Gas Engies

2022

Gas Engines

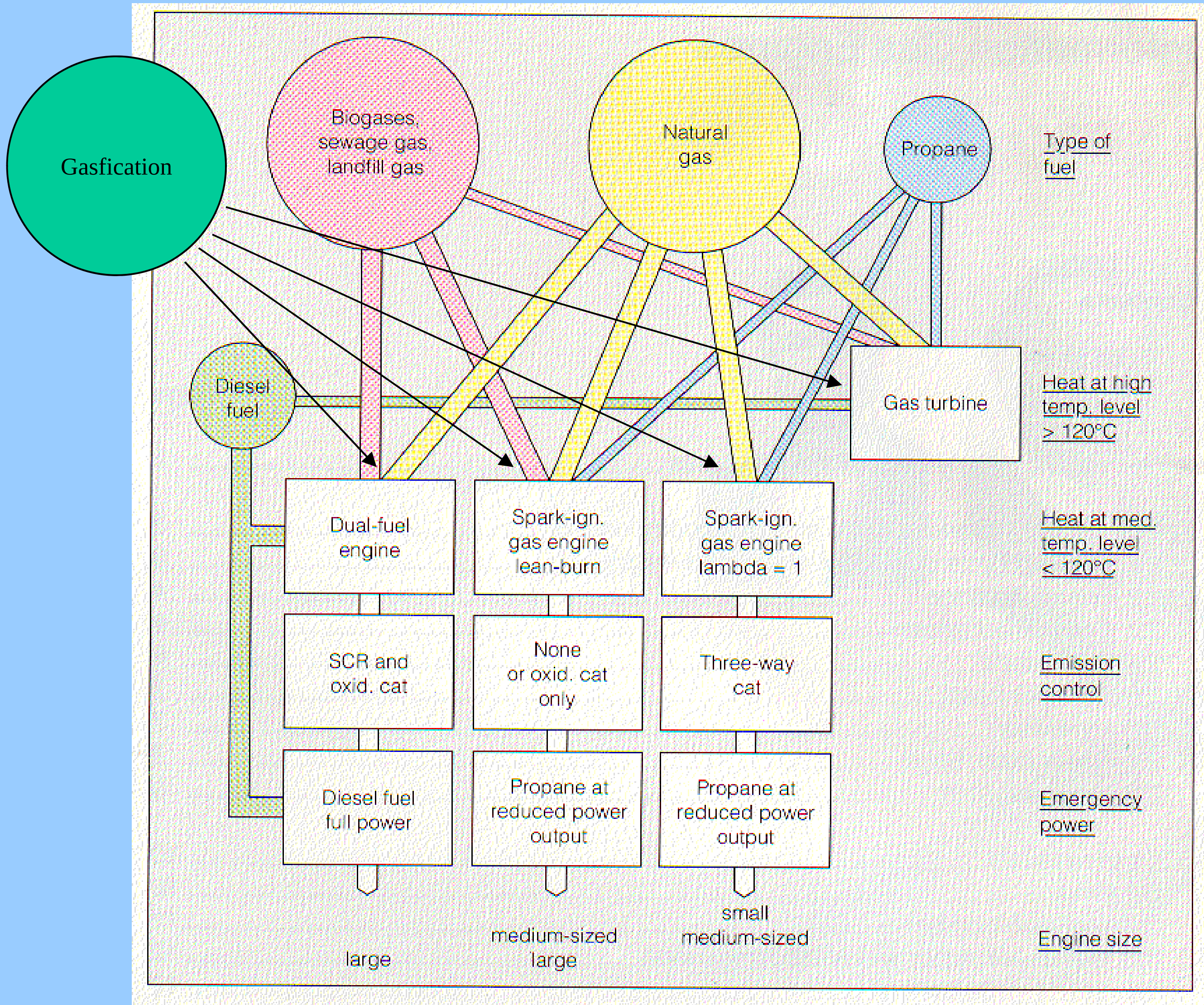
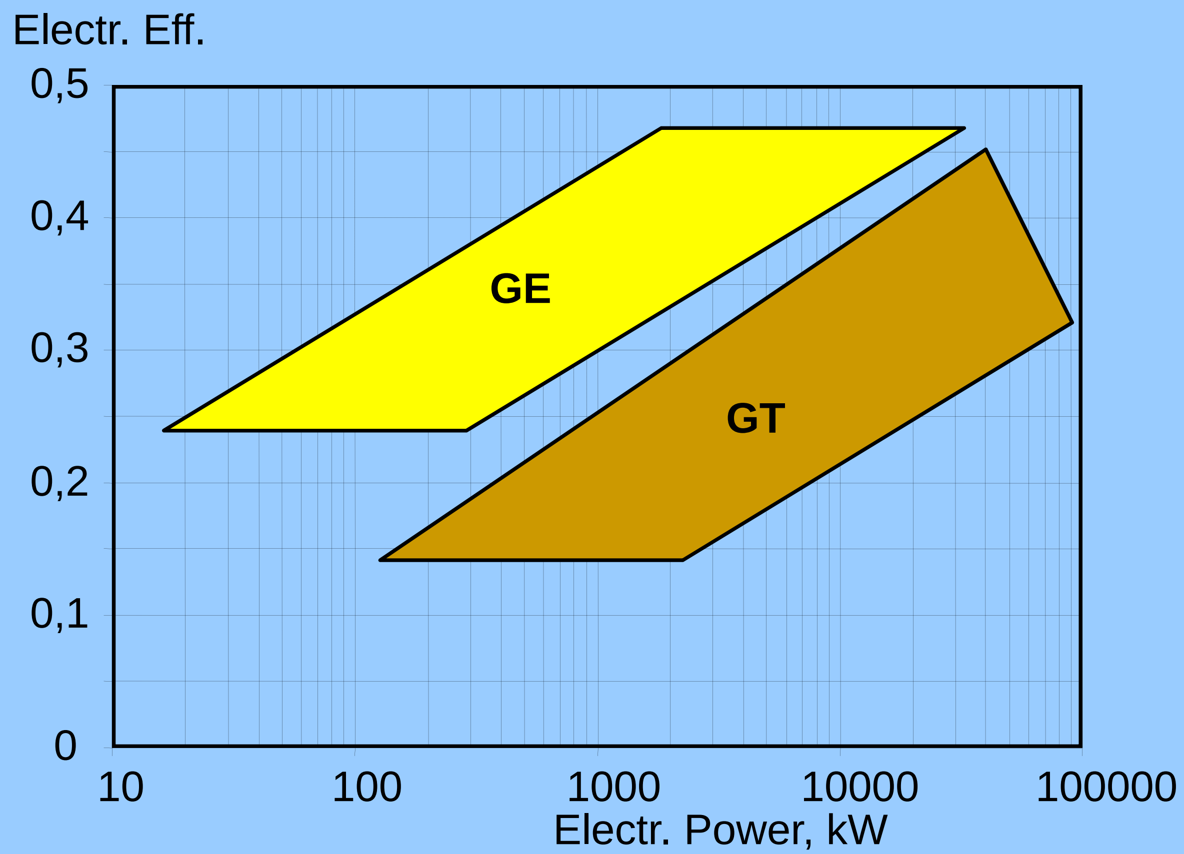


