

Solar Turbines

A Caterpillar Company

CHALLENGES of an EVOLVING WORLD

Enabling the Path to a Low-Carbon Future

What powered the world in 2022

<https://elements.visualcapitalist.com/what-electricity-sources-power-the-world/>

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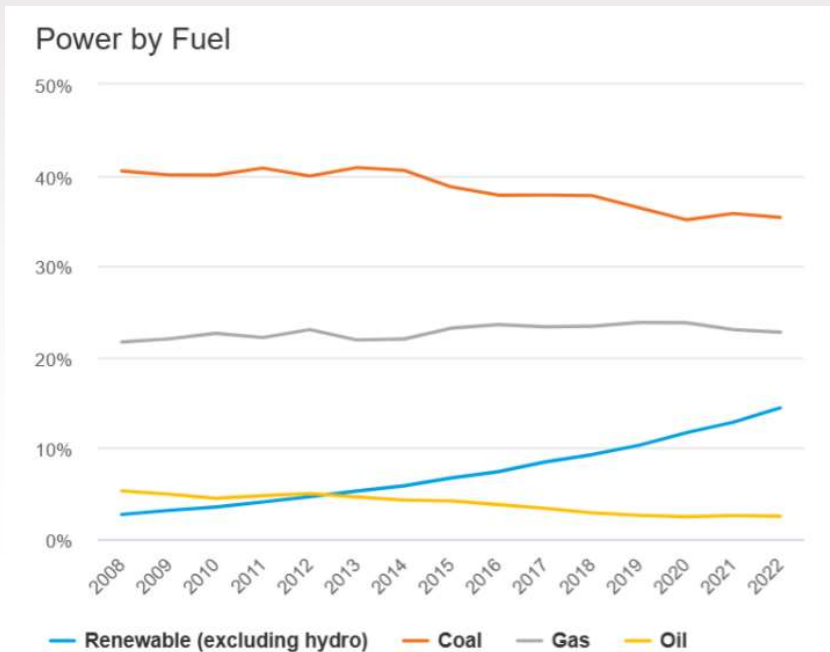
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Coal still the king → 35%

