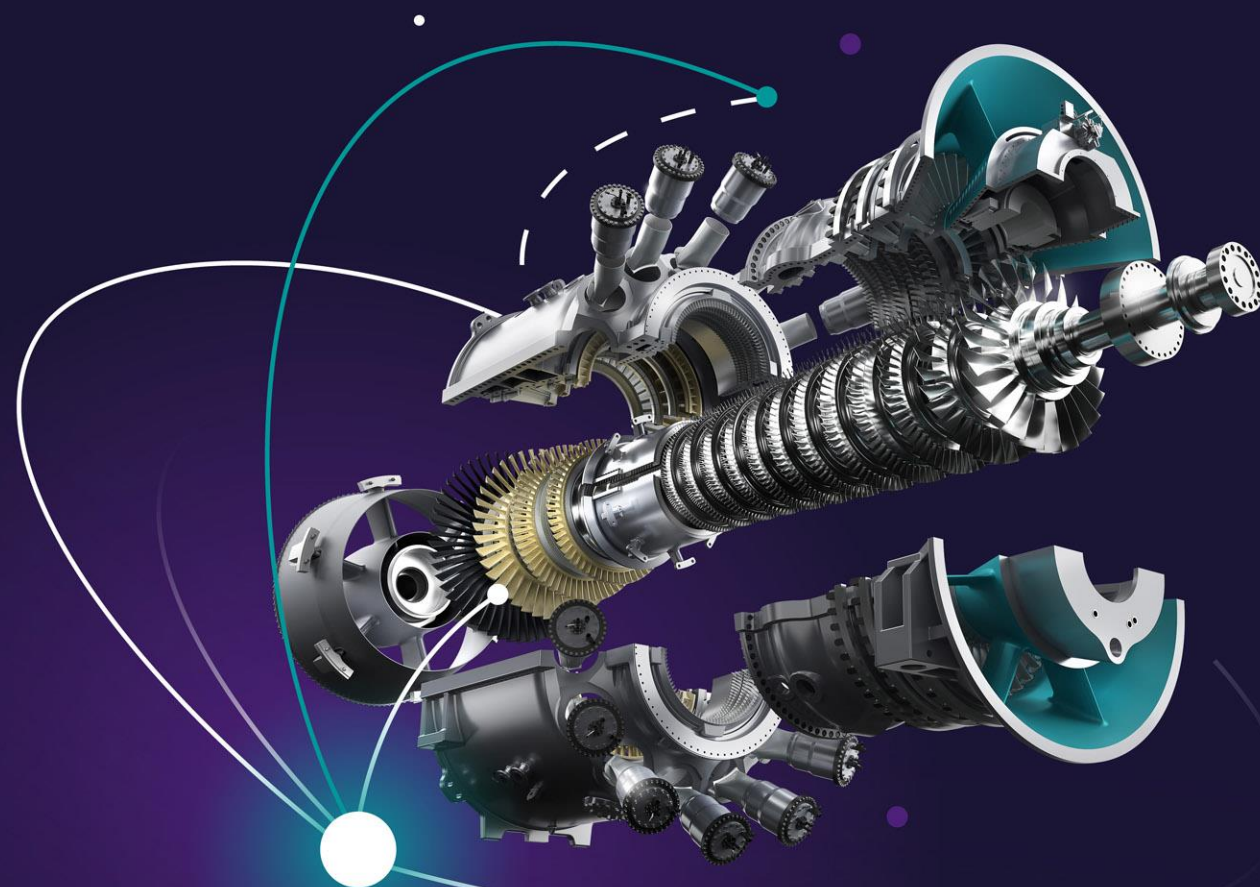


# Testing the big one

# SGT 9000HL

# 20 months on grid

Offshore Energy Conference, November 2nd 2021



Globalization

Demographic change

Urbanization

# Climate change

Digitalization

are drastically changing  
our environment.

At the same time, we expect a ...

**>50%** increase in global  
electricity generation by 2040

And still ...

**770 million people**  
are living without access to electricity

# HL Class Story

## H<sub>2</sub>L helps to decarbonize power generation

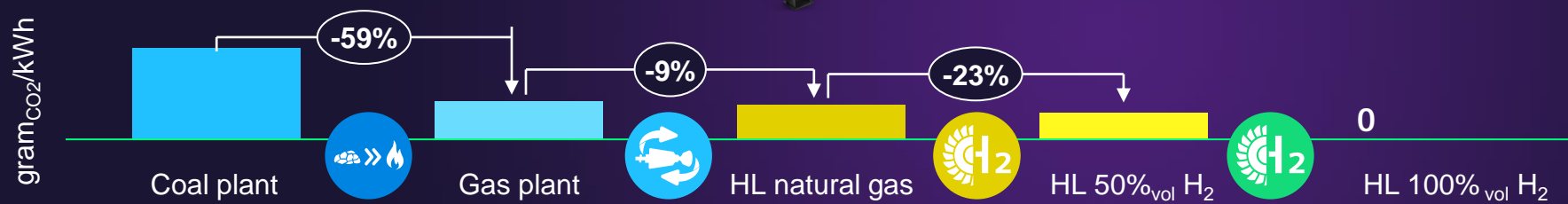
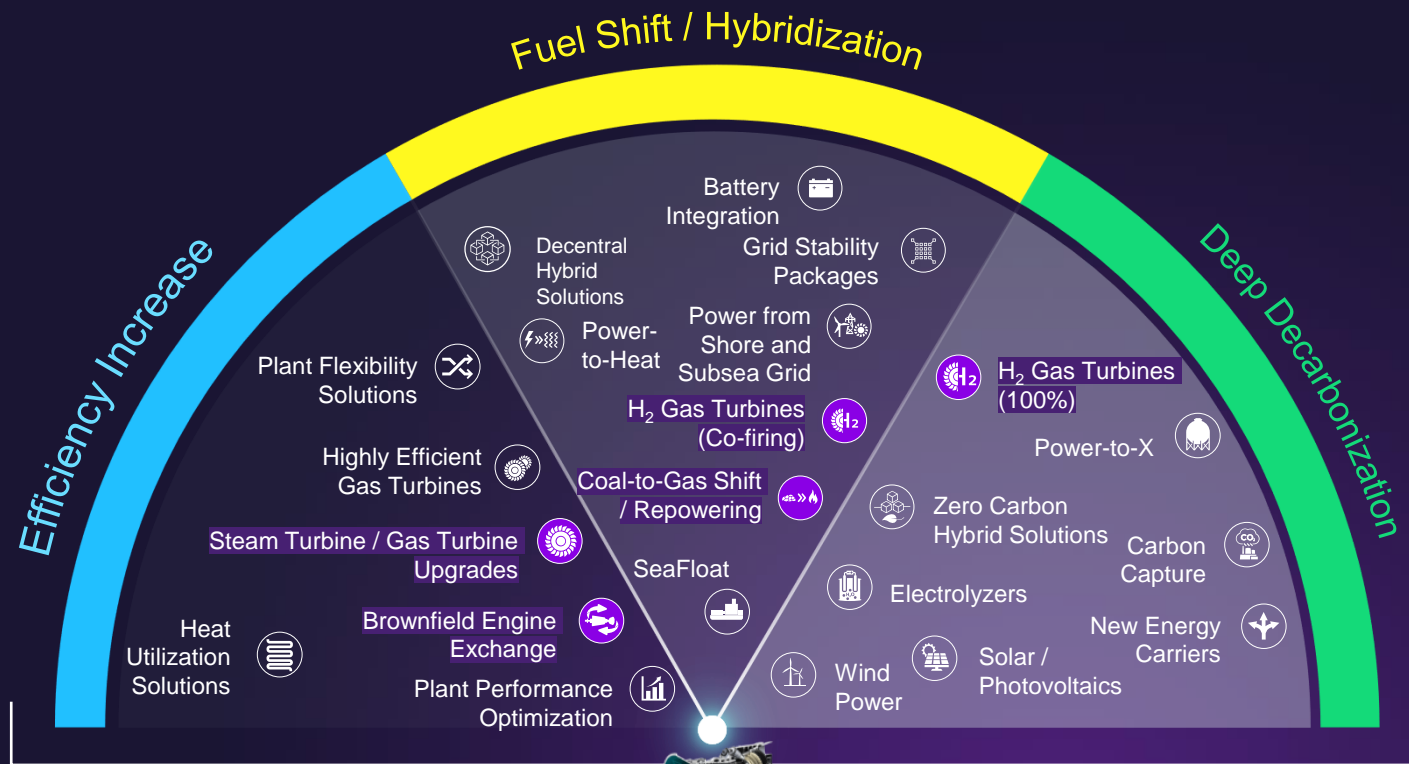


F-class to HL-class  
**-0.2M** t<sub>CO2</sub> / year

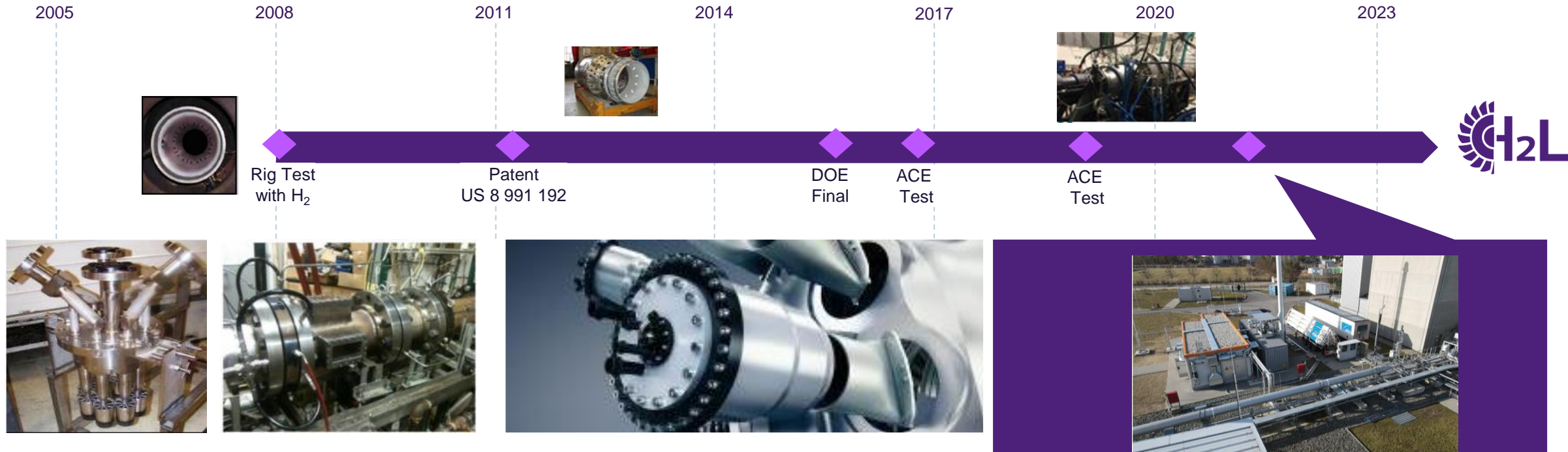
Coal to 5-9000HL  
**-3.7M** t<sub>CO2</sub> / year

