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Innovations in Gas Turbine Technology to Answer the Emissions Challenge Towards Net-Zero Targets

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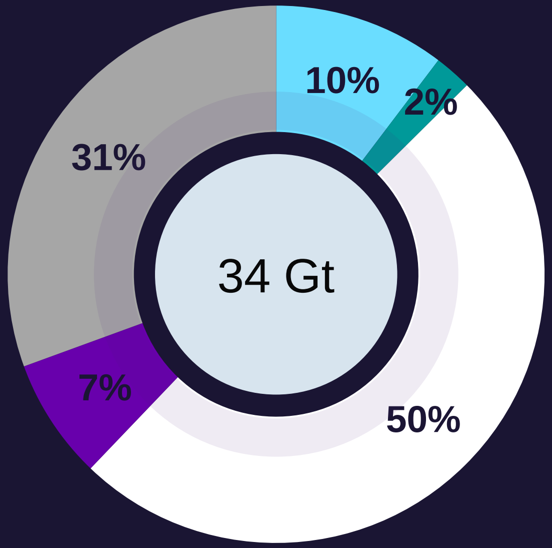
CO_2 Net-Zero targets are increasingly a policy priority

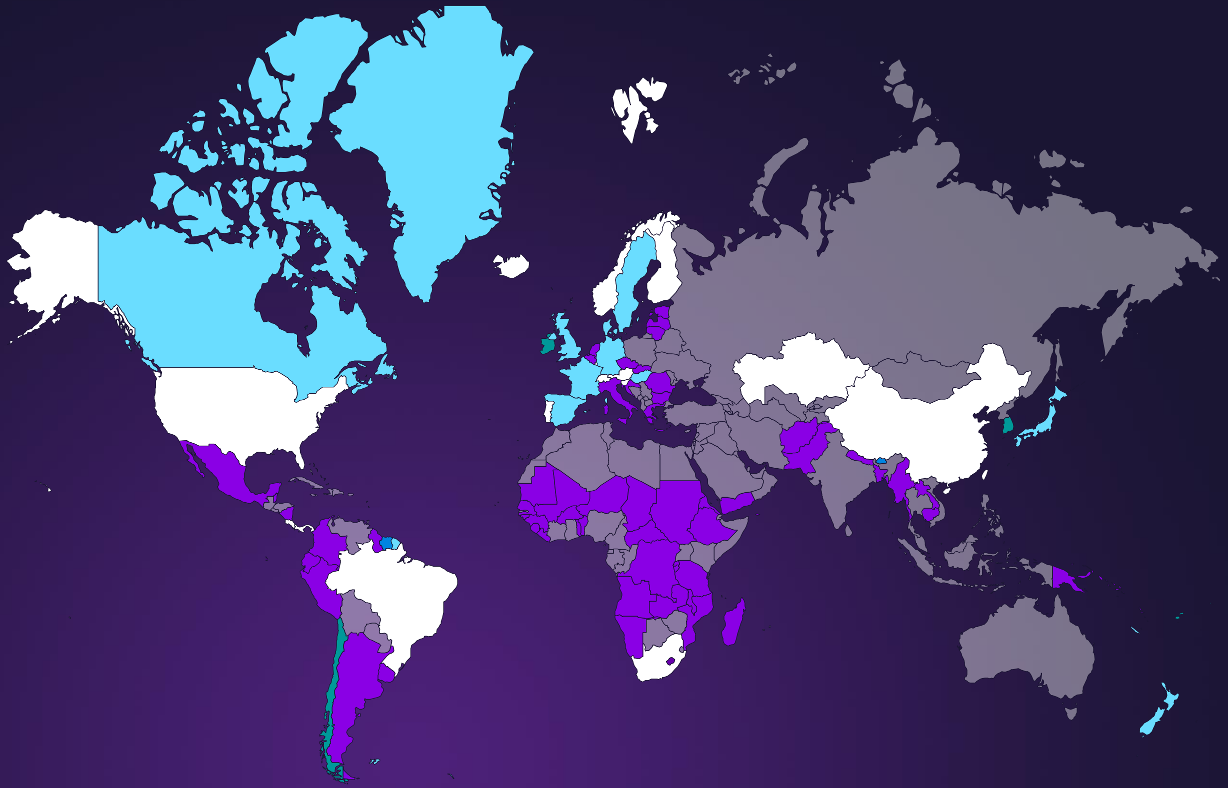
Nearly 2/3 of the World's industrial CO_2 emissions being addressed in net-zero legislation or policy.

CO_2 emissions covered by commitment



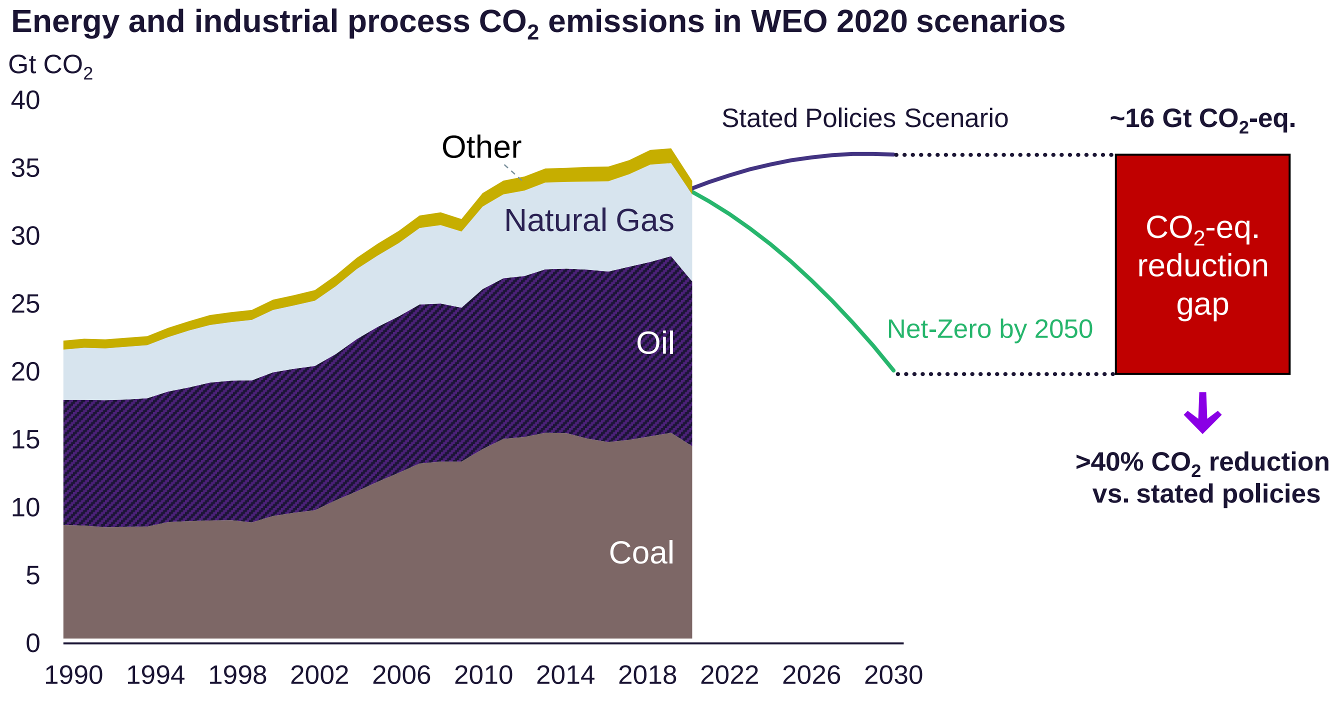
Based on global CO_2 emissions by countries
Source: World Bank (last updated: 07/21), emission data from 2018

- Net-zero achieved (2)
- Net-zero embedded in law (10)
- Net-zero proposed in legislation (4)
- Net-zero in policy document (16)
- Net-zero target under discussion (95)
- No commitment yet (90)



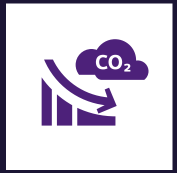
Commitments of countries for Net-zero CO_2 emissions.
Source: Netzerotracker (last updated: 07/21)