Natural gas → 23%

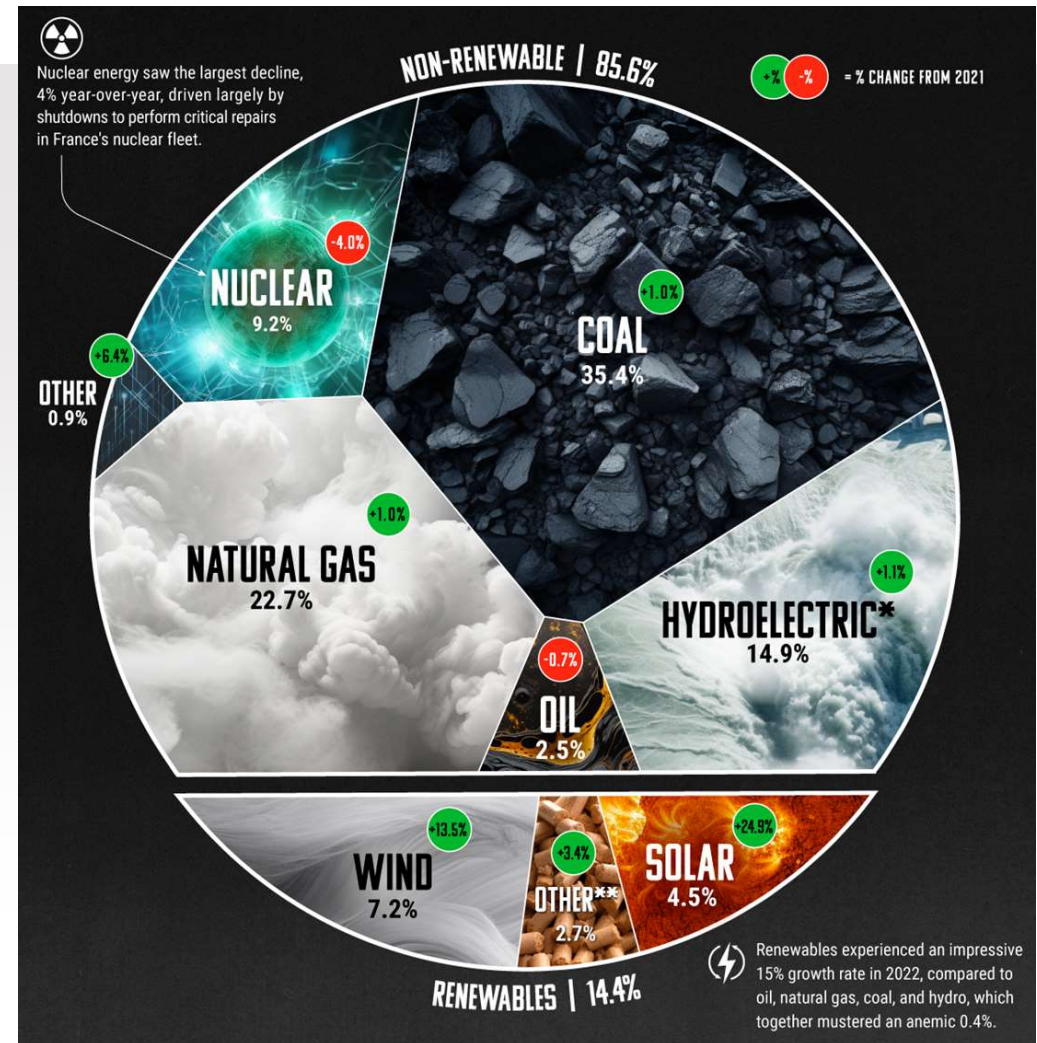
Hydroelectric → 15%

Renewables + Hydro → 29%



Source: Energy Institute

Caterpillar: NON-Confidential



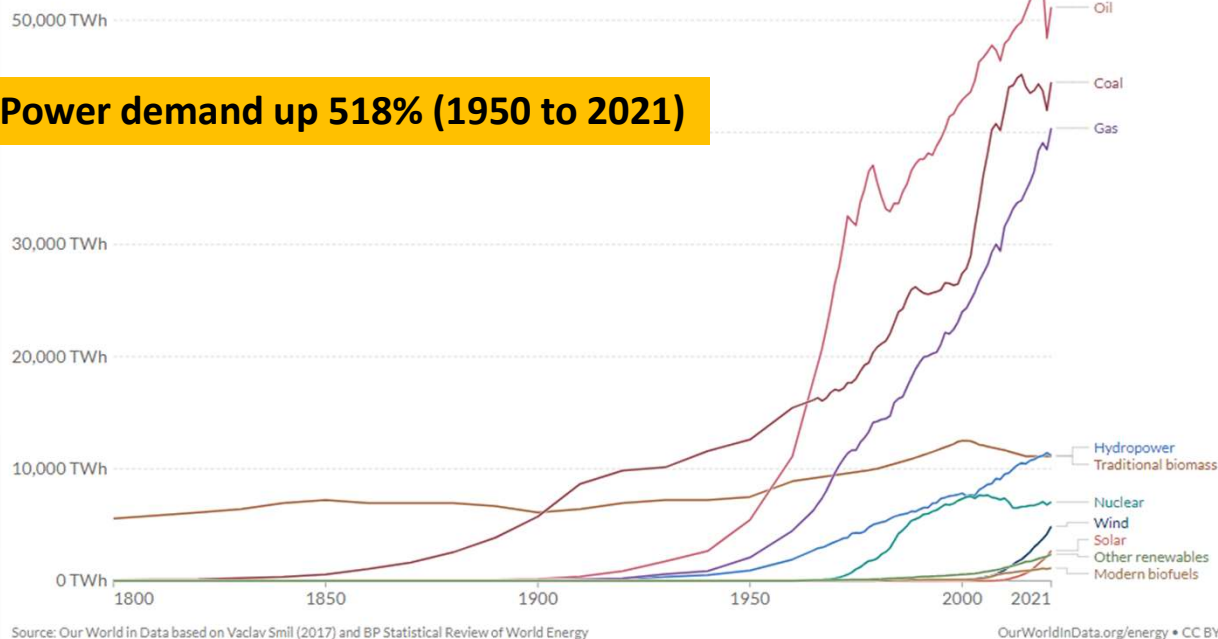
Global Energy Demand

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Global primary energy consumption by source

Global primary energy consumption here is measured by the 'substitution' method which takes account of the inefficiencies of fossil fuel production.

All together ▼



Power demand up 518% (1950 to 2021)

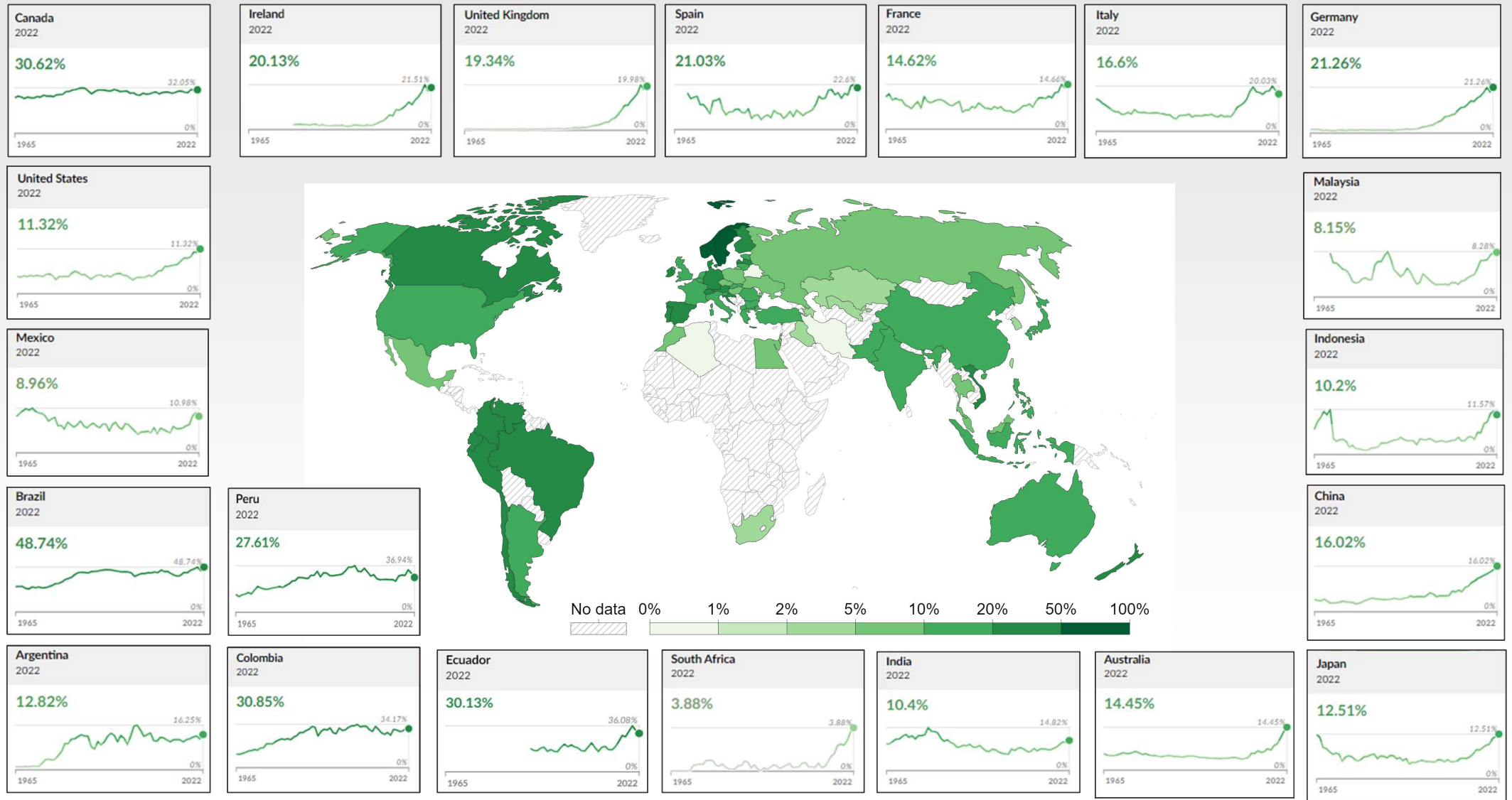
Energy demand soared as ...