HL-class to 50%<sub>vol</sub> H<sub>2</sub>  
**-0.5M** t<sub>CO2</sub> / year

HL-class to 100%<sub>vol</sub> H<sub>2</sub>  
**-2.2M** t<sub>CO2</sub> / year



# SGT-9000HL hydrogen combustion technology build for the future based on a decade of the making



## Ultra Low NOx Rig Test (2008)

- Full pressure testing achieving >30% H<sub>2</sub> by volume

## DOE H<sub>2</sub> Program (2005-2015)

- Combustion technology capable of 60% H<sub>2</sub> and 40% N<sub>2</sub> by volume

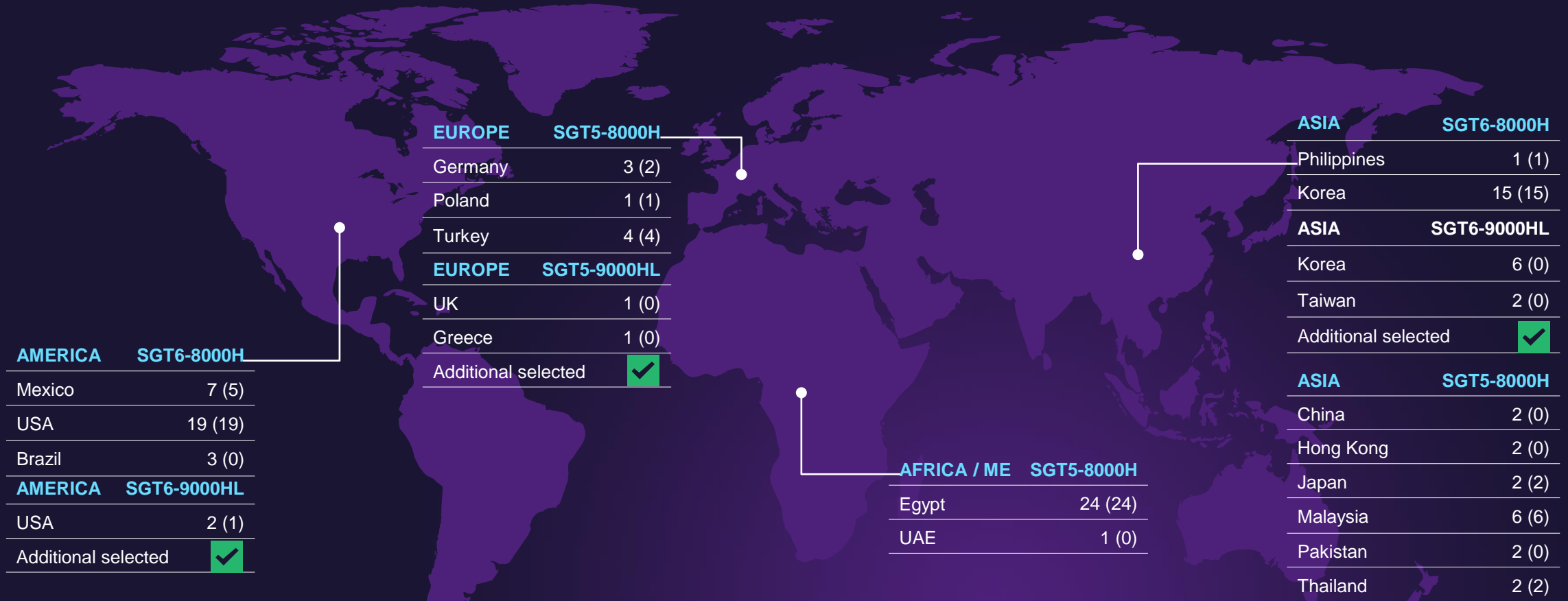
## Advanced combustion system

- Development of the ACE combustion system
- Flexible combustion system for a wide variety of fuels, incl. H<sub>2</sub>, and for high efficiencies

## Latest Test

- Test exceeded expectations
- SGT-9000HL combustion system proven up to 50% H<sub>2</sub> by volume

# HL-class: Based on H-class design and experience >2,000,000 fired hours on 4 continents



**96** H-class  
are under contract

**84** units  
are in commercial operation

**12** HL-class  
are under contract

**Several units**  
are technical selected

# Evolutionary design based on the architecture of H- and F-Class: Decades of proven technology come together

SGT-8000H series



SGT5-4000F



SGT6-5000F



**Shared  
DNA**



Single tie-bolt  
Hirth serration/steel rotor



Air-cooled / 4-stage turbine

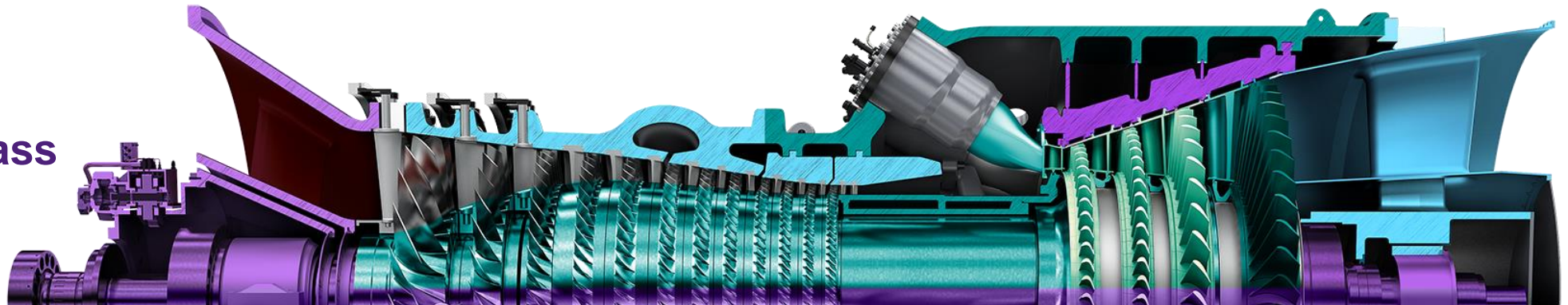


Can annular combustion  
system



Hydraulic Clearance  
Optimization

**New  
HL-class**



# Joined DNA based on proven H-class design

SGT-9000HL series

## Compressor

Enhanced 3D airfoils (3<sup>rd</sup> gen)  
1 Inlet Guide Vane/2 Variable Guide Vanes  
Simplified casing (combined Vane Carrier)  
Individual cantilevered stator vanes

## Mid frame

Rotor Air Cooler  
12/16 combustors

## Turbine

Cooled stage 4, free-standing  
Rotating heat shields

## Turbine exit cylinder

Ambient cooled Turbine Exhaust  
Casing Struts

Combined Journal  
Thrust bearing

topview

SGT-8000H series

Enhanced 3D airfoils (2<sup>nd</sup> gen)  
1 Inlet Guide Vane/3 Variable Guide Vanes

12/16 combustors  
No Rotor Air Cooler

Uncooled Turbine Blade 4, shrouded  
Metallic rings  
Interstage seal housing/Pre-swirler

Compressor bleed-cooled Turbine  
Exhaust Casing struts

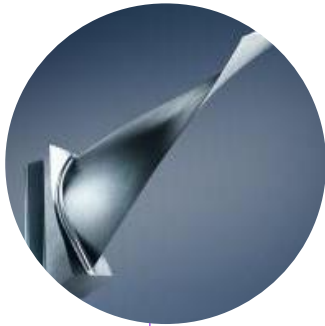


# Cutting-edge technologies for advanced performance >64%

## Future ready technology carrier

### 3D blading

- 3D optimization of airfoils for higher compressor efficiency and higher power density
- Better performance during part-load operation and temperature range



### Advanced combustion system

- Reduced cooling air due to advanced TBC and improved sealing
- Increased number of premix fuel injectors
- Shorter residence time



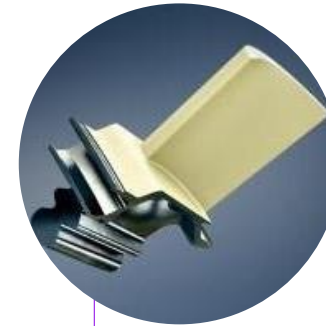
### Super-efficient internal cooling features

- Advanced mikro core geometry
- Directionally solidified blade technology instead of single-crystal design
- Improved blade life



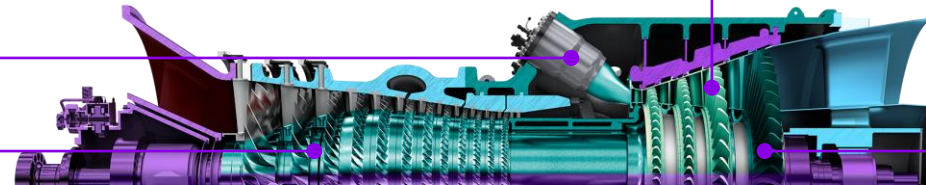
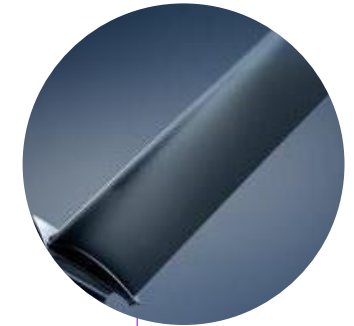
### Advanced thermal barrier coatings

- Enhanced strain tolerance
- Sacrificial layer
- Increased robustness



### Turbine blade 4

- Free-standing
- Internally cooled blade
- Removable without cover lift
- Reduced exit losses



**All technologies thoroughly tested at Siemens Energy owned test facilities and under real conditions**

# HL-Projects achieved Insurance market standard

## Independent external assessments

### Consultants and Insurance Companies

- Early involvement into HL development
- Continuous assessment of HL development
- Independent technology review and assessment
- Reports created

“[...] we see no incremental technical risk with utilizing the SGT5/6-9000HL beyond what was experienced with the SGT5/6-8000H [...]”

