Welcome to the Gas Turbine Association 2019 Congressional Briefing

GasTurbine.org

Introduction & Gas Turbines Overview

Leslie Witherspoon
GTA

What is GTA?

The unified industry voice for US leadership and economic growth with gas turbines

Our commitment

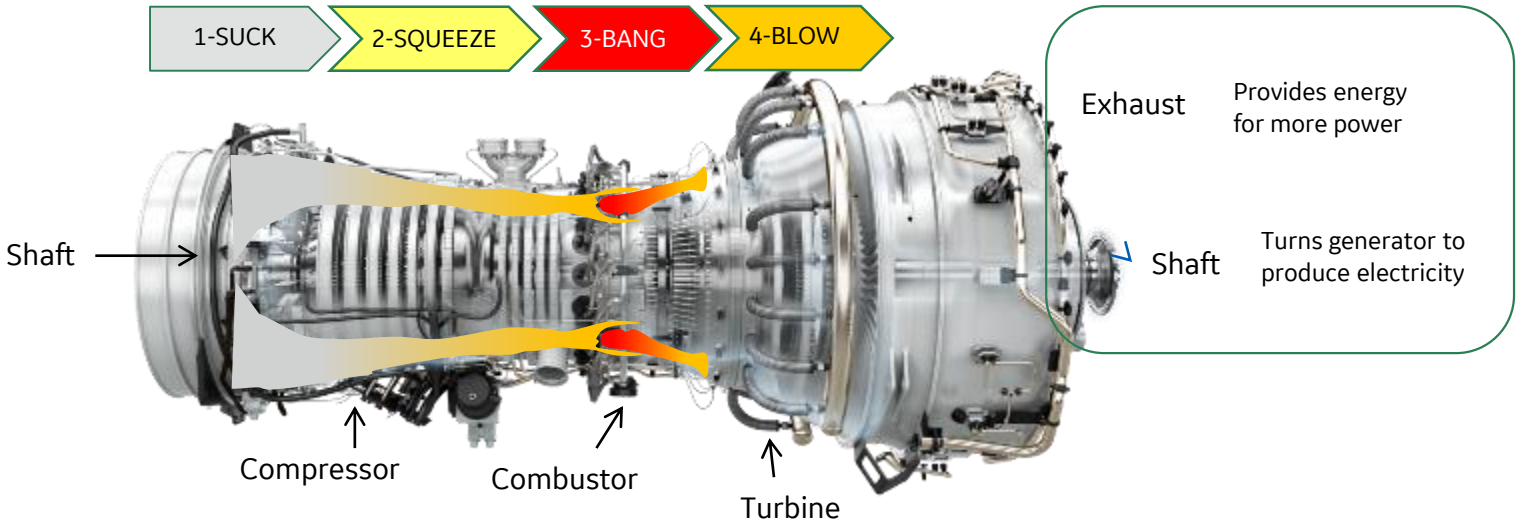
1. Promote gas turbine technology for ***clean, cost-effective & reliable*** **power + oil & gas transmission**
2. Create **high quality US jobs** & **intellectual know-how** … design, manufacturing & operation
3. **Inform public policy & policy makers** on the value & expanded use of gas turbines

Learn more at: GasTurbine.org

Picture of Siemens Large Gas Turbine H Series. Courtesy of Siemens Energy Inc

What is a Gas Turbine?

Gas turbine elements



Applications

Land

Offshore

Aviation

Siemens SGT-800 Combined Cycle Plant Design. Courtesy of Siemens Energy Inc

Why Gas Turbines

Gas turbine uses

- Electric power generation
- Combined heat and power
- Industrial processes and steam
- Waste to energy
- Oil and gas transmission
- Military missions

Benefits

Affordable: **Lowest electric cost** for U.S. rate payers

Clean:

- The most electrical output per square mile
- <50% GHG emissions vs. coal generation
- Efficient use of **abundant natural gas resources**

Reliable:

- **Dispatchable flexible power**… there when you need it
- Perfect complement to renewable sources

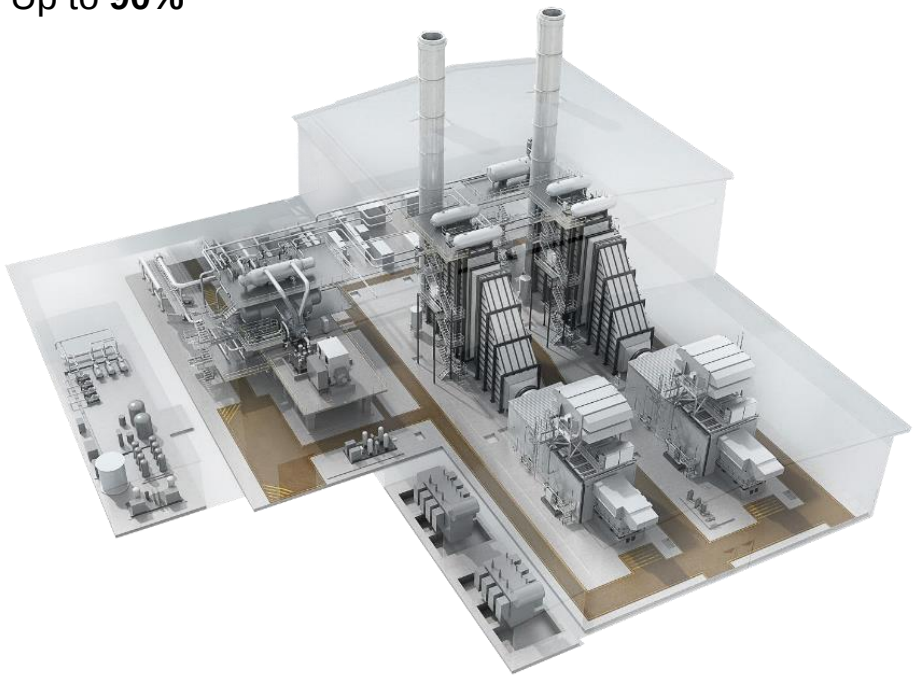
Efficiency targets

Electrical

- Up to **50%+** (gas turbine only)
- **65-67%+** (gas turbine + steam turbine)

Heat & Power

- Up to **90%**



Siemens SGT-800 Combined Cycle Plant Design. Courtesy of Siemens Energy Inc

Gas Turbines Power the U.S. Capitol Complex

The Capitol Power Plant

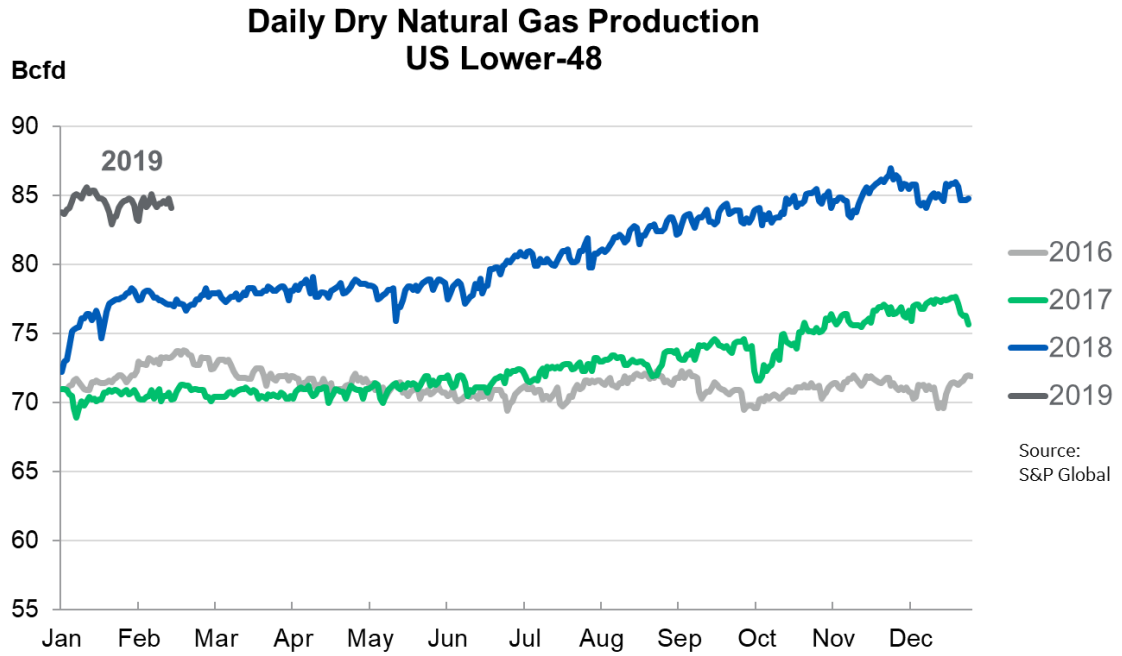
www.aoc.gov/cogeneration

Natural Gas as U.S. Foundation Fuel

Brendan O’Brien, AGA
Bert Kalisch, APGA

Record levels of natural gas production in 2018

Shale gas is responsible for the recent increase in gas resources



Information provided by American Gas Association (AGA) … see appendix

Public Utilities Perspective

- ✓ Natural gas is America's foundation fuel
- ✓ We need more ways to leverage this resource
- ✓ One of the best and most efficient ways is through use of highly efficient gas turbines
- ✓ While energy is the lifeblood of the economy, R&D is the lifeblood of our energy industry

Information provided by American Public Gas Association (APGA) … see appendix

Key Note: The Critical Importance of Advanced Gas Turbines

Guy Deleonardo
GTA President

The Future of Energy

Power is foundational

It is the underpinning of modern life, and a basic human right.