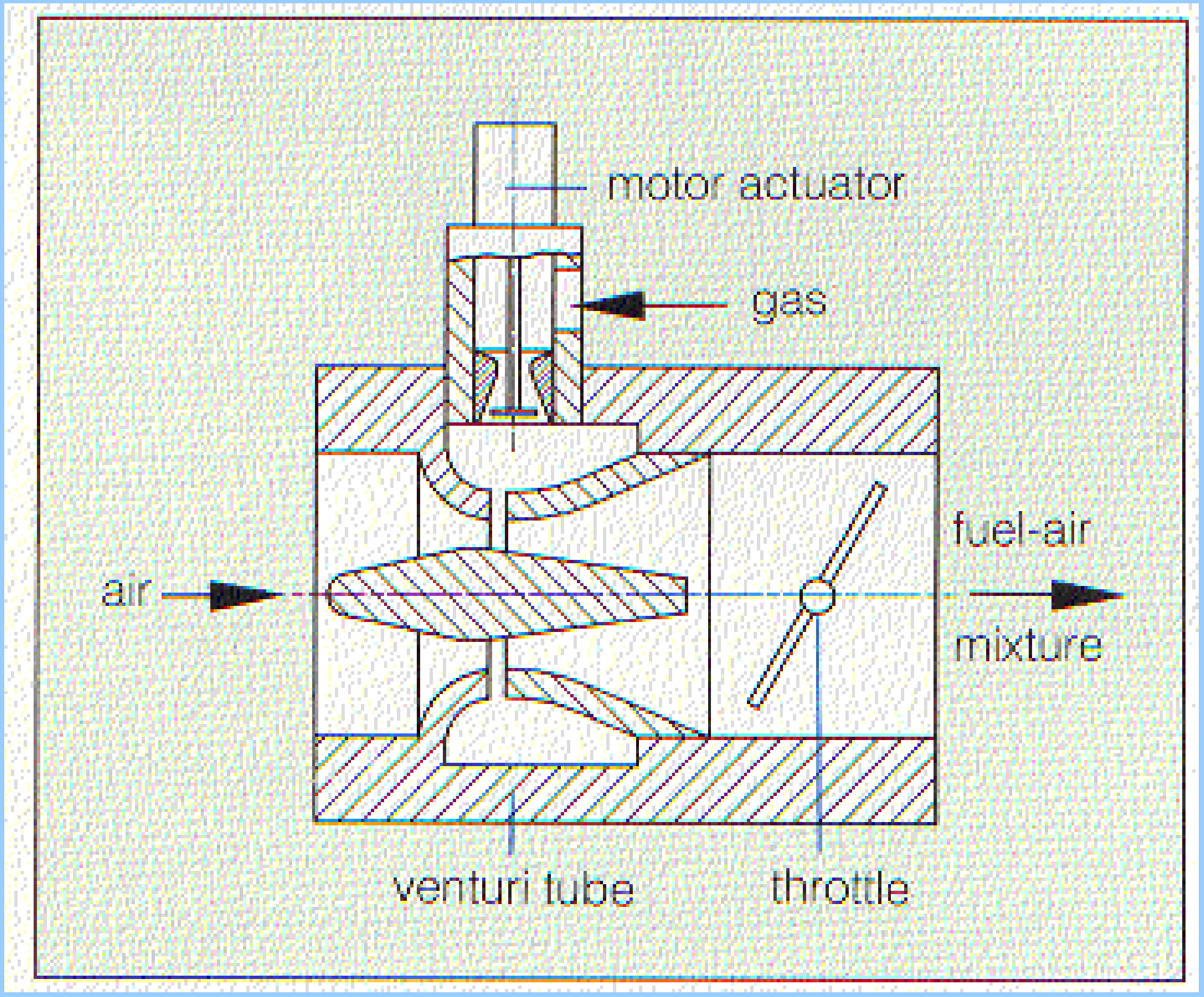
Fig. 1 Chart – Gas engine options

Source: DEUTZ

Gas Engines / Gas Turbine

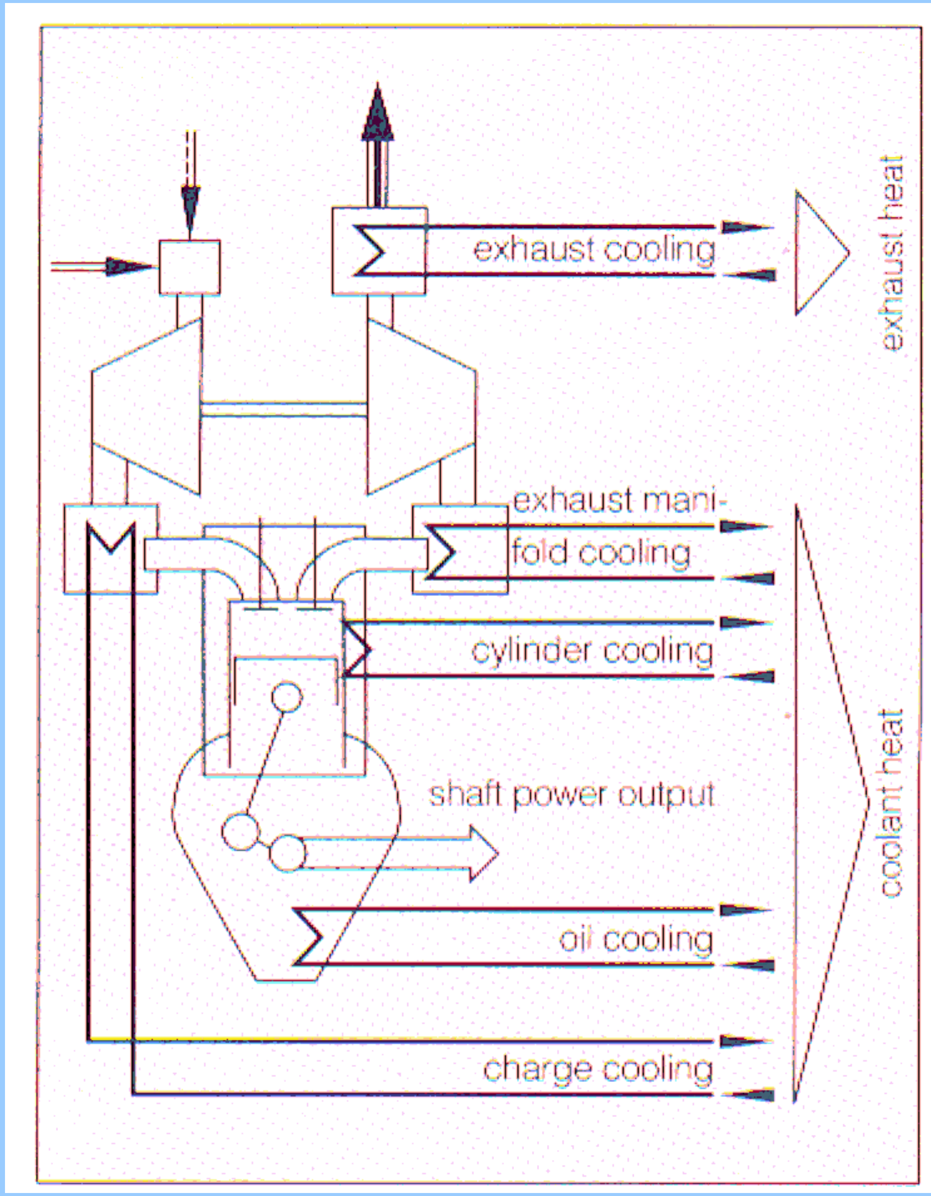


Fuel (gas) – Air mixer



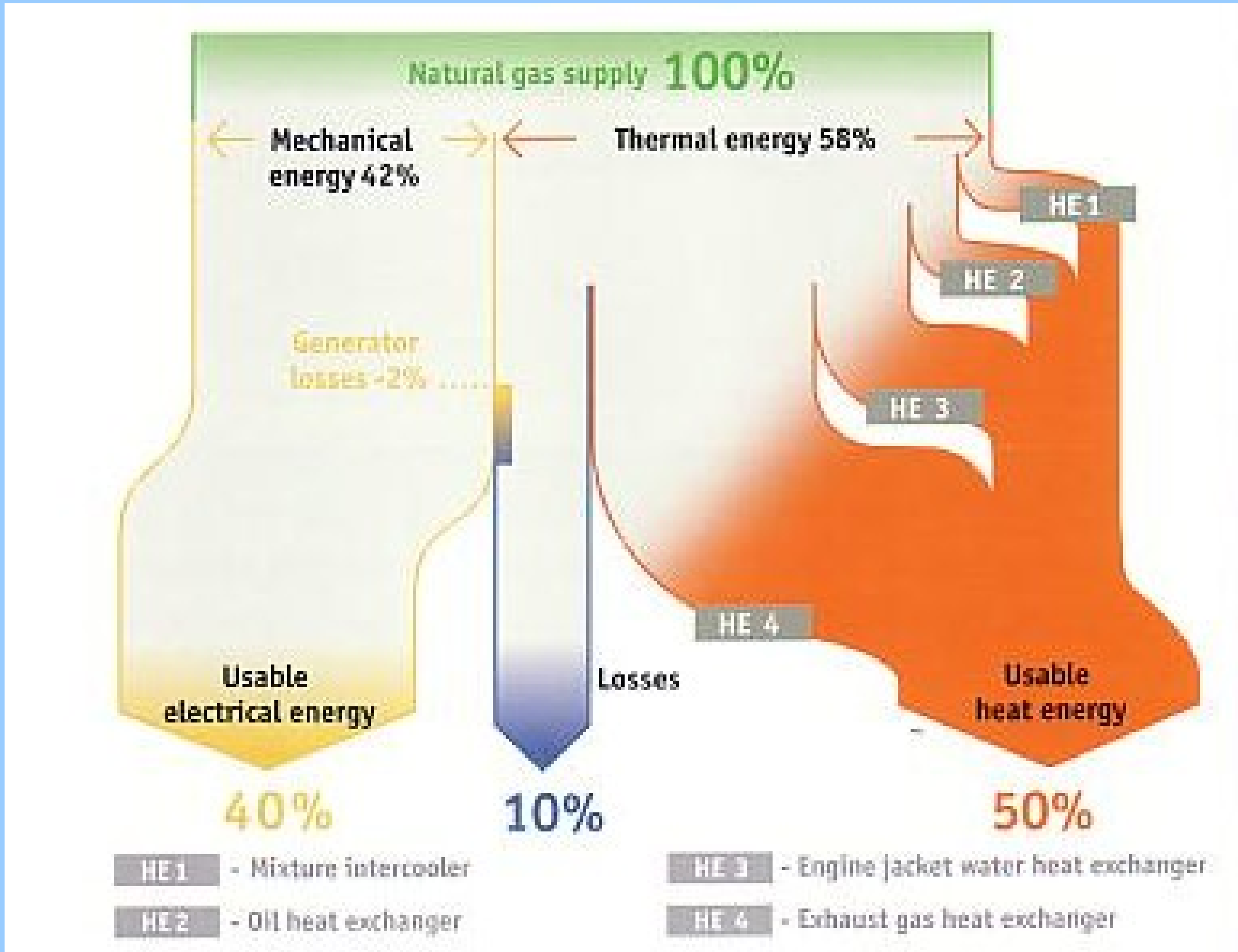
Source: DEUTZ

Heat Flows of Gas Engines



Forrás:DEUTZ

Heat Balance-1



Source: Jenbacher

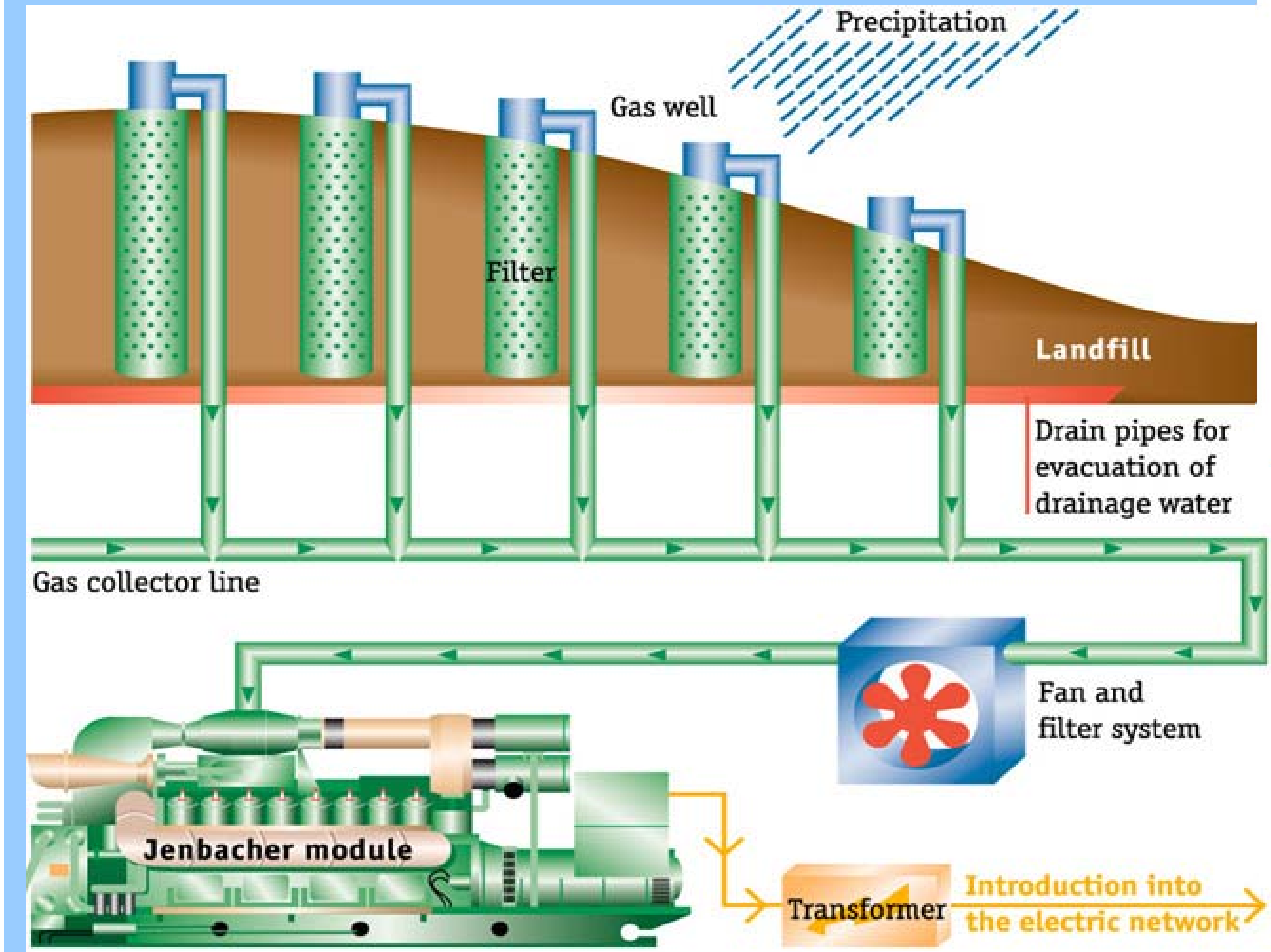
Fuels

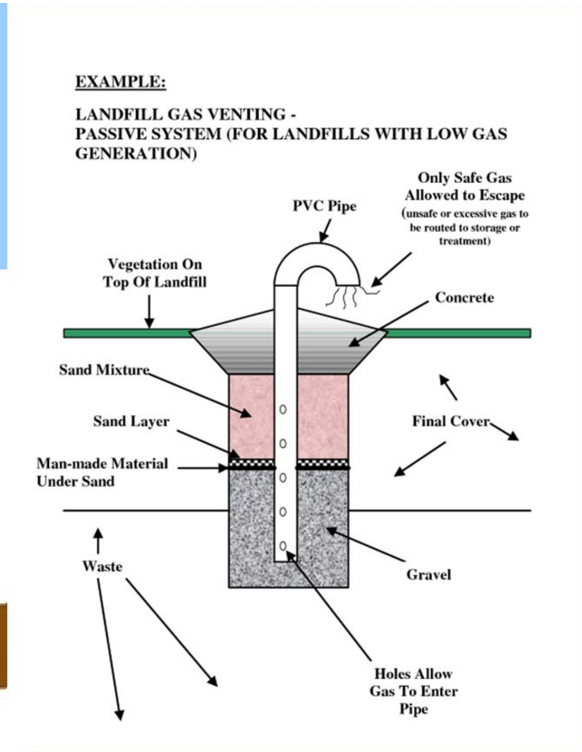
- Fossil:
  - NG (CNG or LNG)
  - LPG (Liquefied Petroleum Gas)
- Renewabel gases:
  - PtG (P2G, electrolysis to produce hydrogen)
  - power-to-methane: power-to-hydrogen system+ carbon dioxide to produce methane using Sabatier reaction or biological methanation,
  - Biogas is produced by anaerobic digestion (Prof. Lezsovits), Landfill Gas, Sewage Gas,
  - Pyrolysis,
  - Gasification.

Different biogases (27/11/20):

\	*Biogas*	*Landfill Gas I*	*Landfill Gas II*	*Sewage Gas*
CH_4	**58,70%**	**35,80%**	**50,60%**	**61,20%**
CO_2	**39,70%**	**32,90%**	**37,10%**	**38,50%**
O_2	**1,60%**	**1,80%**	**2,60%**	**-**
Other:	**-**	**$H_2O + N_2$**	**N_2**	**N_2**
-	**-**	**29,50%**	**9,70%**	**0,20%**
H_2S	**25 ppm**	**-**	**-**	**1350 ppm**

