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

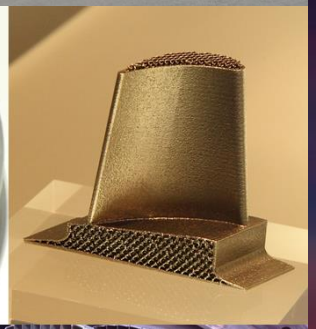
NIST Advanced Manufacturing Consortium for Advanced Production and Engineering of Gas Turbines and Rotating Machinery

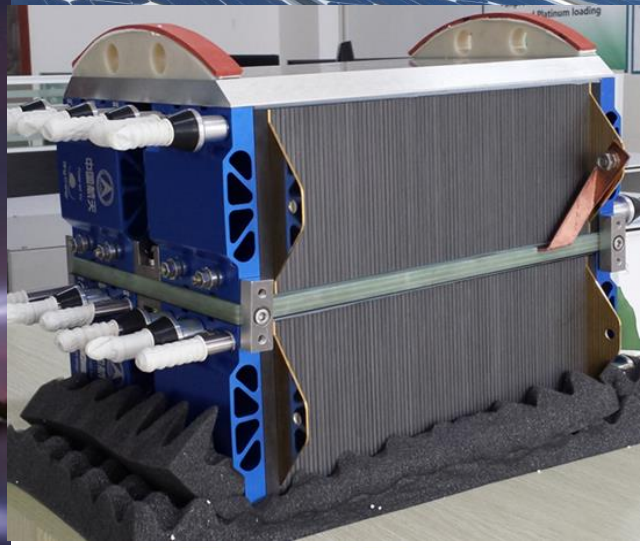
ENERGY FLORIDA

FESC Energy Forum
Florida Polytechnic
Lakeland, FL
July 31, 2017

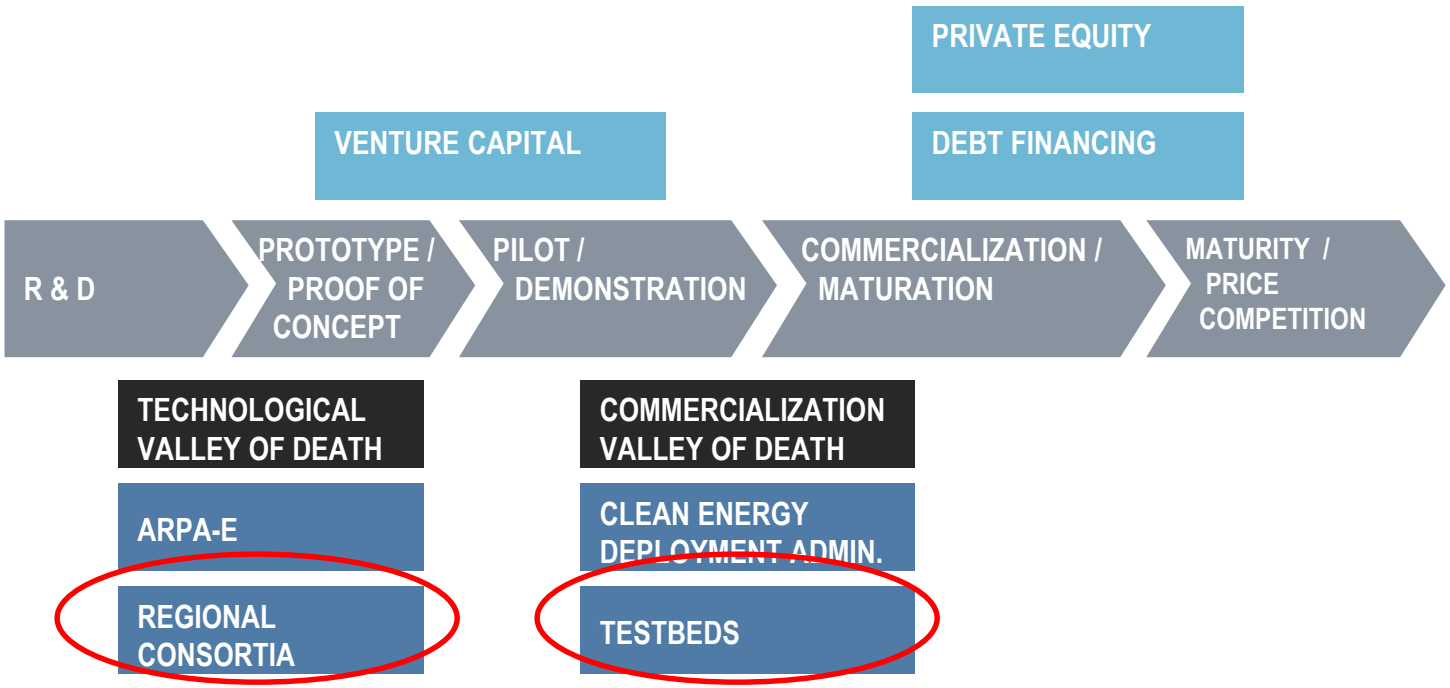
CAPE
Consortium for Advanced Production and Engineering of Gas Turbines