The World needs to dramatically accelerate CO_2 emissions cuts to achieve net-zero by 2050



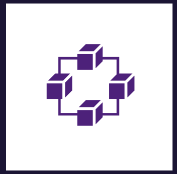
1 Source: IEA World Energy Outlook 2020

Energy Key Trends



Decarbonization

Demand growth

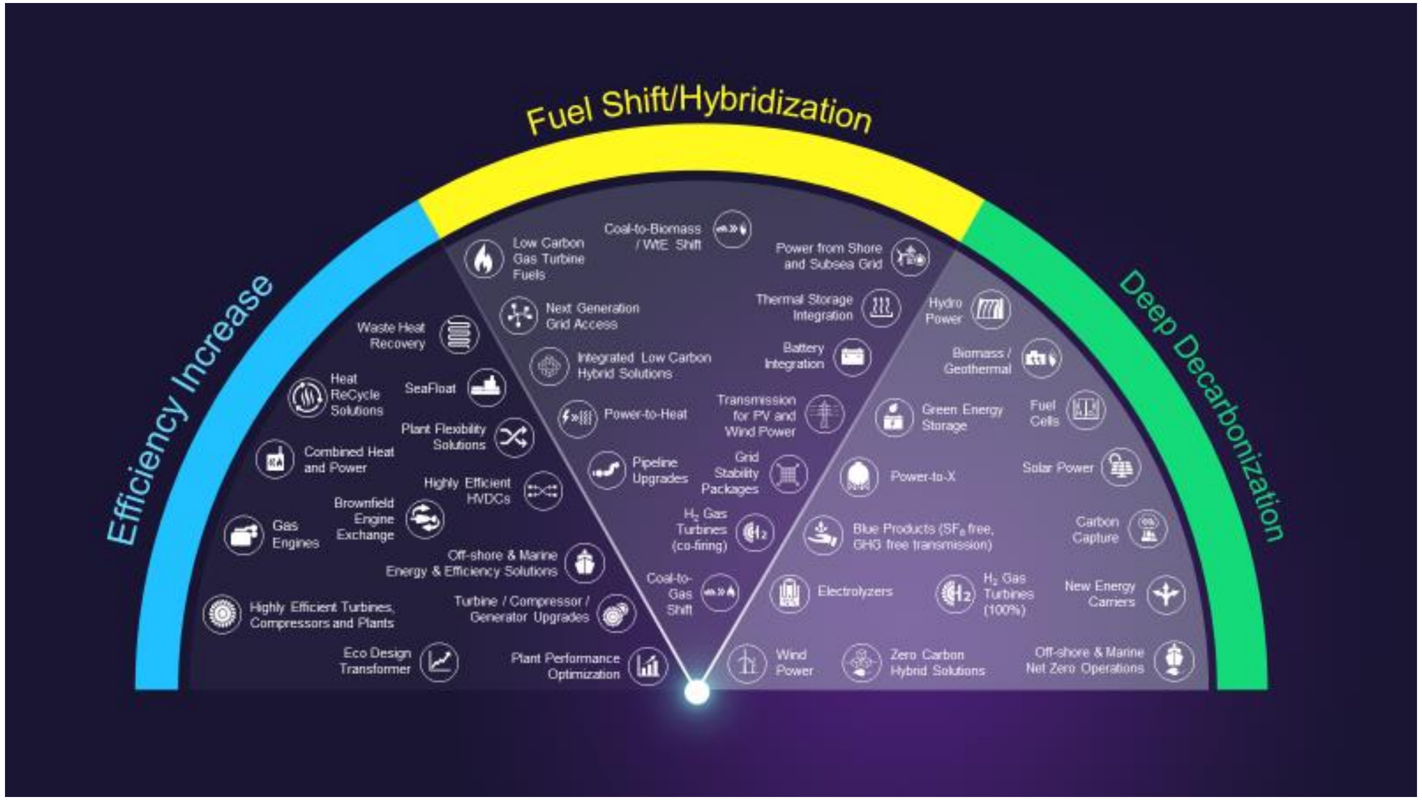


Decentralization

Digitalization

What role can Gas Turbines play ?

Energy Systems Decarbonization "Radar"



https://www.siemens-energy.com/global/en/priorities/decarbonization/decarbonization.html

GT Decarbonization Levers

Efficiency increase

- Repowering of ageing plants + displace coal
- Upgrades of existing assets
- Optimized operation (e.g. spinning reserve)
- Utilization of exhaust heat

Fuel Shift/Hybridization

- Switch to low carbon fuels
- Integration of renewables, storage

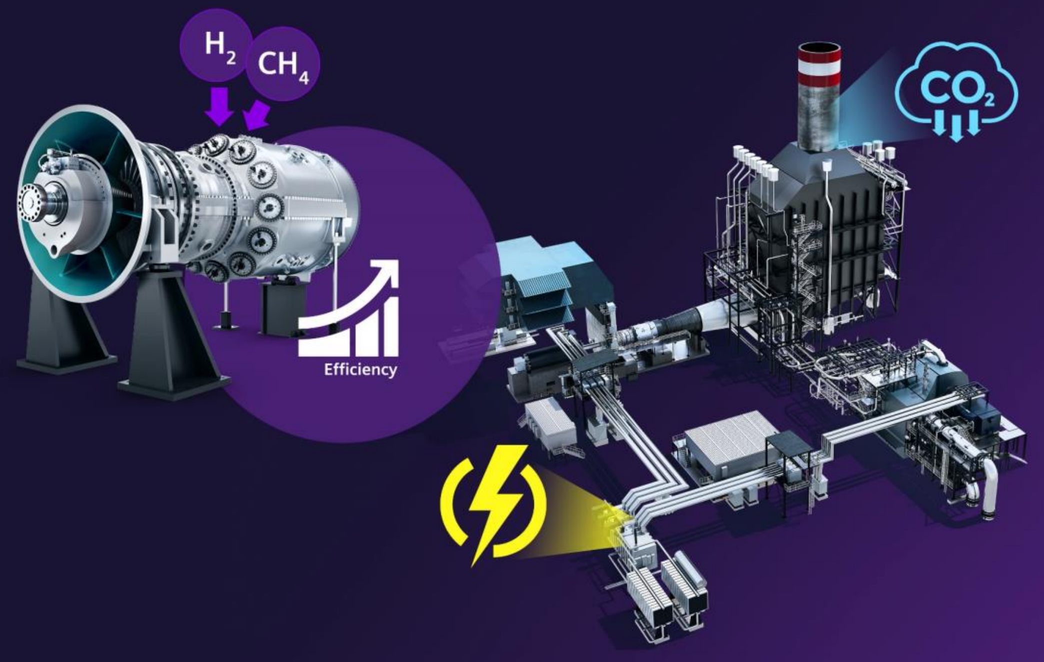
Deep Decarbonization

- Sector coupling, Power-to-X
- Green fuels (H_2 and others)

+ continued focus on Air Quality

Efficiency Increase

Re-powering with highly efficient Gas Turbine plants

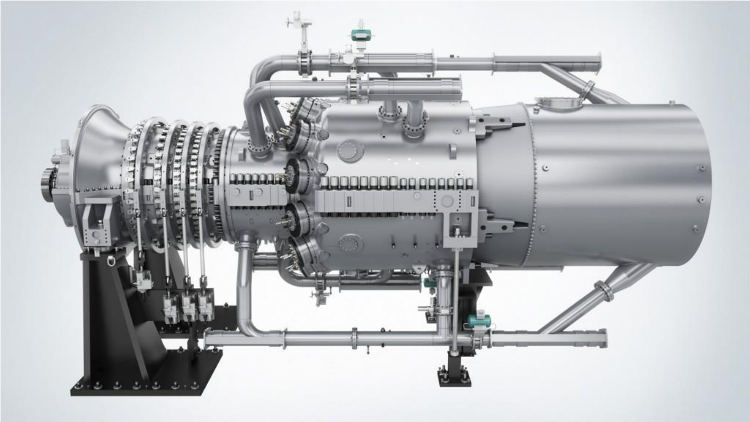


Modern GT plants reduce CO_2 emissions through:

- Ideally supporting the displacement of high-carbon fuels e.g. coal
- Providing highly efficient energy conversion

Decarbonization impact

- Combined Cycle fuel efficiency up to > 64% (gross)
- Major CO_2 cuts when repowering from coal – up to 60% and more
- Ready for H_2 blending, continuing roadmap development for up to 100% H_2 fuel capability
- Ability to integrate with renewable sources & energy storage



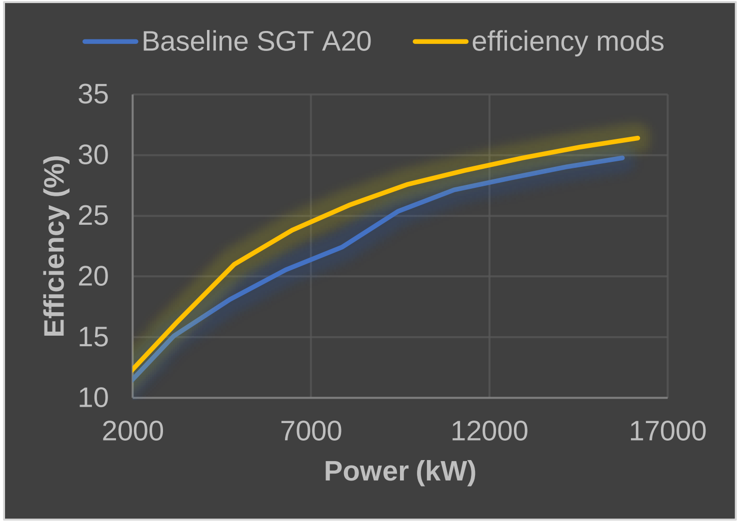
Reference case: 900 MW CCGT Cascade Power Plant reducing up to 5% of Alberta's Carbon emission from energy production

Gas Turbine efficiency mods & upgrades

- Most operating Gas Turbines are ageing units and often not running at their optimal efficiency.
- Technology refresh and operational optimization substantially improve CO_2 footprint with low CAPEX and risk.
- Reliability upgrades reduce the occurrence of unplanned outage / restart emissions.

Example 1: Efficiency upgrades SGT-A20 (Industrial Avon)

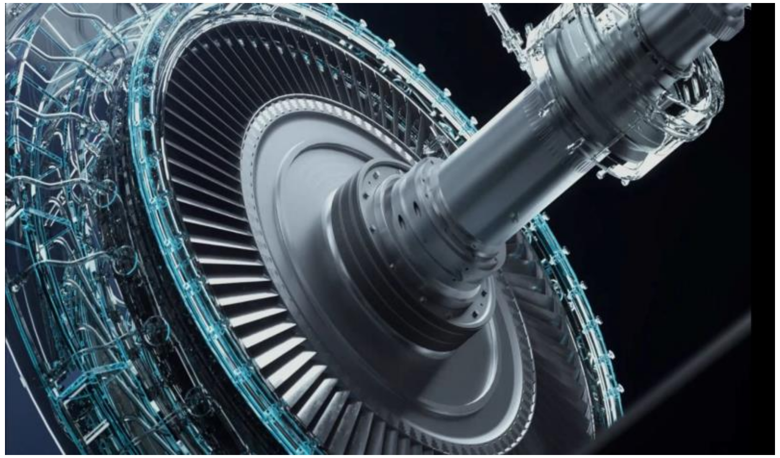
- ❑ **HEPA Air Filters**
- ❑ **Hot section upgrade (Avon 200)**
- ❑ **VIGV Closed Loop**
- ❑ **Bleed Valve Rescheduling**



Up to **14% CO_2 reduction**, greatest benefit for part-load running

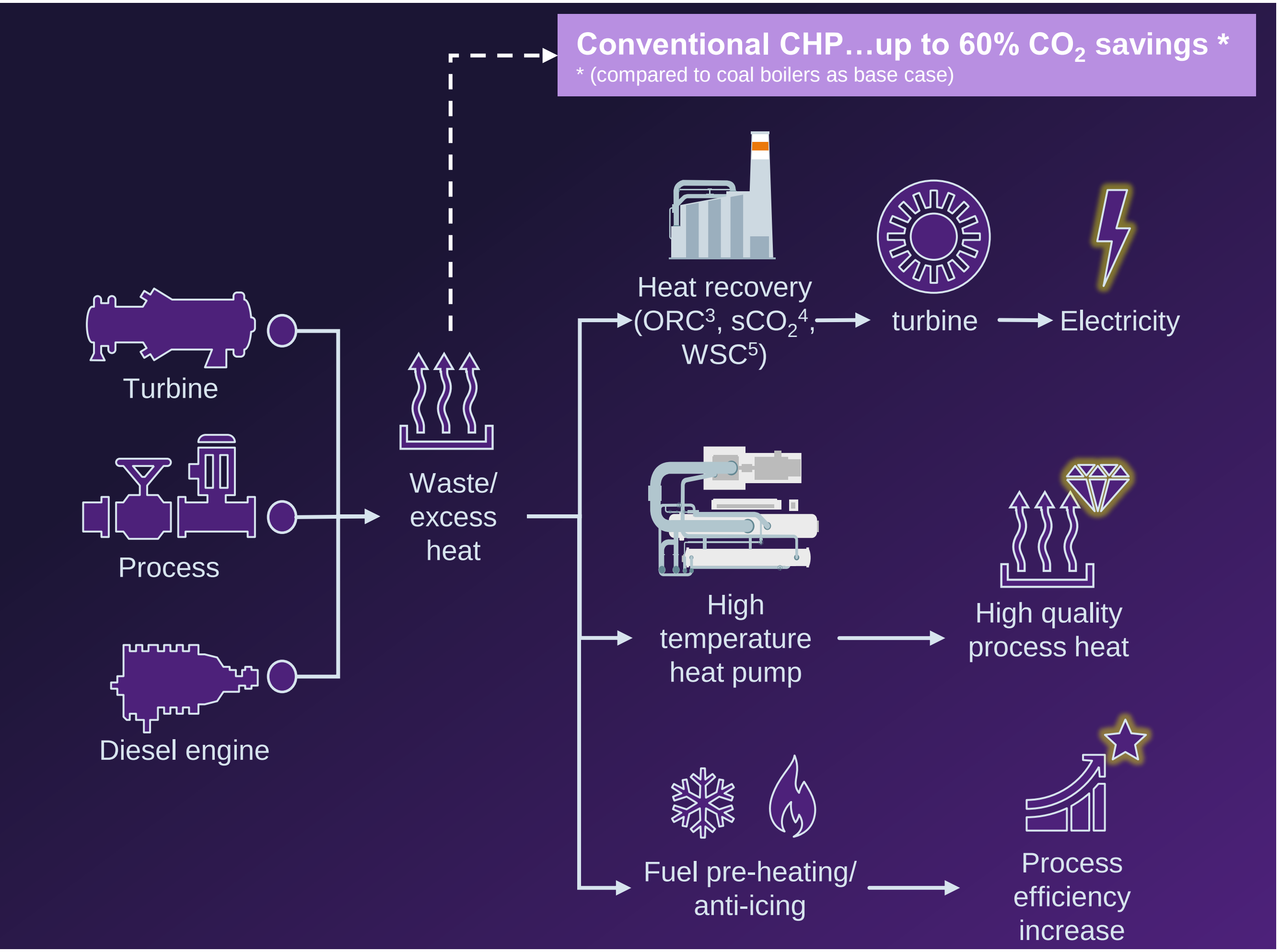
Example 2: RT62X upgrade for SGT-A35 (Industrial RB211)

- ❑ **Power Turbine 3D aerofoils**
- ❑ **Upgraded materials**
- ❑ **Can be configured as power up-rate *or* extended TBO**



