

Support of Carbon Reduction Through Gas Turbine Fuel Flexibility

June 2021

Solar® Turbines

A Caterpillar Company

SUSTAINABILITY: Making the Future our Purpose for Today

Sustainability is part of who we are and what we do every single day. Progress involves a balance of environmental stewardship, social responsibility and economic growth.



COMMUNITY

- People matter
- External corporate narrative
- Corporate social responsibility



BUSINESS

- Culture of sustainability
- Operational excellence
- Long-term reinvestment



ENVIRONMENT

- Low impact energy solutions
- Resource management
- Material recovery and reuse solutions

Gas Turbines are Part of the Carbon Reduction Strategy

Shifting from coal-based power plants to:



Natural Gas



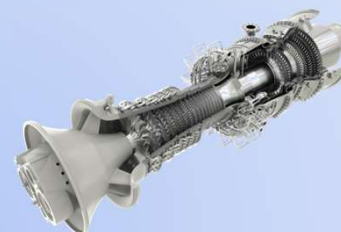
↓ CO₂ by 50%



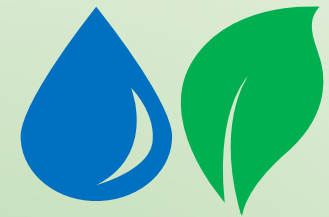
Natural Gas/H₂/Bio



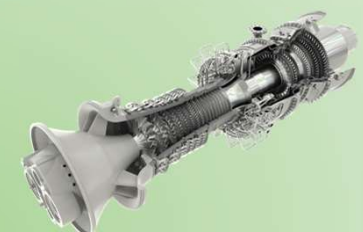
↓ CO₂



H₂/Bio



0% CO₂



2021

2030

- Gas Turbines provide stable base load and support increased renewable penetration
- Hydrogen enables carbon reduction opportunities for gas turbine operation
- Increased hydrogen enables energy storage and transportation in existing natural gas pipelines

The Role of Gas Turbines in the Energy Landscape

- Enable Support / Bridge for Deployment of Transition Fuels
 - BioMethane, SynFuels, H₂/CH₄ blends
- Grid Stability / Frequency Control
 - Rotating Mass vs Variable Supply (Solar PV & Wind)
- Continued Improvements in Efficiency
 - Doing More with Less
- Increased deployment of CHP and use of Heat
 - Increased efficiency of customer applications – reduced cost
- Increased use of Digitalization to bring Value to customers
 - Only consume power when it is most cost-effective

