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
What is a Gas Turbine?

Gas turbine elements

Applications

1-SUCK  2-SQUEEZE  3-BANG  4-BLOW

Shaft  Compressor  Combustor  Turbine  Shaft

Exhaust  Provides energy for more power

Turns generator to produce electricity

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

Efficiency targets

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

**Heat & Power**
• Up to 90%

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
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
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 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

<table>
<thead>
<tr>
<th>Gas Generation</th>
<th>U.S. Average today</th>
<th>Target with R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Cycle</td>
<td>32%</td>
<td>50%+</td>
</tr>
<tr>
<td>Combined Cycle</td>
<td>52%</td>
<td>65%+</td>
</tr>
</tbody>
</table>

Source: Lazard December 2018
The Future of Energy

GLOBAL TOTALS

New Plant Orders
- '17: 304 GW
- '18-'27 avg: 355 GW/yr
- $375B/yr Investment

Electricity Generation
- '17: 25,600 TWh/yr
- '27: 32,300 TWh/yr
- 2.4% CAGR
- 2/3 renewables

USA
- New Plant Orders: 26.9 GW
- '17: 25.7 GW/yr
- '18-'27 avg: 26.9 GW
- $26B/yr Investment

Power sector shift towards increasing renewables, hybrids and gas

© 2019 General Electric Company. All rights reserved. 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 CO₂ emissions 27% from its ’05 peak** … Coal-to-gas switching accounted for 2/3, saving the equivalent of 10% of the transportation sector CO₂ 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. © 2019 General Electric Company. All rights reserved.
An Example of Gas Contribution to CO₂ Reductions

Emissions From the U.S. Electric Power Sector

Million Metric Tons CO₂

Power sector CO₂ ↓ 27% from ‘05 Peak:
• **Coal**: From 50% of TWh to 30%.
• **Gas**: From 19% of TWh to 34%
• **Wind + Solar**: 6% of TWH

Coal to Gas Contribution: 67%
Renewables Contribution: 33%

27% reduction in CO₂ from Power

Transport CO₂ = ↓ 5%

For the first time in history, CO₂ 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
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
LNG Increasing Access to Affordable Gas

**LIQUEFACTION CAPACITY**

- **393 MTPA** existing
- **101 MTPA** in construction
- **843 MTPA** proposed

- **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**

- **824 MTPA** existing
- **130 MTPA** in construction
- **150 MTPA** proposed

- **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

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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**

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**Gas turbine firing temperature °C**

**Combined cycle efficiency %**

- E-class
- F-class
- H-class

- Materials, combustion and cooling technology
- Introduced '72
- Introduced '86
- Introduced '13 air-cooled
- Introduced '03 steam-cooled

**Year**

- 1950
- 1960
- 1970
- 1980
- 1990
- 2000
- 2010

**T$_{turbine}$[°F]**

- 1600
- 2000
- 2400
- 2700
- 3000

**Compound angles**

**Blade Melt Temperature**
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)

**ATS Program (1992–2002)**
- GE delivers most adv. 60% eff. NGCC
- Siemens produces adv. G-class components
- Focus on NG

**H₂ Turbine Program (2005–2015)**
- Solved H₂ combustion problem
- Revolutionized combustion
- Advanced cooling architecture through advanced manufacturing

**AT Program (2014–2025)**
- Moving to 65% efficiencies
- Full scale, full can combustion test at 3100F w/ < 25ppm NOₓ
- 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

![Historical DOE FE Turbine Program Funding (SM)](chart)
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
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 workforce of US students requires significant investments in infrastructure.
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


Committee: House - Science, Space, and Technology
APPENDIX
Natural Gas Landscape
Natural Gas as a Foundation Fuel

Brendan O'Brien
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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

Daily Dry Natural Gas Production
US Lower-48

Source: S&P Global
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


- billion cubic feet per day

- rest of U.S.
- other U.S. shale gas
- Marcellus (Pa., W.Va., Ohio, N.Y.)
- Permian (Texas, N.M.)
- Utica (Ohio, Pa., W.Va.)
- Haynesville (La., Texas)
- Eagle Ford (Texas)
- Barnett (Texas)
- Woodford (Okla.)
- Bakken (N.D., Mont.)
- Niobrara-Codell (Colo., Wyo.)
- Mississippian (Okla.)
- Fayetteville (Ark.)
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
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
Public Utilities Perspective

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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 2700°F CMCs?

The recent National Academy of Sciences study identified 1480°C (2700°F) 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.

Peer countries recognize “turbine CMC” race is on

Japan’s New Energy Development Organization (NEDO) investing $62M into a 2550°F 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