Energy Florida & CAPE are Building Capabilities across Energy, Aerospace & Transportation



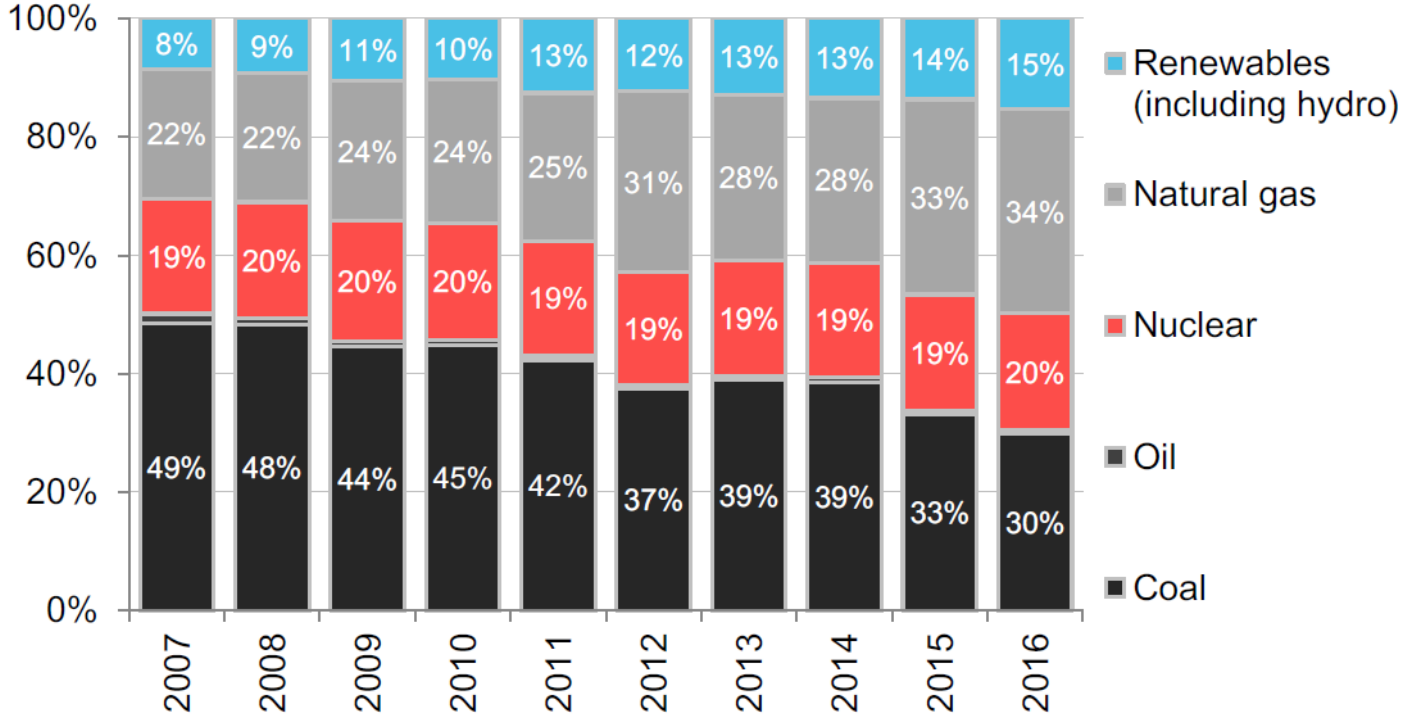


Best Practices: Responses to the "Valleys of Death" for Innovative Technologies



Adapted from "Bridging the Clean Energy Valleys of Death" – the Breakthrough Institute, 2011

Natural Gas & Renewables are the drivers of US Electricity Generation



- 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.

