



Fuel Flexibility Solutions in Distributed Power

PANAMCHAM, Panama

GE Distributed Power
September, 2016

Imagination at work



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GE's Mission:

To invent the next industrial era,
And build, move, power and cure the world

Imagining the things others don't / Building the things others can't / Delivering outcomes that make the world work better



ENERGY
MANAGEMENT
5% | \$7.3B



OIL &
GAS
12% | \$18.7B



POWER
18% | \$27.6B
|



HEALTHCARE
12% | \$18.3B



AVIATION
16% | \$24B



TRANSPORTATION
4% | \$5.7B



CAPITAL
28% | \$42.7B



APPLIANCES &
LIGHTING
6% | \$8.4B

~\$149B Revenue in 2014
\$17B Operating Earnings



The new GE Power

~\$30B '14 revenue ~65,000 employees >120 countries



Steve Bolze, CEO
Schenectady, NY

Gas power systems

Schenectady, NY, USA

High efficiency, scale power

- Power Plants (combined and simple cycle)
- Gas turbines
- Steam turbines
- Generators and controls
- Heat recovery steam generators



Power services

Baden, Switzerland

Optimizing plant performance

- Installation planning/execution
- Maintenance, repairs and outage solutions
- Multi-year service agreements
- Hardware/software blended upgrades
- Data-driven software solutions



Steam power systems

Baden, Switzerland

Advanced steam power expertise

- Complete portfolio, turnkey power plants
- Widest range of generators and Steam Turbines
- Air Quality Control Systems (AQCS) including CCS
- Turbine Island solutions for Nuclear



Distributed power

Jenbach, Austria

Power near and at the point of use

- Reciprocating engines (0.2 to 10MW)
- Jenbacher, Waukesha & Diesel engines, power equipment and services
- High efficiency and fuel flexibility: Natural gas, CHP, oilfield power, diesel and special gas applications



Water/process tech

Trevose, PA, USA

Energy efficient water solutions

- Chemical and monitoring solutions
- Engineered systems
- Mobile water
- Build-own-operate services



GE Hitachi nuclear

Wilmington, NC, USA

Advanced reactor technologies

- ESBWR, ABWR, PRISM
- Outage and asset optimization services
- Fuels and engineering services



PoweringEveryone



Distributed Power

Overview

GE's Distributed Power business is a leading provider of engines, power equipment and services, focused on power generation and gas compression at or near the point of use. Distributed Power's product portfolio includes highly efficient industrial reciprocating engines generating up to 10 MW of power each for numerous industries globally.

Service offerings

GE's global service network provides life cycle support for more than 36,000 reciprocating engines worldwide – anywhere and anytime, backed by our authorized service providers in more than 170 countries.



GE's Distributed Power provides customers of all types the ability to generate reliable, sustainable power whenever and wherever it is needed.

Greenhouse



IPP & Utilities



Oil & Gas

Grid firming



Steel



Agriculture & Food Processing



Mining

Waste-to-Power



Commercial & Industrial Buildings



Distributed Power

Products

Power generation

- Electrical output: 220 – 10,380 kWe, el. efficiency up to 49.9%, overall efficiency up to >90%
- 20,000+ engines installed, 25,000 MW power globally
- Natural gas, CHP, excellence in special gas applications (biogas, LFG, CMG, BFG), oilfield power

Gas compression

- Output: 335 bhp – 5,000 bhp (220 kWe – 3,605 kWe)
- 16,000+ compression engines delivered, over 16 million bhp power globally (12,000 MW)
- Wellhead, gathering, storage/transmission

Diesel

- Output: 2,550-2,780 kWe



Headquarters in Jenbach, Austria



Covering a broad output range with Distributed Power (60 Hz/kWe)

0.1 – 1.5 MW

1.5 – 5 MW

5 – 10 MW

POWER GENERATION



TYPE 2
249 kW – 335 kW



TYPE 3
633 kW – 1.059 MW



Type 4
850 kW – 1.426 MW



Type 6
1.795 MW – 4.498 MW



Type 9
9.35 MW



VGF*
265 kW – 830 kW



VHP*
600 kW – 1.6 MW



275GL+*
2.415 MW – 3.215 MW

MECHANICAL/O&G/MINING/MARINE



VGF*
265 kW – 830 kW



VHP*
600 kW – 1.6 MW



275GL+*
2.415 MW – 3.215 MW

MOBILE/EMERGENCY POWER



J320* generator set
1 MW



mobileFlex* J320/VHP*
Gas Engines 860 kW – 1MW



* Trademark of General Electric Company.

Three main areas of use in power gen

Renewables and waste-to-energy utilization



- Reducing CO₂ emissions
- Alternatives to fossil fuels
- Biogas, landfill gas, coal mine gas, special gases (steel gas, wood gas, process gases)
- Jenbacher Types 2, 3, 4, 6

Decentralized Power generation and cogeneration (natural gas)



- Reliable energy supply for remote areas
- Supporting local power needs
- Avoiding transport and distribution losses
- Enhanced total efficiency
- Jenbacher Types 2, 3, 4, 6, 9
- 616 stationary diesel engines

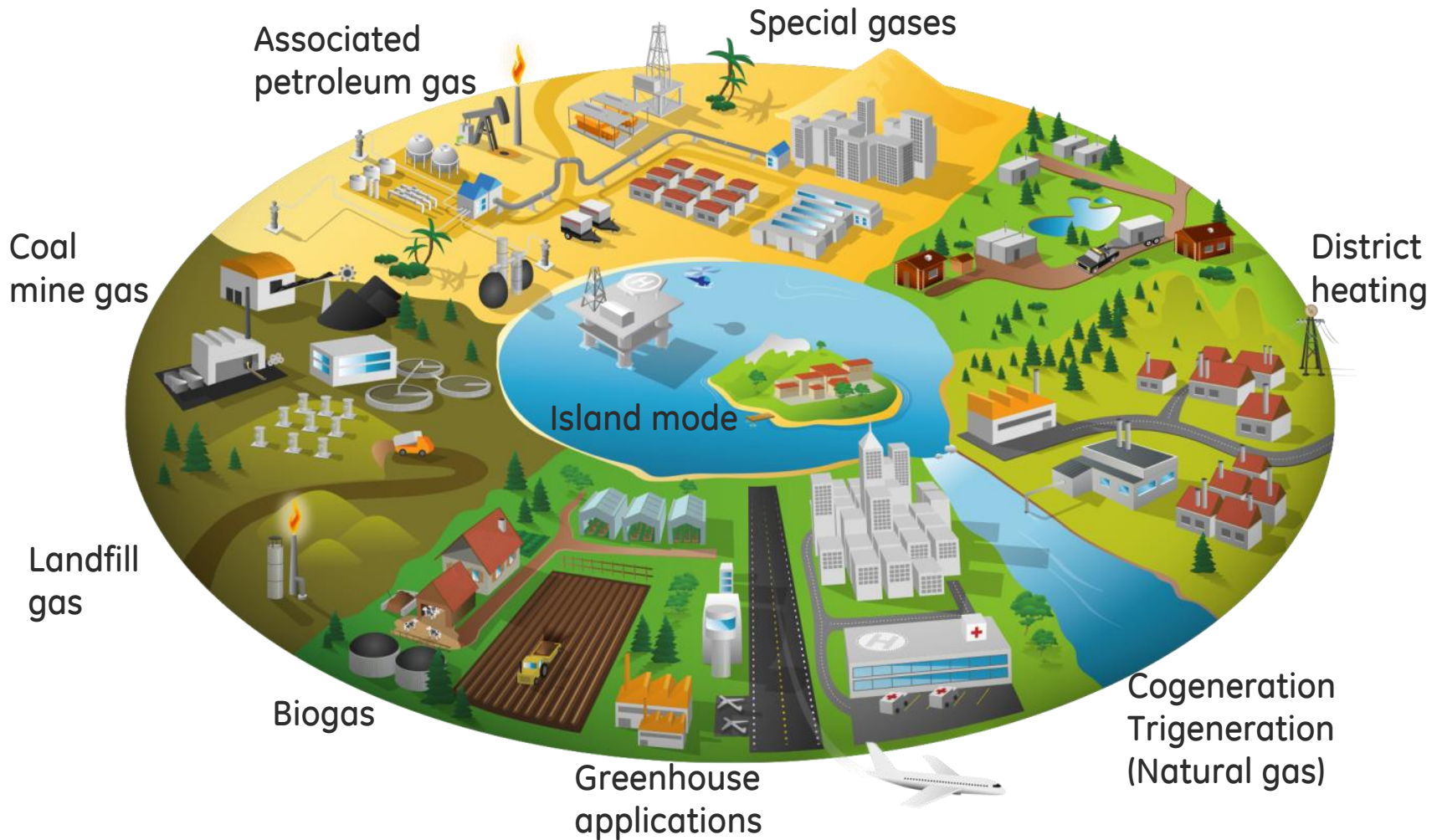
Oilfield Power (associated petroleum gas)



- Reliability for rugged, remote applications
- Increased exploration, development in remote regions
- Emission regulations driving increased use of natural gas versus diesel-powered gensets
- Jenbacher Types 2, 3, 4, 6
- Waukesha Types VGF, VHP, 275GL+



Fuel flexibility and tailor-made solutions



Natural Gas fueled CHP



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- > 6,900 natural gas fueled units >10,900 MWeI worldwide
- Highly efficient generation of power, heat and cooling
- Reduces primary energy use
- Minimizes transmission losses
- Enhanced total efficiency – greater than 95%
- Reduces fossil fuel use and greenhouse gas emissions



GE imagination at work

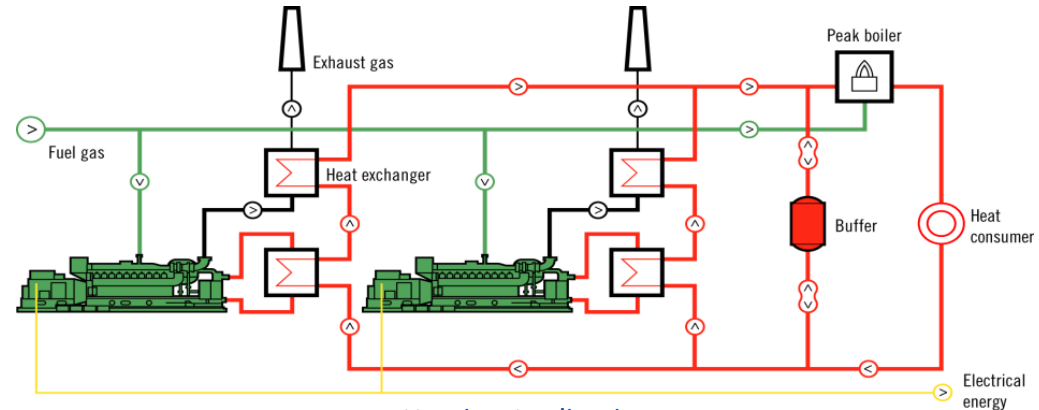
CHP Scheme

The combined simultaneous production of electricity and heat from a single fuel source. In Engine case, CHP is the recovery of waste heat during power generation in order to make hot water or steam or cooling.

