

**European Biogas Workshop and Study Trip
The Future of Biogas in Europe III
14-16. June 2007.**

University of Southern Denmark, Esbjerg, Denmark

**The future of biogas in Europe:
Visions and Targets 2020**

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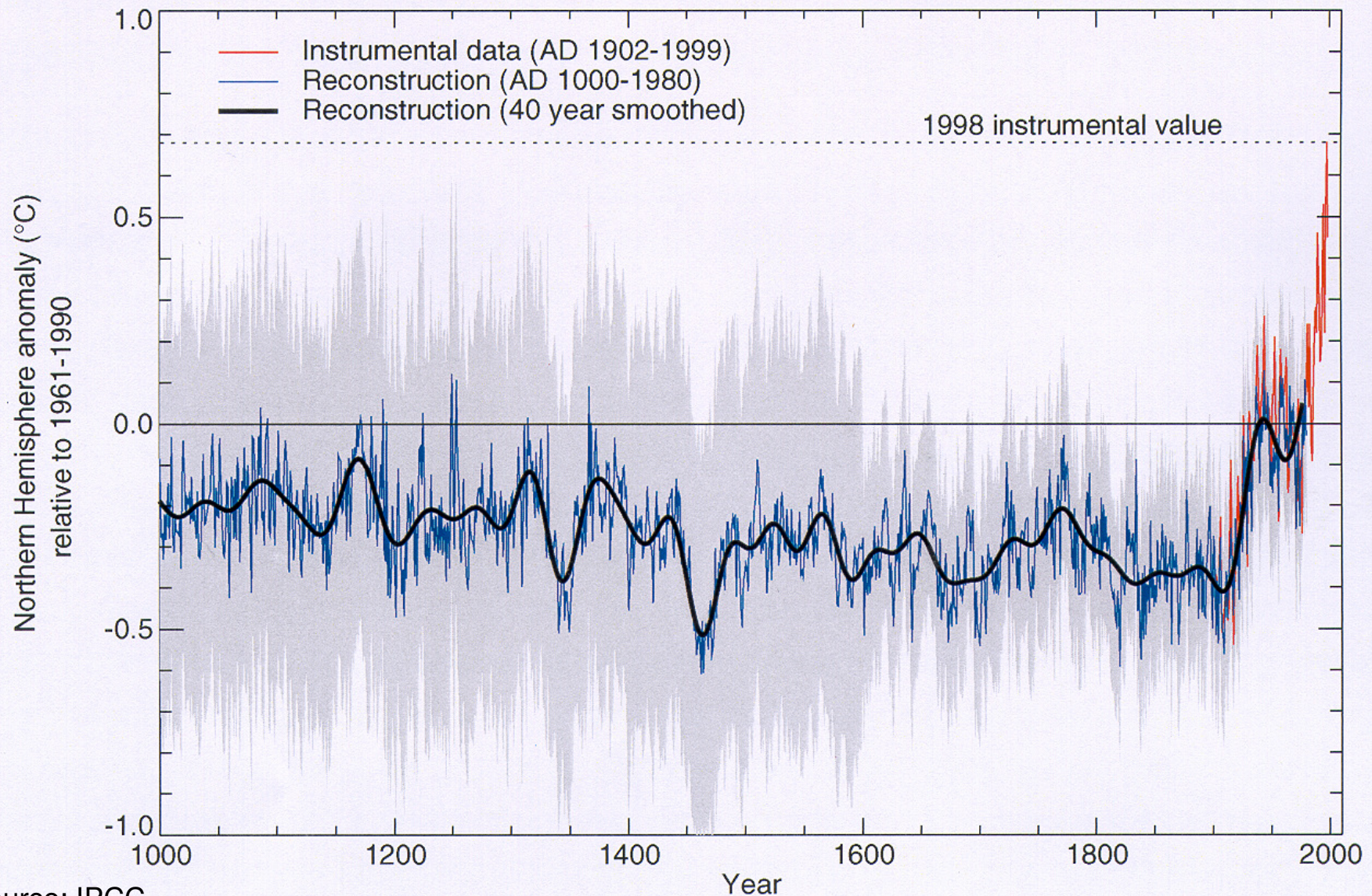
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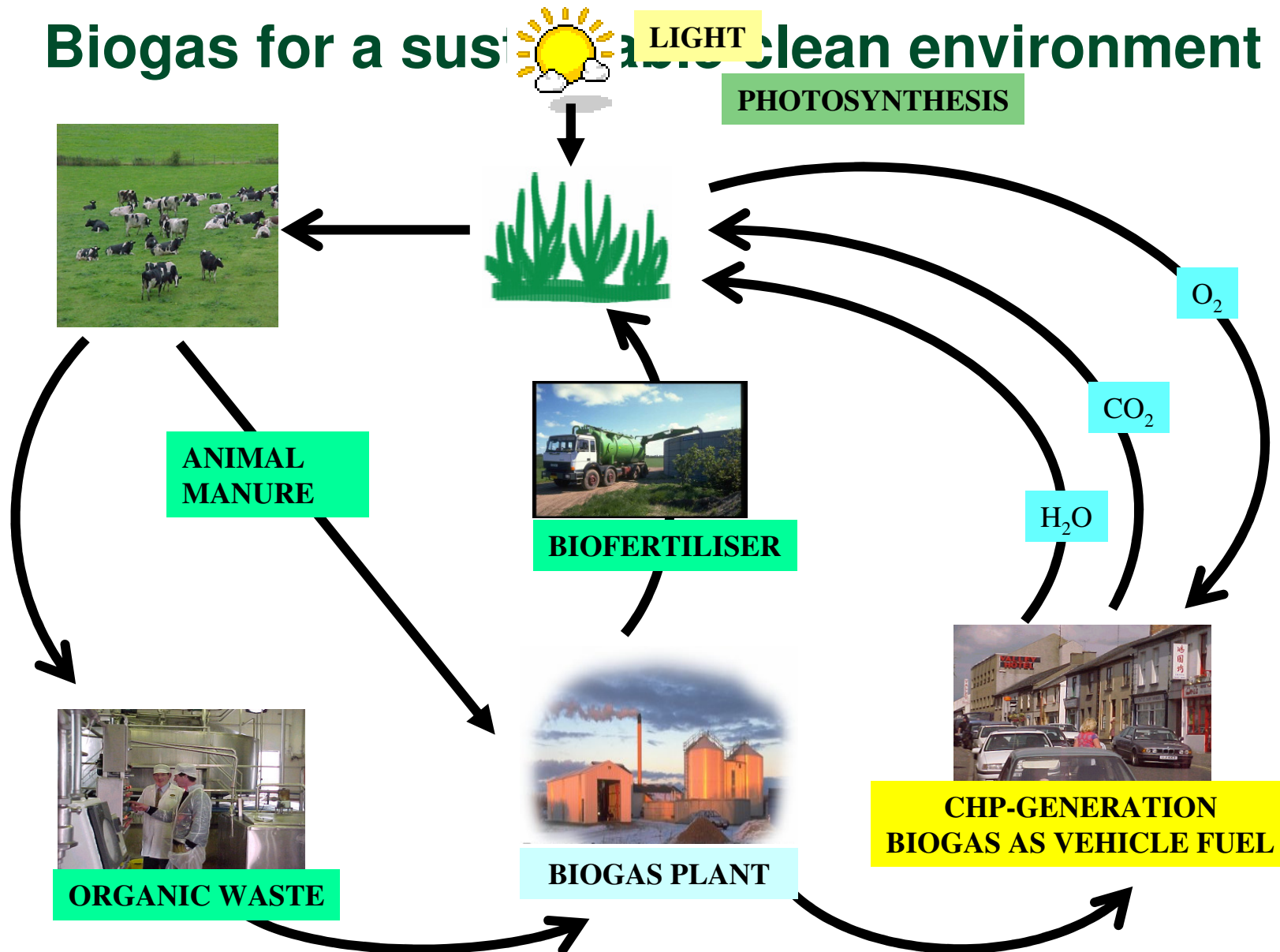
Piotr Oleskowicz-Popiel (SDU)