Solar's Carbon Reduction Strategy Overview



Operational
Efficiency



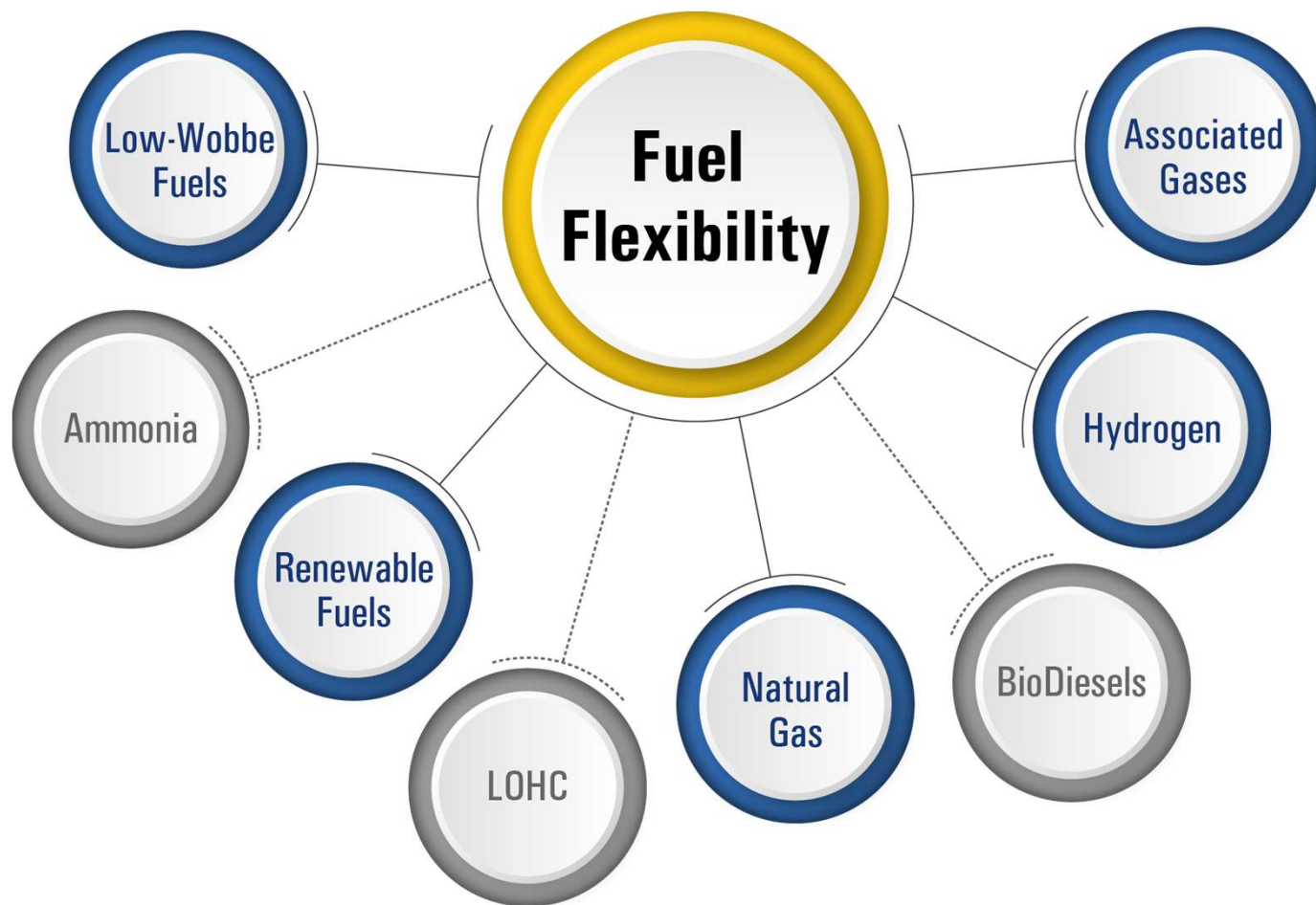
Methane Abatement



Carbon Capture
Storage & Utilization



Hydrogen & Fuel
Flexibility



Hydrogen Market Segments

Pipeline Gas Applications

Hydrogen Content $\leq 20\%$



SoLoNOx™

- H₂ as Energy Storage
- Decarbonization through Fuel Switching
 - Maximize Renewable Energy