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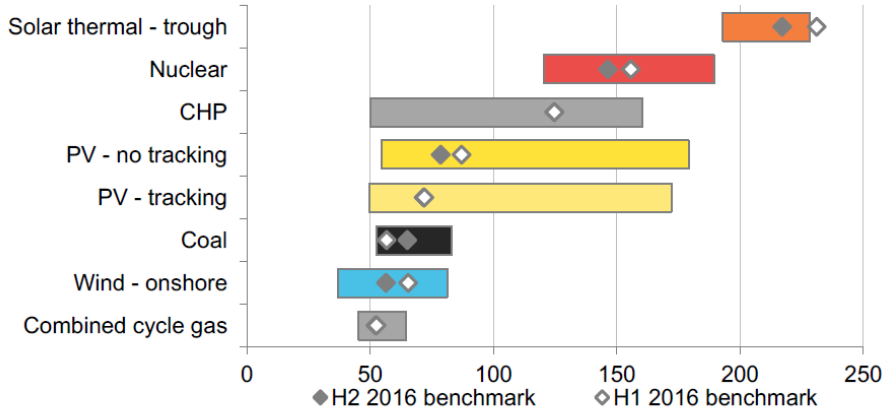
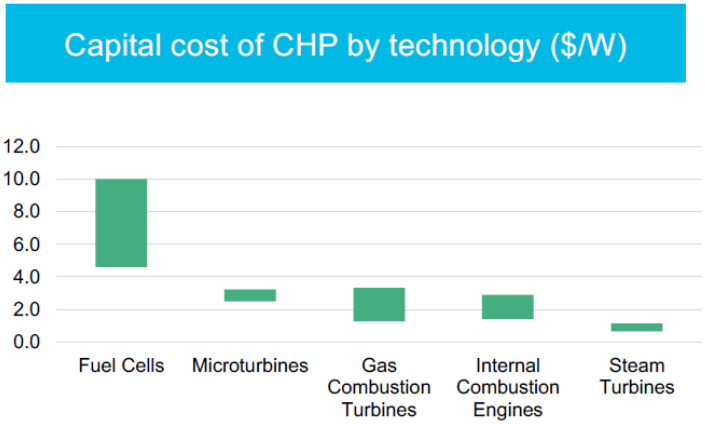
Why are Renewables & Natural Gas Taking Off? Costs are Coming Down

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.

Sources: Bloomberg New Energy Finance, EIA

- 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.

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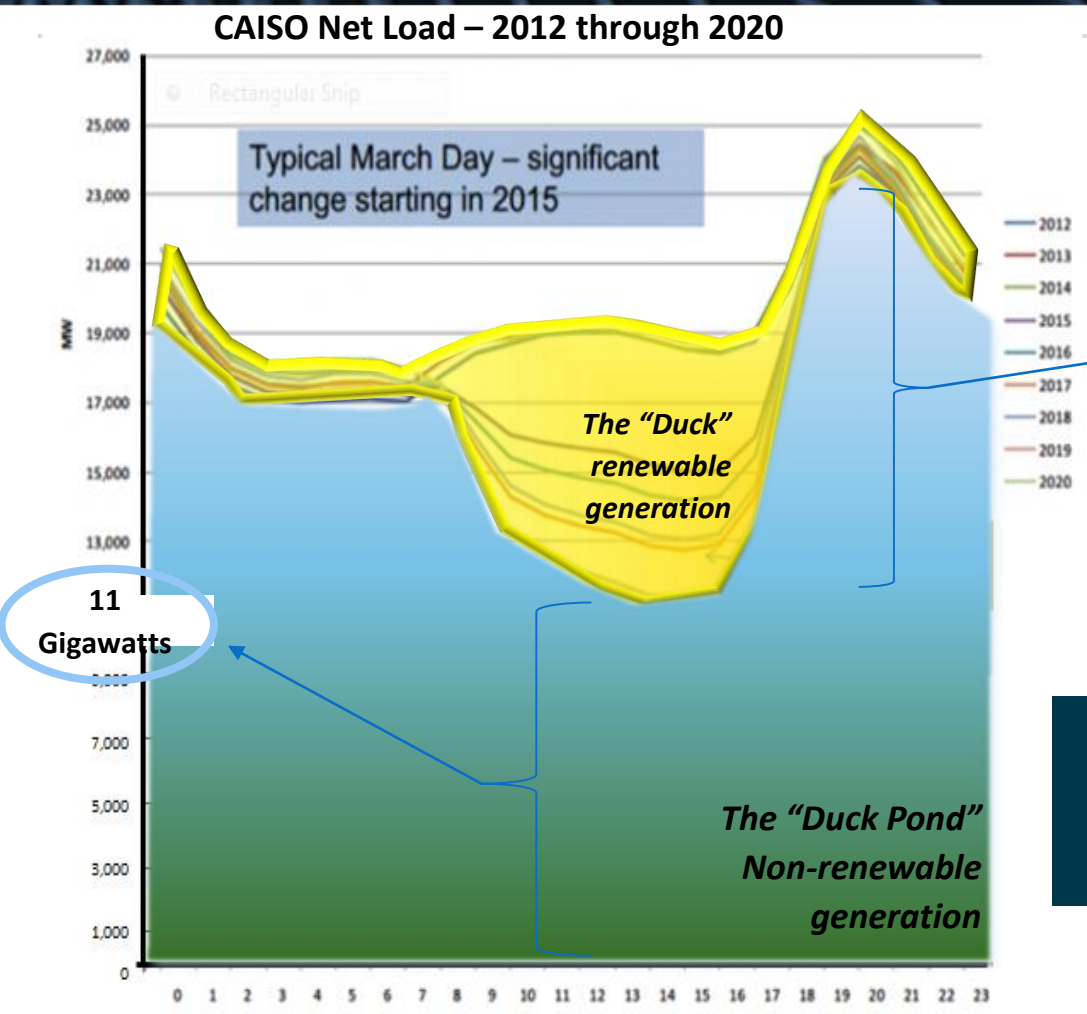
Power Generation on Grids with Renewables: Need Flexible, Controllable Generation Sources



