GE
Energy

Jenbacher gas engines

"Economic utilization of Biomass and Municipal Waste for power generation."

Some energy lasts for generations

ecomagination
a GE commitment

GE imagination at work

GE – facts

- Founded in 1892 by Thomas Edison
- Operations in more than 100 countries
- More than 300,000 employees worldwide; 85,000 in Europe

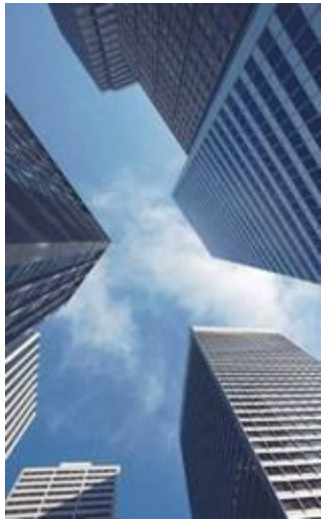
GE imagination at work

GE's portfolio

Energy Infrastructure

Technology Infrastructure

GE Capital



NBC Universal

GE Energy … power gen platforms

Thermal

- **Gas turbines**
  - Heavy duty (40–500MW)
  - Aeroderivatives (18-100MW)
  - Combined cycle systems
- **Coal**
  - IGCC
  - Steam turbines

Nuclear

- New Reactors
- Nuclear Fuel
- Reactor Services
- Performance Services

Renewables

- **Wind**
  - Land based
  - Offshore
- **Solar**
  - Grid connected
  - Stand alone
- **Biomass**
  - Gas engines 0.3-4MW
  - Non natural gas

The Type 6 Gas engine
more than 2200 engines since 1989

Jenbacher gas engines

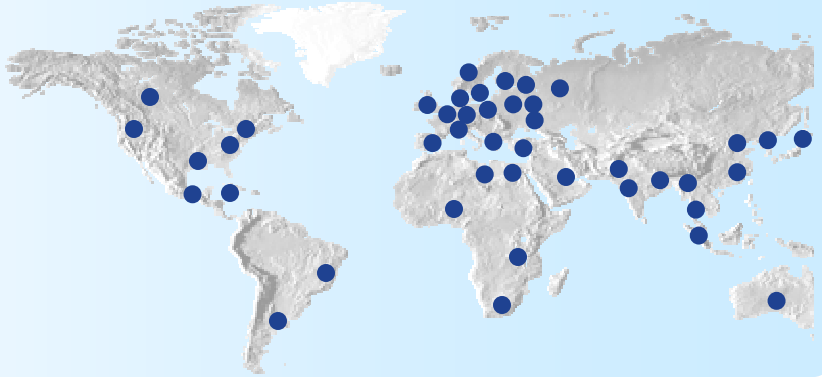
A leading manufacturer of gas-fueled reciprocating engines for power generation

- **Power range:** **0.25MW to 4MW,**
  4 platforms / 11 products
- **Fuel flexibility:** Natural gas or a variety of renewable or alternative gases
- **Plant configurations:** Generator sets, cogeneration systems, container solutions
- **Delivered engines:** about **8,500 units / 9,800 MW**
- **Business:** World wide operations

Headquarters

- Jenbach premises... 1300 employees
  - Production facilities
  - Global Customer support center
  - Repair shop
  - Training center
- Engine assembly in China
- Container assembly in Hungary

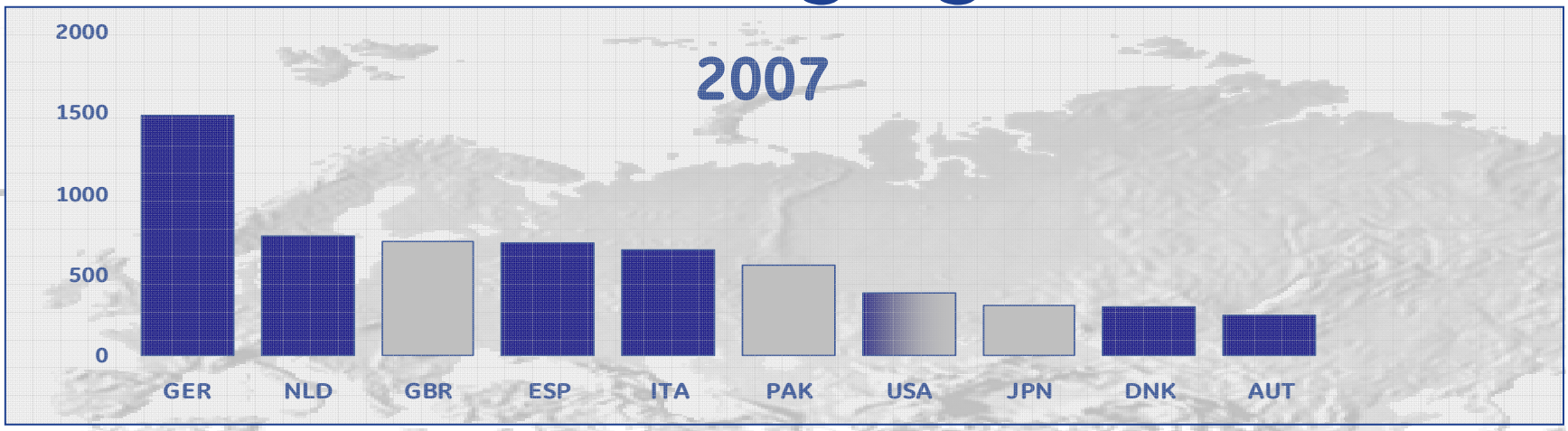
- 1,700 world wide employees
- Business in >60 countries
- 8 Subs + Hubs
- >60 ITPs (independent 3rd parties)