Industrial Processes

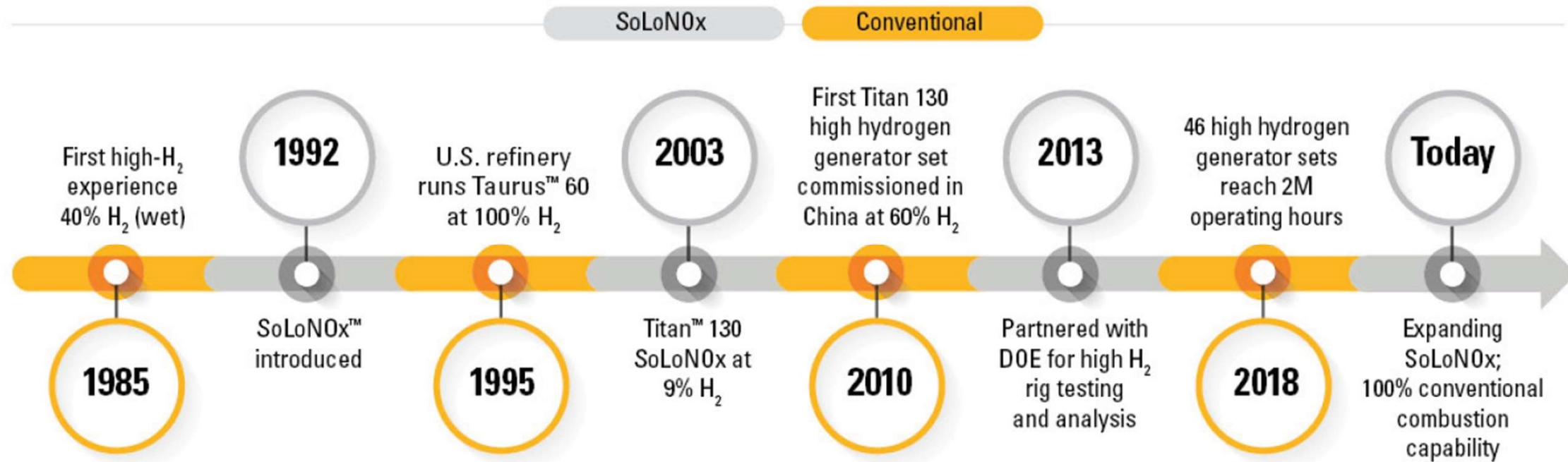
Hydrogen Content $> 20\%$



Conventional Combustion

- Steel Industry Applications
- Industrial Off-Gases & Process Gases
- Waste/Biomass Gasification to Energy

Solar's H₂ Technology Experience



Solar Turbines Hydrogen Capabilities

SoLoNOx™ Up to 20% H₂

- Refineries in United States up to 20% H₂
- Chemical Plant Applications in China & Europe up to 14% H₂



Conventional Combustion Up to 100% H₂

- Steel Industry Applications in China up to 65% H₂
- Propane Dehydrogenation application in Belgium up to 83% H₂
- Refinery Application in the United States up to 37% H₂



H₂ Pipeline Demonstration Projects



Site: Italy

Units: Mars 100-16000S

Test H2 Content: 10%

Timeline: Q4 2021



Site: Germany

Units: Titan 130-20502S

Test H2 Content: 20%

Timeline: Q4 2022

The Tiered Approach – Options to Fit Customer Needs

Solar Equipment Only

Feasibility Study

Tier 1

General H₂ feasibility analysis with suggested upgrades and scope with a price range.

Detailed Study

Tier 2

Detailed analysis of package systems and components with recommended upgrades and budgetary pricing.

Detailed Study with FAS

Tier 3

Tier 2 H₂ study plus comprehensive Fleet Assessment including carbon reduction options.

We proudly deliver the digital technology solutions that enable Customer success.



Less Planned & Unplanned Downtime

- Analytics
- Advanced Vibration
- Smarter Alerting



Lower Total Lifecycle Costs

Time Based →
Condition Based Overhaul



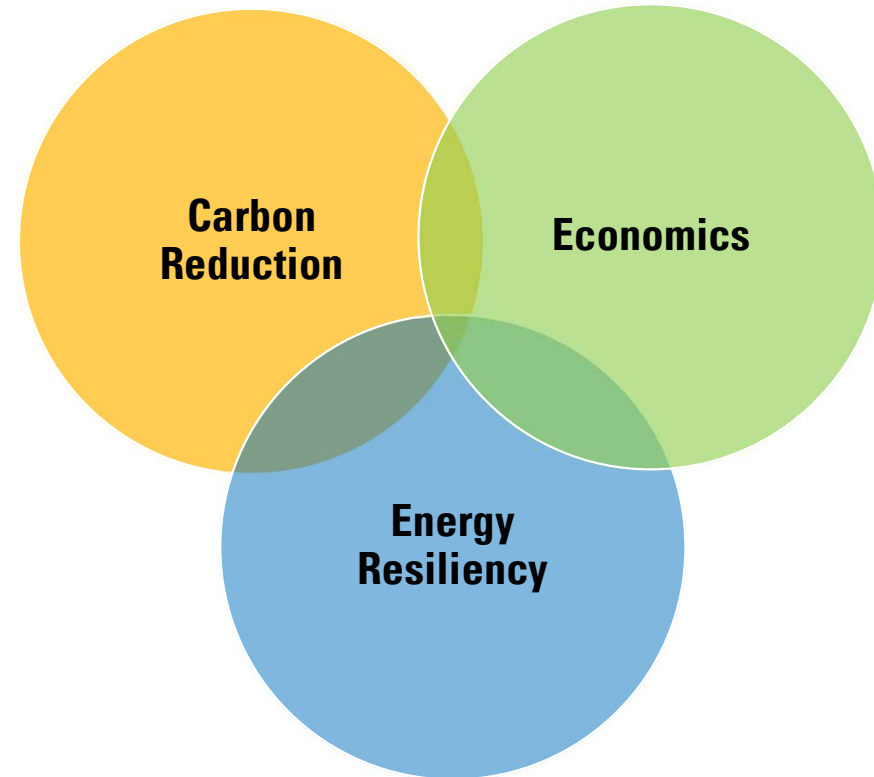
Reduce their Carbon Footprint

- Optimization:
- Power
 - Compression
 - Energy



Summary

- Gas Turbines provide stable base load and support increased renewable penetration.
- Hydrogen enables carbon reduction opportunities for gas turbine operation.
- Increased Hydrogen enables energy storage and transportation opportunities for Gas Turbines and Gas Compressors with natural gas pipelines.
- Solar has a large Gas Turbine fleet running on Hydrogen rich fuels.
- Solar's Gas Turbines, Packages and Compressors are hydrogen-ready now.
- Solar is increasing investment in Hydrogen solutions



