Improving the Flexibility and Efficiency of Gas Turbine-based Distributed Power Plant

Mike Welch
Siemens Industrial Turbomachinery Ltd.

Disclaimer

This document contains forward-looking statements and information – that is, statements related to future, not past, events. These statements may be identified either orally or in writing by words as “expects”, “anticipates”, “intends”, “plans”, “believes”, “seeks”, “estimates”, “will” or words of similar meaning. Such statements are based on our current expectations and certain assumptions, and are, therefore, subject to certain risks and uncertainties. A variety of factors, many of which are beyond Siemens’ control, affect its operations, performance, business strategy and results and could cause the actual results, performance or achievements of Siemens worldwide to be materially different from any future results, performance or achievements that may be expressed or implied by such forward-looking statements. For us, particular uncertainties arise, among others, from changes in general economic and business conditions, changes in currency exchange rates and interest rates, introduction of competing products or technologies by other companies, lack of acceptance of new products or services by customers targeted by Siemens worldwide, changes in business strategy and various other factors. More detailed information about certain of these factors is contained in Siemens’ filings with the SEC, which are available on the Siemens website, www.siemens.com and on the SEC’s website, www.sec.gov. Should one or more of these risks or uncertainties materialize, or should underlying assumptions prove incorrect, actual results may vary materially from those described in the relevant forward-looking statement as anticipated, believed, estimated, expected, intended, planned or projected. Siemens does not intend or assume any obligation to update or revise these forward-looking statements in light of developments which differ from those anticipated.

Trademarks mentioned in this document are the property of Siemens AG, its affiliates or their respective owners.
TRENT® and RB211® are registered trade marks of and used under license from Rolls-Royce plc. Trent, RB211, 501 and Avon are trade marks of and used under license of Rolls-Royce plc.

Contents

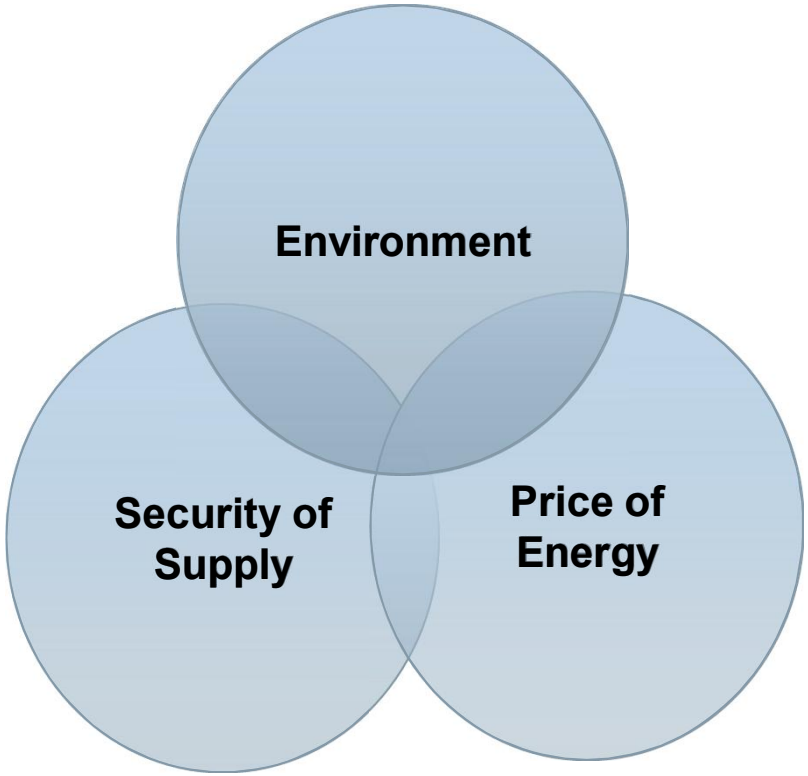
- **Introduction**
- **Decentralised Power**
- **Addressing the Energy Trilemma with Flexible Decentralised Power**
  - Cost of Energy
  - Security of Supply
  - Environment
- **Conclusions**

Introduction

The Energy Trilemma

- Growing demand for affordable electricity
- Modern society requires security of power supplies
- Need to limit impact of power generation on both the local and global environment