Landfill Gas





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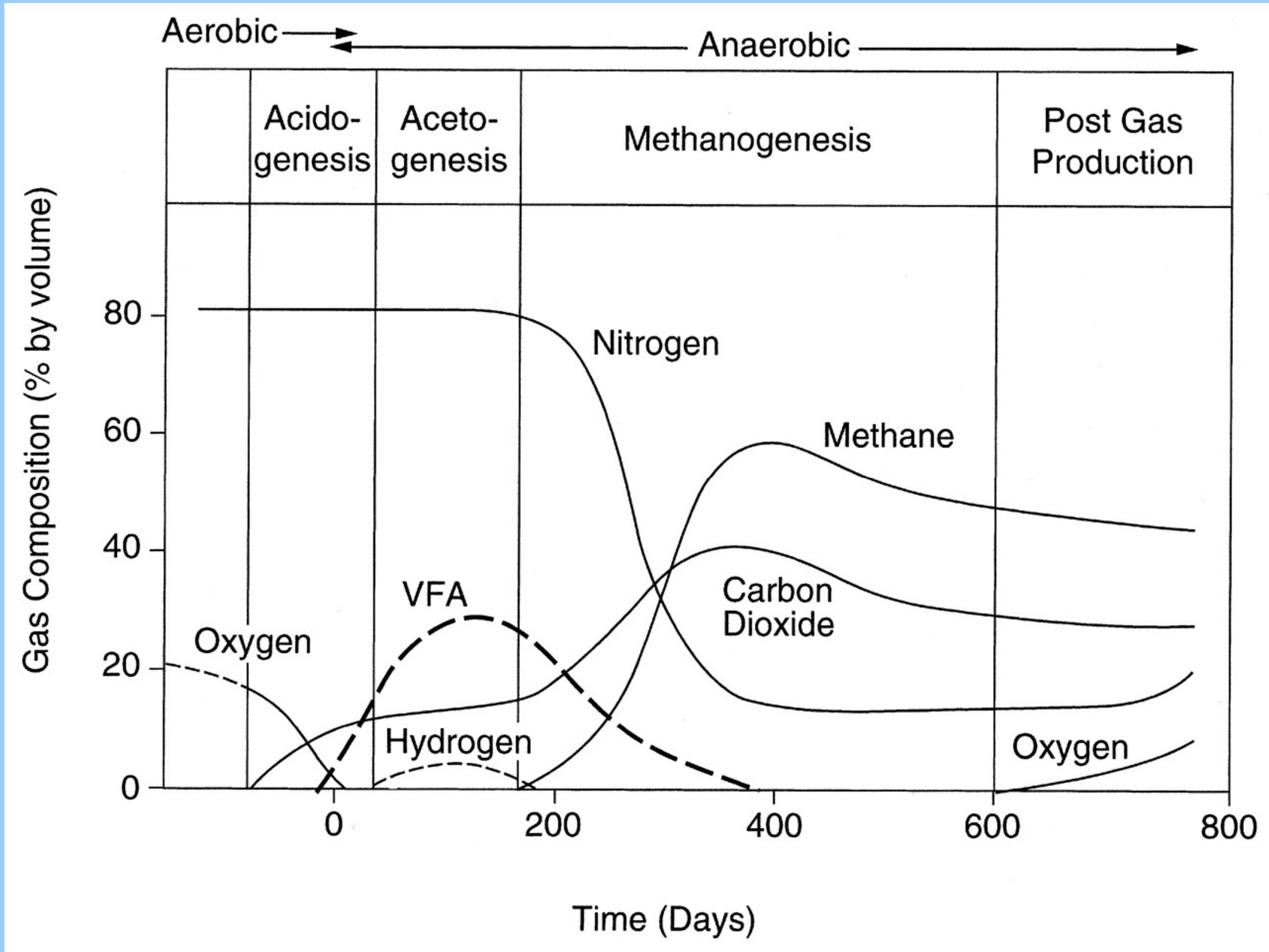
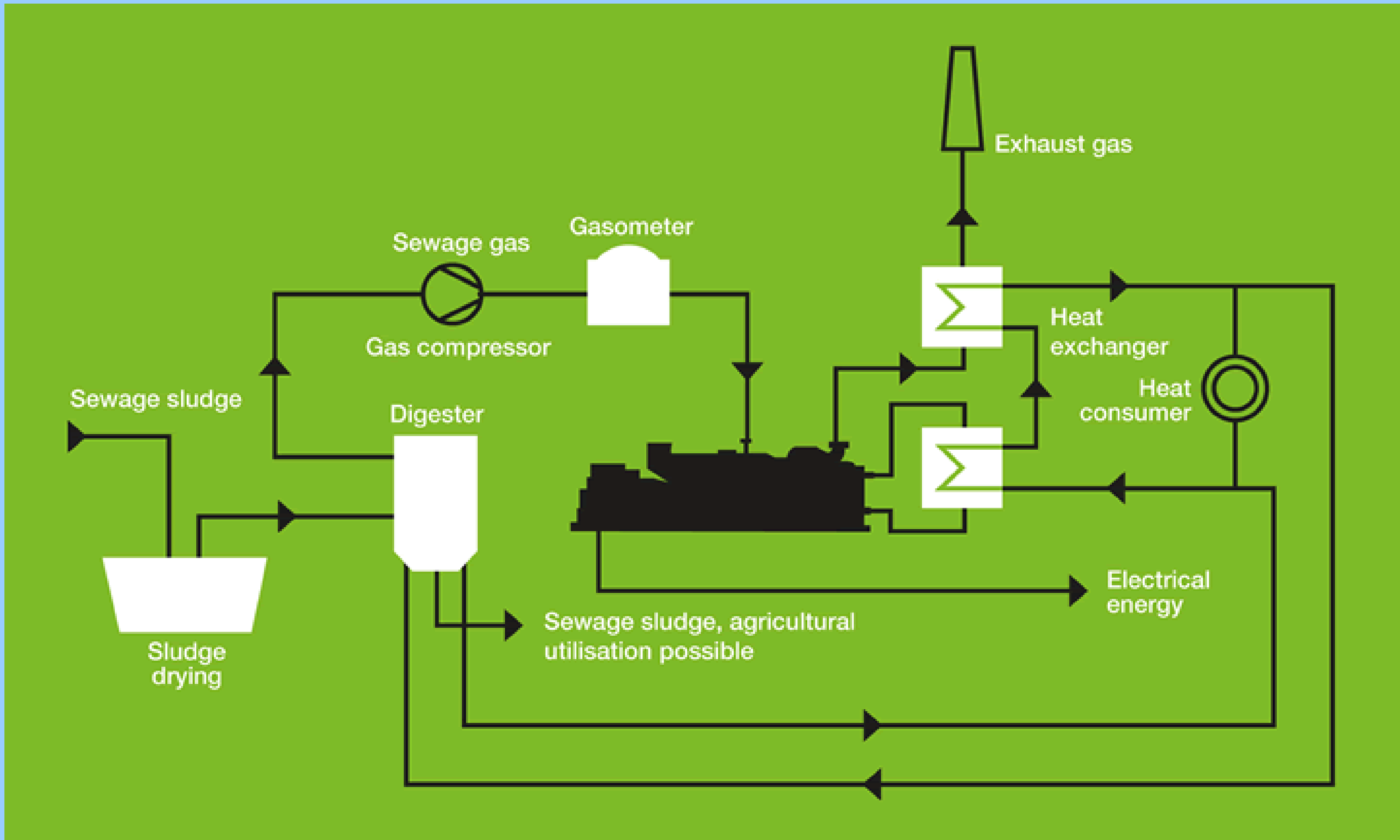
Landfill Gas



DAVID A. C. MANNING:Carbonates and oxalates in sediments and landfill: monitors of death and decay in natural and artificial systems

Sewage Gas



www.clarke-energy.com

Gasification

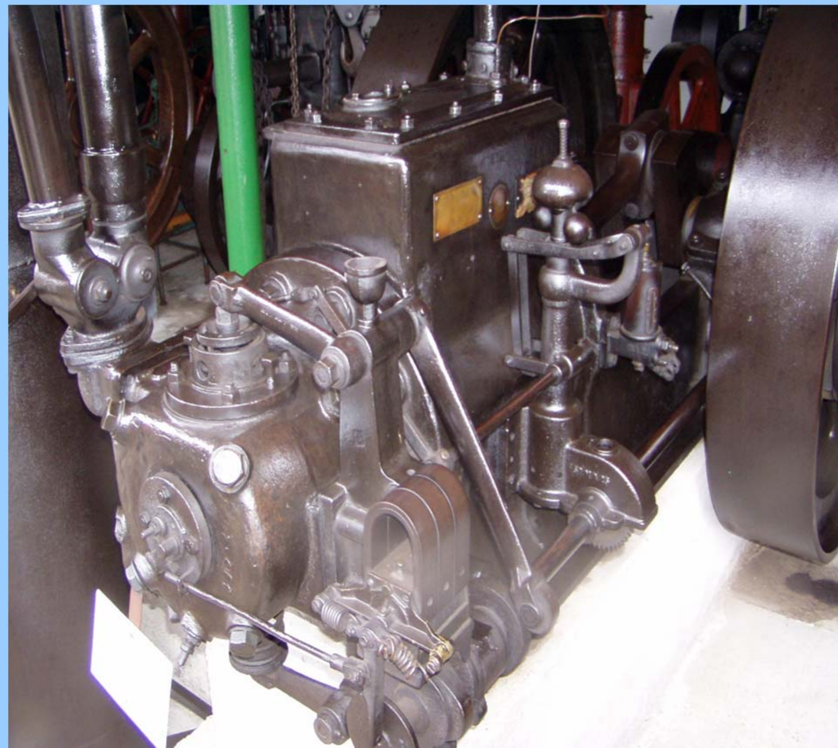
- The *pyrolysis* process occurs at around 200-300°C. Volatiles are released and char is produced,
- The *gasification* process occurs as the char reacts

$$C + H_2O \rightarrow H_2 + CO$$

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

(water gas shift reaction)

Gasifier



Gasifier

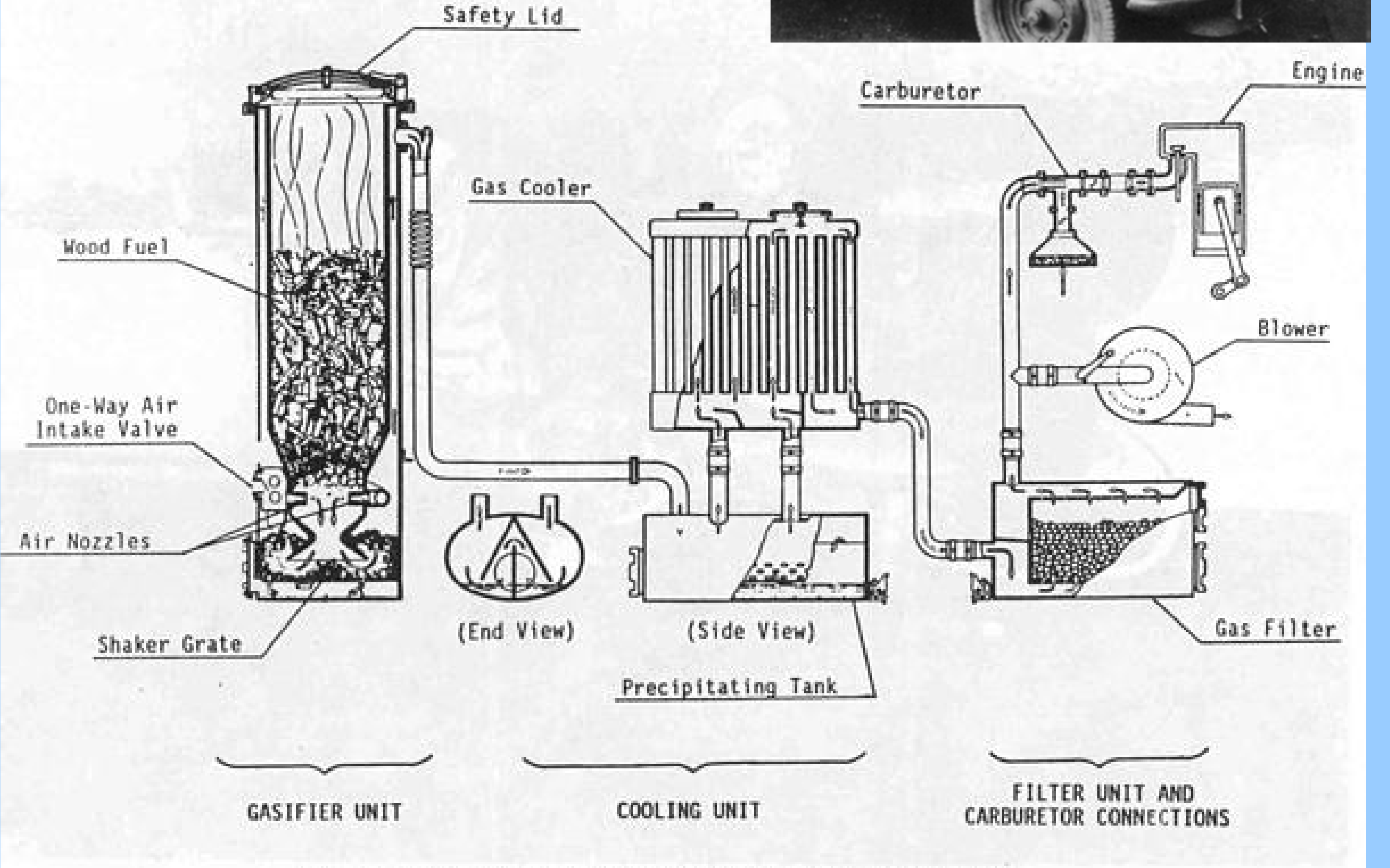


Fig. 1-2. Schematic view of the World War II, Imbert gasifier.