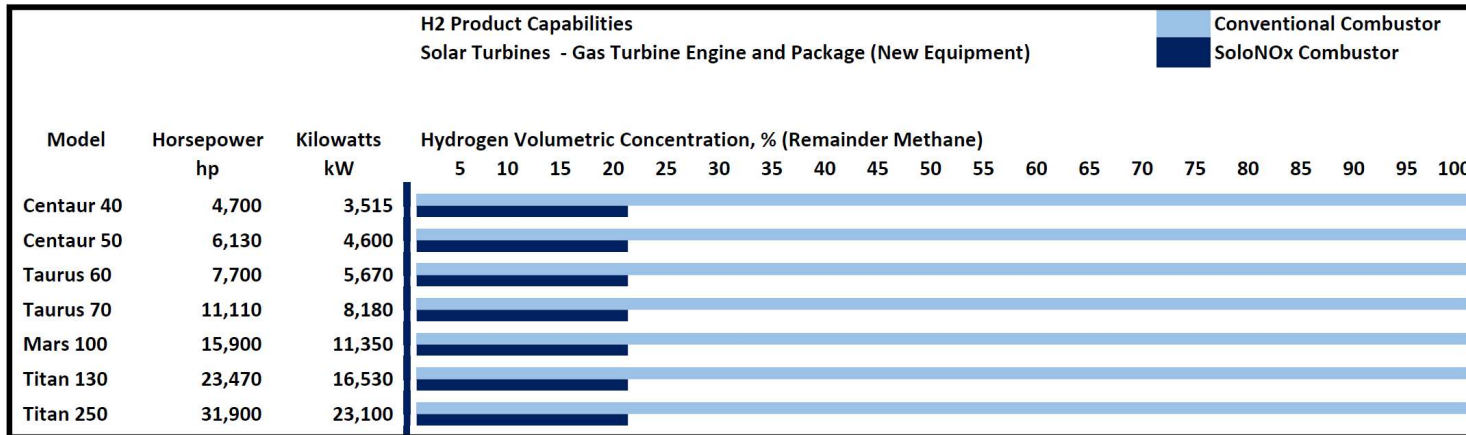
THANK YOU

Solar Turbines

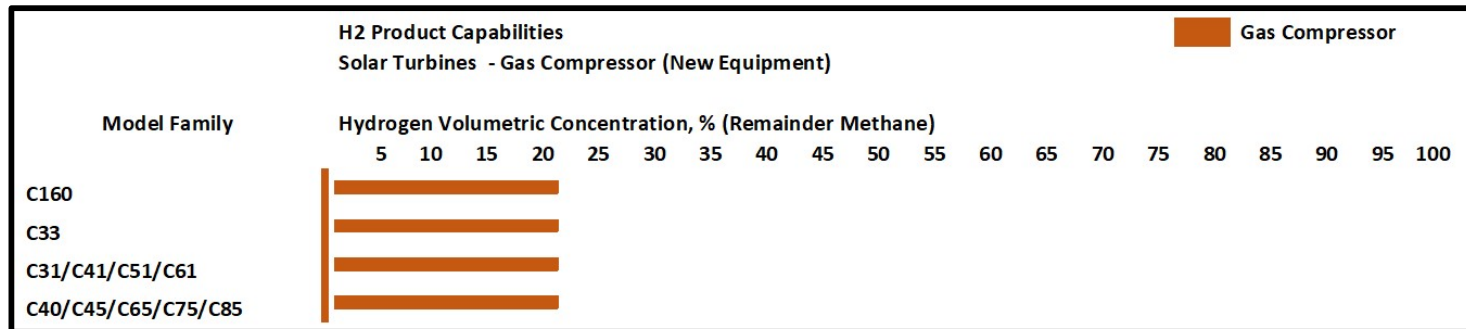
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Questions ?