- Economic activity rose
- The quality of life improved
- Fossil fuels became plentiful
- Fossil fuels became affordable

In the last 50-years ...

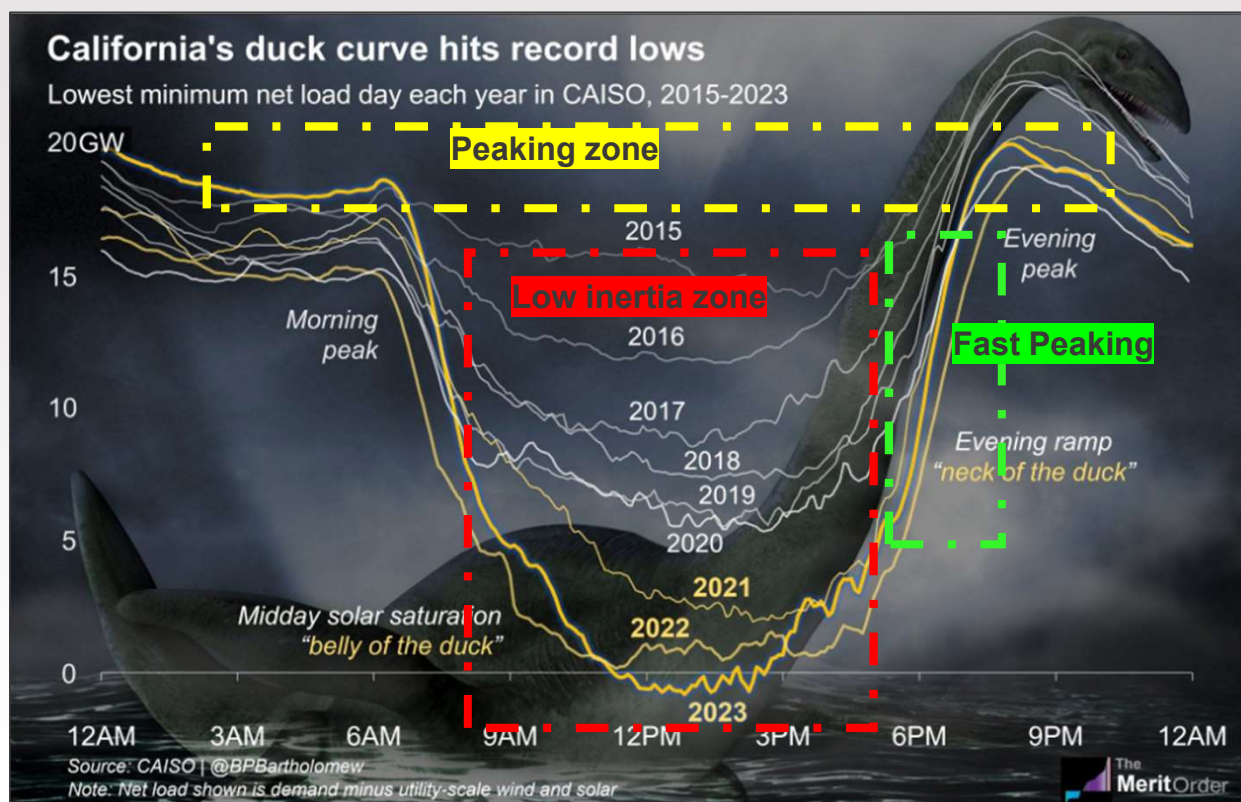
- New energy sources have emerged
 - Nuclear (1970's)
 - Natural gas (fracking)
 - Renewables (wind and solar)
- But older sources have not disappeared
- The percentage of energy provided by wood is the same today as it was in the '800
- Structural changes in the energy landscape take decades to develop