“... the HL is a typical Siemens engine”

**Independent external assessments confirm evolutionary design**

## Insurance


### Insurance –Panel

- HL complies with Insurance Market
- Project specific Insurability Letters available on request
- Market-common conditions and premiums for HL-projects

## HL-Project Conditions

LEG 2 equivalent 

Erection all risk (EAR) 

Advance Loss of Profit / Delay in Start Up (ALOP) 

Property All Risks / Machinery Breakdown (PD/MB) 

Business Interruption(BI) 

Premium

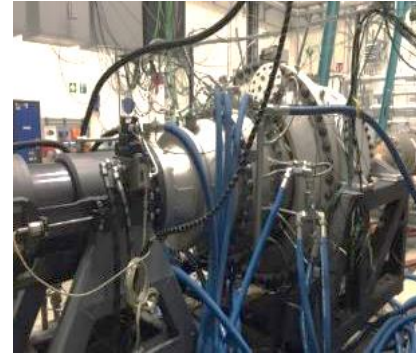
Market common

**Testing and validation as integral part of the Siemens Energy gas turbine development ensures high reliability and availability for products and technologies**



## Thorough 3-step testing and validation concept

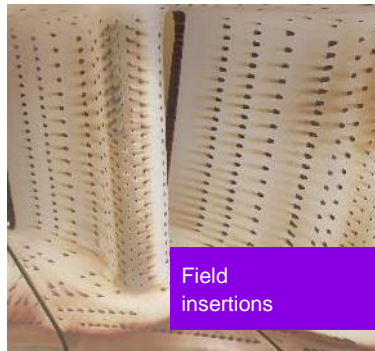
**Component testing  
e.g. Clean Energy Center**



**Prototype testing  
Berlin Test Facility**



**Testing & validation under site conditions  
Field insertions + full engine**



# Engine testing & validation under site conditions

## Duke Energy Lincoln County



Fuel gas and fuel oil, part load, (fast) WetC, fuel gas heating

Fast ramping, start/stop, hot ambient simulation (APH), high load and fast fuel transfer, grid code

Full rotor dynamics, endurance runs, flutter, leakage, compressor surge, thermal paint

NO<sub>x</sub>, CO, CO<sub>2</sub>

## SSE Keadby II



Fuel gas, part load, (fast) WetC, ST Co-Start, combined cycle optimization

Fast ramping, start/stop, UK grid code

Full rotor dynamics, endurance runs, flutter, leakage, compressor surge, thermal paint

NO<sub>x</sub>, CO, CO<sub>2</sub>





# Improvements based on testing & validation and > 1 year On Grid Experience

  
performance

Power output  
Efficiency

880 MW / 655 MW  
>64% / >64%

  
durability

Baseload operation  
Starting reliability

exceeded\*  
100% ignition



Constructability

Proven in biggest  
CCGT power plant

  
emissions

GT-Emissions base  
GT-MEL  
GT-Emissions optimized  
according to 50Hz / 60Hz Market needs

25ppm NO<sub>x</sub> 10ppm CO  
≤28%  
15 / 9 ppm NO<sub>x</sub>

  
Fuel flexibility

NG, LNG, LPG  
Diesel  
H<sub>2</sub> (vol.)

100%  
100%  
50%

\*Baseload Operation with Power Output beyond Duke contract values  
GT=Gasturbine

# SGT6-9000HL Validation-Results at Lincoln County



GT ExWorks

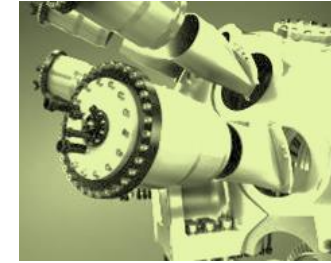


SGT6-9000HL gas turbine successfully achieved first fire

First Fire

## 60Hz

Grid Sync.

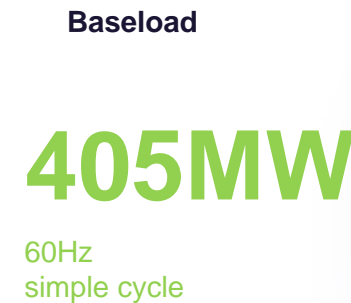
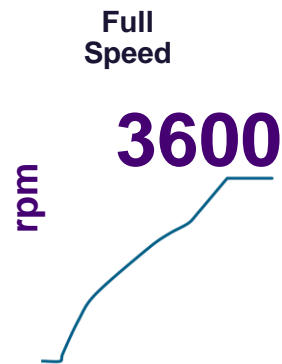


Emissions Technology



Endurance Run

Fuel Oil Testing

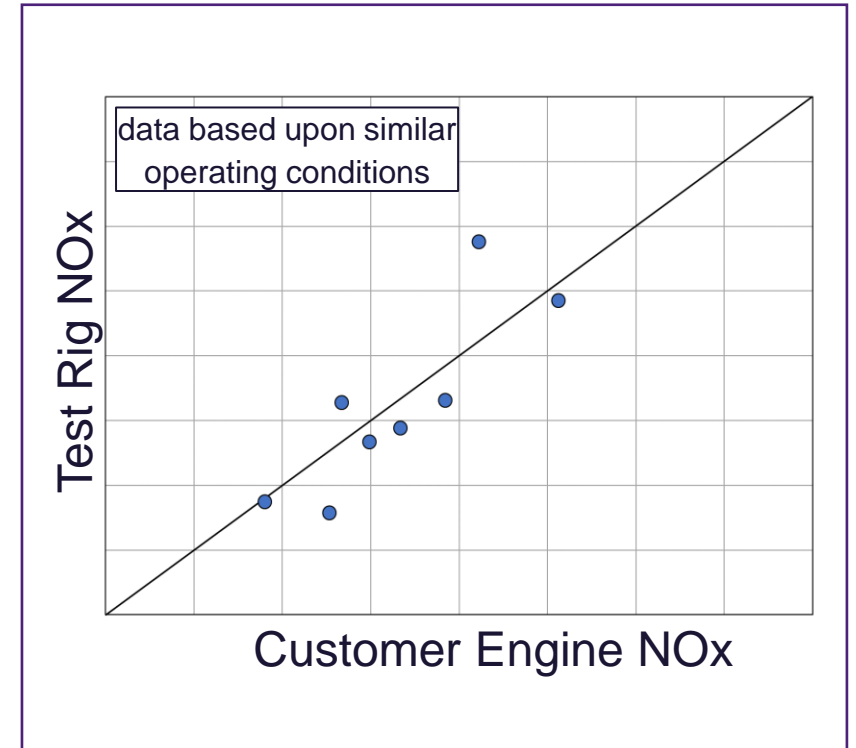
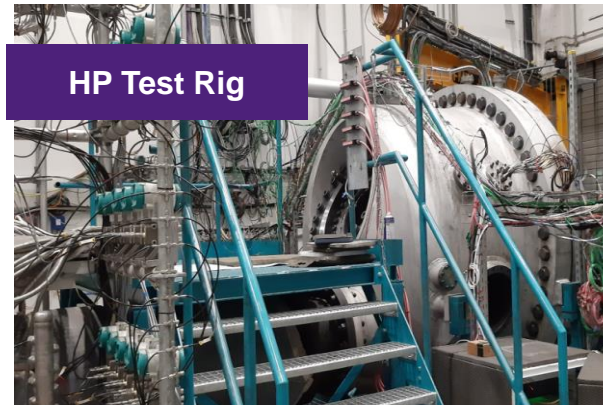
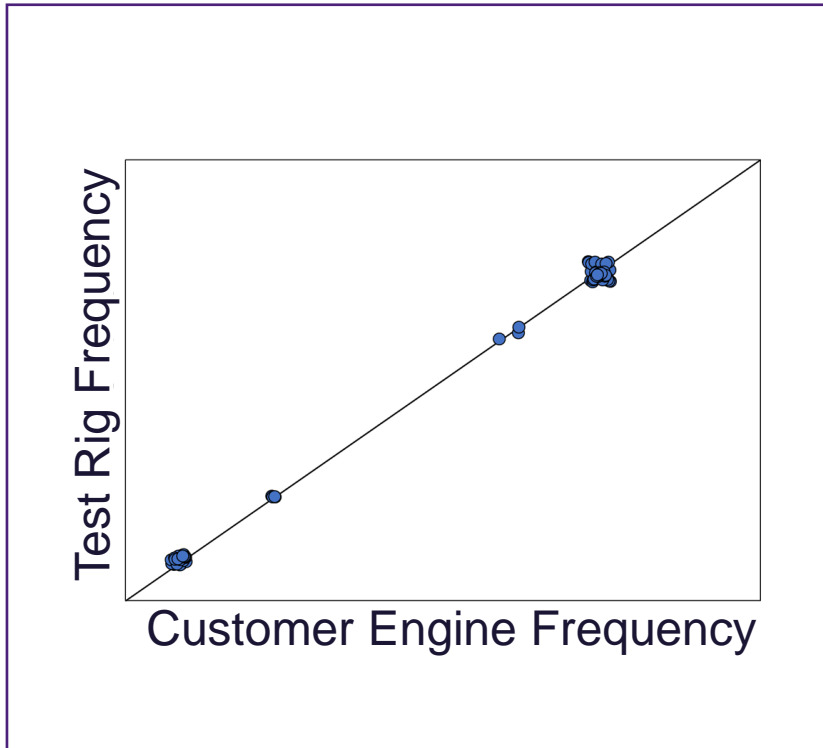


Commercial Dispatch

Thermal Paint Test

The SGT6-9000HL has successfully completed various test and validation milestones

# Frequency / ACE NOx Emissions Rig to Engine Correlation



**NOx emissions and frequencies are aligned with high pressure combustion rig**

# Duke Lincoln County Commercial Dispatch Operation



June 17, 2021

Subject: Gas Turbine Agreement

To whom it may concern:

Siemens Energy and Duke Energy have entered in an agreement for the construction, testing and handover of a 9000HL gas turbine at the Duke Energy Lincoln Combustion Turbine Station ("Agreement").

The gas turbine is undergoing testing and verification by Siemens Energy. Siemens Energy, under the Agreement, will implement further upgrades to the gas turbine in due course before the targeted handover in 2024. Duke Energy has been requested by Siemens Energy to certify the achievements of that unit.

Notwithstanding any rights and obligations under the Agreement, Duke Energy thus documents as follows:

### Certificate of Commercial Dispatch

Duke Energy herewith confirms that the Siemens Energy gas turbine 9000HL at Duke Energy's Lincoln Combustion Turbine Station in North Carolina has been commercially dispatched starting on May 8, 2020.

