Powering the Future From Florida: Combined Heat and Power, Smart Grid(s) and the CAPE

NIST Advanced Manufacturing Consortium for Advanced Production and Engineering of Gas Turbines and Rotating Machinery
Energy Florida & CAPE are Building Capabilities across Energy, Aerospace & Transportation
Best Practices: Responses to the “Valleys of Death” for Innovative Technologies

Adapted from “Bridging the Clean Energy Valleys of Death” – the Breakthrough Institute, 2011
Natural gas has eclipsed coal as the largest contributor to the US electricity mix, hitting 34% in 2016. Coal sank to second place, providing 30% of the mix – its lowest share on record.

Since 2007: coal’s share plummeted from 49% to 30%, while natural gas’s grew from 22% to 34% and renewables from 8% to 15%.

Source: EIA  Notes: Values for 2016 are projected, accounting for seasonality, based on latest monthly values from EIA (data available through November 2016). In chart at left, contribution from ‘Other’ is not shown; the amount is minimal and consists of miscellaneous technologies including hydrogen and non-renewable waste. The hydropower portion of ‘Renewables’ includes negative generation from pumped storage.
Why are Renewables & Natural Gas Taking Off? Costs are Coming Down

US Unsubsidized Levelized Cost of Electricity (LCOE) in 2016, $/MWh

- On a levelized cost basis, renewables are competitive with coal and natural gas-fired power.

- Natural Gas and Renewables are the most cost-competitive generation options at current prices, even without subsidies factored into the analysis. NG < Coal

- Combined Heat and Power (CHP) installation prices vary, driven by scale & complexity of project(s) and underlying prime mover technology

- Steam turbines, natural gas turbines and reciprocating engines are the least expensive CHP options ($/Watt), in that order.

Sources: Bloomberg New Energy Finance, EIA
Power Generation on Grids with Renewables: Need Flexible, Controllable Generation Sources

- Lots of non-renewable generation is operating all of the time.
- "Duck Pond" non-renewable generation remains more influential to overall power delivery than the renewable generation.

- Flexibility & dispatchability is key.
- 10 GW – 12 GW ramp-up over ~4 hour period during PM peak.

Source: CAISO
Natural Gas Represents Large Portion of Generating Capacity Additions Over the Next 20-30 Years

- Global Industrial Gas Turbine Installations, 2016-2035
  - $600 Billion Worldwide

- Service Revenues
  - $440 Billion Worldwide

- Total projected revenues, 2016-2035
  - $1.04 Trillion

Sources: Forecast International, 2016 Turbomachinery Handbook and US EIA
Why are Advanced Gas Turbines Important?

• “Apex Technology” at the convergence of aviation, aerospace & power generation

• Critical to U.S. Economic Security
  – Primary type of Aviation Propulsion
  – Job Creation
  – Manufacturing & Exports

• Critical to U.S. National Security
  – Affordable & Effective Mission Capability – Air, Land, Sea & Space
  – Maximize Resources for Operational Needs & Reduce Installation Energy Costs

• Critical to U.S. Energy Security & Clean Energy Goals
  – Largest Share of Electric Power Generation
  – US Natural Gas sourced from and supporting production in North America
  – Significant Role as Backstop for Intermittent Generation Sources
Coordinating a strategy to enable future development of the U.S. gas turbine industry

**Major Strengths of the U.S. Turbine Sector**

- High Level of Innovation
- Re-shoring Manufacturing to U.S.
- Supply Chain Diversity/Depth
- Over 250,000 jobs in U.S. tied to turbine design, manufacturing & maintenance

**Enormous market opportunity as demand for turbines and related parts and components expands around the world**

- $1 trillion market in power generation by 2035
- $3 trillion in aviation gas turbine engines by 2035
ICF/Gas Turbine Association estimates that unless investments are made, U.S. industry’s share of our domestic market could be cut in half by 2037.

With U.S. R&D investment, U.S. industry retains more than 2/3rds of U.S. domestic market share by 2037.
Gas Turbines have a Geographically Distributed Industrial Base

Legend
- Repair/Overhaul
- Engineering/R&D
- Manufacturing

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Florida is a Turbine Industry Hotspot

Local Industrial Connectivity
We have a unique industry cluster in Florida!

