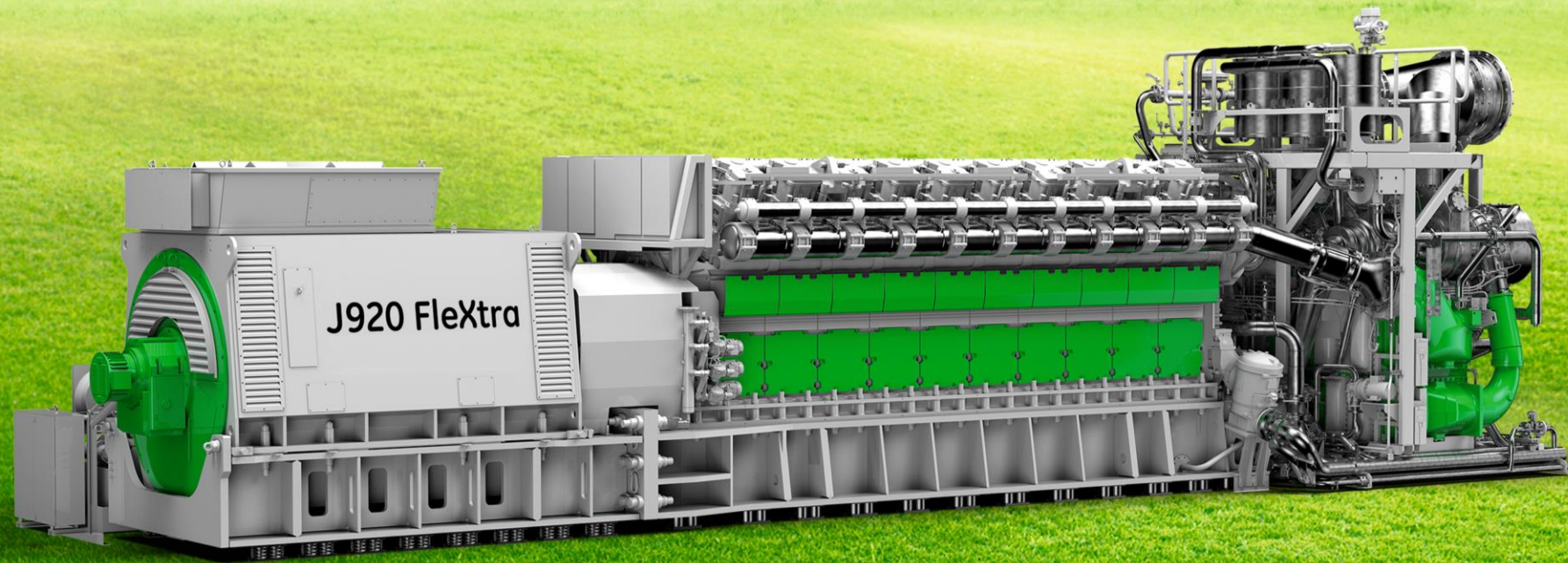




Supporting the Energy Transition with highly efficient, flexible gas engine technology



The clean, fast alternative to coal fired power generation

Michael
Zainer

Brian Moloney

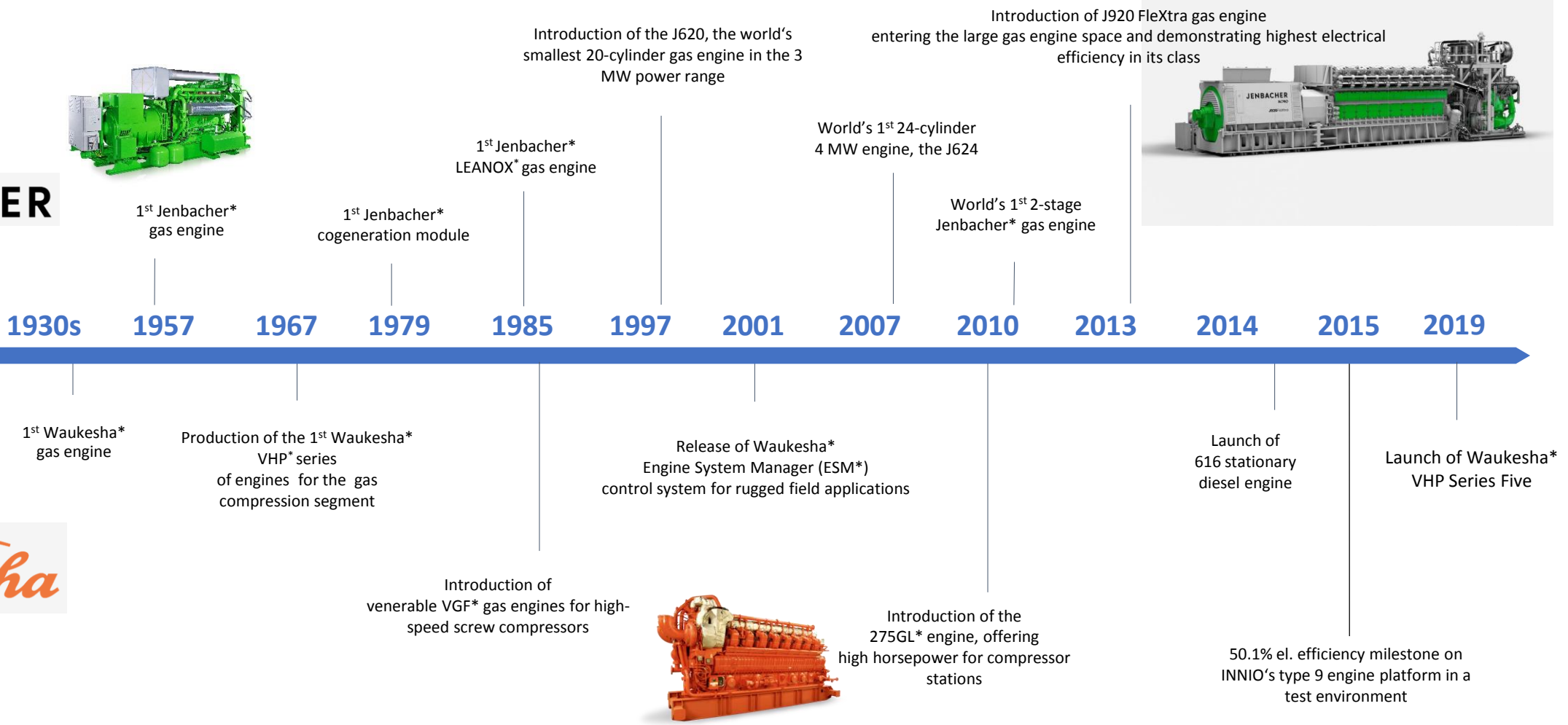


The Jenbach Campus

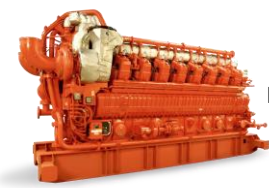
17.5 hectares in size, 65,000 m² production floor,
1.500 employees, 1.350 engines / year

INNOVATIVE GAS ENGINE TECHNOLOGY

JENBACHER

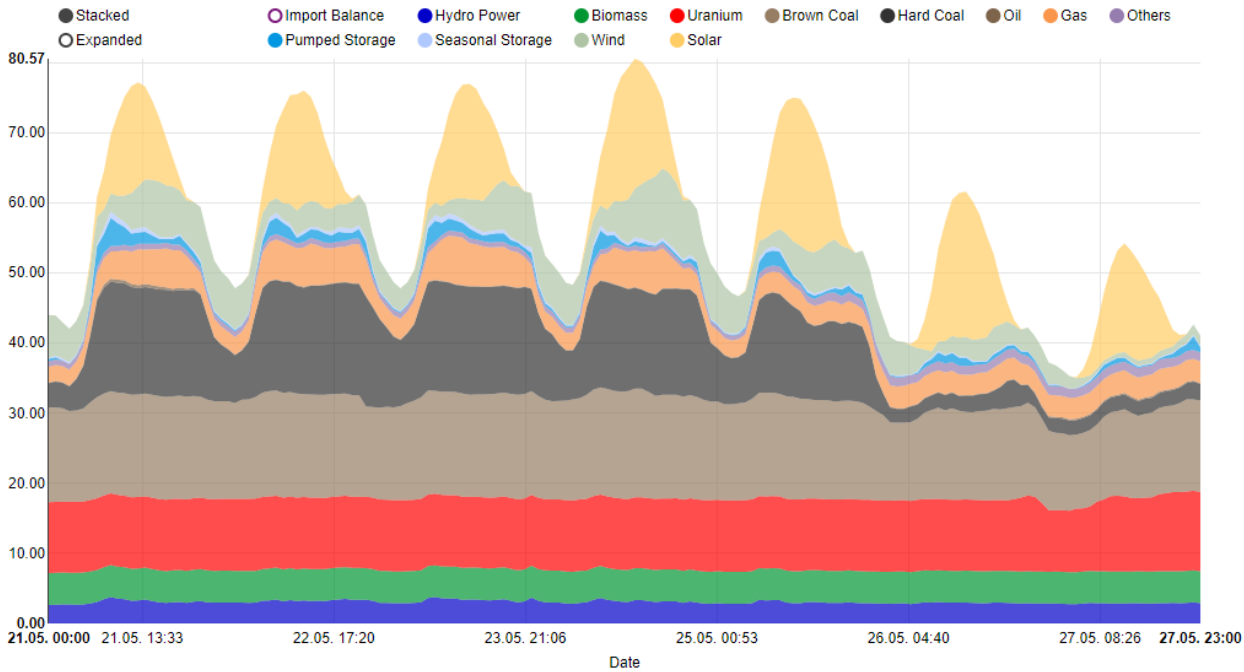


Waukesha

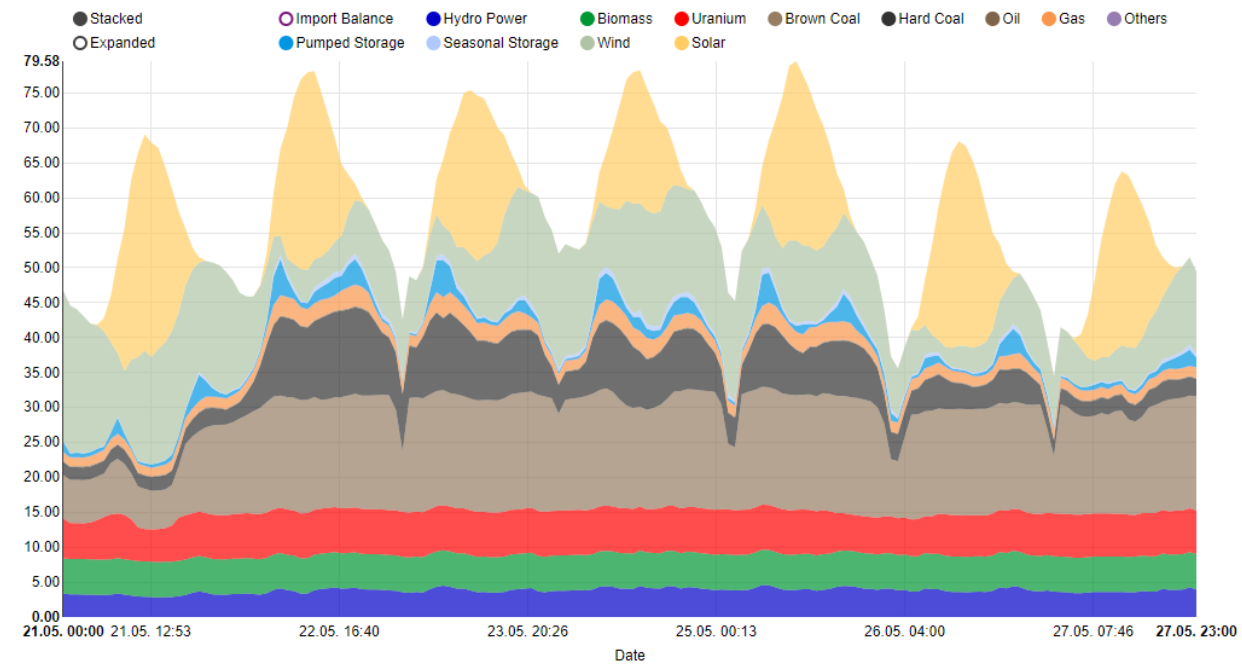


50.1% el. efficiency milestone on INNIO's type 9 engine platform in a test environment