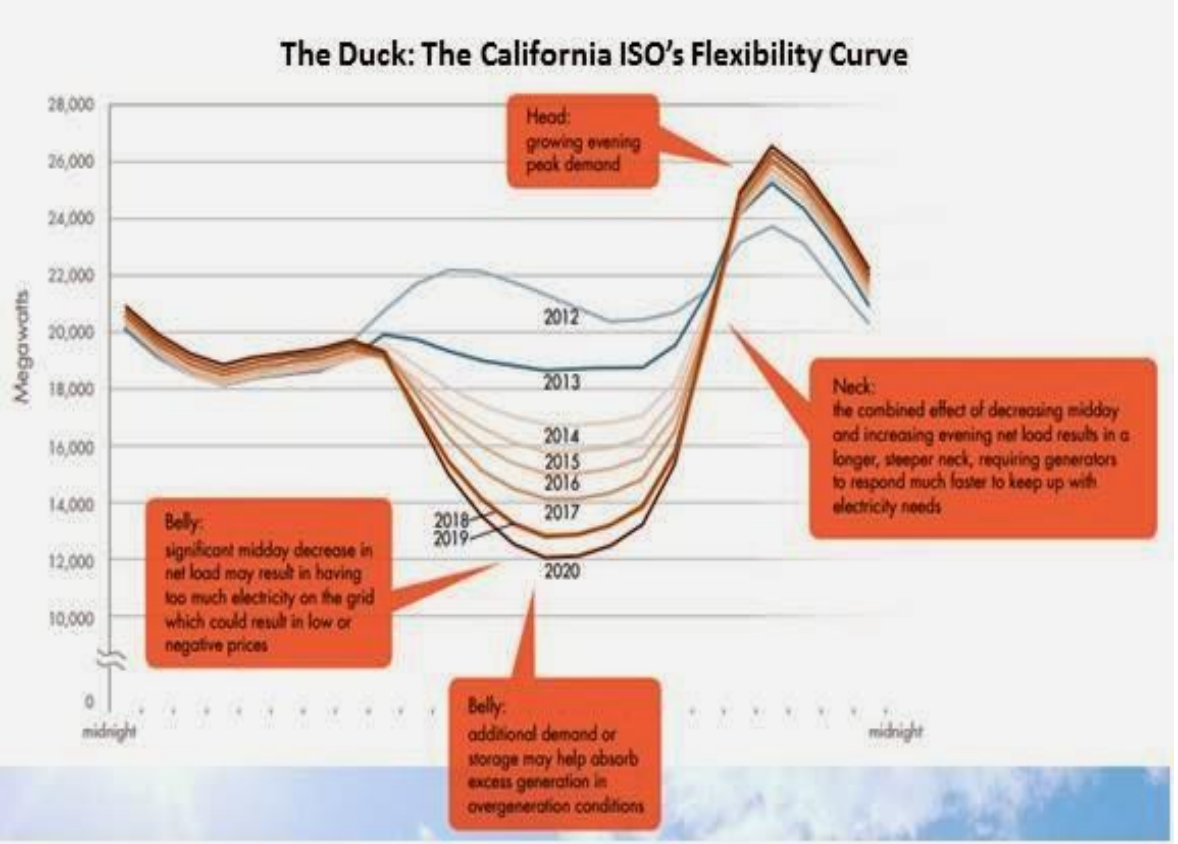
- *Focus on only one area can cause problems*
- High penetration of intermittent renewables has created security of supply and price problems
- Change in operational requirements of fossil fuel power



Introduction

Changing Operational Needs

- Rapid changes in fossil fuel power generation output caused by non-despatchable intermittent renewables
- Power plant designed for base load having to operate as mid-merit or peaking plant
- Part-load operation of centralised fossil plant or maintained as spinning reserve
- ‘Clean’ natural gas fossil fuel generation under cost pressures
- Security of supply risks, increased emissions
- Water constraints



(the ISO's *Building A Sustainable Energy Future; 2014-2016 Strategic Plan*)

Introduction

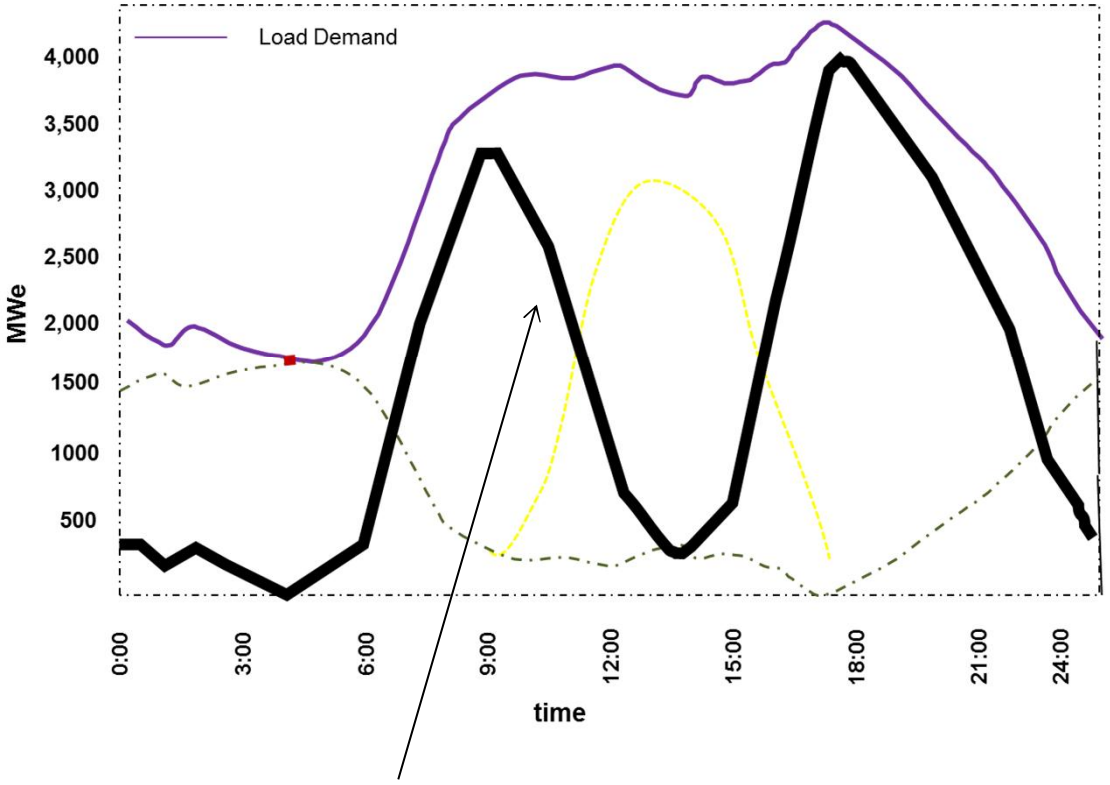
Changing considerations for future Power Plant design