Sincerely,

Gary Thompson  
Project Director



Regis and Christian ringing the bell, commemorating the successful completion of the first phase of testing



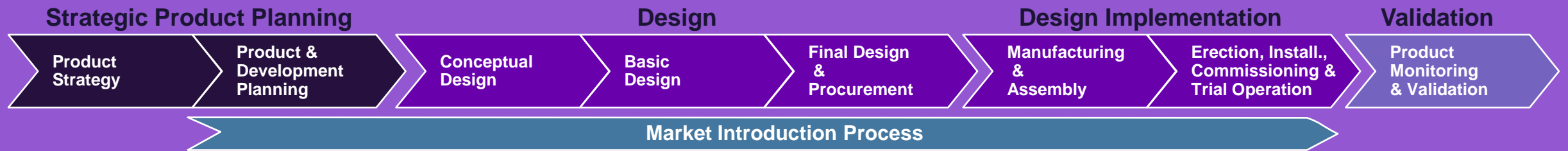
Regis Repko (SVP, Duke Energy) and Christian Bruch (CEO, Siemens Energy) touring the first operating SGT-9000HL site at Lincoln County, North Carolina, USA.



# Integrated Product Development

## Concurrent Engineering including Test and Validation

### Testing & Validation: An integral part of the Product Development Process



Parts testing

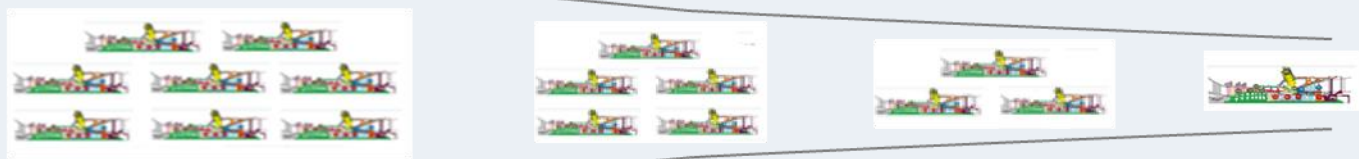
Component testing

System/GT testing

GT field testing

CC field operation

- Set based Design**
- Superior solutions are able to be identified.
  - Development risk is managed



Set variants down selected as design maturity increases

Final down selection at engine validation test

### Set Based Design to effectively manage risk in the product development process



“When we look at a new generating asset, we consider performance, efficiency and maintenance cost over the entire life cycle, so we look out 30 years.”

Kevin Murray

Duke Energy's Vice-President for Project Management and Construction



performance



flexibility



durability



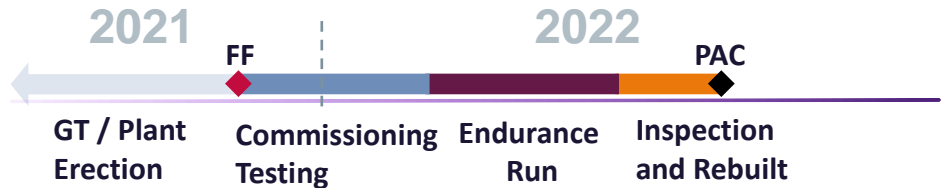
emissions

## SGT6-9000HL at Duke Lincoln County: Highlights after one year of testing

- ✓ We exceeded the **contractual committed performance**
- ✓ Successful **completion of emissions air permit** operational protocol, together with governmental body
- ✓ **Testing is ongoing according to our validation protocol**, with a conservative approach **prioritizing safety of personnel and hardware**
- ✓ **In spite of the effects of COVID-19**, the team has done an exceptional job to keep the **testing plan on track**
- ✓ We are **already provided electricity on customer request** for dispatch optimization and grid/fleet support

# SGT5-9000HL validation and endurance run

## Keadby 2, UK – World's largest 1x1 CCGT plant



performance

Fuel gas, part load, (fast) WetC, ST Co-Start, combined cycle optimization



flexibility

Fast ramping, start/stop, UK grid code



durability

Full rotor dynamics, endurance runs, flutter, leakage, compressor surge, thermal paint



emissions

NO<sub>x</sub>, CO, CO<sub>2</sub>

- Constructability approach proven
- GT, AIP installed
- CI with robot proven
- Mechanical erection done
- Additional commissioning for engine validation (3000 sensors + testing)
- Extensive endurance run / Inspections
- Data acquisition in commercial operation

# GT Auxiliary Integrated Package (AIP)

Improved **constructability**

Single lift and installation of modules  
Modules test fit at shop & interfaces verified  
by laser scanning / photogrammetry

Designed for **serviceability**

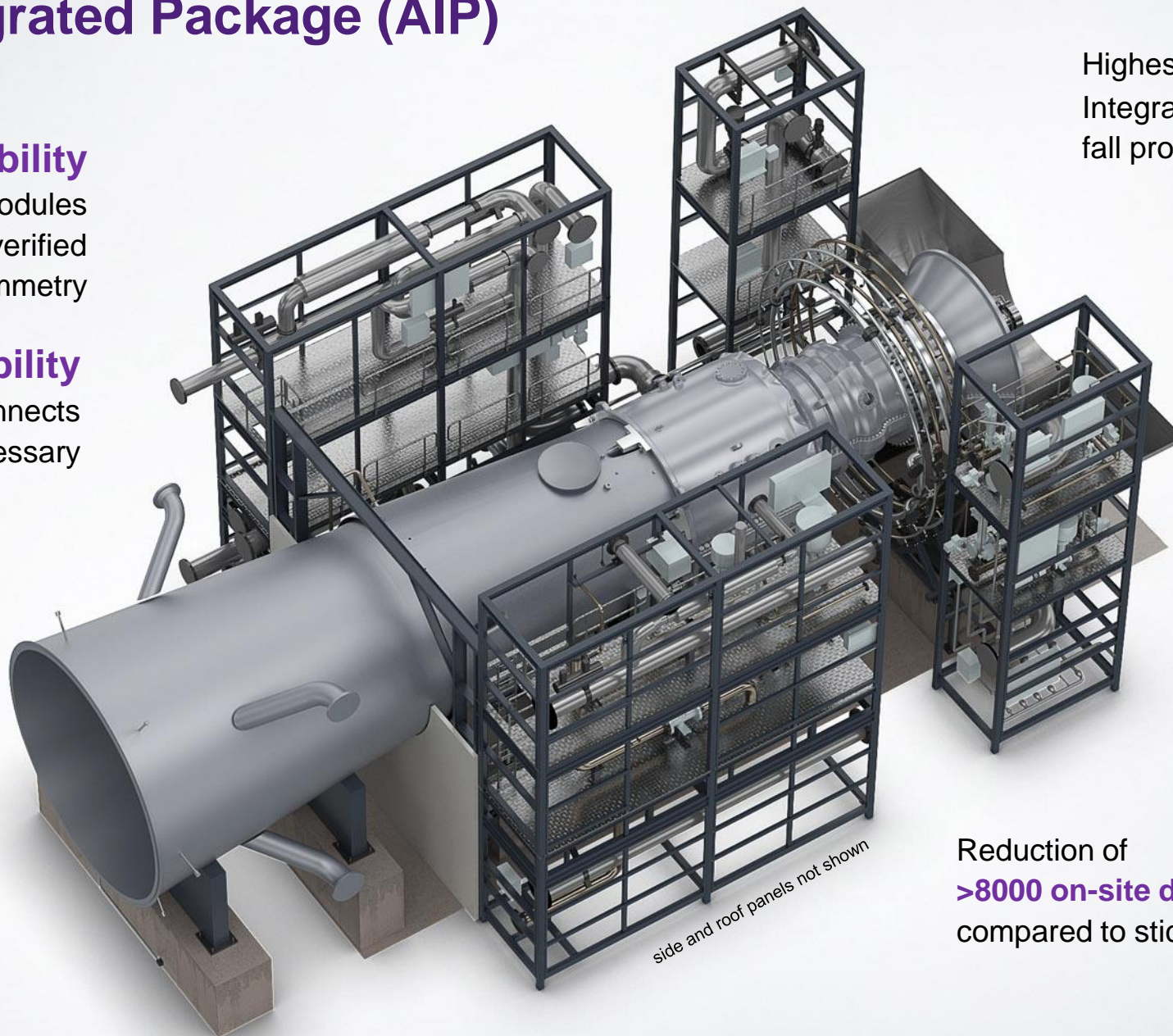
Quick removal of panels and disconnects  
of flanges where necessary

**>40%** pre-wired signals

**10** pre-fabricated steel racks

**+35%** of pipes pre-assembled  
compared to stick-built

Minimizes field welding  
**down to 17 field welds**



Highest **safety**

Integrated lifting lug &  
fall protection tie-off points

Truck

**transportation**

Enhanced **quality**

Installation in clean,  
shop-controlled  
environment

**>90%** pre-fabricated  
inline components  
like valves and  
instrumentation

Reduction of

**>8000 on-site direct man hours**  
compared to stick-built

# GT Auxiliary Integrated Package (AIP)

Reduction of >8000 on-site direct man hours compared to stick-built



**10** pre-fabricated steel racks

Highest **safety**

**>90%** pre-installed inline components

Down to **17** field welds

Improved **constructability**

Designed for **serviceability**

**>40%** pre-wired signals

Enhanced quality

**35%** more pipes pre-assembled\*

\*compared to stick built



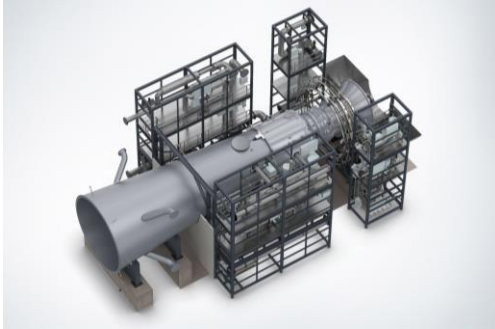
side and roof panels not shown

21

21

# Proven plant concepts

From 3D model...



Verification of  
constructability approach

... to reality



“I have listed some of the things below that my team liked about the AIP’s.

## We really didn’t see anything that we didn’t like.

- **Piping and E&I pre-installed** will cut down on congestion of work crews onsite.
- **Piping being tested** already will speed up the completion and sell off the piping systems.
- Insulation of piping offsite will allow the turbine area to stay **cleaner** during **construction**.
- Alignment pins to help ensure **proper fit** up of modules at site.
- Modules being **test assembled** offsite to allow for custom spacer fabrication.
- Overall, the modules will **reduce the construction time** onsite and cut down on the saturation of craft in the area with traditional installation.”