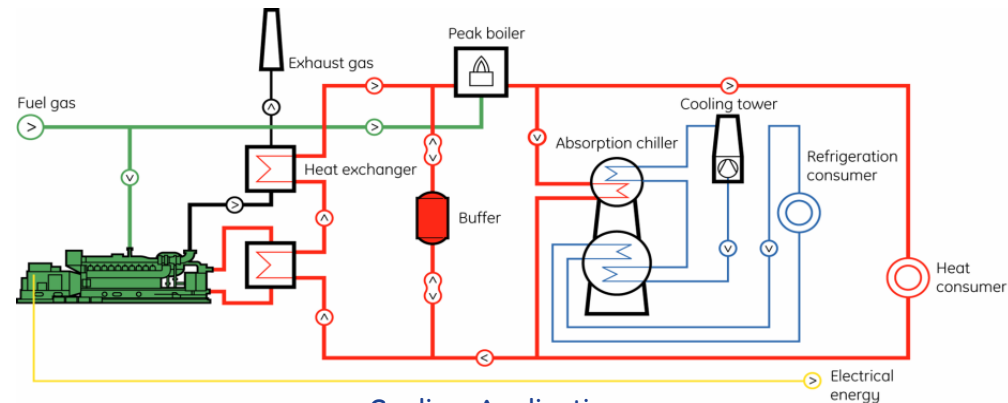
The Term “Cogeneration” is used interchangeably with CHP.

CHP Application may Include:

- Electricity
- Steam
- Hot water
- Process Heating
- Cooling and Refrigeration
- Drying
- Mechanical Drives



Heating Application



Cooling Application

CHP is not a single technology

NG CHP – Cost of Electricity

Segments

1) District Heating

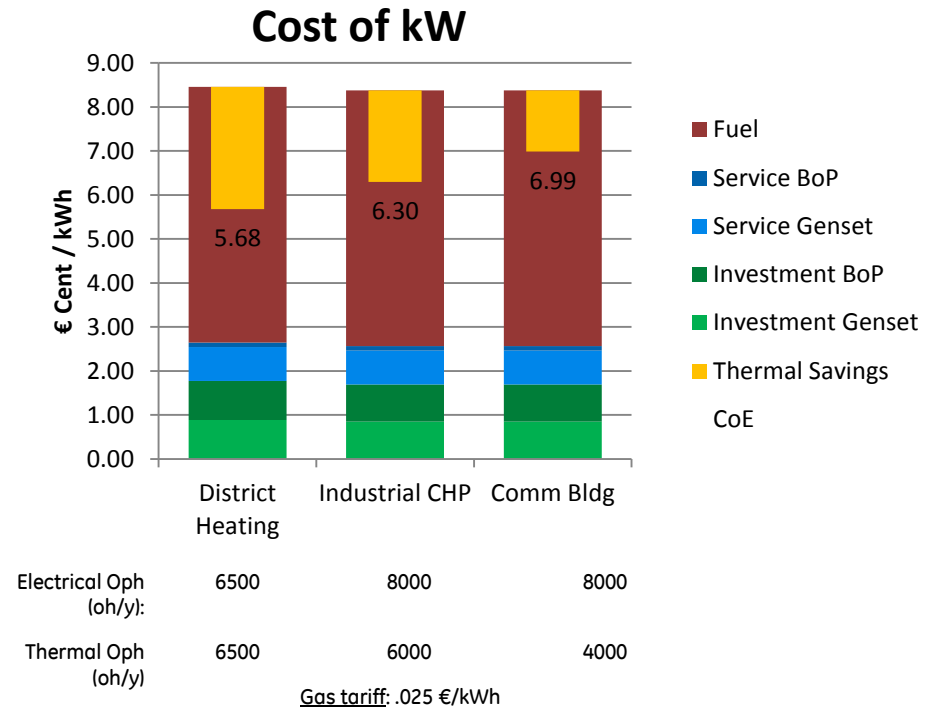
(Utilities, Municipal Utilities)

2) Industries

(Textile, Chemical, Food, Beverage,...)

3) Commercial Buildings

(Hospitals, Airports, Shopping Malls, Universities, Hotels)



Gas cost/efficiency and heat utilization drive CoE

Helping Coca Cola to reduce CO₂-emissions

Coca-Cola Hellenic Bottling plants throughout Europe use GE's Jenbacher CHP engines, reducing operational costs and eliminating up to 40% of their annual emissions. For instance, in Coca Cola Hellenic's Romania bottling facility two J620 engines are supplying a total of 6 MW.



Biogas

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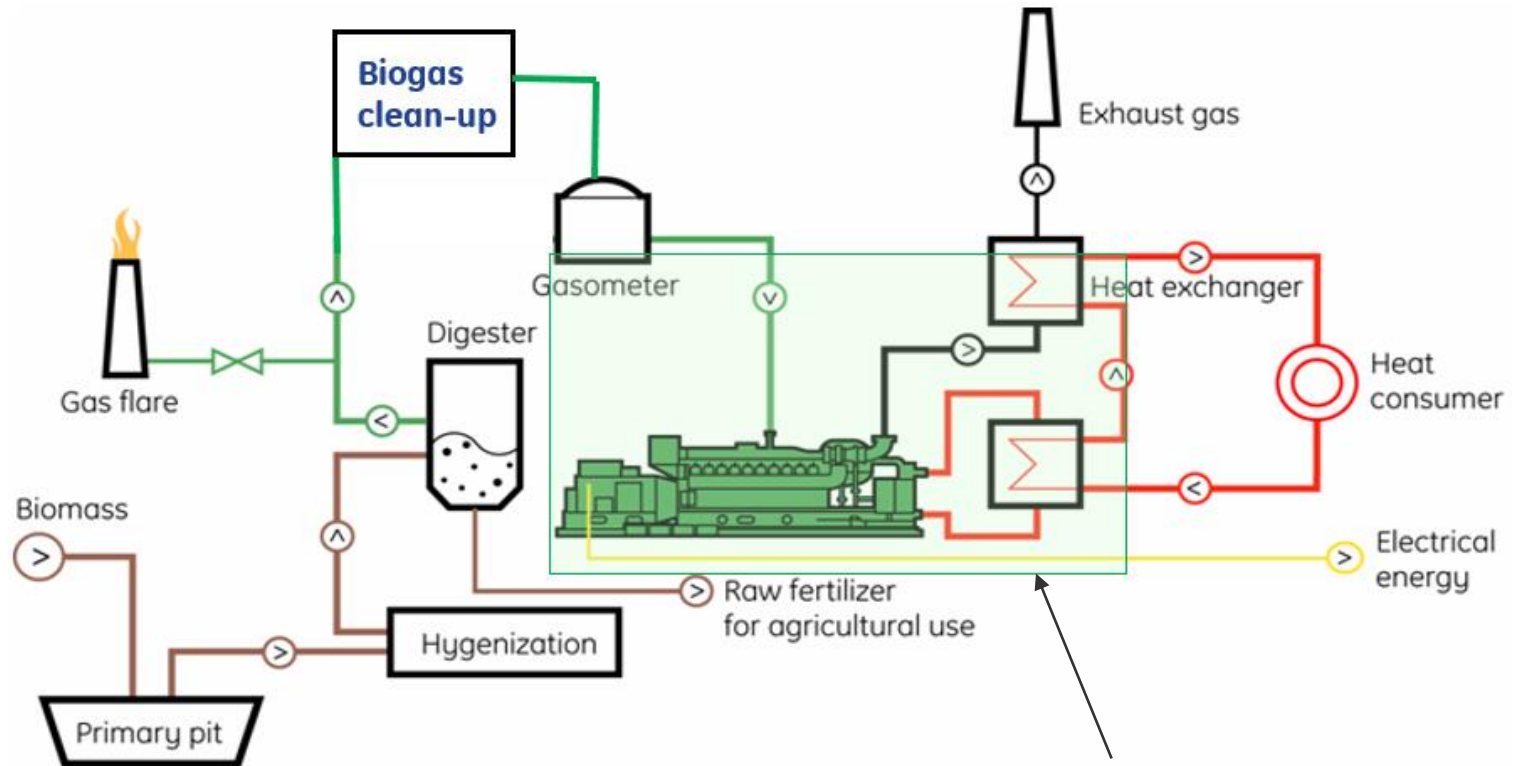


- > 4,290 Jenbacher biogas engines >3,000 MW worldwide
- Anaerobic digestion produces fuel gas
- Renewable – from organic and animal waste
- 7,000 cows can power 1 MW plant