Flexibility

ast Response

requent Cycling

uel Switching



Decentralised Power

Decentralised Power can help address the challenges of the Energy Trilemma

- Located close to load demand centres
  - Reduced transmission losses
  - Connected to distribution network
  - Frequency and voltage support
  - Can satisfy a local heat demand

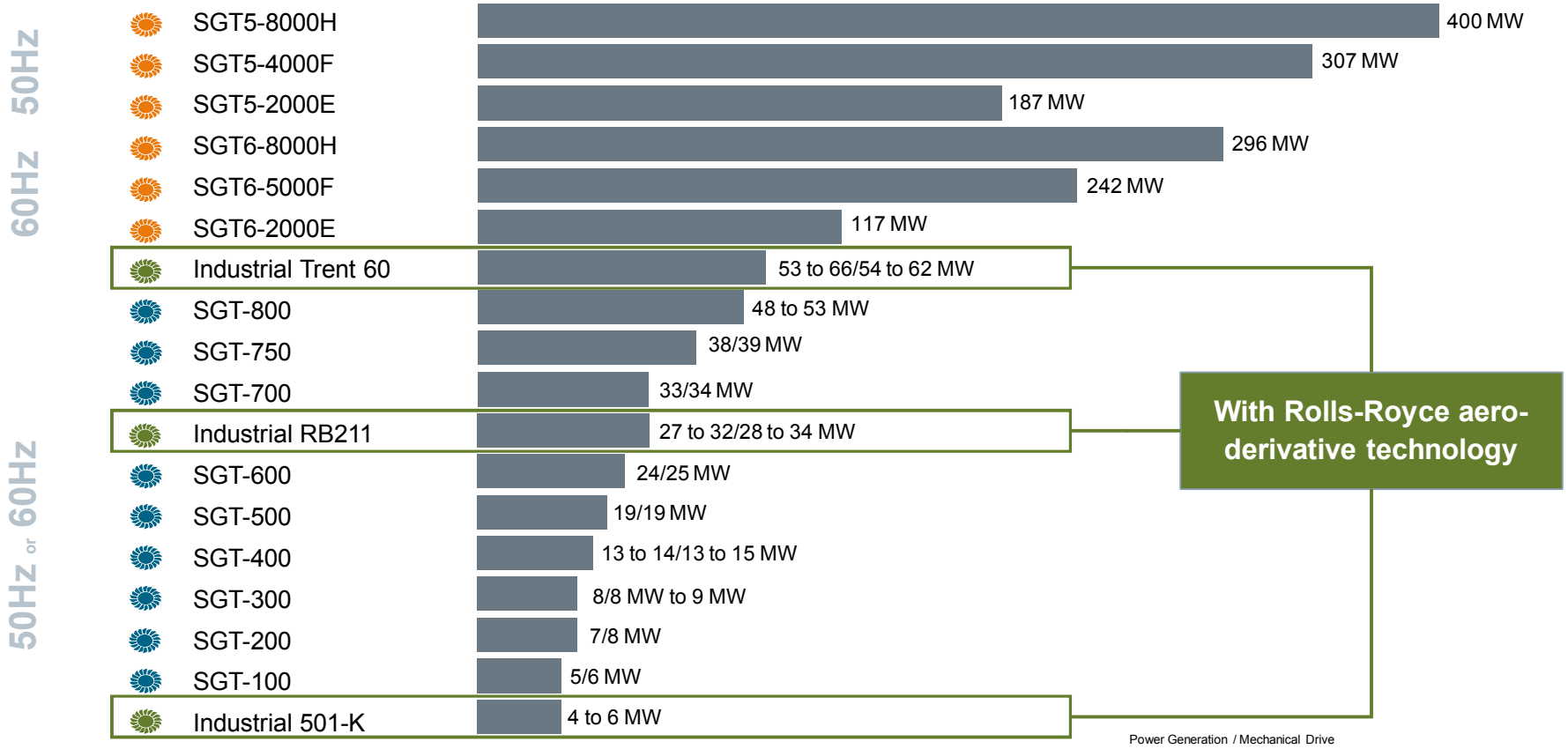
- Multiple units
  - Increased availability
  - Enhanced operational range
  - High efficiency across wide load range
  - Minimised environmental footprint
  - Low initial investment
    - Easy expansion