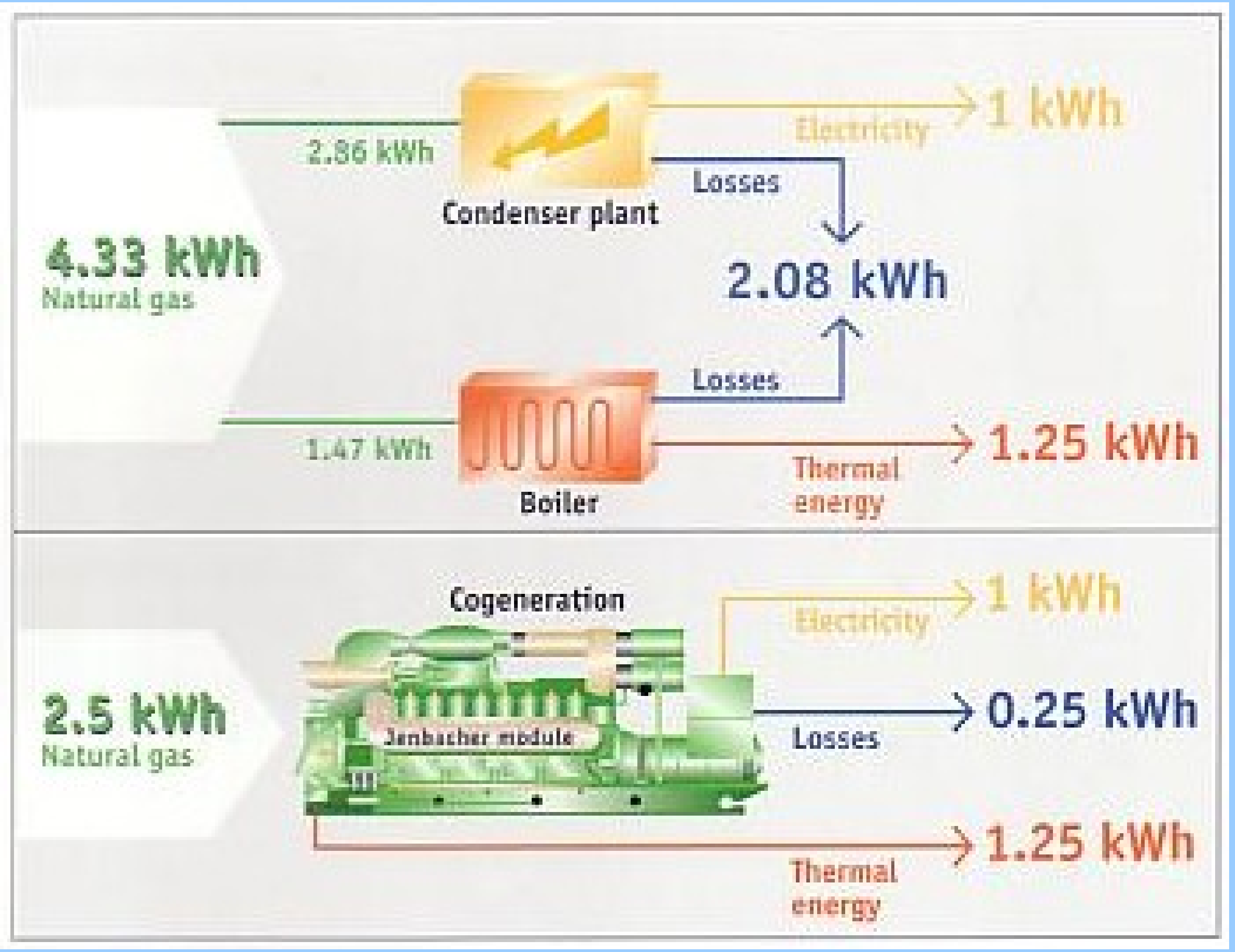
http://www.gengas.nu

Dry comp.:

Components	anaerob (wood)gas	producer gas	synthesis gas	Natural Gas
CH_4 [%]	8	5	3	98
CO_2 [%]	20	5	17	0,1
CO [%]	20	20	40	-
H_2 [%]	38	20	40	-
N_2 [%]	14	50	0	1-2
Hi [MJ/m3]	9,5	6,48	10,45	35,72

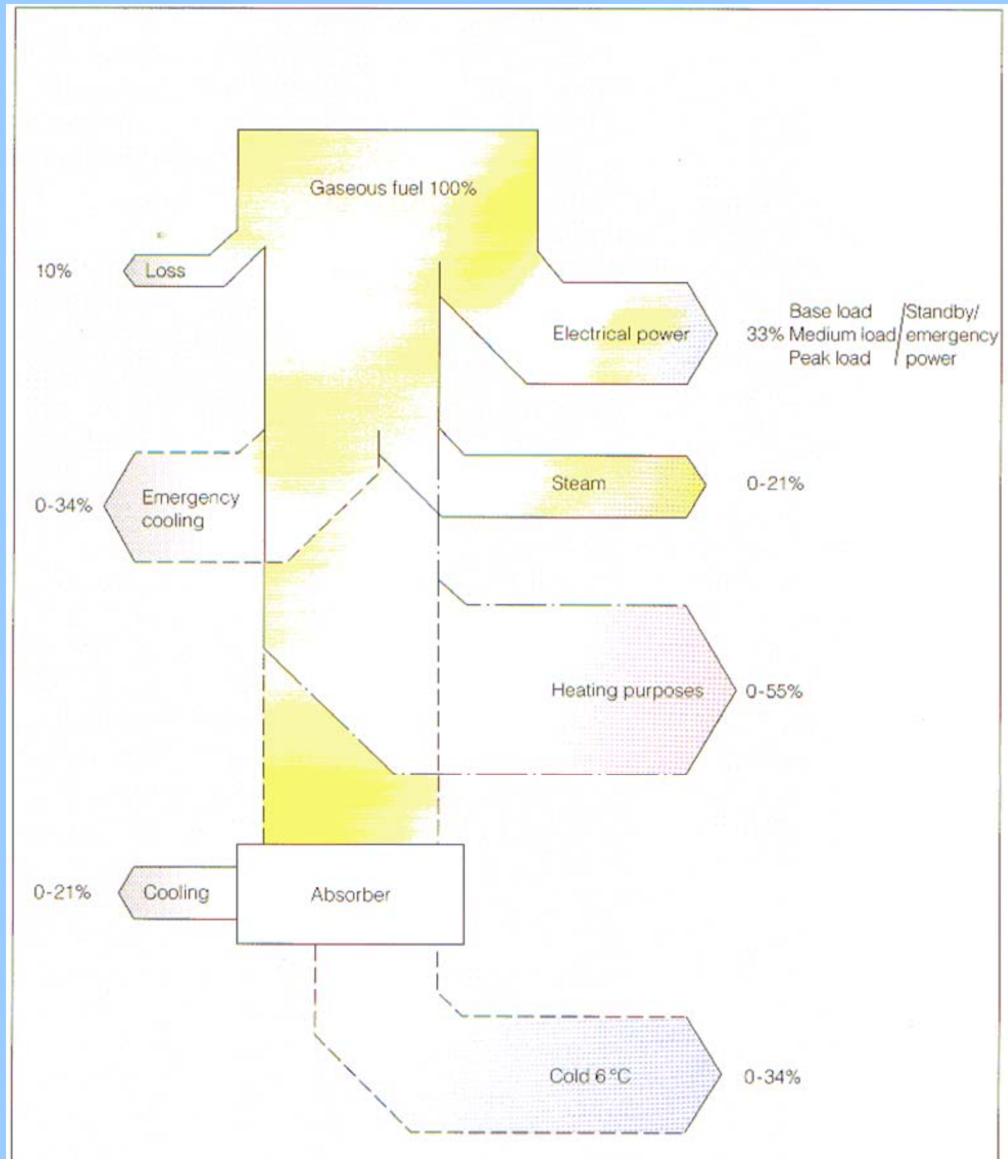
- anaerob (wood)gas : oxygen-free gasification,
- aerob gases:
  - producer gas : gasification with air
  - synthesis gas : gasification with controled O_2 and Steam

Cogeneration



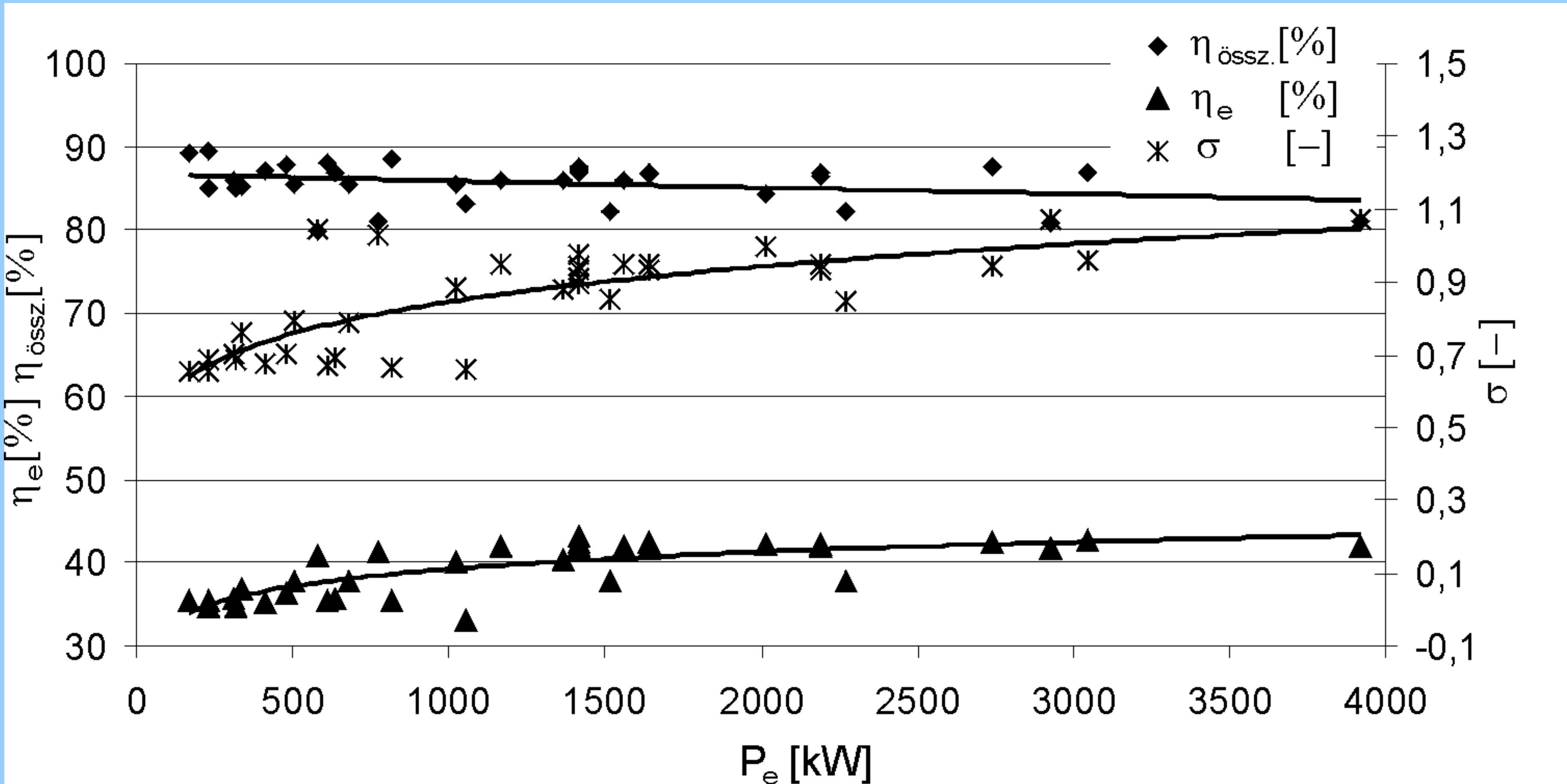
Source: Jenbacher

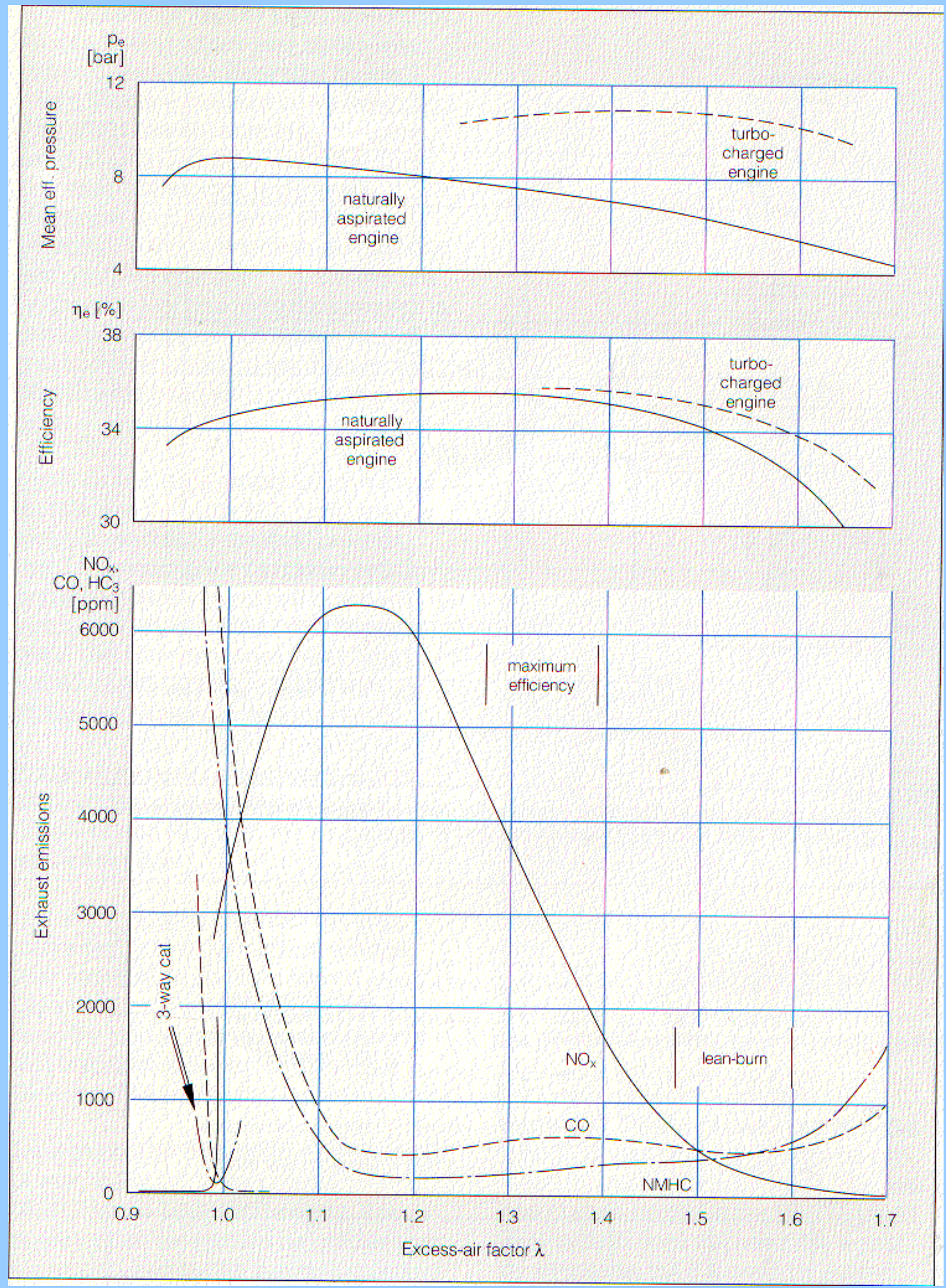
Versatility of energy conversation (power, heat and cold)