It's the spark that sets progress in motion, moving the world forward, enabling growth, health, connection and safety in communities large and small.

The Top 10 Challenges Facing Humanity for the Next 50 Years

Richard Smalley, Rice University

1. Energy
2. Water
3. Food
4. Environment
5. Poverty
6. Terrorism & War
7. Disease
8. Education
9. Democracy
10. Population

Access to affordable, reliable, and more sustainable power is critical to address nearly every one of these challenges.

The Global Energy Landscape is in the Midst of a Grand Transformation

The world is shifting towards a combination of distributed and central generation.

Strong renewable growth continues, as flexible thermal generation plays an important, but changing role.

Battery storage enables intra-day shifting, but inter-day and seasonal storage requires a technology shift.

Electric vehicles will transform both the transportation and power sectors.

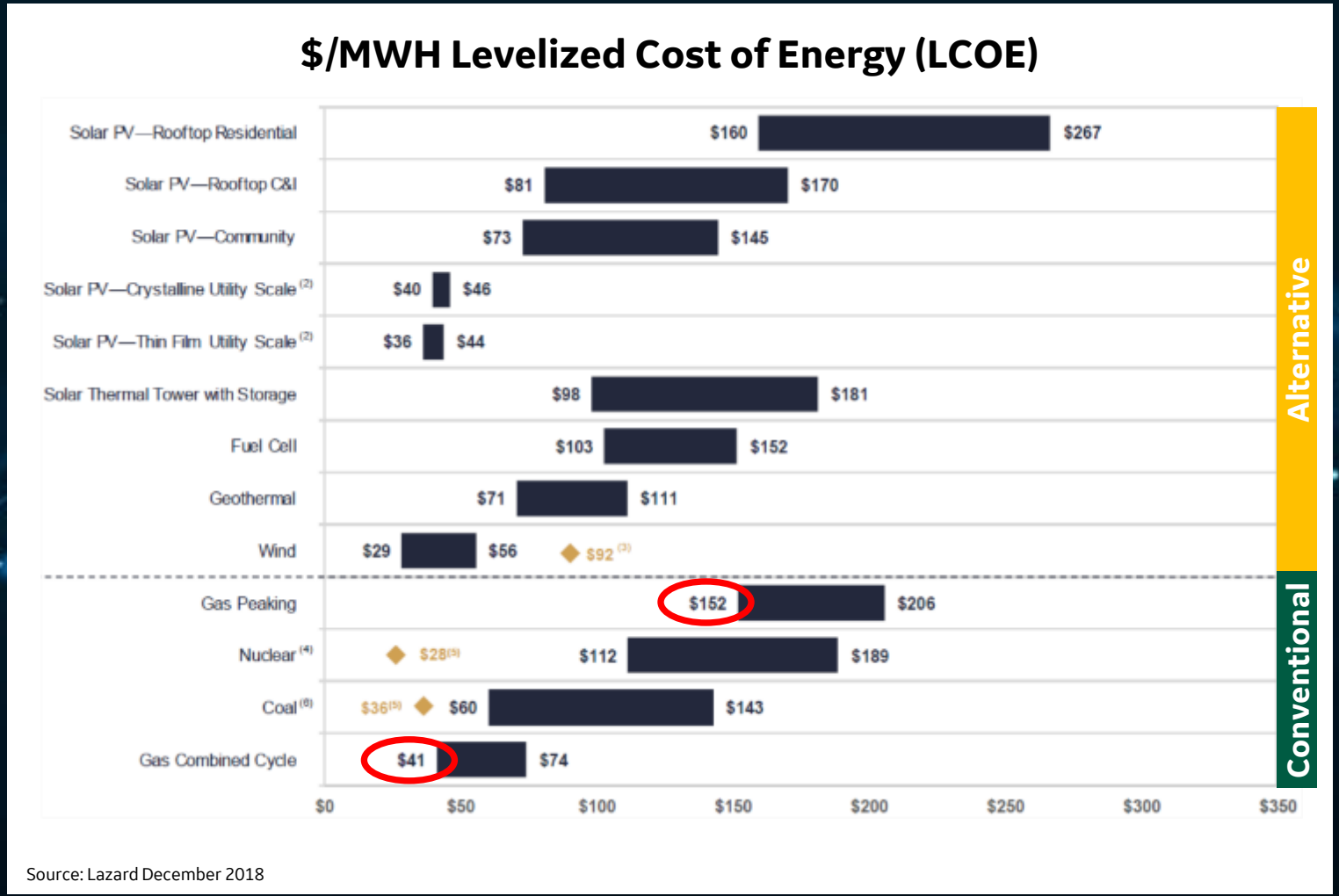
Digital technologies will be pervasive and transformative, opening up new business models.

Regional differences and nuances affect how this plays out

Levelized Cost of Energy … Shifting Gas Lower

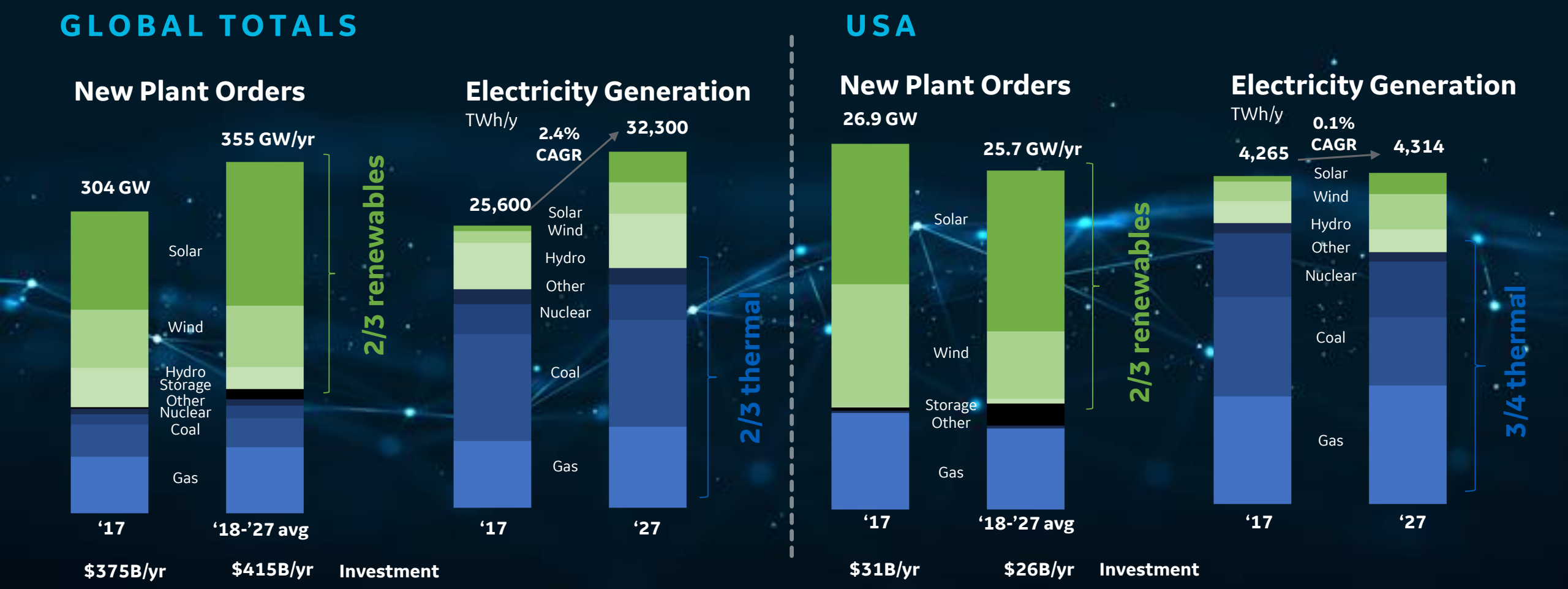
- **Alternative source LCOE driven by capital cost to install**
- **Gas lowest capital cost with fuel cost 60-80% of LCOE**
- **Increase efficiency directly lowers cost & emissions**

Gas Generation	U.S. Average today	Target with R&D
Simple Cycle	32%	50%+
Combined Cycle	52%	65%+



Source: Lazard December 2018

The Future of Energy



Power sector shift towards increasing renewables, hybrids and gas

Source: GE Power Strategic Marketing 2018 Outlook

Renewables Growth is Real and Unabated

- ✓ **Renewables** forecasted to account for **2/3** of global new plant investment over the next decade
- ✓ **Solar** orders in 2017 **exceeded** new **gas** capacity orders
- ✓ **Increasing end-consumer demand** … for zero-carbon power alternatives
- ✓ **California** received **more power** from **solar than gas** in May