Development in global mean temperature



Source: IPCC

Biogas for a sustainable and clean environment



Data of total area and areas of interest for biomass production for each member of EU-27; area data in millions of hectares

	Total area (10 ⁶ Ha)	Agricultural area (10 ⁶ Ha)	Arable land (10 ⁶ Ha) (% of total area)		Hectares of agricultural land per capita
Austria	8.4	3.4	1.4	17	0.42
Belgium	3.1	1.4	0.8	27	0.13
Bulgaria	11.1	5.3	3.3	30	0.68
Cyprus	0.9	0.1	0.1	11	0.18
Czech Republic	7.9	4.3	3.1	39	0.42
Denmark	4.3	2.7	2.3	53	0.49
Estonia	4.5	0.8	0.5	12	0.63
Finland	33.8	2.2	2.2	7	0.43
France	55.2	29.7	18.5	33	0.49
Germany	35.7	17.0	11.8	33	0.21
Greece	13.2	8.4	2.7	20	0.77
Hungary	9.3	5.9	4.6	50	0.60
Ireland	7.0	4.4	1.2	17	1.09
Italy	30.1	15.1	8.0	26	0.26

Data of total area and areas of interest for biomass production for each member of EU-27; area data in millions of hectares

	Total area (10 ⁶ Ha)	Agricultural area (10 ⁶ Ha)	Arable land (10 ⁶ Ha) (% of total area)		Hectares of agricultural land per capita
Latvia	6.5	2.5	1.8	28	1.08
Lithuania	6.5	3.5	2.9	45	1.02
Luxemburg	0.3	0.1	0.06	24	0.28
Malta	0.03	0.01	0.01	31	0.03
Netherlands	4.2	1.9	0.9	22	0.12
Poland	31.3	16.2	12.6	40	0.42
Portugal	9.2	3.7	1.6	17	0.37
Romania	23.8	14.7	9.4	39	0.66
Slovakia	4.9	2.4	1.4	29	0.45
Slovenia	2.0	0.5	0.2	9	0.26
Spain	50.5	30.2	13.7	27	0.73
Sweden	45.0	3.2	2.7	6	0.36
U. K.	24.4	17.0	5.7	23	0.28
EU-27	433.1	196.6	113.5	26	0.41

Cultivation of non-food crops in Germany in 2006

Raw materials	Surface area in ha			Total
	Base areas*		Set aside	
	without energy crop premium	with energy crop premium		
Rapeseed	610,000	172,000	318,000	1,100,000
Oilseed lin	3,000			3,000
Sunflower	4,000		1,000	5,000
Other energy crops(incl.maize)	30,000	188,000	77,000	295,000
Starch	128,000			128,000
Sugar	18,000			18,000
Fibres	2,000			2,000
Pharmaceutical crops	10,000			10,000
Total	805,000	360,000	396,000	1,561,000*

***1,561,000 ha is 13.2% of the German arable land**

Energy crop potential in EU-27, depending on percentage of utilized arable land and achieved crop yield

Yield	10% arable land in EU-27		20% arable land in EU-27		30% arable land in EU-27	
	PJ	Mtoe	PJ	Mtoe	PJ	Mtoe
10 t TS/ha	2,042 PJ	46 Mtoe	4,084 PJ	91 Mtoe	6,127 PJ	137 Mtoe
20 t TS/ha	4,084 PJ	91 Mtoe	8,169 PJ	182 Mtoe	12,253 PJ	274 Mtoe
30 t TS/ha	6,127 PJ	137 Mtoe	12,253 PJ	274 Mtoe	18,380 PJ	410 Mtoe

New EU energy plan include a cut in CO₂ emissions by at least 20% by 2020. The commission will propose increasing the use of renewable energy sources to 20% of the total demand, to limit global temperature changes to no more than 2°C above pre-industrial levels. It also wants to improve the EU's energy efficiency by 20%. This would make Europe the most energy-efficient region in the world.