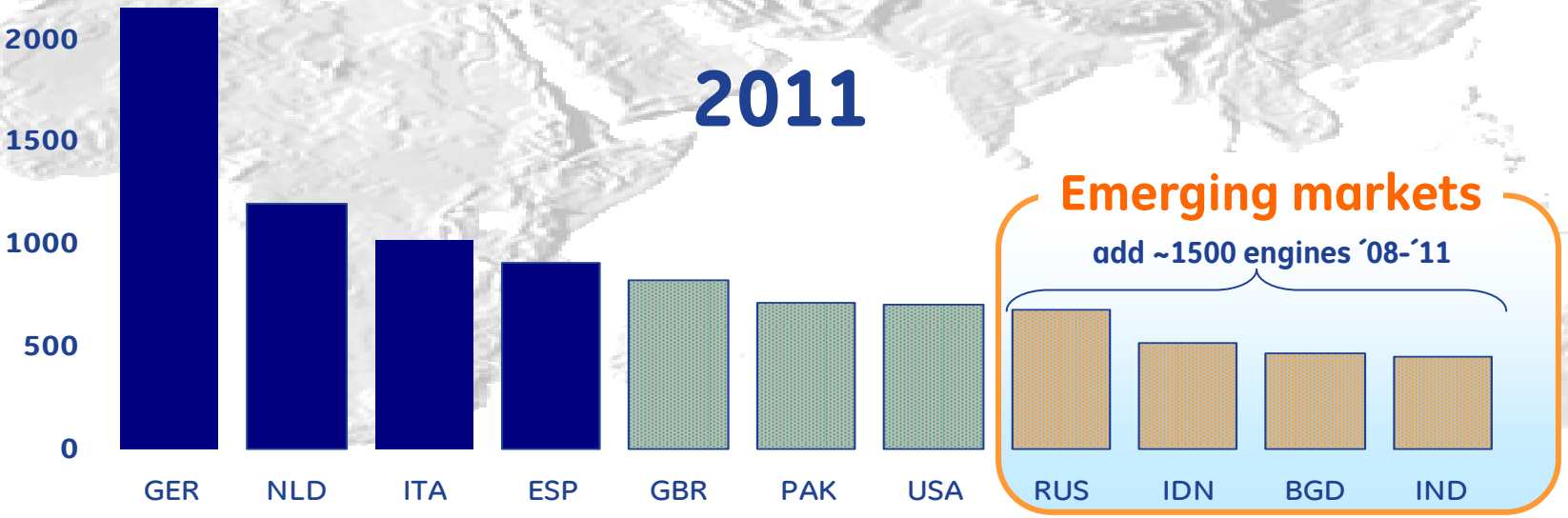


5 decades of experience

1957	1st gas engine
1979	1st cogeneration module
1985	1st LEANOX® gas engine
1994	1st 20 cylinder gas engine JW 320
1997	World's smallest 20 cylinder gas engine in the 3 MW power range
2000	Presentation of "High Efficiency Concept" J420 GS
2003	May: GE acquires Jenbacher
2004	December: 1st Mechanical Drive unit in field operation, Louisiana (US)
2006	Opening of assembly hall 2
2007	world's 1st 24-cylinder 4 MW engine on test bench (J624)

...but world is changing





Distributor:

Clarke | Orient | misc | Power Solutions | Navigat | Orient | Clarke

(# of units installed)

GE imagination at work

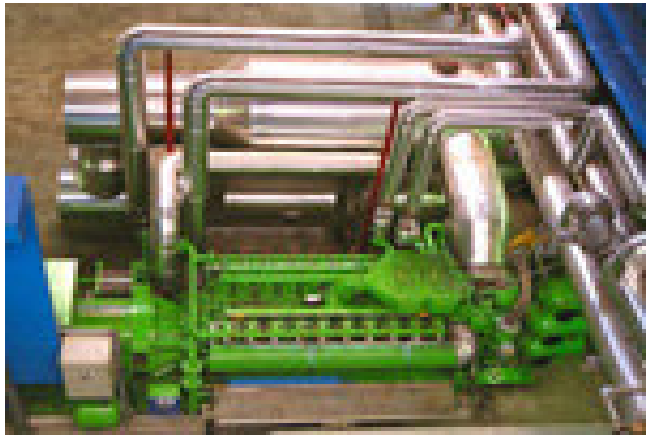
Product range

Gen-Sets

- On-site generation of electricity
- Base load or peaking
- Island / grid mode

Container modules

- Container solutions for type 2, 3, 4 engine
- Gas supply and electricity connectivity needed
- Also as CHP solution