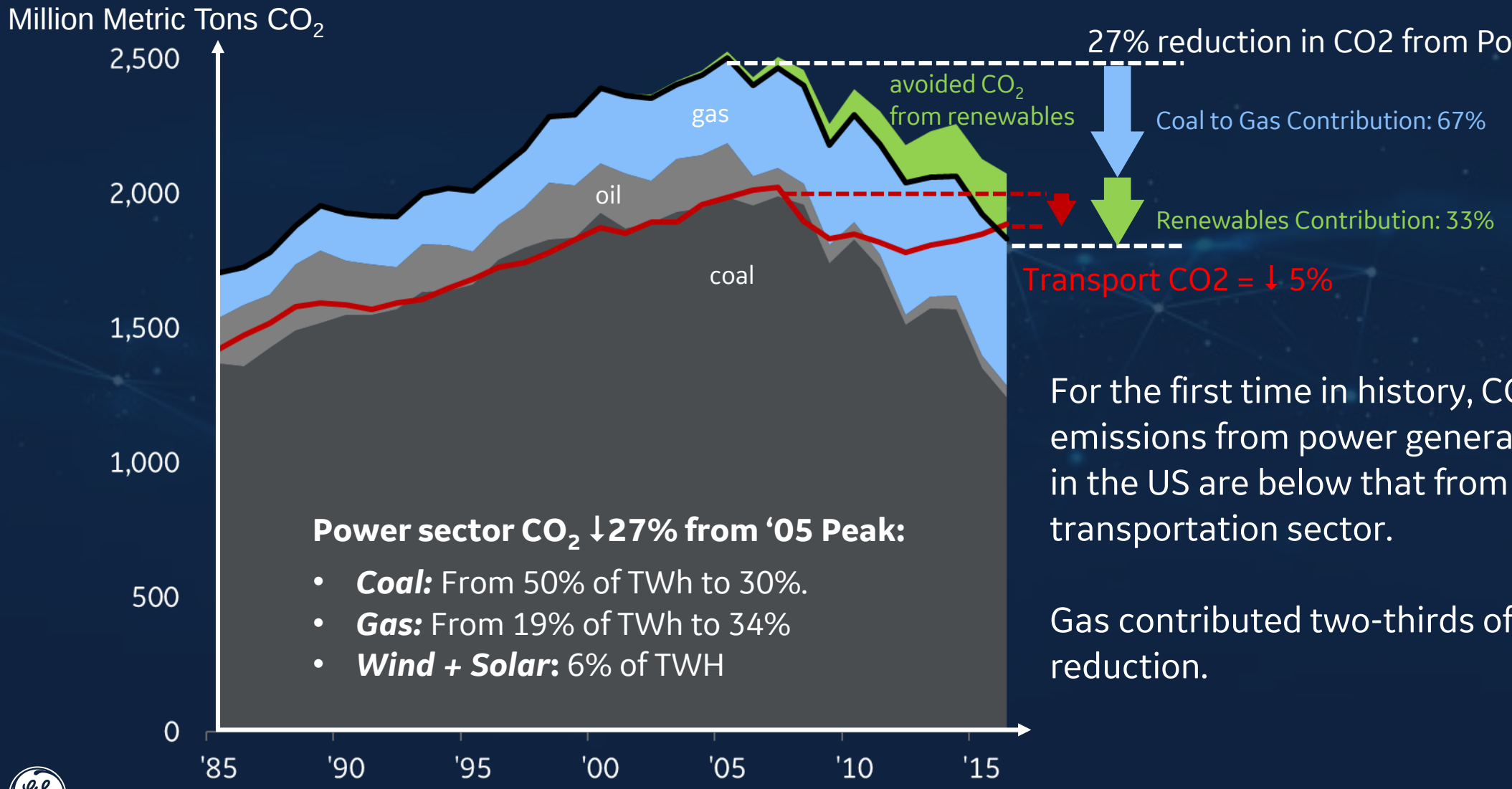
Natural Gas is the Best Complement

- ✓ **US reduced CO_2 emissions 27% from its '05 peak** … Coal-to-gas switching accounted for 2/3, saving the equivalent of 10% of the transportation sector CO_2 emissions (~65M passenger vehicles)
- ✓ **Dispatchable** … there when needed
- ✓ **Flexible** … fast start and ramping, low turn-down
- ✓ **Affordable** … lowest capex technology, good for firming
- ✓ **Fast to meet urgent needs** … simple cycle on-line as fast as 90 days

Sources: EIA. Table 12.6 Carbon Dioxide Emissions From Energy Consumption: Electric Power Sector, Table 7.2a Electricity Net Generation: Total (All Sectors), February 2018; GE Power Strategic Marketing Outlook

An Example of Gas Contribution to CO_2 Reductions

Emissions From the U.S. Electric Power Sector



For the first time in history, CO_2 emissions from power generation in the US are below that from the transportation sector.

Gas contributed two-thirds of the reduction.

Source: EIA. Table 12.6 Carbon Dioxide Emissions From Energy Consumption: Electric Power Sector, *Table 7.2a Electricity Net Generation: Total (All Sectors), February 2018*

Power Density Matters

City density is growing

- **1/4** of global population is in cities of **1M+ people**
- **10%** are in megacities with **10M+ people**

Cities are electrifying

- NYC plans to electrify all transit busses **by 2040**
- Satisfying this power load with solar PV alone would require **covering 15%** of Manhattan with panels

Gas is most land-efficient

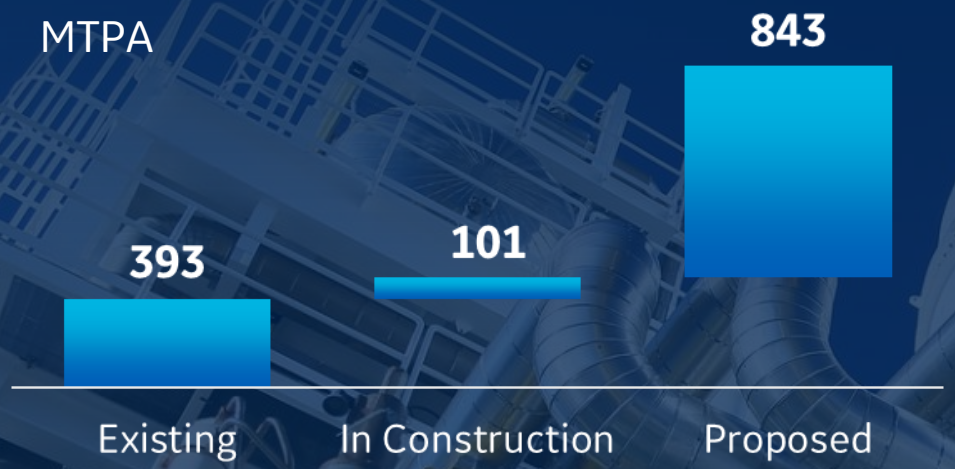
- Natural gas requires **50-100 times** less space per MWh generated compared to renewables + storage

Gas generation plays a vital role in dense urban areas where space is a premium

Source: World Bank, UN, EIA, SEIA, US DOE, NACS, NYC MTA, GE Power Marketing

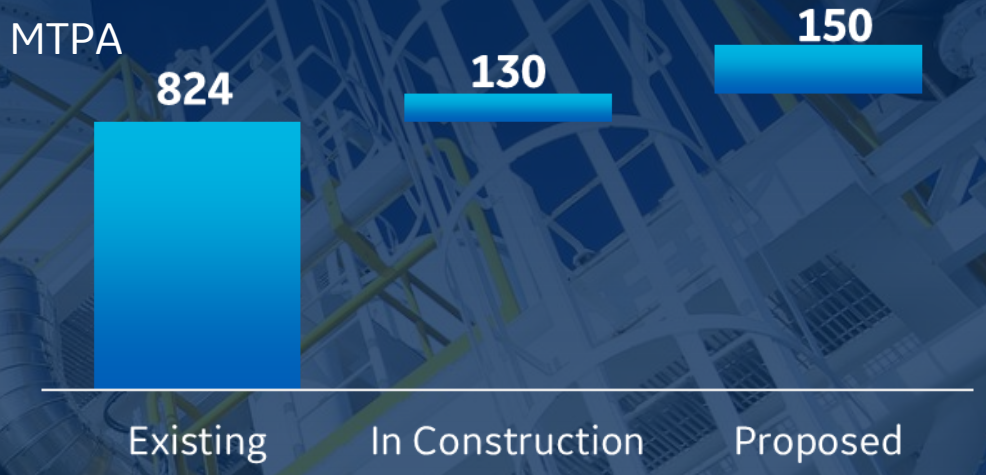
LNG Increasing Access to Affordable Gas

LIQUEFACTION CAPACITY



- **28 MTPA added in 2018**
- **19** countries with capacity … **6** countries have **2/3** of the capacity … Qatar, Australia, Malaysia, Indonesia, Algeria, Nigeria
- **40%** of proposed new capacity in US

REGASIFICATION CAPACITY



- **23** MTPA added in 2018
- **37** countries with capacity
- In-construction capacity bringing LNG access to **5** additional countries … Bahrain, El Salvador, Ghana, Philippines, Croatia

