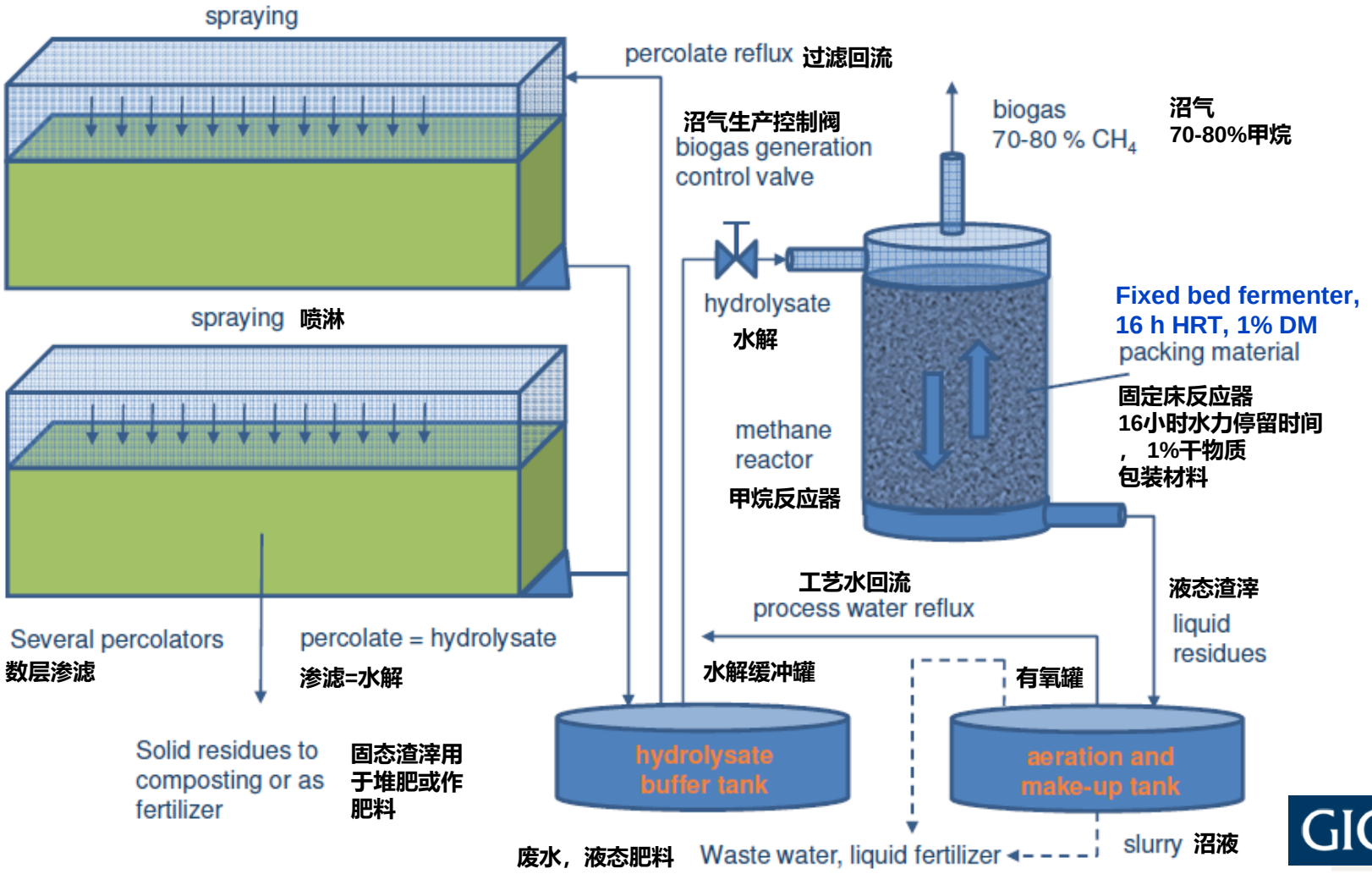
percolation liqid storage tank with integrated heating system