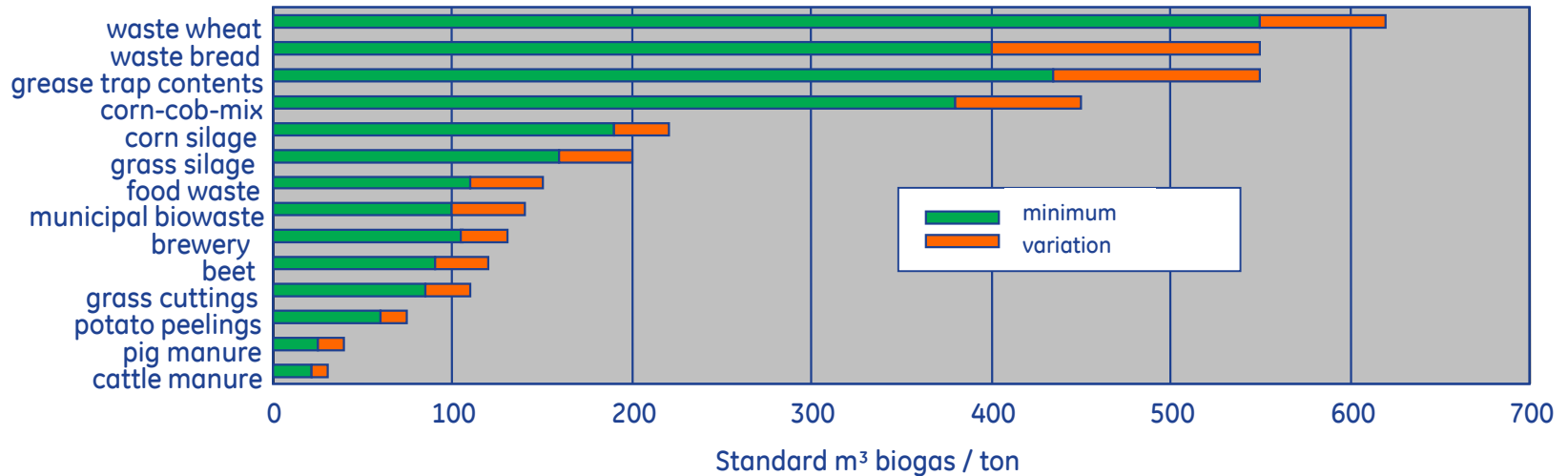
GE imagination at work

Biogas Scheme



**GE scope ~35% of total biogas plant capex:
Jenbacher engine, heat exchangers, generator**

Biogas yield of biomasses



Gas mixture composition:

- 50 – 70% methane (CH₄)
- 30 – 50% carbon dioxide (CO₂)

Dry matter concentration

- dry fermentation: 20 - 30%
- wet fermentation: 10 - 15%
- Absence of oxygen
- pH value from 6.5 to 7.5

Temperature

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

Retention time

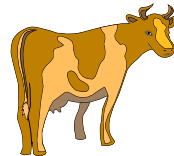
- minimum 15 days
- range: 20 - 50 days
- common: 25 - 30 days

Biogas yield of animal waste

Energy potencial

1 Live Stock Unit (LSU) = 500 kg live weight respectively

1 LSU = 0.6 - 1.2 milking cow
approx. 1.3 m³ Biogas/LSU, day
LHV = approx. 6.0 kWh/Nm³
~7,000 cows = 1 MWeI



1 LSU = 2 - 6 hogs
approx. 1.5 m³ Biogas/LSU, day
LHV = approx. 6.0 kWh/Nm³
~70,000 hogs = 1 MWeI



1 LSU = 250 - 320 layers
approx. 2 m³ Biogas/LSU, day
LHV = approx. 6.5 kWh/Nm³
~1.4 million layers = 1 MWeI



Advantages of anaerobic digestion

For the Farmer

- Improvement of manure properties: odor reduction, elimination of acid components, viscosity decrease, mineralization of organic nitrogen, reduction of pathogenic germs and weed seeds
- Additional income from heat and power production

For the Environment

- Reduction of methane and ammonia emissions from manure
- Reduction of nitrate wash-out into groundwater
- Recycling of fertilizer compounds from organic wastes
- Reduction of carbon dioxide emissions by substitution of fossil resources

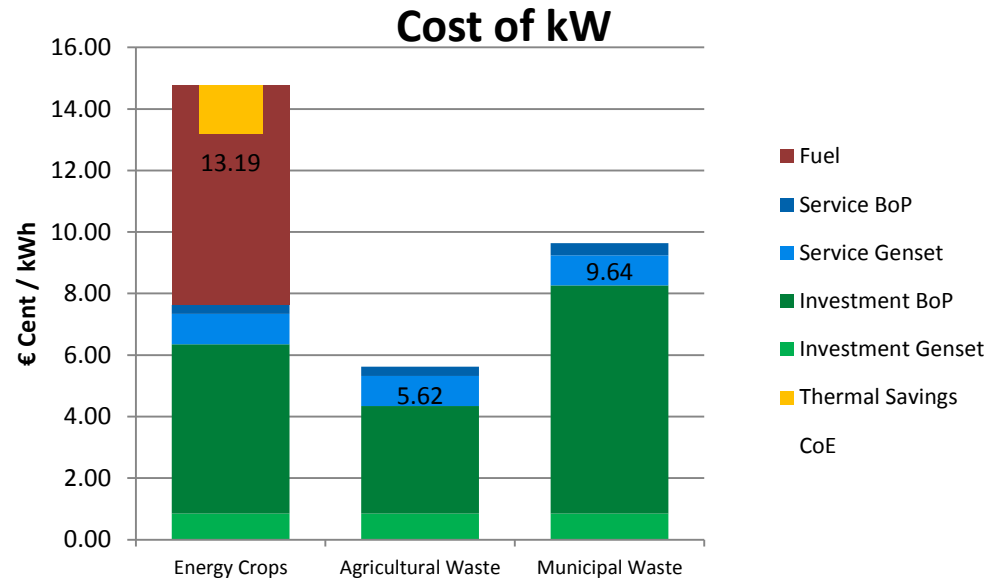
Biogas – Cost of Electricity

Segments

1) Energy Crops

2) Agricultural Waste

3) Municipal Waste



Electrical Oph (oh/y):	8000	8000	8000
Thermal Oph (oh/y)	4000	4000	4000
Gas tariff:	.03 €/kWh	Free	free



GE Jenbacher - Reliable operation on biogas

Biogas Gosdorf/AT

Achieved 8,740 out of 8,760 oph/y in 2005

99.8% Availability with Biogas

Average >98% fleet reliability at Biogas (1,000+ units)



Landfill gas



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- Jenbacher gas engines achieves > 41% electrical efficiency, 8,000 OpH
- More than 1,900 Jenbacher gas engines around the world with an electrical power of more than 1,900 MW
- By capturing landfill gas instead of emitting it directly into the atmosphere and using it for power generation in place of fossil fuels, these engines can reduce greenhouse gas emissions of about 60 million metric tons each year.



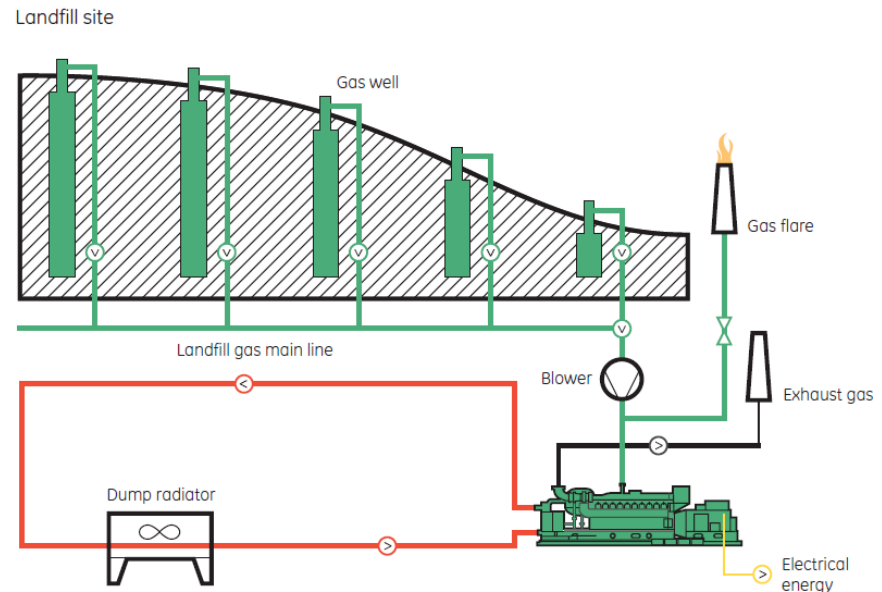
GE imagination at work

Landfill Gas Scheme

These fuel gases are produced by the conversion of liquid or solid organic substances by micro-organisms. Like associated petroleum gas, they are characterized by a medium to high methane content and the constituents N₂ and CO₂. However, as this gas emanates from highly heterogeneous substances, special care must be taken with regard to trace substances and impurities.

How does it work

Municipal waste contains about 150 to 250 kg of organic carbon per ton. These substances are biologically degradable and are converted by microorganisms into landfill gas. Stable, anaerobic methane fermentation begins one to two years after the waste is deposited in the landfill



Landfill Gas – Cost of electricity

Segments

1) Landfill gas (developed)

2) Landfill gas Undeveloped

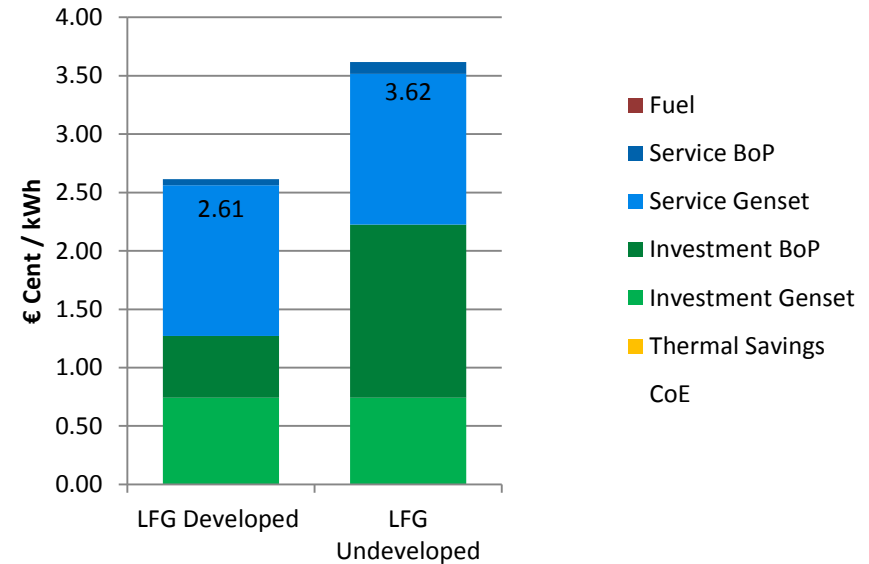
Assumptions

Electricity from Landfill gas has an approximate cost as low as 33 €/MWe if the cost to install the piping and gas collection in an existing landfill site is avoided.