Up to **2.5% CO_2 reduction**, plus life cycle OPEX benefits

Waste Heat utilization
Useful energy without incremental emissions



Features

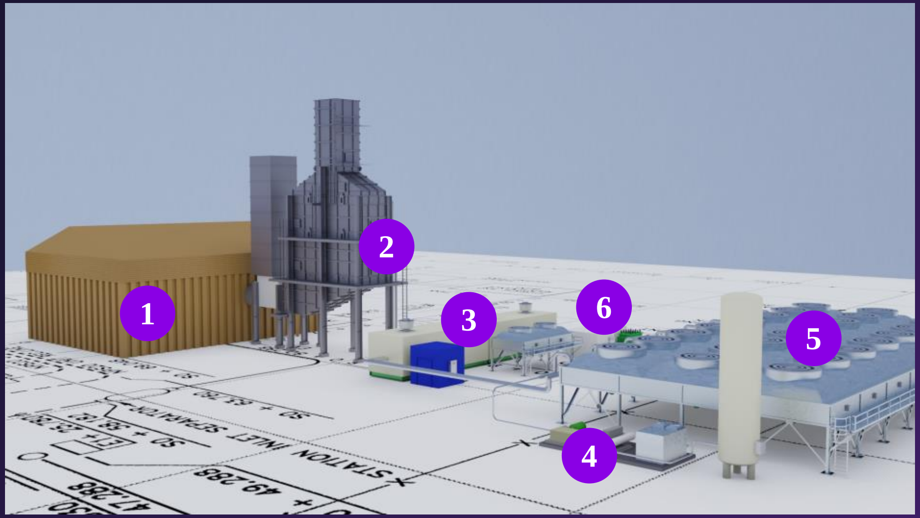
- CHP / CoGeneration or District Heating with GTs is well established
- Bottoming Cycles with various types of Transfer media:
  - Water Steam Cycle – all ranges
  - Supercritical CO_2 Cycle for medium temperature operations
  - Organic Rankine Cycle (ORC) for water-free and low temperature operations
- High temperature heat pumps:
  - Generating high quality process heat
- Fuel preheating and anti-icing with waste heat

Sustainability impact

- Increased overall fuel efficiency
- Energy without additional CO_2 -, CO-, NO_x - or SO_x emissions
- Relevant in all GT applications e.g. reducing carbon footprint of offshore upstream production

Supercritical CO_2 power cycle

Increase power output and efficiency of simple cycle gas turbine installation, emissions-free.



1. Existing compressor station
2. Primary Heat Exchanger
3. Heat Engine + Auxiliaries
4. CO_2 Mass Management
5. Cooling System (air or water)
6. Electrical Service Building

Pilot project

- Agreement with TC Energy to commission first-of-kind system at existing pipeline compression station in Alberta
- Convert waste heat from Gas Turbine into emissions-free power
- Supported by Emissions Reduction Alberta's (ERA) Industrial Efficiency Challenge

Sustainability impact

- Generate electricity for 10,000 homes without additional fuel burn
- 10% increase in overall compressor station fuel efficiency
- 25 – 40% smaller footprint than steam-based systems
- Equivalent GHG reduction of 44,000 tons per year
- Potential to generate ~ 300 MW of emissions-free power from compression stations in Western Canada alone

Dry Low Emissions (DLE) combustion

Technology Focus

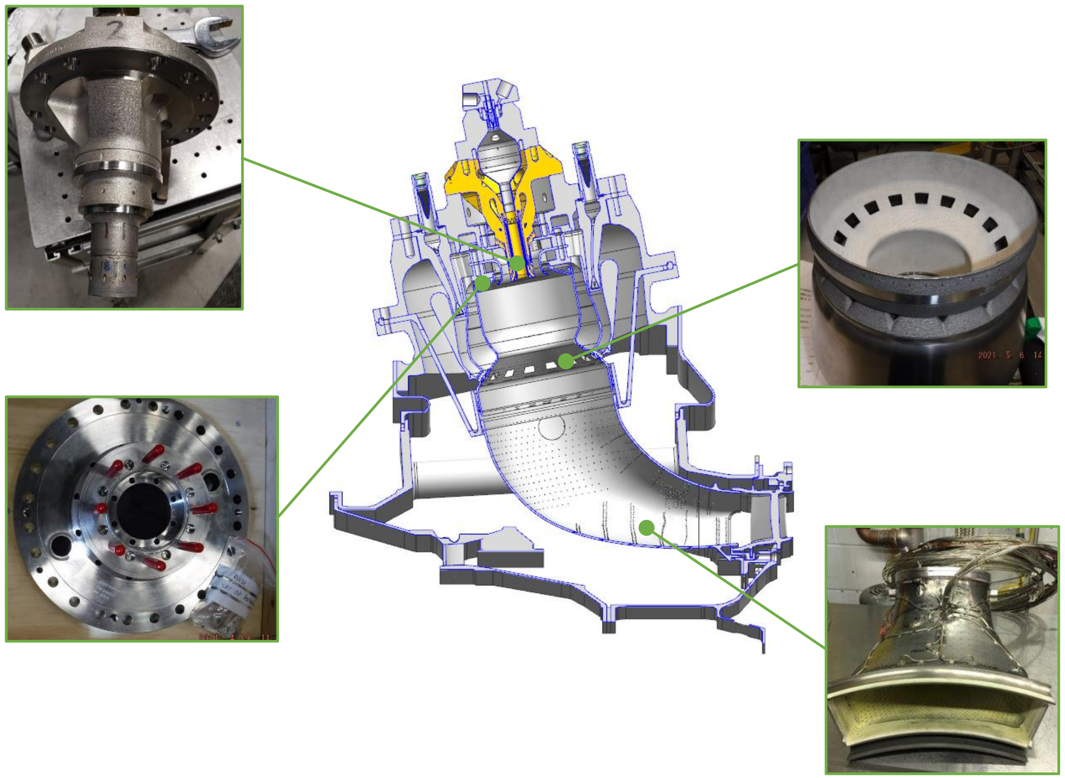
- Continuing regulatory drive to reduced NO_x limits
- Improved part-load fuel efficiency e.g. CO “turn-down”
- Capability with low-carbon fuels e.g. Hydrogen
- Improve maintenance life cycle

- Incremental enhancement of proven designs
  - Ease of retrofit to installed units, and new units
  - Use Additive Manufacturing where beneficial

Considerations

- Regulation has historically focused on NO_x and CO
- However today’s global challenge are CO_2 emissions
  - Need to consider potential trade-offs
  - Focus the R&D investment to address the key priority

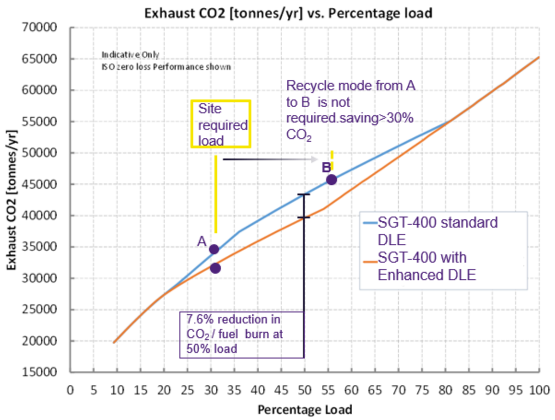
SGT-A35 DLE enhancements

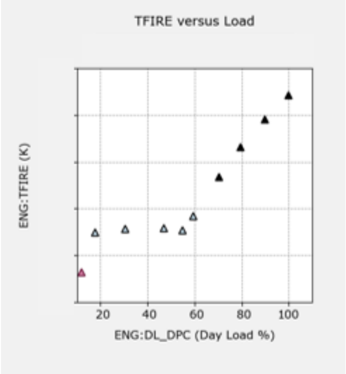


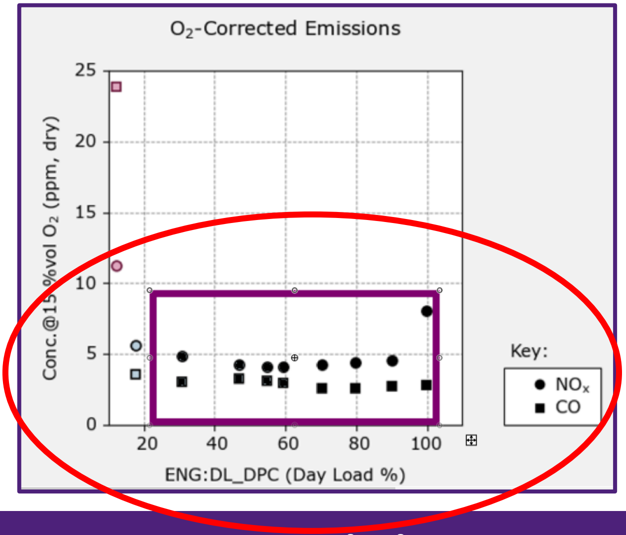
SGT-400 13MW Enhanced DLE

Full Engine Development Test

- April 2021 – demonstration test of SGT-400 with enhanced DLE
- Remote witness option for users via virtual link
- Single digit NO_x and CO demonstrated
- Emissions maintained over 30-100% load range
- Up to 7% reduction in fuel burn / CO_2 in part load operation