Electricity production in Germany in week 21 2012



Electricity production in Germany in week 21 2018



Electricity production in Germany in week 21 2012

Source	Minimum Power (GW)	Date	Maximum Power (GW)	Date
Import Balance	-7.494	24.05.12 15:00	5.874	26.05.12 20:00
Hydro Power	2.64	21.05.12 00:00	3.762	21.05.12 09:00
Biomass	4.547	21.05.12 00:00	4.547	21.05.12 00:00
Uranium	0.76	27.05.12 04:00	11.369	27.05.12 23:00
Brown Coal	10.572	27.05.12 05:00	15.509	24.05.12 19:00
Hard Coal	1.621	27.05.12 00:00	15.899	22.05.12 20:00
Oil	0.052	22.05.12 04:00	0.45	21.05.12 09:00
Gas	2.259	21.05.12 02:00	6.838	23.05.12 11:00
Others	0.634	23.05.12 09:00	1.347	26.05.12 00:00
Pumped Storage	0.02	27.05.12 04:00	4	21.05.12 09:00
Seasonal Storage	0.055	27.05.12 04:00	0.062	21.05.12 09:00
Wind	0.522	27.05.12 09:00	10.089	24.05.12 18:00
Solar	0	21.05.12 00:00	20.941	25.05.12 13:00

Net generation of power plants for public power supply.
 Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, EEX
 Last update: 15 Dec 2018 18:19

Electricity production in Germany in week 21 2018

Source	Minimum Power (GW)	Date	Maximum Power (GW)	Date
Import Balance	-13.068	21.05.18 14:00	3.078	25.05.18 20:00
Hydro Power	2.831	21.05.18 14:00	4.591	25.05.18 07:00
Biomass	5.062	21.05.18 00:00	5.062	21.05.18 00:00
Uranium	1.029	21.05.18 12:00	6.504	22.05.18 07:00
Brown Coal	5.532	21.05.18 14:00	16.867	24.05.18 22:00
Hard Coal	1.815	21.05.18 04:00	12.407	22.05.18 20:00
Oil	0.138	21.05.18 06:00	0.145	25.05.18 16:00
Gas	1.187	21.05.18 13:00	3.029	22.05.18 19:00
Others	0.068	24.05.18 19:00	0.081	22.05.18 04:00
Pumped Storage	0.185	27.05.18 03:00	5.25	23.05.18 08:00
Seasonal Storage	0.021	27.05.18 06:00	0.034	24.05.18 13:00
Wind	1.782	26.05.18 09:00	21.547	21.05.18 00:00
Solar	0	21.05.18 00:00	30.955	21.05.18 12:00

Net generation of power plants for public power supply.
 Datasource: 50 Hertz, Amprion, Tennet, TransnetBW, EEX
 Last update: 03 Jun 2018 00:13

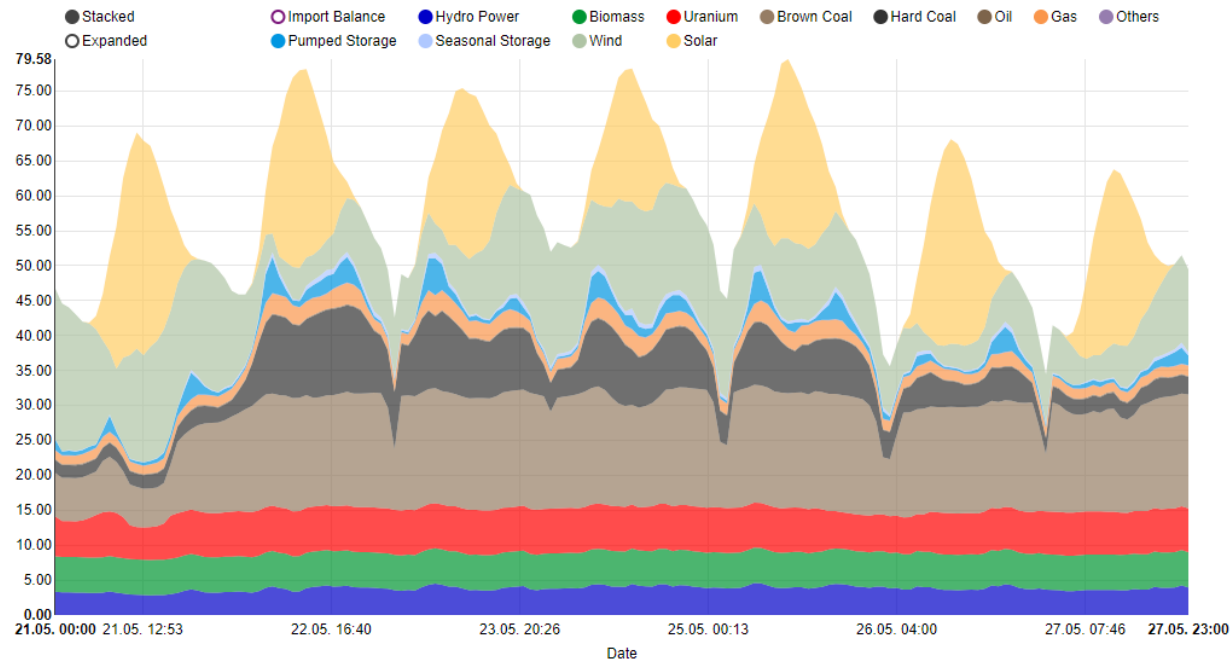
2012	Maximum Wind/Solar:	31 GW	Minimum Brown Coal:	10.6 GW	Max/min Brown Coal:	5 GW
2018	Maximum Wind/Solar:	52.5 GW	Minimum Brown Coal:	5.5 GW	Max/min Brown Coal:	11.3 GW

Renewables new base load

Displacing coal

Increasing volatility

Electricity production in Germany in week 21 2018



The new value creators in a volatile market:

- Efficiency (electrical & total e.g. CHP)
- Start & stop time
- Part & full load electrical efficiency
- Grid stabilisation → ancillary services
- Modularity → output reliability
- Low environmental impact

TRENDS DISRUPTING THE POWER SECTOR



DECARBONIZATION

By 2040, **RENEWABLES** will represent **30%** of global net electricity ... **or more?**

IMPACT

- Generation is becoming difficult to forecast & variable
- Grid stability, Congestion Volatility on electricity markets



DECENTRALIZATION

GROWING PENETRATION of distributed resources
(renewable, storage, efficient devices)

IMPACT

- End user becomes an active actor of the power system ('prosumer')
- Growing complexity of distribution grids



DIGITIZATION

GROWING THE NUMBER of connected devices & smart sensors

IMPACT

- Allowing decision making based on dynamic and nodal prices

INNIO'S LARGEST J920 FLEXTRA GAS ENGINE PLANT



EXISTING

Hard coal plant

- 323 MW net electric output
- 295 MW heat output
- >50 % total efficiency
- Age: ~50 years



NEW

Costal Power Plant K.I.E.L.

- 20 x 9.5 MW → plant net electric output
- 20 x 9.6 MW → heat output
- ~91% → net total efficiency
- <5 min. start up time
- 4 MW minimum stable load with 1 engine part load

~70% CO₂
EMISSIONS
REDUCTION

190 MW COAST POWER PLANT KIEL, GERMANY



CHIMNEYS

ELEKTRODE BOILER 35 MW

4 X 5 J920 FLEXTRA

CONTROL ROOM

TRANSFORMER

SHOP

PUMP HALL

HEAT STORAGE

42,000 m³
30,000 m³ used
~1,500 MWh
60/115 °C
Ø 31,2 m
60 m height

PLANT UNDER
CONSTRUCTION

MARK VIDEO PLACEHOLDER FOR KIEL

WHY DID KIEL CHOOSE GAS ENGINES FOR A 190 MW CHP PLANT?

	J920	GTCC	Hybrid J920+GTCC
El. Output	↑	↔	↔
El. Efficiency Power mode	45 %	~52-55 %	~50 %
El. Efficiency CHP mode	45 %	~45-47 %	~45-46 %
Heat Output	↔	↔	↔
Tot. Efficiency	91 %	~88 %	~89 %
Startup time OpFlex	5 min.	30 min.	5 / 30 min.
Installed Cost	↓	↑	↑
CoE	↓	↑	↓
Installed Technologies	Engines	GT + ST	GT + ST + Engines

Advantages for Engines

- Scaling with multiple engines
- No steam cycle, no steam extraction
- Lower energy losses through chimney / exhaust
- Pre-heated engine in <5 min. at full load
- only 50% of heat from additional exhaust gas heat exchanger

1 technology vs. 3

J920 FleXtra Reciprocating gas engine



JENBACHER J920 FLEXTRA GAS ENGINE



...potential to power more than 20,000 EU households

	Units	J920 Flextra (50Hz / 1,000 rpm)
El. Output	kWel	10,380
El. Efficiency	%	49.1
Heat Rate	BTU/kWh	6,950
Thermal Output	kWth	8,600+
Total Efficiency	%	90-95

Output and efficiency at generator terminals, ISO 3046 incl. 5% tolerance, Nat. Gas MN >80, Power Factor 1.0, 500 mg/Nm3 (@ 5% O2) NOx, Efficiency at LHV, all direct driven pumps incl.

Specification

Fuel	Nat. gas
RPM	1,000
MN	>68
Gen. Voltage 50Hz / 60Hz	10.5 – 11 kV / 12.47 – 13.8 kV
Start-up time down to	3 min.
No Derating up to	48 °C
Std. NO _x emissions	500 mg/Nm3 @5% O2
Power factor range:	0.8 inductive / 0.95 capacitive

	Lengths	Width	Height	Weight
Engine	8.4 m	3.2 m	3.3 m	91 ton
Generator	4.0 m	2.7 m	3.4 m	45 ton
TC Module	3.2 m	3.9 m	5.1 m	26 ton

	Lengths	Width	Height	Weight
Engine	27.5 ft	10.5 ft	11.2 ft	201,000 lb
Generator	17.1 ft	8.2 ft	9.5 ft	130,000 lb
TC Module	10.5 ft	12.8 ft	16.7 ft	57,300 lb

J920 FLEXTRA SCOPE – BALANCE OF PLANT SYSTEMS

LV distribution = 480V bus bar

genset dedicated auxiliaries

commons and master control

building installation

oil supply, compressed air, ...