- The penetration of renewables is increasing (17.7% in 2021)
- But energy demand growth is out pacing renewable growth
- Fossil fuel consumption continues to climb



Renewables impact on Energy Supply and Distribution Systems

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The “duck curve” represents the difference in electricity demand and the demand net of variable renewables

TSO and DSO are investing in resiliency

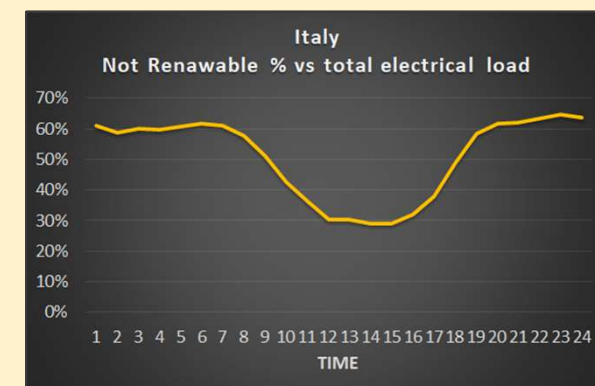
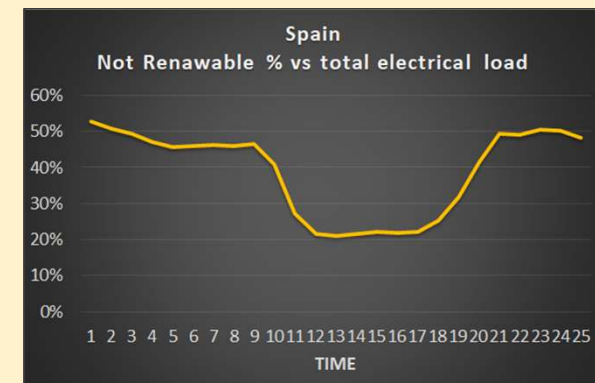
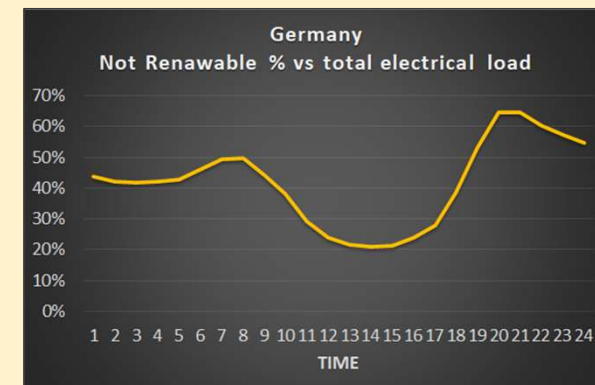
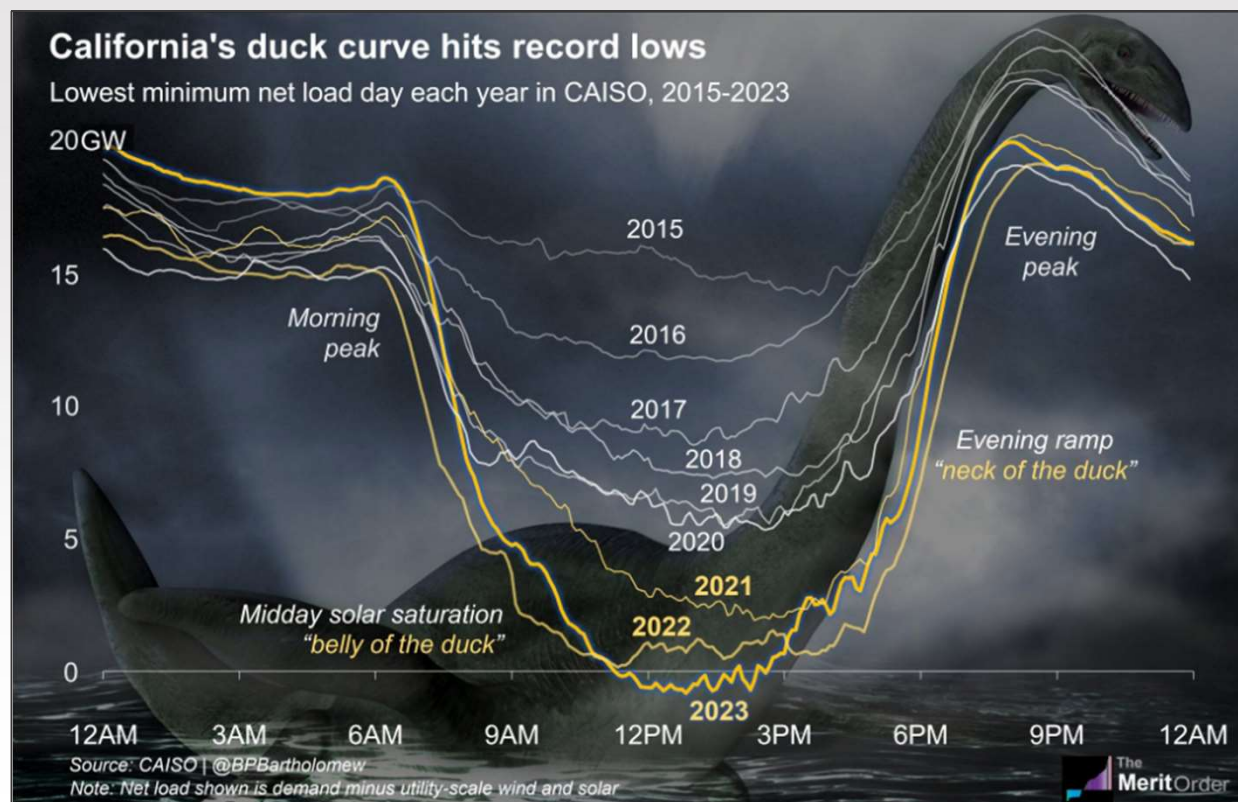
GRID FIRMING