Source: DEUTZ

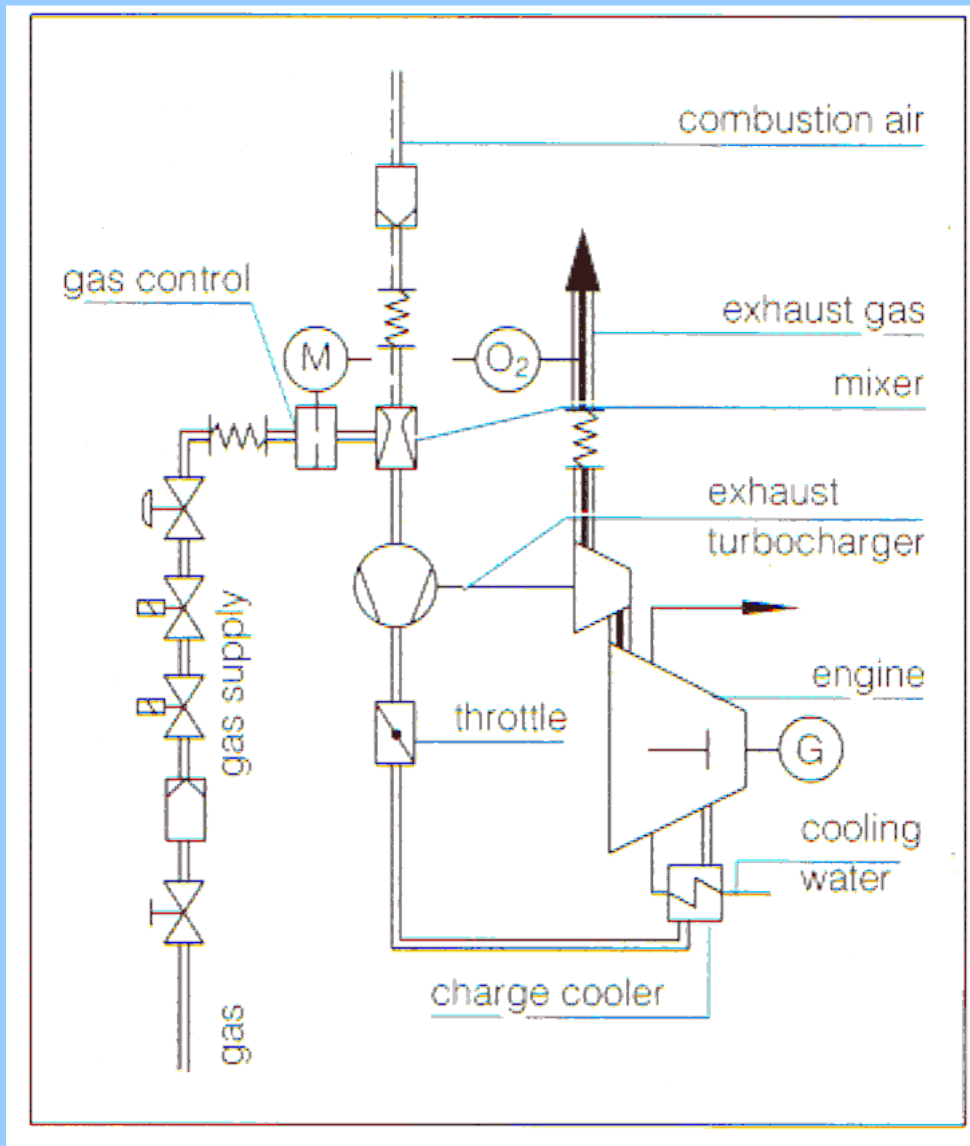
Electrical, total Efficiency and power-to-heat ratio





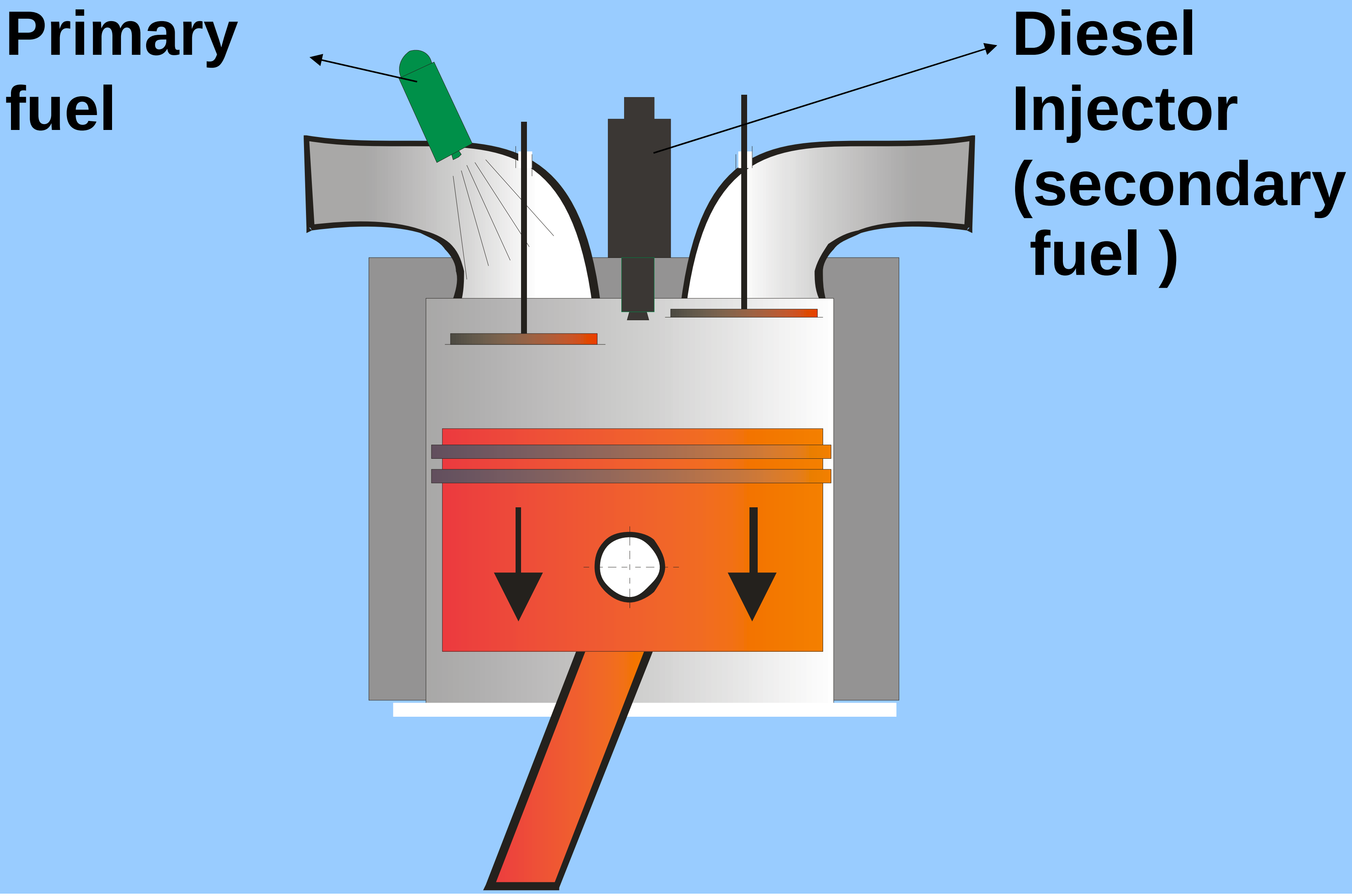
Source:DEUTZ

Fuel – Air mixture formation



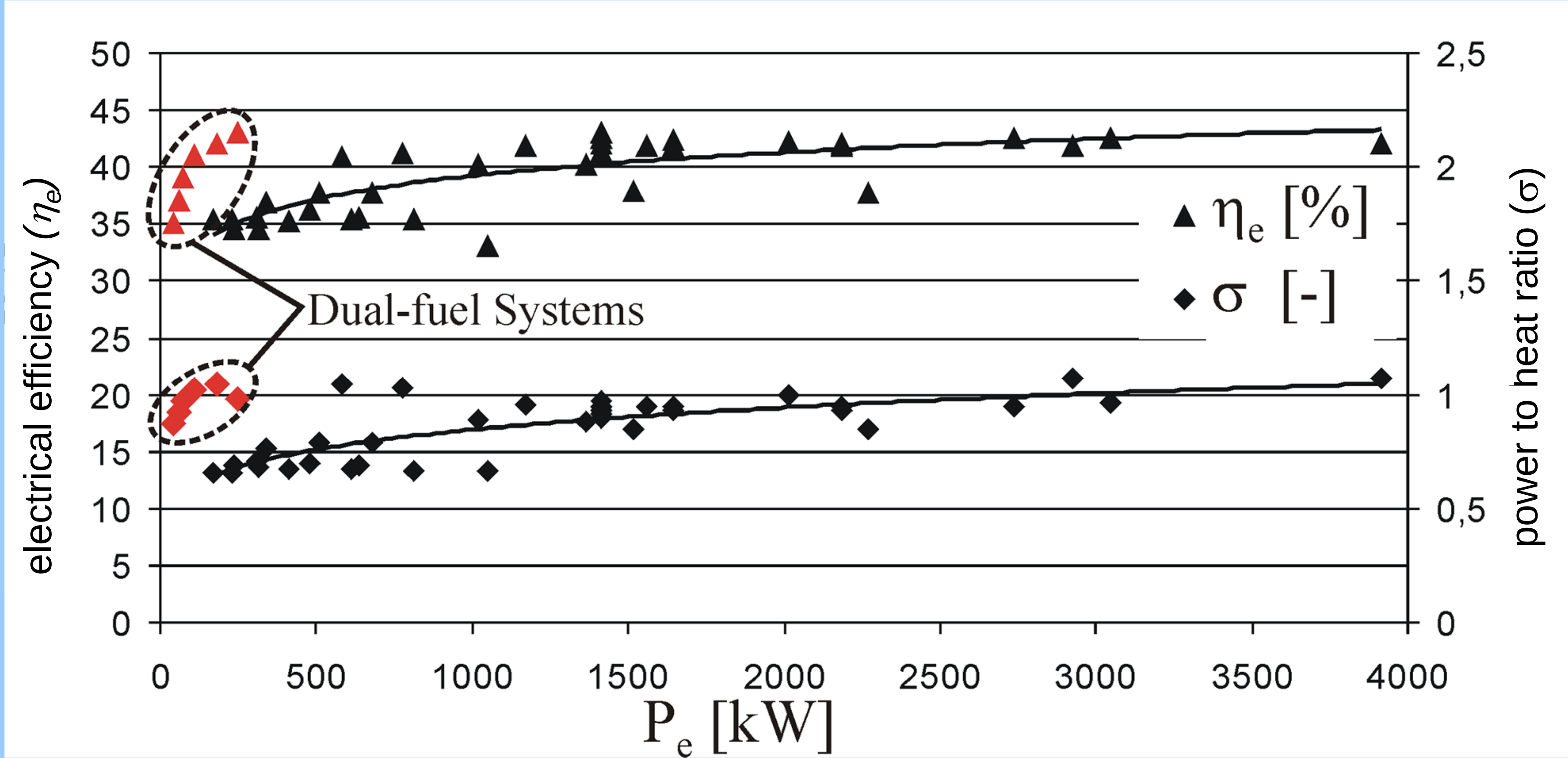
Source: DEUTZ

Dual fuel type CI Engines



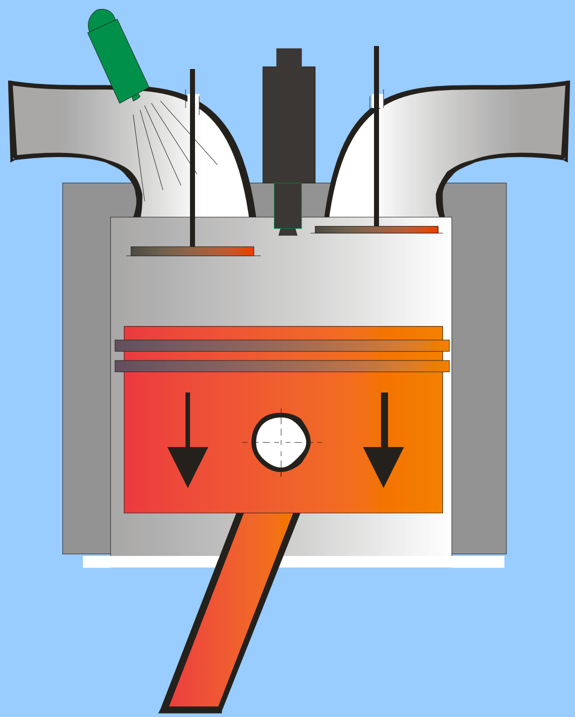
Dual fuel engine systems

(different biogas engines)