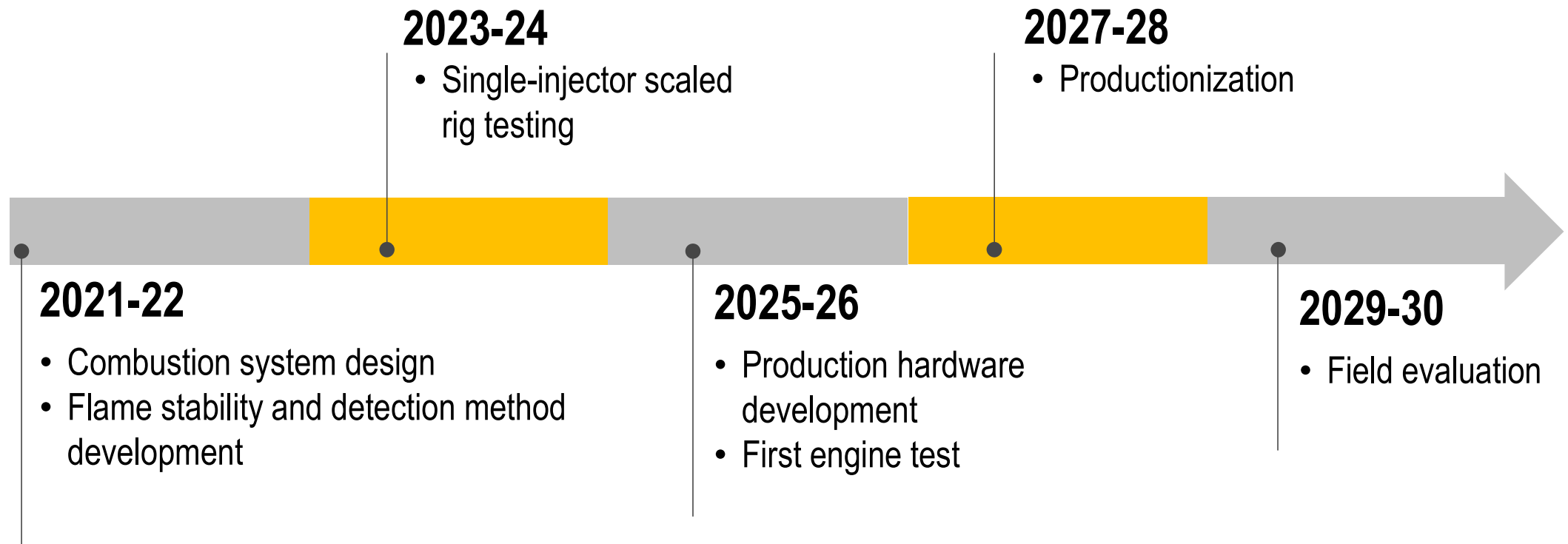
Solar Product Hydrogen Capabilities* - March 2021 (O&G)



*Hydrogen capabilities shown are for new equipment configurations. Depending on operating conditions and requirements, some restrictions and/or additional engine, package, and gas compressor hardware and software modifications may apply. Higher hydrogen requirements can be considered on a case-by-case basis.



Solar's High-H₂ DLE Roadmap to 100%



Note: Roadmap dependent on actual market conditions.

Case Study: Propane Dehydrogenation Plant (PDH)

- T130 (15MWe ISO) Gas Turbine (Conventional)
 - Low-Noise Requirement
 - HRSG supplied with integrated deaerator
 - SCR for NOx emissions
- PDH plant produces off-gas high in H₂ content (>80% by vol.)
- CO₂ Reduction
 - Use of H₂ rich fuel
 - Efficient combined-cycle solution to ensure Electrical and full steam production



REDUCED CO2 EMISSIONS
REDUCED FLARE OPERATIONS
QUICK RETURN ON INVESTMENT
SUSTAINABILITY

Case Study: China, Steel Industry Application

- 4x Titan 130 gas turbines burning high-H₂ (>50% H₂) to produce electricity
- Exhaust heat used to produce steam with >80% efficiency
- The 55 MW CHP system has avoided CO₂ emissions of more than 300k metric tons/year
- Customer received a Certificate of Avoided GHG Emissions from U.S. EPA CHP Partnership

