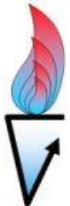


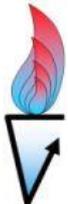
# Biogas Upgrading Scenarios in Europe – *Status & Prospects*

Dr Prasad Kaparaju  
University Lecturer



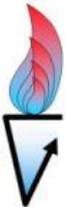
# EU's renewable energy and transport system

- Transport sector
  - Highest energy consuming sector
  - Accounts for 30% total energy mix
  - Difficult to reduce associated GHG emissions
  - Difficult to switch to alternative fuels
- EU Directives
  - Renewable Energy Source Directive (RES Directive 2009/28/EC)
    - 10% share of RE in transport
  - Clean Vehicles Directive (2009/33/EC)
  - Climate and Energy Package (SEC(2003)650)



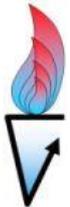
# Importance of biomethane in EU's renewable energy and transport system

- Established technology for biogas production
  - upgrading and end-user applications is now matured
- Temporary decoupling of production and utilization
  - Utilize in new geographical and remote areas
  - Possibility of cross-border transactions
- Use of natural gas distribution and storage system
  - Increase storage capability
- Multiple & flexible use
  - Heat/ and/or electricity
  - Upgraded for grid injection or vehicle fuel use
- Reduce the GHG emission associated with transport
- Achieve the biofuel directive targets

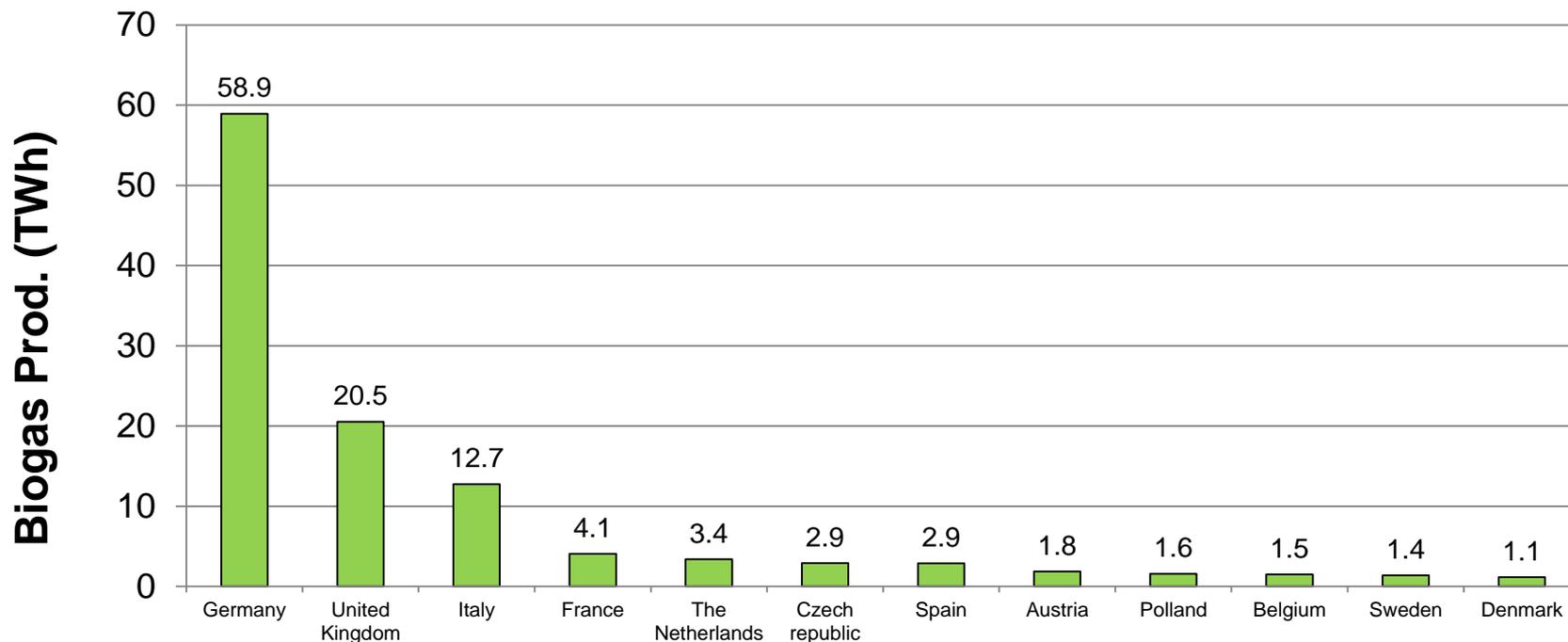


## Biogas industry in Europe

- 12000 biogas plants in Europe
- Germany - leading country
  - In 2011, 1310 new biogas plants
  - Total 8792 biogas plants
  - Total power production capacity: 2904 MW
  - Account 60.9% of total biogas electricity in EU
- United Kingdom and Italy are the two next largest biogas power producers in the EU.



## Top 12 biogas producing countries in EU

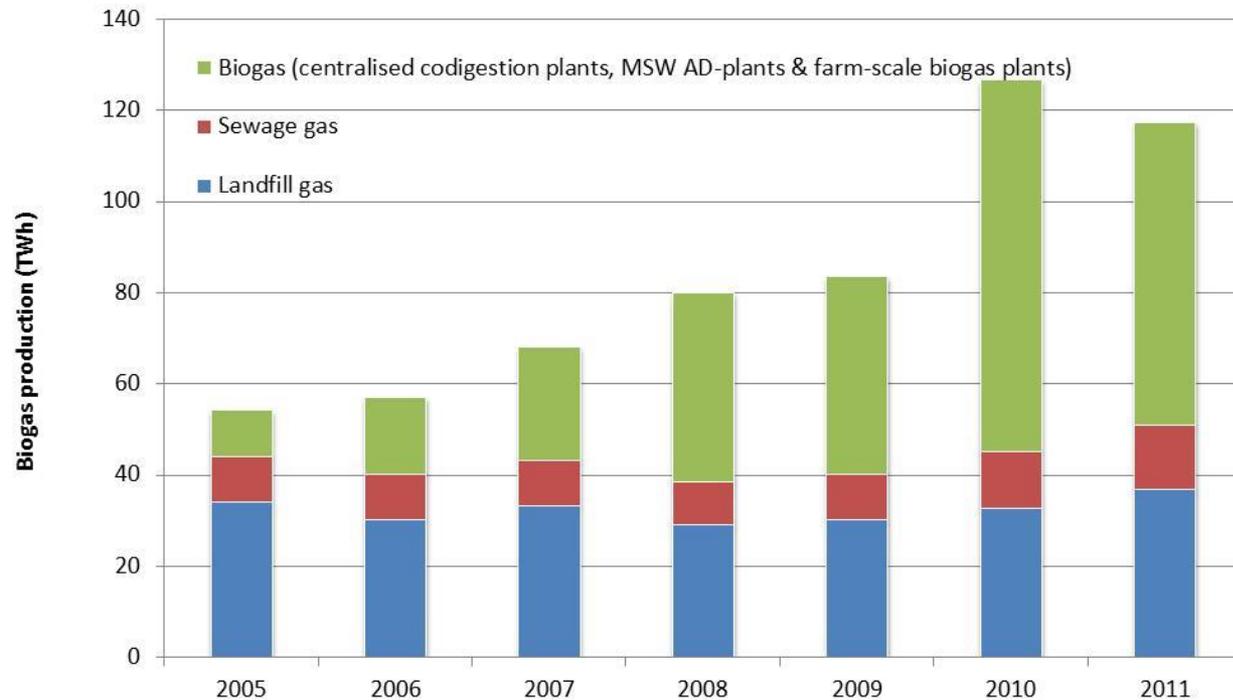


1 ktoe = 11.630 GWh

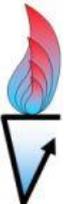
(Source: EurObserv'ER 2012)

## Biogas industry in Europe

- Decreased from 126 TWh in 2010 to 117.2 TWh in 2011
- Share of biogases in total biogas production (2011)
  - Landfill gas : 31.3%
  - Sewage gas: 12%
  - Other biogases: 56.7%

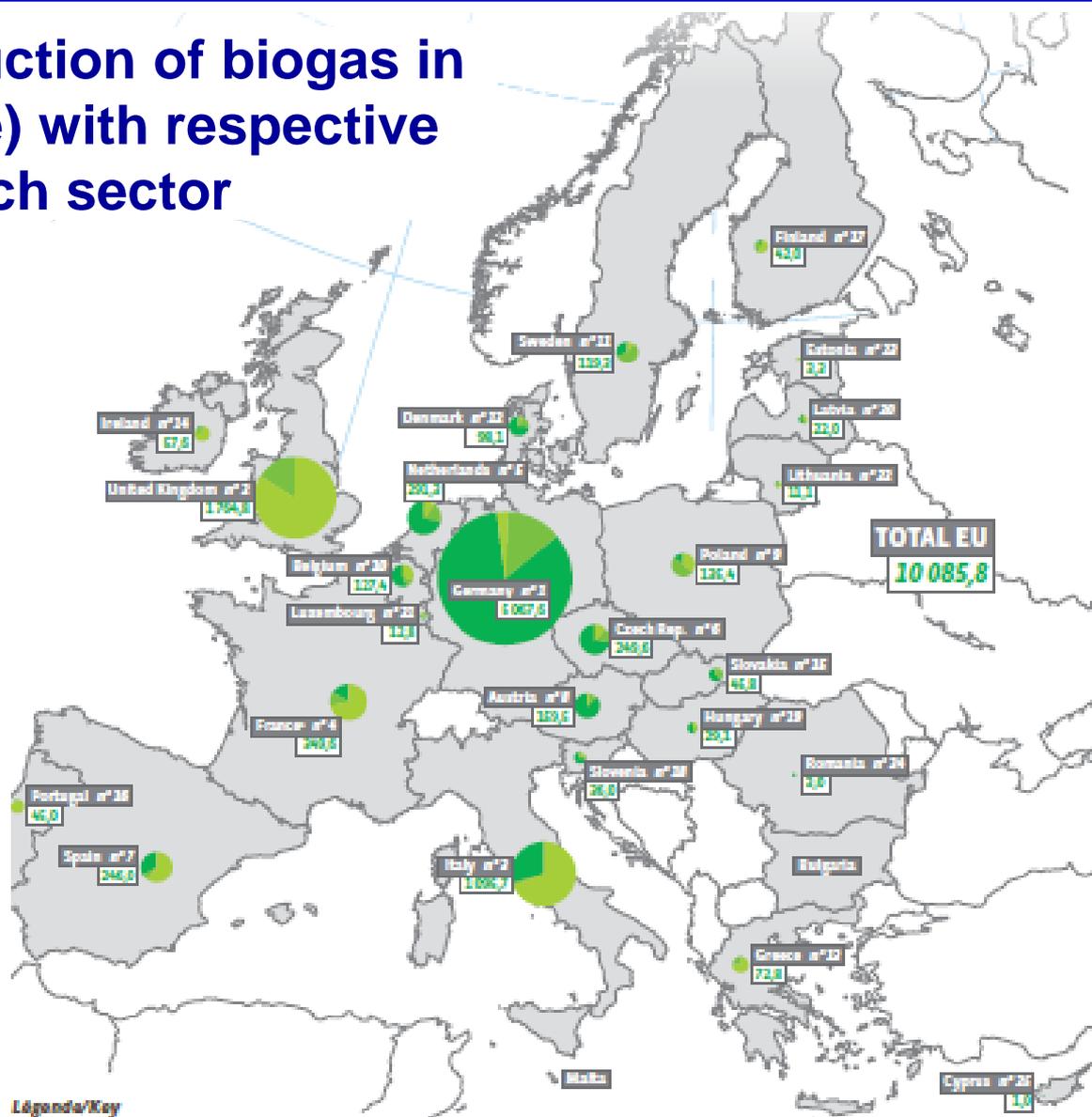


(Source: EurObserv'ER 2008-2013)