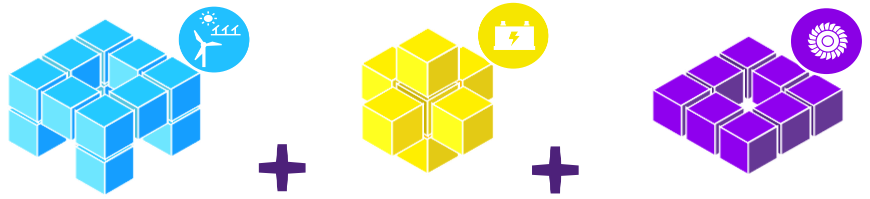




Enhanced DLE – Proven Technology. Lower GHG Emissions. Greater Operational Flexibility.

Fuel Shift / Hybridization

Hybrid systems
Integrating renewables, storage and gas-powered generation



Renewable energy

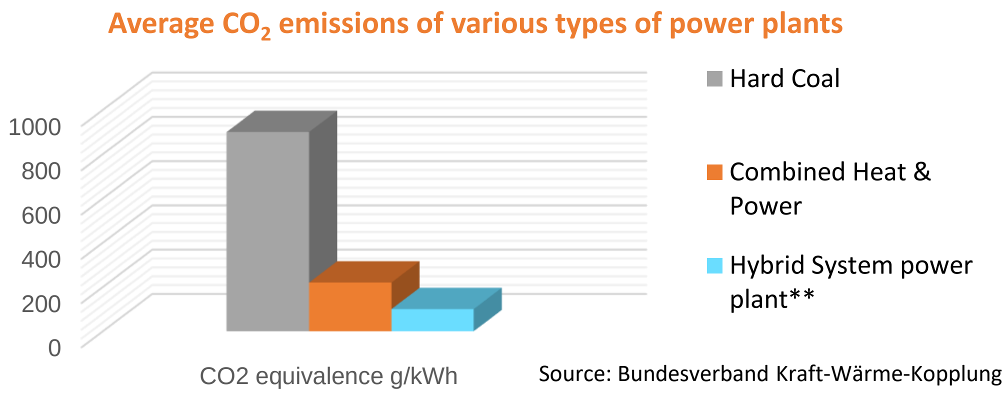
+ Sustainable
+ Zero Emissions
- Intermittent

Storage e.g. battery

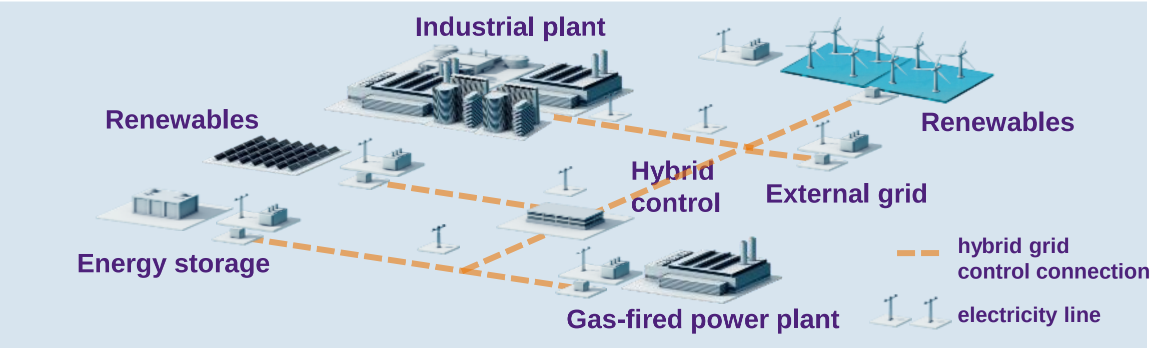
+ Instantaneous
+ Zero Emissions
+ Dispatchable
- Limited time

Gas-fired power

+ Reliable output
+ Economical
+ Highly efficient
- Emits CO_2

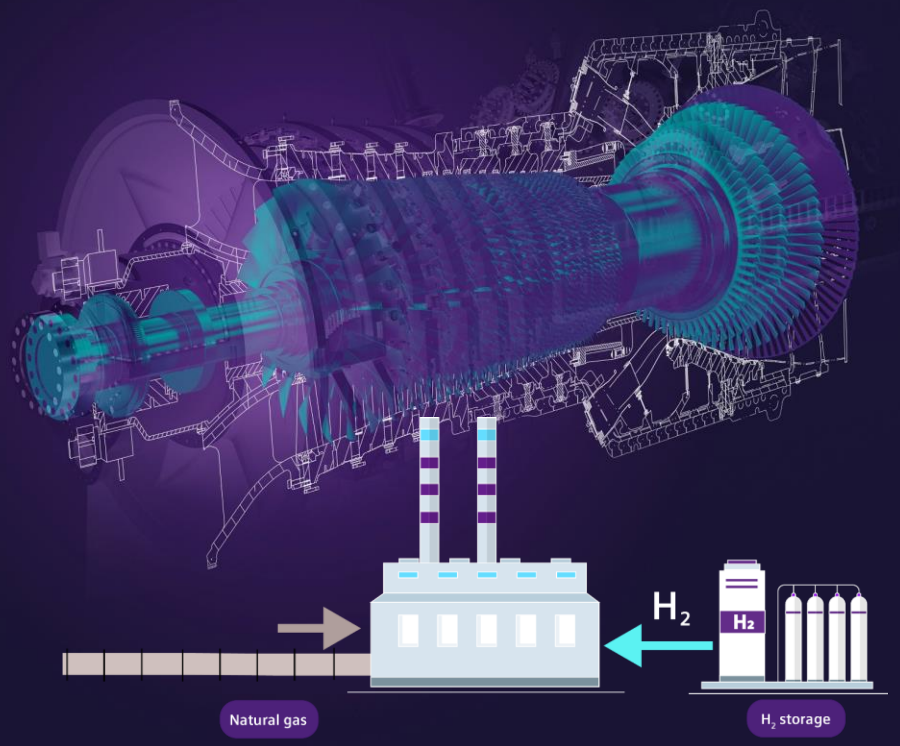


Source: Bundesverband Kraft-Wärme-Kopplung
** average, depending on location and setup



- ❑ Fast-starting, flexible GTs significantly reduce the size / CAPEX of required energy storage
- ❑ Integrated GT & Battery Energy Storage Systems (GT-BESS) provide an ideal backup to renewable sources
- ❑ Competitively positioned in flexible electricity markets
- ❑ Ready for increased penetration of low-carbon fuels