If the power generation system require gas treatment, COE could increase only an additional 4%.

1 MWe requires approx. 520 Nm³/h of LFG. Equivalent to € 660.000 of investment to develop LFG site.

Cost of kW



Electrical Oph (oh/y):	8000	8000
Thermal Oph (oh/y)	0	0

Gas tariff: free

Supporting one of California's largest landfill gas-to-energy plants

An 11.5 MW landfill gas plant with six J616 of GE's Jenbacher engines located at the Ox Mountain Landfill provides renewable electricity to the San Francisco Bay region. The output of the plant is enough to provide electrical power for 7,500 to 10,000 average U.S. homes.



Coal mine gas



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Coal mine gas

- > 250 Jenbacher coal mine gas engines > 600 MWe_{el} worldwide
- Reduces greenhouse gas emissions
- 1 MW plant saves more than 30,000 tons CO₂ per year
- Degasification improves mine safety

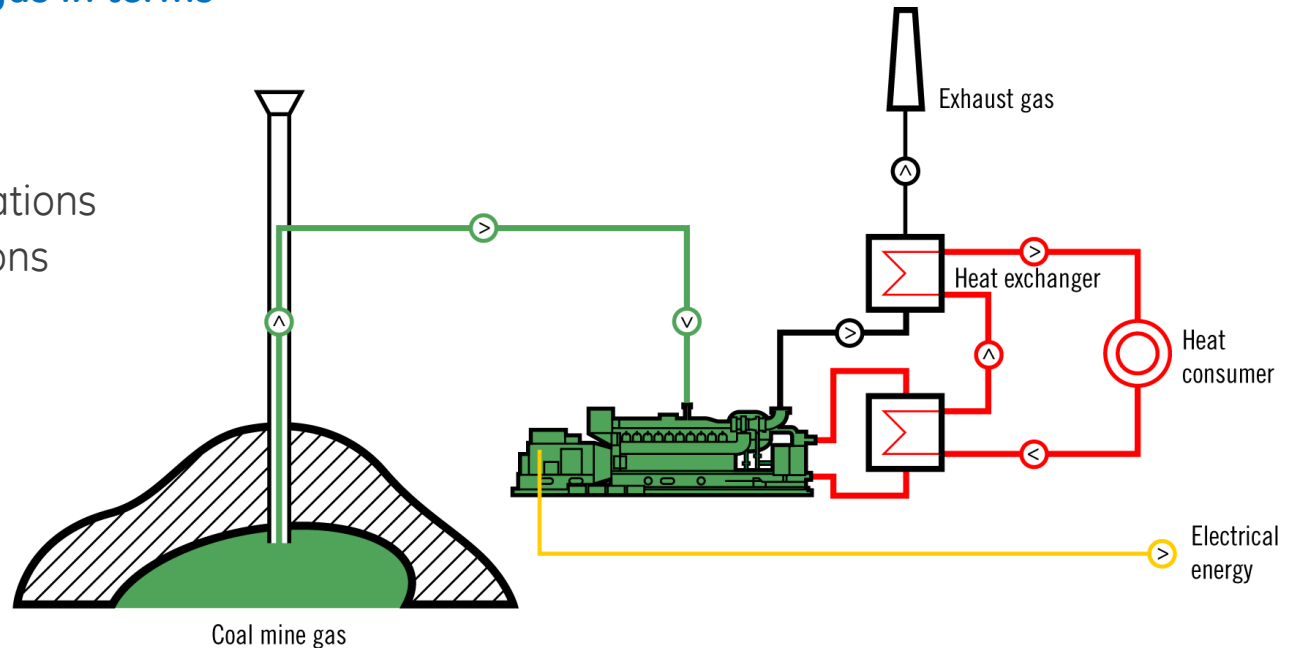


GE imagination at work

Coal mine Scheme

Similar to natural gas in terms of combustion but

- gas contaminations
- gas humidity
- gas pressure fluctuations
- Quick CH₄-fluctuations



Fuel cost and net efficiency drive COE



GE imagination at work

Coal mine gas – Cost of Electricity

Segments

1) CMM from active mines

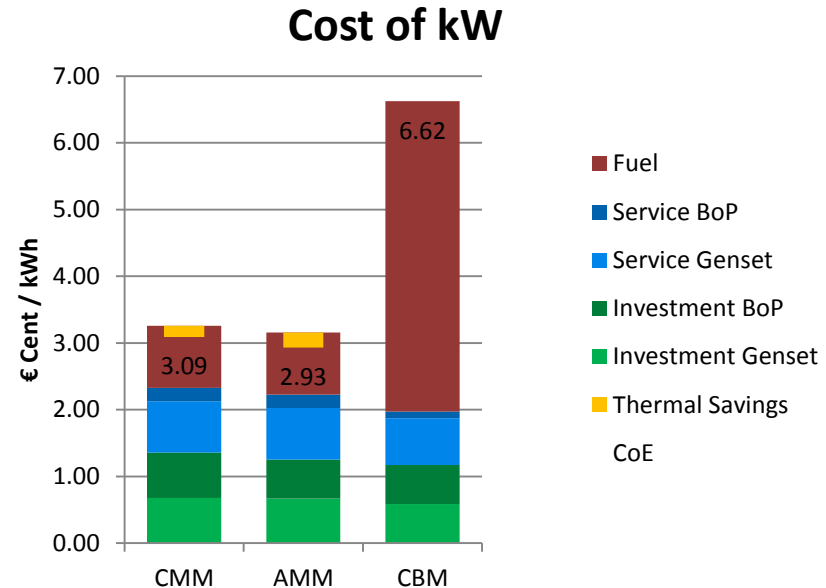
Coal Mine Methane
Local Mines, International Utilities,
Authorities, Carbon Developers

2) AMM from abandoned mines

Abandoned Mine Methane
Gas Right Owners, Local Utilities, EPCs

3) CBM from virgin coal seams

Coalbed Methane
International CBM Developers, EPCs



Electrical Oph (oh/y):	8000	8000	8000
Thermal Oph (oh/y)	3000	4000	0
Gas tariff €/kWh :	.004	.004	.02

Greenhouse gas reduction & mine safety drive business



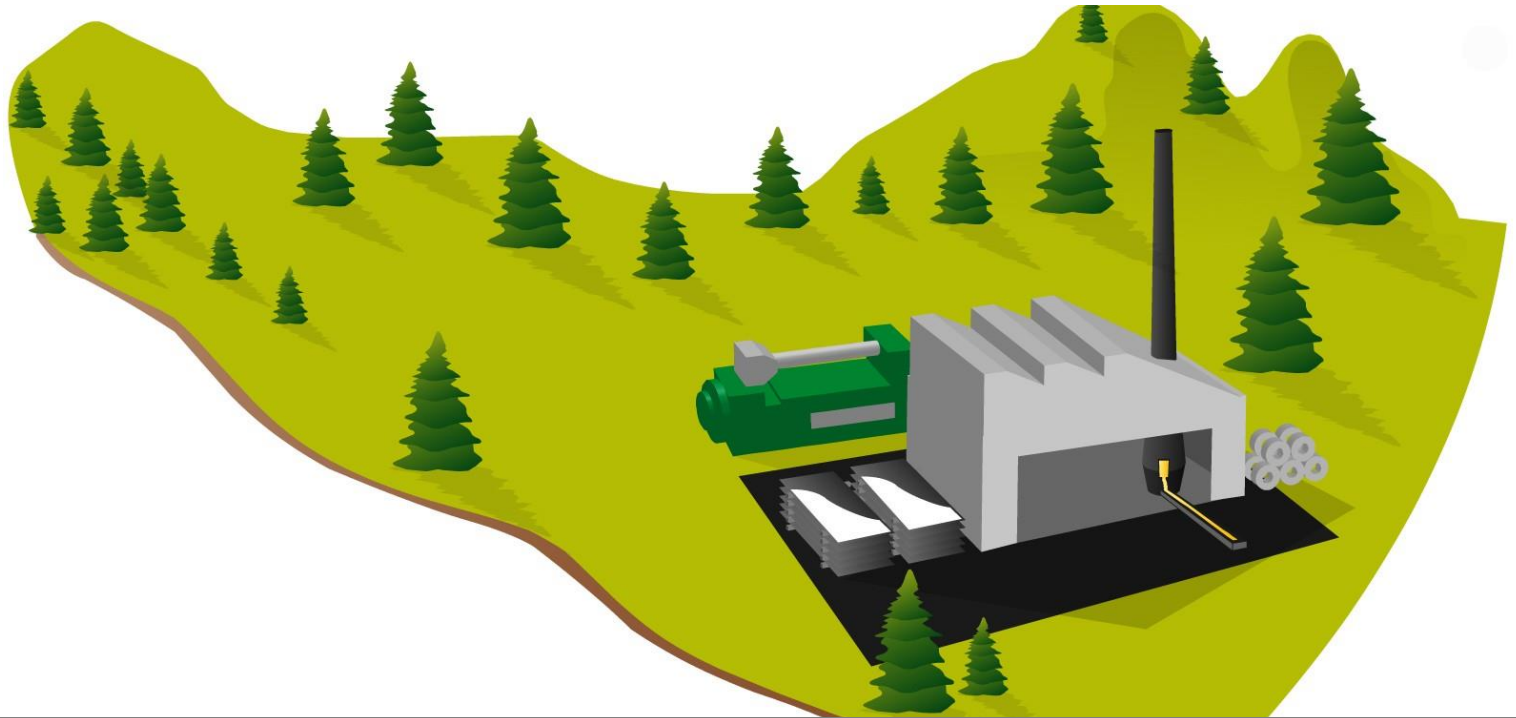
GE imagination at work

Helping to reduce the environmental impact of Australia's coal mines



A 45.6 MW alternative energy plant is located at Anglo Coal's Moranbah North mine saving 1.3 million tons of CO₂ equivalent per year – or the average of taking 330,000 cars off the road.