Methane potential originated from energy crops from 5% of the arable land in EU-27 with the cropping yield equal to 10, 20, and 30 tTS/ha

Energy crop yield	10 tTS/ha	<u>20 tTS/ha</u>	30 tTS/ha
Methane potential	25.3 billion m ³ CH ₄	50.7 billion m ³ CH ₄	76.0 billion m ³ CH ₄
	22.8 Mtoe	<u>45.5 Mtoe</u>	68.5 Mtoe

Estimated amounts of animal manure in EU-27 (based on Faostat, 2003)

Country	Cattle	Pigs	Cattle	Pigs	Cattle manure	Pig manure	Total manure
	[1000Heads]	[1000Heads]	1000livestock units	1000livestock units	[10 ⁶ tons]	[10 ⁶ tons]	[10 ⁶ tons]
Austria	2051	3125	1310	261	29	6	35
Belgium	2695	6332	1721	529	38	12	49
Bulgaria	672	931	429	78	9	2	11
Cyprus	57	498	36	42	1	1	2
Czech R.	1397	2877	892	240	20	5	25
Denmark	1544	13466	986	1124	22	25	46
Estonia	250	340	160	28	4	1	4
Finland	950	1365	607	114	13	3	16
France	19383	15020	12379	1254	272	28	300
Germany	13035	26858	8324	2242	183	49	232
Greece	600	1000	383	83	8	2	10
Hungary	723	4059	462	339	10	7	18
Ireland	7000	1758	4470	147	98	3	102
Italy	6314	9272	4032	774	89	17	106
Latvia	371	436	237	36	5	1	6
Lithuania	792	1073	506	90	11	2	13
Luxembourg	184	85	118	7	3	0	3
Malta	18	73	11	6	0	0	0
Netherlands	3862	11153	2466	931	54	20	75
Poland	5483	18112	3502	1512	77	33	110
Portugal	1443	2348	922	196	20	4	25
Romania	2812	6589	1796	550	40	12	52
Slovakia	580	1300	370	109	8	2	11
Slovenia	451	534	288	45	6	1	7
Spain	6700	25250	4279	2107	94	46	140
Sweden	1619	1823	1034	152	23	3	26
U.K.	10378	4851	6628	405	146	9	155
EU-27	91364	160530	58348	13399	1284	295	1578

Energy potential of pig and cattle manure in EU-27

Total manure	Biogas	Methane	Potential	Potential
[10 ⁶ tons]	[10 ⁶ m ³]	[10 ⁶ m ³]	[PJ]	[Mtoe]
1,578	31,568	20,519	827	18.5

Methane heat of combustion: 40.3 MJ/m³; 1 Mtoe = 44.8 PJ
 Assumed methane content in biogas: 65%