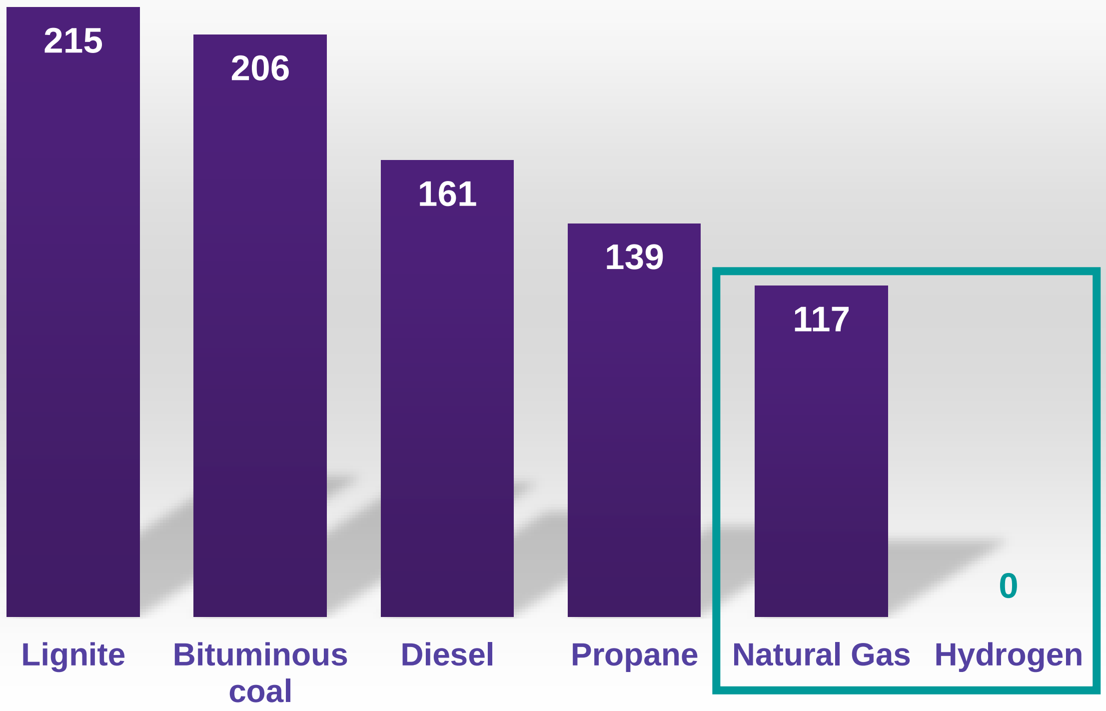
Gas Turbines support a transition to low carbon fuels



Ability of gas turbines and plants to use a mixture of natural gas and hydrogen to minimize CO_2 emissions.

CO_2 Emissions from combustion only in lb/MMBTU

Source: EIA



Blending of H_2 into Natural Gas can substantially lower CO_2 emissions in the power & industrial sectors

Hydrogen as a Gas Turbine fuel

H_2 combustion physics vs. Natural Gas

Higher reactivity and flame velocity

- Propensity to Auto-Ignition & Flashback in air / fuel mix

Higher flame temperature

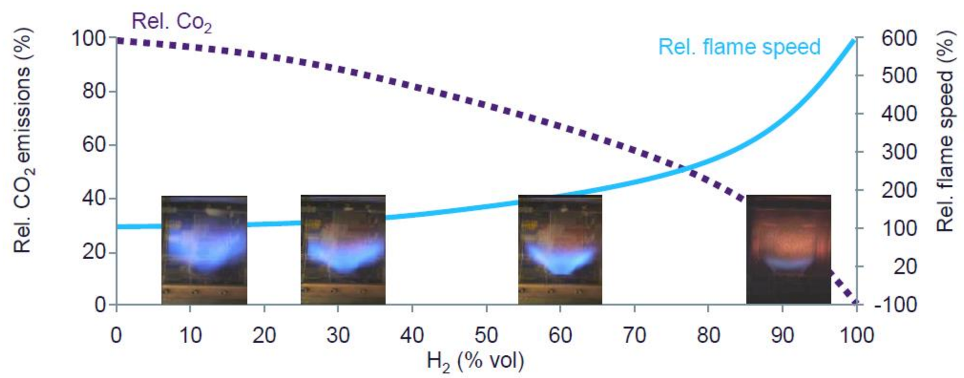
- Increased creation of NO_x for high amounts of H_2

Lower energy content per unit volume

- Higher volume flow in fuel systems

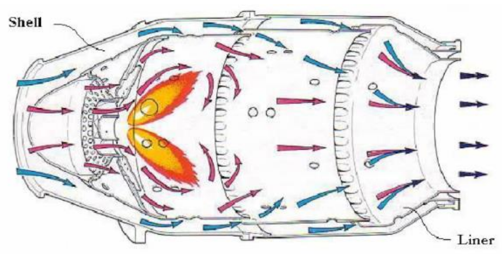
Explosivity characteristics

- Modifications in auxiliary protection systems

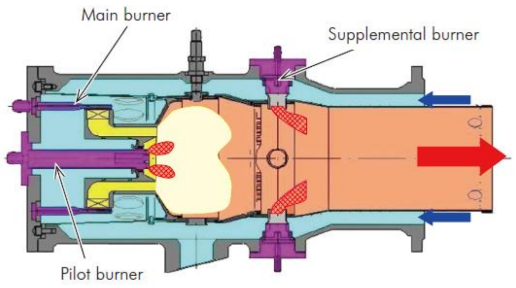


Values shown are relative to natural gas (indicative only)

Source: Siemens Energy



WLE – Wet Low Emissions
(diffusion flame)



DLE – Dry Low Emissions
(air / fuel pre-mixing)

WLE combustion – up to 100% H_2 with little change

- ❑ Diffusion flame easier to manage
- ❑ Water injection to manage NO_x
- ❑ Some auxiliary changes needed

DLE combustion – up to 75% H_2 & viable roadmap to 100%

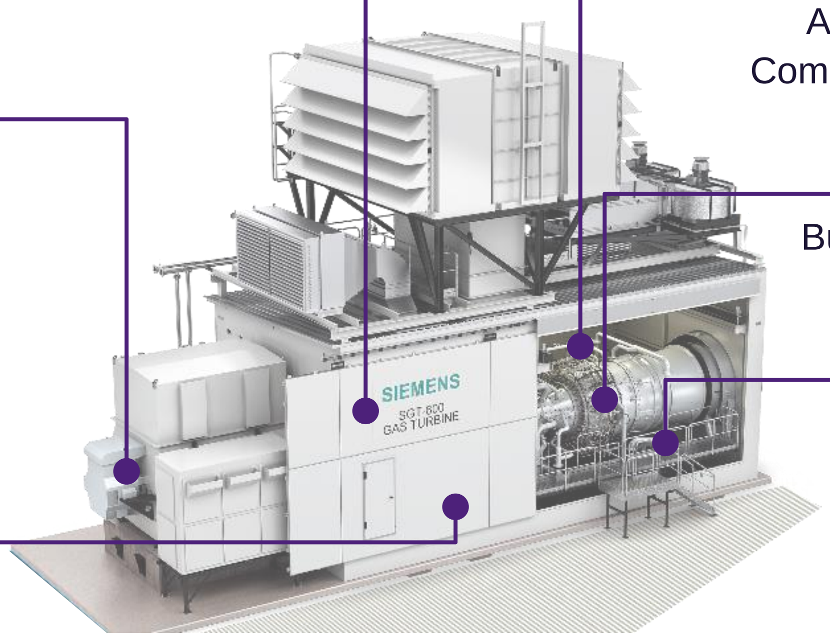
- ❑ Burner adjustments and testing
- ❑ Manage Auto-Ignition, Flashback, Combustion noise and Emissions
- ❑ Incremental technology matching GT cycle (e.g. pressure ratio)