LNG enabling fuel substitution in power sector

Source: International Gas Union 2019 World LNG Report

Gas Power Role in the Future of Energy

- **Strong renewable growth continues** … flexible gas generation is the best complement
- **Gas generation key for national & energy security** … dispatchable & reliable
- **Coal to gas switching & higher gas generation efficiency** … effective path for decarbonization
- **U.S. economic benefits significant** … high quality jobs & high value exports
- **Significant areas of gas technology R&D** … requires investment & support

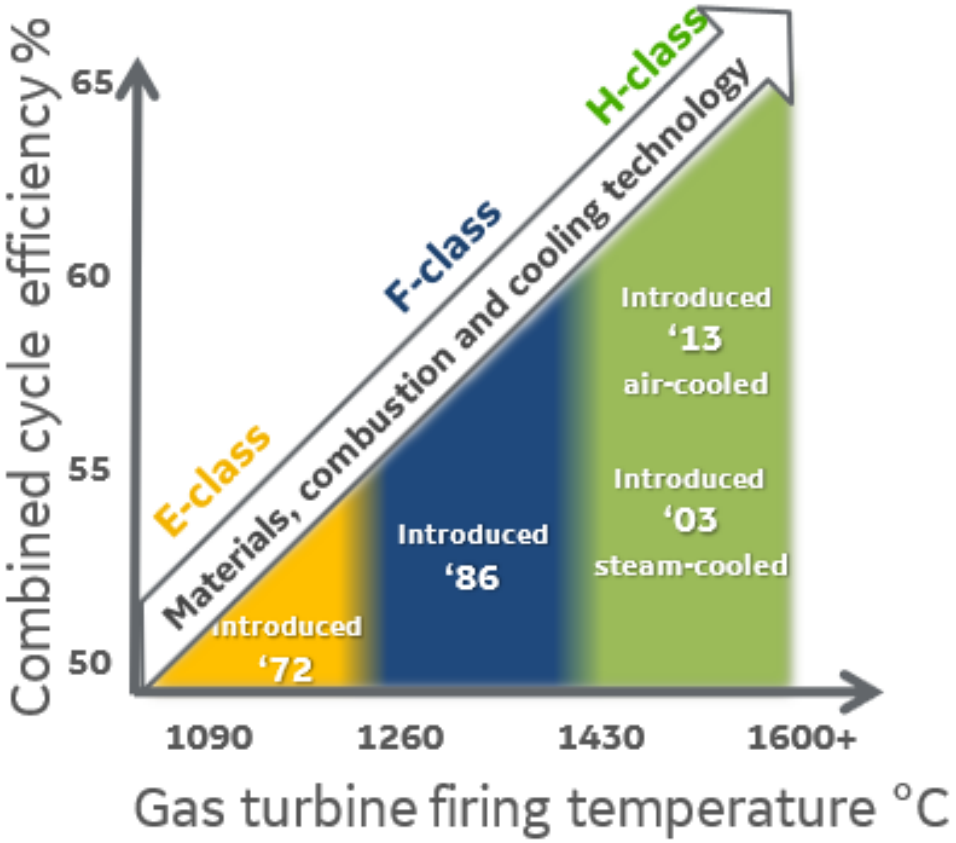
Position the U.S. to lead in gas turbine technology

Advances Needed in Gas Turbine Research and Development: Industry, Universities, and Government Collaborations Lead to Success

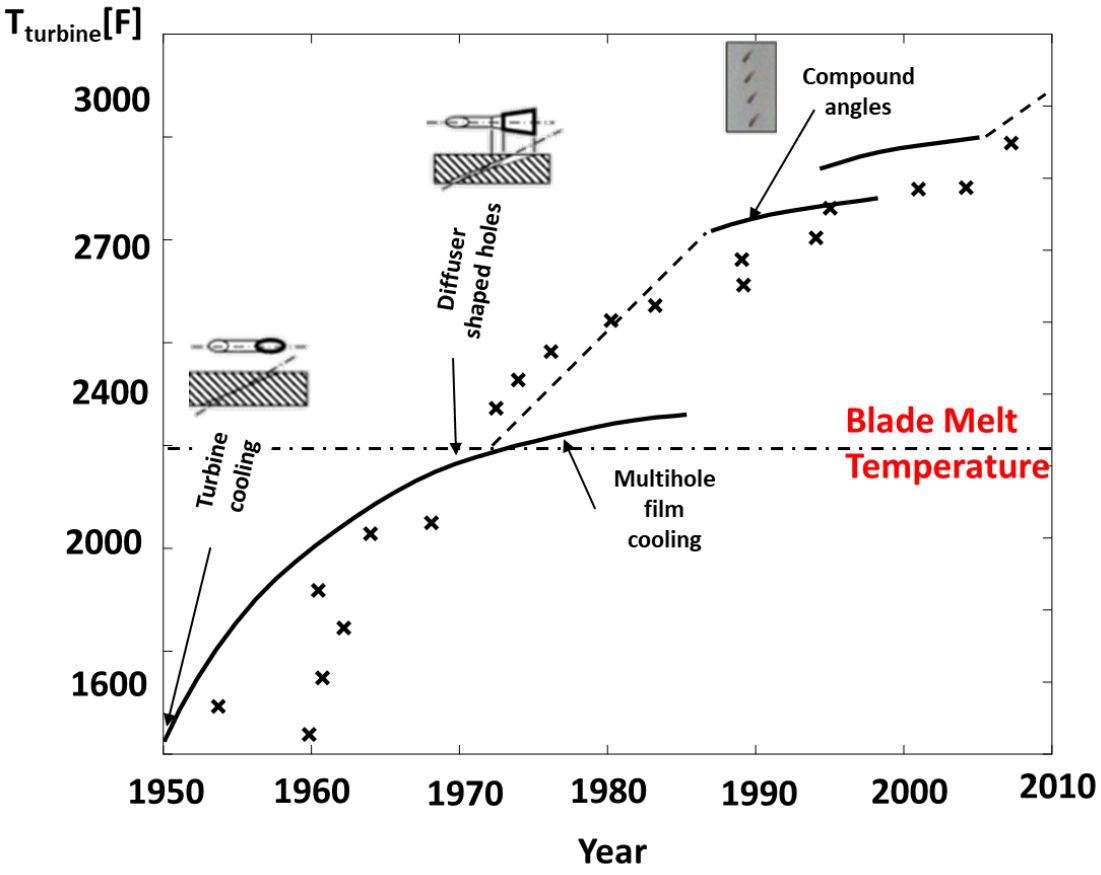
Professor Karen A. Thole

High turbine efficiencies, which translate to lower CO_2 emissions, are directly related to turbine inlet temperatures

Thermal efficiencies increase as turbine inlet temperatures increase



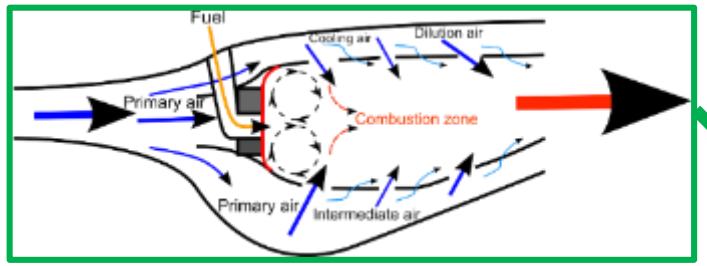
Improved cooling technologies permit increases in turbine inlet temperature