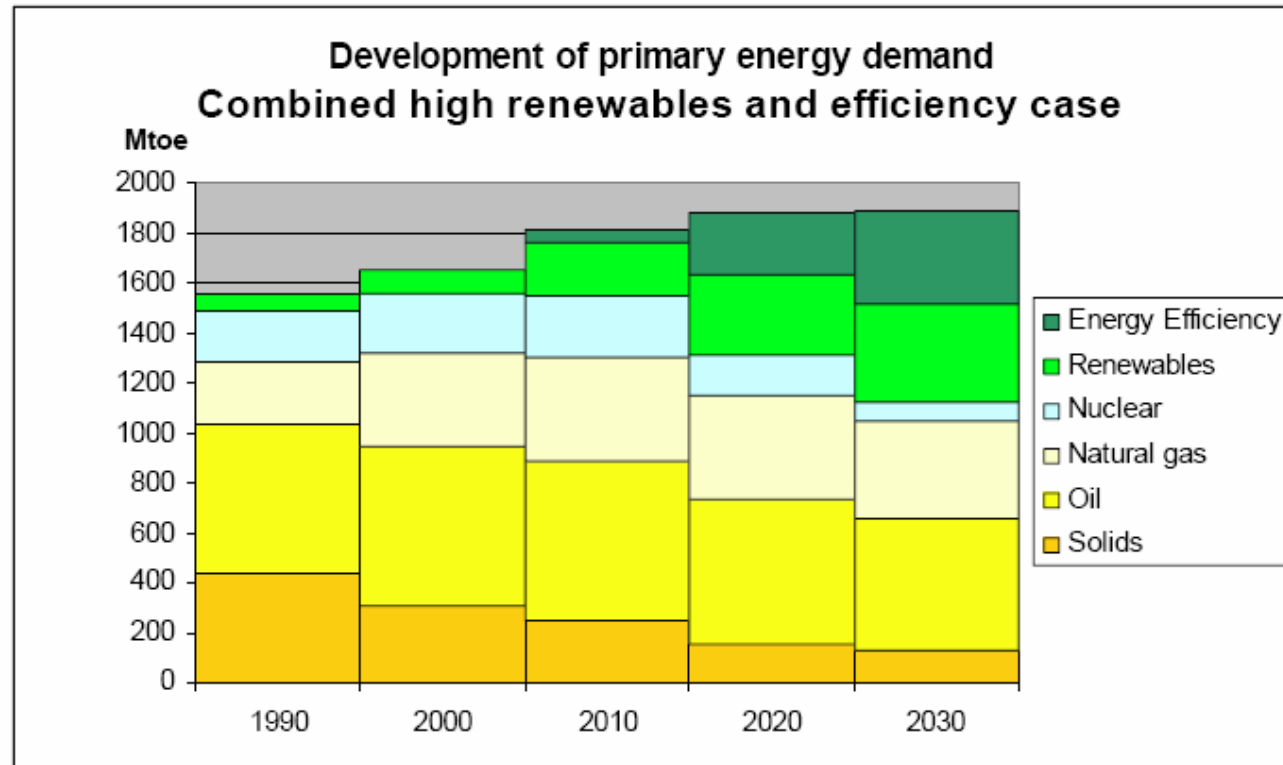


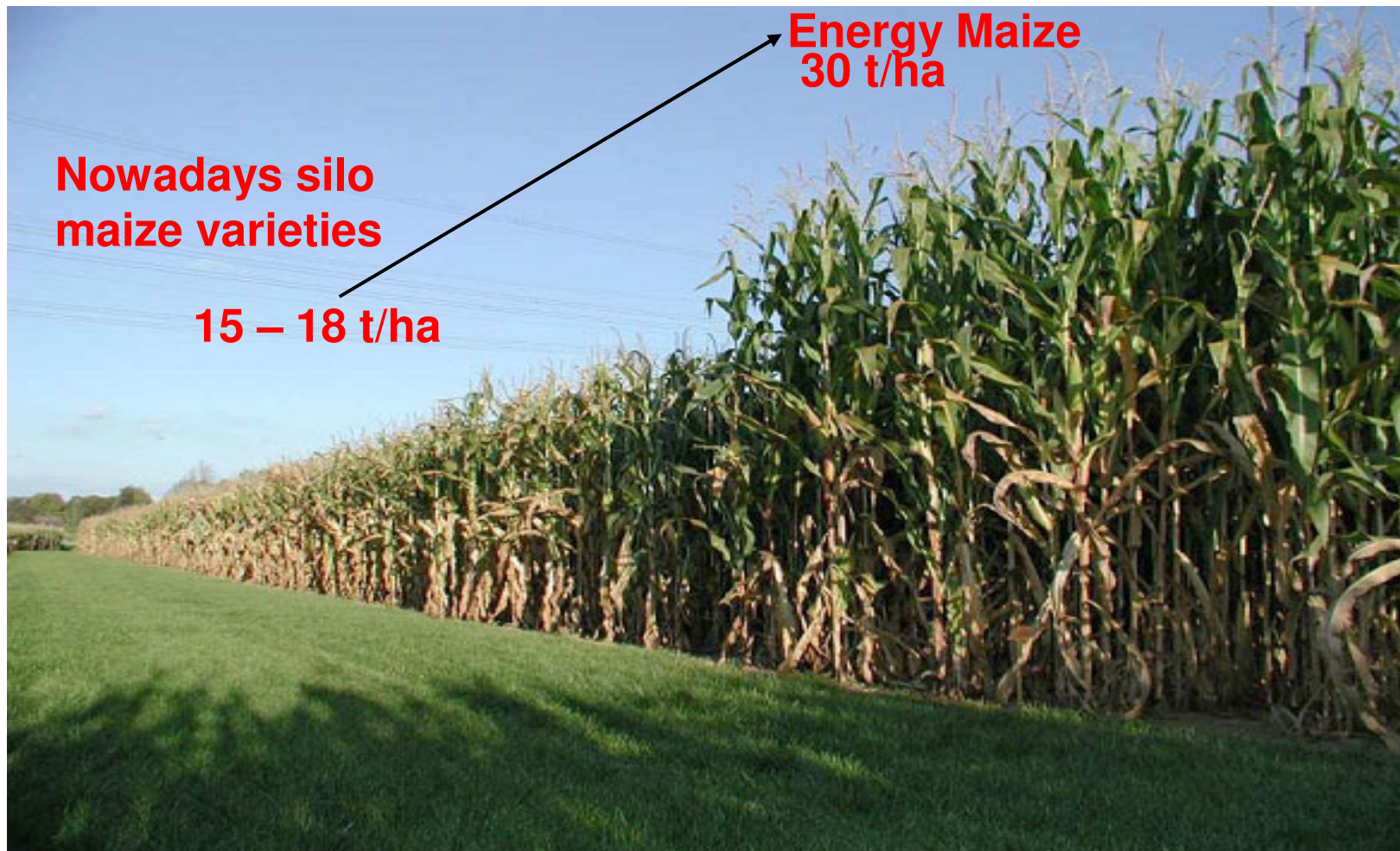
Figure 9: Impact of the strong renewable energy and energy efficiency penetration on the EU's primary energy demand (PRIMES modelling results)