combined heat and power unit





Dry fermentation – 2-step batch operation
干式发酵 – 两步法批式发酵



Pohlsche Heide BMW Biogas Plant, BEKON Technology
BEKON技术，餐厨垃圾沼气工程

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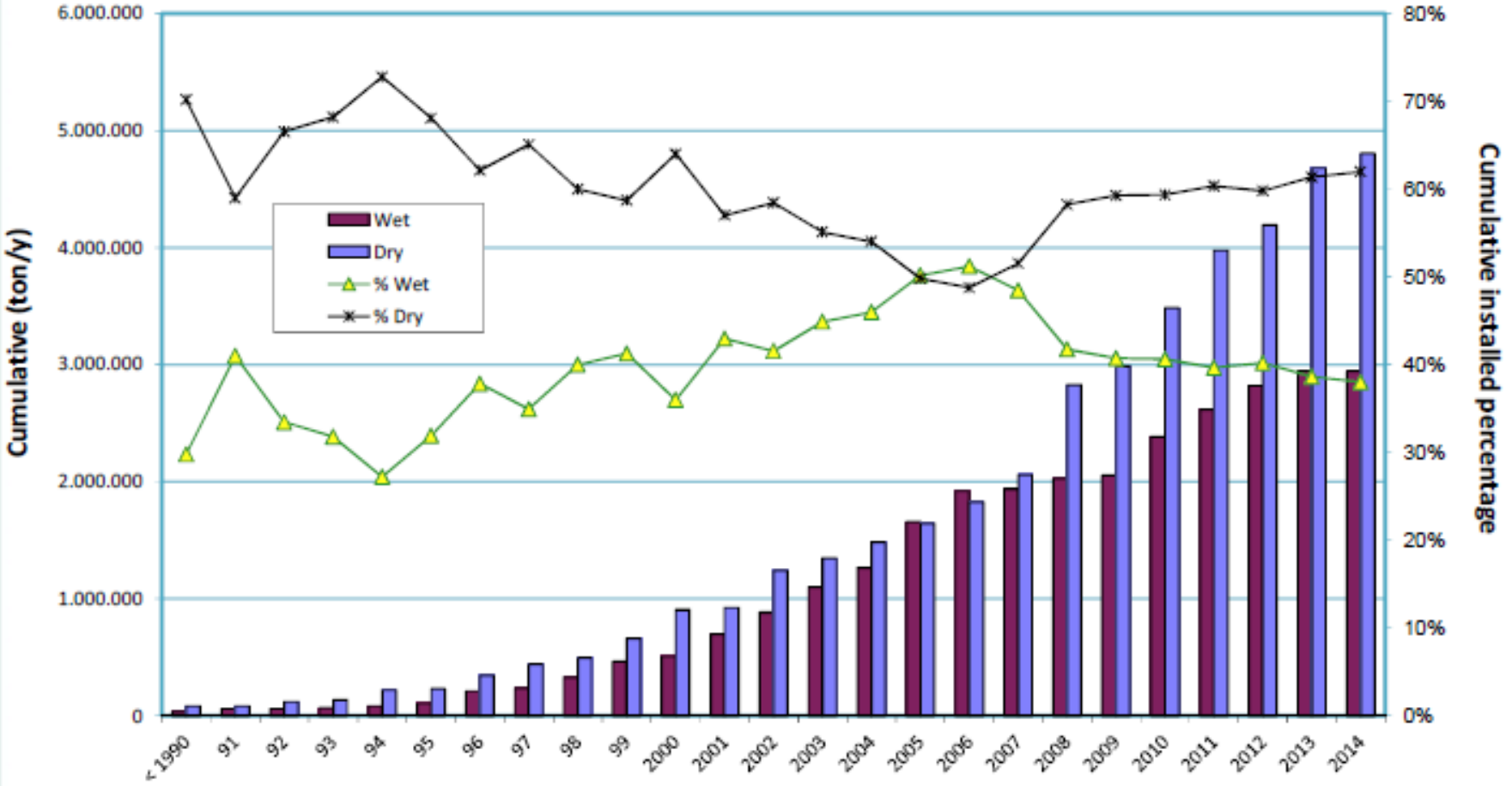
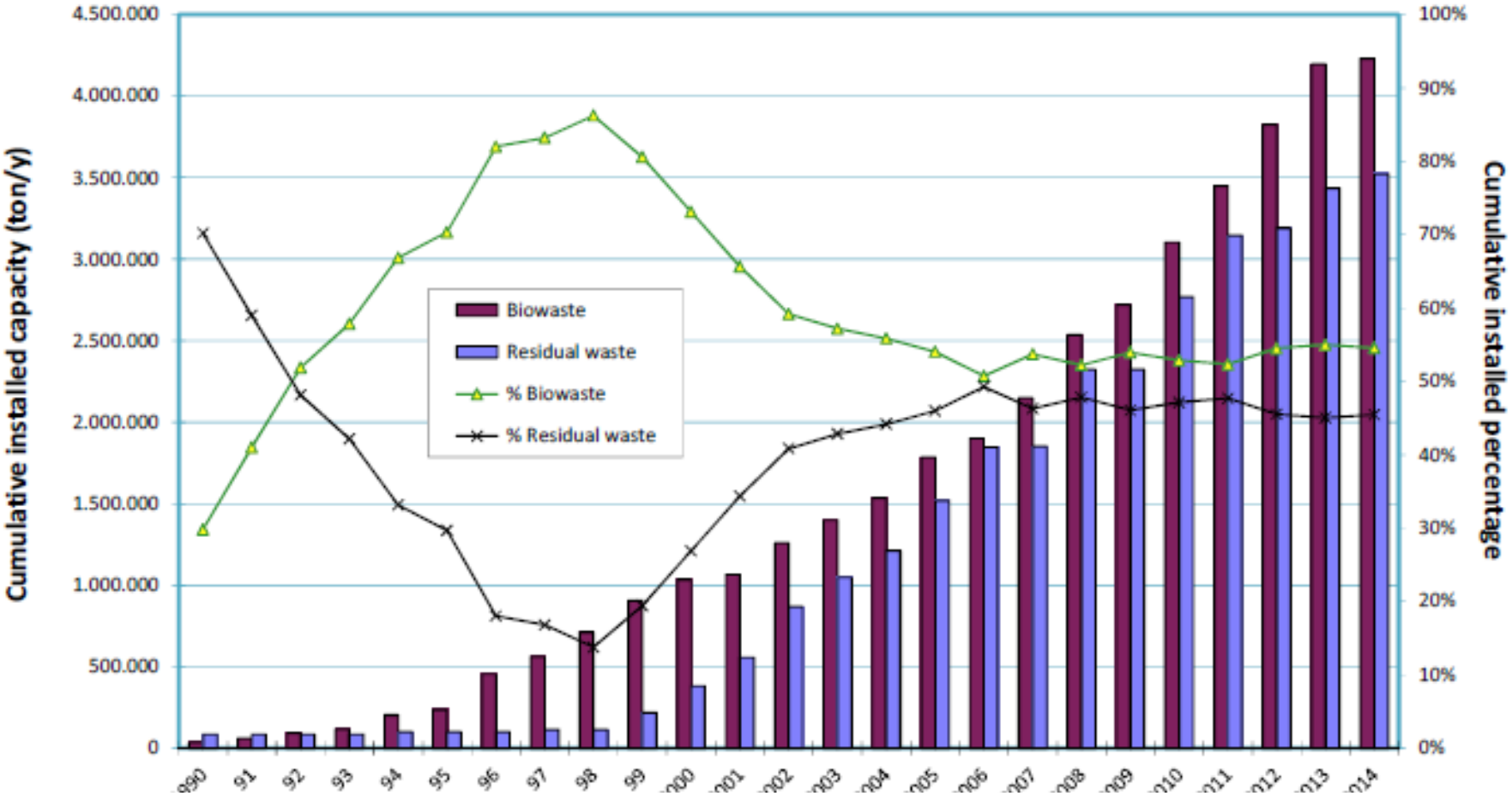
Input 原料	Kitchen waste (Biowaste bin) 厨余垃圾（绿桶）	40,000 tons 吨/ year年
Output 产品	Effluent fertilizer 沼渣肥	25,000 tons 吨 / year 年
Fermenter 发酵仓	12,000m³, 600 m³ each (26m × 5m ×5m),	TS=30% 35℃
HRT 停留时间	21days 天	
Ratio old to new feedstock 新旧原料比		1:1
Biogas production 沼气产量	60-90m³/t BMW 垃圾	500 m3 / hr, CH4 55-60%
Biogas utilization 沼气利用	Biomethane to grid (Carbotec PSA) 变压吸附，提纯入管网	250 m3 / hr, CH4 96%