MV distribution = 12.47/13.8 kV bus bar

step-up trafo to HV

Engine module control

step-down trafo 12.47/13.8 kV/480V

Electrical

expansion vessels

maintenance water tank w/ pump

HT fin-fan coolers

LT fin-fan coolers

Cooling

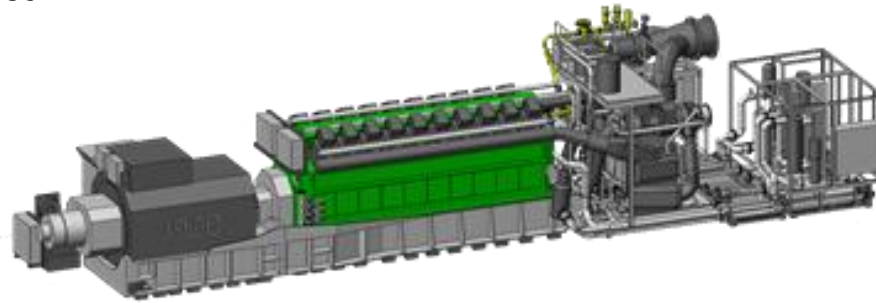
SCR+OXI Catalyst

urea tank

exhaust gas heat exchanger steam generators

silencer w/ stack

Exhaust



Induction & Ventilation

inlet silencer

ventilators

filtration

Air

air receiver tank

air compressors

Fuel

gas booster /reduction station

Oil

daily oil tank

temporary oil tank

waste oil tank

fresh oil tank

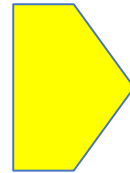
J920 FleXtra
Reciprocating gas
technology advantages



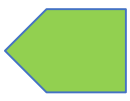
ACHIEVING HIGH FUEL UTILIZATION OF MORE THAN 90%

~250 g/kWh avoided CO₂ with CHP

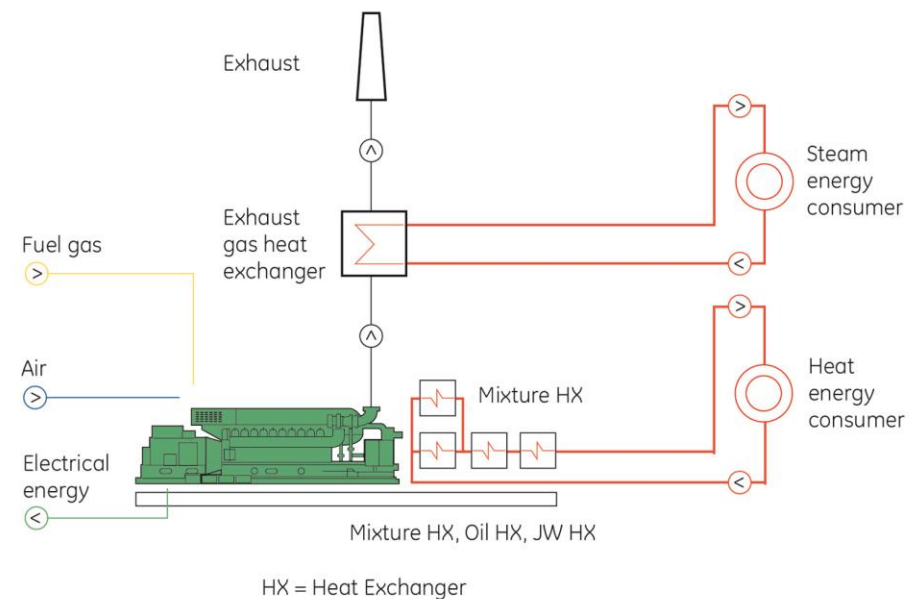
Fuel
100%



Electricity
~46 %



Losses
~9%



Exhaust Heat
23%



Cooling Heat
23%



92% fuel utilization factor ... CHP coefficient of ~1

OPTIMIZATION EXAMPLE FOR HEATING WITH HOT WATER CHP

Version C01	
Eta_el	49.1%
Eta_total	88.0%

2%pts better el. efficiency (compared to J624)

Electricity: 1,700,000 EUR fuel savings

Heat : base

NG @ 25 EUR/MWh, 7 €/GJ, 250 €/1000m³, 8.5 \$/mmBTU
8,000 oh/yr, 10 yrs
Heat Sales Prices ~10-20% above NG price

Version C101	
Eta_el	48.2%
Eta_total	92.0%

4%pts better tot. efficiency

Electricity: 1,200,000 EUR fuel savings

Heat : 1,000,000 EUR add. Heat Rev.

NG @ 25 EUR/MWh, 7 €/GJ, 250 €/1000m³, 8.5 \$/mmBTU
8,000 oh/yr, 4,000 oh/yr CHP, 10 yrs
Heat Sales Prices ~10-20% above NG price

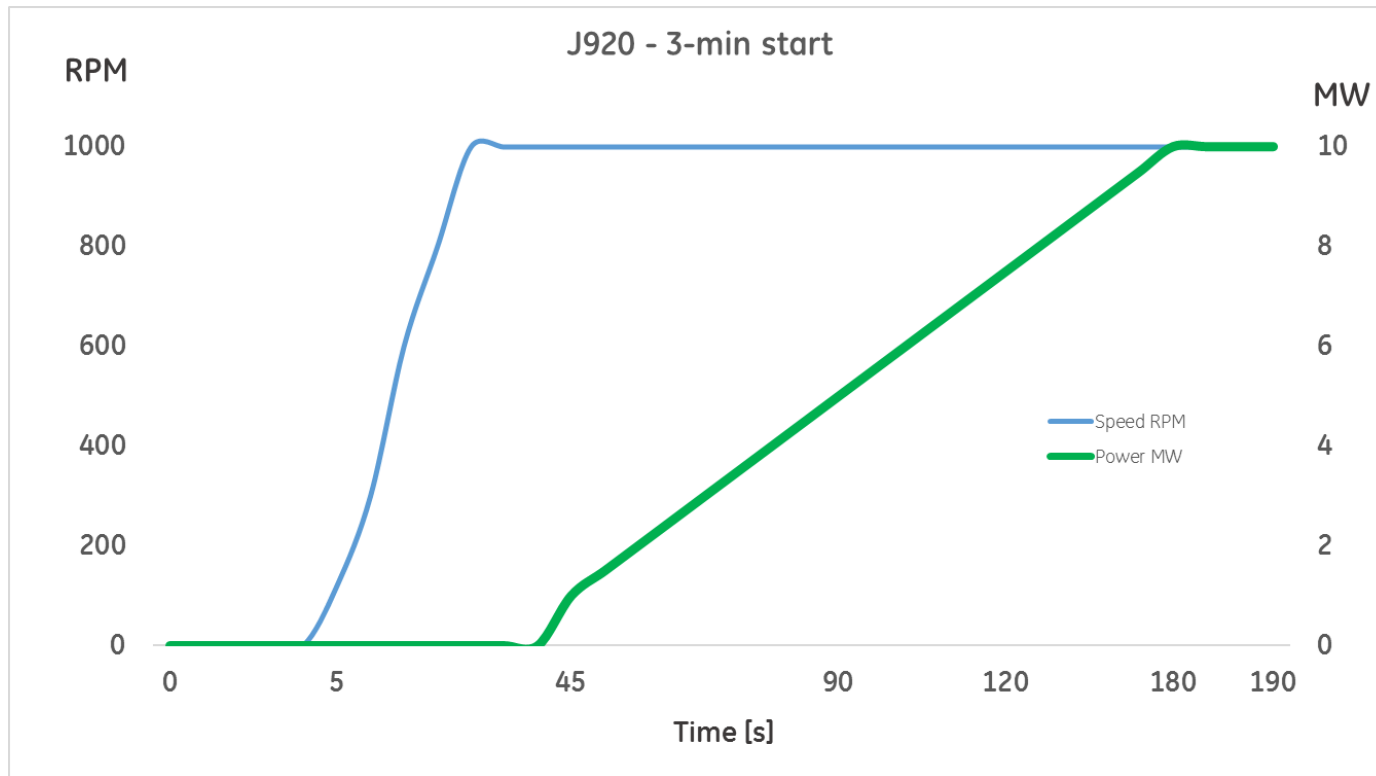
Cold wtr. temp.
50 – 80 °C

Hot wtr. temp.
90 – 130 °C

Maximum fuel efficiency over 90 %

First engine with 2-stage turbocharging ... 3-4 %pt better tot. efficiency

J920 FLEXTRA FAST START AND STOP CAPABILITY

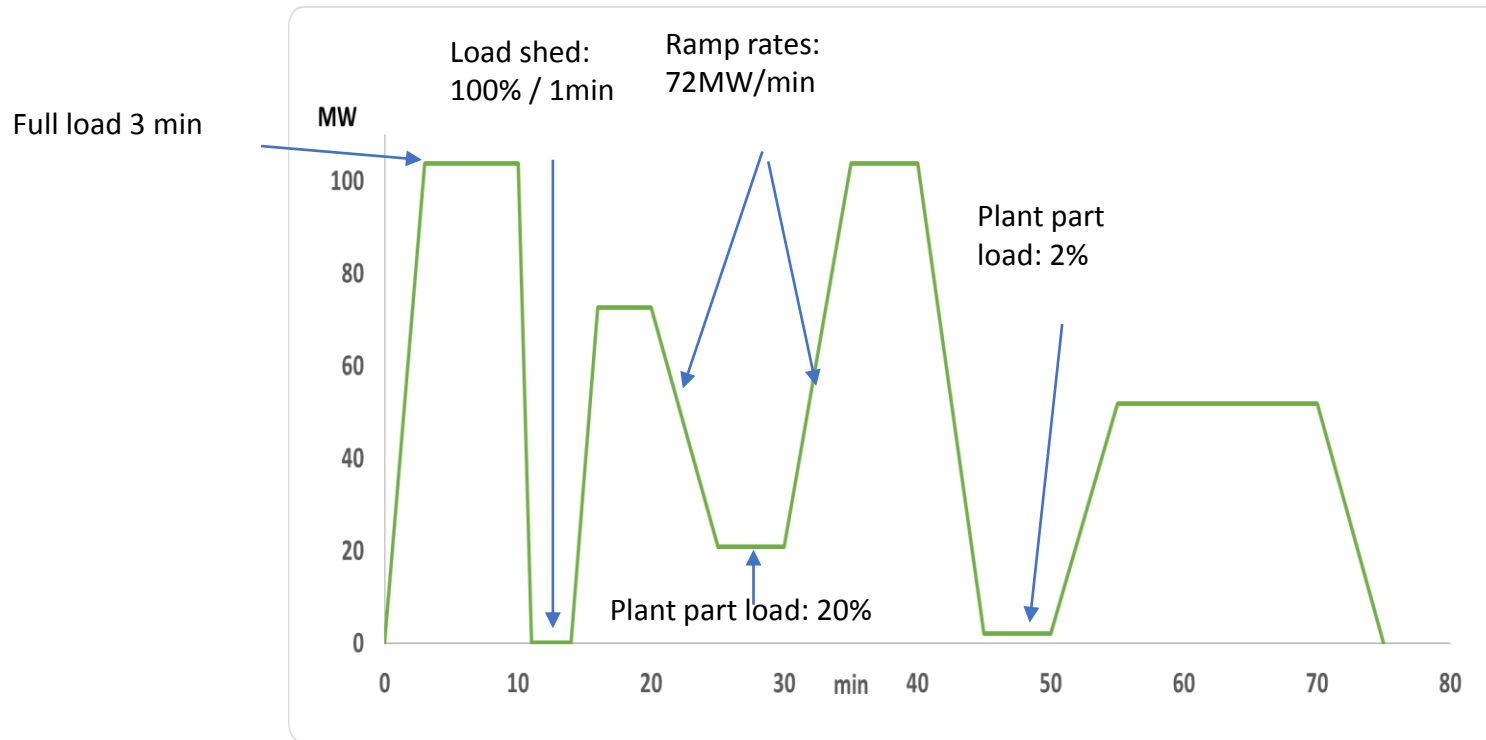


- ✓ Start-up in 3-mins with pre-heated engine
- ✓ 10% load after 45 sec.
- ✓ Starting ramp rate of up to >100kW/s
- ✓ 100% load shed in 1 min