# Primary energy production of biogas in the EU in 2011\* (ktoe) with respective shares of each sector

- Landfill gas – UK, IT,FR,ES
- Agril Biogas – DE, AT
- Sewage gas - SE



**Légende/Key**

- 348.6 Total biogas production in ktoe
- Landfill gas
- Sewage gas
- Other biogases from agricultural wastes and energy crops



1 ktoe = 11.630 GWh

(Source: EurObserv'ER 2012)

# Biogas composition

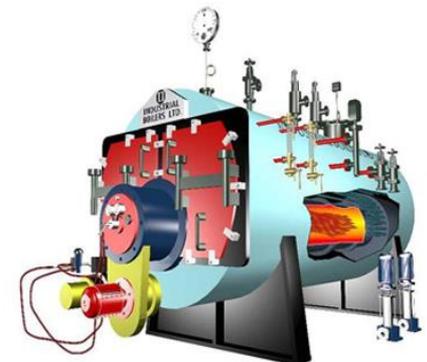
Parameter	Farm-scale AD-plant	Centralised AD-plant	Landfill	Sewage Treatment plant	Natural gas (Holland)
CH <sub>4</sub> (vol-%)	55-60	60-70	30-65	60-65	81-89
Other hydro carbons (vol-%)	0	0	0	0	3.5-9.4
H <sub>2</sub> (vol-%)	0	0	0-3	0	-
CO <sub>2</sub> (vol-%)	35-40	30-40	25-45	35-40	0.67-1
N <sub>2</sub> (vol-%)	<1-2	2-6	<1-17	<1-2	0.28-14
O <sub>2</sub> (vol-%)	<1	0.5-1.6	<1-3	<0.05-0.7	0
H <sub>2</sub> S (ppm)	25-30	0-2000	30-500	<0.5-6800	0-2.9
NH <sub>3</sub> (ppm)	≈100	≈100	≈5	<1-7	0
Halogenated compounds (as Cl <sup>-</sup> , mg/m <sup>3</sup> )	<0.01	<0.25	0.3-225	0-2	-
Siloxanes (mg/m <sup>3</sup> )	<0.03-<0.2	<0.08-<0.5	<0.3-36	<1-400	-
Wobbe index (MJ/m <sup>3</sup> )	24 – 33	24 – 33	20 - 25	25 - 30	44-55
Lower heating value (MJ/Nm <sup>3</sup> )	23	23	16	22	31-40

The composition of biogas depends on several variables such as the type of waste or the treatment process used to digest it.



# BIOGAS UTILIZATION

- Traditional
  - Cooking, Lighting
- Commercial
  - Heat and steam
  - Electricity and/or heat (cogeneration in CHP)
  - Vehicle fuel
  - Fuel cells
  - Injection to natural gas grid



## Utilization of biogas in EU

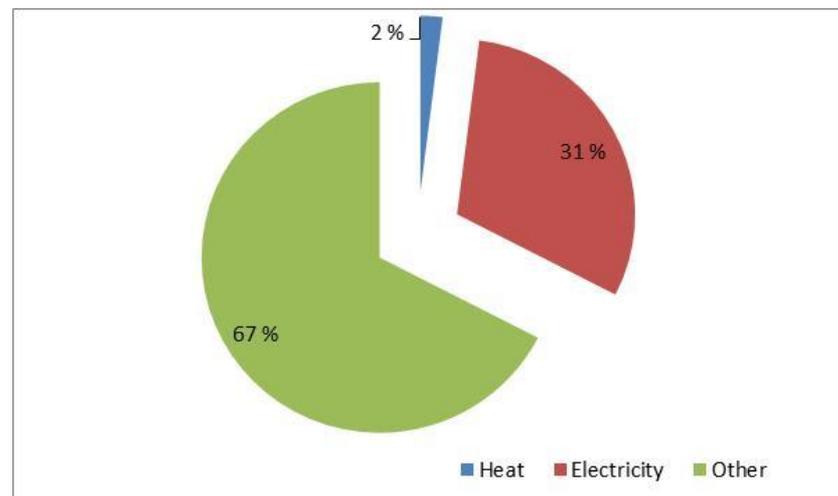
### 1. Electricity and power generation in cogeneration plants

#### a. Electricity – 35.8 TWh

1. Electricity only: 21.3 TWh
2. CHP electricity: 14.6 TWh

#### b. Heat – 2.3 TWh

1. Heat only: 0.6 TWh
2. CHP heat: 1.7 TWh



### 2. biomethane (purified biogas) injection into natural gas grids – EU is laying the groundwork for a third recovery option:

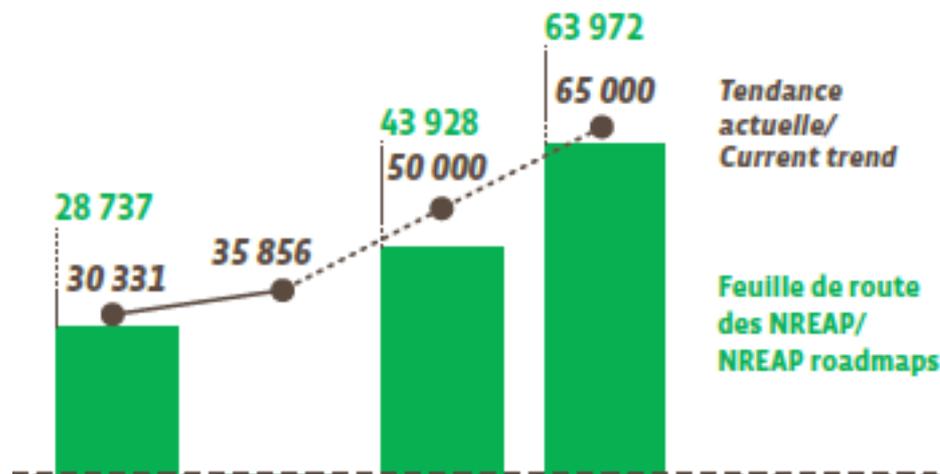


1 ktoe = 11.630 GWh

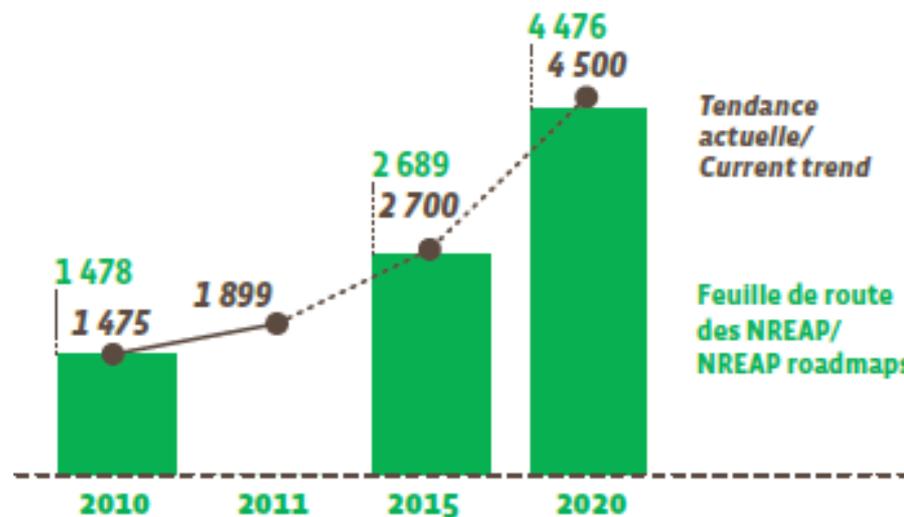
(Source: EurObserv'ER 2012)

# Comparison of current trend of electricity and heat production from biogas with NREAP roadmap

Electricity (GWh)



Heat (ktoe)



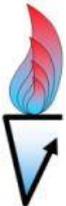
1 ktoe = 11.630 GWh

NREAP: National Renewable Energy Action Plans)

(Source: EurObserv'ER 2012)

## Biomethane production in Europe

- Biomethane production in 14 countries
- Grid injection : Austria, Switzerland, Germany, Spain, Finland, France, Luxemborg, The Netherlands, Norway, UK
- Vehicle fuel : Austria, Switzerland, Germany, Finland, Hungary, Iceland, Norway, Sweden
- Limitation on grid injection for biomethane produced from landfill and sewage gas in several countries
  - (e.g. Austria, France, Germany, Switzerland)