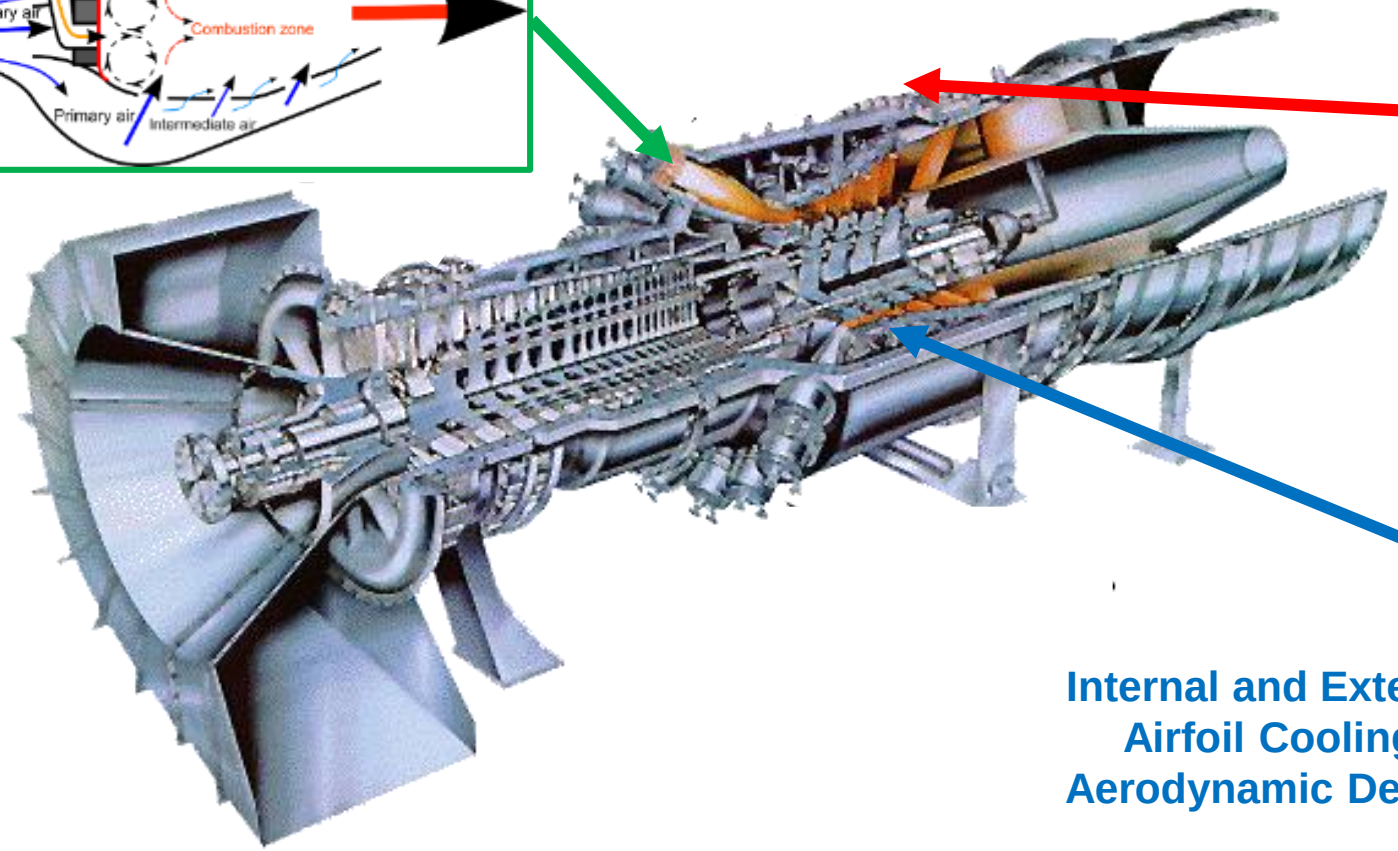
Courtesy of GE

Needed technology development to advance gas turbine components: compressor, combustor, and turbine

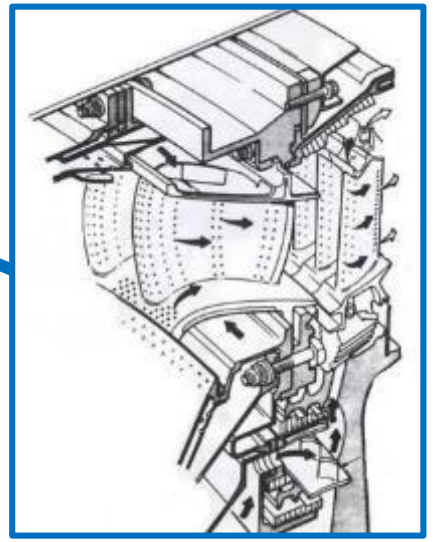
Advanced Combustor Designs, Reduced Instabilities, Flexible Fuels



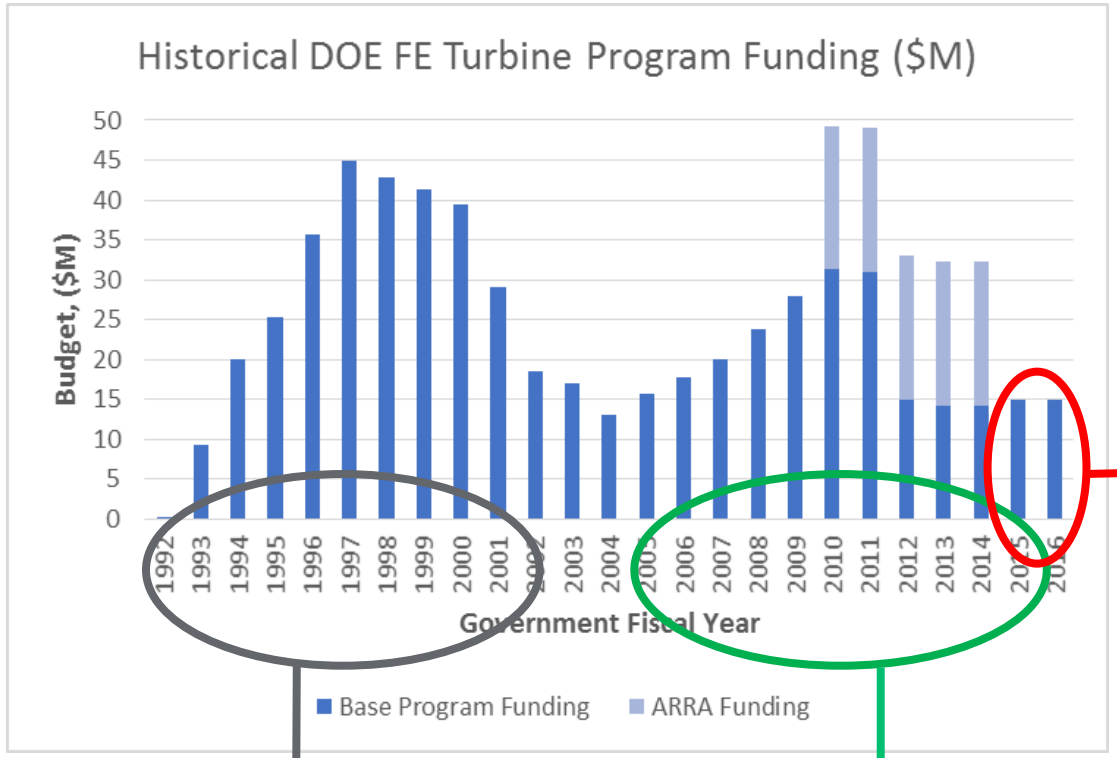
Advanced Manufacturing for Complexity and Speed; High Temperature Material



Internal and External Airfoil Cooling; Aerodynamic Design



DOE funding for turbine research is directly applicable to improving efficiencies (reducing impact to the environment)



AT Program (2014–2025)

Moving to 65% efficiencies

Full scale, full can combustion test at 3100F w/ < 25ppm NO_x

CMC nozzle design selected

CMC combustor components down-selected from 50 concepts to 2

Dry gas seal initial design completed for end seal in utility scale SCO2 expander

ATS Program (1992–2002)

GE delivers most adv. 60% eff. NGCC

Siemens produces adv. G-class components

Focus on NG

H_2 Turbine Program (2005–2015)

Solved H_2 combustion problem

Revolutionized combustion

Advanced cooling architecture through advanced manufacturing

Courtesy of DOE-NETL

Gas Turbine R&D: Industry, Universities, and Government

Why is it important?

Universities contribute to the DOE's goals of clean energy technology through efficient, reliable, robust, low emission turbines by doing research with direct applications

Through teaching and research, universities educate the future workforce where advanced degrees with practical experience are a requirement

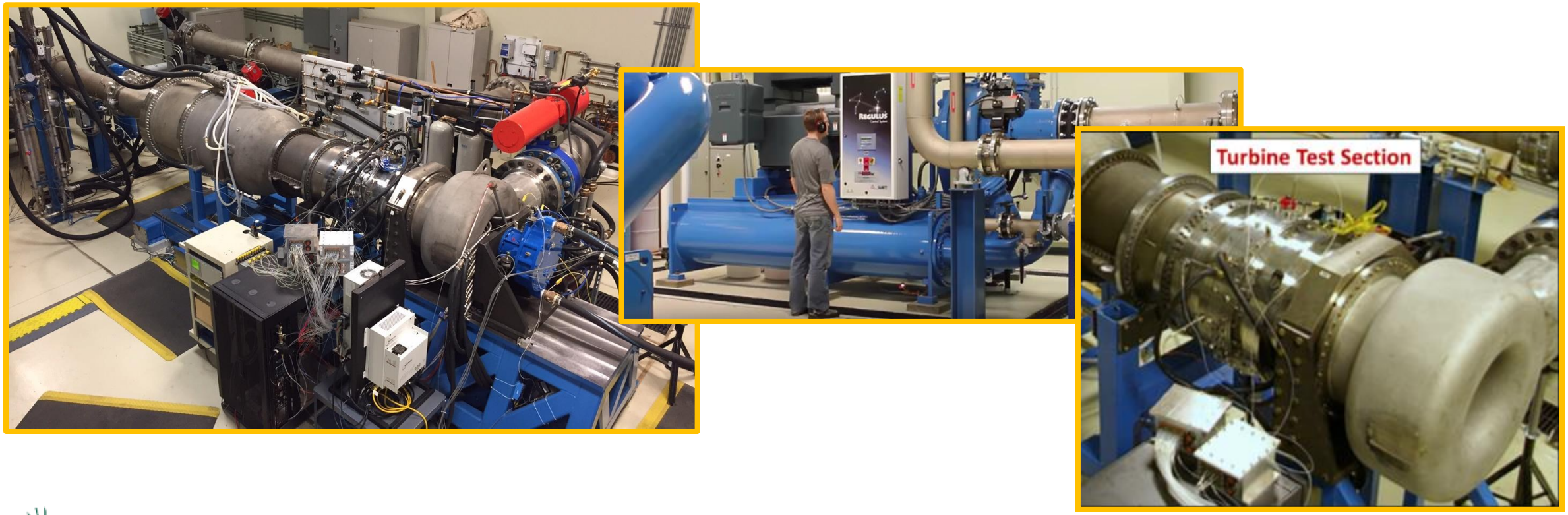
Pratt & Whitney's Center of Excellence at Penn State

An Illustration of a Successful University-Industry-Government Partnership

PennState College of Engineering

START

U.S. DEPARTMENT OF ENERGY | Fossil Energy



GTA GAS TURBINE ASSOCIATION

Summary

Investment is needed in a range of technologies to advance turbine efficiencies

Gas turbine research through DOE is impactful to the industry and ensures universities are doing relevant research

Educating the future work force of US students requires significant investments in infrastructure

PennState College of Engineering

GTA Gas Turbine Association

GTA requests support for H.R.2659

“To establish a research, development, and technology demonstration program to improve the efficiency of gas turbines used in combined cycle and simple cycle power generation systems.”