100% load within 3 mins ... 10% load after <45s

DESIGNED FOR FLEXIBLE OPERATION

Customers face dynamic environments, Jenbacher understands their challenges and economics



J920 makes the most out of all operating scenarios and can be adapted to project needs

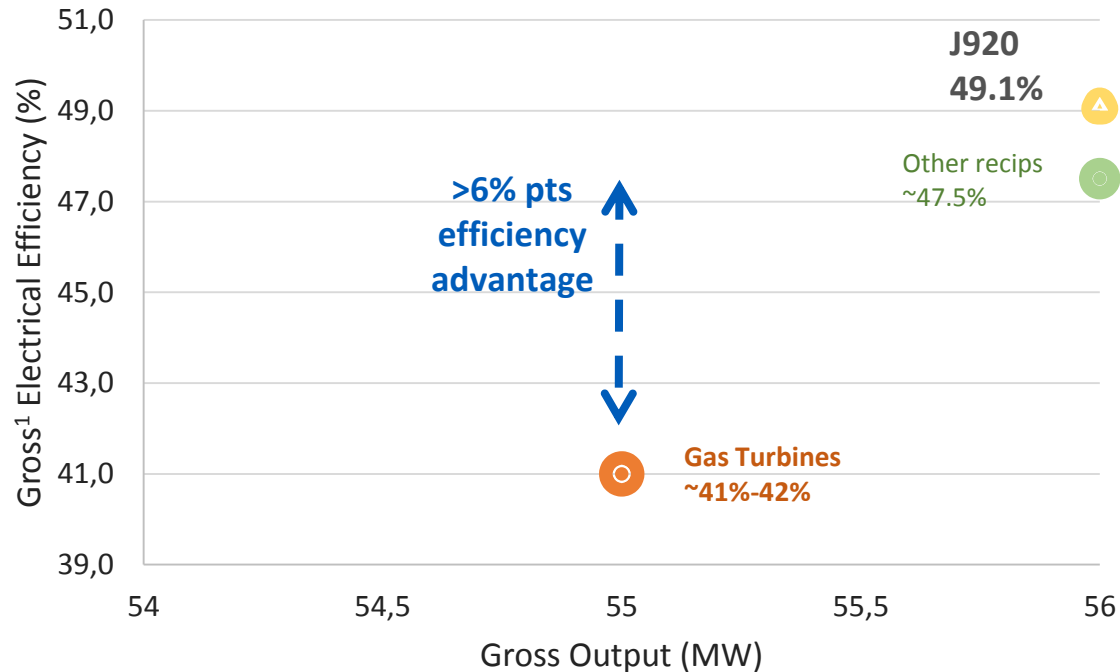
The J920 FleXtra solution:

- Full plant output synchronizing
- Multiple design & operating modes
- Flexible solutions for dynamic markets
- High efficiency at part load
- Fast load ramping and shedding
- 10MW unit: 20% load on unit
- 100MW plant: turn down to 2% load

J920 FleXtra has superior load-following capabilities compared to turbines

CREATING CUSTOMER VALUE

Best-in-class SC efficiency



1. 60 Hz, ISO, no tolerance, pf 1, LHV, genset terminals
Source: Gas Turbine World, Product Brochures from websites

Unique features create value

- ✓ High efficiency ... increased # of dispatch calls
- ✓ Fast-start for peak grid price realization
- ✓ Redundancy for high power availability
- ✓ Redundancy for max revenue capture
- ✓ No water usage
- ✓ No derating up to 48°C

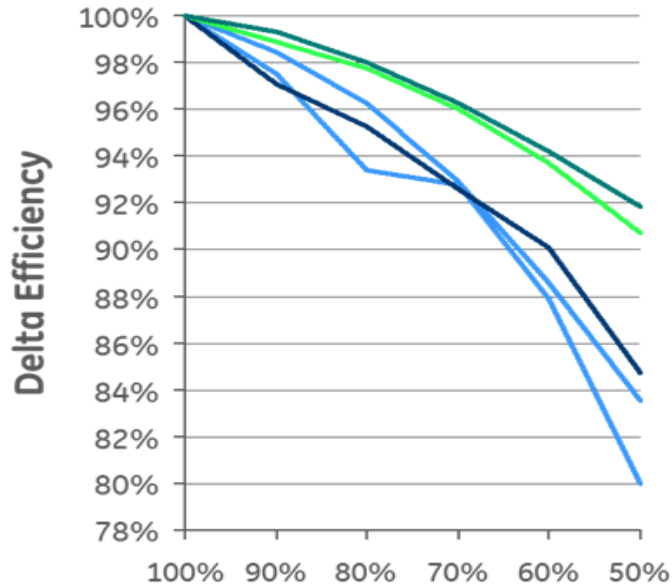
J920 Flextra delivers significant lifetime fuel savings vs GT in SC

PERFORMS BETTER ON HOT DAYS AND AT HIGH ALTITUDES

Gas Turbine w/EVAP Other reciprocating player J920

Efficiency vs Part Load (%Diff)

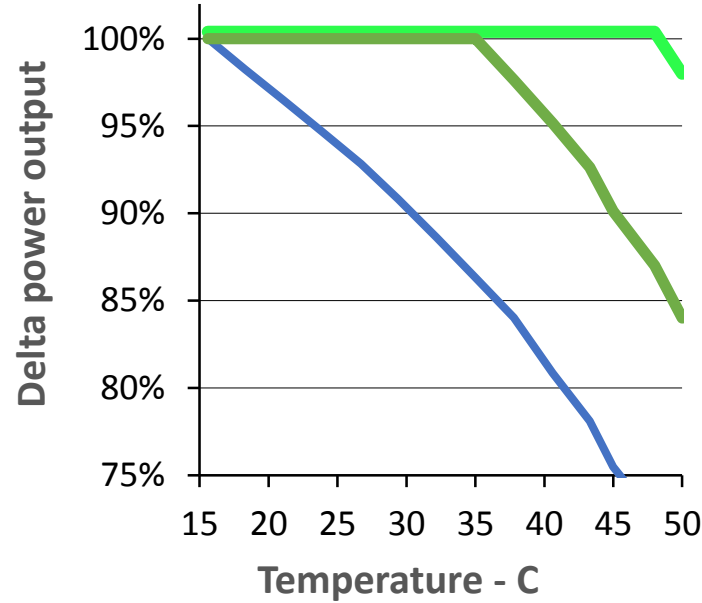
Areo, HD & Recips x 1 unit – EVAP, 60Hz, 25C, 60%RH



High part load efficiency

Power vs. temperature

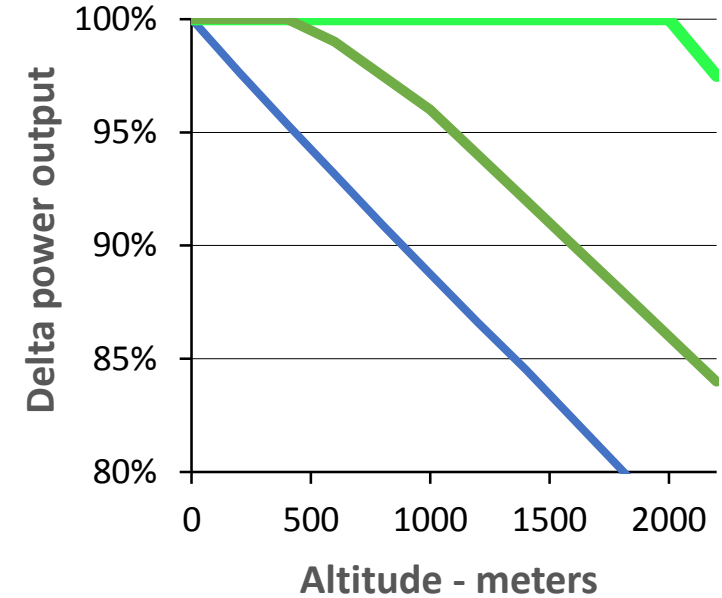
GT w/ EVAP - 60 Hz, 0m, 60% RH



No derating 48°C

Power vs. altitude

Aero w/ EVAP - 60 Hz, 25C, 60%RH

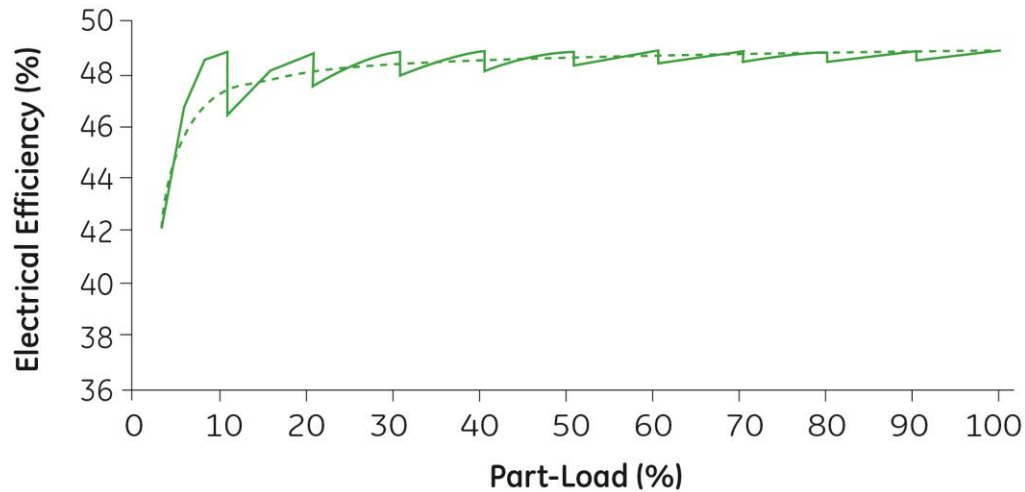


Full output up to 2000m

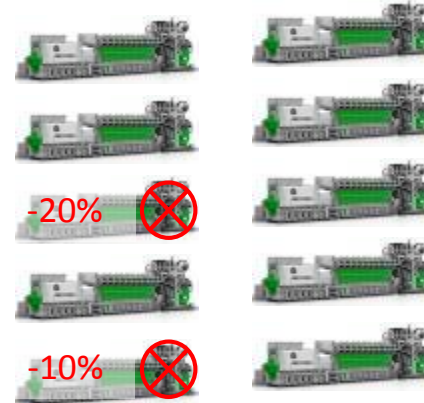
J920 FleXtra performs no matter what the conditions