Source: European Commission

182 Mtoe can be achieved from biomass cultivated on 20% of arable land in EU-27.

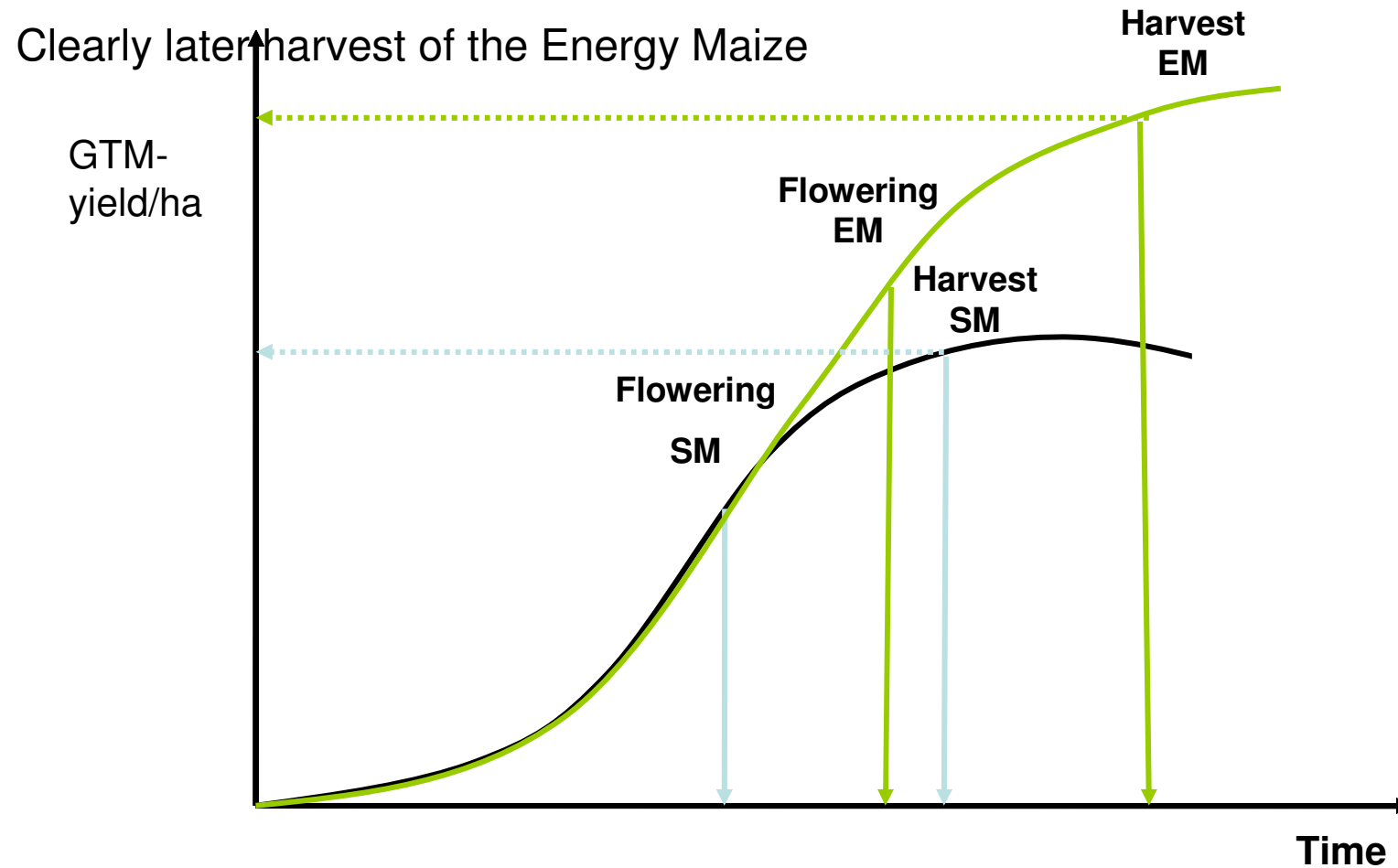
This corresponds to more than 10% of primary energy demand in 2020, equals 50-60% of the RES share.