Upgrade of existing GT units for higher H_2 content

Potential system upgrades to operate higher H_2 content

Fire Protection System
Gas Detection System

Gas Group IIC
electrical equipment



Additional Flame Control and
Combustion Monitoring Systems

Burner Adjustment/Exchange
Purging system

Fuel Gas System
material and set-up

H_2 compatibility of plant
auxiliary and peripheral systems

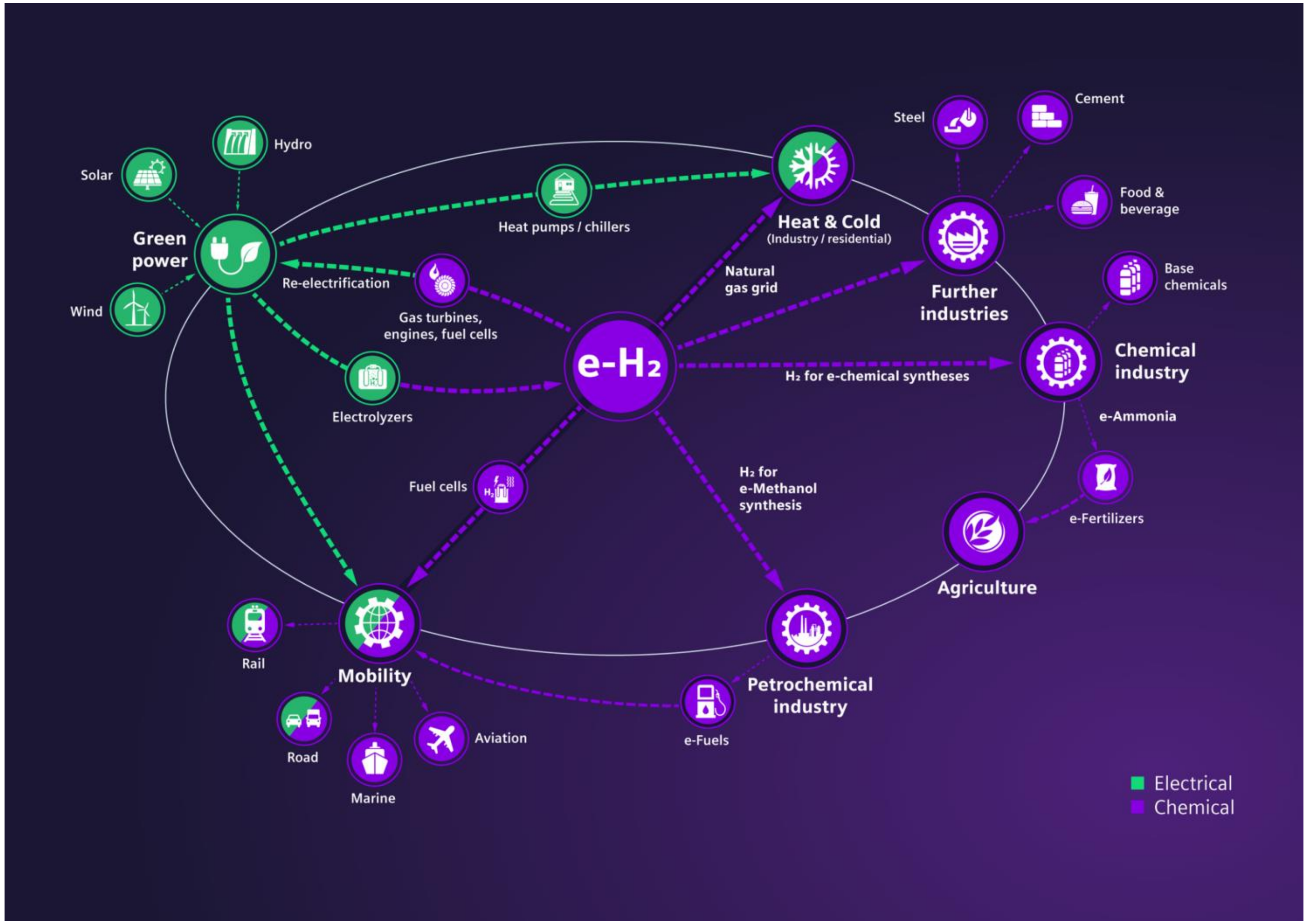
Consequences and solution

- Project specific evaluation and decision on required modifications
- Power output control to ensure compliant NOx emission levels
- Conventional/non-H_2 fuels may be required for start-up and shutdown
- Re-certification with respective authorities might be required

EU Turbines has published Sep 2021 a common definition for H_2 readiness of GT plants: https://www.euturbines.eu/h2-ready/

Deep Decarbonization

Sector Coupling



Sector Coupling Characteristics

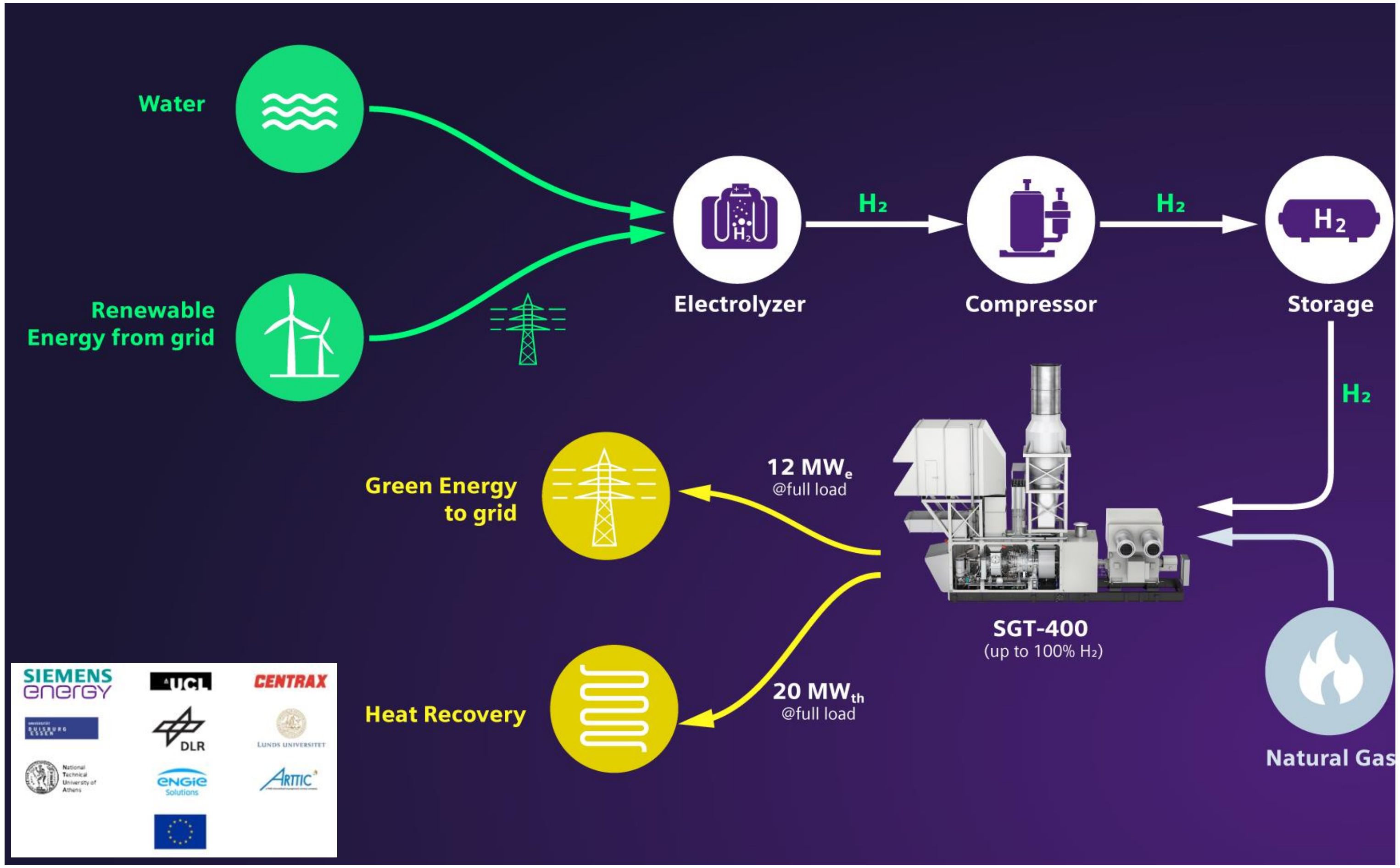
Definition

- Link between power sector and energy-consuming sectors
- Use energy vectors produced from renewable power (Power-to-X)
- Pathway to de-carbonize industrial sectors

Value Proposition

- GHG reduction for sectors that are harder to electrify
- Utilization of excess renewable power by storage through chemical media
- Higher overall energy efficiency
- More diverse and interdependent energy supply

Industrial-scale Renewable Hydrogen Power
EU-funded HYFLEXPOWER Project (France)



http://www.hyflexpower.eu/

Description

- Brownfield transformation of existing GT site
- H_2 generation via electrolysis, compression & storage
- SGT-400 upgrade for up to 100% H_2 pilot (DLE)