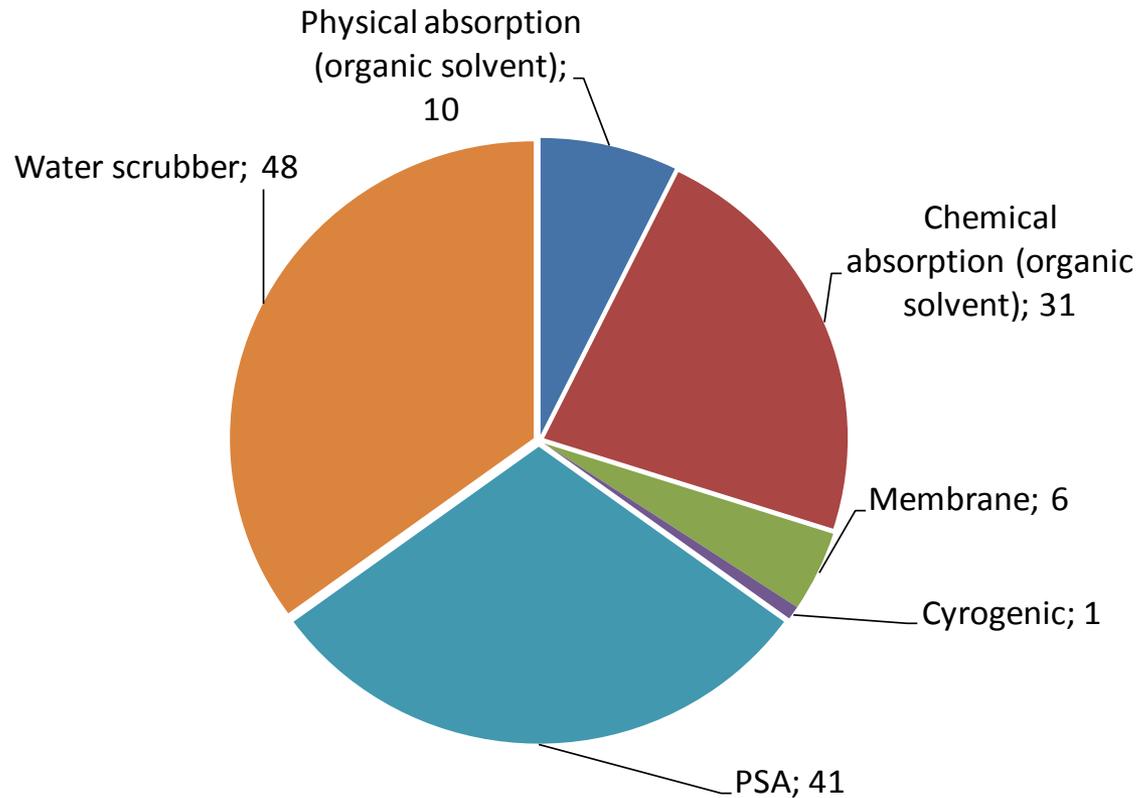
# Status quo of biomethane plants 2011

- 177 biomethane plants in Europe (1.5% of total biogas plants)
  - 128 plants – Grid injection (72%).
  - 49 plants – vehicle fuel
  - 160000 Nm<sup>3</sup>/h of raw gas capacity

Country	Biomethane plants	Biomethane plants feeding the grid	Biogas plants total (approx.)	Agricultural	Biowaste (incl. organic MSW)	Sewage	LFG
Austria	10	7	503	approx. 300	55	134	14
Croatia	-	-	4	2	-	1	1
France	3	1	283	40	98	74	71
Germany	84	82	8.792	approx. 7.000	92	1.700	
Hungary	1	-	58	36	-	14	8
Italy	-	-	667	approx. 300	32	135	200
Netherlands	13	13	130				
Poland	-	-	219	17	2	approx. 200	
Slovakia	-	-	24	12	-	12	-
UK	2	2	360		60	100	> 200
Sweden	47	8	229	14	23	135	57
Switzerland	17	15	600		140	460	
<b>TOTAL</b>	<b>177</b>	<b>128</b>	<b>11.869</b>				

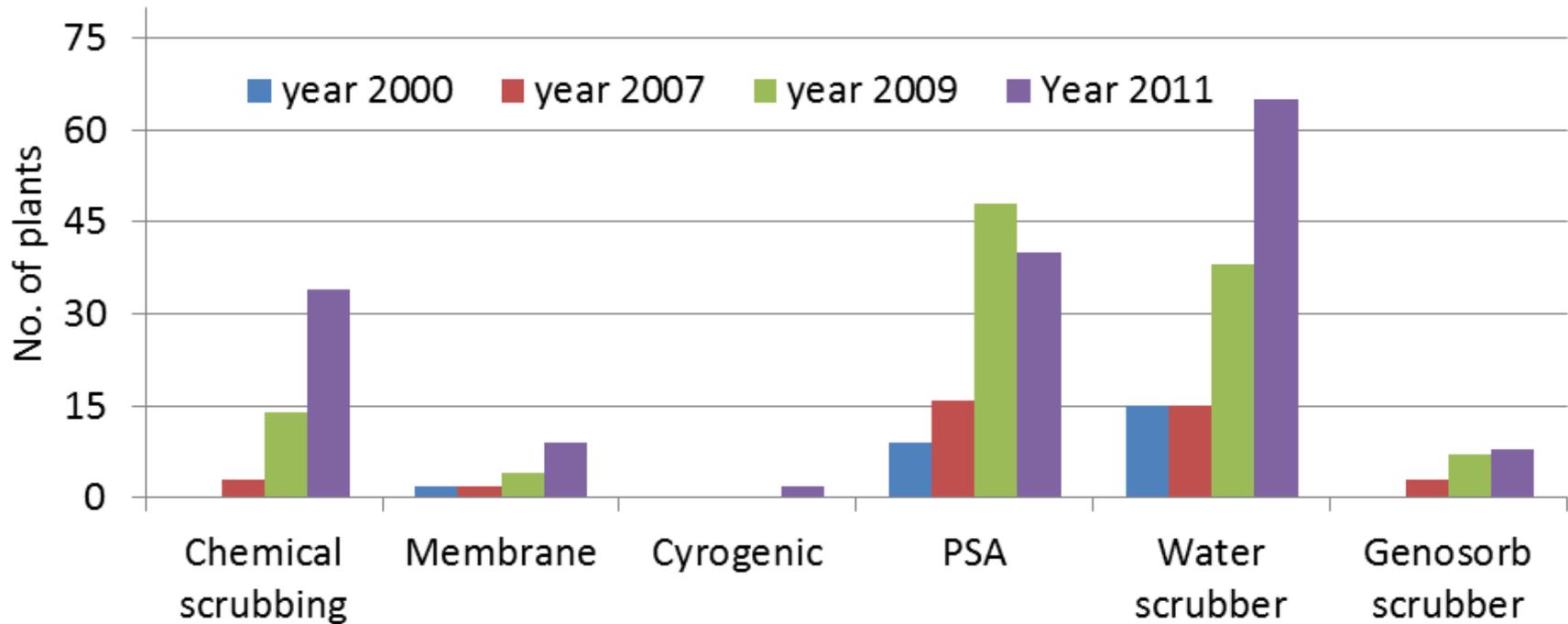
(Source: Fraunhofer Umsicht, 2012)

# Biogas Upgrading in Europe – Technology

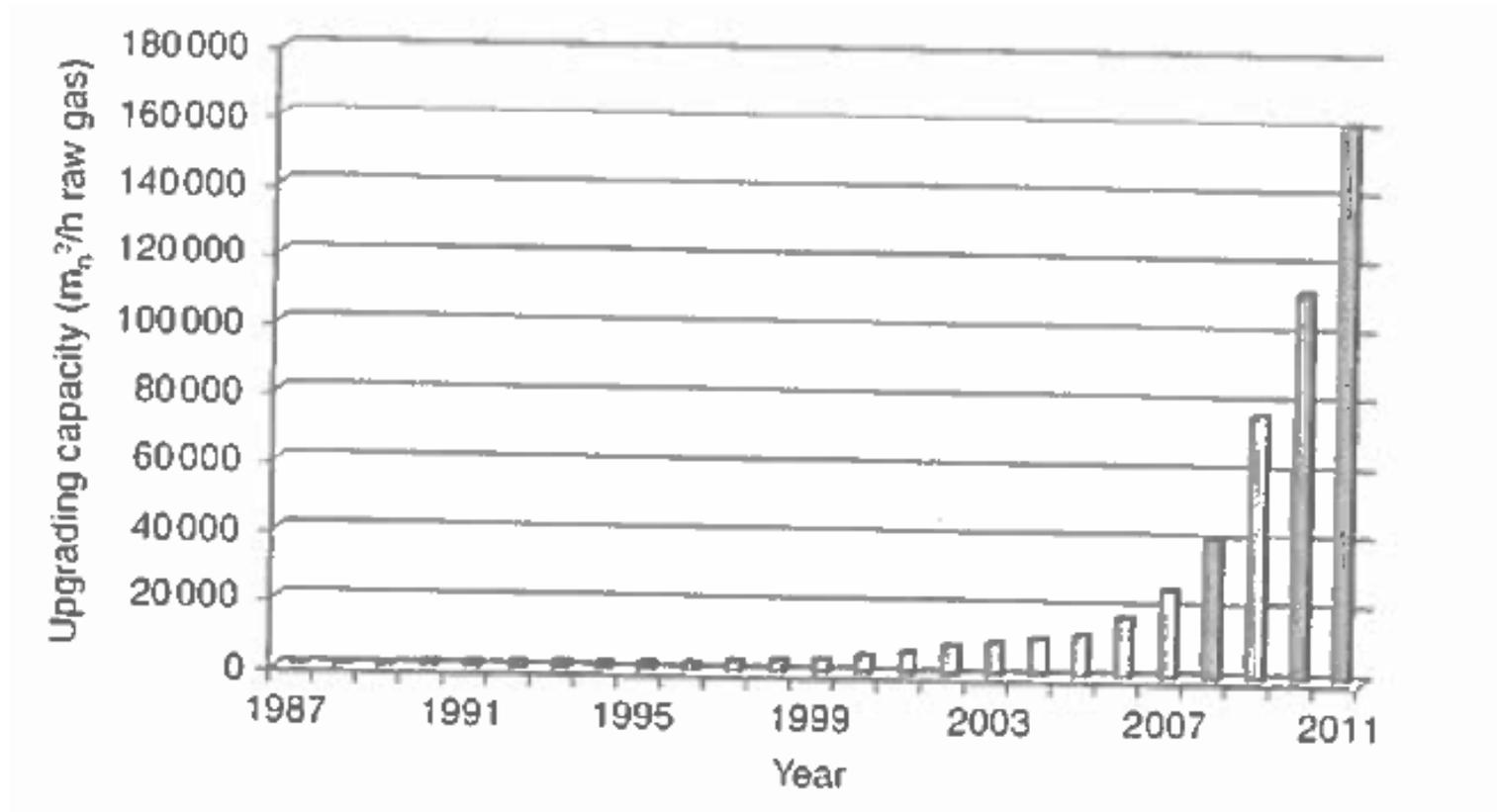


(Source: IEA Bioenergy, 2011)

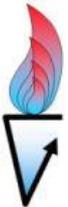
# Biogas Upgrading in Europe – Technology