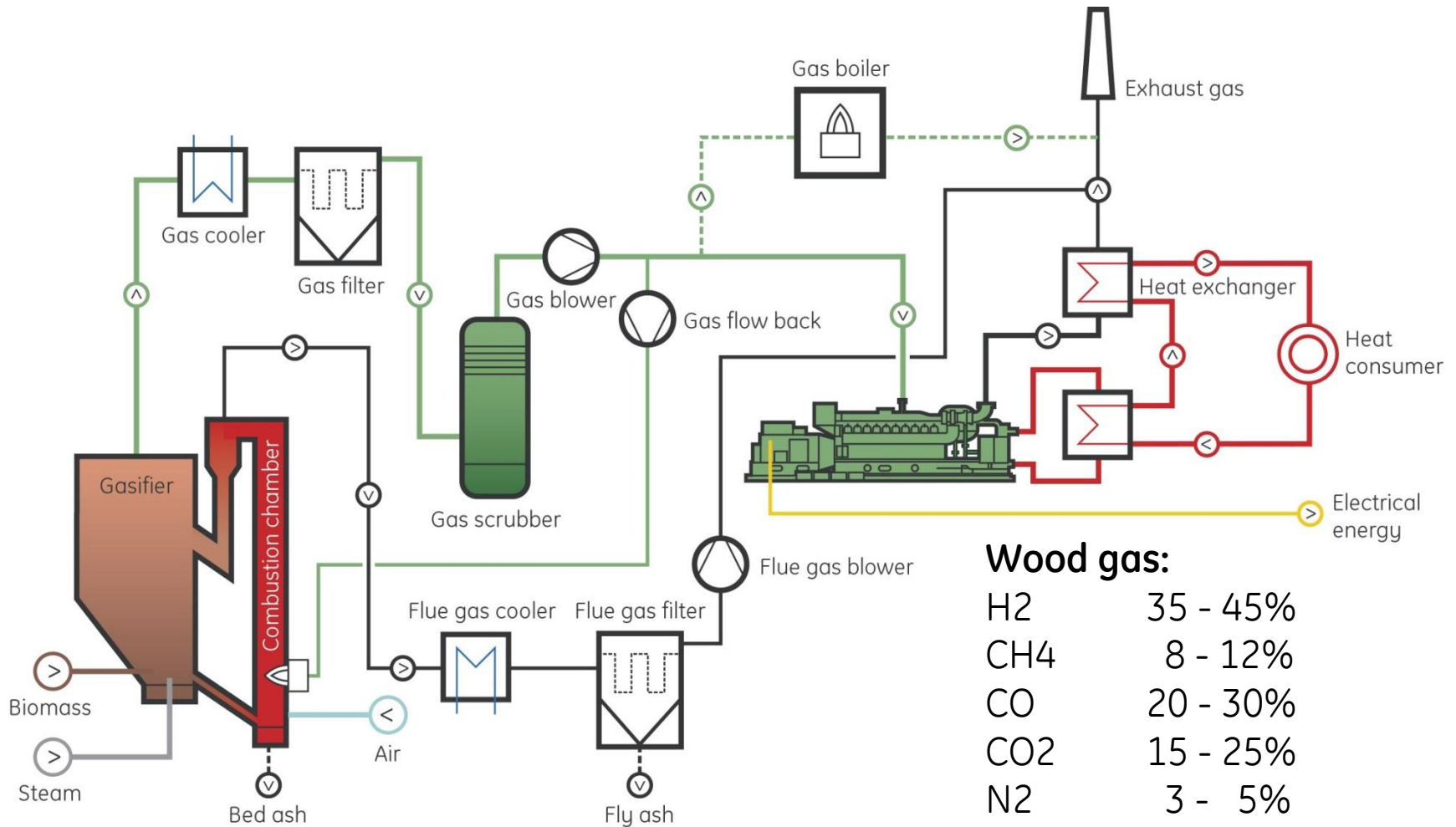
Special Gas



- Industrial waste gases
 - Power produced from steel and chemical industry waste gases
 - Industries become more energy efficient
- Synthetic gases from gasification
 - Highly efficient power generation with biomass and waste gasification



Wood gas application



Wood gas:

H₂ 35 - 45%

CH₄ 8 - 12%

CO 20 - 30%

CO₂ 15 - 25%

N₂ 3 - 5%

LHV = 3 - 3.5 kWh/m³N

Wood gas – Cost of Electricity

Segments

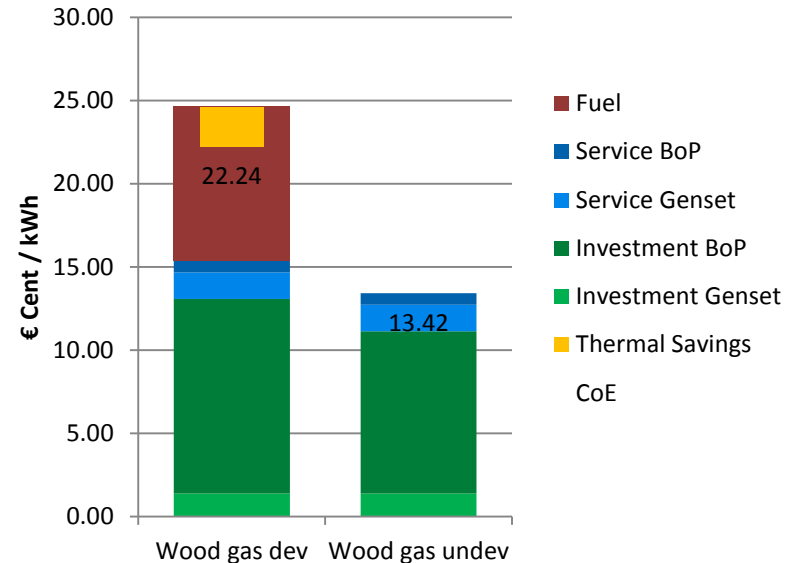
1) Wood Gas developed in Europe (CHP)

- High sophisticated approach
- Significant incentives needed
- District heating

2) Wood Gas in Undeveloped/Developing countries

- Power generation for rural areas
- Low tech approach
- Manual operation

Cost of kW



Electrical Oph (oh/y):	7200	7200
Thermal Oph (oh/y)	4000	4000
Fuel cost (€/kWh):	.035	Free

Capex drive high CoE
Strong incentive scheme required

Highly efficient power generation with special gas



The efficient combustion of wood gas requires highly sophisticated gas engines. One J620 engine provide power and heat at the wood gas plant in the town of Güssing, Austria.

Steel gas – Cost of Electricity

Segments

1) Blast Furnace Gas

Steel industry (integrated steel plant)

2) Coke gas

Coke industry or steel industry (integrated steel plant)

3) LDG

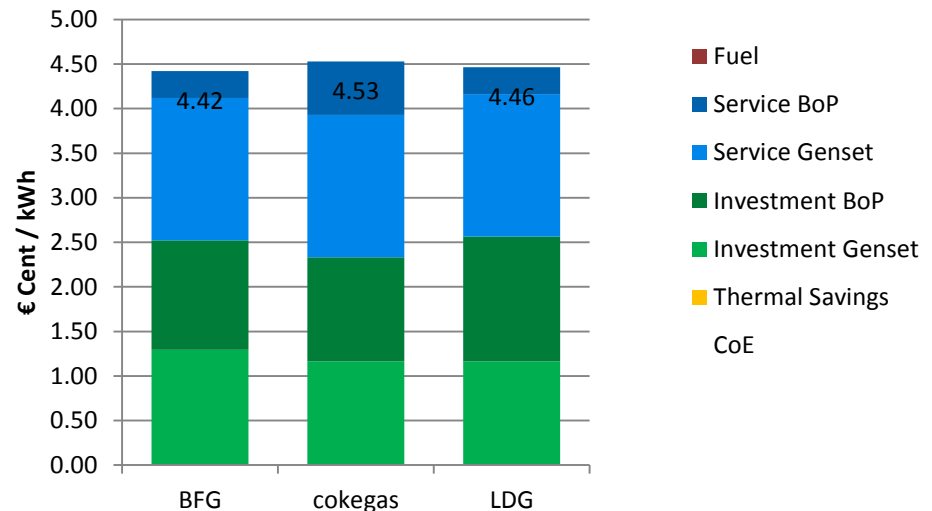
Converter Gas

Steel industry

Furnace Off Gas

Non ferrous metals industry (FeCr; FeMn; FeTi;.....)

Cost of kW




Electrical Oph (oh/y):	8000	8000	8000
Thermal Oph (oh/y)	4000	4000	4000

Gas tariff: free

Capex/opex for gas cleaning could be high



Sophisticated, customer oriented solutions for the steel industry



GE provides highly developed Jenbacher gas engine technology for efficient power generation with coke gas, blast furnace gas and converter gas. The Arcelor Mittal steel factory in Avilés, Spain operates 12 J620 Jenbacher gas engines, using LD converter gas.