Siemens Gas Turbine Portfolio for Decentralised Power

Heavy-duty gas turbines

Industrial gas turbines

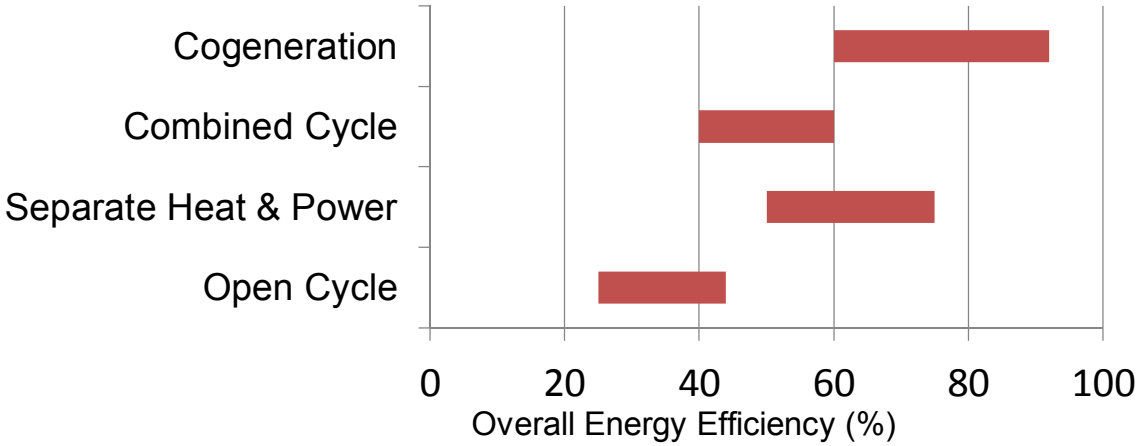
Aeroderivative gas turbines

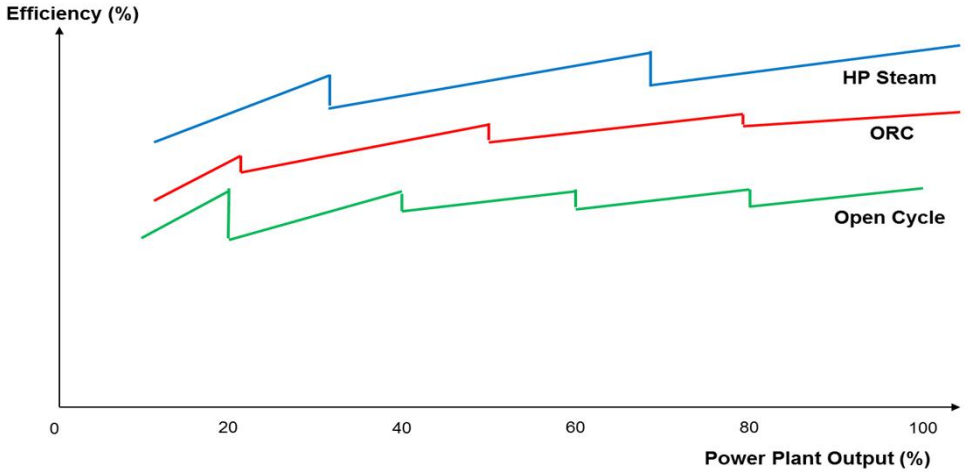


Addressing the Energy Trilemma with Decentralised Power

Price of Energy

- High Energy Efficiency
- Competitive Installed Costs
- Compact Modular Packages
  - Small footprint, ease of future expansion
- Low maintenance and plant manpower costs
  - Core exchange principal
- Fast start-up possibilities with no maintenance penalties
  - No EOH on Industrial Trent aero-derivative
- Low cost fuel potential
- Low waste disposal
  - Lube oil & water treatment chemicals