PLANT FLEXIBILITY AND RESILIENCY WITH HIGH EFFICIENCY

Constant high simple cycle plant efficiency – 100MW example



Example: 10 x 10MW units
Unit reliability of 98%



Example: 1 x 100MW units
Unit reliability of 98%



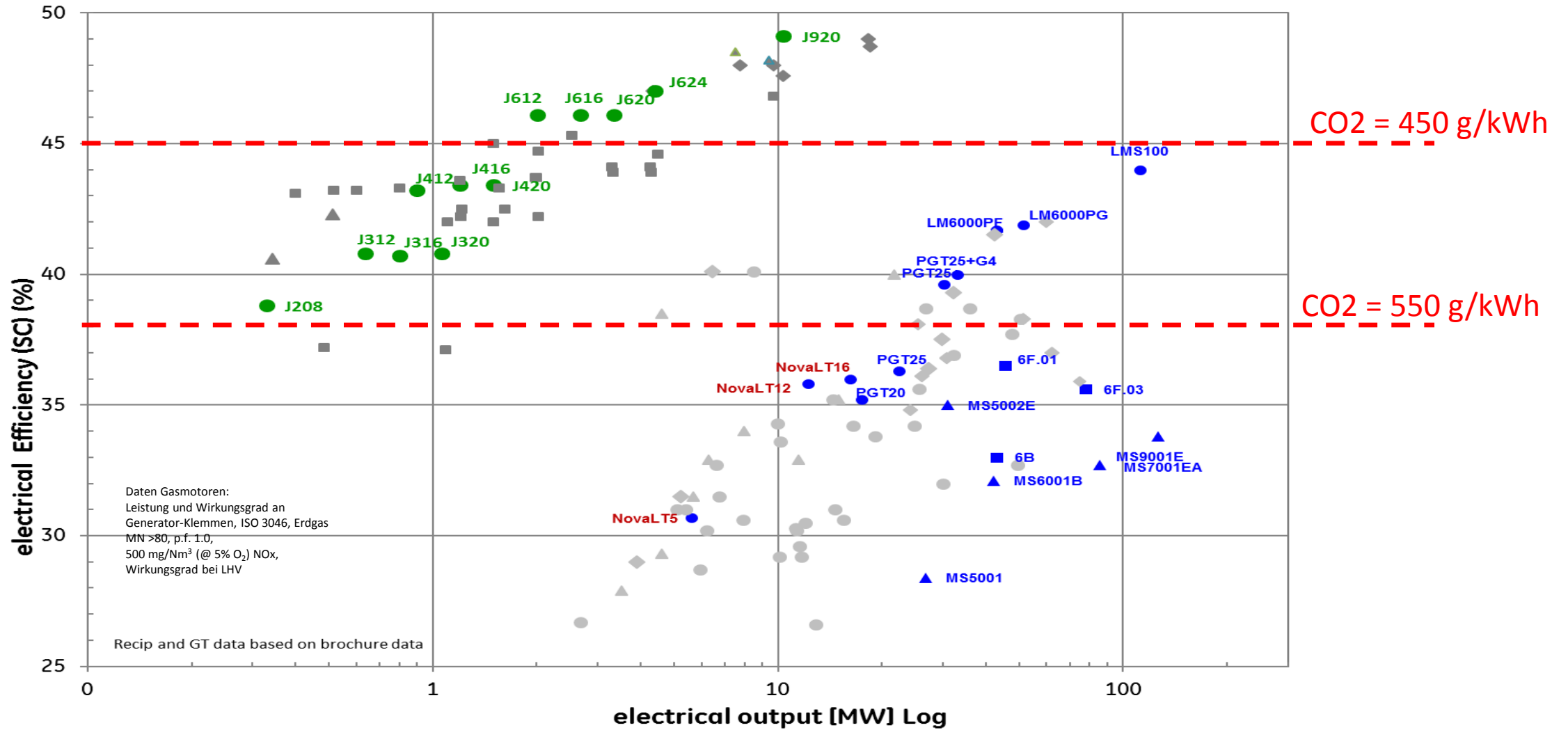
- Engine dispatching to maintain plant efficiency
- Run individual engines at part load with minor effect on total plant efficiency
- Suitable for grid firming (ancillary services)
- Plant turn down to 20% load or 2% with one engine

- Modularity provides lower plant output drop if unit trips
- Statistically unlikely more than 1 or 2 units tripped at the same time
- Drives high plant output reliability, availability & redundancy

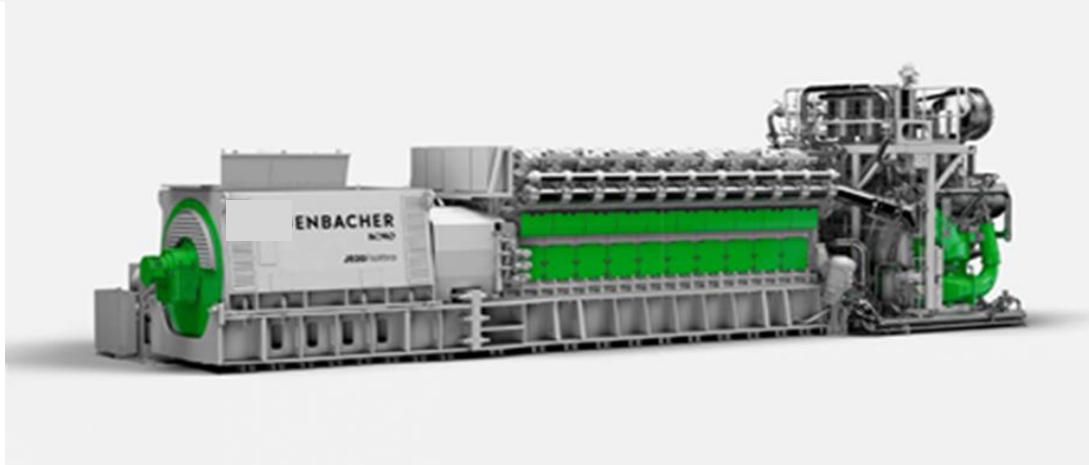
Grid or island power reliability is improved with modular gas engines

GAS ENGINES VS. GAS TURBINES

Efficiency vs Output (50Hz)



J920 FLEXTRA ENVIRONMENTAL FOOTPRINT



NO_x mg/Nm³ @5% O₂:

- Engine out: 500mg or 250mg
- Less than 25mg or 7.5ppm with after-treatment

Water usage:

- Closed loop engine circuit uses no water
- Radiator cooling circuit ~3L per week

Noise:

- 75dB(A) @ 10m standard
- 55dB(A) @ 10m option

Aesthetics:

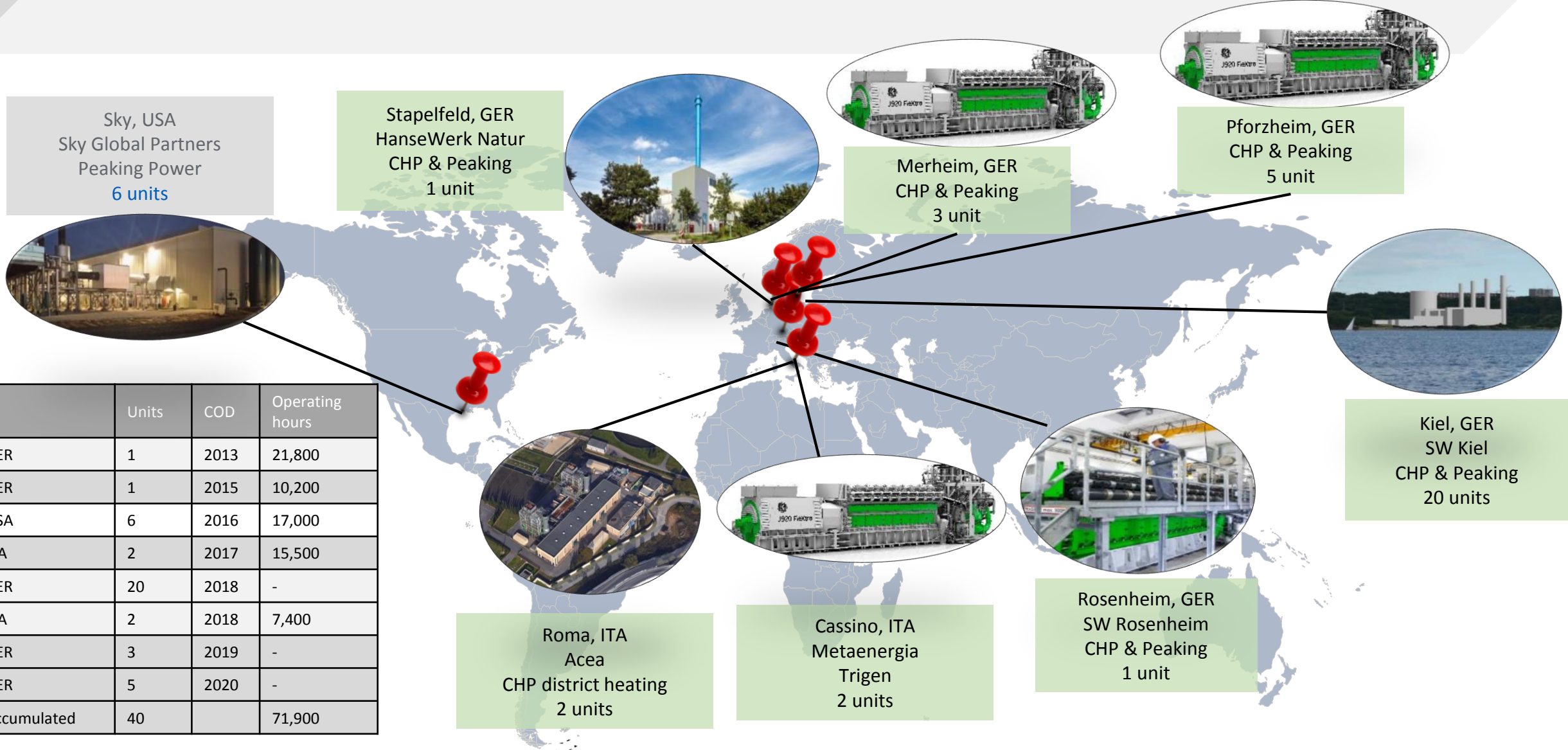
- Low silhouette with no visible emissions

The J920 Flextra ... Creating a New Power Plant Environment

INNIO's J920 FleXtra

- 10.38MW / 9.35MW, >49% eff.
- Full power to 48°C
- High plant flexibility & availability
- No water usage
- Modular design for ease of transport, installation, & service
- Long-term service agreement