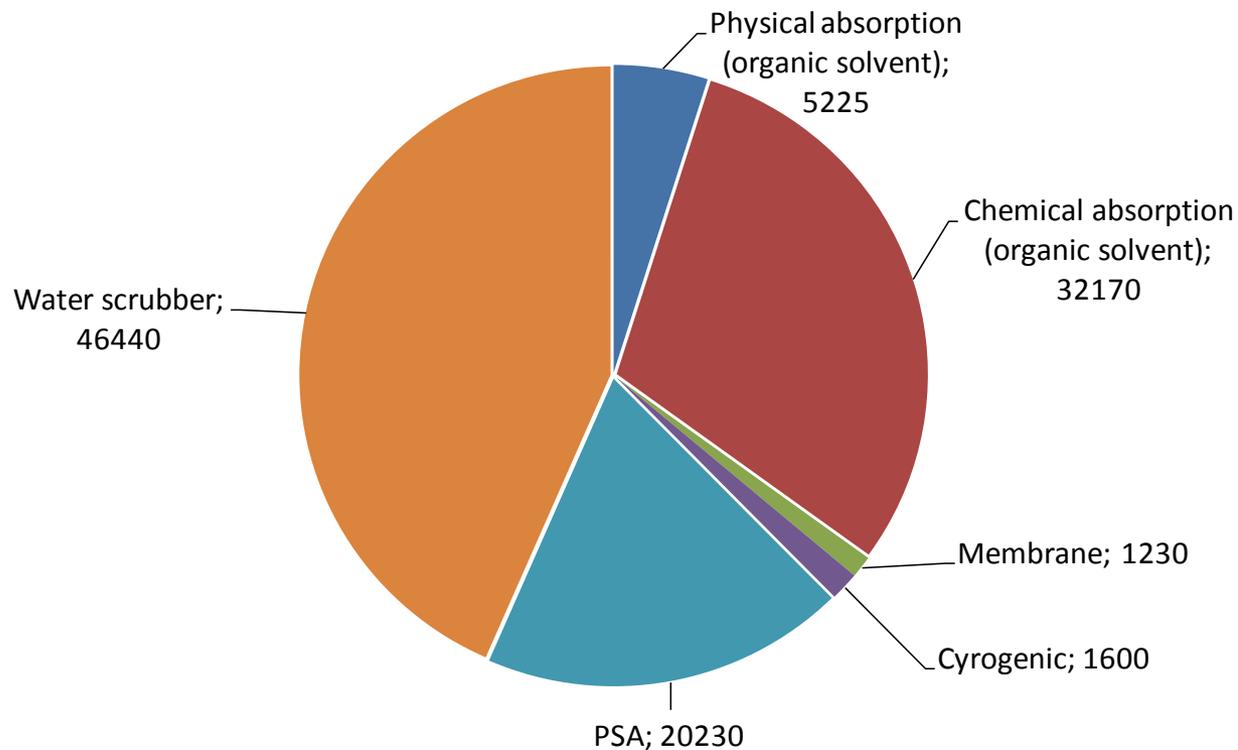
## Upgrading capacity of European biogas upgrading plants during 1987—2011



(Copyright: Fraunhofer IWES, 2012).



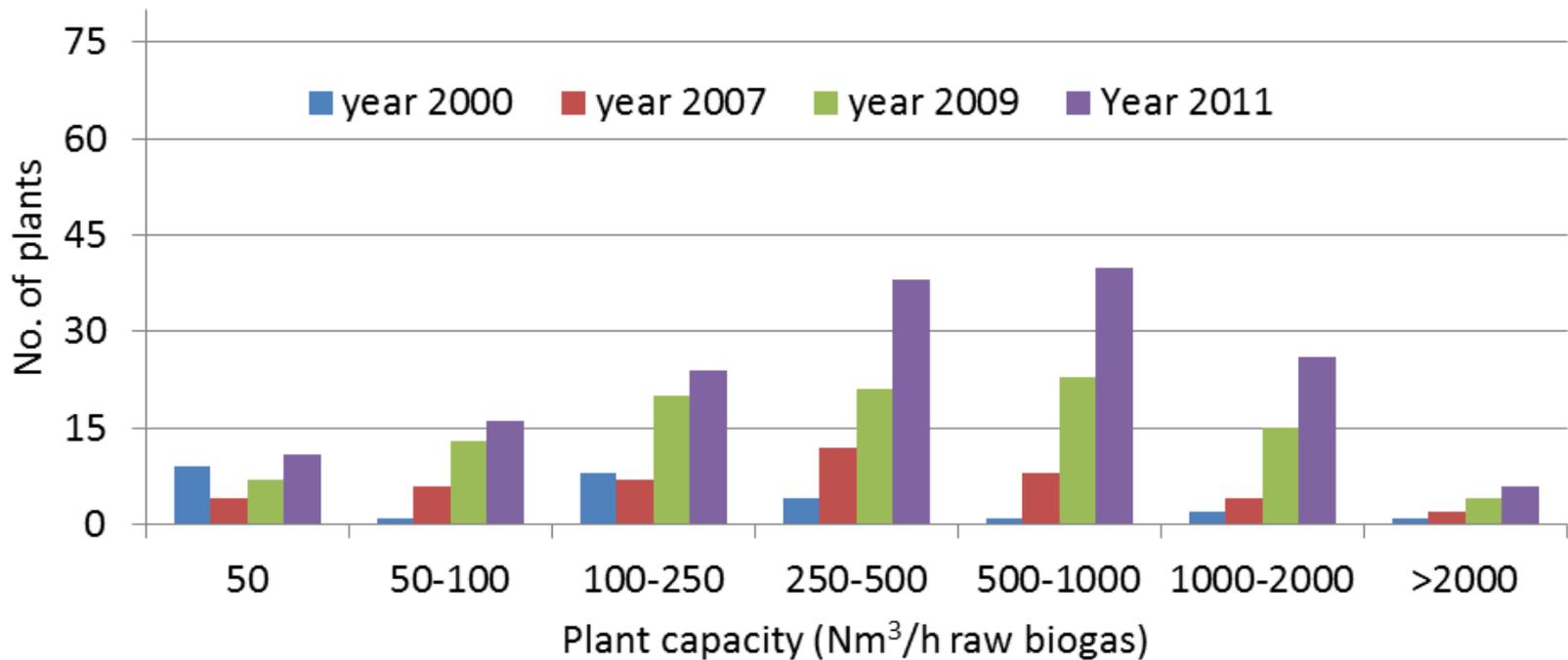
# Biogas Upgrading – Technology and raw biogas capacity (Nm<sup>3</sup>/h)



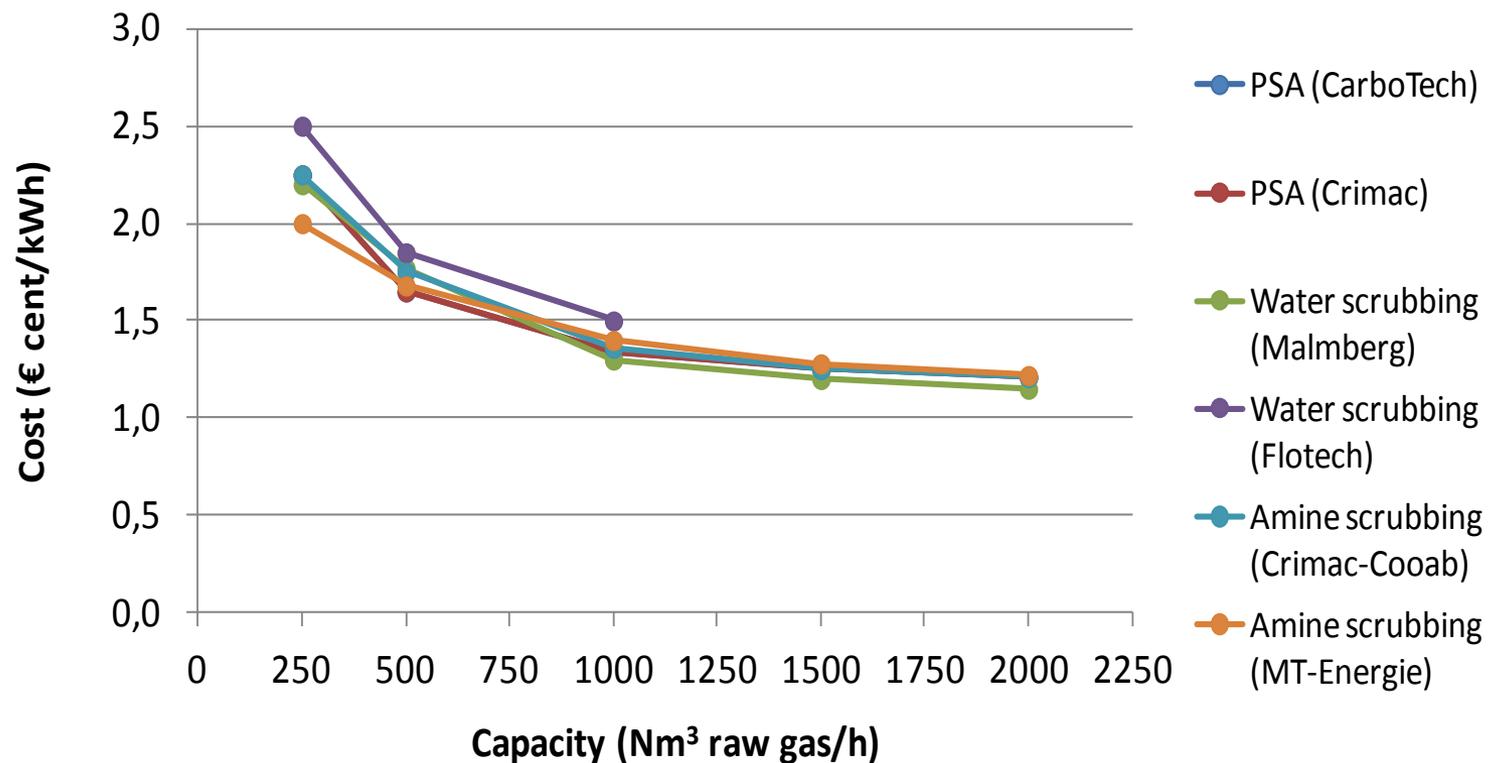
(Source: IEA Bioenergy, 2011)



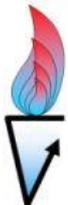
# Biogas Upgrading in Europe – Plant capacity