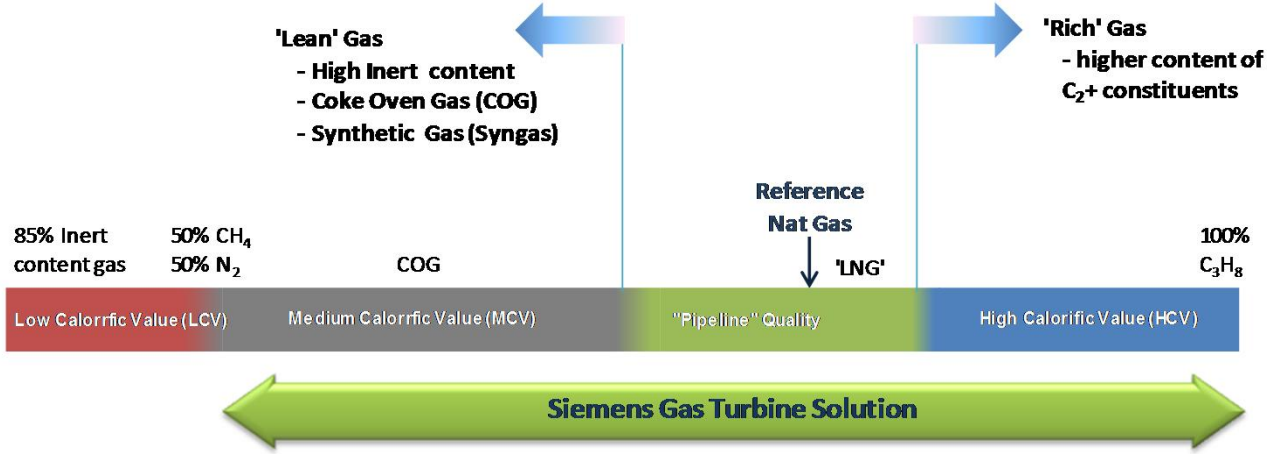


Addressing the Energy Trilemma with Decentralised Power

Price of Energy

- Use of Opportunity Fuels to reduce costs
- US$0.50/ MMBTU ≈ US$2 million / year for a 50MW class gas turbine
- Wide range of potential fuels, even in DLE combustion systems
- Can show environmental benefit too
  - Reduced flaring
  - Ethane or propane to replace diesel

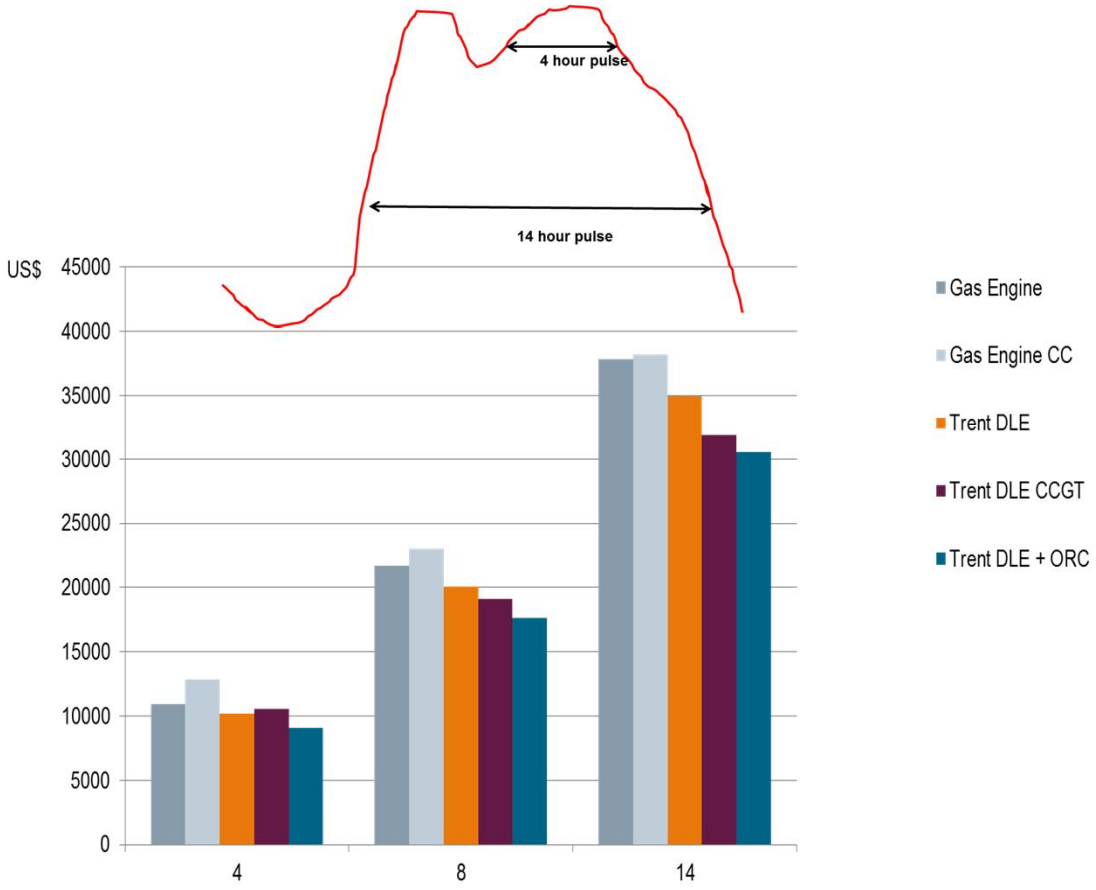
7.7MW tri-fuel gas turbine installed in a cogeneration plant in the USA