Contractor Site Manager

# AIP Product Features



**Open Bays for GT Access**



**Tie-Off points**



**Detent Pins & lanyards**

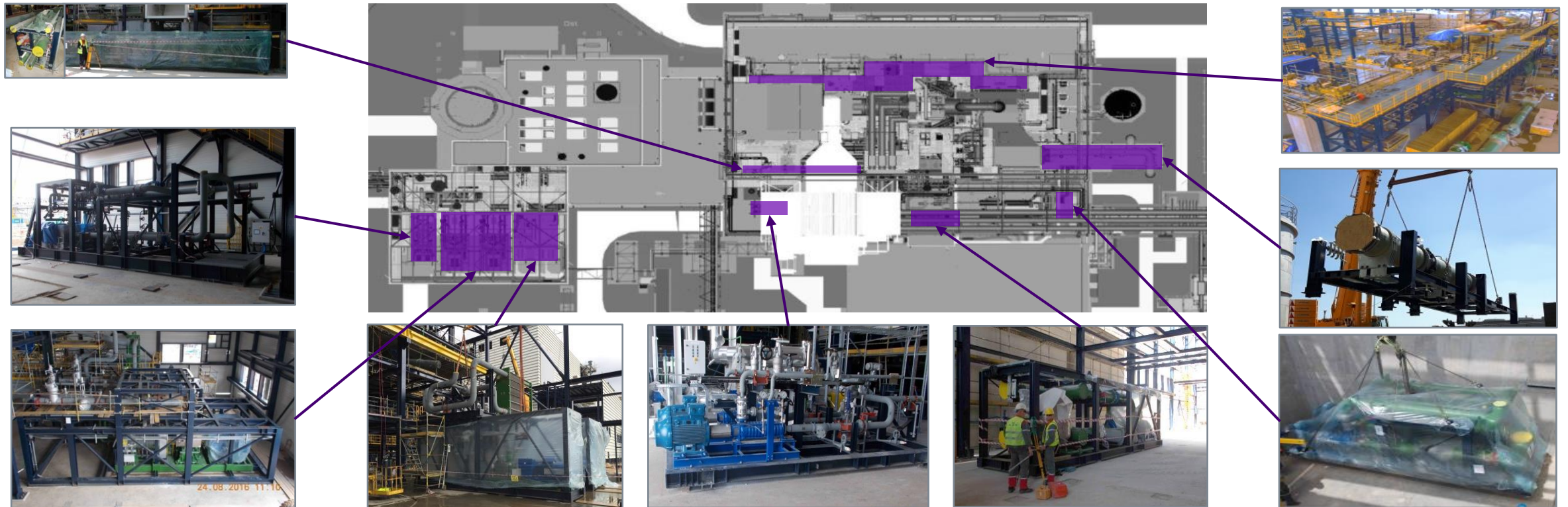


**Removable Service Sections**



**Service Robot**

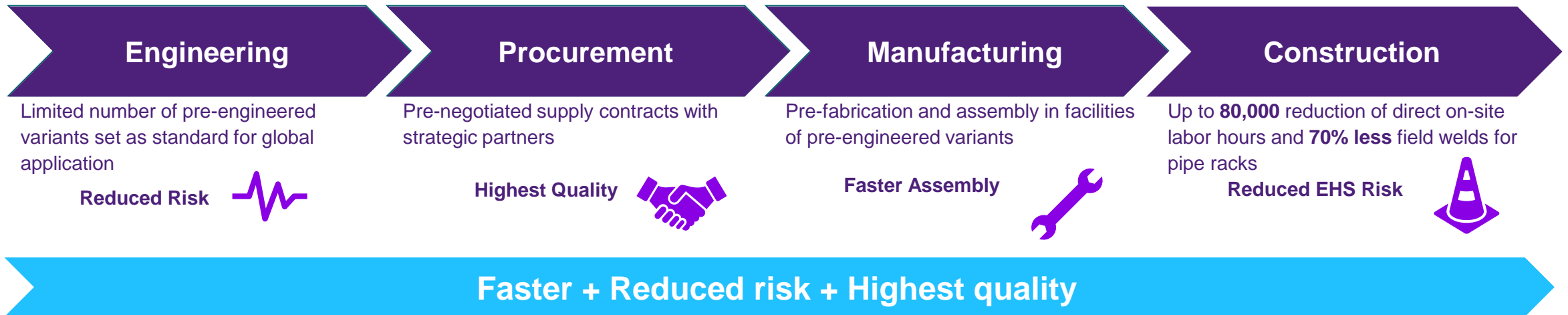
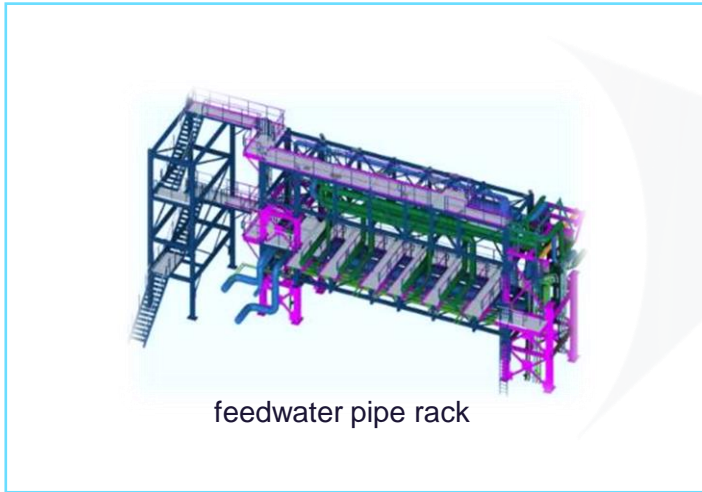
# Prefabricated Modules for Water Steam Cycle



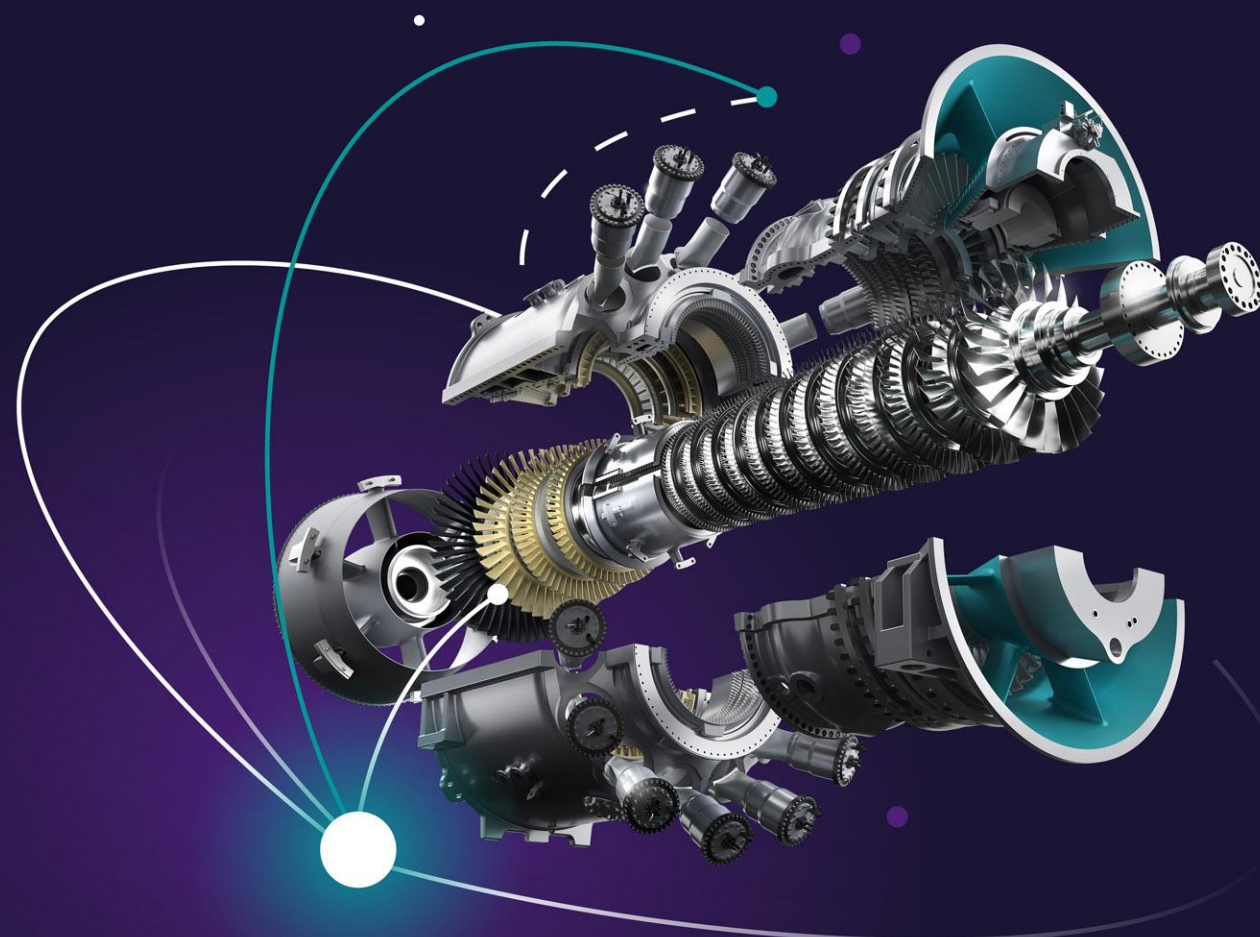
Stringent Concept for the whole Power Plant