J920 FLEXTRA REFERENCE PROJECTS



Sky, USA
Sky Global Partners
Peaking Power
6 units

Stapelfeld, GER
HanseWerk Natur
CHP & Peaking
1 unit

Merheim, GER
CHP & Peaking
3 unit

Pforzheim, GER
CHP & Peaking
5 unit

Kiel, GER
SW Kiel
CHP & Peaking
20 units

Roma, ITA
Acea
CHP district heating
2 units

Cassino, ITA
Metaenergia
Trigen
2 units

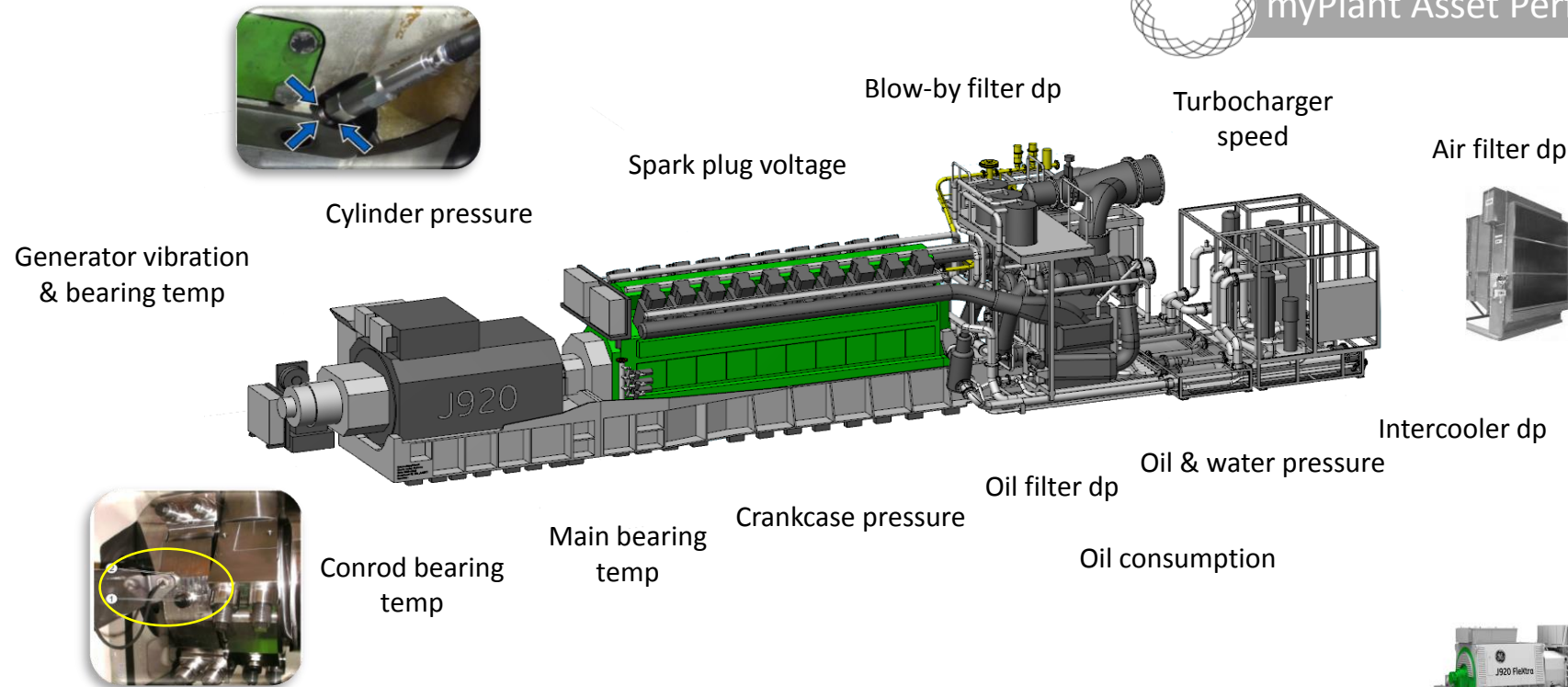
Rosenheim, GER
SW Rosenheim
CHP & Peaking
1 unit

	Units	COD	Operating hours
GER	1	2013	21,800
GER	1	2015	10,200
USA	6	2016	17,000
ITA	2	2017	15,500
GER	20	2018	-
ITA	2	2018	7,400
GER	3	2019	-
GER	5	2020	-
Accumulated	40		71,900

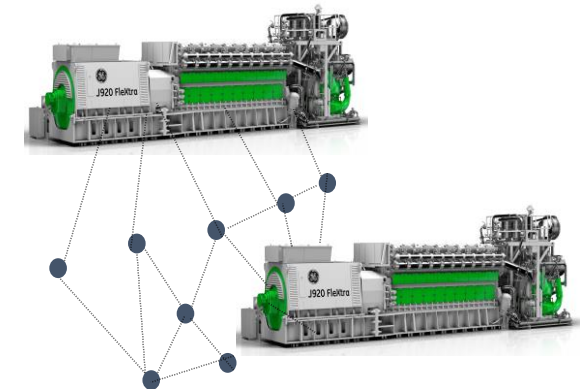
DIGITIZATION – IN OUR SMALL WORLD



myPlant Asset Performance Management



Digital twin:
A copy of a physical asset or process,
which evolves over its lifetime



J920 FleXtra Service

DESIGNED FOR EASE OF MAINTENANCE



Power Unit benefits

Each cylinder is separated

Exchange **power unit as an assembled set** for fast maintenance or in traditional way

Less than 4 hours for one complete power unit exchange

Other Benefits

Modular engine & component design

Easy access to turbocharger from top

Air intercooler with **inserts** for fast cleaning

Segmented Camshaft

Alternator bearing **self-lubricated** (same oil type than engine)

Consumables (e.g filters or ignition parts) are easy to access and to maintain

FLEXIBLE AND TAILORED AFTER SALES SOLUTIONS

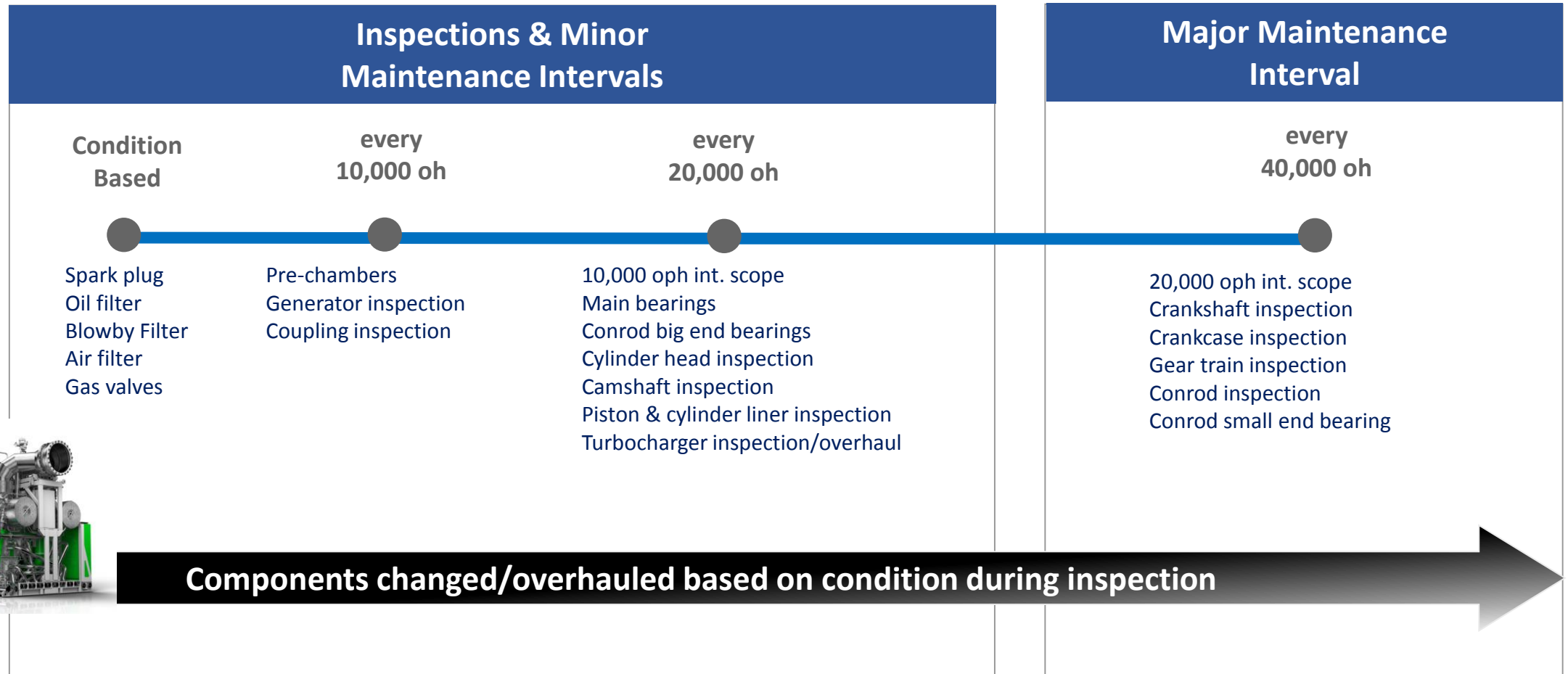
Some ideas how we can help to create customer value



- ✓ Scope ranging supervision of maintenance, planned maintenance, unplanned maintenance to full power plant operation
- ✓ Boost plant availability with condition based maintenance (CBM) via predictive analytics (myPlant* – remote monitoring system)
- ✓ 24/7 remote support and diagnosis
- ✓ Outage planning and coordination
- ✓ On-the job trainings for customer technician or operators
- ✓ Equipment upgrades to latest level of technology to increase customer revenue or reducing cost of operation
- ✓ ... and many more

Let's create YOUR tailored after sales solution together

J920 STANDARD MAINTENANCE

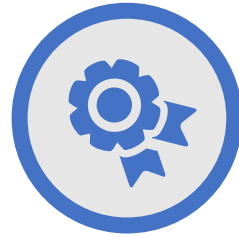


MULTIPLE VALUES FOR OUR CUSTOMERS



Fuel flexibility

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



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 (NOx, CO, SOx, etc.)
- / Ability to reduce CO2 footprint:
 - Use of renewable gases
 - High overall efficiency



Durability and reliability

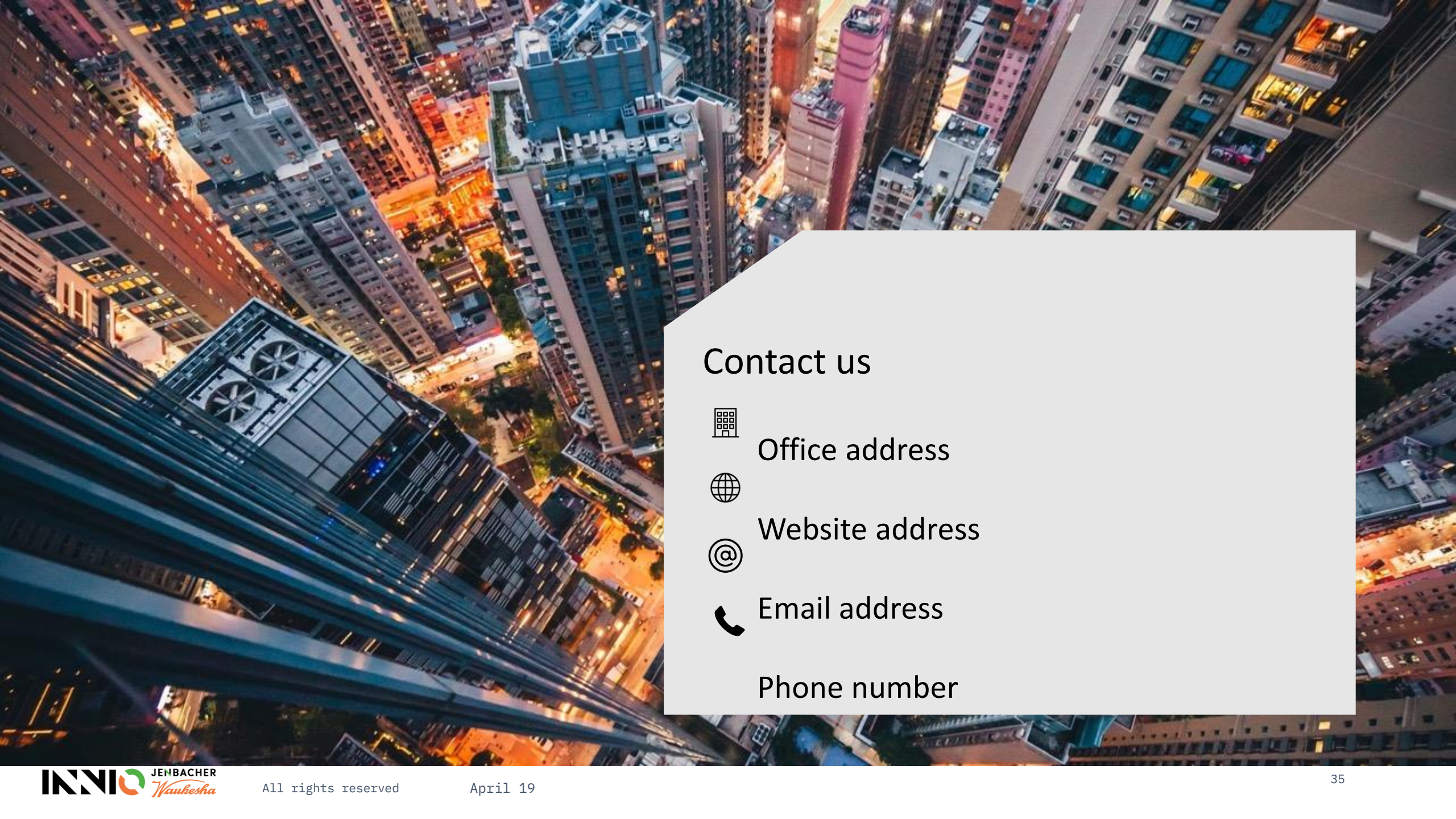
- / Established, field-tested designs
- / Optimized, robust engine components
- / Stationary engine concept
- / Increased operational safety and availability
- / Proven control and monitoring concept
- / Continuous focus on product development