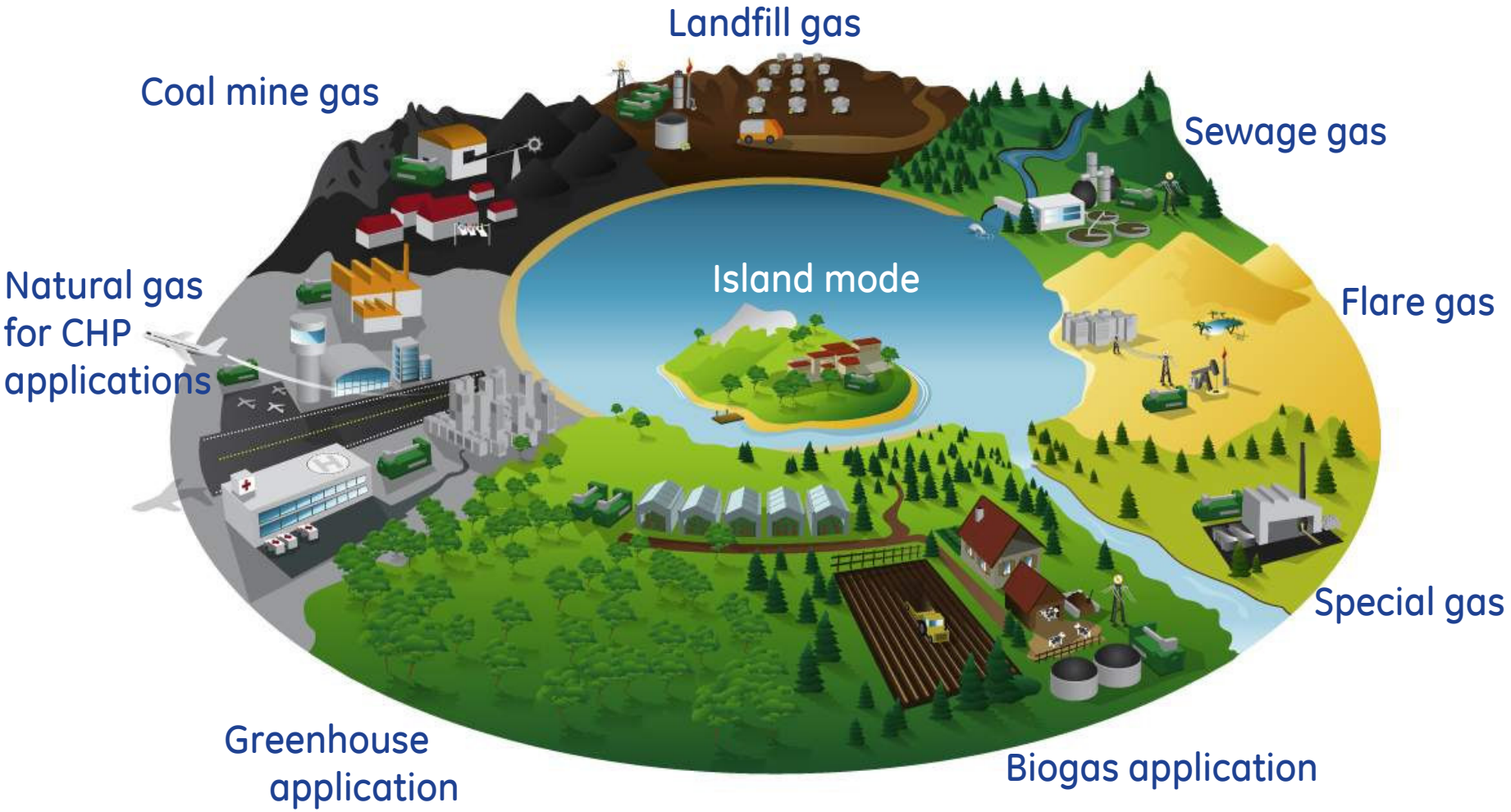


Cogeneration plant

(or combined heat & power (CHP) plant)

- produces electricity and heat
- > 90% degree of (total) efficiency
- transform heat from combustion, internal water/oil-circuitry

Jenbacher gas engines core applications



Advantages of on-site energy supply

Energy supply directly at the load source allows to reduce or avoid transport and distribution losses.

Key features of Jenbacher plants

- High electrical efficiencies of up to 44%
- Overall efficiencies (electrical and thermal) of over 90%
- Minimum NOx-emissions through the patented LEANOX® lean mixture combustion
- Specially designed engines for use of alternative, renewable energy sources and special gases
- Maximum operational safety and availability
- High power density