CATER Connection:

- Out of the 7 major, multi-national OEM's for turbo-machineries for power generation and aviation: Siemens, GE/Alstom, Mitsubishi, Pratt & Whitney, Rolls Royce, Doosan, and Ansaldo with global name recognition, ALL except Rolls Royce have major operation here.

- Of the top three airframe manufacturers, #3 Embraer has major operation here, with one of the top two, Airbus, is located right outside of the FL panhandle.

- Two of the major rocket engine manufacturers, Aerojet Rocketdyne and ATK have significant activities here.

Source: UCF - CATER
CAPE Technical Focus Areas: Next-Generation Gas Turbine Manufacturing

- **Additive Manufacturing / Rapid Prototyping**
  - Material Characterization and Quality
  - Baseline Process Parameters
  - In-situ monitoring and data analysis tools

- **Advanced Materials and Alloys**
  - Thermal Barrier Coatings (TBCs)
  - Refractory Metals and High Entropy Alloys
  - Ceramics and Ceramic Matrix Composites (CMCs)

- **Manufacturing Processes & Supply Chain**
  - Joining of Disparate Materials
  - Non-Destructive Evaluation and Modeling Techniques
  - Impact of manufacturing process(es) on material properties

- **Maintenance, Repair and Overhaul (MRO)**
  - Repair/Reconditioning techniques
  - Single Crystal Repair
  - Repair through Additive Manufacturing
    - On-Demand and Legacy Parts
CAPE Road Map Strategic Plan: Align Incentives to Effect Change

Pathways to Performance

Drivers
- OEMs
  - Development Time
  - Development Cost
  - Time to Market
  - Profitability
  - Production Efficiency
- Small Business and Suppliers
  - Market Share (Foothold)
  - Access to Fundamentals
- Customers
  - Emissions
  - Life Cycle Cost
  - Maintenance, Repair and Overhaul

Focus Areas
- Additive Manufacturing
- Maintenance, Repair, and Overhaul
- Manufacturing Processes
- Advanced Materials and Alloys
- Non-Destructive Evaluation/Metrology
- Database
- Supply Chain

Objectives
- Efficiency
- Emissions
- Rate of Improvement

Precompetitive

Competitive
What Is Combined Heat & Power?

The Cogeneration Principle
Combined Heat and Power (or Combined Cooling, Heat & Power) harnesses a larger proportion of the energy consumed for useful work.
Combined Heat and Power (CHP) is a Major Player in the United States’ Energy Mix

- 4,300 CHP Sites (2013)
- 82,700 MW – installed capacity
- Saves 1.8 quads of fuel each year
- Avoids 241 M metric tons of CO₂ each year
- 80% of capacity – industrial
- 70% of capacity – natural gas fired
CHP installations are primarily powered by gas turbines

Natural gas and biomass have taken small chunks of the market from coal, reflecting a broader transition away from coal-fired power. Natural gas remains the most popular source for cogeneration by far, representing 71% of installed CHP capacity.

Source: Bloomberg NEF, Alliance for Industrial Efficiency
 Combined Heat and Power in Florida

- 68 installations* in FL listed in Department of Energy’s national CHP installation database as of December 2016
  - Total rated capacity of 7.4 GW co-generation within Florida, of which 3.28 GW listed in database *
- 19 installations totaling 347 MW designated as “critical infrastructure” (no downtime) – hospitals, public safety, airports, water & sewage treatment plants, universities & military installations

**Shands Hospital in Gainesville, FL**
- 4.3 MW gas turbine-powered CHP facility
- Provides 100% of hospital’s electric & thermal needs
- Guarantees 100% uptime w/ 75% thermal efficiency
- Partnership with GRU saved UF ~$30 million capex

- U.S. Alliance for Industrial Efficiency has estimated that **Florida could save up to $13 billion in energy costs to ratepayers in the next 15 years** (through 2030) by implementing available CHP and industrial efficiency improvements with short-to-midterm paybacks (Florida ranks #5 among all US states in available savings)

*Does not include combined-cycle power plants owned & operated by utilities

Sources: EIA, AIE, DoE CHP-TAP
Microgrids provide resiliency and flexibility for power supply and demand, protecting critical community resources (hospitals, police & fire, public services, and military installations).
Benefits of Microgrids

Microgrids can improve the resiliency of power supplies (storm hardening) and allow communities to integrate renewables and energy storage at the local level.
Grid management requires real-time coordination among a number of technologies via control systems, balancing of power generation & demand in real time.