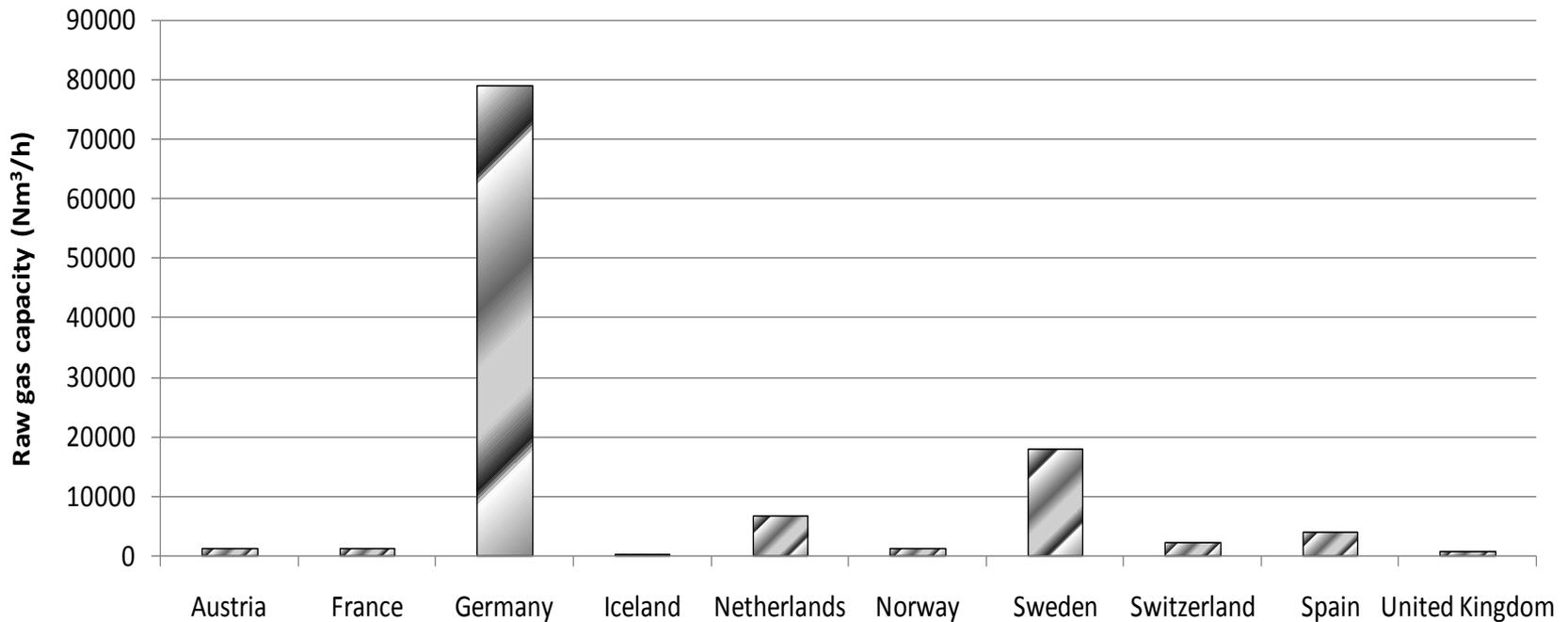
## Costs for biogas upgrading



Source: (Persson and Wellinger, 2006).



## Biogas upgrading in Europe – raw gas capacities in major European countries in Nm<sup>3</sup>/h



(Source: IEA Bioenergy, 2011)



# Comparison of biogas upgrading technologies

	Water scrubbing	Chemical (amine) scrubbing	PSA	Membrane	Cryogenic
Operation pressure (bar)	4-10	0.05-4	1-10	7-20	10-25
Temp. process ( °C)	--	106-160	--	--	--
Electricity demand (kWh/Nm <sup>3</sup> biogas)	0.20-0.30	0.06-0.17	0.16-0.35	0.18-0.35	0.18-0.25
Heat demand (kWh/Nm <sup>3</sup> biogas)	0	0.4-0.8	0	0	0
CH <sub>4</sub> loss (%)	0.5-2	0.1	1.5-10	1-15	0.1-2
CH <sub>4</sub> recovery rate (%)	98-99.5	99.9	90-98.5	85-99	98-99.9
Off-gas treatment (if >1% CH <sub>4</sub> loss)	yes	no	yes	yes	Yes
H <sub>2</sub> S removal	no	yes	yes	recommended	yes
Investment cost (€/yr)	265,000	353,000 <sup>a</sup> -869,000 <sup>d</sup>	680,000	233,000 <sup>a</sup> -749,000 <sup>b</sup>	908,500
Maintenance cost (€/yr)	110,000	134,000 <sup>a</sup> -179,500 <sup>b</sup>	187,250	81,750 <sup>a</sup> -126,000 <sup>b</sup>	397,500
Cost per Nm <sup>3</sup> biogas upgraded (euros)	0.13	0.17 <sup>a</sup> -0.28 <sup>b</sup>	0.25	0.12 <sup>a</sup> -0.22 <sup>b</sup>	0.44

## Biogas as vehicle fuel

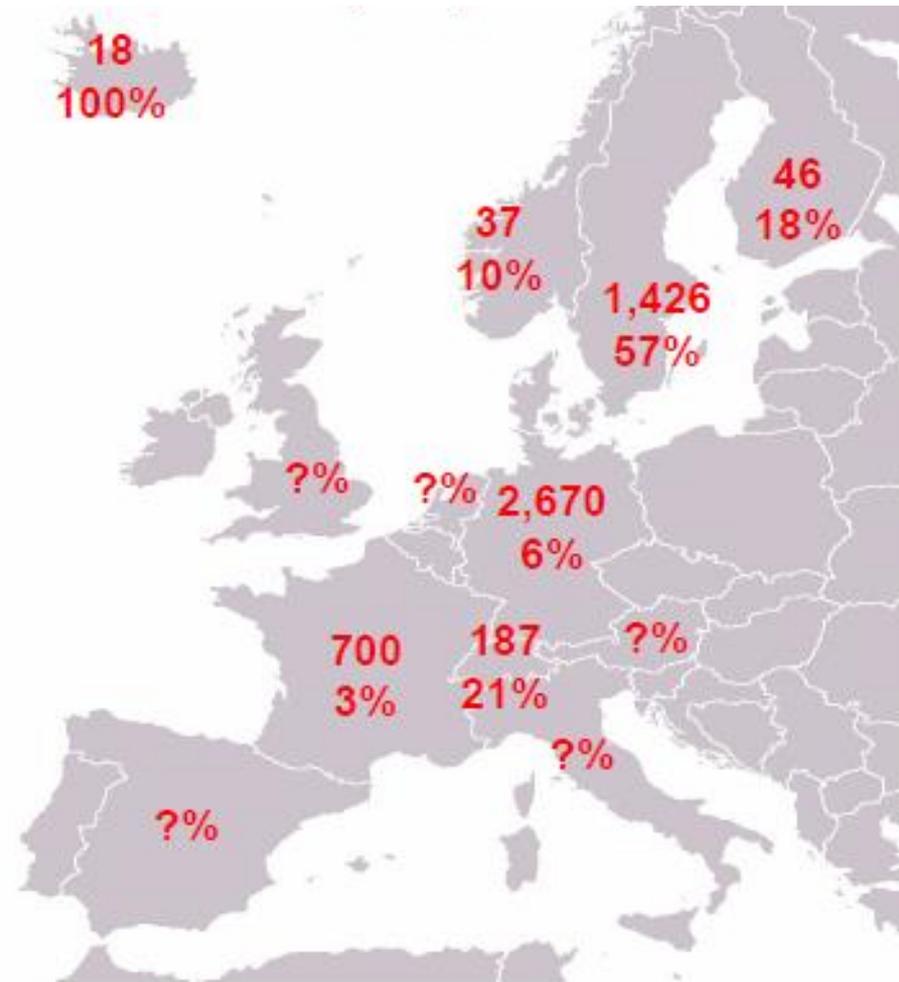
- Biomethane can be used in vehicles operated with natural gas without any engine modification.
- Bifuel vehicles use gas and gasoline
  - Range with gas 200-400 km
- Dual fuel vehicles use methane and diesel
- Biomethane is compressed to 200 bars for on-site storage or transport by road.
- It is also distributed through natural gas grid or separate on-site fuelling stations



## Biomethane in road transport

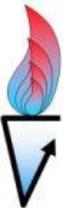
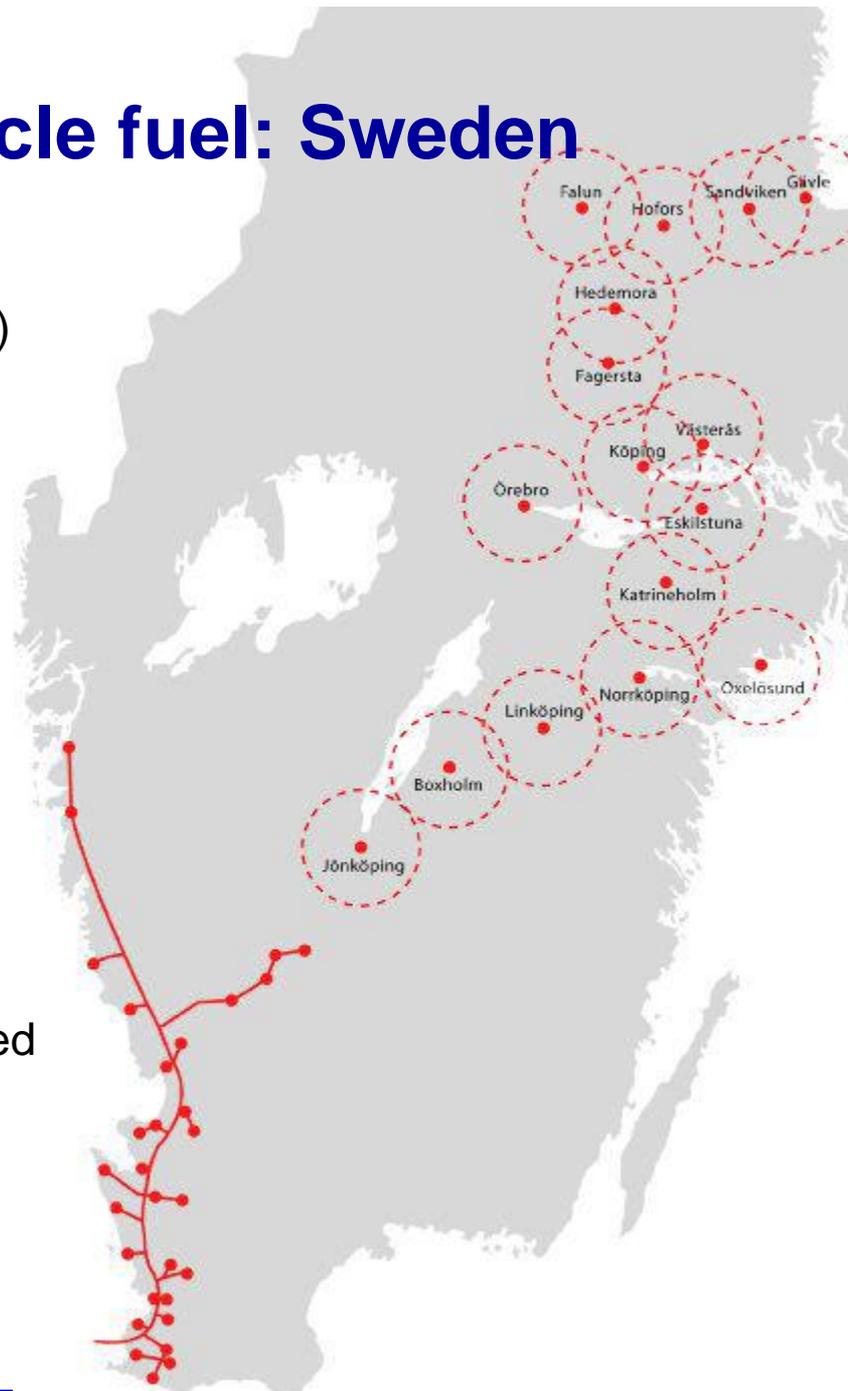
- Most common in Europe,
- Sweden forerunner country
- **Small but growing market**
  - Estimate: 1.5-3 TWh