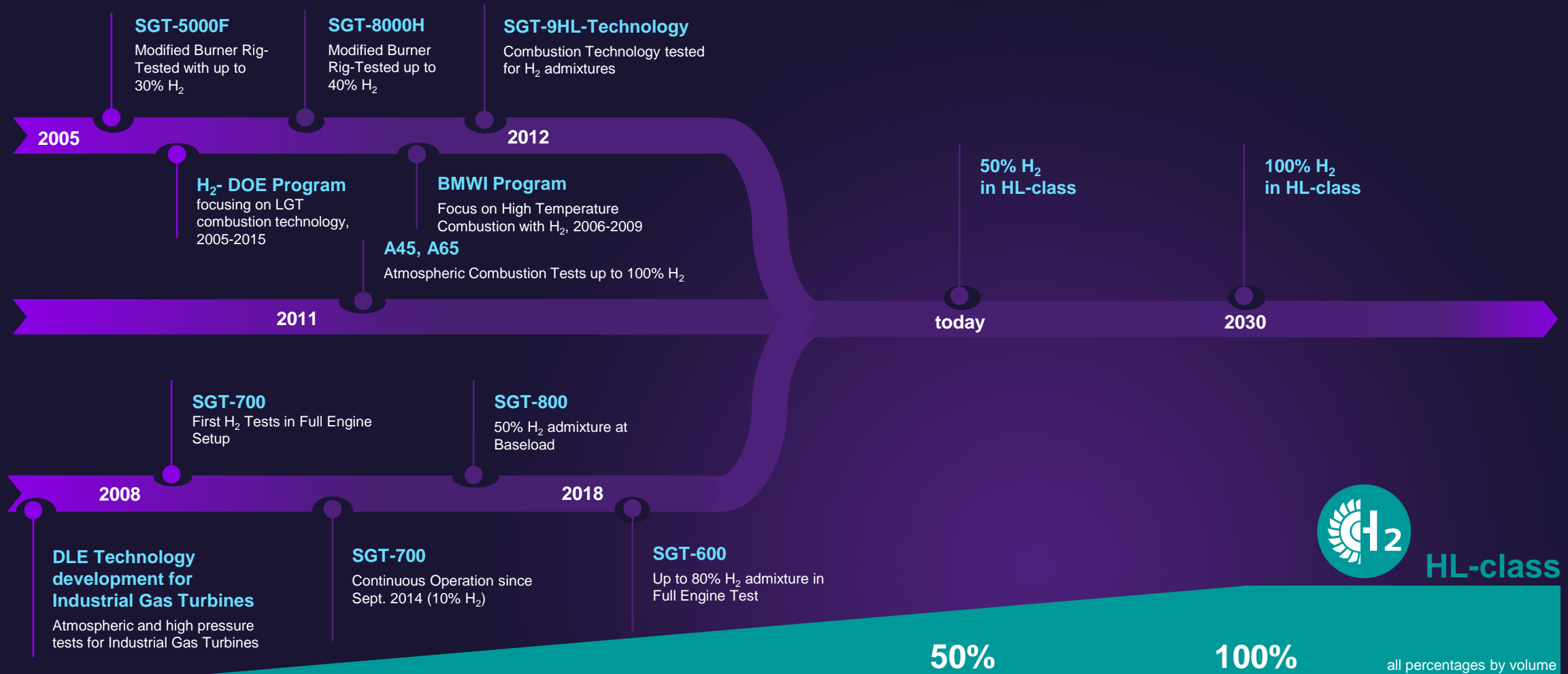
# HL-class Power Core applying Siemens Solution Blocks



# Future ready



# HL-class has a clear roadmap to 100% hydrogen, based on extensive combustion technology experience



# Disclaimer



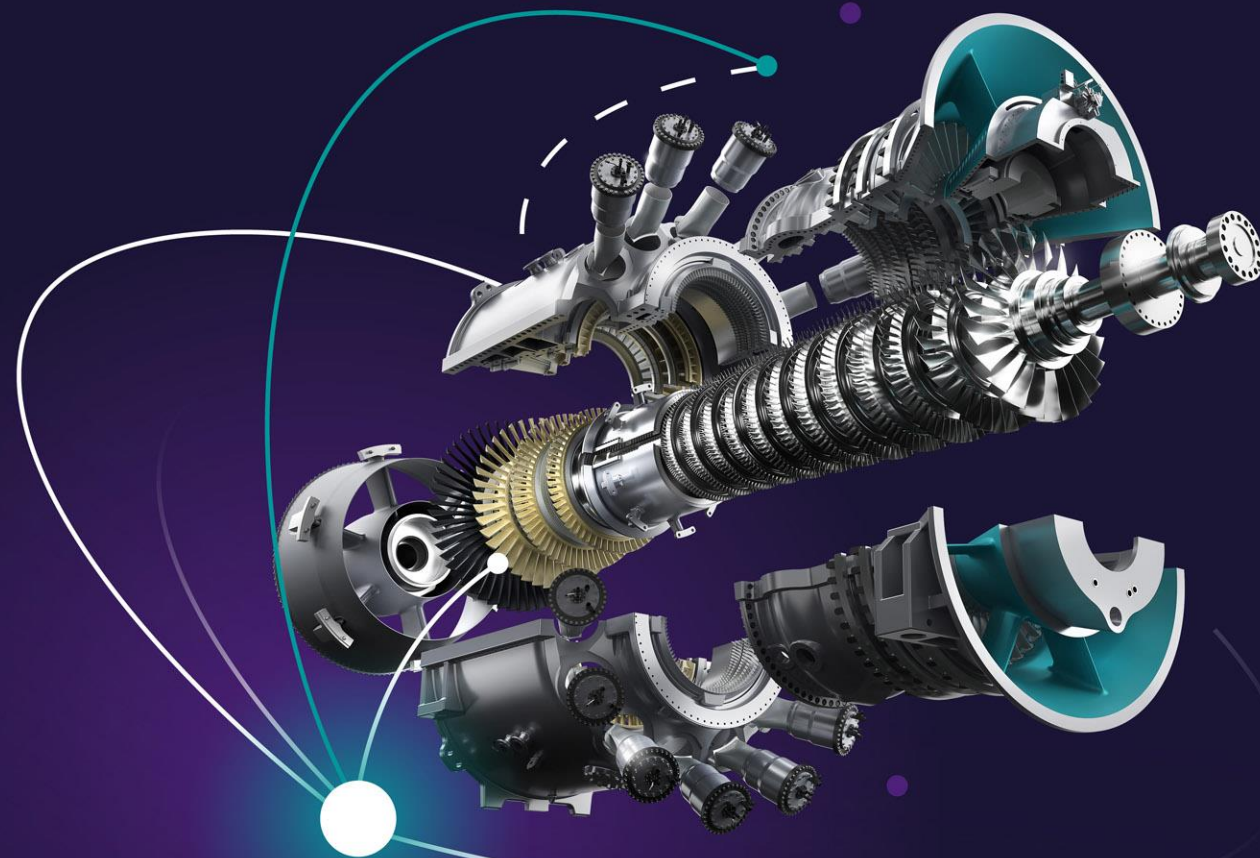
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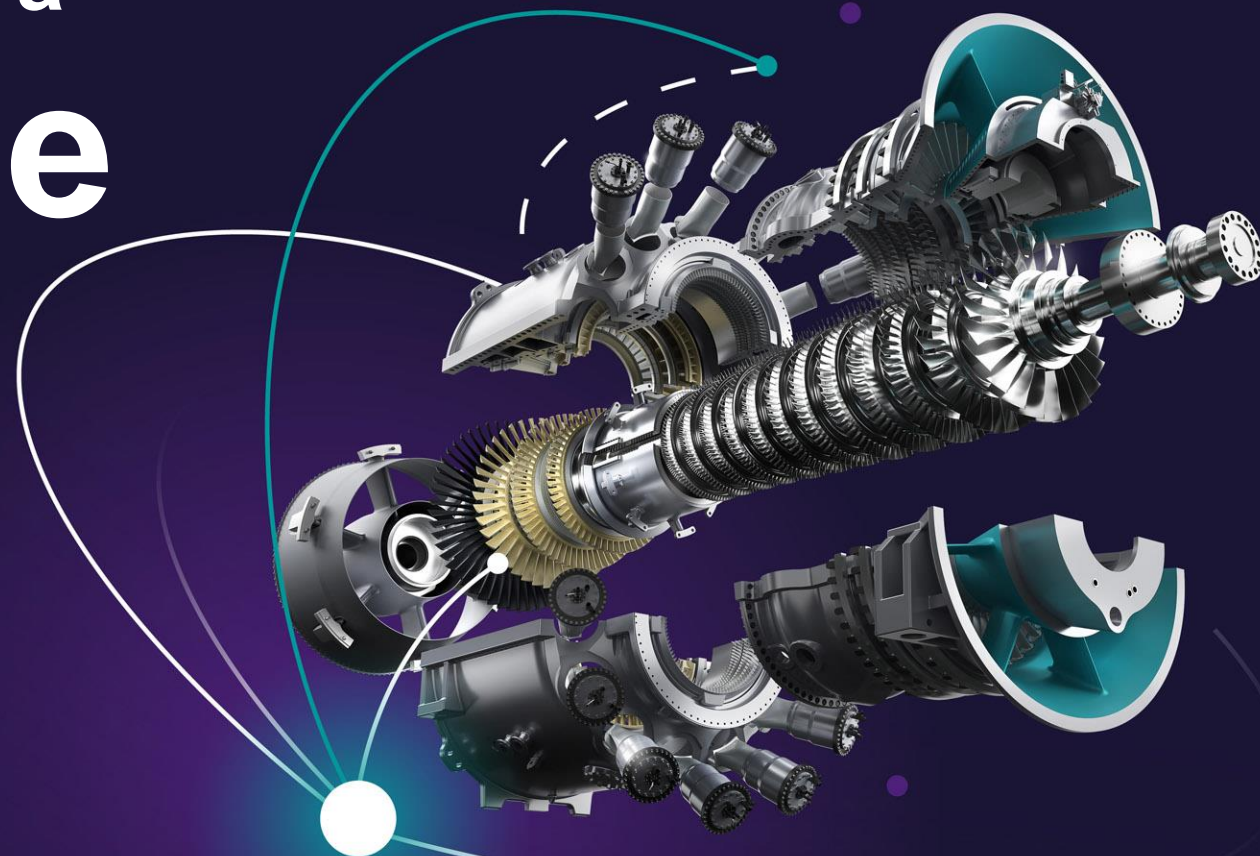
Note: All performance at ISO conditions is estimated and not guaranteed. All information is subject to change without notice.