Addressing the Energy Trilemma with Decentralised Power

Price of Energy: Pulse Load Operation

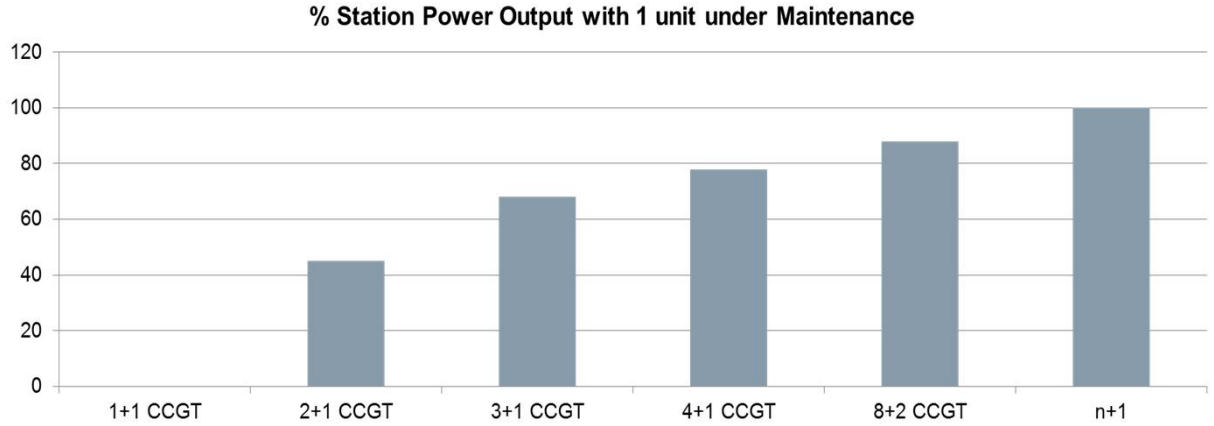
100MW Power Plant		ICE	CC ICE	Trent DLE OC	Trent DLE CCGT	Trent + ORC
Full Load Net Efficiency	%	44	49.2	41.87	53	52
Start-up time	Mins	5	50	10	40	20
Shut-down time	Mins	1	20	5	20	10
O&M costs (2000 hrs/yr operation)	$/MWh	5.5	5.5	4	5	4.5
Start-up costs	$/MW	-	-	-	-	