Benefits

- Carbon savings 65,000 t p.a. (SGT-400 baseload)
- Store excess intermittent renewable energy
- Grants from EU (€10.5 mn funding EU Horizon 2020)

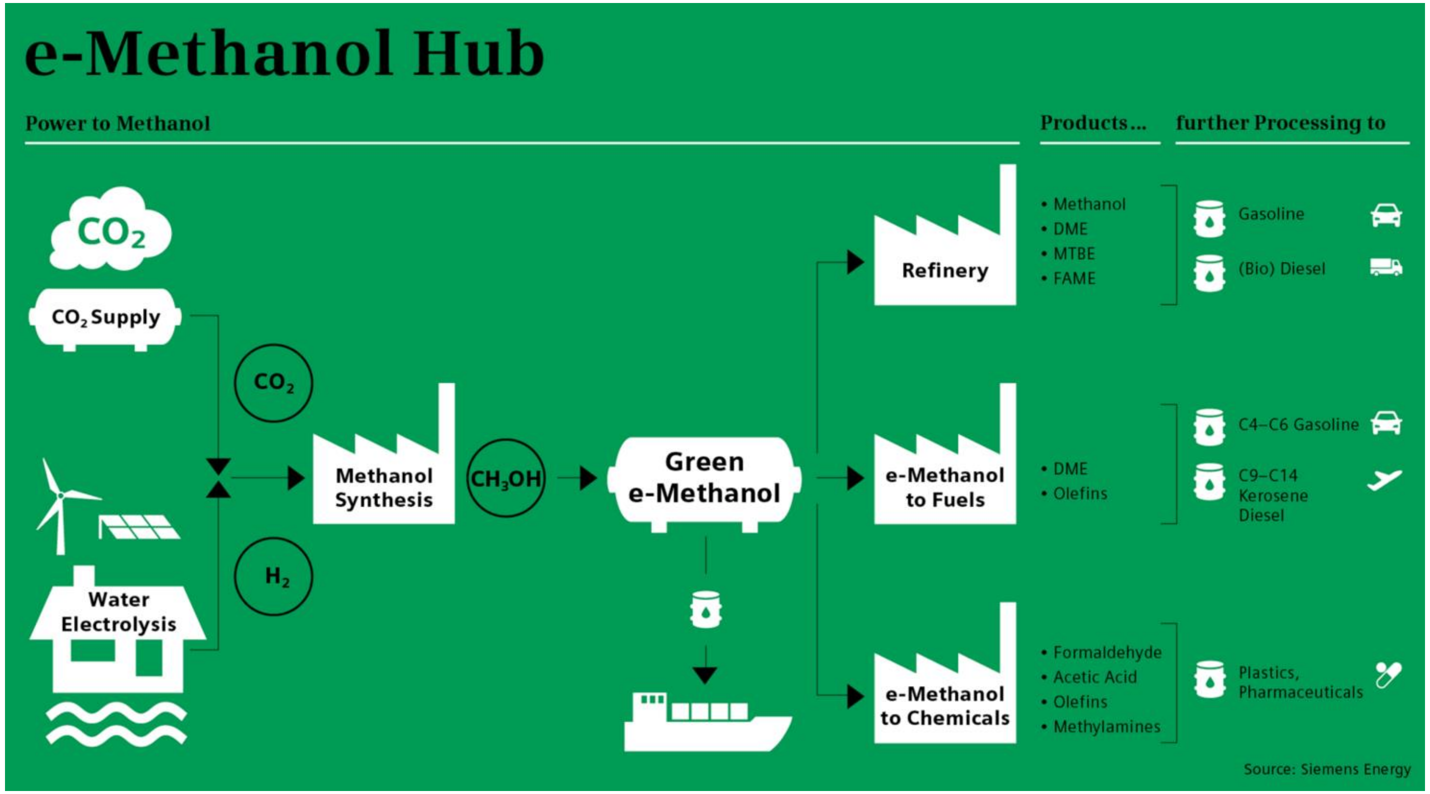
Other e-Fuel avenues to decarbonization

Challenges of H_2 as Energy Vector

- Low energy density per mass
- Energy efficiency for transport over long distance
- Suitability of existing distribution infrastructure
  - Compression
  - Transport by pipeline
  - End users (industrial, residential, etc.)

Alternative e-Fuels

	Pros	Cons
Ammonia (NH_3)	• Energy density • Easy to liquify • Known processes	• Toxic • Reactivity as fuel • NO_x emissions
Methanol (CH_3OH)	• Liquid fuel • Also made as biofuel / from waste	• Carries Carbon • E-Synthesis requires H_2, CO_2



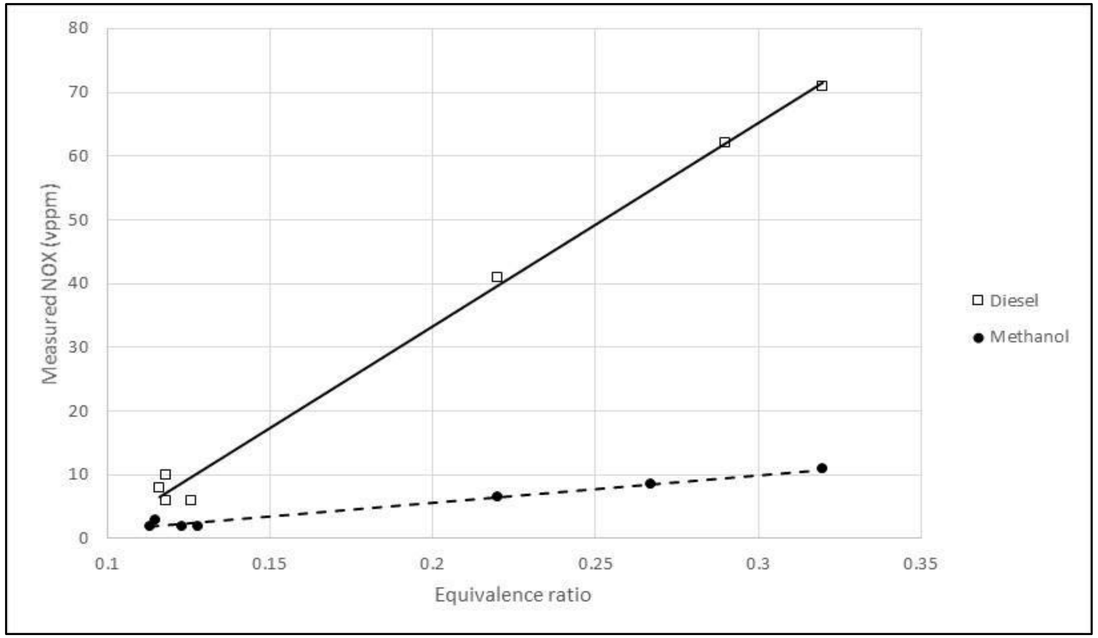
Methanol as Gas Turbine Fuel

Sustainable Methanol can be produced from waste, as biofuel or as e-Fuel.

Ideal replacement for Diesel fuel in Gas Turbines:

- Reduced CO_2 emissions
- Reduced NO_x emissions (lower flame temp.)
- No Sulphur – improved maintenance OPEX and no NO_x emissions
- No visible exhaust plume

Experience using as fuels for Aero GTs, upgrades needed mostly limited to fuel handling systems.



Rig testing of industrial Olympus showing NO_x reduction of at least 80%

Engine Demonstration testing planned for:

- ❑ **SGT-A20 (Industrial Avon)**
- ❑ **SGT-A35 (Industrial RB211)**

Conclusions

- ❑ **Transformation of Energy** is a reality
- ❑ Achieving **Net Zero targets is a huge challenge**…not one “ready” solution

Gas Turbines can contribute in all key levers of Decarbonization

- ❑ **Energy efficiency** – displace coal, modernize the infrastructure
- ❑ **Fuel shift / Hybridization** – shift to lower carbon fuels, integration with Renewables
- ❑ **Deep Decarbonization** – sector coupling, “Power-to-X” models

Collaboration between Industry & Regulators is needed to harness the benefits

Thank You for your attention!

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