Introduced: 05/10/2019

Sponsors: Rep. Paul Tonko [D-NY] and Rep. David McKinley [R-WV]

Committee: House - Science, Space, and Technology

APPENDIX

Natural Gas Landscape

Natural Gas as a Foundation Fuel

Brendan O'Brien
Energy Manager, Energy Analysis
American Gas Association

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AGA 100 YEARS

Find Us Online

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- www.truebluenaturalgas.org
- http://twitter.com/AGA_naturalgas
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- www.linkedin.com/company/50905?trk=tyah

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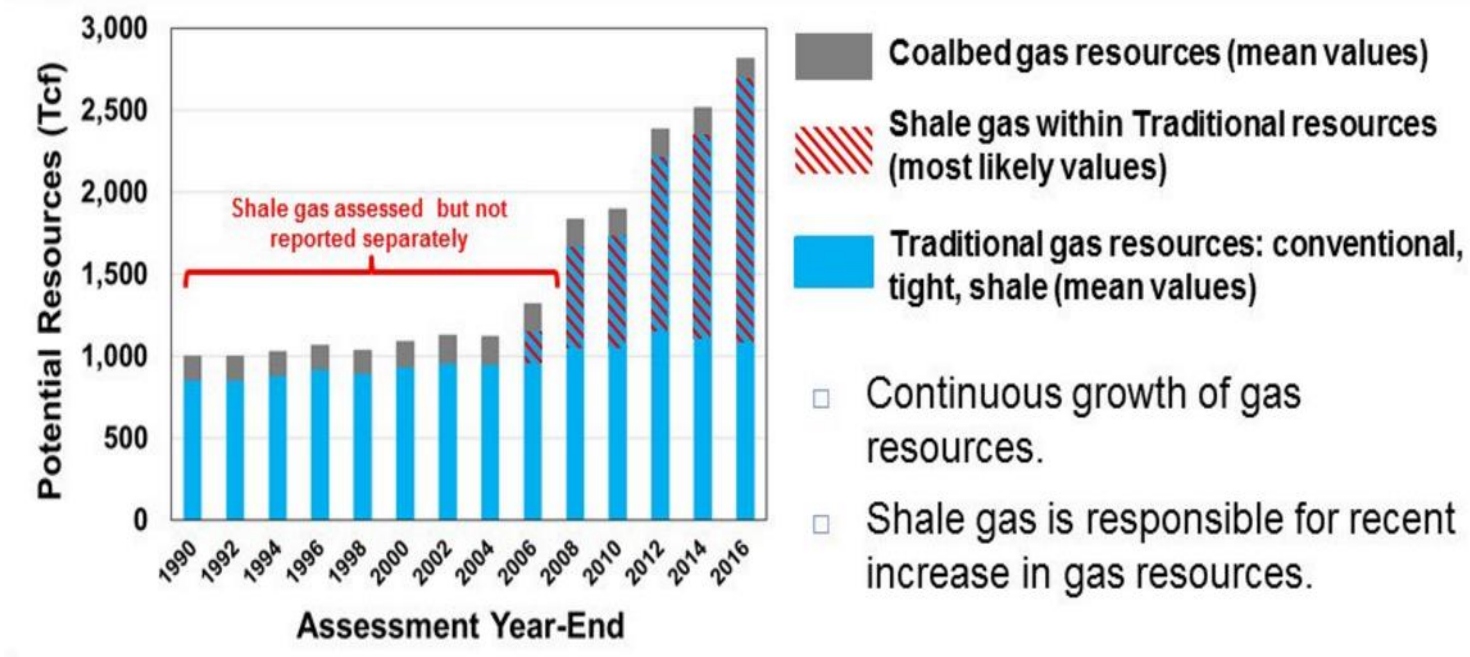
Natural gas as a potential resource continues to grow

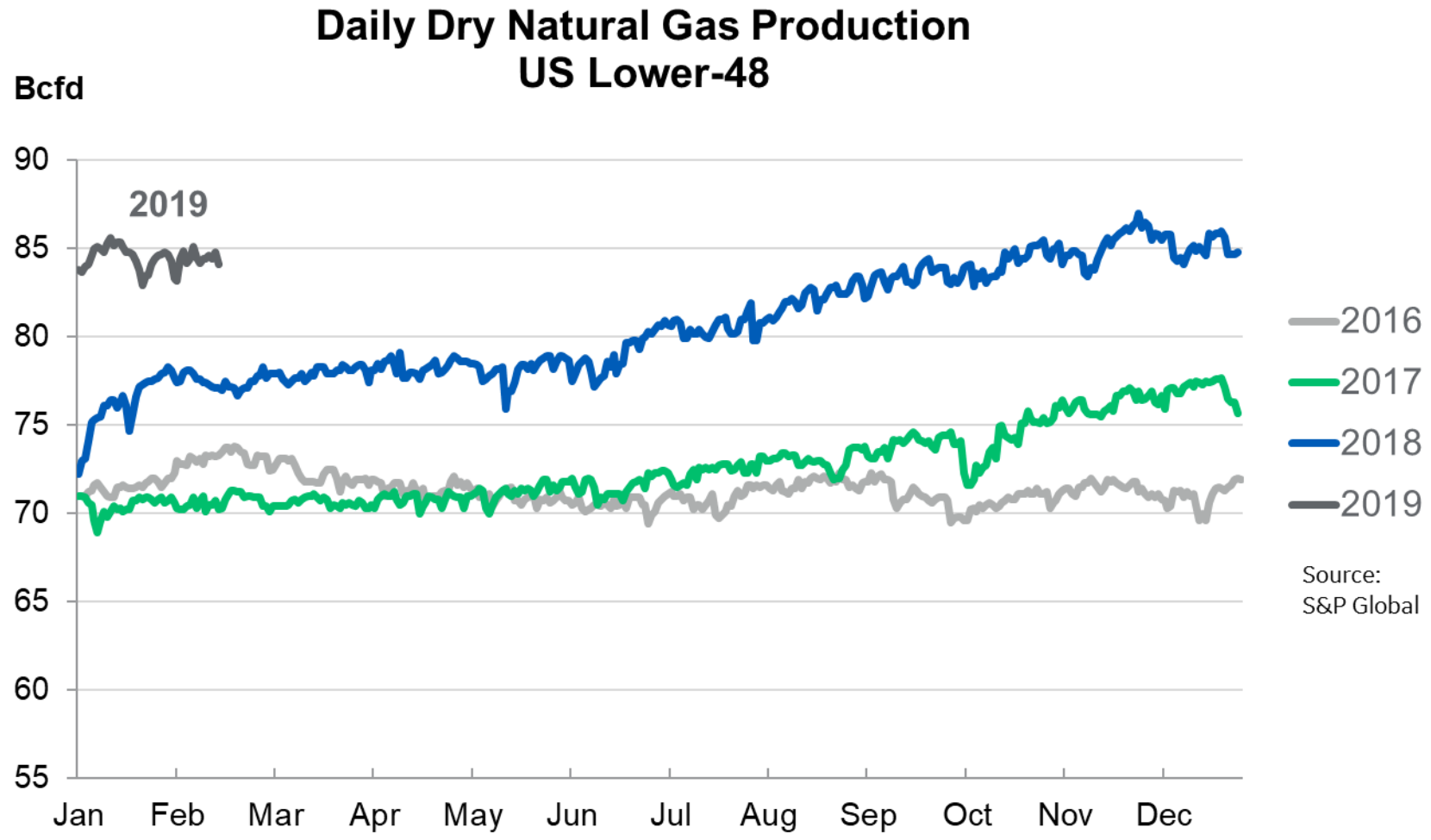


Source: Potential Gas Committee, Colorado School of Mines

And Then There Was Abundance

The U.S. estimated future supply of natural gas (reserves plus resources) stood at 3,141 Tcf at year end 2016—enough natural gas to meet America's diverse energy needs for more than 100 years. The estimated future supply has more than doubled for the period 1990–2016.