Combined Heat and Power and controllable co-generation play a key role in power modulation and grid stability within the implementation and management of microgrid(s).
# Power Modulation Challenges Faced by Grid Operators

<table>
<thead>
<tr>
<th>Disturbance</th>
<th>Waveform</th>
<th>Origin</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Sag / Undervoltage</td>
<td><img src="image1.png" alt="Waveform" /></td>
<td>Short circuits in the network grid or on another radial radial    Startup of large motors</td>
<td>Disconnection of sensitive loads                                    Fail functions.</td>
</tr>
<tr>
<td>Voltage Swell/ Overvoltage</td>
<td><img src="image2.png" alt="Waveform" /></td>
<td>Earth fault on another phase                                          Shut down of large load                                                   Lightning strike on network structure                     Incorrect substation settings</td>
<td>Ageing of insulation                                           Disconnection of Equipment                                       May harm equipment with inadequate design margins</td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td><img src="image3.png" alt="Waveform" /></td>
<td>Non-linear loads                                                      Resonance phenomena                                                        Transformer saturation                                      Notches</td>
<td>Extended heating                                                  Fail function of electronic equipment</td>
</tr>
<tr>
<td>Transients</td>
<td><img src="image4.png" alt="Waveform" /></td>
<td>Lightning strike                                                      Switching event</td>
<td>Insulation Failure                                                 Reduced lifetime of equipment: transformers, motors, etc.</td>
</tr>
<tr>
<td>Voltage Flicker</td>
<td><img src="image5.png" alt="Waveform" /></td>
<td>Welding                                                                Wind turbines                                                           Arc furnaces                                                        Sawmill, crushing mill, Start up of large motors</td>
<td>Flicker                                                           Fail functions                                                Ageing of insulation</td>
</tr>
<tr>
<td>Short-duration Interruptions</td>
<td><img src="image6.png" alt="Waveform" /></td>
<td>Direct short current                                                   Disconnection                                                             False Tripping                                                       Load Shedding</td>
<td>Disconnection</td>
</tr>
<tr>
<td>Unbalanced Phases</td>
<td><img src="image7.png" alt="Waveform" /></td>
<td>One phase loads                                                       Weak connections in the network</td>
<td>Voltage quality for overloaded phase                                   Overload and noise from 3 phase equipment</td>
</tr>
</tbody>
</table>

Source: NYSERDA

These issues can impact all grids, but can have an especially large impact on a microgrid if improperly managed.
Resources to Learn More

- US Department of Energy – CHP Technical Assistance Partnerships (CHP-TAP)
  - [https://energy.gov/eere/amo/chp-deployment](https://energy.gov/eere/amo/chp-deployment)

- US Environmental Protection Agency – CHP Partnership
  - [https://www.epa.gov/chp](https://www.epa.gov/chp)

- Alliance for Industrial Efficiency
  - [http://alliance4industrialefficiency.org](http://alliance4industrialefficiency.org)

- Energy Florida
  - [https://energyflorida.org/consulting](https://energyflorida.org/consulting)
  - [https://energyflorida.org/programs](https://energyflorida.org/programs)

- Florida State University System - Florida Solar Energy Center (UCF) & FESC (UF)
Energy Florida Can Help!

- Energy Florida Consulting, EFC, strives to build customized services tailored to a company’s special needs.

- What services EFC offer:
  - Access to Funding
  - Business Plan Development
  - Market Assessment
  - Market/Sector Surveying
  - Market/Lead Development
  - Asset Mapping & Site Evaluation
  - Grant Writing/Proposal Development
  - Industry Network Building
  - Engineering Ecosystems / CHP & Microgrid Implementation
  - Business startup and development
  - Supply chain analysis and development
  - Energy efficiency programs & financing
  - Transportation energy technology
  - Gas turbine technology for power and propulsion
  - Strategic Coordination with Federal, State and Local Governments’ Energy Policies
EFC represents a robust, multi-talented team of industry experts and partners

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Thank You!

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