- Energy Storage
- Flexible Generation
- Advanced Grid Management
- Grid Interconnections
- Grid Modernization
- Distributed Energy Resources (DERs)

ANCILLARY SERVICES

- Frequency Regulation
- Voltage Control
- Reactive Power Support
- Load Following
- Black Start Capability
- Reserve Capacity
- Demand Response
- Spinning and Non-Spinning Reserves

It's the typical profile where intermittent renewables feed the grid (PV & Wind)



Energy Transition Takes Time



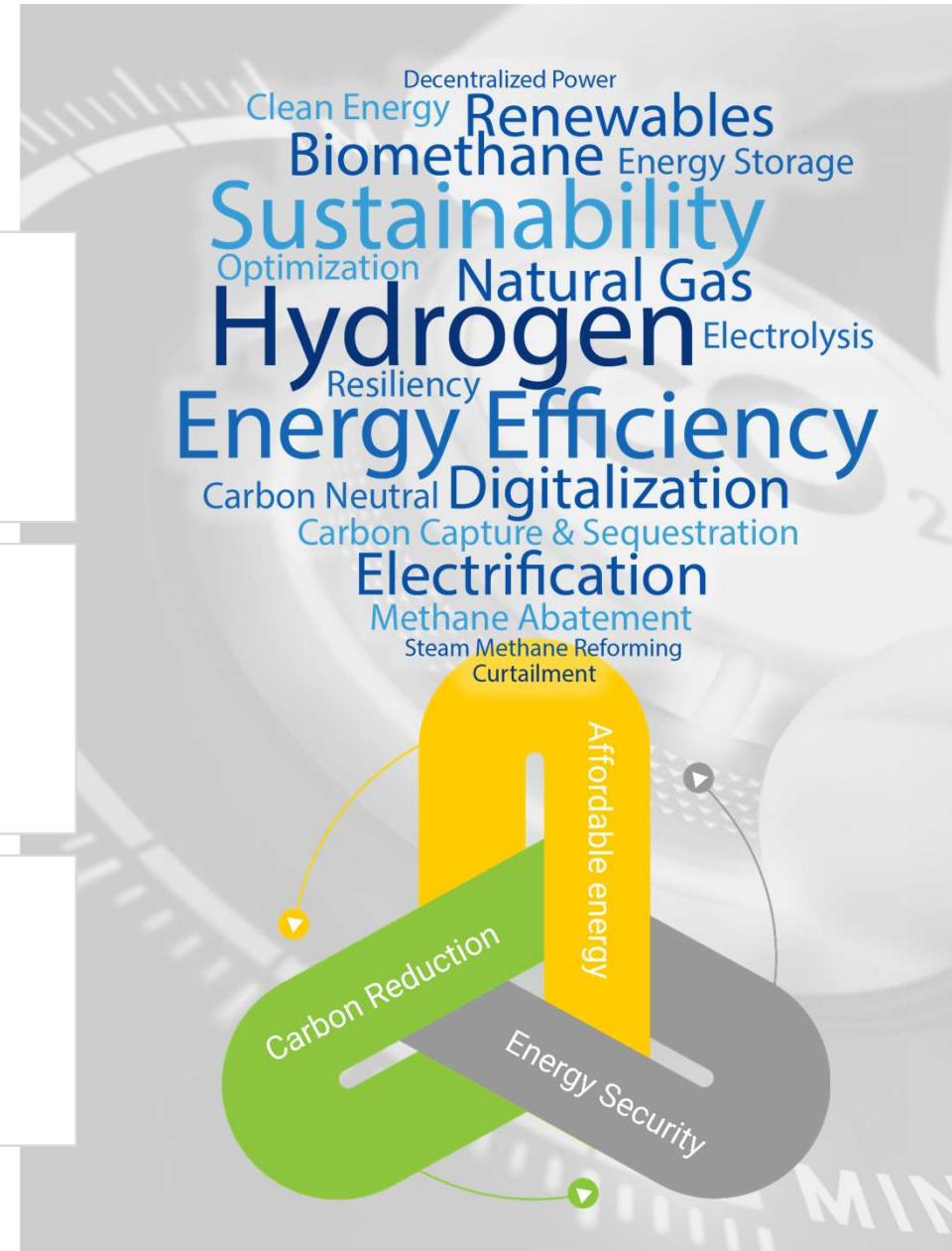
Diversification to enhance security of supply



Balanced approach supporting the speed of the energy transition



Energy solutions adapted to specific regional Requirements



Economics and Sustainability: the key drivers

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<https://carboncredits.com/carbon-prices-today>

“Carbon prices need to reach \$ 130/ton by 2030 and \$ 250/ ton by 2050 in advanced economies to meet net-zero ambitions, according to the International Energy Agency. It is critical for advancing decarbonization technologies.” (IEA)