Record levels of natural gas production in 2018



Shale vs. Convention Gas Production

Jelly Donut

Conventional Drilling
Basic Vertical Penetration
Limited Formation Contact

Illustration © James Scherrer 2014

Tiramisu

Unconventional Drilling
More Sophisticated Horizontal Penetration
Extensive Formation Contact

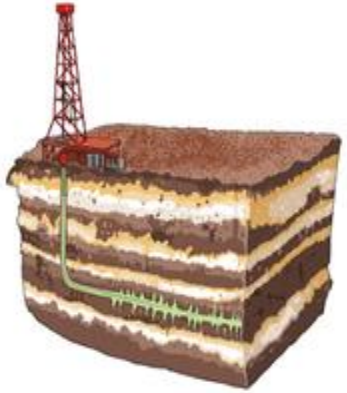
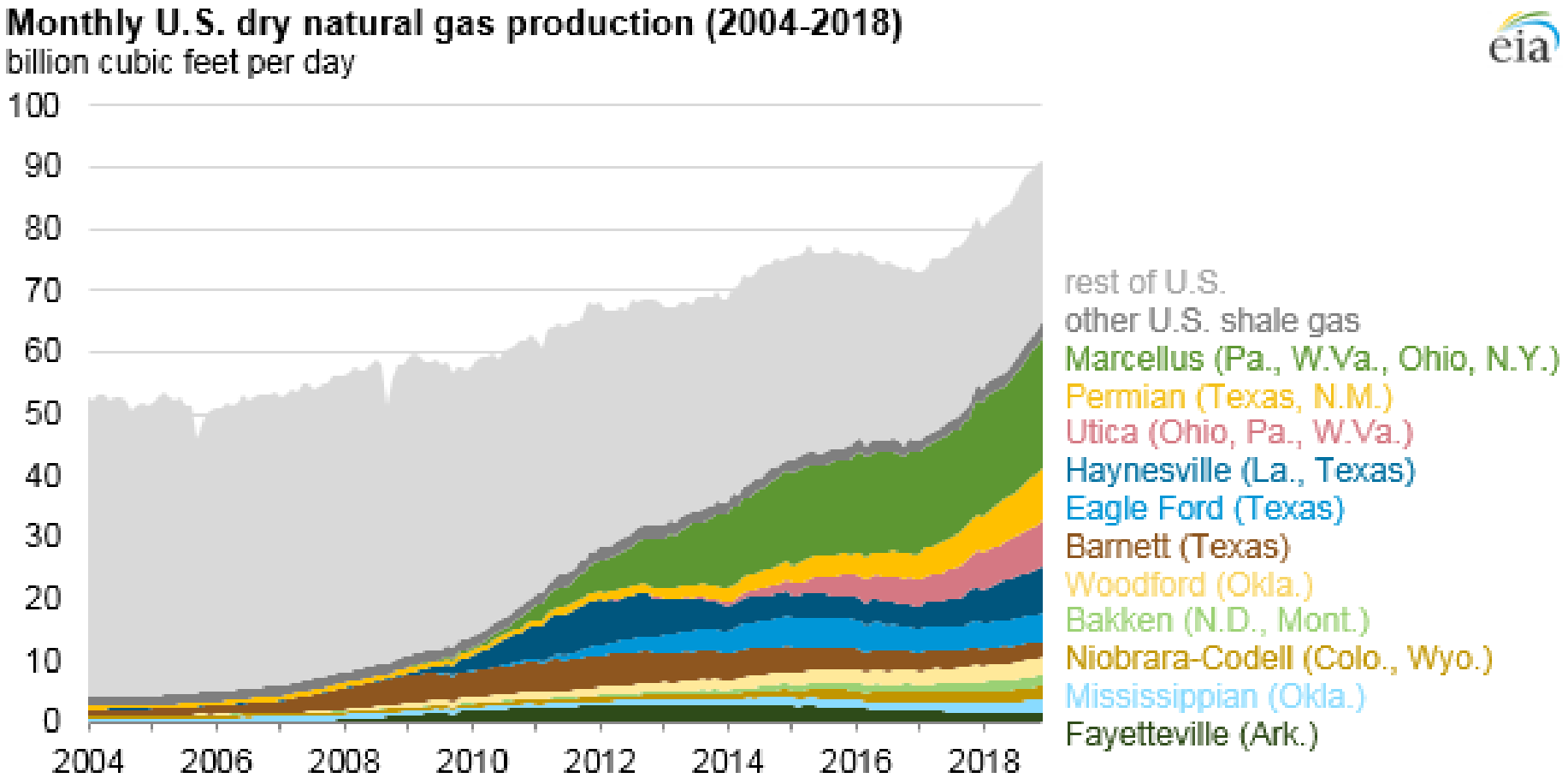


Illustration © James Scherrer 2014

Drilling into conventional sources is like sticking a straw in a jelly donut – the petroleum is trapped in a large single formation that just flows out under pressure. Drilling into unconventional sources like oil and gas shale is quite different, more like tiramisu – the petroleum is in many layers that have to be individually tapped using horizontal drilling and fracking methods to open up the rock. Saudi Arabia has a bunch of really big jelly donuts. The United States has lots of tiramisu, plus some pretty good jelly donuts as well. Source: Jim Scherrer

Domestic Shale Gas Production



Public Utilities Perspective

Bert Kalisch
President and CEO, American Public Gas Association

Who is APGA?

- 1,028 Publicly Owned Gas Systems in U.S.
- 741 are APGA Members
  - States Served: 37 states
  - Serve approximately 5 million customers
  - Employees: 21,000
  - Miles of Main: 120,000

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American Public Gas Association

APGA Mission

The **Safe** and **Reliable** delivery of **affordable** natural gas at **just and reasonable** rates.

The Benefits of Direct Use

- Reliable
- Affordable
- Abundant / Domestic
- Direct-Use: 92% Efficient
- Reduces consumer energy costs
- Reduces greenhouse gas emissions
- Resilient

GTA GAS TURBINE ASSOCIATION

American Public Gas Association

Public Utilities Perspective

- ✓ Natural gas is America's foundation fuel
- ✓ We need more ways to leverage this resource
- ✓ One of the best and most efficient ways is through use of highly efficient gas turbines
- ✓ While energy is the lifeblood of the economy, R&D is the lifeblood of our energy industry

Public Utilities Perspective

A move away from large remote generation to more distributed generation

- Higher efficient units
- Greater reliability
- Smaller T&D losses

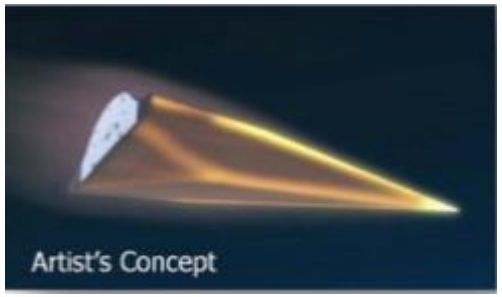
The United States Advanced Ceramics Association

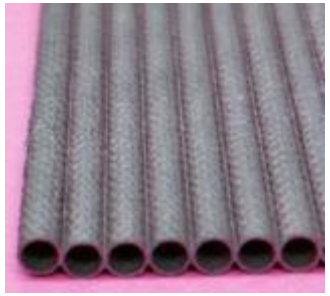
John Holowczak
USACA Chair

What are Advanced Ceramics?

Lightweight, strong materials capable of performing in extreme environments:

- High Temperature and Pressure
- High Stiffness and Durability
- Ultra Hard & Tough Surface

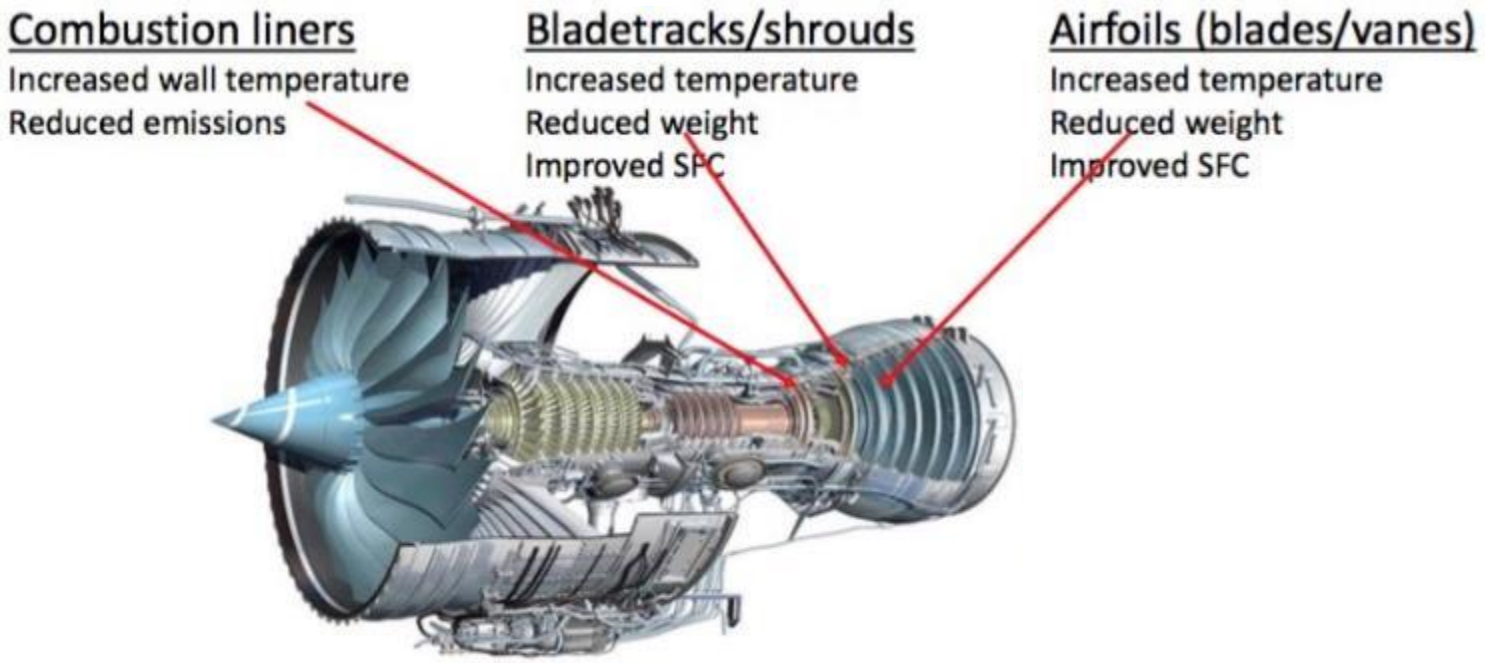




Not This!