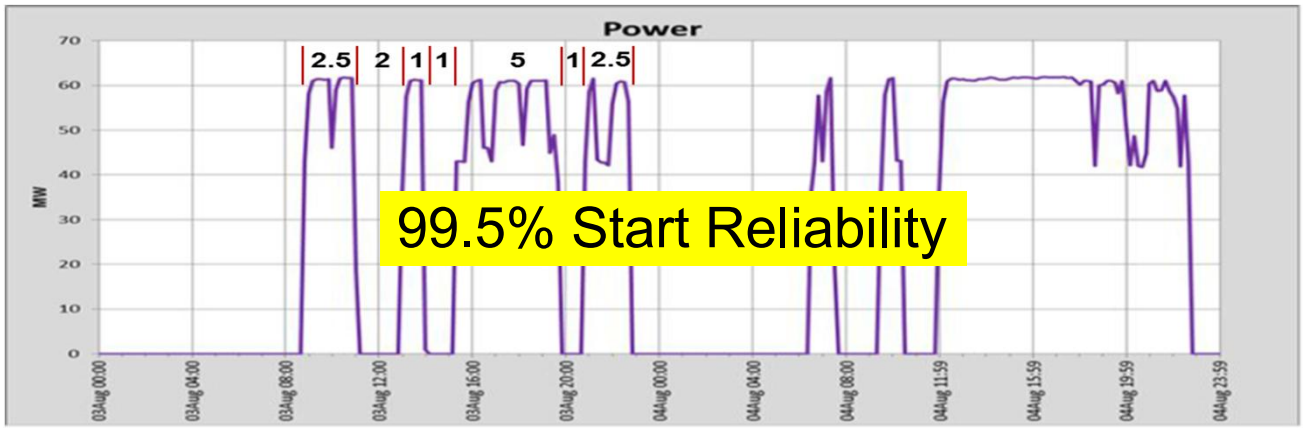


Addressing the Energy Trilemma with Decentralised Power

Security of Supply

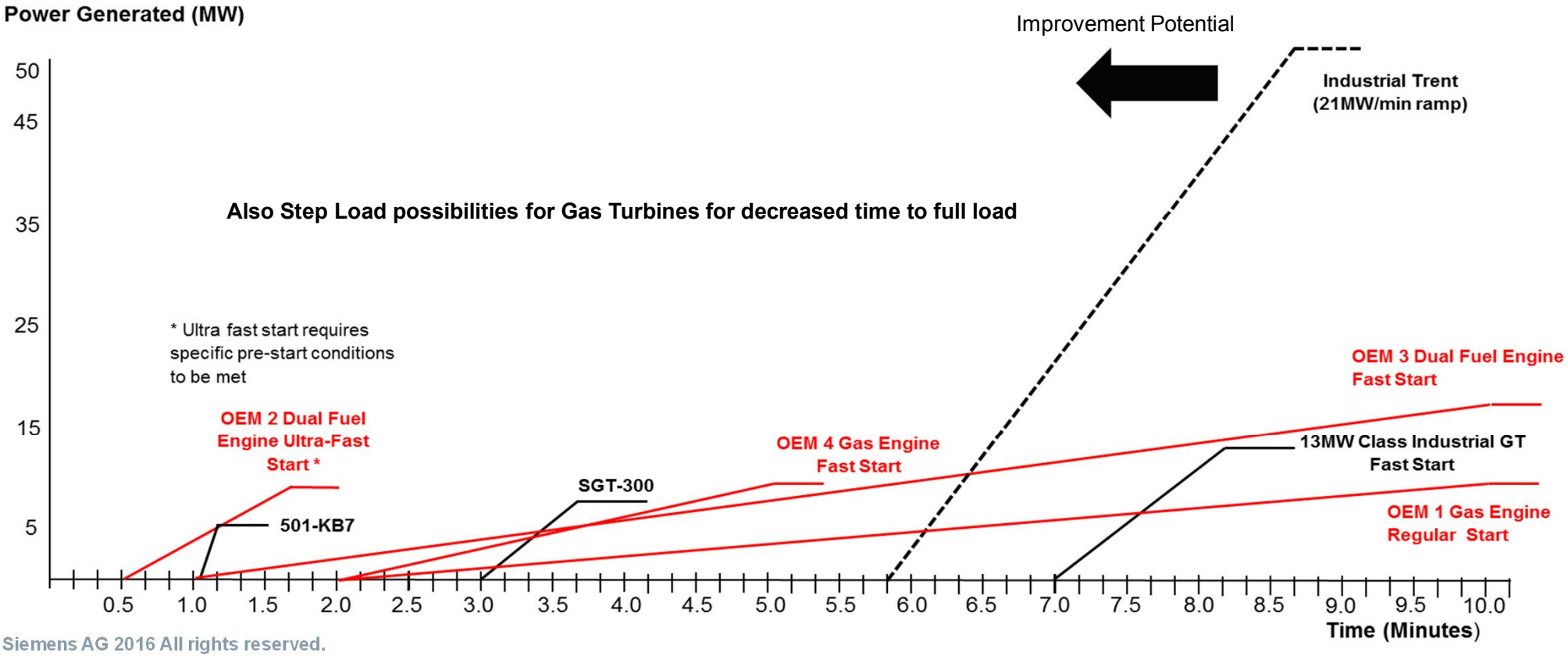
- Potential to connect to Grid at Distribution level
- Voltage and frequency support to avoid the need for load shedding
- Multiple units: high station availability / low maintenance downtimes
- Black start and multi-fuel capability
- Low starting power
  - Potential to combine with energy storage solutions
- Fast start and cycling capability





Addressing the Energy Trilemma with Decentralised Power

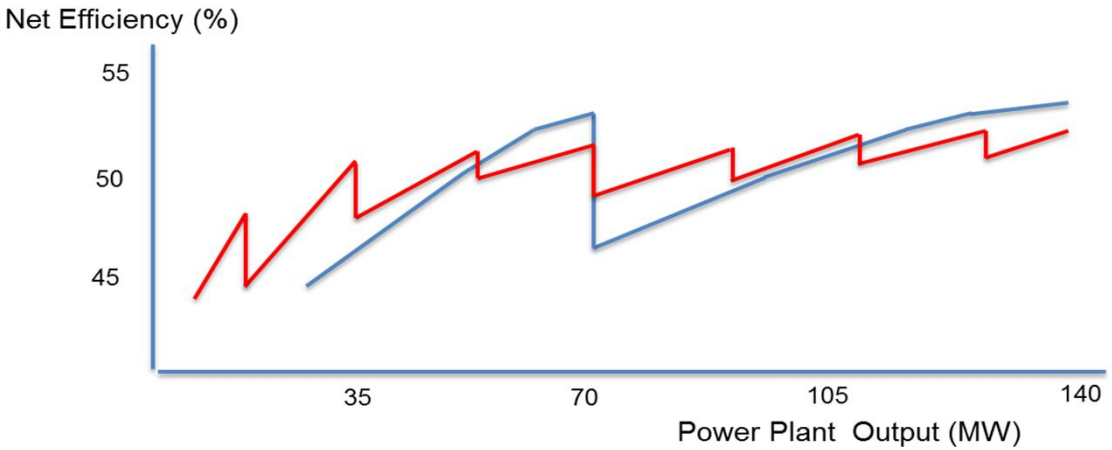
Security of Supply

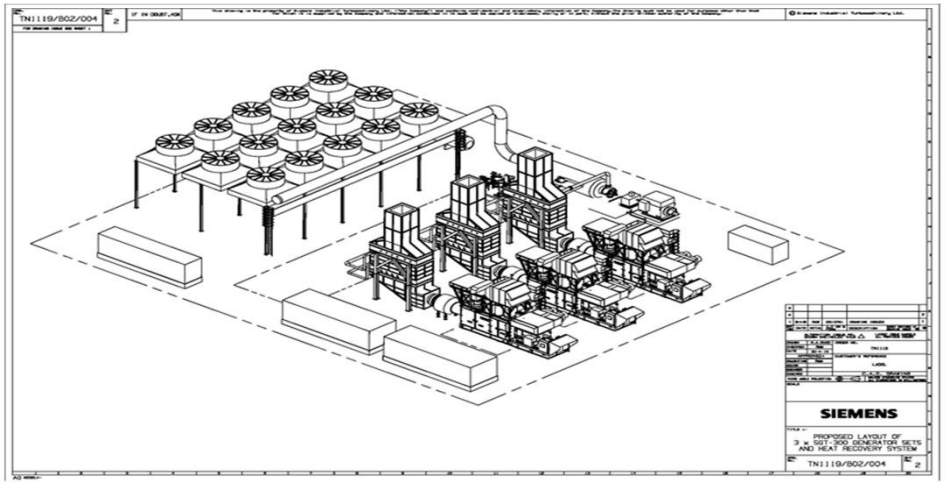


Addressing the Energy Trilemma with Decentralised Power

Environment

- High Efficiency across wide load range through multiple units
- Low combustion emissions across wide load range and on start-up
  - NOx, CO, UHC, Methane Slip
- Water-free CCGT potential
  - Organic Rankine Cycle
  - Supercritical CO_2
- Reduced construction times through modularity
- Compact Footprint
- Biogas, syngas and hydrogen fuel potential