CNG sales 2012 (GWh)/share biomethane



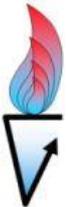
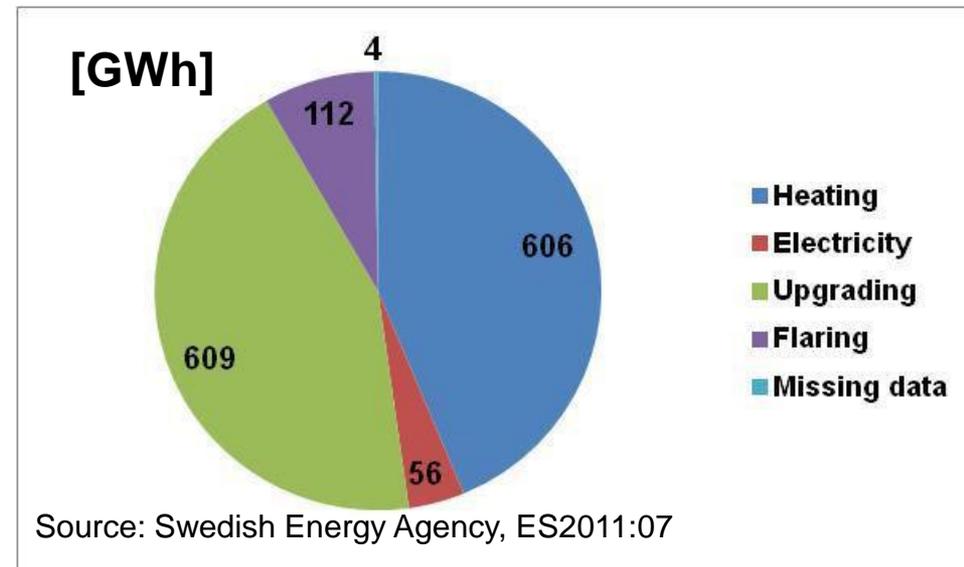
## Biomethane as vehicle fuel: Sweden

- The Swedish Energy mix
  - Plenty of hydro- and nuclear power (30%)
  - High share of solid biofuels (25%)
- Weak support for natural gas
  - Introduced 1985
  - Only 2% of the energy mix (EU-27: 24%)
  - Gas grid only along the west coast
- Grid expansion is politically "dead"
  - Continuous market expansion requires growing proportion of renewable gas!
  - LNG solutions may be accepted
  - The synergies of joint utilisation of biomethane and CNG
  - Build on a successful biomethane powered NGV market
- waste management
  - Public-Private-Partnerships



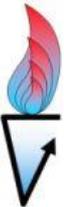
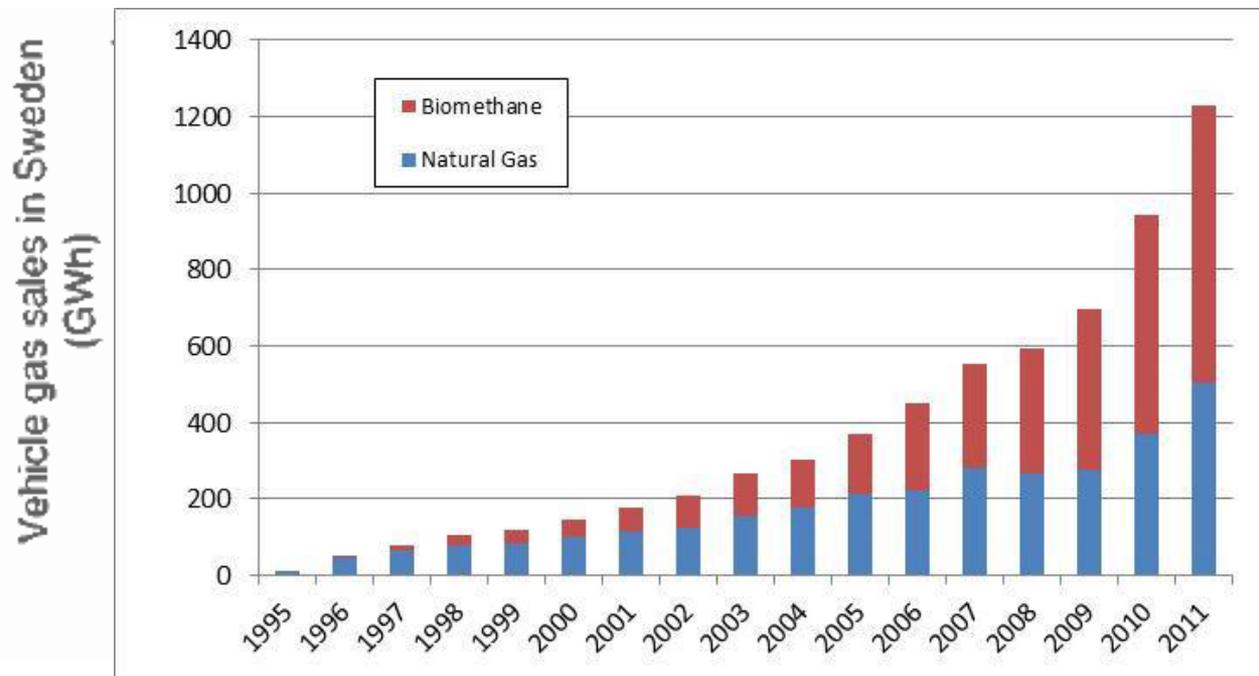
## Biogas production in Sweden

- **Trend toward final utilization as automotive fuel**
  - 2007-2011: from 275 to 726 GWh
  - Supplied by WWTP's and centralized co-digestion plants
  - 2.5TWh biogas prod. anticipated within 2014
- In 2010: 47 upgrading facilities (8 with grid injection, 170GWh)
- 1.38 TWh in total (2010)



## Biomethane market in Sweden

- Sweden has the greatest biomethane sales in the world
- In 2011, biomethane market was 1228 GWh
- Share was 60% of renewable energy
- Represent only 1/100 of the total Swedish road transport market



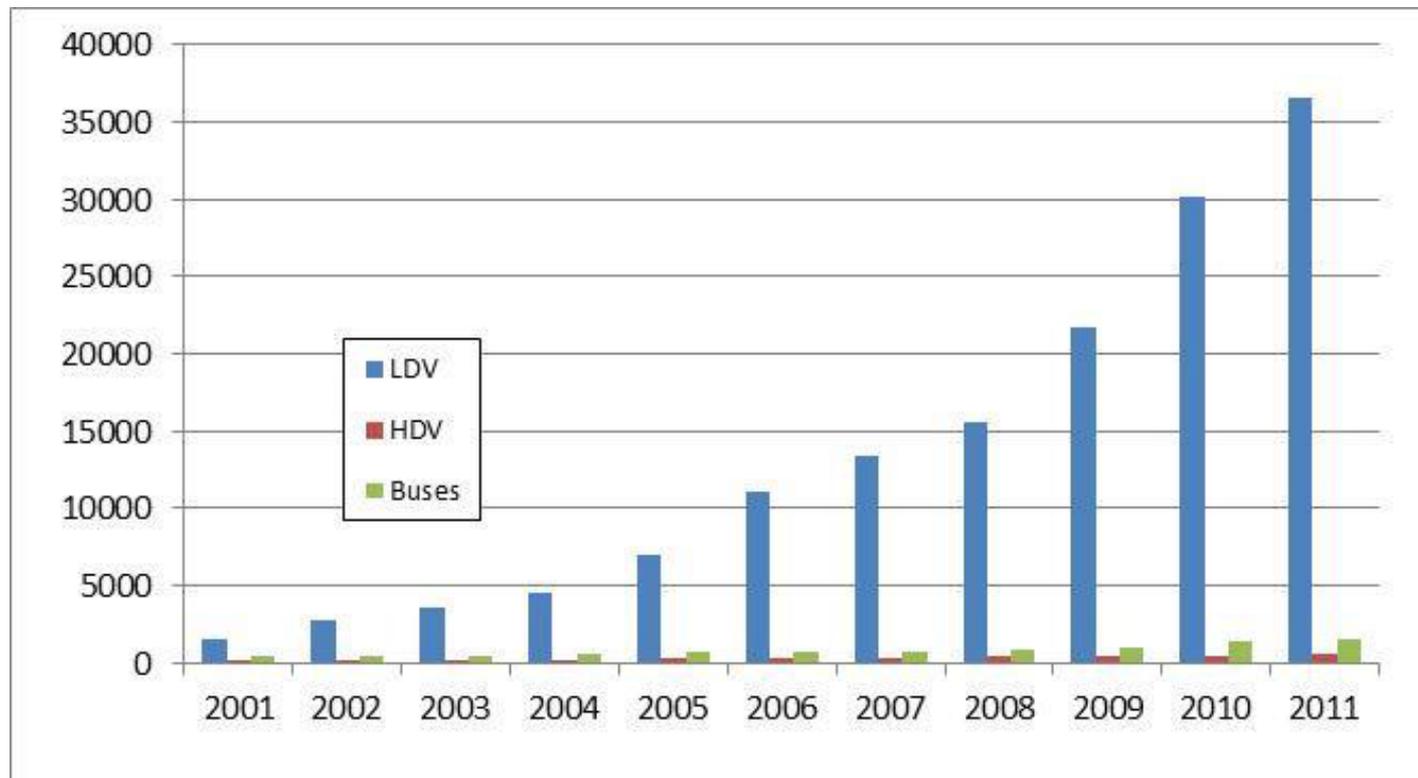
# Supportive policy measures in Sweden

- Fuel tax exemptions
- Fringe company car tax reductions
- Parking benefits, congestion fee exemptions
- Environmental demands regarding fuels and vehicles in regional and local government procurements and contracts
- Creation of clean(er) vehicle definition, preferably national
- Investment grants, refueling stations and waste biomethane production
- Establish national and/or international standards regarding storage, handling, transport and utilisation of biomethane



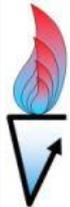
## No. of NGV's in Sweden

- The NGV market base: Captive bus fleets (1 bus  $\approx$  20-30 LDV's)
- 2011: 38,609 (LDV 36528; HDV 552; Buses 1529)
- 2009 onwards : Intro. of new LDV models improved sales



## NGV market dynamics of Sweden

- Local pollution problems + no grid access = biomethane buses
- Grid connected cities of Malmö and Gothenburg
- Converting to NG buses to solve local pollution problems
  - NG companies searching for a new market segment
- Environmental state funding to municipals decisive (1998-2010)
  - Non-grid cities upgraded to biomethane to fuel their buses – grid cities followed
  - Captive bus fleets shown\* providing the essential niche of the emerging NGV market in Sweden