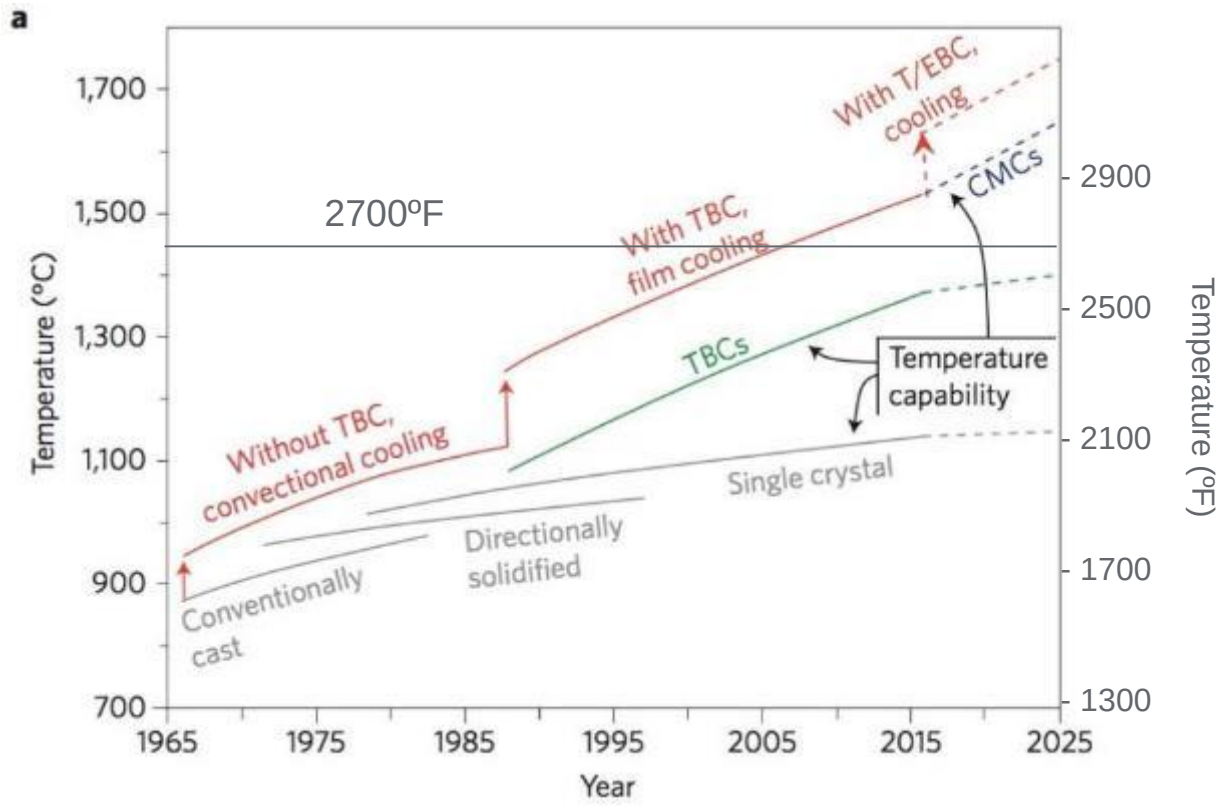
CMC Applications in Advanced Gas Turbines

Ceramic Matrix Composites (or CMCs) are a subgroup of ceramics made from ceramic fibers embedded in a ceramic matrix.



Applications in both static and rotating components.

Why 2700ºF CMCs?

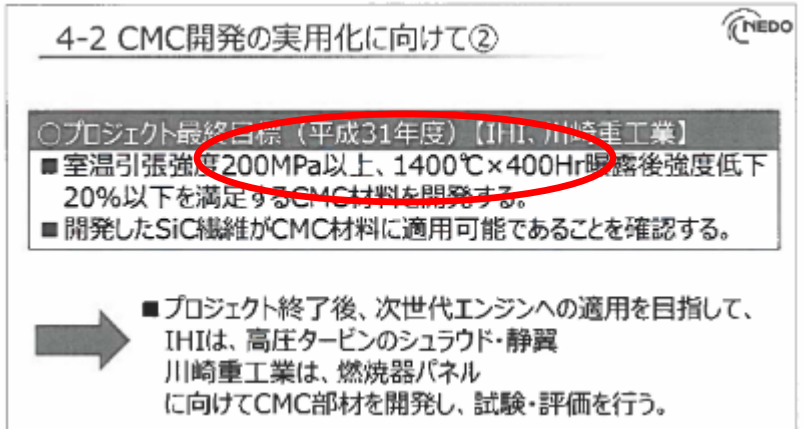


The recent National Academy of Sciences study identified 1480ºC (2700ºF) CMCs of particular research interest.

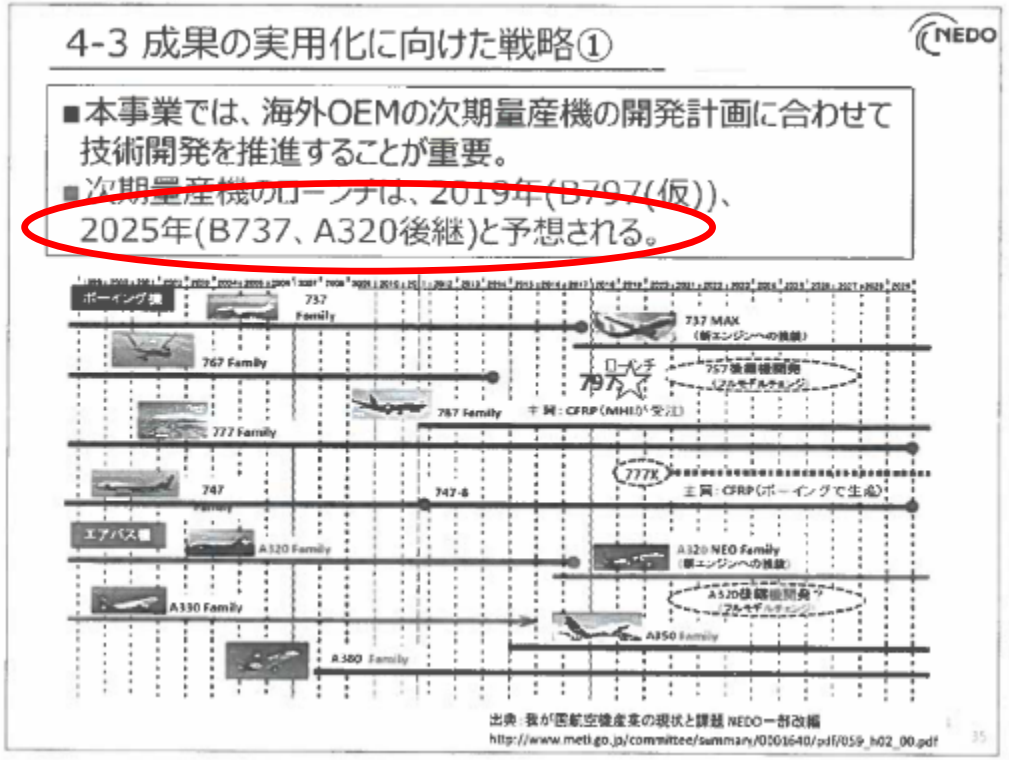
These could dramatically reduce or eliminate cooling in many parts of an engine and thus boost efficiency and lower weight.

Adapted from a) Nature Materials, V15, 8/16 and b) NAS Commercial Aircraft Propulsion and Energy Systems Research: Reducing Global Carbon Emissions, 2016.

Peer countries recognize “turbine CMC” race is on



2019 NEDO CMC material capability goal



Japan’s New Energy Development Organization (NEDO) investing $62M into a 2550ºF class CMC material development; engine component demonstrations as next step, targeting turbine component market, temperature exceeds U.S. industry capability

Potential for U.S. to lose its manufacturing base in turbine components