Biogas

Landfill gas

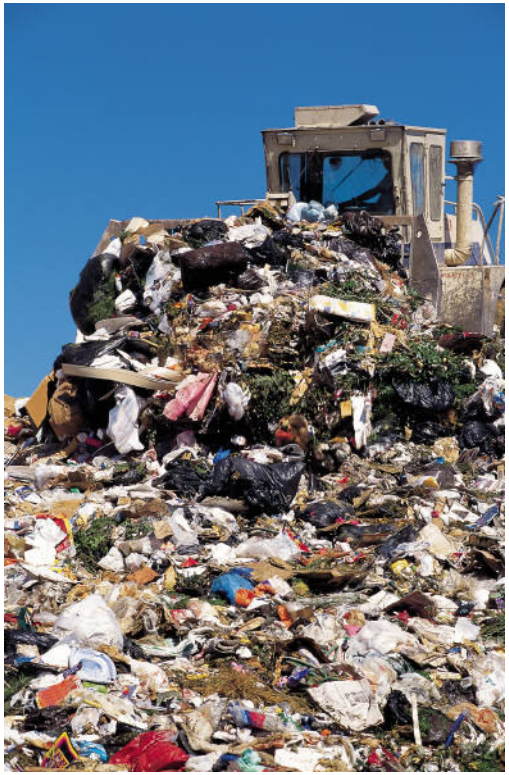
Sewage gas

Agricultural waste

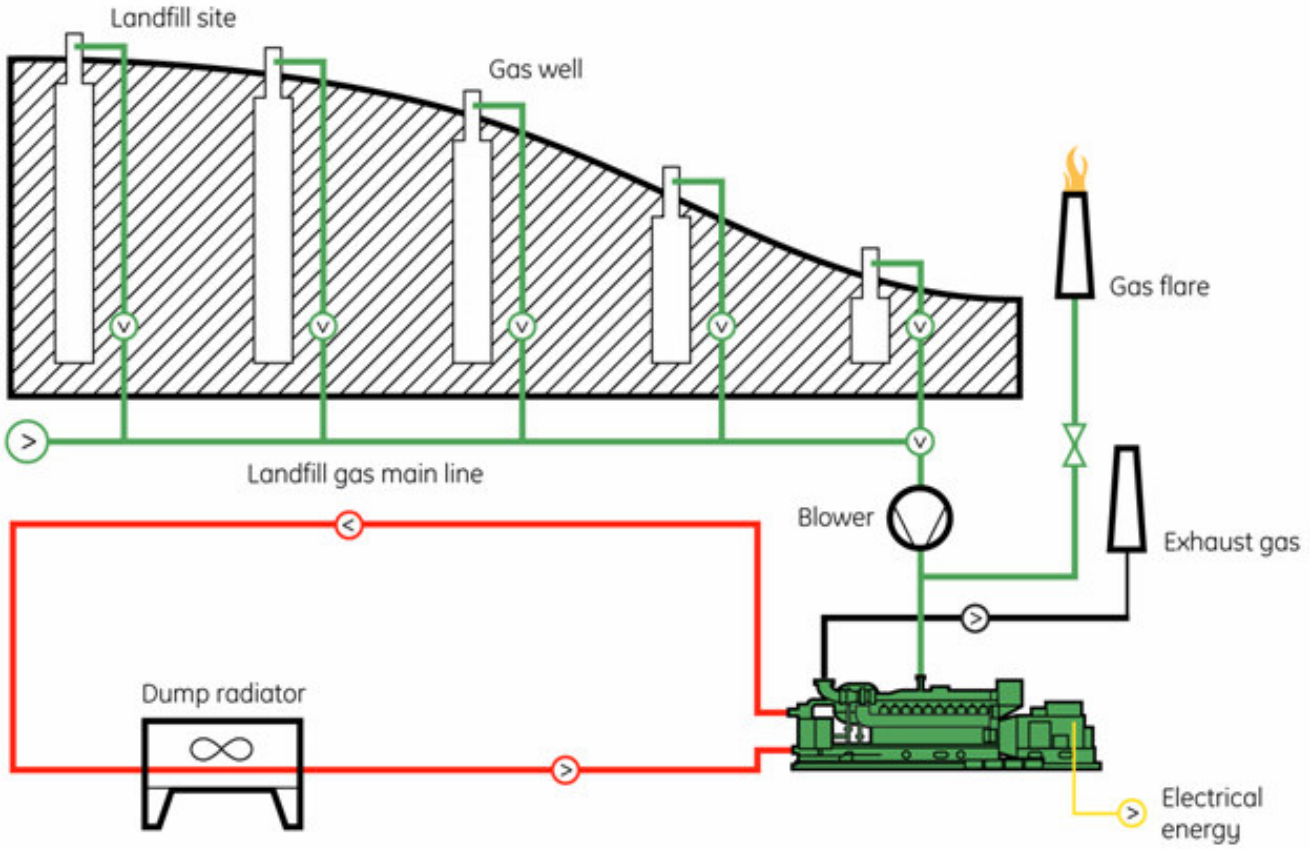
Organic waste

Biodegradable waste components turn into landfill gas (LFG)

- Landfill gas is created during the decomposition of organic substances under anaerobic conditions
- Landfill gas consists of methane, carbon dioxide, nitrogen and oxygen
- With a calorific value of 4.5 kWh/m^3_N, landfill gas is a high-value fuel for gas engines



Customer-oriented solutions

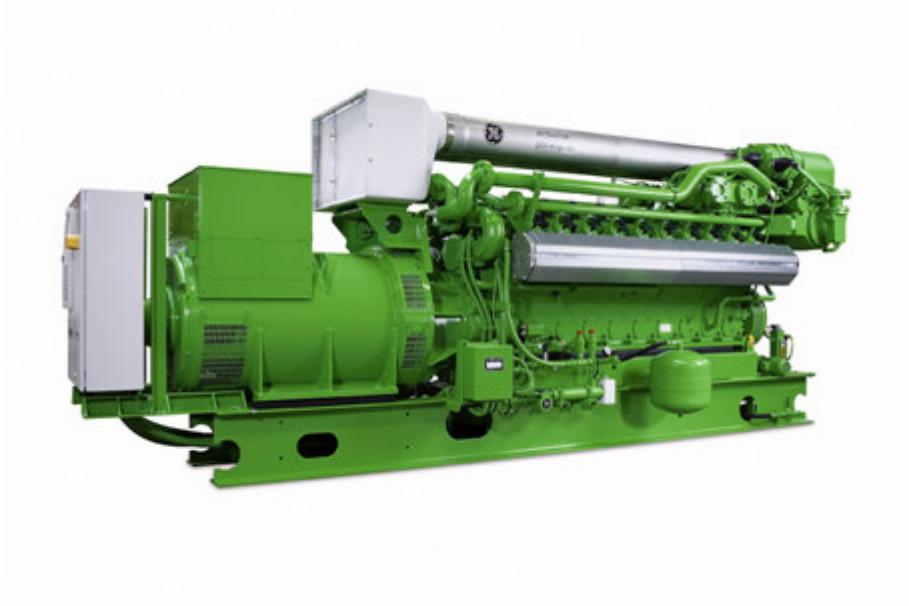


Landfill gas is captured by wells and turned into energy with Jenbacher gas engines

One J320 gas engine (1 MW) running with LFG reduces annually emissions equivalent to:

- 46,500 tons of CO_2
- Emissions of 1,000 cars
- Planting 9,000 acres of forest
- Averting the use of 60,000 light bulbs

=> while producing sufficient energy to provide 2,700 EU homes with electricity



ecomagination
a GE commitment

GE is a competent partner for your landfill gas solution

- **25 years of experience in the combustion of landfill gas**
- **More than 1,300 Jenbacher landfill gas systems worldwide**
- **About 1,300 MW total electrical output**

The Jenbacher product team offers an unparalleled breadth of expertise, references and solution variants.