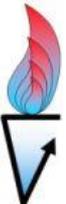


# Biogas Highway Göteborg - Stockholm

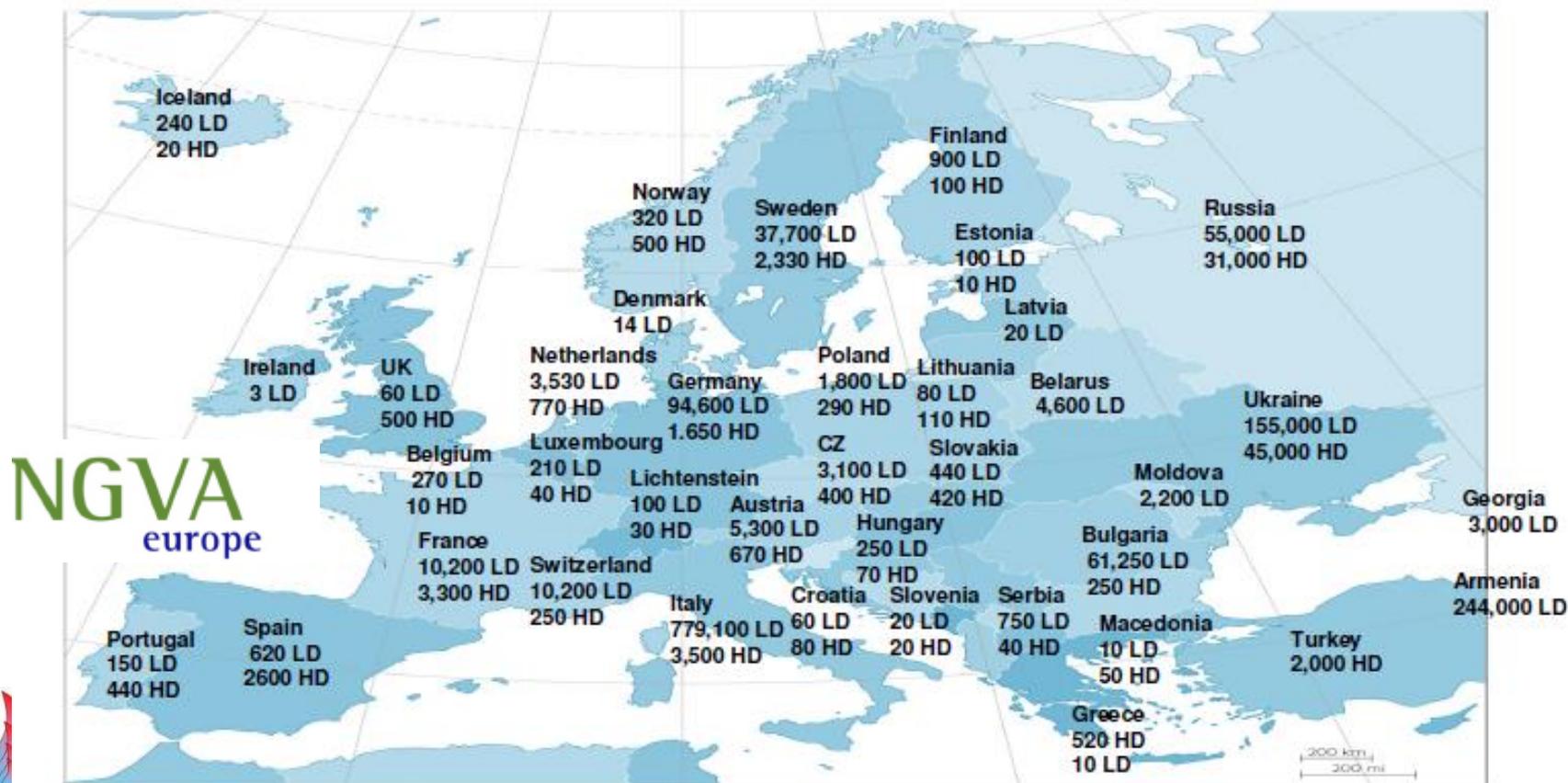
- 500 km
- 12 biomethane fuelling stations



# Biogas as vehicle fuel



- NGV's increased from 0.5 (2003) to 1.6 million (2011) in Europe
- Italy # 1: 779 100 (LDV) + 3500 (HDV)



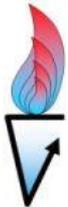
1,470,800 cars, 46,100 buses, 50,800 trucks and 800 other NGVs

4020 filling stations

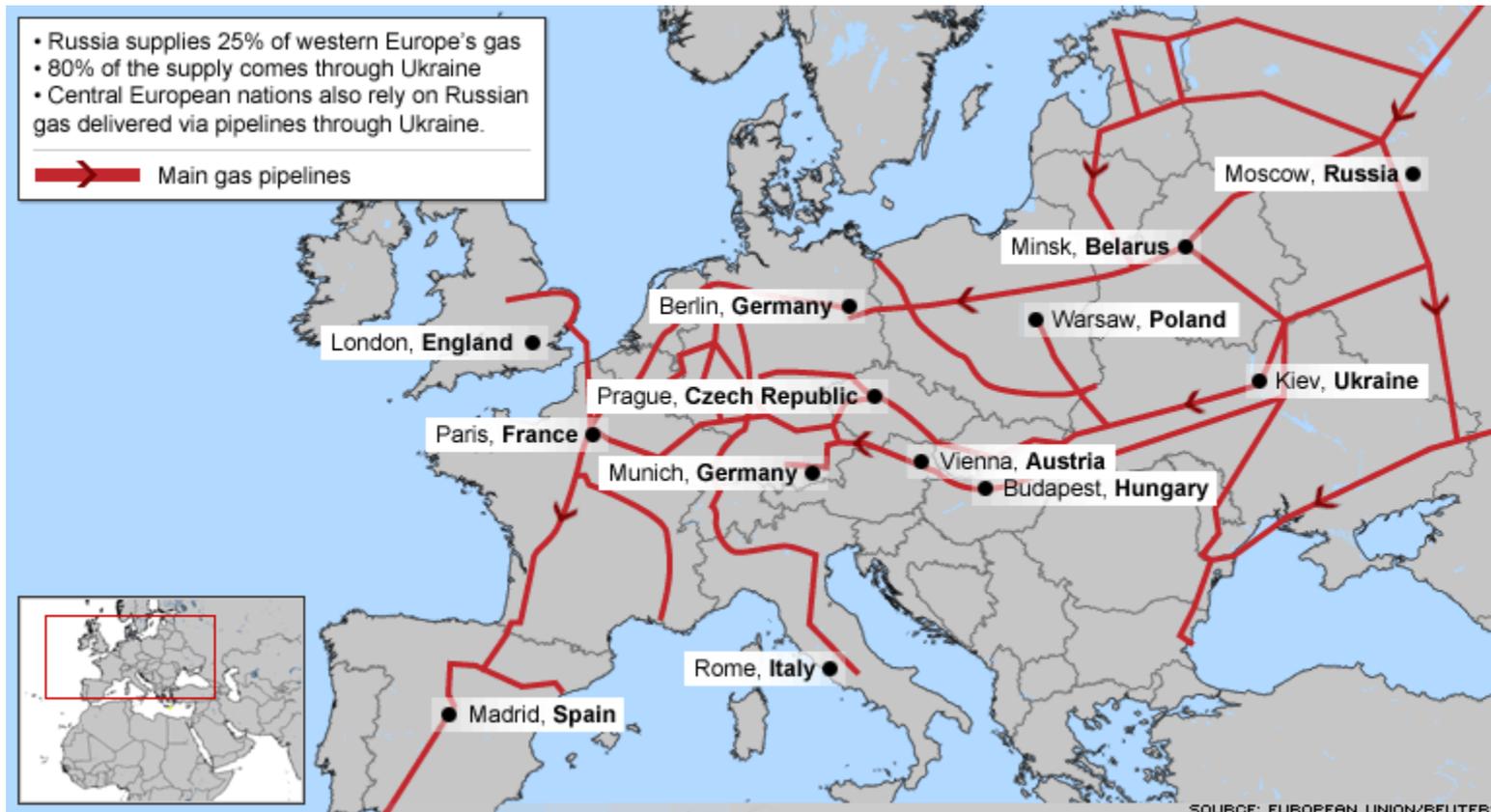
6.7 billion Nm<sup>3</sup> (5.5 Mtoe)  
52 % consumed in HD vehicles

# Biogas injection to natural gas grid

- Biogas can be distributed via natural gas grid
- Grid connects the production site with more densely populated areas
- Some countries have standards for gas injection to grid
  - CH<sub>4</sub>, CO<sub>2</sub>, sulphur compounds, moisture, Wobbe index, siloxanes...
  - Low- and High value gas
- Biogas is cleaned & upgraded before injection
  - Odourisation
  - If necessary, heating value adjustment
  - Commercially available technology

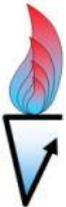


# Natural gas network in Europe



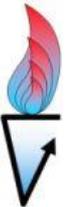
# Overview on different support measures for biomethane in Europe

- At the consumption side
  - Feed-in tariffs
  - Renewable gas
  - Renewable electricity from CHP
- Investment support
  - CHP-systems,
  - CNG cars,
  - Bus and vehicle fleets
- Beneficial tax policy featuring tax exemption or refund, e.g. in terms of
  - Energy tax,
  - Fuel tax,
  - Electricity tax,
  - Income tax
- Revenues from emission trade



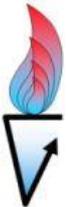
# What are the bottle necks ?