**Cultivation target:
Stepwise increase of the energy yield to
approximately 100 % in 10 years**



Source:
KWS

Growth Progress of a Conventional Silo Maize (SM) and an Energy Maize (EM)



Source: KWS

Harvest of energy maize



Maize silos, digester and gas storage of the Energy Crop Digestion Plant Reidling



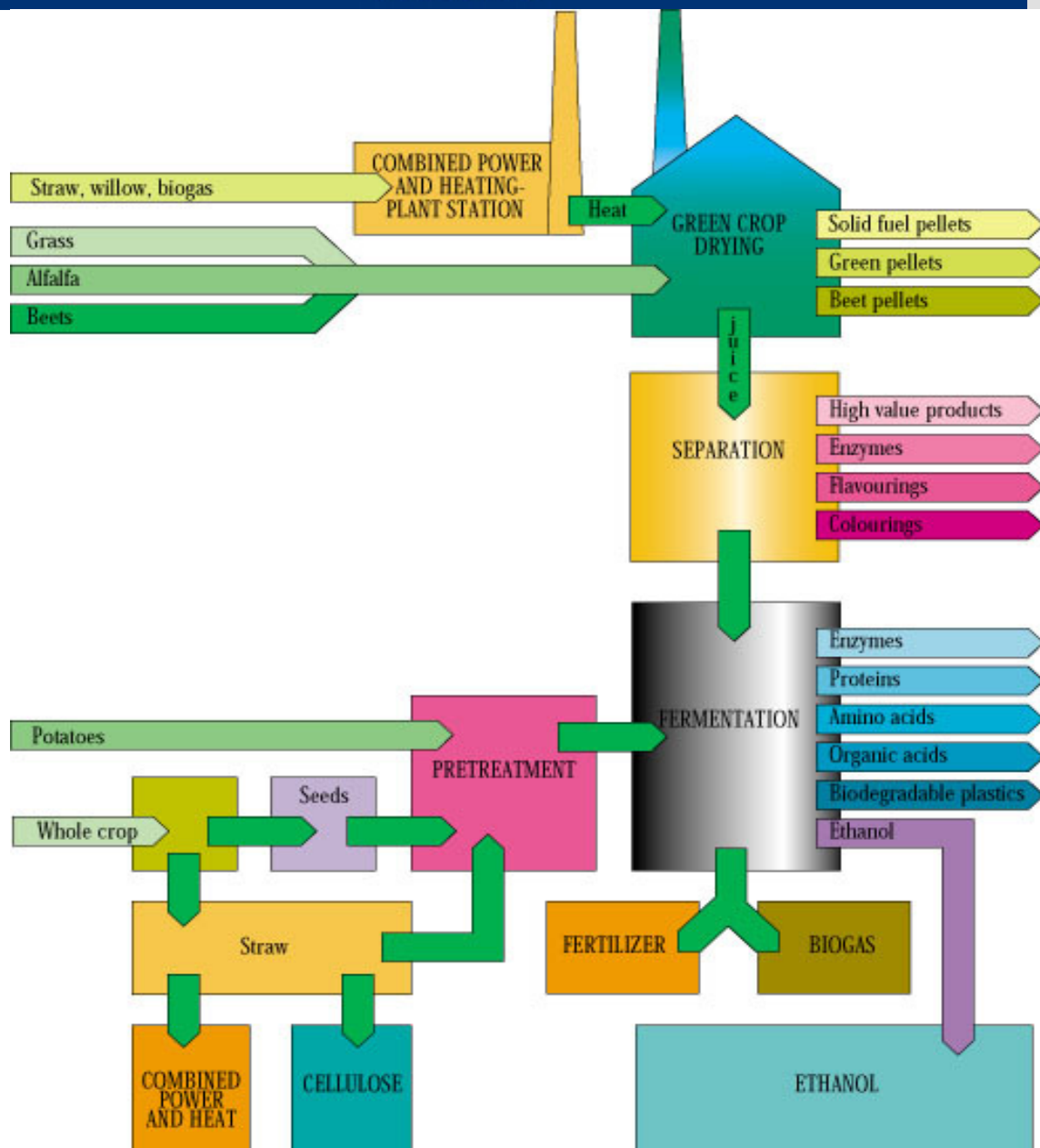
Source: R. Braun, IFA, Austria

Increasing biomass cultivation for biogas production

	2004 [ha]	2005 [ha]
Maize crop	10,628	66,988
Total crop cultivation for biogas	13,603	86,912

Source: Shusseler P. Fachagentur Nachwachsende Rohstoffe e.V. (FNR - Agency of Renewable Resources). Personal communication, 2006.

The Green Biorefinery



Source:

P. Kiel & J.B. Holm-Nielsen
University of Southern Denmark
1994



Source: T. Al Seadi, Department of Bioenergy, SDU, Denmark



Source: T. Al Seadi, Department of Bioenergy, SDU, Denmark



Source: T. Al Seadi, Department of Bioenergy, SDU, Denmark



Ribe Biogas; 15 years of production, 18.000 m³ biogas/day.
.Source J. B. Holm-Nielsen, Bioenergy Dept., SDU, Denmark.