Biogas – renewable fuel able to substitute fossil fuels

For a wide range of organic substances from agriculture, food waste or food industry anaerobic fermentation is a superior alternative to composting.

Biogas ...

- results from anaerobic digestion of organic materials
- is a mixture of methane and carbon dioxide
- serves as a high-energy, CO2-neutral fuel

Operational conditions of the fermentation process

- **Temperature**
  mesophile process: 35 - 40°C
  thermophile process: 50 - 55°C

- **Retention time**
  minimum 15 days
  range: 20 - 50 days
  typical: 25 - 30 days

Dry matter concentration
dry fermentation: 20 - 30%
wet fermentation: 10 - 15%

- Absence of oxygen
- pH value from 6.5 to 7.5

Gas composition:

50 – 70% methan (CH_4)

30 – 50% carbon dioxide (CO_2)

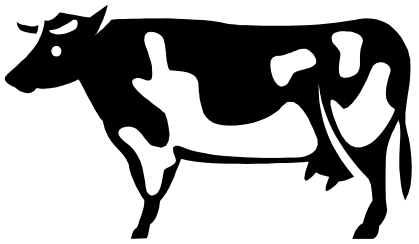
Biogas yields of 1t suitable organic materials

Kind of material	%DM	Biogas [Nm³/t]	El. Energy [kWh/t]	El. Output [kW*/1000t]	Residue after fermentation [t]
Meat & Bone meal	90	860	2200	268,3	0,3
Oil-seeds residues	90	600	1443	176,0	0,4
Corn (grain)	73	525	1030	125,6	0,48
Waste bread	70	500	925	112,8	0,5
Slaughterhouse waste (innards)	30	320	770	93,9	0,77
Grease trap residues	25	250	640	78,0	0,82
Corn silage	40	260	510	62,2	0,74
Food waste	18	180	450	54,9	0,87
Pomace (vine)	40	180	430	52,4	0,8
Grass silage	33	200	384	46,8	0,8
Flotate (slaughter house)	15	145	375	45,7	0,87
Blood	20	140	336	41,0	0,86
Organic waste	30	120	290	35,4	0,85
Chicken Manure	25	100	240	30,0	0,95
Draff (beer)	20	75	185	22,6	0,93
Vegetable residues	12	70	174	21,2	0,91
Vinasses (sugar)	65	150	120	14,6	0,85
Whey (dairy)	2	25	60	7,3	0,98
Cow manure	8	40	80	6,6	0,98
Pig manure	6	21	50	6,1	0,98
distiller's wash	4	19	47	5,7	0,98
Sewage sludge	4,4	14	32	3,9	0,98

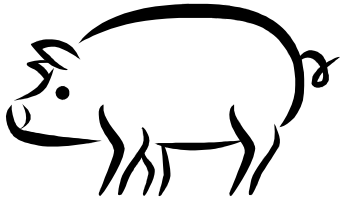
* Based on 8, 200 op.hrs/a ; Source: AAT

Energy potential of biomass

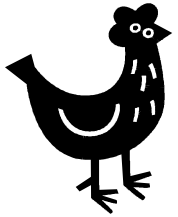
1 JMS 312 GS-B.L with 500 kWel
can be fueled by manure of:



3,600 dairy cows



14,000 feeding pigs



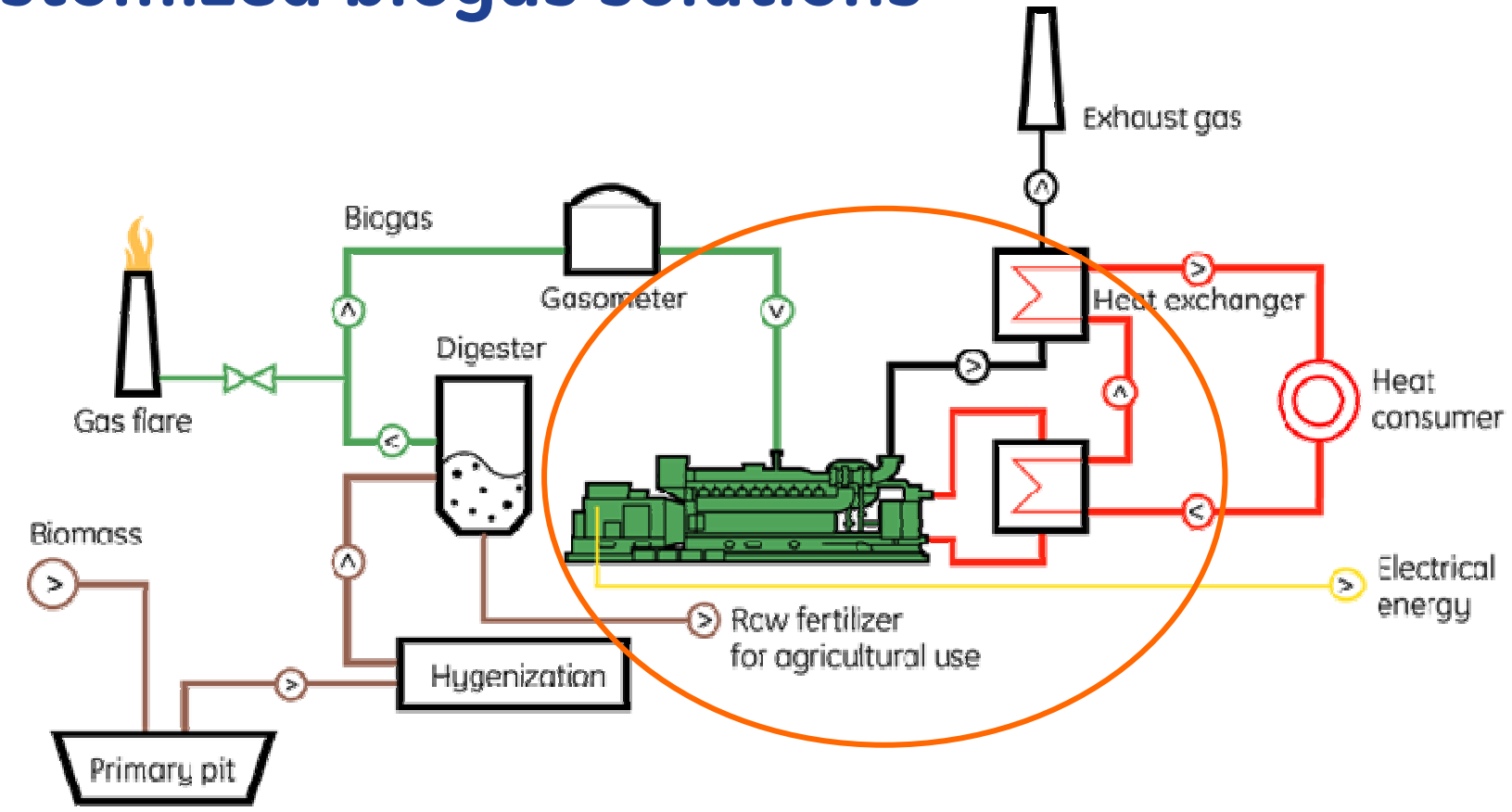
700,000 laying hens or chickens

Or biogas generated from:

250 ha cultivated corn

20.000 tons/a of organic household waste

GE's Jenbacher gas engine business offers customized biogas solutions



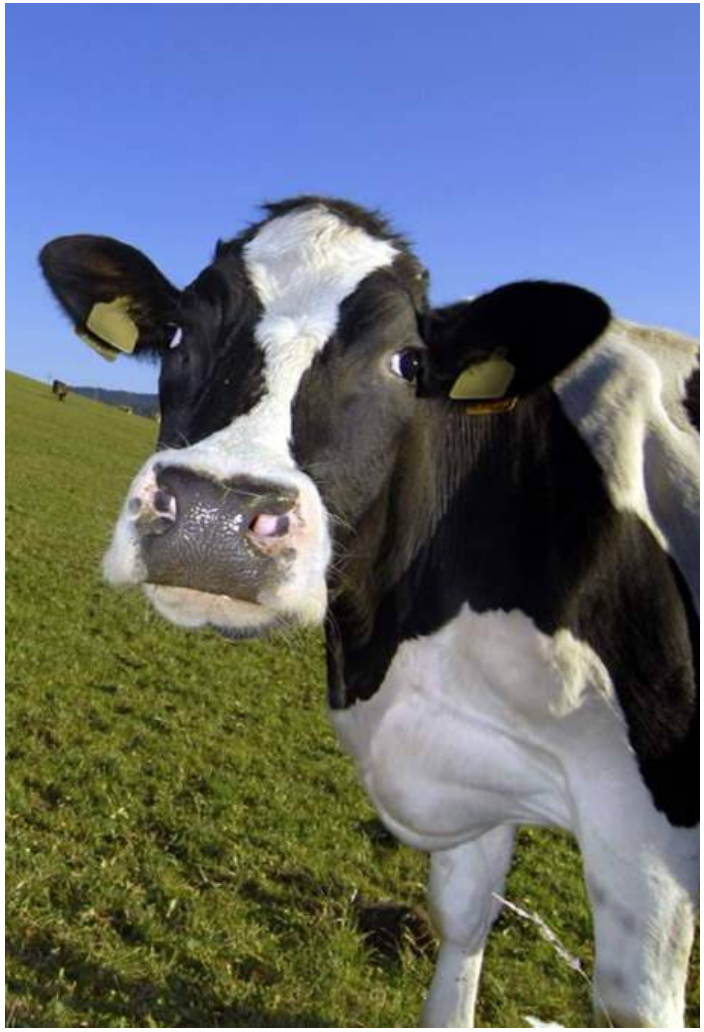
(in case of food waste)

Jenbacher biogas-cogeneration units are core part of biogas plant, but enhanced digester-technology

GE is a competent partner for your biogas solutions

- **more than 1,450 Jenbacher biogas systems worldwide**
- **over 985 MW total electrical output**

Jenbacher cogeneration technology fueled with biogas enables maximum economic and ecological benefits.