- Methane emission (slip)
- Market volume
- Trade
- Regulation



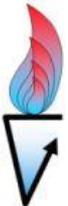
# Regulatory restrictions

- Germany: - Limited access due to feed-in tariff
  - Preference for CHP
- Italy: - No gas injection allowed so far
- Austria: - Only biomethane from agricultural origin
- U.K.: - Stringent requirements for oxygen (< 0.2%)
- France: - Hygienic limits (no gas injection for WWTP & landfills)
  - Chemical restrictions
  - so far no gas injection possible

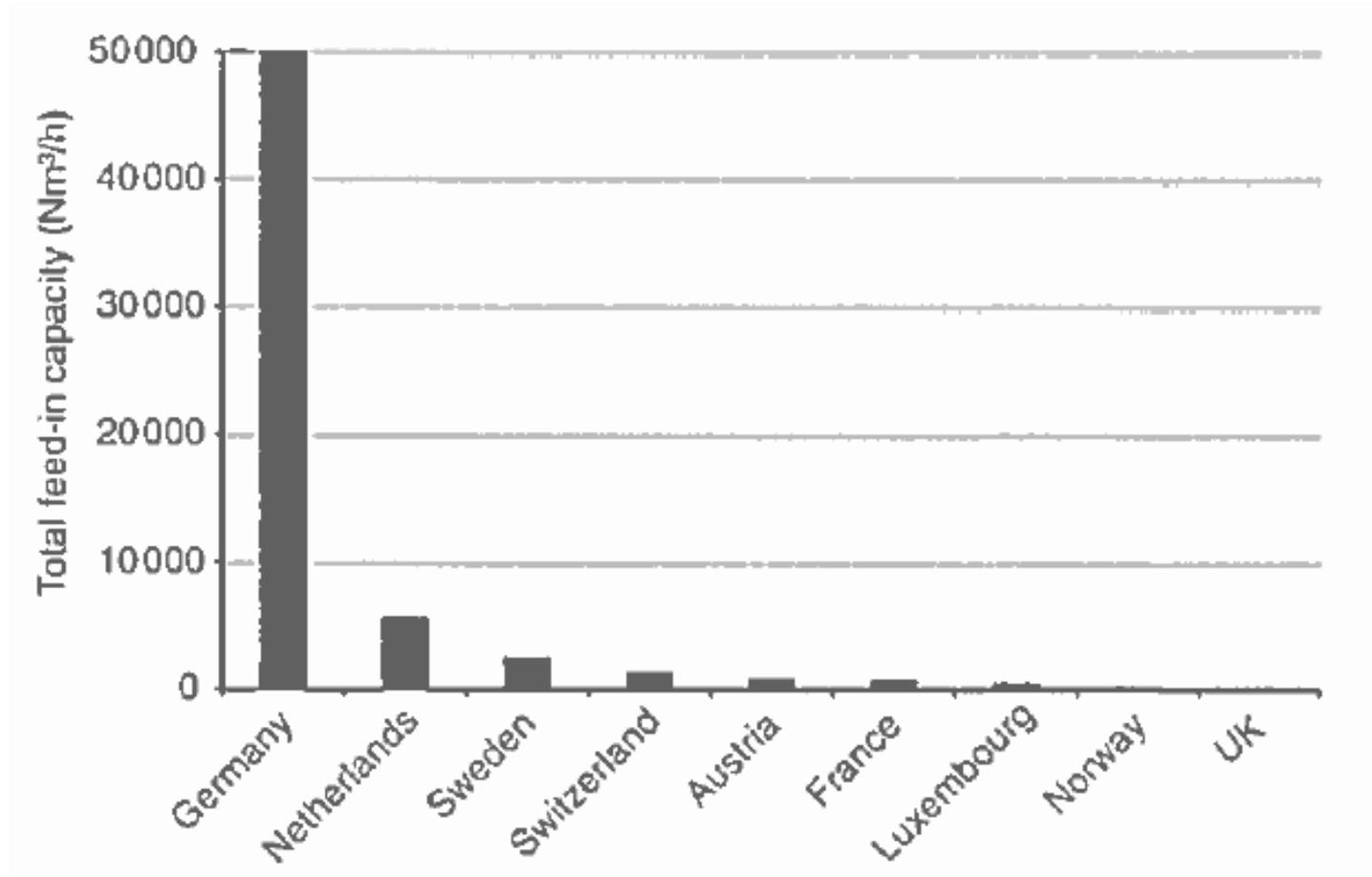


# Is it legal to inject biomethane?

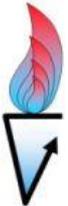
- Countries with standards:
  - Austria, Czech Republic, Germany, France, Poland, Spain, Sweden, Switzerland, The Netherlands
  
- Countries without standards:
  - United Kingdom, Finland, Norway, Luxembourg, Denmark
  
- Countries that consider feed into grid without standards:
  - Poland, Belgium, Ireland, Italy, Croatia, Turkey



# Biomethane feed-in capacities in Europe.



(Copyright: Fraunhofer IWES, 2012).

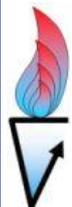
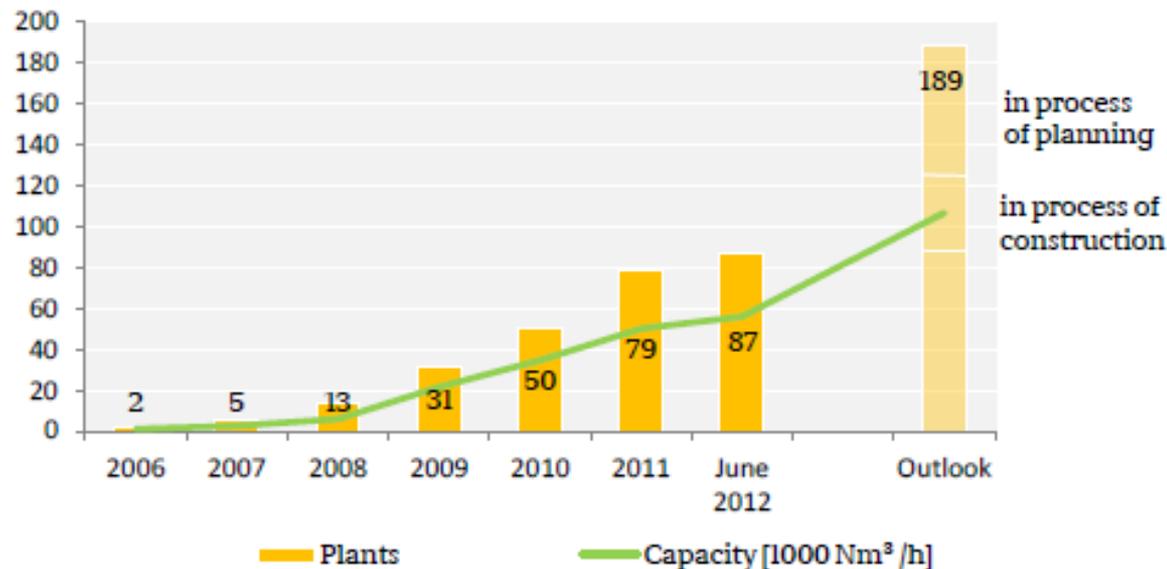


# Biomethane in Germany – facts and figures

- 90 plants for biogas upgrading
- 87 plants for biogas injection in 2012
- Capacity of 55930 Nm<sup>3</sup>/h
- 39 plants under construction
- 63 plants in planning
- Moderate increase

- 189 plants ->
- 10679 Nm<sup>3</sup>/h

Market development 2006 - 2012  
and outlook (construction/planning)



# UNIVERSITY OF JYVÄSKYLÄ

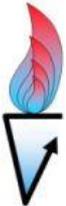
## Biomethane standards for grid injection or vehicle fuel use

Compound	France <sup>1</sup>		Germany <sup>2</sup>		Sweden <sup>3</sup>	Switzerland <sup>4</sup>		Austria <sup>5</sup>	Holland <sup>6</sup>
	L gas	H gas	L gas	H gas		Limited injection	Unlimited injection		
Lower Wobbe Index (MJ/Nm <sup>3</sup> )					43.9-47.3				
Higher Wobbe Index (MJ/Nm <sup>3</sup> )	42.48-46.8	48.24-56.52	37.8-46.8	46.1-56.5				47.7-56.5	43.46-44.41
CH <sub>4</sub> (vol-%)					97	>50	>96		>80
CO <sub>2</sub> (vol-%)	<2		<6			<6		<2 <sup>6</sup>	
O <sub>2</sub> (vol-%)	<0.01		<3		<1	<0.5		<0.5 <sup>6</sup>	
H <sub>2</sub> (vol-%)	<6		<5			<5		<4 <sup>6</sup>	<12
CO <sub>2</sub> +O <sub>2</sub> +N <sub>2</sub> (vol-%)					<5				
Water dew point (°C)	<-5 (at MOP downstream from injection point)		<t <sup>4</sup>		<t <sup>4</sup> -5			<-8 <sup>7</sup>	-10 <sup>8</sup>
Relative humidity (%)			0.55-0.75			<60%			
Total S (mg/Nm <sup>3</sup> )	<100 (instant content) <75 (Annual average)		<30		<23	<30		<5	<45
MON (Motor octane number)					>130				
NH <sub>3</sub> (mg/Nm <sup>3</sup> )					<20				
H <sub>2</sub> S (mg/Nm <sup>3</sup> )						<30			

**Thank you for your attention**

EU FP7 Valorgas project: Valorisation of Food Waste  
to Biogas

**VALORGAS**



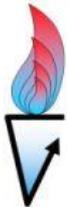
# The biomethane market in Sweden

- **Formation of regional PPP's (Public – Private – Partnership)**
- **Local/regional government as key actors leading the way**
- **Cooperation among many actors**
  - Biomass supplier, biogas producer, digestate receiver
  - Distributors, Refuelling network operators
  - Vehicle manufacturers, auto repair shops, regulatory authorities
  - End customer: From large captive fleets down to the private car owner
- **Barriers to overcome during early formation of market**
  - Weak infrastructure
  - Low level of knowledge and support
  - Regulations & weak supportive policies
  - High investments
  - Balancing supply and demand



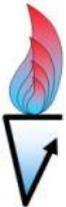
## The biomethane market in Sweden

- Capital intensive business with small profit margins
  - Need additional drivers and good framework conditions
- Tax exemption + high fossil fuel taxes
  - Upgraded biogas: buy at 0.5-0.8 €/m<sup>3</sup>, retail at 1.6 €/m<sup>3</sup>
  - Long-term high-volume contracts securing the market
  - Waste management + procurement of public transport
- Escalating substrate costs in harmony with market growth?
  - Learning curves + Increasing and volatile fossil fuel prices increase better profit margins
  - Challenge: Starting with free or cheap waste, now followed by more expensive substrates, e.g. energy crops
- Extension of existing policies and no new ones to facilitate production growth



# BIOMETHANE STANDARDS: What is the status?

- CEN/TC 408 new scope encompasses:
  - both biomethane and natural gas as fuels,
  - biomethane for injection into natural gas grids.
- 17 Countries :
  - Austria (ASI), Belgium (NBN), Bulgaria (BDS), Czech Republic (UNMZ), Denmark (DS), Finland (SFS), France (AFNOR), Germany (DIN), Greece (ELOT), Italy (UNI), Latvia (LVS), Norway (SN), Slovenia (SIST), Slovakia (SUTN), Spain (AENOR), Sweden (SIS), United Kingdom (BSI)
- 7 liaisons with EU organisation :
  - NGVA Europe, EBA, Farecogaz, GIE, Marcogaz, Afecor, ENTSOG
- 3 Liaisons with technical committees :
  - CEN/TC 19, CEN/TC 234 and WG 11, ISO/PC 252
- Stakeholders :
  - Car manufacturers, Grid operators, Biomethane producers, Fuel producers, Natural gas suppliers, Manufacturers of gas fuelling stations



## Barriers for biomethane market

- Lack of a common European biomethane specification for grid injection and vehicle fuel use
- Availability of proper incentive schemes, favouring grid injection and/or vehicle use over biogas for electricity production
- Availability of Natural Gas Vehicle (NGV) refuelling infrastructure
- Availability of an EU-wide NGV market in terms of vehicle offer