1 ton

01/2021
34 €/t
286 k€/y

01/2023
85 €/t
714 k€/y

2030
130 €/t
1.1 M€/y

2050
250 €/t
2.1 M€/y

SOLAR TURBINES ROADMAP TO SUPPORT NET ZERO CARBON TARGETS

FLEXIBLE, MODULAR and EFFICIENT power generation solutions

FUEL FLEXIBILITY and CAPABILITY to H2 and Low-C Fuels

MAKE CARBON CAPTURE more FEASIBLE and AFFORDABLE

SMART GRID connected with ENHANCED DIGITAL SOLUTIONS



Solar at a Glance

Solar® Turbines
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**World's Largest
Manufacturer of Industrial
Gas Turbines**
(1 to 23 MW)



Subsidiary of Caterpillar Inc.
SINCE 1981



**Installations in
100+ Countries**

Direct End-to-End
Sales and Service



**Sales and Service
Locations**



16,000+
Gas Turbines Sold



6,500+
Gas Compressors
Sold

Global Workforce

9,000+
Employees



Dispatchable Generation Technology

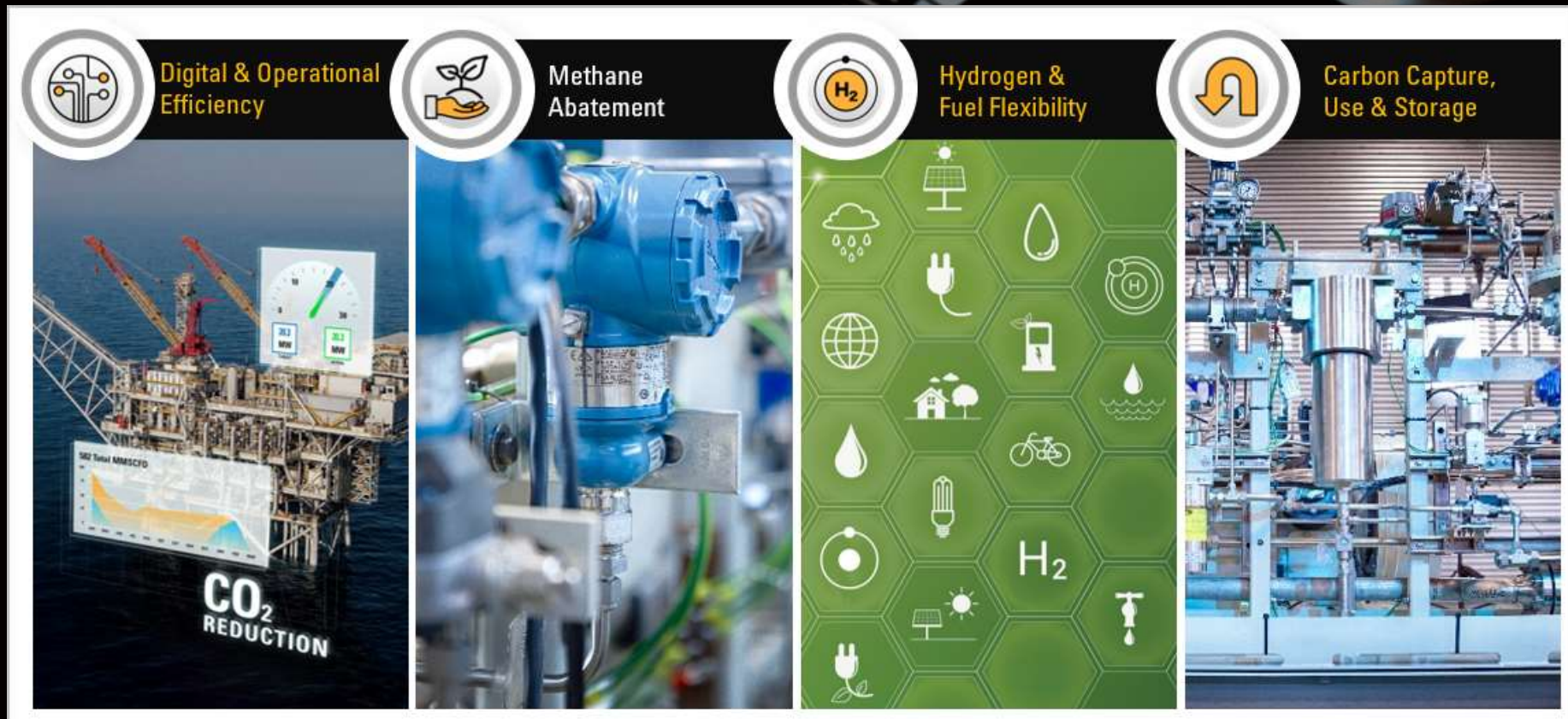
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- Modular PGM (3-38 MWe)
- Mobile (SMT60 and SMT130)
- Quick Start (< 5 min)
- Quick response
- Multiple (Low Carbon) Fuels
- Flexible and Reliable
- SMART connectivity
- Future-Ready Solutions