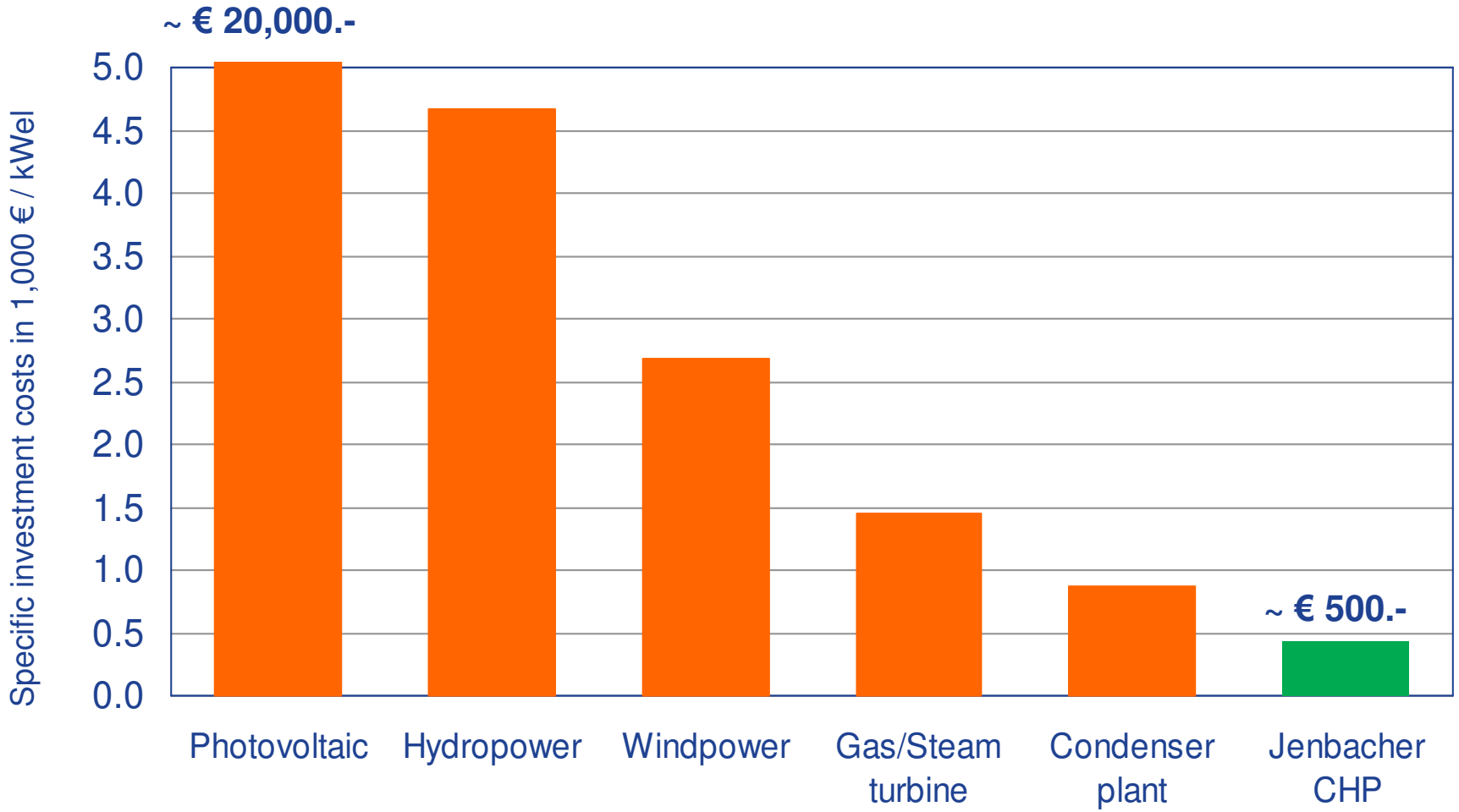


Biogas

Market dynamics

GE imagination at work

Comparison of investment costs by type of power plants in Austria



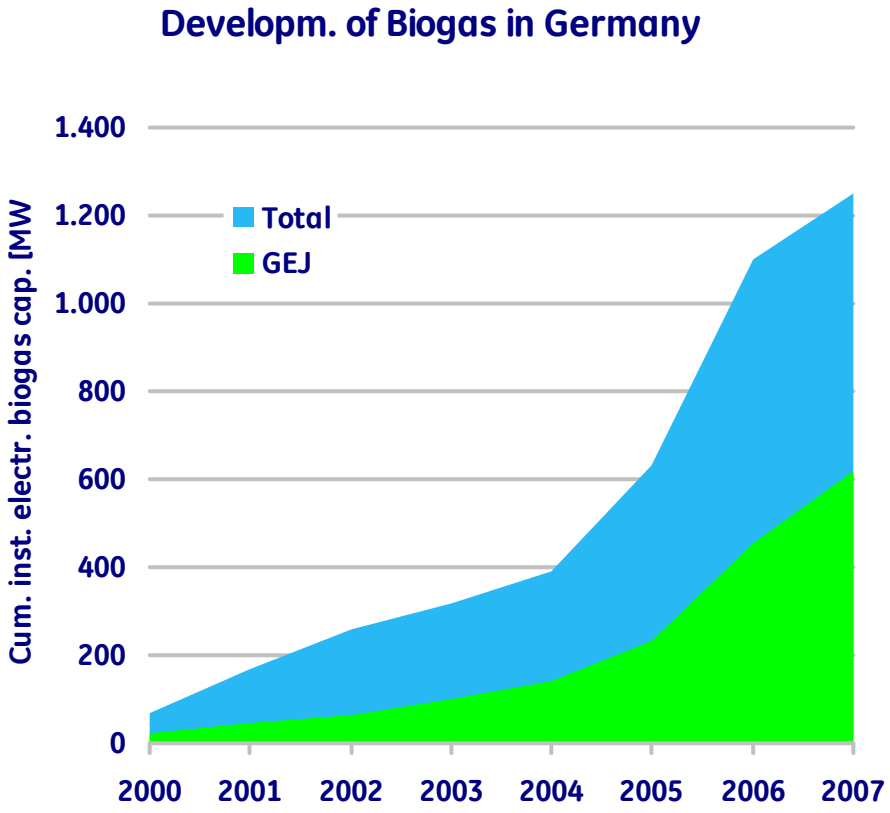
Development of Biogas in Germany

EEG in Germany

- Long-time tariff-guarantee (currently 0.19 €/kWh) for operators of Eco-power-plants (20 years)
- Fair tariffs including index-adaptation
- Obligation to buy eco-power
- Criteria for Energy Efficiency and Innovation bonus

EEG as Job engine in Germany

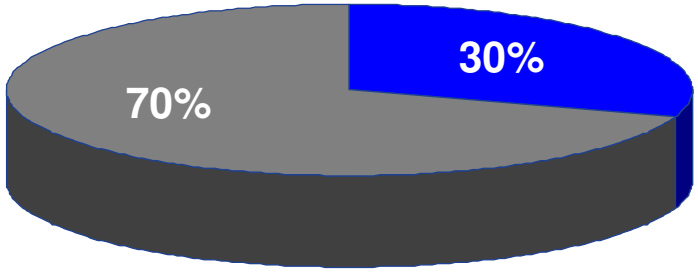
- **134,000 Jobs** are directly related to the EEG
- German Suppliers play key role internationally



Germany's biogas plants deliver decentralized energy at the volume of large thermal power plant

Biomass Digestion:

Investment costs – based on European figures:



Biomass preparation, digester, Gas holder,...

Containerized Cogeneration plant

European spec. investment for biogas plant

- 500 kWel. plant – approx. 3,000 – 3,500 € per kW
- 1000 kWel. Plant - approx. 2,300 – 2,800 € per kW

Cost of Asian biogas plants are significantly lower (~-40%)

Biomass Digestion:

Initial cost of electricity – **€ Cent/kWhel**:

- assumption – University Leipzig 2003 - **for Germany:**
  - 8000 operation hours per year
  - 12 years

	330KW	1000KW
Biomass: 95% manure	**~ 10**	**~ 8**
Biomass: 2/3 energy crops (Corn silage cost: 30 €/t)	**~ 16**	**~ 13**

Calculation – **for Asia:**

- 8000 operation hours per year
- 10 years

	500KW
Biomass: palm oil mill effluent	**~ 4-6**

Source: http://www.bmu.de/files/pdfs/allgemein/application/pdf/stromerzeugung_biomasse.pdf

Summary – Biogas in CHP

- **Biogas** plants are operated – weather independent – for base load supply
- **Biogas** plants can be seen as **state-of-the-art technology**
- Because of low energetic density of source materials, **biogas** should be used **decentralized**
- Using biogas in **CHP-modules** generates **highest GHG-savings**