Germany

P. Weiland

Federal Agricultural Research Centre (FAL)
Institute of Technology and Biosystem Engineering

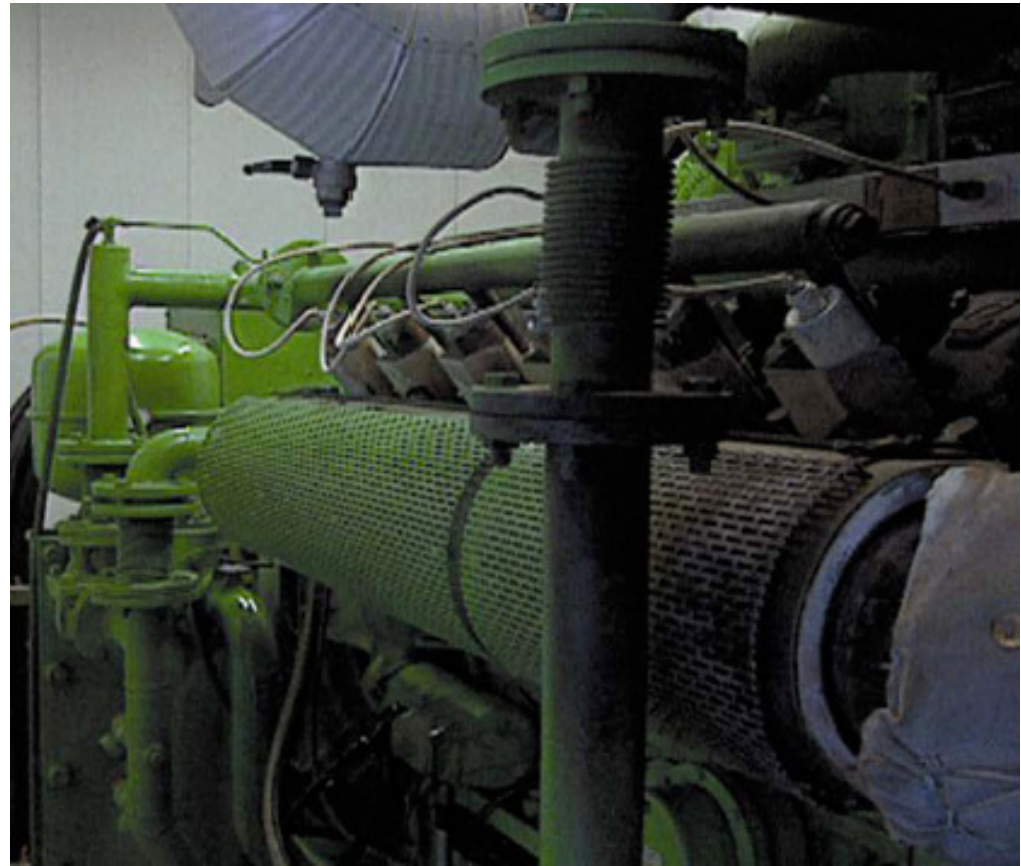


Biogas plants and substrates Germany; Weiland, FAL

- **At the end of 2006 about 3.500 biogas plants with a total electric capacity of 1,100 MW are in operation.**
- **Most of the new installed biogas plants have an electrical capacity between 400 - 800 kW_{el}.**
- **A first industrial biogas energy park “Klarsee” with 40 biogas plants (total capacity: 20 MW_{el}) has come into operation.**
- **Energy crops are the main substrate and manure is only used with a share lower than 50 %.**
- **Industrial companies mainly built plants for mono-fermentation of energy crops.**
- **350,000 ha agricultural land (2 %) is used for cultivation of biogas energy crops.**

Biogas Utilization

- Boilers
- Internal combustion engines
- Gas turbines
- CHP applications
- Industrial utilisation
- Fuel cells



Biogas in the natural gas grid

- Dynamic and flexible utilisation
- Supplementary supply to N-gas
- Multi purpose utilisation
- Combining and synergies

Demands for integration:

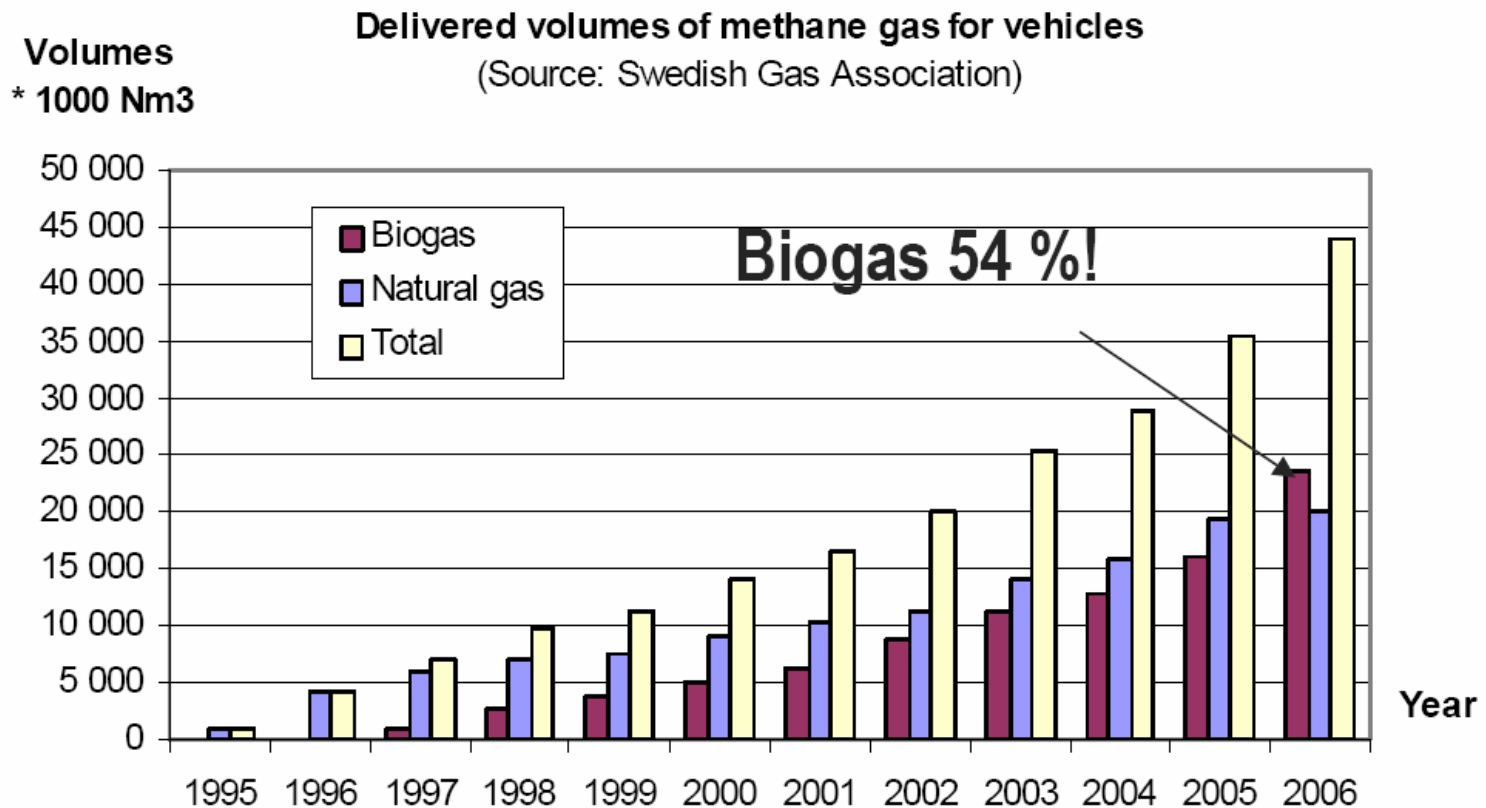
1. Cooling, draining and drying
2. Cleaning for H_2S – biological and/or chemical
3. Separation of CO_2 and upgrading into natural gas quality