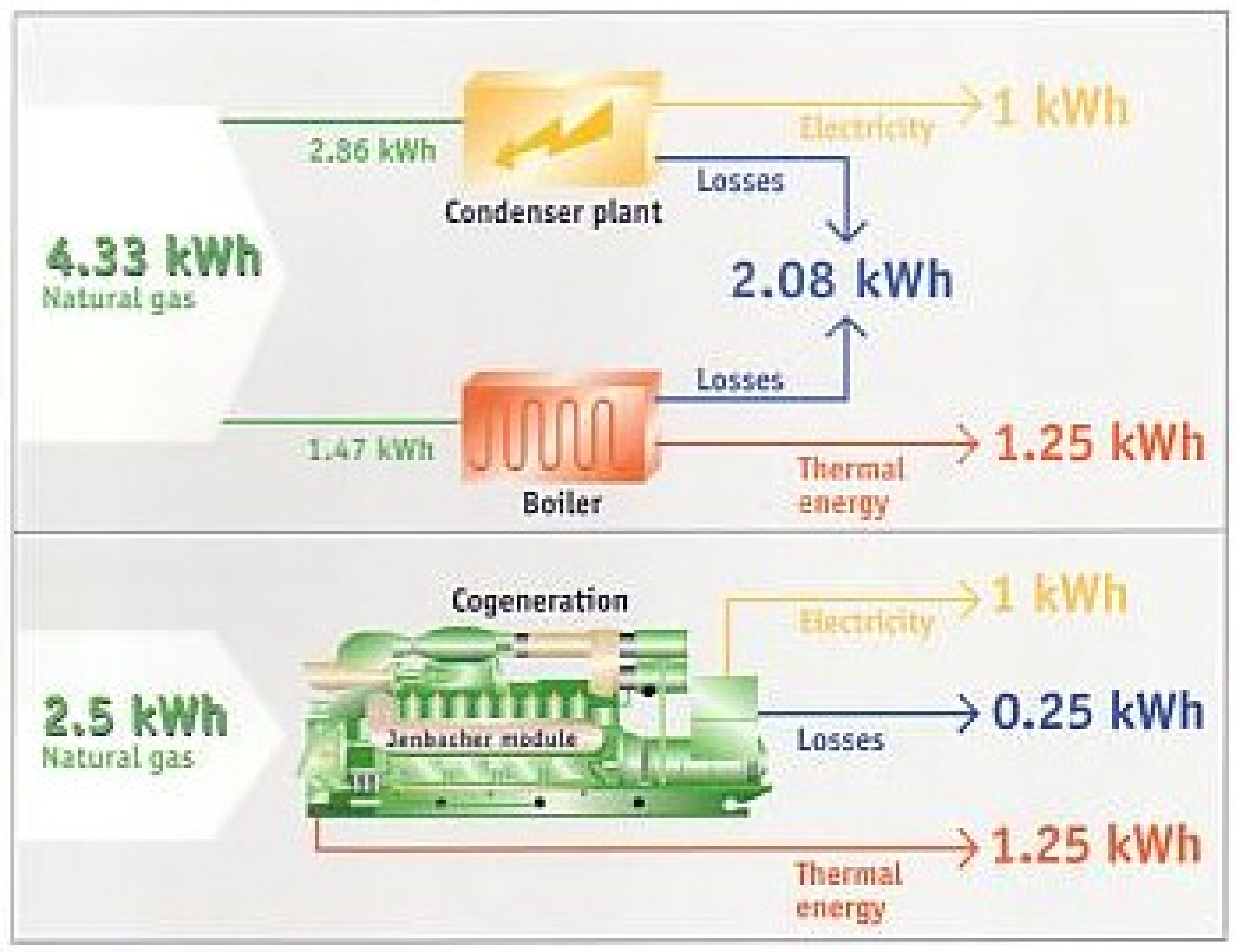


Benefits of the Dual Fuel Engines

- High Compression ratio
- Qualitative power control
- Fuel Flexible



Cogeneration



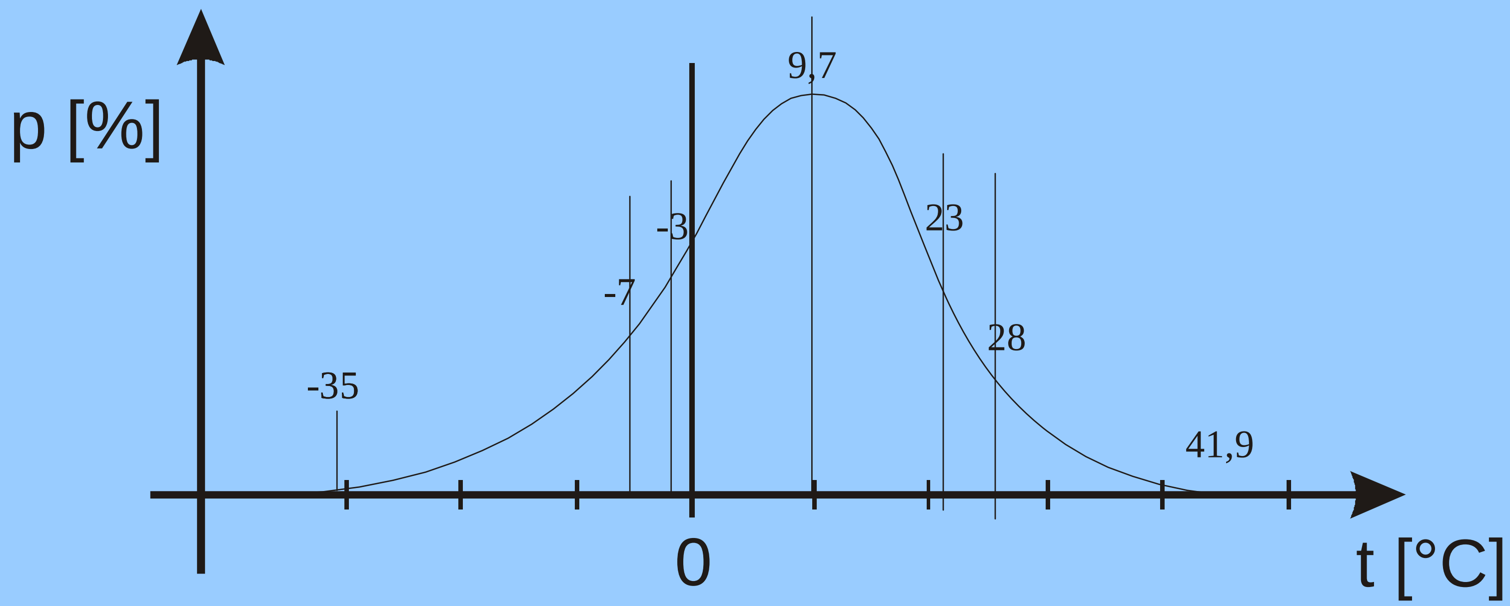
Source: Jenbacher

Gasengine Cogeneration

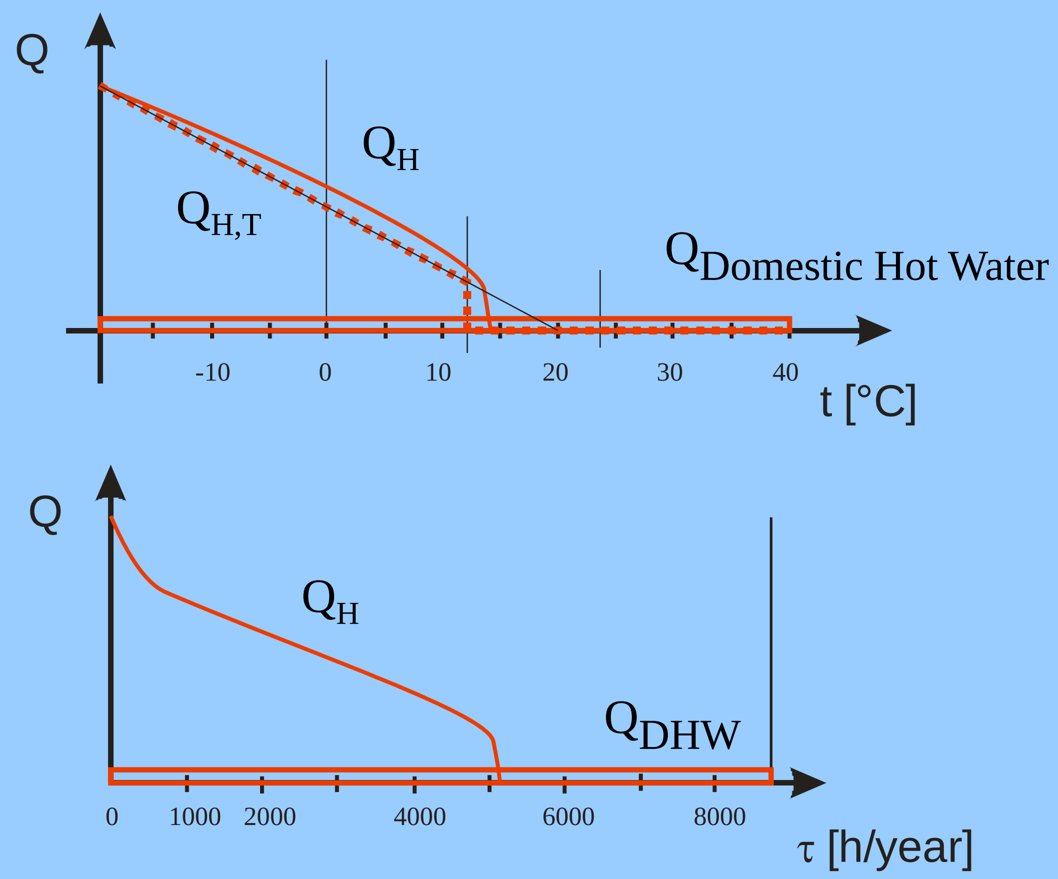
Utilisation:

- Low temperature heating purposes (heating of flats or buildings).
- High Electrical power costs are generate good retunrs, better than a boiler.
- Major industrial facilities, primarily in the electricity supply to the primary heat recovery while at the same time.