Sewage gas

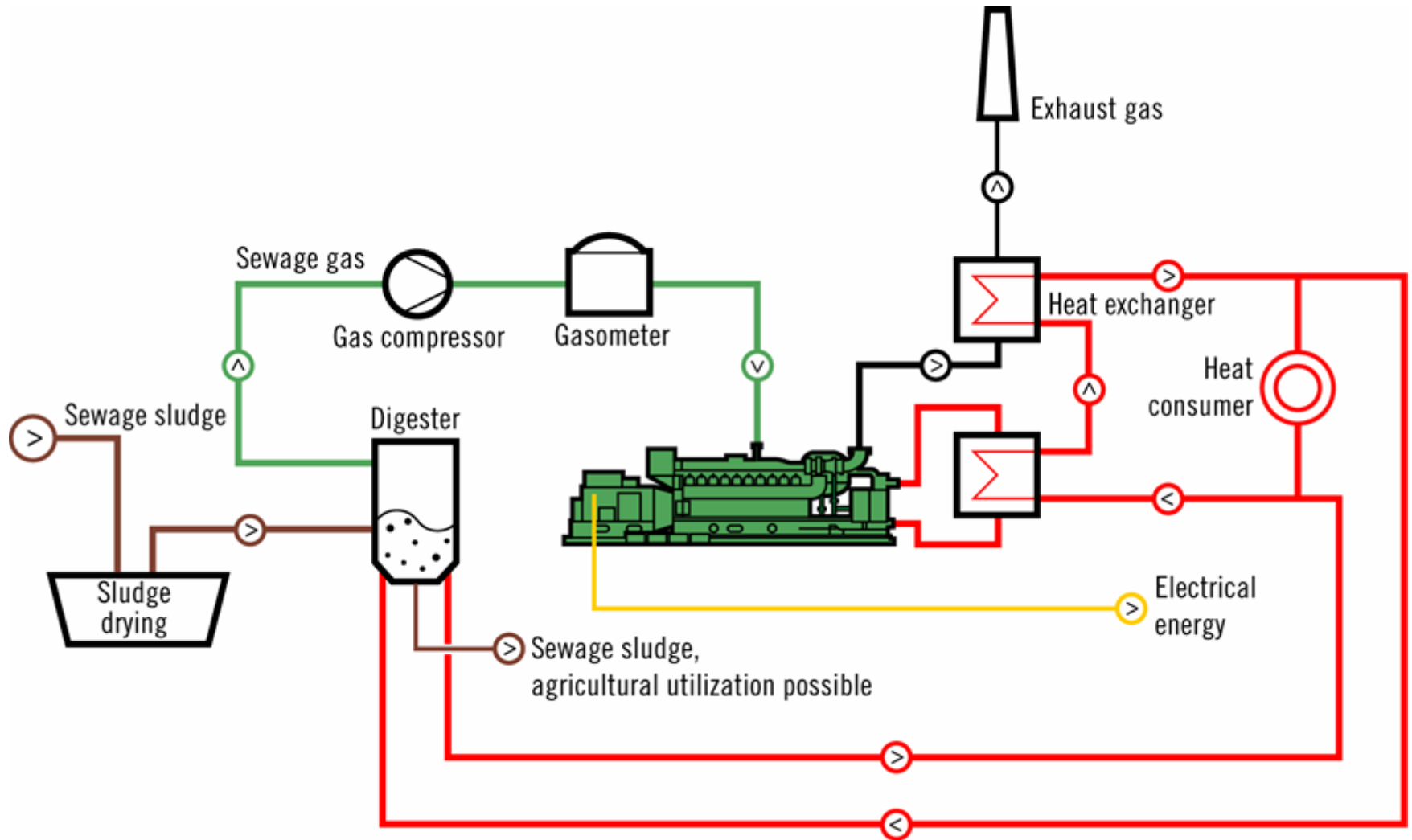


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- > 600 Jenbacher sewage gas engines > 450 MW worldwide
- Sewage fermentation produces fuel gas
- Waste water from city of half a million powers 1 MW plant
- Covers up to 100% of energy needed for sewage plant



Sewage Gas - Scheme



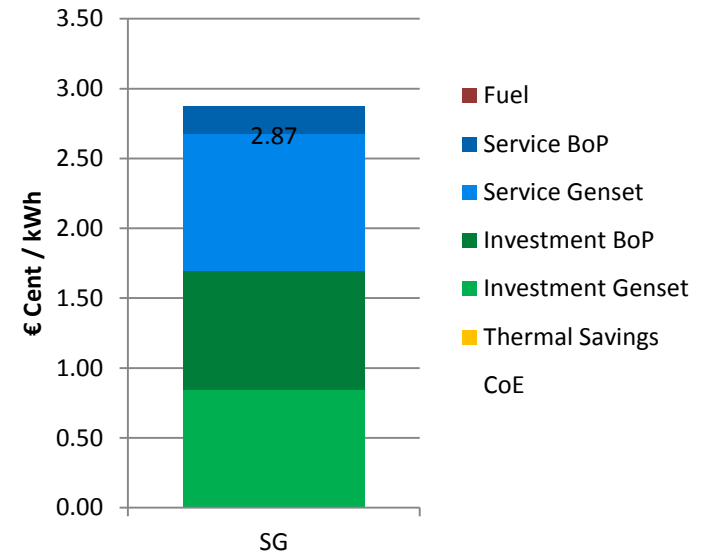
Sewage gas – Cost of Electricity

Applications:

1) Municipal WWTP:

Municipalities, Utilities, specialized EPCs
500,000 inhabitants approx. 1MWeI

Cost of kW

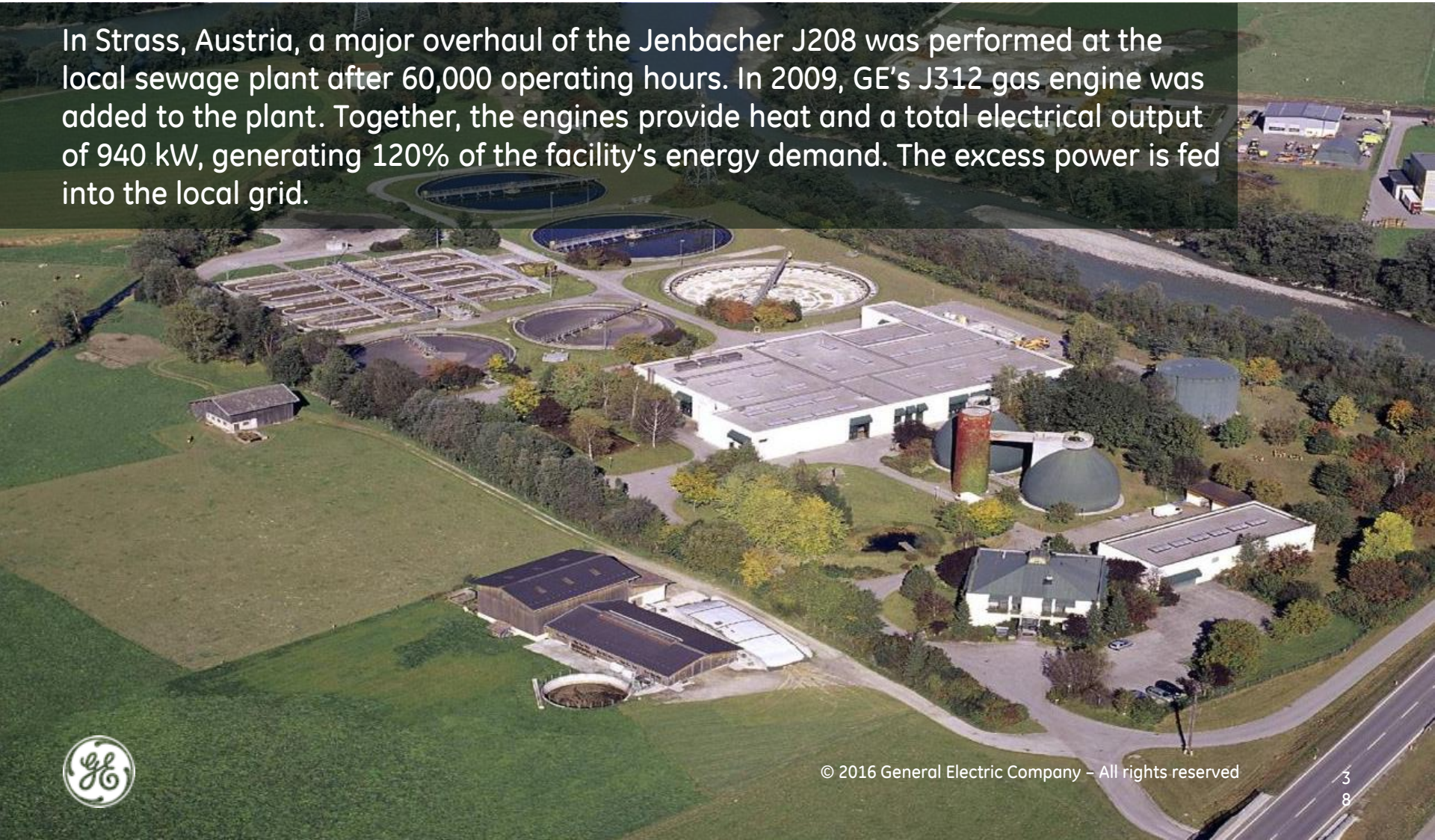


Electrical Oph (oh/y):	8000
Thermal Oph (oh/y)	4000
Gas tariff:	Free

Anaerobic vs. aerobic fermentation decisive

Maximum power with wastewater

In Strass, Austria, a major overhaul of the Jenbacher J208 was performed at the local sewage plant after 60,000 operating hours. In 2009, GE's J312 gas engine was added to the plant. Together, the engines provide heat and a total electrical output of 940 kW, generating 120% of the facility's energy demand. The excess power is fed into the local grid.