Dispatchable Generation System for a Sustainable Energy Landscape

Carbon Reduction Pillars



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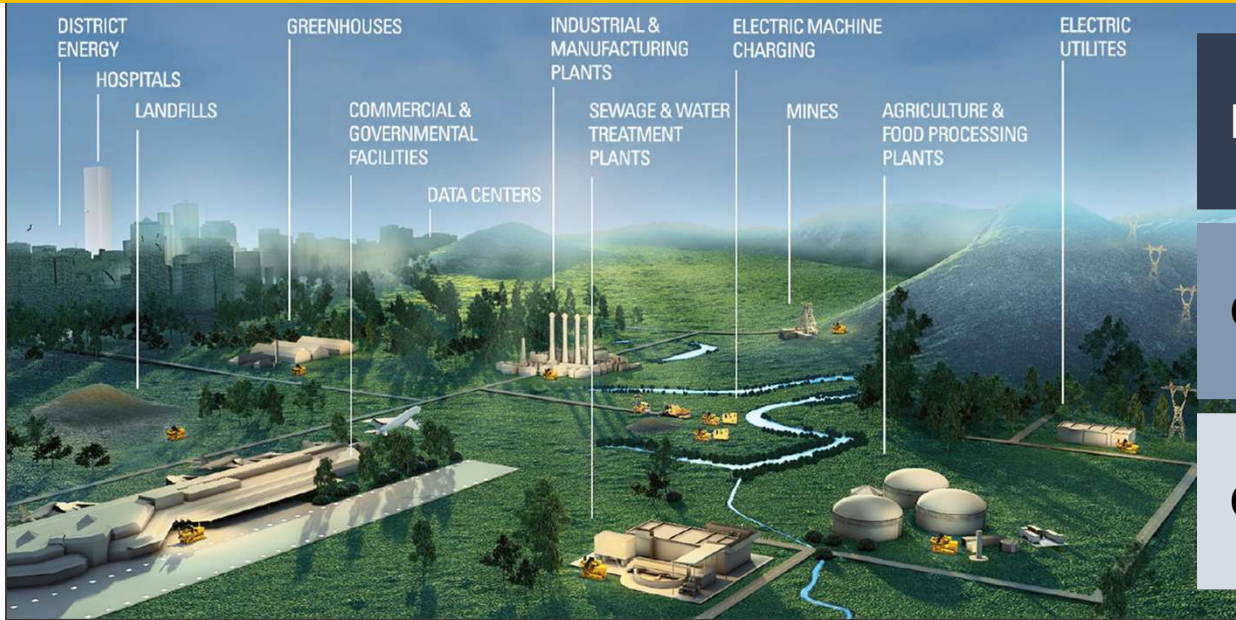
Caterpillar: NON-Confidential

DIGITAL – the enabling factor

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Produce where you need it, when you need it and affordably



KPI monitoring

Costs reduction

Operations optimization

From closed architecture to SMART connected and integrated to the Energy Ecosystem

Enhanced operational efficiency and KPIs maximization

New Energy Markets opportunity

Solar DIGITAL Solutions

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Reduced Mobilizations

Remote Troubleshooting Tools Reduce Equipment & Personnel Travel



Digital Asset Equipment Life Extension

Component Reuse & Time Between Overhaul (TBO) Extension



CO2 Emissions Monitoring

Establish Baseline Metrics, Tracking Improvements, and Identify Bad Actors



Operational Optimization

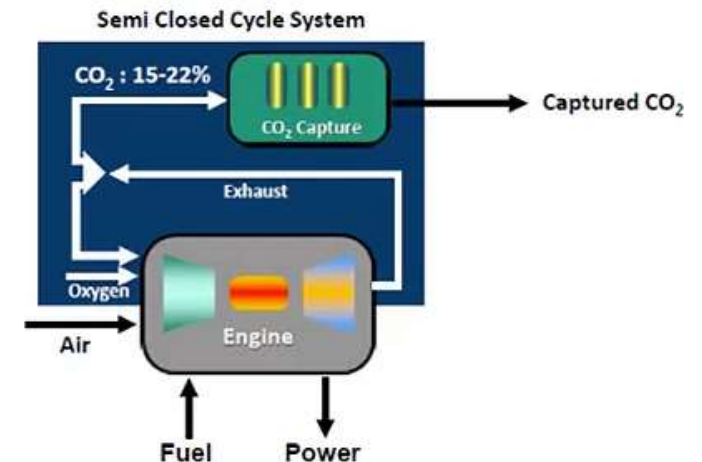
Do More with Less, Operate More Efficiently & Reduce Fuel Consumption