Wet vs Dry
湿法vs干法



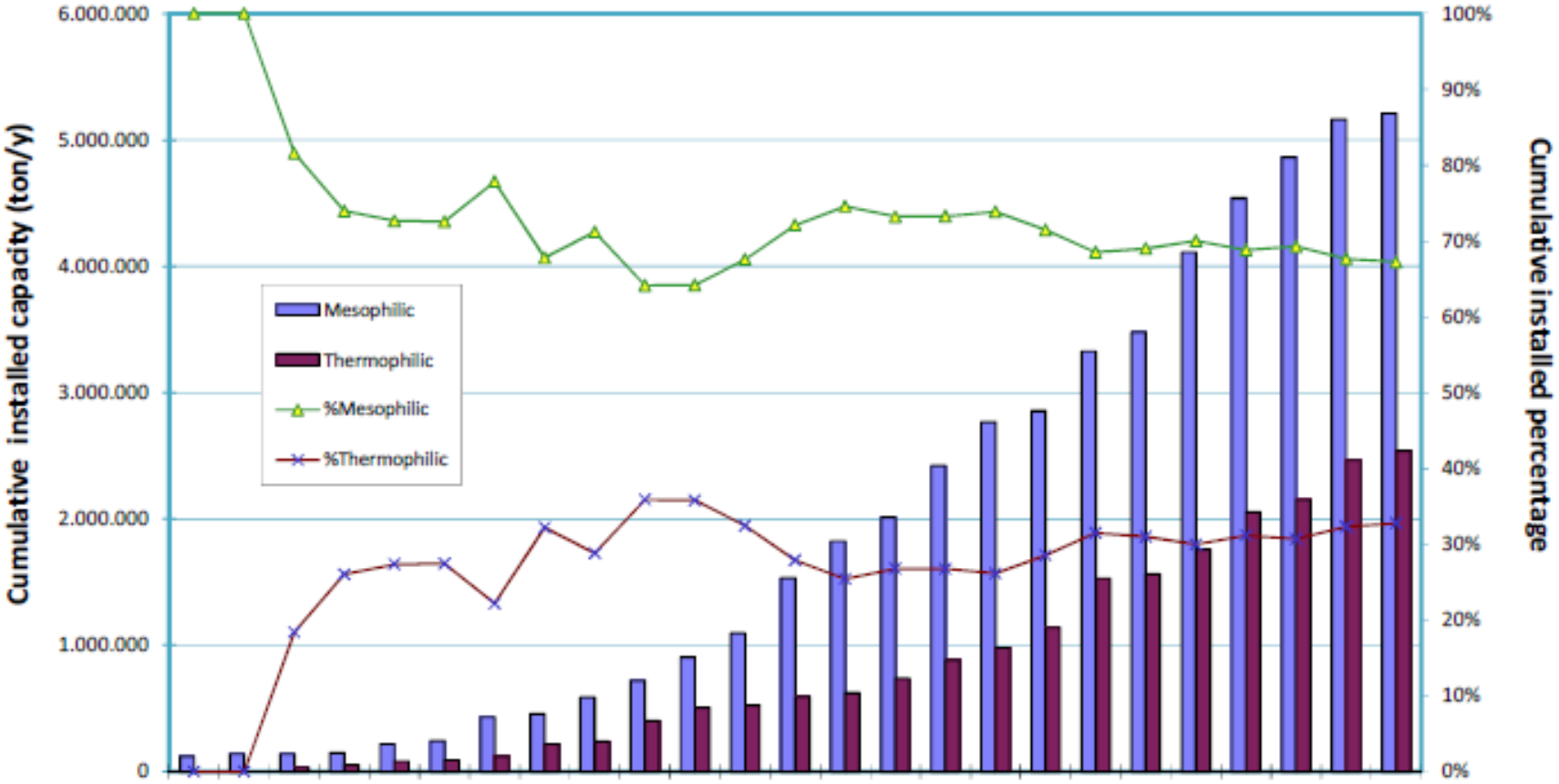
5-year development	1991-1995	1996-2000	2001-2005	2006-2010	2011-2014*
wet installed / 5y	71.500	401.750	1.148.250	727.750	562.000
dry installed / 5y	144.500	676.000	739.700	1.839.350	1.320.250
% wet digestion	33	37	61	28	30
% dry digestion	67	63	39	72	70

Biowaste vs residual waste
有机垃圾vs混合垃圾



5-year development	1991-1995	1996-2000	2001-2005	2006-2010	2011-2014*
Biowaste installed / 5y	201.000	797.250	749.750	1.318.950	1.125.750
Mixed waste installed / 5y	15.000	280.500	1.138.200	1.248.150	756.500
% biowaste	93	74	40	51	60
% mixed waste	7	26	60	49	40

Mesophilic vs thermophilic
中温vs高温



5-year development	1991-1995	1996-2000	2001-2005	2006-2010	2011-2014*
mesophilic installed / 5y	123.500	663.750	1.511.450	1.689.850	1.101.750
thermophilic installed / 5y	92.500	414.000	376.500	877.250	780.500
% mesophilic	57	62	80	66	59
% thermophilic	43	38	20	34	41

Choice of technology in selected countries
不同国家的技术选择

	Germany	Spain	Netherlands	Switzerland	Belgium	France
Wet	35%	55%	25%	0%	14%	1%
Dry	65%	45%	75%	100%	86%	99%
Mesophilic	62%	86%	52%	10%	35%	61%
Thermophilic	38%	14%	48%	90%	65%	39%
Biowaste	80%	15%	73%	100%	100%	21%
Mixed Waste	20%	85%	27%	0%	0%	79%

Thank you for your attention !

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Integrated Waste Management
NAMA Project