Facts: Biogas in the natural gas grid - 14 European upgrading facilities exists 2006, and more is in construction.

Biogas utilization:

- **Biogas is mainly used in CHP. 2/3 of the new erected plants use gas engines, 1/3 dual fuel engines.**
- **Biogas upgrading and feeding into the gas grid finds increasing application:**
 - **Pliening (PSA, supplementary gas, 45 bar)**
 - **Straelen (PSA, exchange gas, 16 bar, addition of LPG)**
 - **Kerpen (PSA, industrial gas grid, 100 bar)**
 - **Teterow (in construction)**
 - **Werlte (in construction)**
- **A first biogas-CHP is coupled with an ORC-turbine in order to increase the electric efficiency by more than 8 %. A total electric efficiency of 45 % seems possible (pilot plant Biburg).**

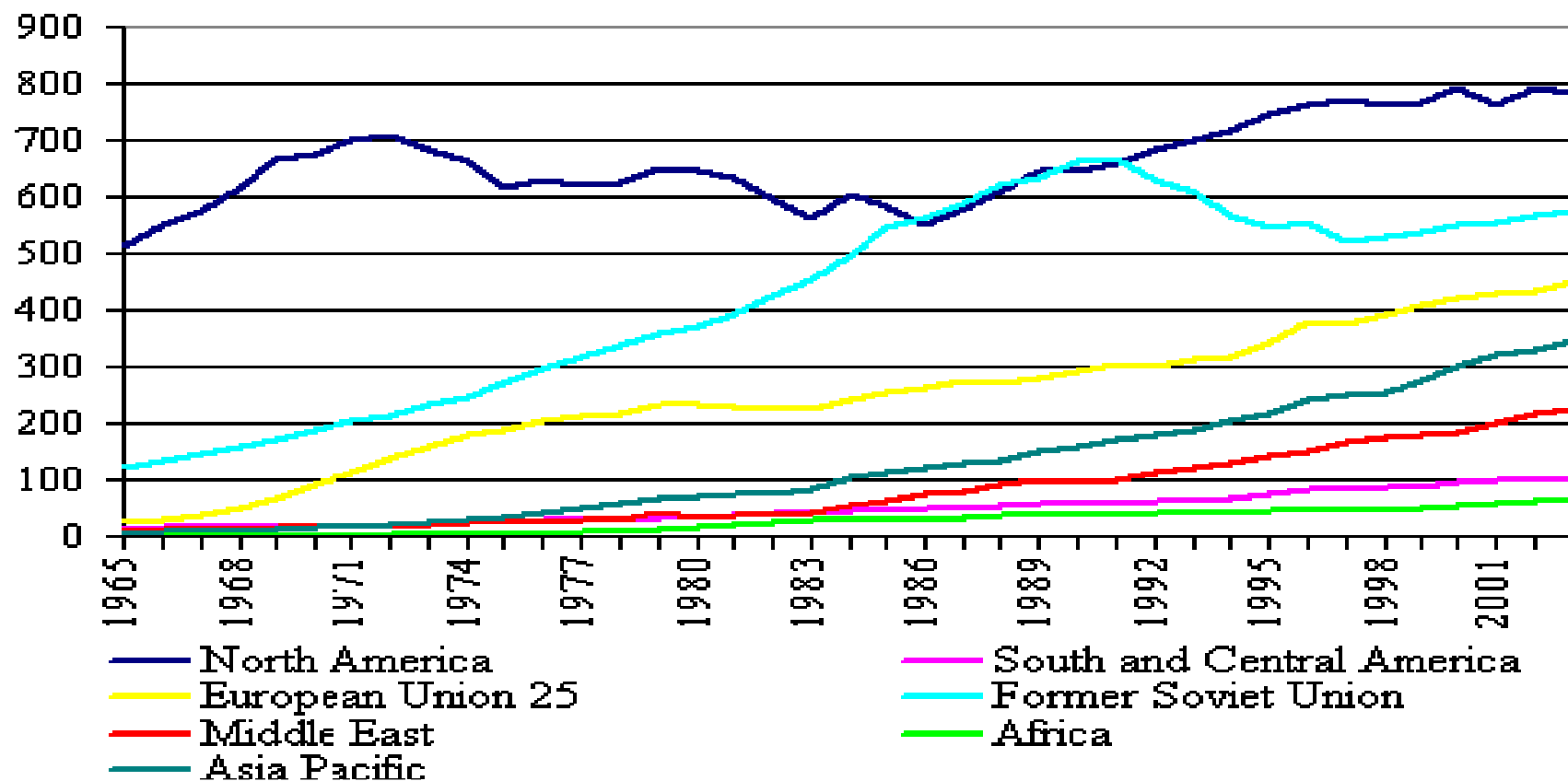
Development of gas vehicle market



Selected news from SE biogas plants

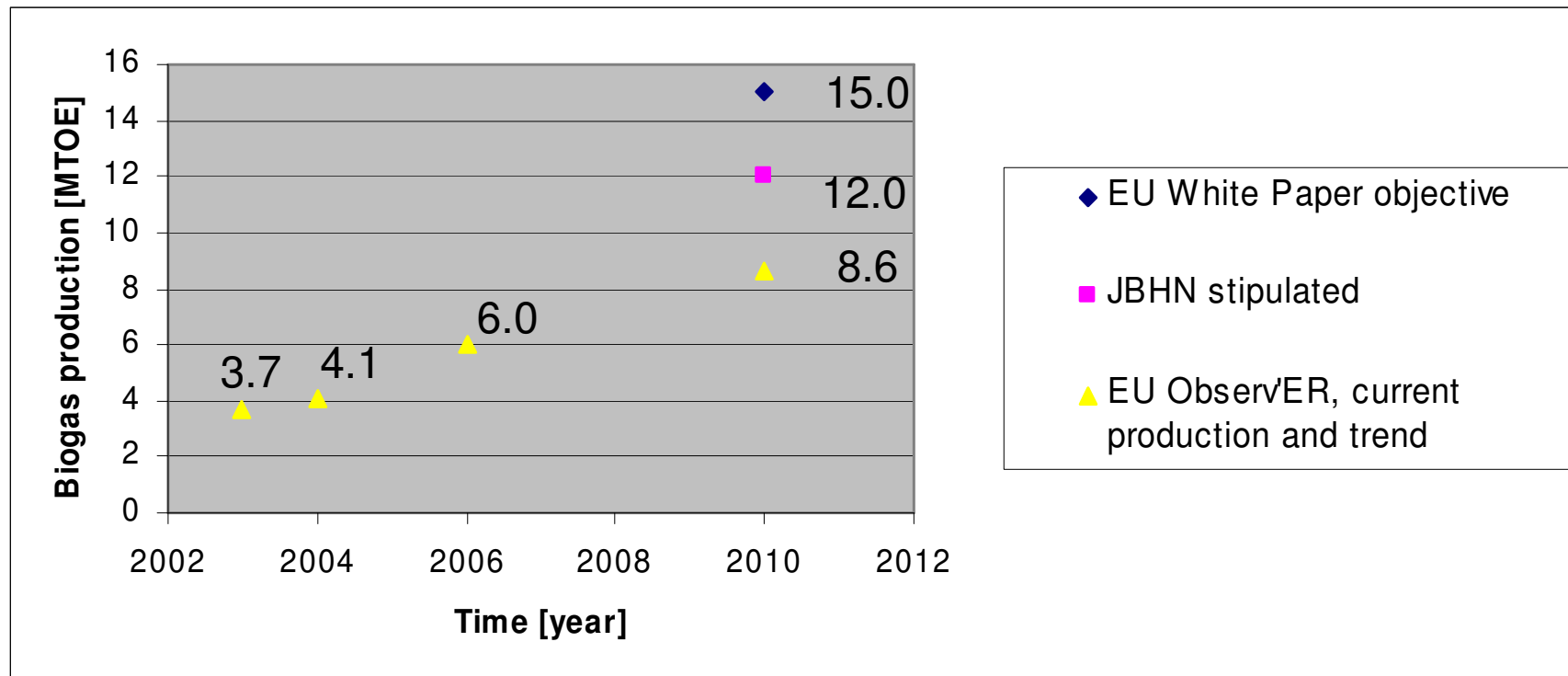
- Örebro, Östersund, Falköping, Lund, Varberg, Helsingborg – ongoing projects for new upgrading plants (sewage)
- Water scrubber dominating method





Source: UNCTAD based on data from BP Statistical Review of World Energy June 2005

Figure 1: World's natural gas consumption in billion cubic metres, 1965-2004 (International Energy Outlook 2007, Energy Information Administration)



The future of biogas in Europe! How to continue a real movement!

- Biogas upgrading & utilisation for:
 - * Biogas for combined heat and power production.
 - * Biogas & Natural gas; integration in the European gas grid (Combining and synergies of Renewable gas and fossil gas)
 - * Biogas as transportation fuel
 - * Biogas for high performing gas combi power plants
 - * Biogas as fuel for micro CHP, - gas grid
 - * Biogas as fuel in fuel cells, - gas grid
 - * Biogas for multiple purposes; bio-industrial processing

World energy scenarios – Future goals

No.			Source
1.	Non collected straw (50%)	75 000 PJ/year	Sanders J.: <i>Biorefinery, the bridge between Agriculture and Chemistry</i> . Wageningen University and Researchcenter. Workshop: Energy crops & Bioenergy.
2.	Collected waste processing (50%)	45 000 PJ/year	
3.	Forest/pastures (50%)	150 000 PJ/year	
4.	10% of arable land – World Wide (20tTS/ha)	51 000 PJ	Holm-Nielsen J.B., Madsen M., Popiel P.O.: <i>Predicted energy crop potentials for biogas/bioenergy. Worldwide – regions – EU25</i> . AAUE/SDU. Workshop: Energy crops & Bioenergy.
5.	20% of arable land – World Wide (20tTS/ha)	101 000 PJ	
6.	30% of arable land – World Wide (20tTS/ha)	152 000 PJ	
Sum: 1+2+3+5		371 000 PJ	

	Predicted value	Source
Total energy required year 2050	1 000 000 PJ/year	Sanders J.: <i>Biorefinery, the bridge between Agriculture and Chemistry</i> . Workshop: Energy crops & Bioenergy.
Total energy demand year 2050	1 300 000 PJ/year	Shell's World Energy Scenario

Thank you for your attention!

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