Reference Sites

GE imagination at work

Biogas plant – Bösch Herisau - Switzerland:

Biomass: up to 40.000 to/a:

- manure from pigs
- waste from slaughter houses
- food waste

Used biomass will be dehydrated – reduce amount to 25% - sold as fertilizer

1 x JGS 320 GS-B.L.C

Power output:
1064 kWel.

Landfill gas plant Busan, Korea

No. of units and engine type:	6 x JGC 320 GS-L.L
Fuel:	Landfill gas
Electrical output:	6,348 kW
Commissioning:	May 2003

GE imagination at work

Puchong Landfill, Malaysia

Fuel: Landfill gas
Engine type:
2 x JGC 320 GS-L.L with
Electrical output: 1,064 kW

Commissioning: 2004

GE imagination at work

Foodwaste plant Busan, Korea

No. of units and engine type:	2 x JGS 320 GS-B.L
Fuel:	Bio gas from Foodwaste
Electrical output:	1,116 kW
Commissioning:	January 2005

GE imagination at work

Biogas plant DeQingYuan, China

No. of units and engine type:	2 x JMS 320 GS-B.L
Fuel:	Biogas from Chicken Dung (3 Mio chicken)
Electrical output:	2126 kW
Thermal output:	1234 kW
Commissioning:	Sept 2008

Cow manure biogas plant in Ludhiana/India

Biomass Input: 235 ton/day cattle manure
Electrical output: 1 MW
Organic fertilizer: 35 ton/day

No. of units and engine type: 1 x JMC 320 GS-B.L

AD of biomass – Kanoria I + II - India:

Biomass:

Spent wash – 675 m3/d

-> effluent removed after fermenting sugar cane molasses (ethanol production)

1 x JMS 320 GS-B.L

1 x JMS 420 GS-N/B.L

Power output:
1034 kWel. / 1416 kWel.
Thermal output:
Water:586 kWth. / 748 kWth.
Steam: ~ 1350 kg/h; 10bar
Commissioning: 1998 / 2003

AD of biomass – Natural palm Oil - Thailand

Biomass:

- POME - palm oil mill effluent

Basic conditions:

- 12m3/h PMOE
- Temperature of PMOE fresh from mill 80°C -> cooling-down in open lagoon

1 x JGS 320 GS-B.L.C

Power output:
1064 kWel.
Commissioning:
2005



Lets put hands together for GROWTH!

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