The power of the SGT5-  
9000HL gas turbine equals

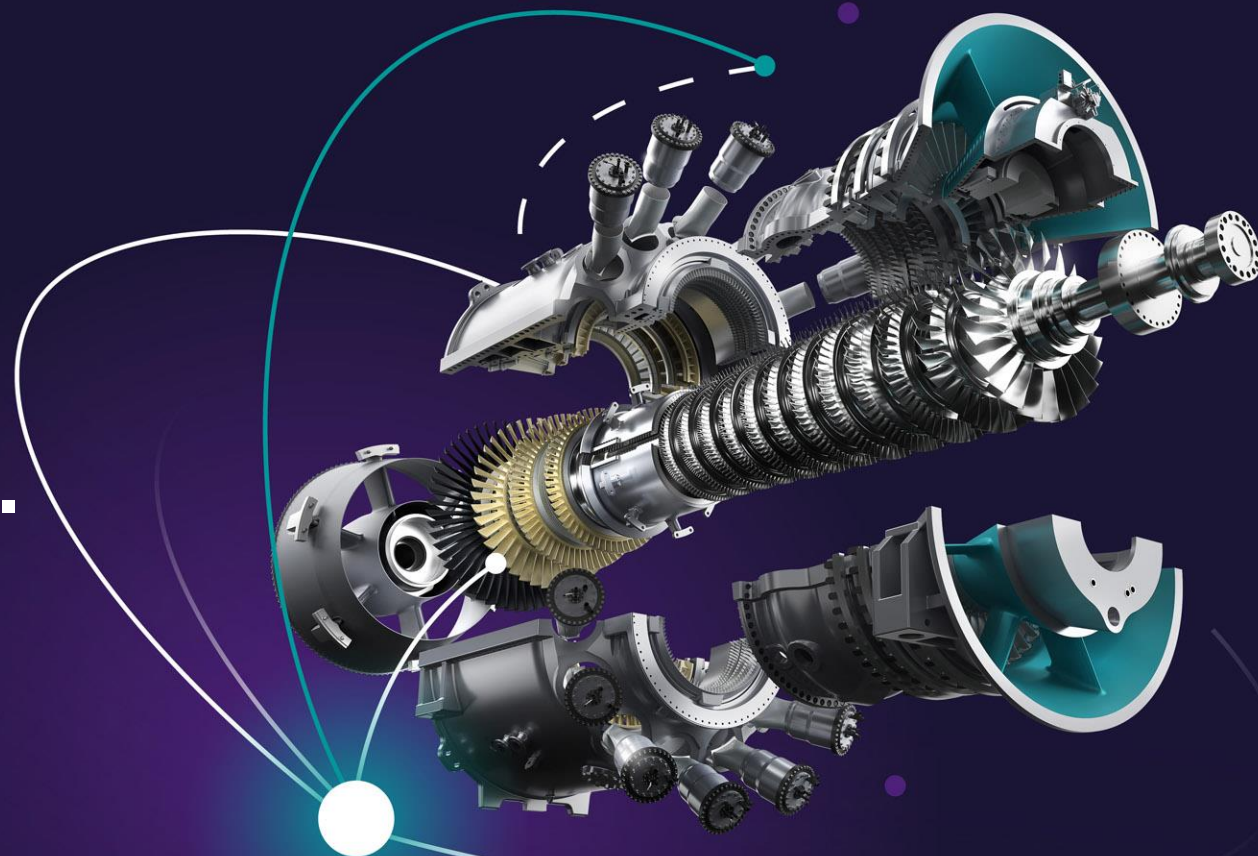
**1,400  
Porsche 911  
Turbo.**



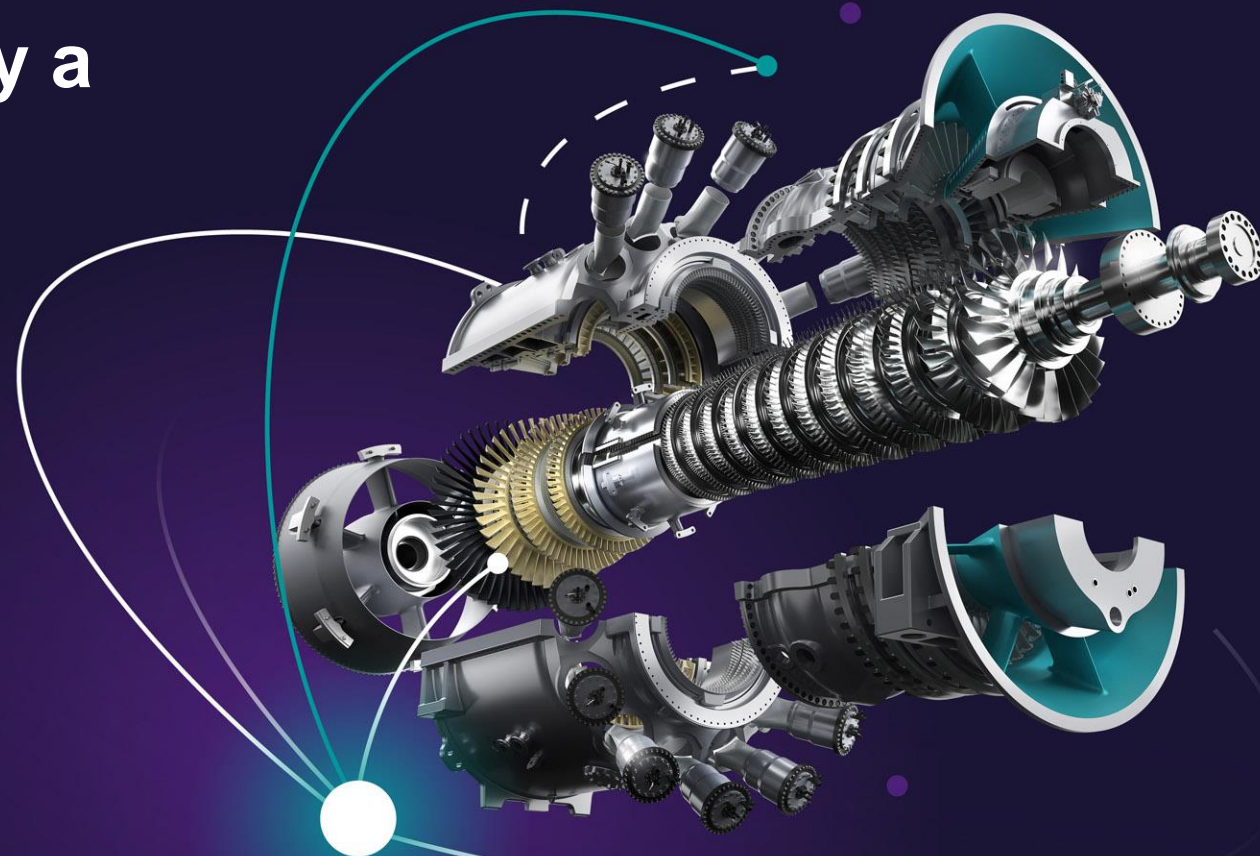
21 SGT5-9000HL have  
approximately the power of a  
**space shuttle**  
**at takeoff**  
- true rocket science.



The weight of the SGT5-9000HL gas turbine is as much as a **fueled Airbus A380.**



The SGT5-9000HL gas turbine  
provides enough energy to supply a  
city with **3.3 million**  
**inhabitants.**  
That is almost the size of  
**Berlin.**





Two %-points efficiency increase with an Siemens HL-class combined cycle

power plant, means a reduction of CO2-emissions by **63,000**

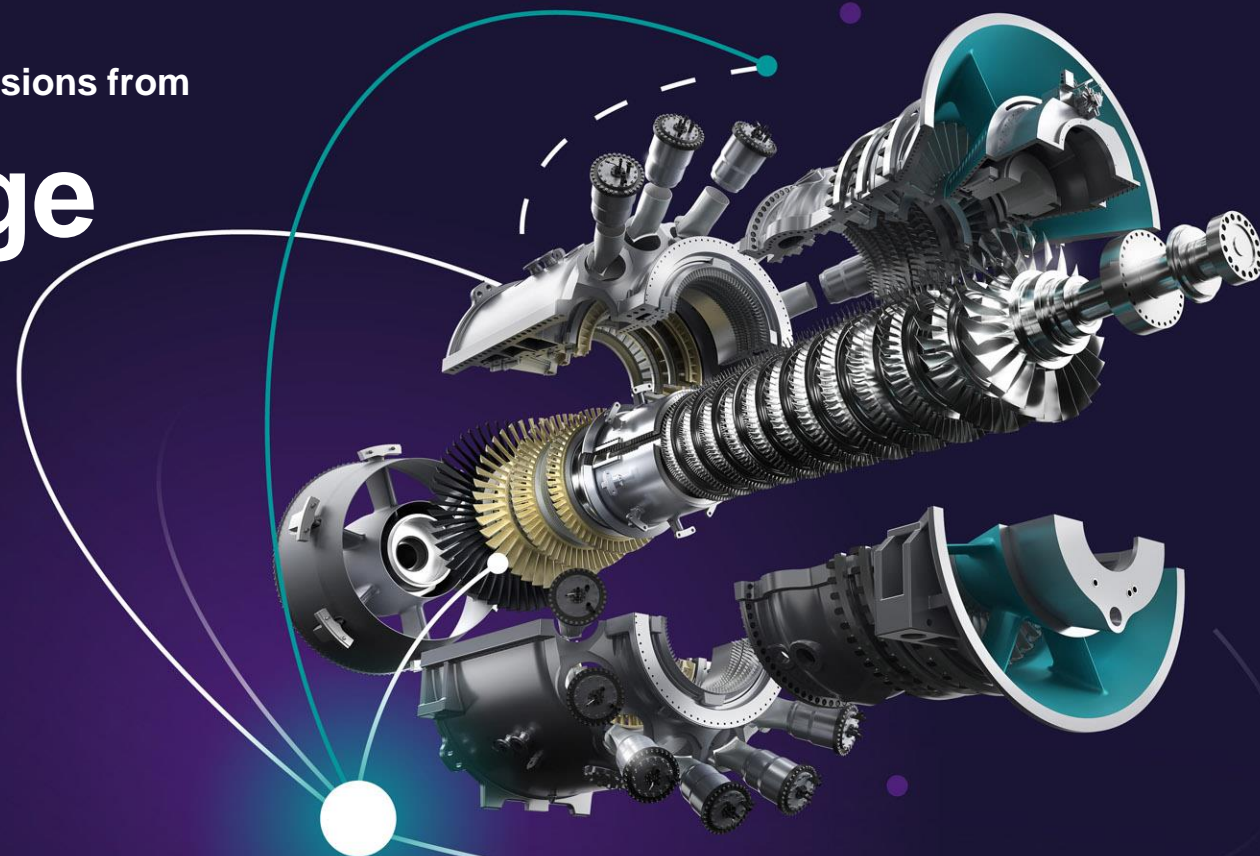
**tons/year**. This equals the annual CO2 emissions from