Greenhouse applications

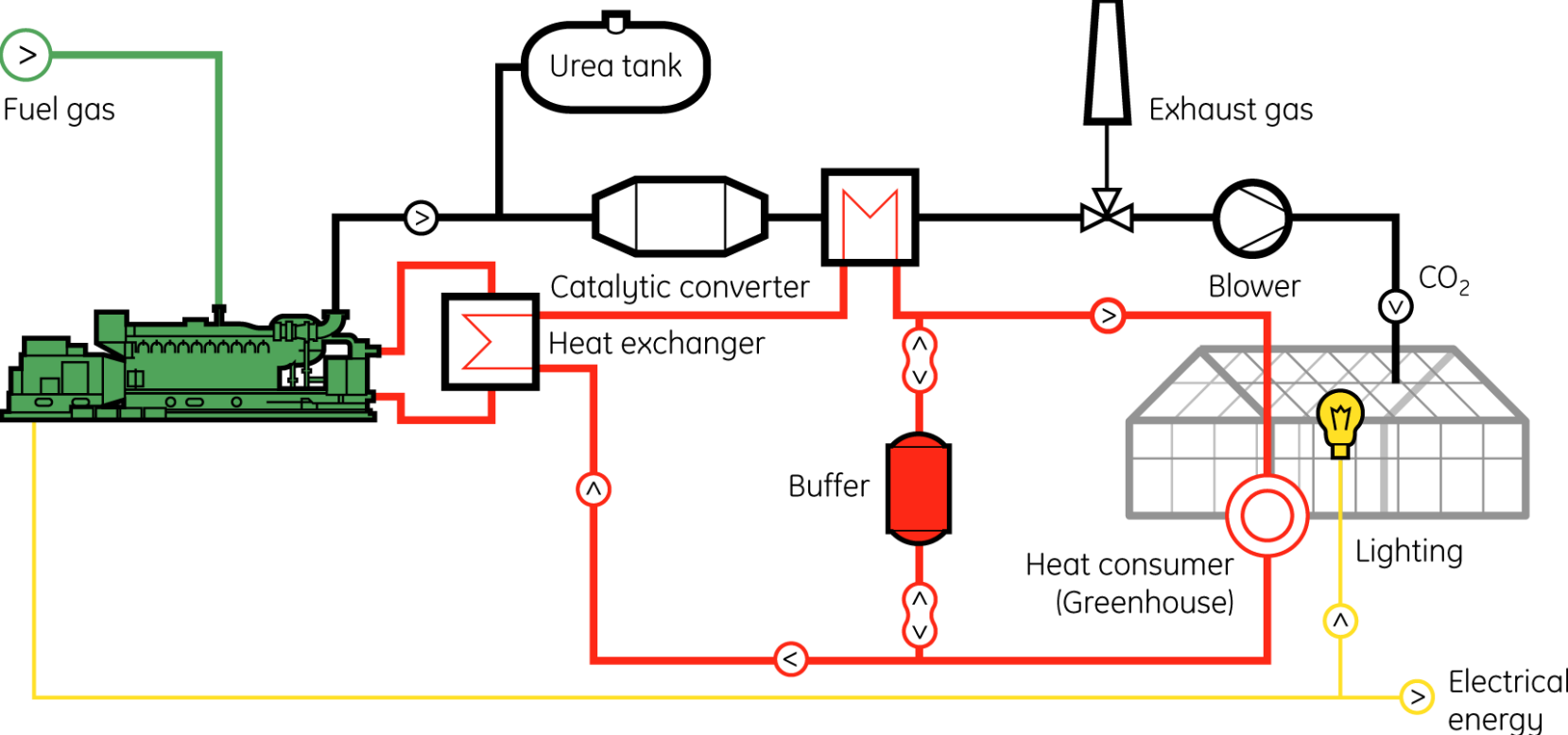


About 1,200 Jenbacher CO₂ fertilization plants with an electrical output of more than 2,400 MW worldwide

- Powers grow lights
- Provides heat for greenhouses
- Purified exhaust used as fertilizer



Greenhouse Fertilization



Greenhouse – Cost of Electricity

Segments

1) Greenhouse with CO₂ fertilization

Growers or investors

Other financial benefits:

Increase of crop (production, quality)

Less illness and damage, Increased CO₂ level

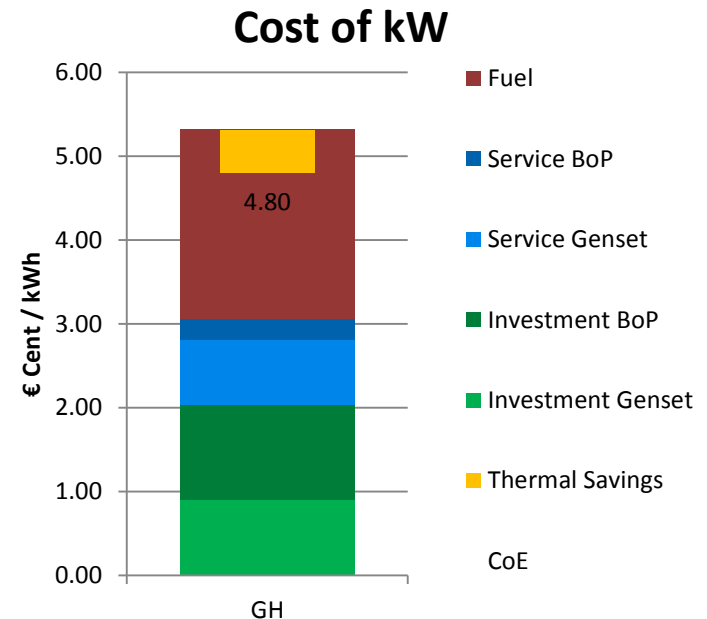
Timing of harvest (setting)

Price deviation throughout the year

Minimize the amount of pesticides

Prevent bugs from coming in, and bees from flying out

Lower energy cost

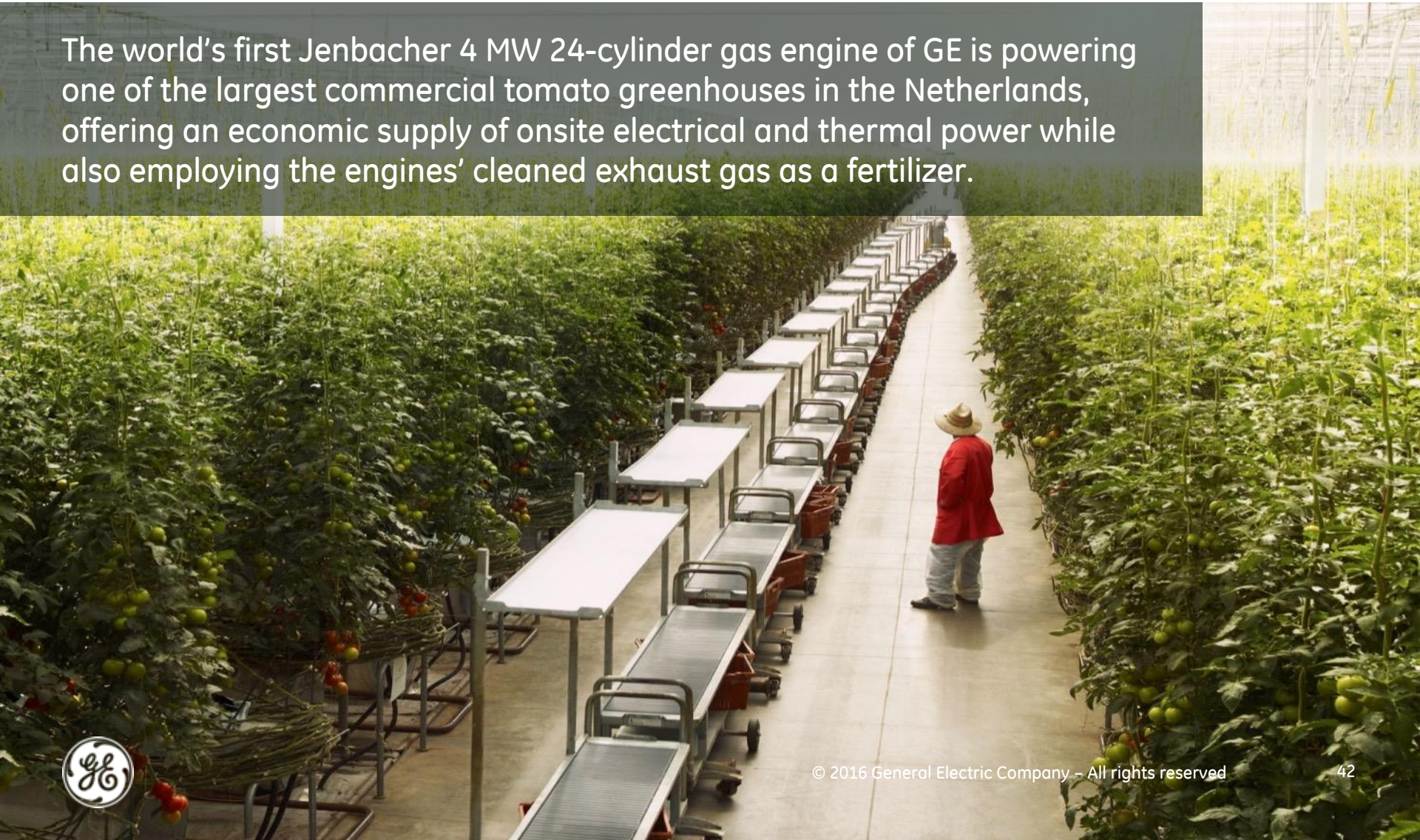


Electrical Oph (oh/y):	6000
Thermal Oph (oh/y)	2500
Gas tariff (€/KWh):	.01

**Flexible & highly efficient power, high CO₂/heat ratio
100% load in island with light control**

Driving innovation: the world's first 24-cylinder gas engine

The world's first Jenbacher 4 MW 24-cylinder gas engine of GE is powering one of the largest commercial tomato greenhouses in the Netherlands, offering an economic supply of onsite electrical and thermal power while also employing the engines' cleaned exhaust gas as a fertilizer.