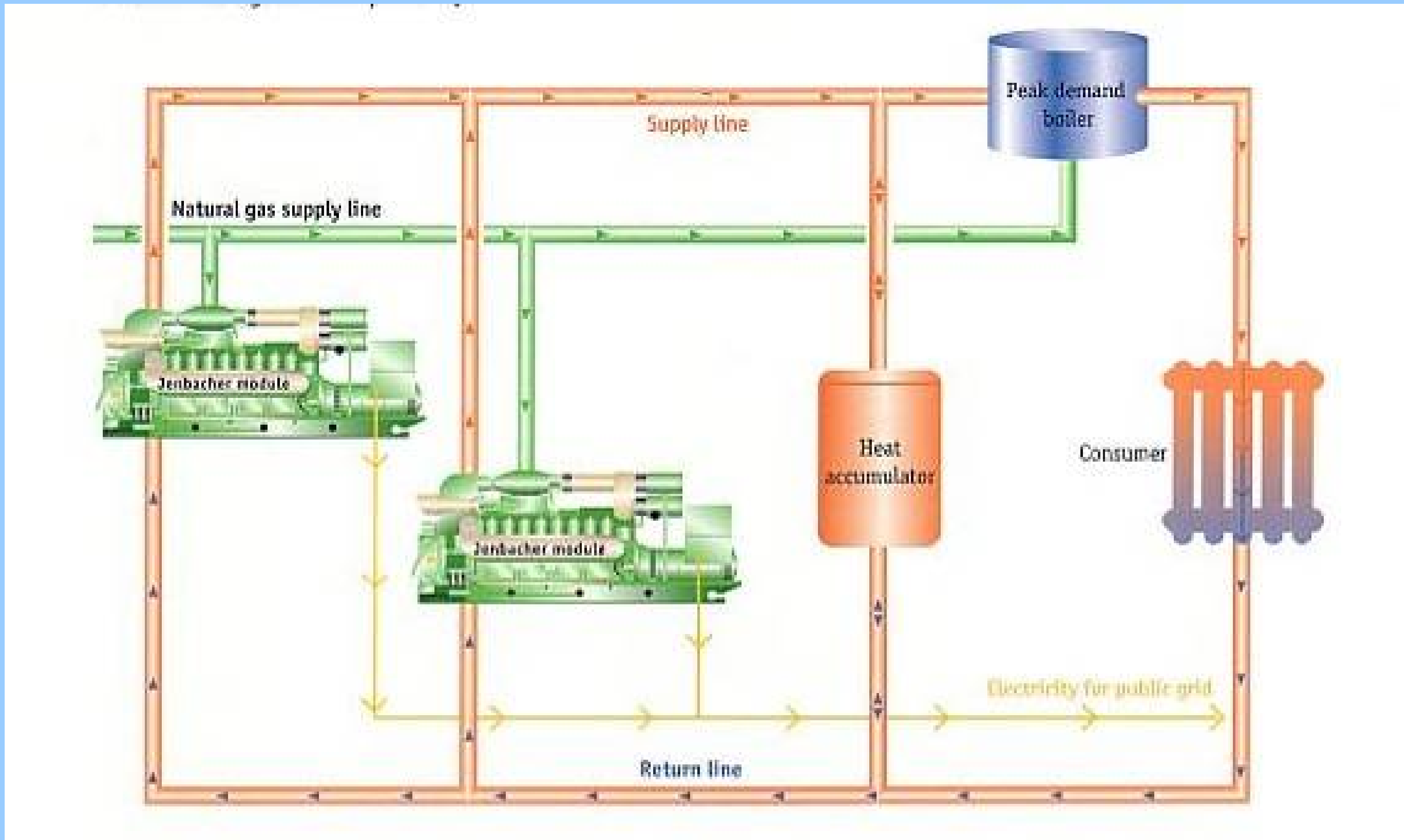
Annual temperature fluctuations



Heating demand

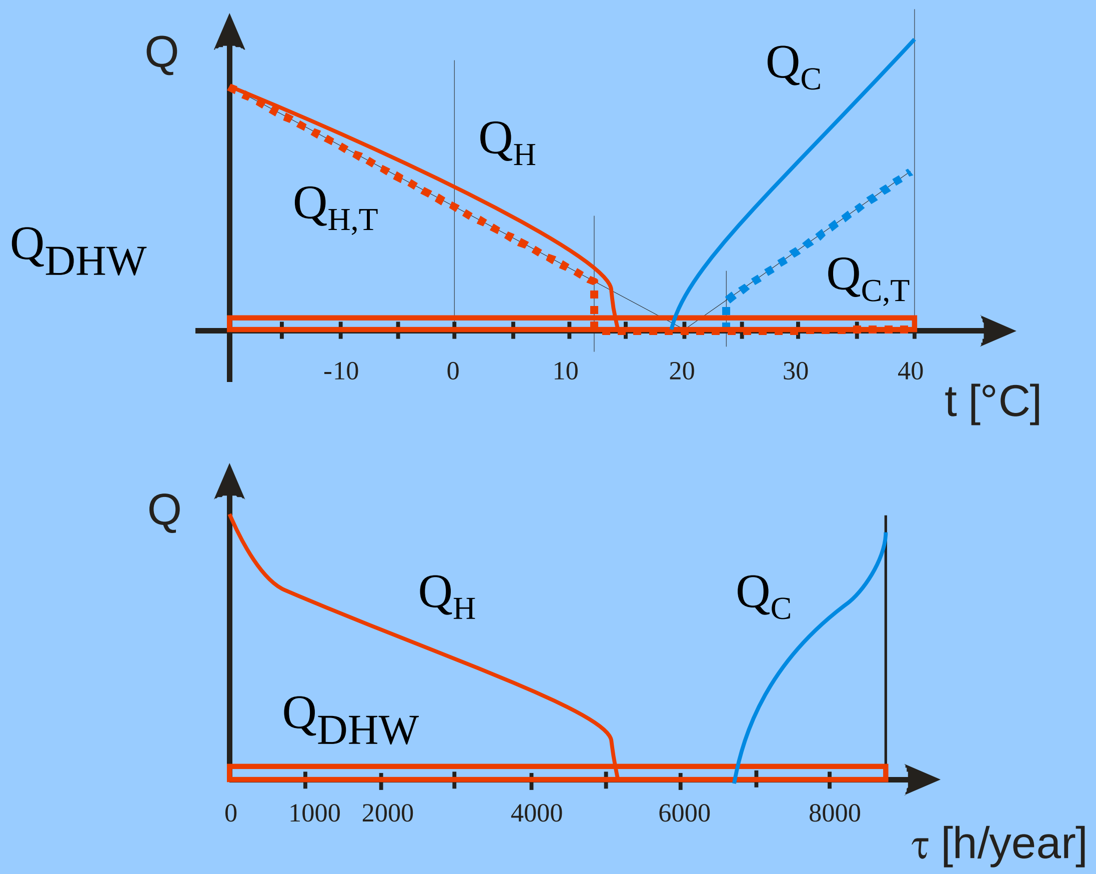


Cogeneration

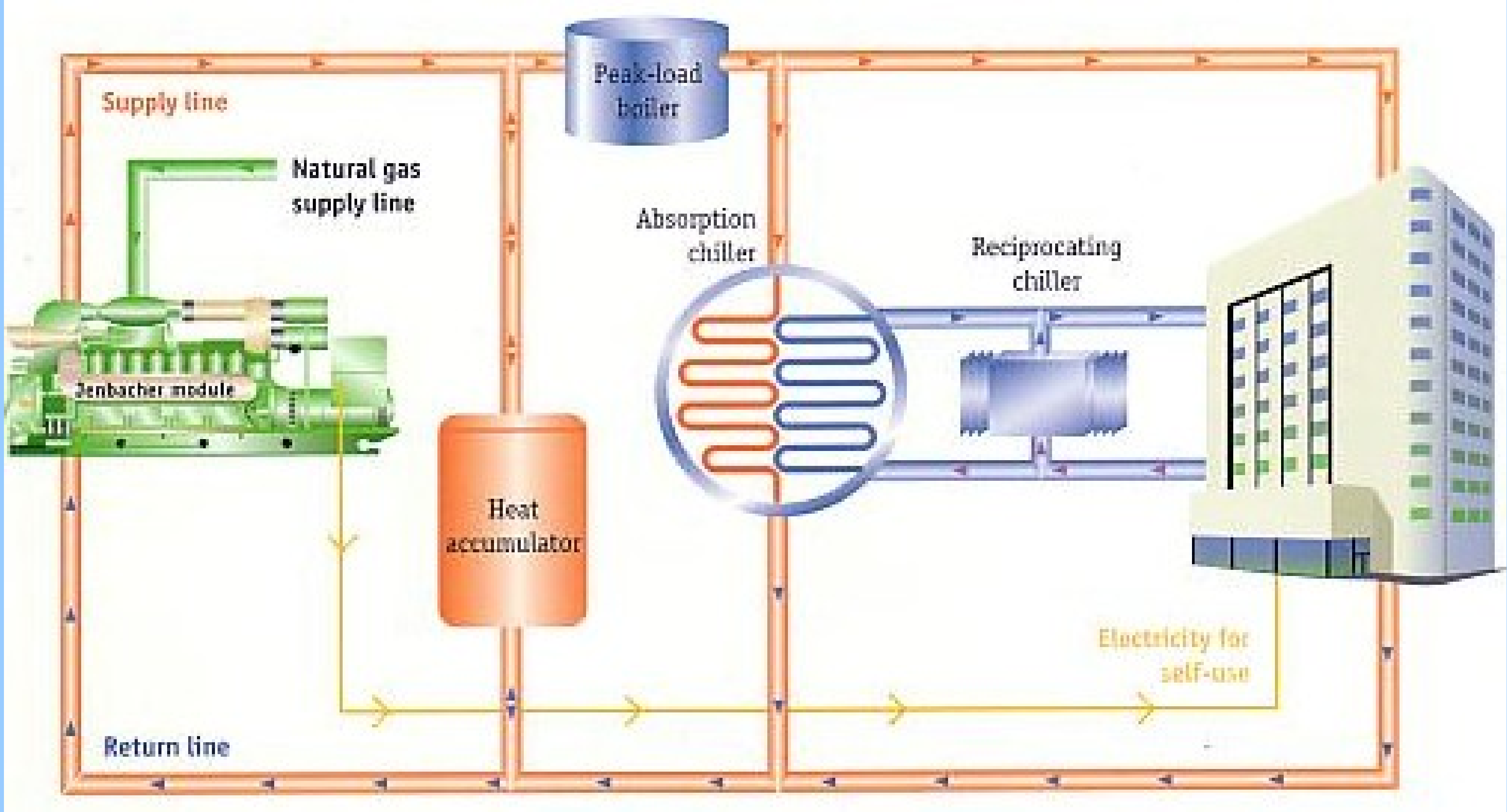


Source: Jenbacher

Cooling and Heating demand

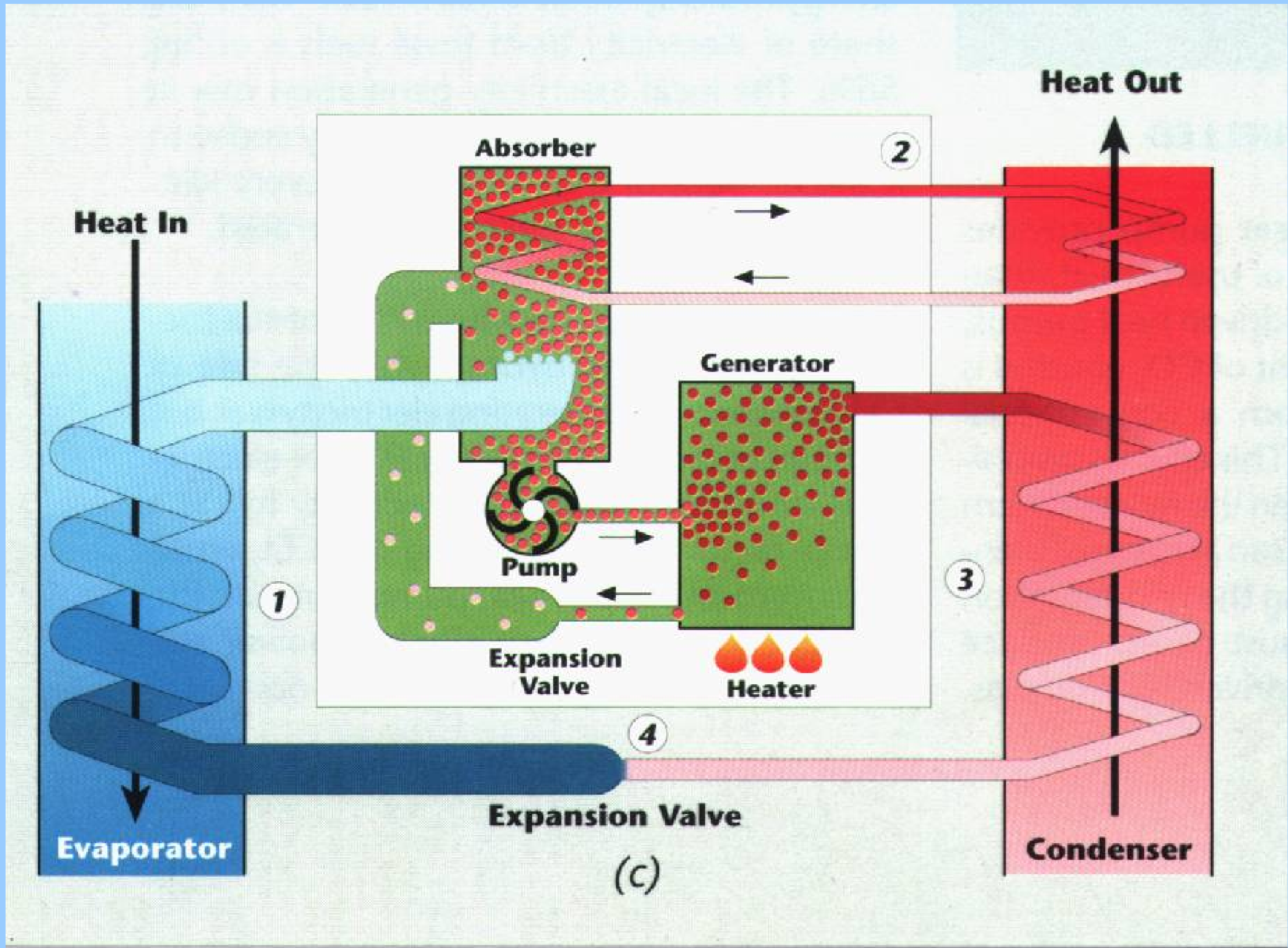


Trigeneration



Source: Jenbacher

Absorption cooler



Source: https://iitbuildingscience.wordpress.com/2013/10/07/absorption-cooling/

Advantages through the combination of cogeneration with absorption chillers

- increase of the module operation time through additional utilization of exhaust heat on summer
- decrease of the connected electrical load and hence reduction of energy costs.