approximately **15,000 mid-range**

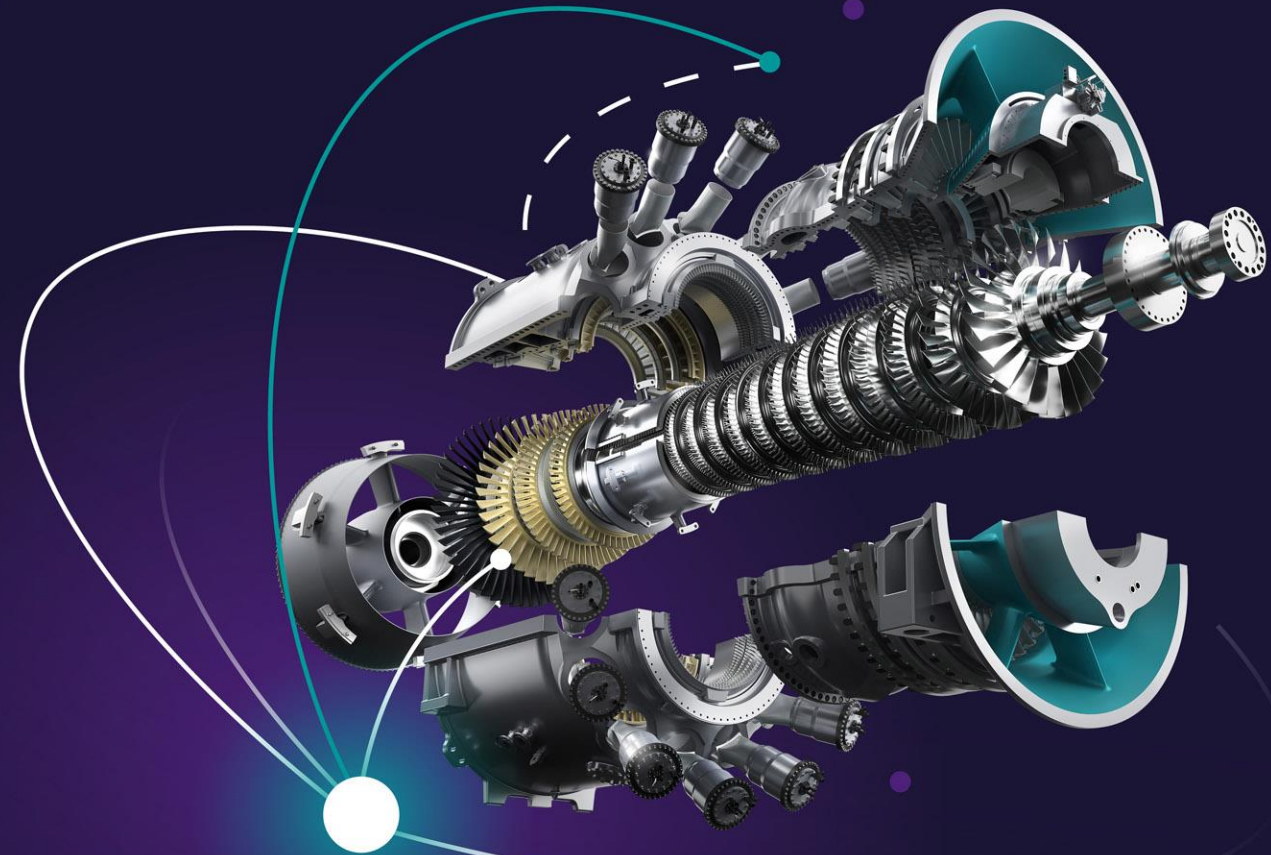
**cars** clocking up 20,000 km a year or

the amount of carbon captured by nearly **75,000**

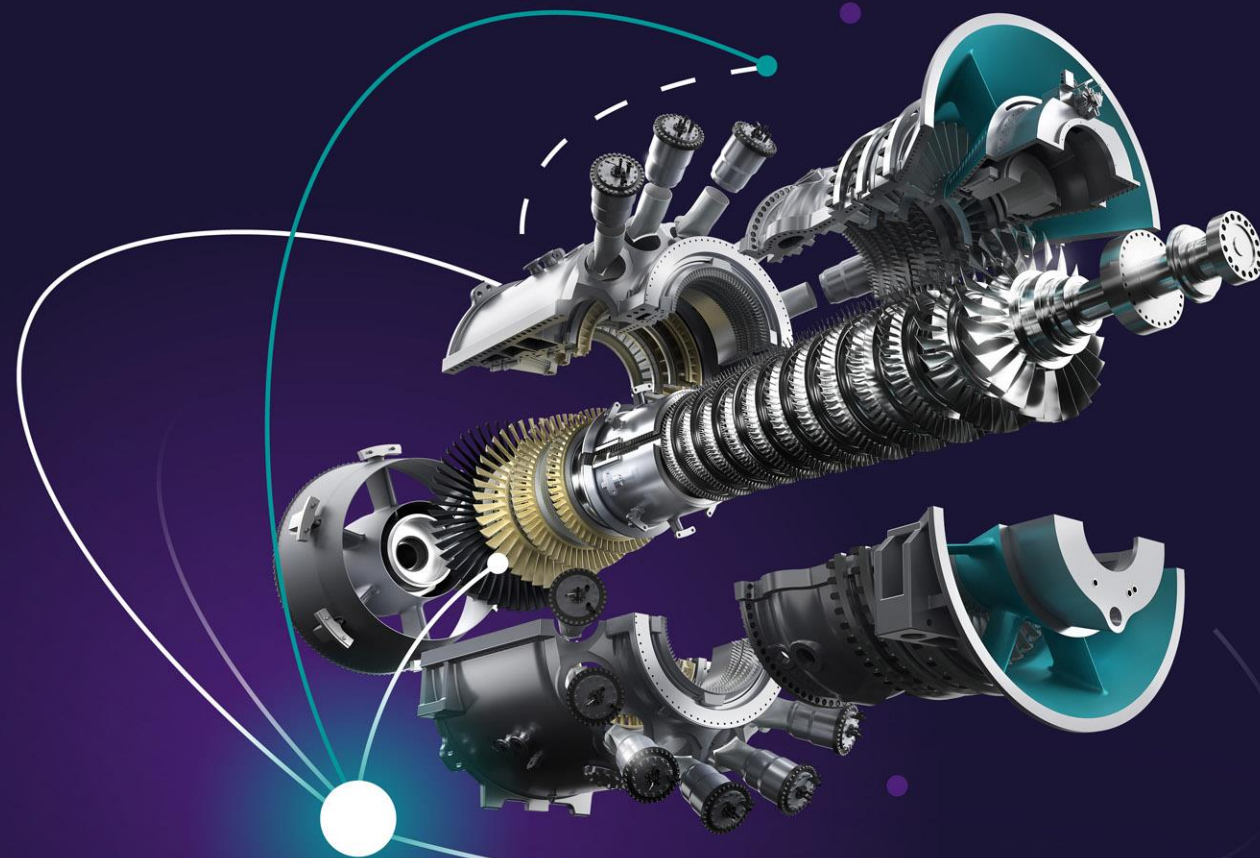
**acres of forests** in a year.



SGT5-9000HL in simple cycle has the potential to provide power for about **2.3 million modern electric cars**. Average conventional cars would emit **~5.5 million tons of CO<sub>2</sub>**.



The turbine SGT5-9000HL  
turns with the frequency of  
the grid. That is **3000**  
**times** per minute  
and about **200**  
**times faster**  
than a wind turbine.



The tip of the longest SGT5-9000HL blade

moves with a speed of more than

**2,100 km/h.** That is

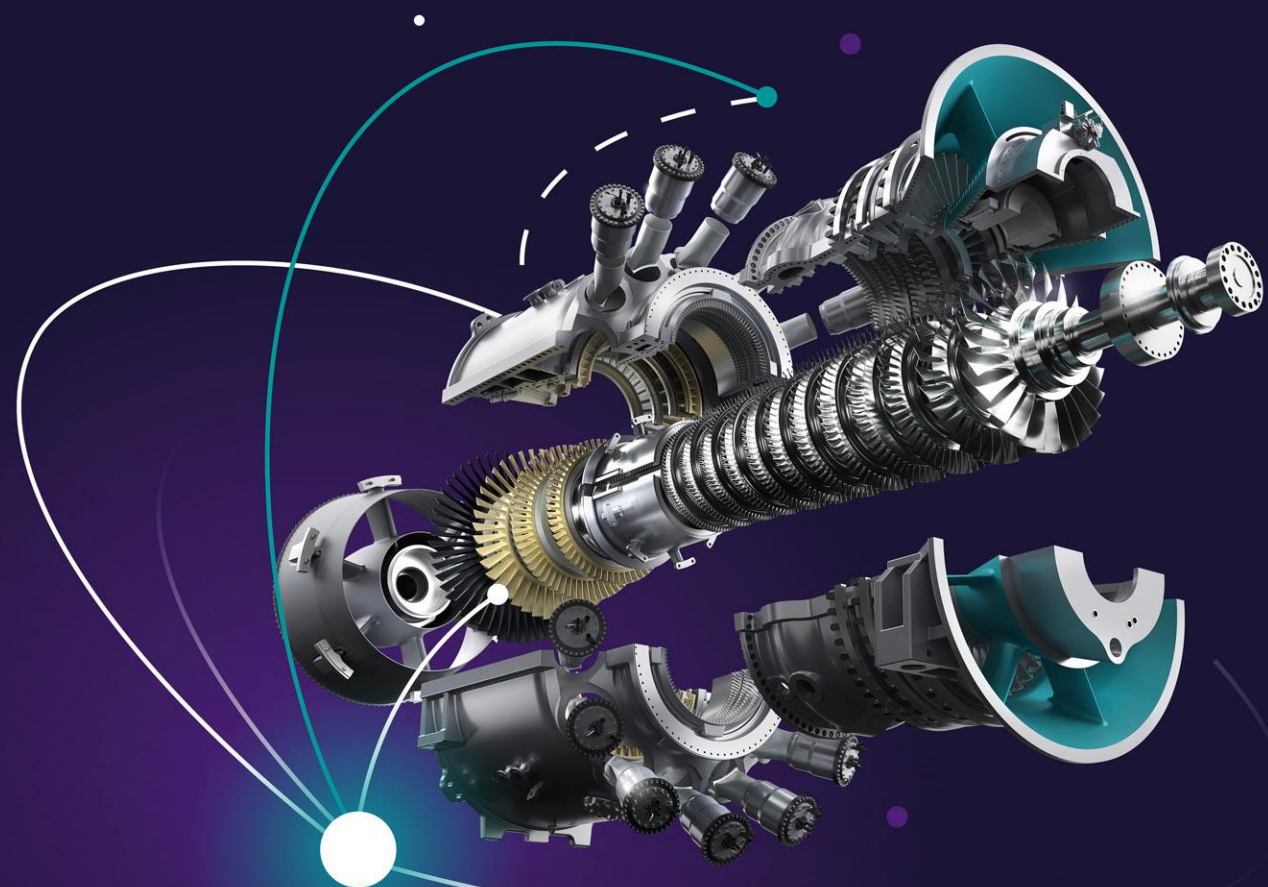
almost the speed of a

**Eurofighter** / more than

**twice the speed**

of a **passenger**

**aircraft.**



The blades of the SGT5-9000HL  
has to withstand more than

**10,000 g**  
**centrifugal**  
**acceleration.**

A jet pilot feels 9 g.