Flare gas

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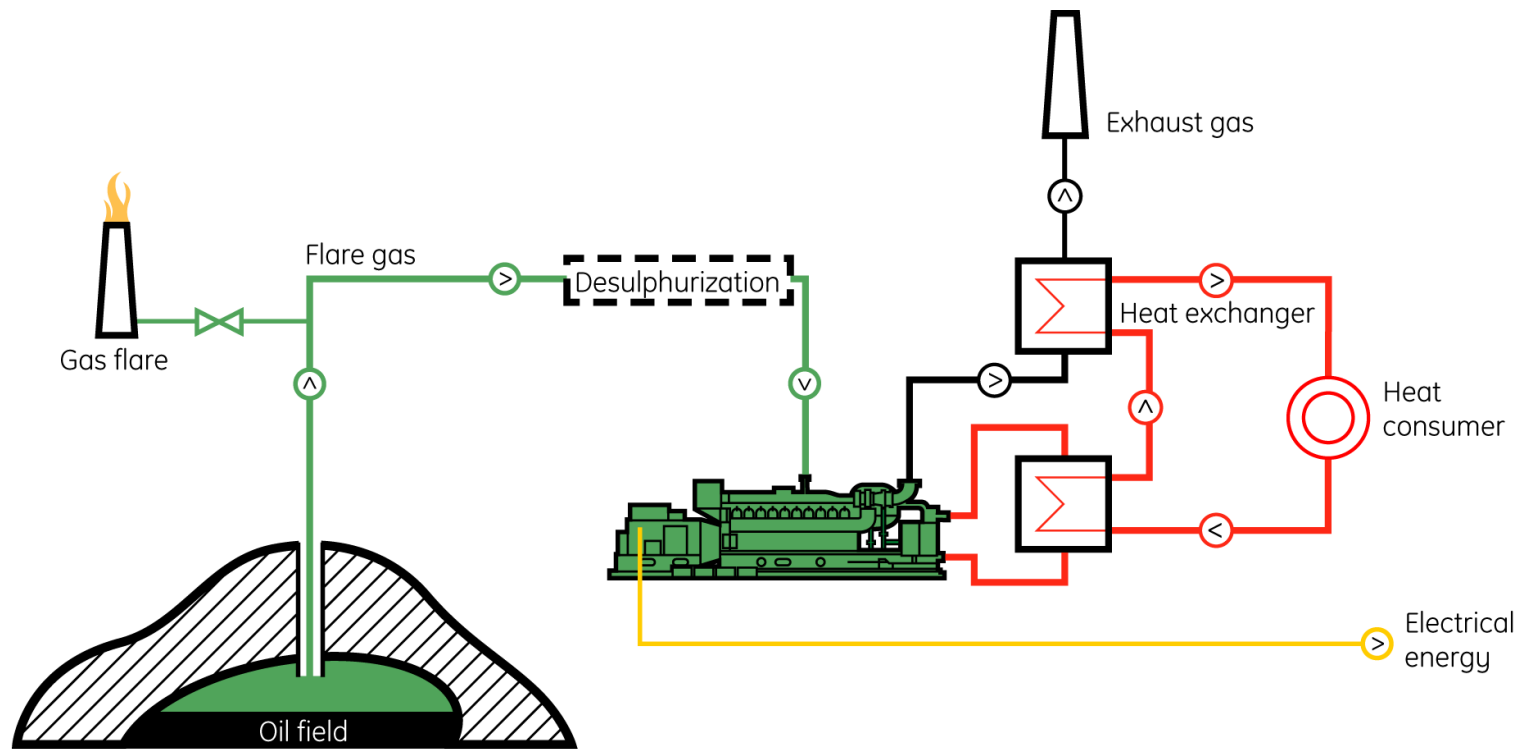


- > 330 Jenbacher gas engines > 450 MWel worldwide
- 150 billion m³ gas flared per year
- Equals annual natural gas demand of France and Germany
- Substitutes diesel oil for power generation and avoids transportation costs
- 1 MW plant saves 2 million liters of diesel per year



GE imagination at work

Flare gas Scheme



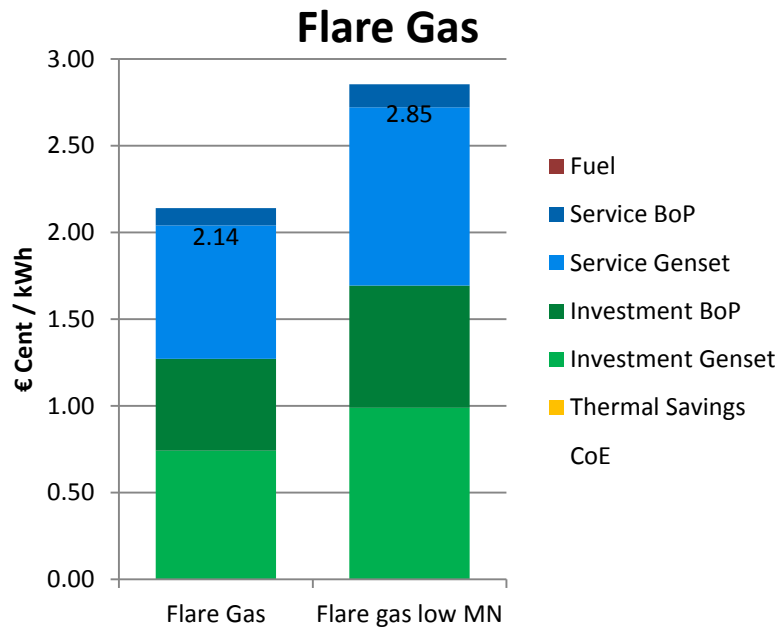
GE imagination at work

Flare Gas – Cost of Electricity

Segments

1) Flare gas

Petroleum production.



Electrical Oph (oh/y):	8000	8000
Thermal Oph (oh/y)	4000	4000
Gas tariff:	Free	Free

Penalties drive implementation

GE's 30 MW power plant supports energy demand of oil field production

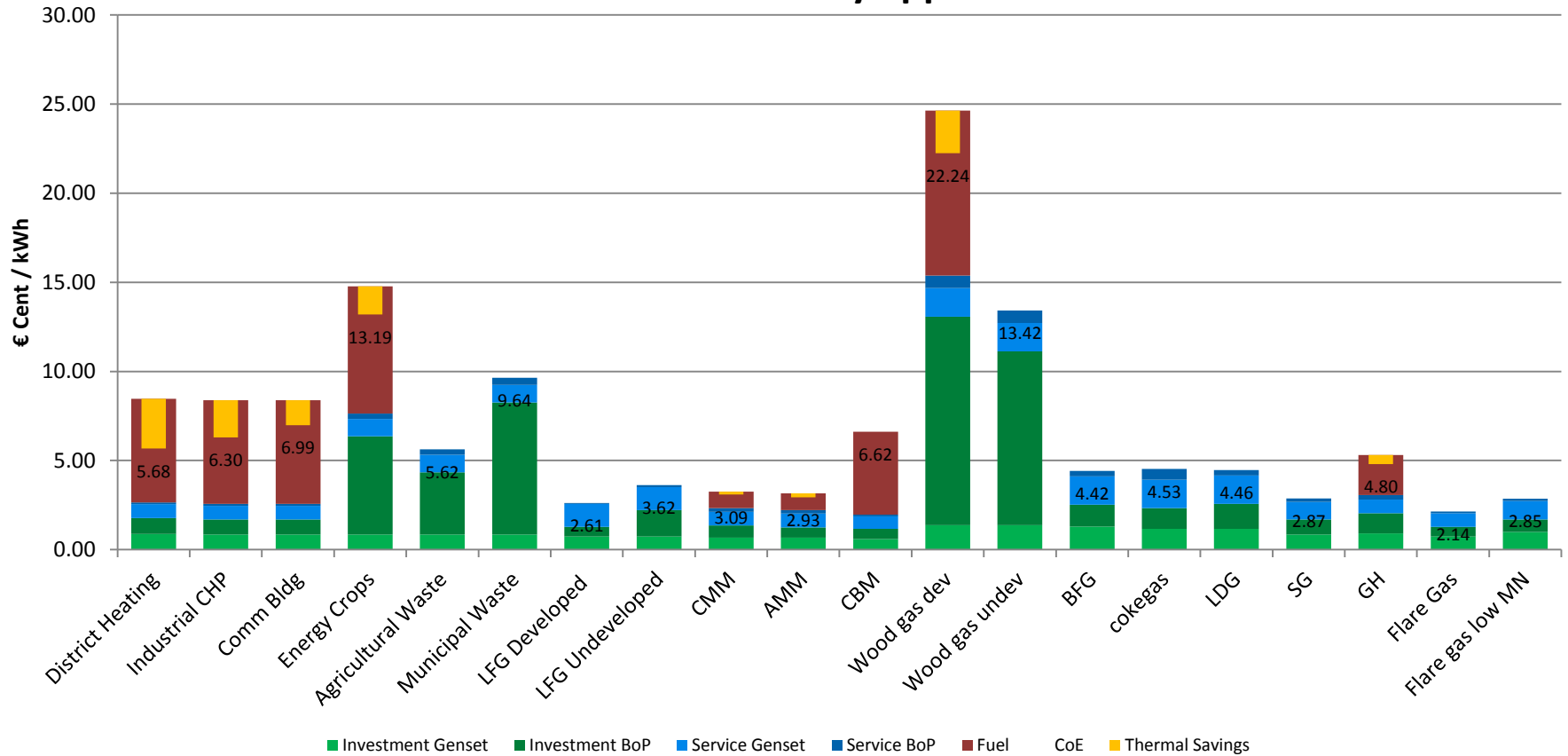


In Southwestern Argentina, 20 of GE's Jenbacher gas engines are fueled by untreated associated gas from the oil and gas fields. The 30 MW power plant provides a reliable electricity supply to overcome the country's energy shortages.



CoE Comparison

Cost of kW by applications



Multiple values for our customers

Fuel flexibility

- Natural gas
- Renewable gases
- Waste gases and special gases
- Associated petroleum gas
- Diesel

Top efficiency and service

- Electrical efficiency up to 49.9%
- Overall efficiency: >90%
- High power density
- Extended service intervals
- Low life cycle costs

Environmental benefits

- Low emissions (NO_x, CO, SO_x, etc.)
- Ability to reduce CO₂ footprint:
 - Use of renewable gases
 - High overall efficiency

Durability and reliability

- Established, field-tested designs
- Optimized, robust engine components
- Stationary engine concept
- Maximum operational safety and availability
- Proven control and monitoring concept
- Continuous focus on product development



Multi-year agreements

Improve your performance at lower cost

- Collaboration with you to achieve your business goals
- A service agreement tailored to complement your capabilities: maintenance coverage, performance guarantee, operation support
- GE expertise and operations excellence at your service



Meeting customer needs through digital-industrial solutions



Business optimization	Market intelligence and forecasting		Portfolio optimization		Fuel nominations		Financial settlement		
Operations optimization	Performance metrics	Station optimization	Outage management	Fuel supply management	Financial planning and reporting	Regulatory compliance			
Asset performance	Machine and equipment health			Diagnostics and response			Maintenance optimization		
CIO	Predix* platform								
	Cyber security		Mobility		Controls/sensor		IT integration		Digital twin

A SINGLE PANE of glass and source of truth to improve customer assets, stations, and fleet



* Trademark of General Electric Company.

Our customer's success determines our future.

We are dedicated to delivering innovative, custom-tailored solutions designed to meet our customers' specific power Generation and mechanical drive needs.