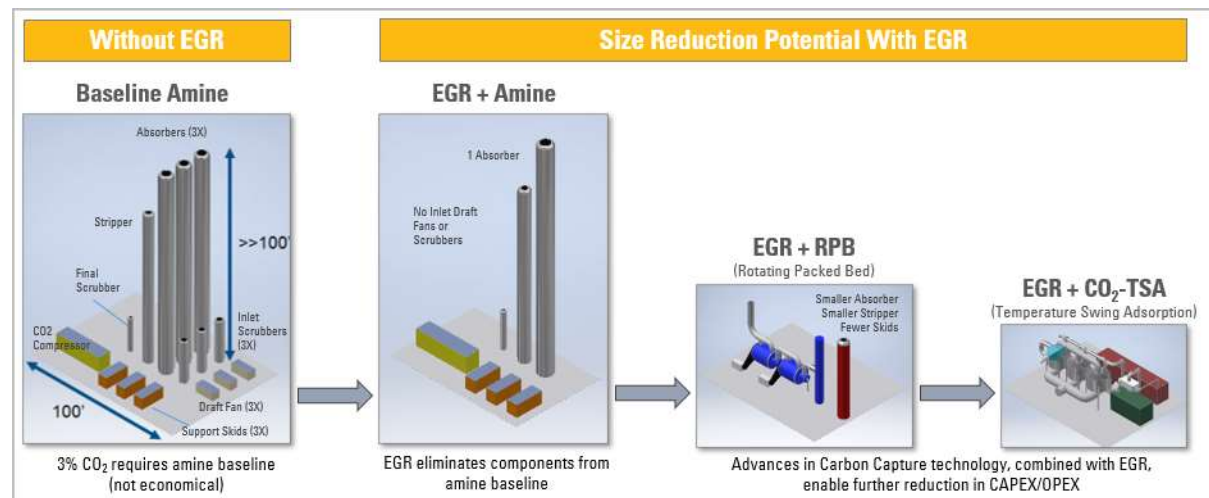
Solar® DIGITAL

Carbon Capture

- CAT acquired CarbonPoint Solutions in 2021
- Patented processes to concentrate CO₂ and reduce capture system cost (EGR)
- CO₂-TSA to capture >95% CO₂ emissions



- Concentrating CO₂
 - Enables cost-effective capture at distributed scale
 - Agnostic of CC technology
- Technology Pilots ongoing



FUELS CAPABILITY

Gaseous Fuels

- Natural Gas
- LNG / LPG
- Associate Gas
- Raw Natural Gas
- Refinery off Gas
- Landfill Gas
- Digester Gas
- Coke Oven Gas
- Gasified Biomass

Liquid Fuels

- Diesel #2 and #1
- Kerosene
- Naphta
- LNG
- LPG
- Gasoline

- Hydrogen
- Syngas
- Biomethane & Biogas
- Renewable Natural Gas (RNG / e-NG)
- Biopropane

- B20-B50 Biodiesel mix
- Renewable Diesel (e-diesel)
- HVO (Hydrogenated Vegetable Oil)*

- Ammonia

- B100 Biodiesel*
- Ethanol*
- Dimethyl Ether (DME)*
- Oily and liquid Biomasses

**Low Carbon
&
Renewable
Fuels**

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Available

Under Development

* Available on some product configurations

Solar's Hydrogen Technology Experience

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1985



First high-H₂ experience
at 40% H₂ (wet)

1995



U.S. refinery runs
Centaur 50 at 100% H₂

2003



Titan 130 SoLoNOx
at 15% H₂

2007



First Coke Oven
Gas Application

2018



46 Gas Turbines
Up to 65% H₂

2023



Titan 130
up to 83% H₂

- **35+ years of experience in high hydrogen application**
- **55 units in operations with over 2M operating hours**

Three Combustion Platforms

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Conventional Combustion (Diffusion Flame)



**100%
READY TODAY!**

SCR available for low NOx emission

- **Steel Industry** Applications in China
- **Propane Dehydrogenation** application in Belgium
- **Refinery** Application in the United States

SoLoNOx



Validating higher
percentage level

- **Refineries** in United States
- **Chemical Plant** Applications in China & Europe
- **20% H2-ready packages** (Europe)

100% DLE



Concept evaluation, Injector testing
today (2021-2024)

First Engine test target:
2025-2026

Hydrogen Demonstration Projects

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Solar Turbines Partners with
GRTgaz Deutschland and OGE

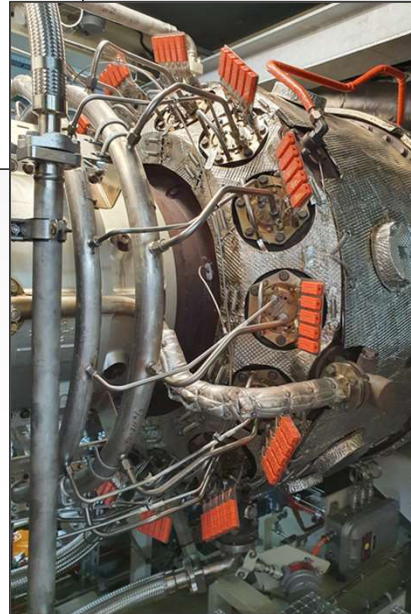
February 23, 2023

Site: Germany

Units: Titan 130-20502S

Test H2 Content: 24+%

Timeline: September 2022



Site: California, USA

Centaur 40 4501S GenSet

Test H2 Content: up to 50%

Timeline: Q4 2023

project portfolio operations technology  sustainability investors about

newsroom topics press releases events archive media

emissions solutions

hydrogen-fueled gas turbine engine could lead to lower carbon intensity

2 min read | march 02, 2023



Solar Turbines is working with Chevron on a turbine engine partially fueled by hydrogen.

Chevron and Caterpillar-owned Solar Turbines are working together to adapt a low-emissions turbine engine partially fueled by hydrogen. Blending hydrogen with traditional fuels to power the engine could help reduce its greenhouse gas emissions.

Our Commitment

- *Investing in Efficient GT technology*
 - *Enabling Lower Carbon Intensity Solutions*
- *H₂, E-fuel, Biofuel → SOLAR is ready today for the tomorrow fuels*
 - *Solar has the current largest Gas Turbine fleet running on Hydrogen rich fuels*

SOLAR DIGITAL supports growth for Renewable Energy and SMART applications

THANK YOU

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Paolo Masiero

*Power Generation Marketing
and Product Strategy*

Caterpillar: Non-Confidential