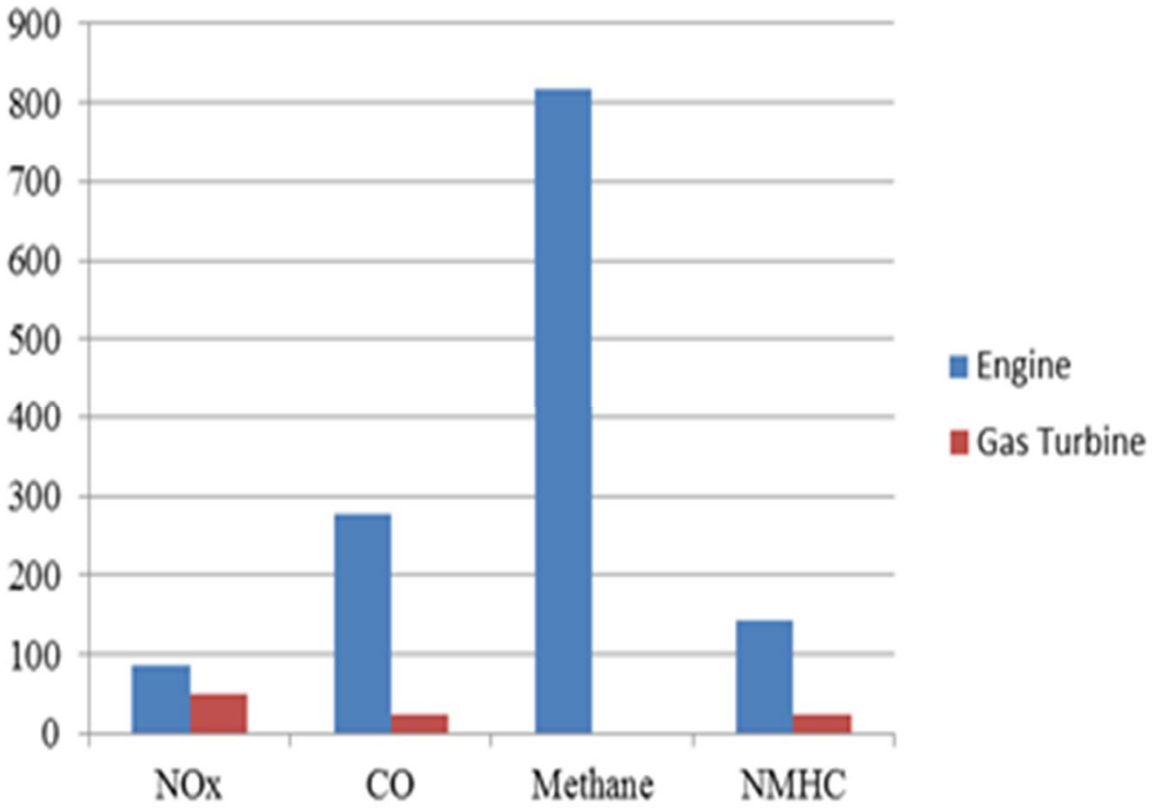




Addressing the Energy Trilemma with Decentralised Power

Environment

- Growing concern over impact of methane emissions to atmosphere
- Several studies in Marine applications on using LNG as fuel
- Methane slip reduces CO_2 benefit of LNG compared to diesel or HFO
- 9MW spark ignition gas engine with typical 5g/kWh methane slip at full load is > 1 tonne/hour CO_2 eq.
  - Methane slip increases as load decreases: typically 40g/kWh at 25% load



Comparison of combustion emissions in mg/Nm^3 from a 4MW class gas engine and small gas turbines (gas engine data from Waukesha 16V275GL data sheet)

Conclusions

Gas Turbine-based Decentralised Power can play a major role in the future of Power Generation

- Flexibility to meet Market requirements
- Applicable for any power output needs
- Helps address the Energy Trilemma
  - Affordable cost of energy
  - Secure supplies
  - Minimised environmental footprint
- Support for Grids with high penetration of Intermittent Renewables
- Combined with other technologies to maximise operational flexibility
- Non-fossil fuel potential

Thank you for your attention!

Mike Welch
Industry Marketing Manager
Siemens Industrial Turbomachinery Ltd.

Waterside South
Lincoln, United Kingdom

Phone: +44 (1522) 584000
Mobile: +44 (7921) 242234

E-mail: welch.michael@siemens.com

siemens.com/power-gas