Parameters of the Gasous Fuels

- Heating Value
- Metan Number
- Ignition Limits
- Wobbe number
- ….
- ..

Parameters of the Gasous Fuels

Fuel	Denomination; composition % by vol.	M kg/kmol	V_{mF} m_n^3/kmol	ϱ_F Density kg/m_n^3	H_o kWh/kg	H_u kWh/kg	H_u kWh/m_n^3	L_{min} m_n^3 L/m_n^3 F	$V_{of.}$ m_n^3/m_n^3 F	$V_{otr.}$ m_n^3/m_n^3 F	ϱ_A Density/Exh. gas kg/m_n^3	Ignition limits λ_u	Ignition limits λ_o	MZ	λ_5	$V_{5tr.}$ m_n^3 5%/m_n^3 F	g(CO_2) kg(CO_2)/kWh F
H_2	Hydrogen	2.016	22.43	0.0899	39.39	33.33	2.996	2.379	2.878	1.88	–	9.83	0.14	0	1.247	2.467	0
C	Carbon	12.01	(22.41)	(0.536)	2.87	2.87	(4.88)	4.762	4.756	4.756	–	–	–	–	1.312		0.402
S	Sulphur	32.06	(22.41)	(1.431)	2.57	2.57	(3.68)	4.762	4.739	4.739	–	–	–	–	–	–	0
CH_4	Methane	16.042	22.38	0.717	15.42	13.89	9.971	9.537	10.53	8.53	1.234	1.99	0.59	100	1.280	11.195	0.198
C_2H_4	Ethylene	28.052	22.25	1.261	13.97	13.10	16.521	14.39	15.38	13.37	1.287	2.25	0.14	15	1.290	17.548	0.239
C_2H_6	Ethane	30.068	22.17	1.356	14.41	13.19	17.89	16.85	18.35	15.32	1.256	1.92	0.36	43.7	1.284	20.107	0.221
C_3H_6	Propylene	42.078	21.973	1.915	13.59	12.72	24.35	21.86	23.37	20.31	1.287	2.03	0.37	18.6	1.290	26.657	0.247
C_3H_8	Propane	44.094	22.01	2.003	13.99	12.88	26.00	24.24	26.26	22.19	1.265	1.92	0.39	33	1.286	29.122	0.228
C_4H_{10}	Butane	58.12	21.50	2.703	13.76	12.71	34.34	32.26	34.84	29.63	1.270	2.04	0.33	10	1.287	38.893	0.230
H_2S (burnt to SO_2)	Hydrogen sulphide	34.082	22.15	1.538	–	4.23	6.52	7.23	7.71	7.00	1.407	3.06	0.17	–	1.290	8.791	0
CO	Carbon monoxide	28.01	22.41	1.250	2.81	2.81	3.51	2.381	2.875	2.875	1.502	2.94	0.14	75	1.377	3.775	0.563
CO_2	Carb. dioxide	44.01	22.26	1.9771	–	–	–	–	–	–	–	–	–	–	–	–	–
Nat. gas	CH_4 = 88.5 C_2H_6 = 4.7 C_3H_8 = 1.6 C_4H_{10} = 0,2 N_2 = 5,0	(17.83)	(22.29)	0.798	11.05	12.68	10.14	9.684	10.72	8.73	1.238	1.90	0.59	80–90	1.282	11.462	0.201
Sew. gas	CH_4 = 65 CO_2 = 35			1.158		5.65	6.5	6.20	7.20	5.89	1.271	1.94	0.54	134	1.297	7.736	0.303
Landf. gas	CH_4 = 50 CO_2 = 40 N_2 = 10			1.274		3.94	4.77	4.77	5.77	4.77	1.286	1.90	0.49	136	1.312	6.254	0.355
Diesel fuel	C=86% by wt. H=14% by wt.			–		11.6		11.25	12.0	10.5	1.295	–	–	–	1.2	13.4 per kg	0.264

Basic data acc. to [2]

- M — molar mass
- V_{mF} — molar volume
- H_o — gross calorific value
- H_u — net calorific value
- L_{min} — min. air requirements
- $V_{of.}$ — wet exhaust gas volume at $\lambda = 1$
- $V_{otr.}$ — dry exhaust gas volume at $\lambda = 1$
- ϱ_A — exhaust gas density

Ignition limits λ_u, λ_o converted from $z = 100/(1 + \lambda \cdot L_{min})$, for gas mixtures acc. to [3] and [7]

- MZ — methane number
- λ_5 — excess-air factor at 5% O_2 in dry exhaust gas
- $V_{5tr.}$ — dry exhaust volume, related to 5% O_2 = vital reference quantity for emissions
- g(CO_2) — fuel-specific CO_2 formation in the exhaust gas
- F and index F — related to fuel, i.e., gaseous fuel

Fig. 16 Fuel characteristic values

Source: DEUTZ

Parameters of the Gasous Fuels

Fuel	Denomination; composition % by vol.	M kg/kmol	V_{mF} m_n^3/kmol	ϱ_F Density kg/m_n^3	H_o kWh/kg	H_u kWh/kg	H_u kWh/m_n^3	L_{min} m_n^3 L/m_n^3 F	$V_{of.}$ m_n^3/m_n^3 F	$V_{otr.}$ m_n^3/m_n^3 F	ϱ_A Density/Exh. gas kg/m_n^3	Ignition limits λ_u	Ignition limits λ_o	MZ	λ_5	$V_{5tr.}$ m_n^3 5%/m_n^3 F	g(CO_2) kg(CO_2)/kWh F
H_2	Hydrogen	2.016	22.43	0.0899	39.39	33.33	2.996	2.379	2.878	1.88	–	9.83	0.14	0	1.247	2.467	0
C	Carbon	12.01	(22.41)	(0.536)	2.87	2.87	(4.88)	4.762	4.756	4.756	–	–	–	–	1.312		0.402
S	Sulphur	32.06	(22.41)	(1.431)	2.57	2.57	(3.68)	4.762	4.739	4.739	–	–	–	–	–	–	0
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CO_2	Carb. dioxide	44.01	22.26	1.9771	–	–	–	–	–	–	–	–	–	–	–	–	–
Nat. gas	$CH_4=88.5$ $C_2H_6=4.7$ $C_3H_8=1.6$ $C_4H_{10}=0{,}2$ $N_2=5{,}0$	(17.83)	(22.29)	0.798	11.05	12.68	10.14	9.684	10.72	8.73	1.238	1.90	0.59	80–90	1.282	11.462	0.201
Sew. gas	$CH_4=65$ $CO_2=35$			1.158		5.65	6.5	6.20	7.20	5.89	1.271	1.94	0.54	134	1.297	7.736	0.303
Landf. gas	$CH_4=50$ $CO_2=40$ $N_2=10$			1.274		3.94	4.77	4.77	5.77	4.77	1.286	1.90	0.49	136	1.312	6.254	0.355
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S	Sulphur	32.06	(22.41)	(1.431)	2.57	2.57	(3.68)	4.762	4.739	4.739	–	–	–	–	–	–	0
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C_4H_{10}	Butane	58.12	21.50	2.703	13.76	12.71	34.34	32.26	34.84	29.63	1.270	2.04	0.33	10	1.287	38.893	0.230
H_2S (burnt to SO_2)	Hydrogen sulphide	34.082	22.15	1.538	–	4.23	6.52	7.23	7.71	7.00	1.407	3.06	0.17	–	1.290	8.791	0
CO	Carbon monoxide	28.01	22.41	1.250	2.81	2.81	3.51	2.381	2.875	2.875	1.502	2.94	0.14	75	1.377	3.775	0.563
CO_2	Carb. dioxide	44.01	22.26	1.9771	–	–	–	–	–	–	–	–	–	–	–	–	–
Nat. gas	CH_4 = 88.5 C_2H_6 = 4.7 C_3H_8 = 1.6 C_4H_{10} = 0,2 N_2 = 5,0	(17.83)	(22.29)	0.798	11.05	12.68	10.14	9.684	10.72	8.73	1.238	1.90	0.59	80–90	1.282	11.462	0.201
Sew. gas	CH_4 = 65 CO_2 = 35			1.158		5.65	6.5	6.20	7.20	5.89	1.271	1.94	0.54	134	1.297	7.736	0.303
Landf. gas	CH_4 = 50 CO_2 = 40 N_2 = 10			1.274		3.94	4.77	4.77	5.77	4.77	1.286	1.90	0.49	136	1.312	6.254	0.355
Diesel fuel	C=86% by wt. H=14% by wt.			–		11.6		11.25	12.0	10.5	1.295	–	–	–	1.2	13.4 per kg	0.264

Basic data acc. to [2]

M molar mass
V_{mF} molar volume
H_o gross calorific value
H_u net calorific value
L_{min} min. air requirements
$V_{of.}$ wet exhaust gas volume at $\lambda = 1$
$V_{otr.}$ dry exhaust gas volume at $\lambda = 1$
ϱ_A exhaust gas density

Ignition limits λ_u, λ_o converted from $z = 100/(1 + \lambda \cdot L_{min})$, for gas mixtures acc. to [3] and [7].
MZ methane number
λ_5 excess-air factor at 5% O_2 in dry exhaust gas
$V_{5tr.}$ dry exhaust volume, related to 5% O_2 = vital reference quantity for emissions
g(CO_2) fuel-specific CO_2 formation in the exhaust gas
F and index F related to fuel, i.e., gaseous fuel

Fig. 16 Fuel characteristic values

Source: DEUTZ

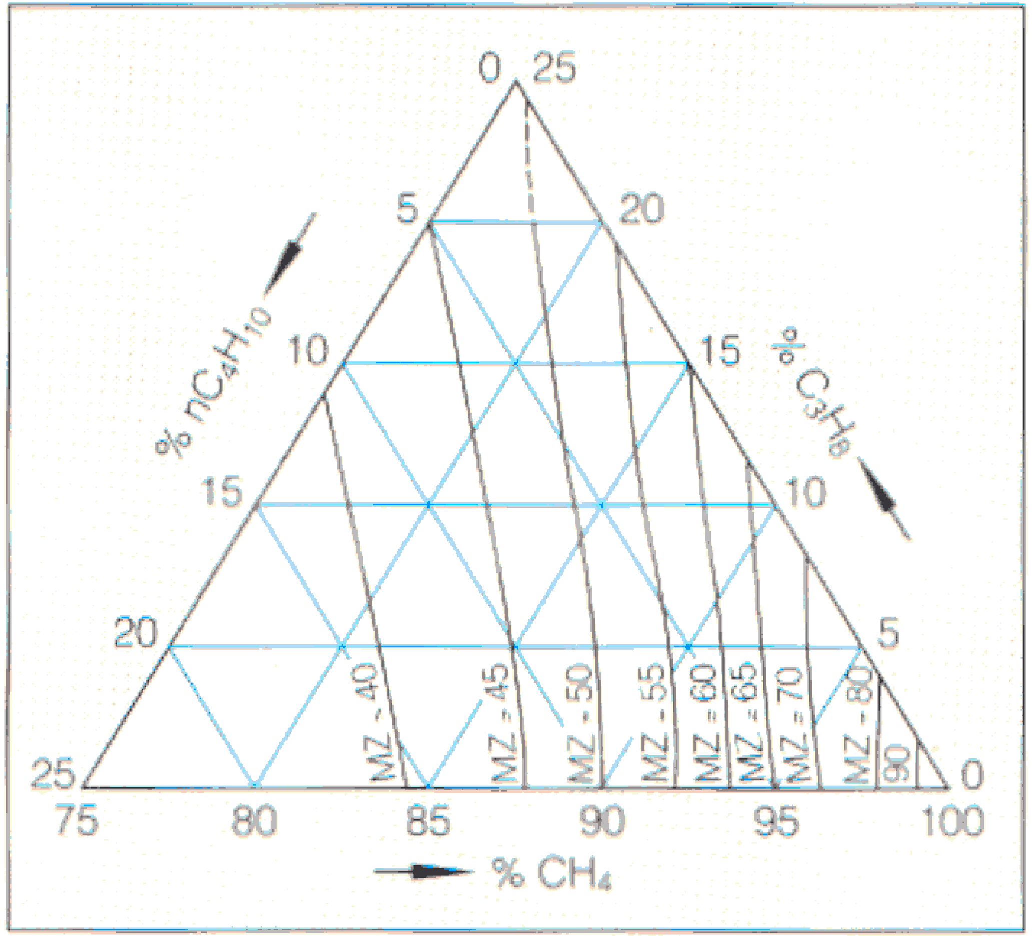

Fig. 17 Determining the methane number of the three-component mixture of methane/propane/butane

Source: DEUTZ

Wobbe index

- The Wobbe index is a measurement of the degree to which fuels can be interchanged.

$$Wobbe\ Index = Wo = \frac{LHV}{\sqrt{d}}\ [\frac{kJ}{kg}]$$

LHV: lower heating value

d: Relative density of the fuel compared with air

$$d = \frac{\rho_{mix.}}{\rho_{air}}$$