INNIO

* Indicates a trademark

INNIO





Contact us



Office address



Website address



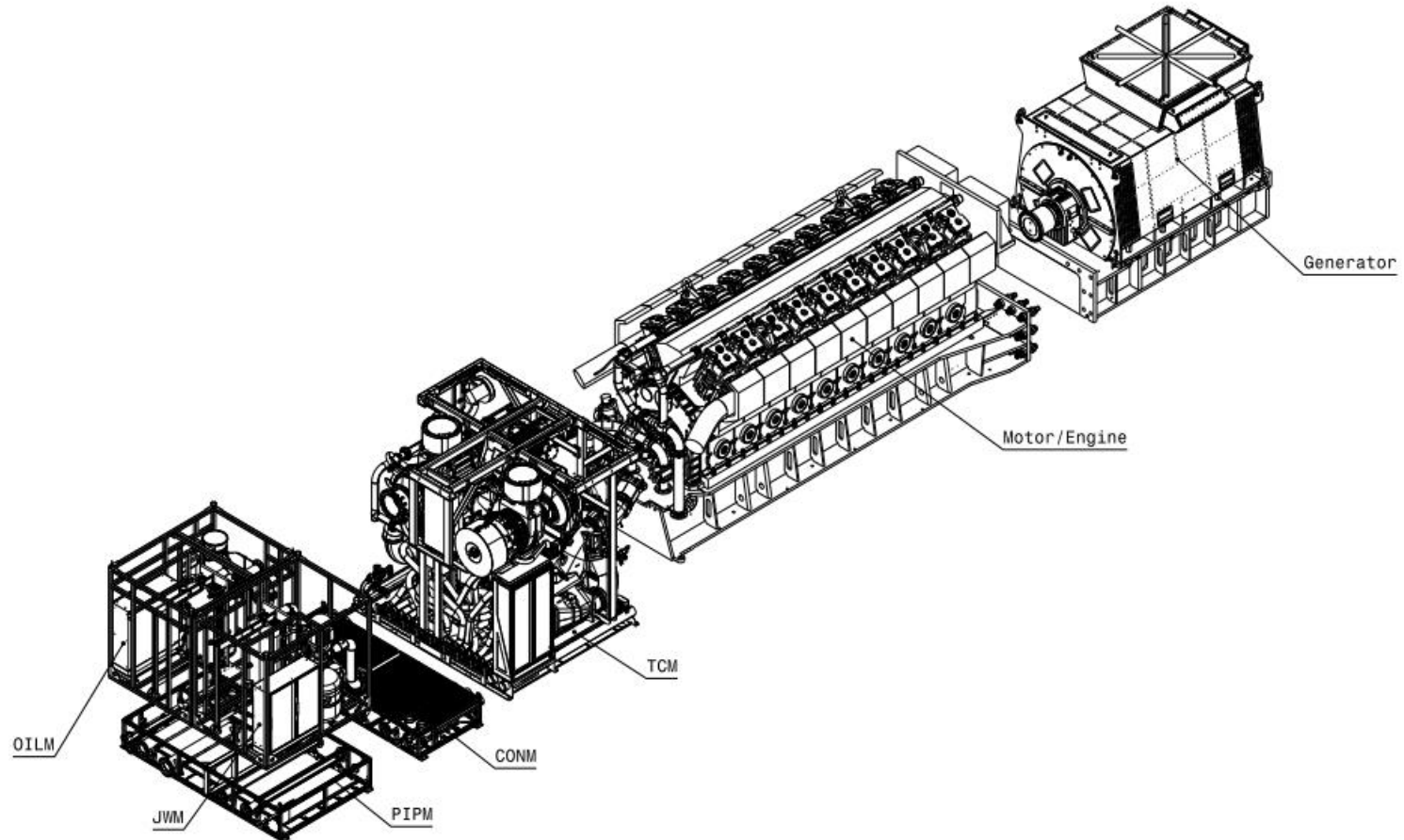
Email address



Phone number

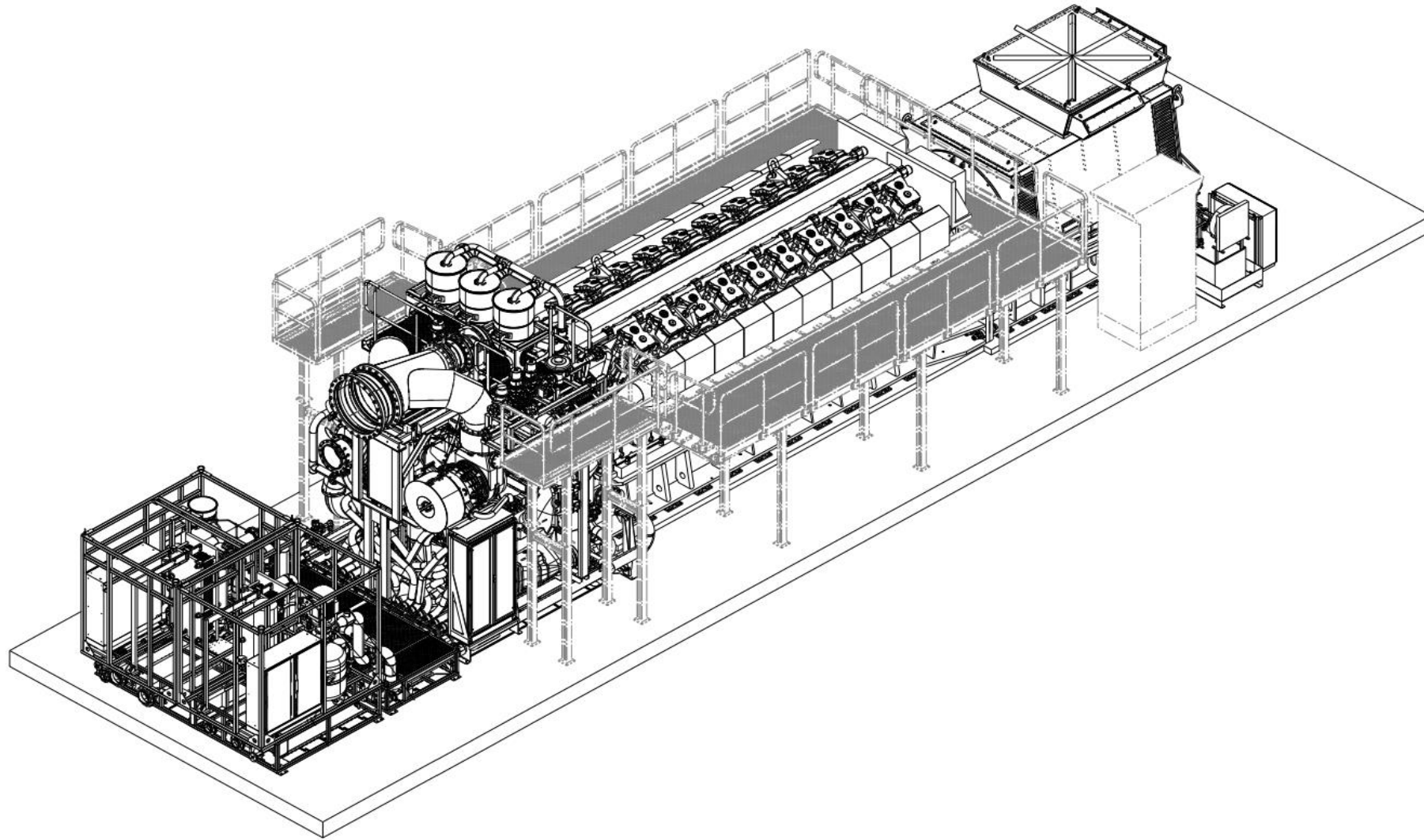


Modular design for easier installation



All main modules pre-fabricated and factory tested

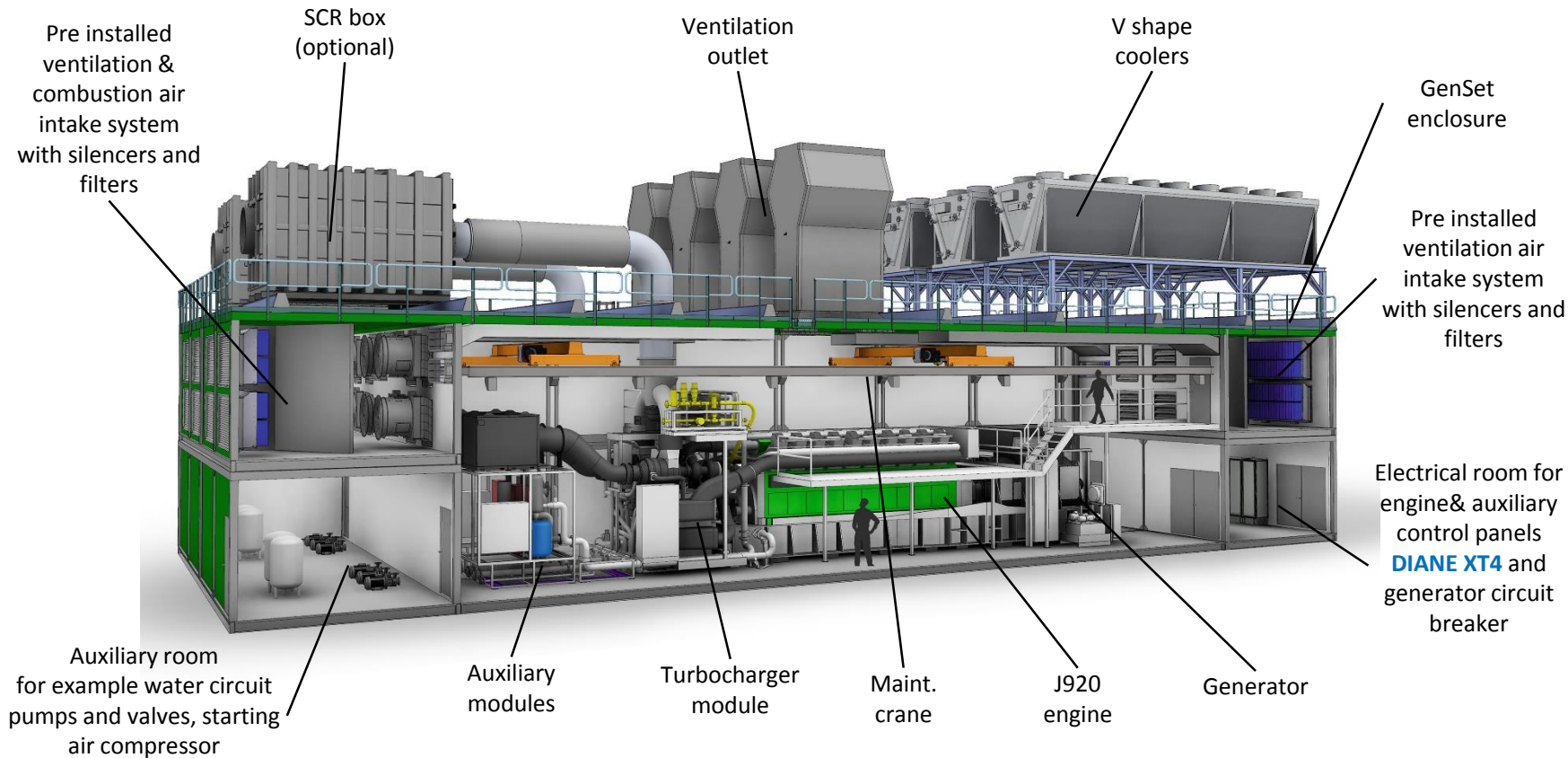
J920 - assembled



J920 FleXtra Reciprocating gas solutions



J920 PowerPack solution overview

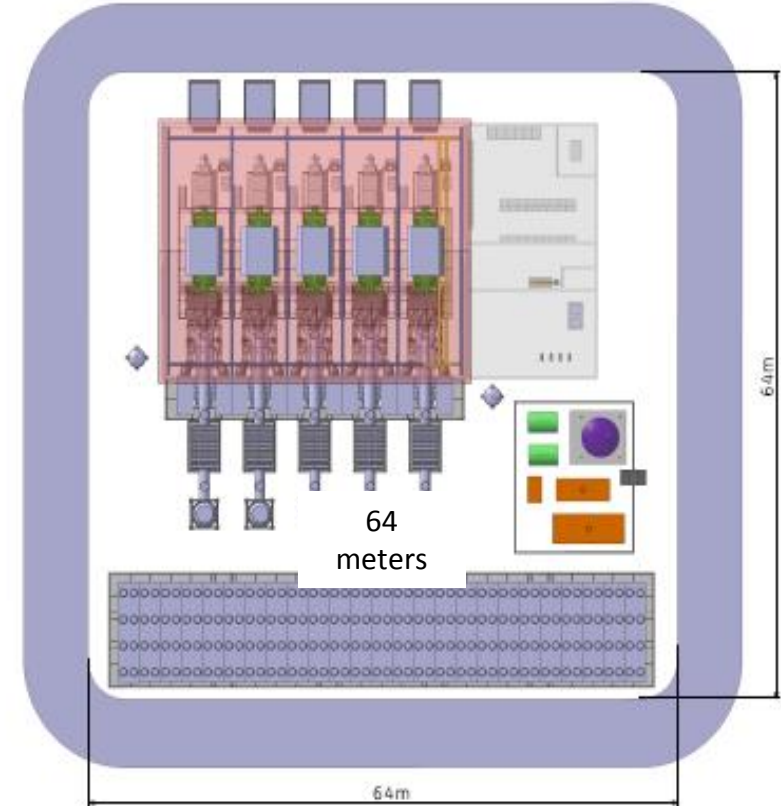
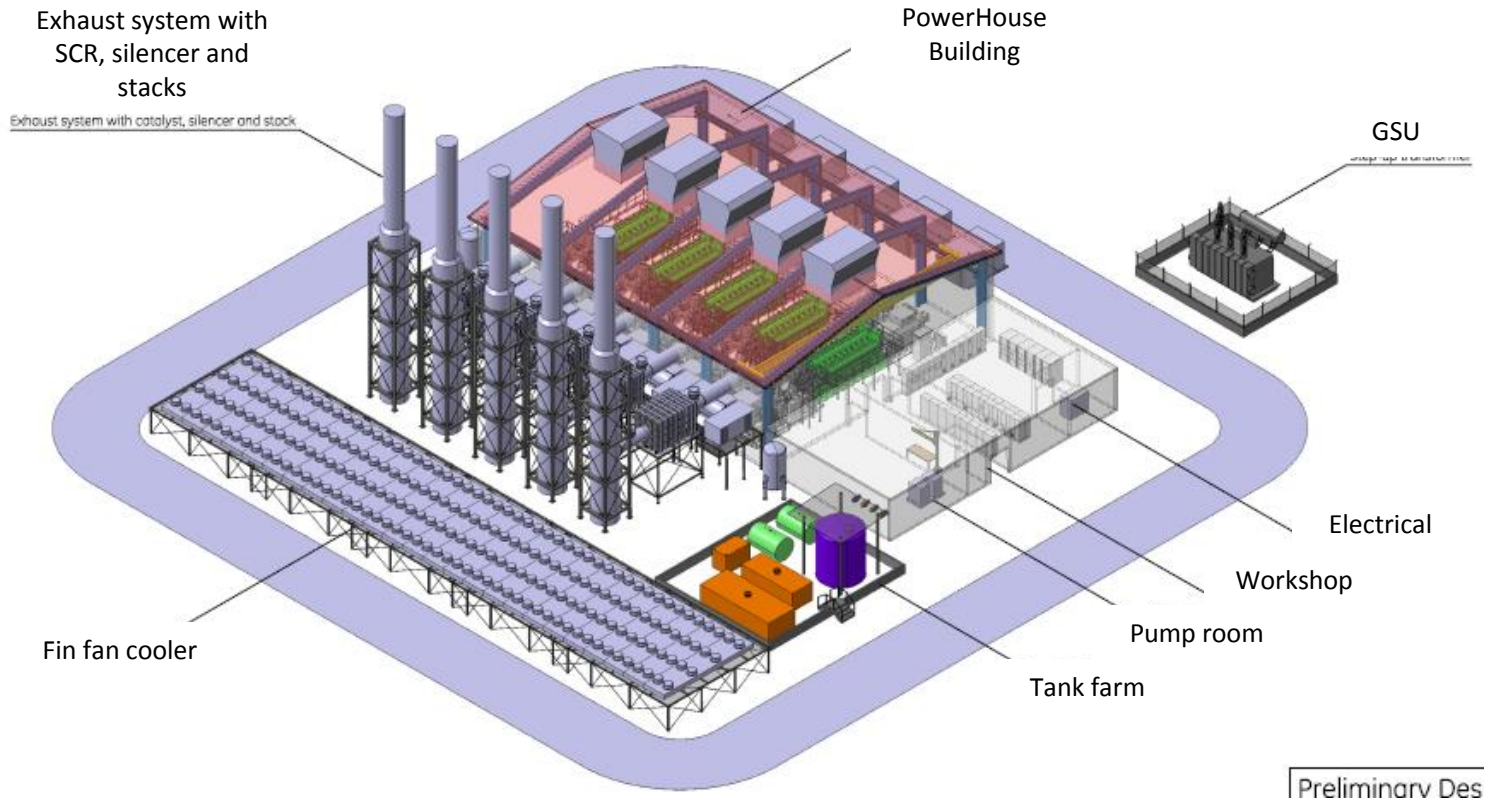


Advantages:

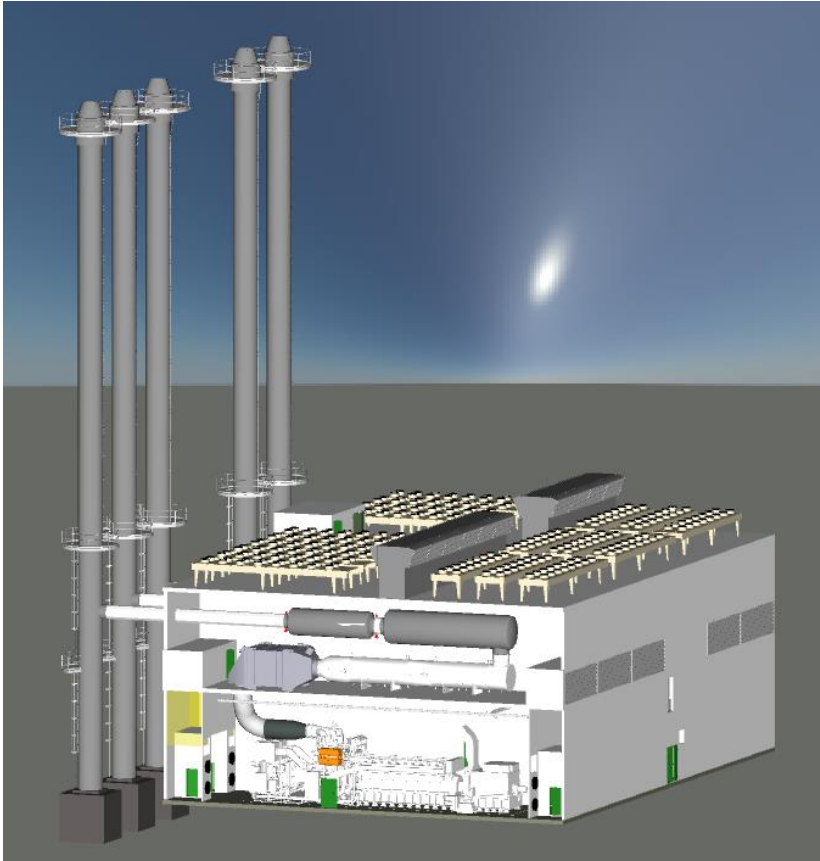
- Any power range
- Pre-engineered
- Pre-fabricated
- Pre-tested modules
- Fast installation <8 wks
- Fast commissioning <8 wks
- <14 months order to COD
- Sound: 75dB(A) @10m, lower if required
- Remote start/stop & surveillance
- Modular, mobile & easy MW additions
- Perfect for Remote sites or power islands

J920 PowerPack ... fast, flexible power at a competitive installed cost

5x J920 FleXtra power plant – 50Hz



J920 FleXtra CHP+ and Innovative CHP+ solutions



Advantages:

- 10MW to 200MW
- CHP+ with ~92% total efficiency
- >95% total efficiency with innovative CHP+ including an integrated heat pump
- Single or multiple engines per room
- Vertically integrated lowering footprint
- Suitable for operation within city limits
- Sound 75dB(A) @10m – lower if required
- Heat storage capability
- Suitable for ancillary services
- Engineered solutions from GE

J920 FleXtra CHP Solutions ... up to 95% total efficiency