Source: CAISO

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

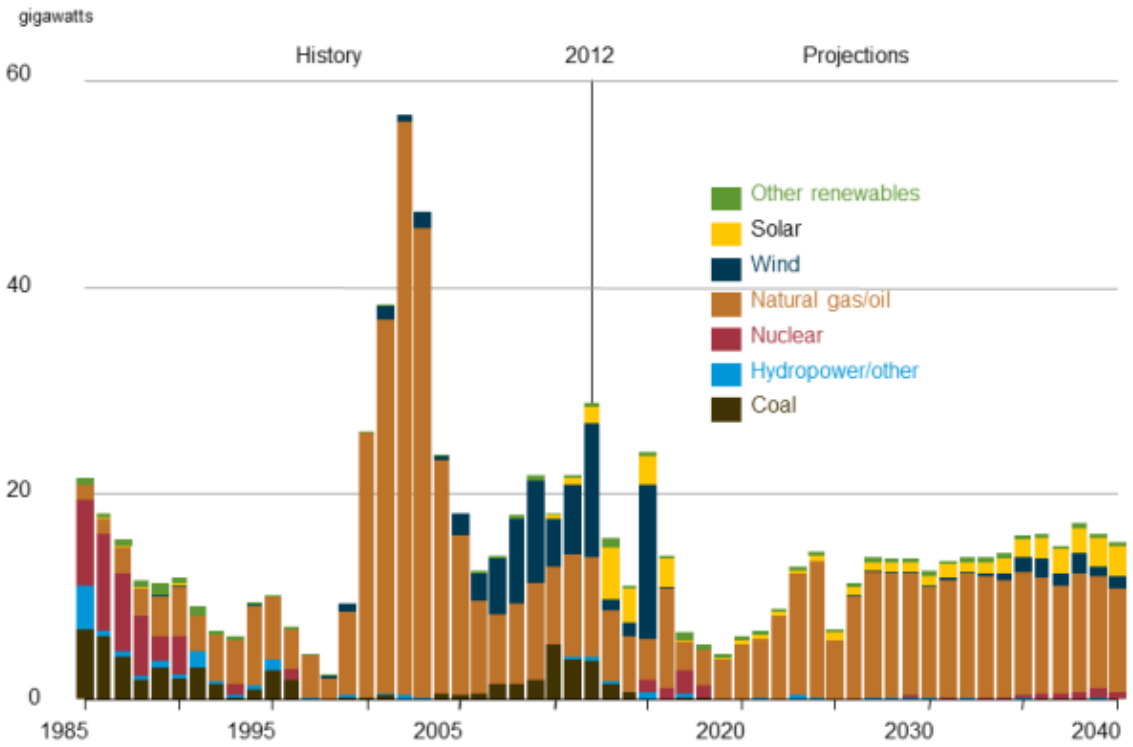
Lots of ***non-renewable generation is operating all of the time***

Non-renewable sources remain more influential to overall power delivery than the renewable generation

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

Figure MT-32. Additions to electricity generating capacity in the Reference case, 1985-2040



eia

Sources: Forecast International, 2016 Turbomachinery Handbook and US EIA

NETL

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**
  - **<u>Affordable & Effective Mission Capability – Air, Land, Sea & Space</u>**
  - **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**

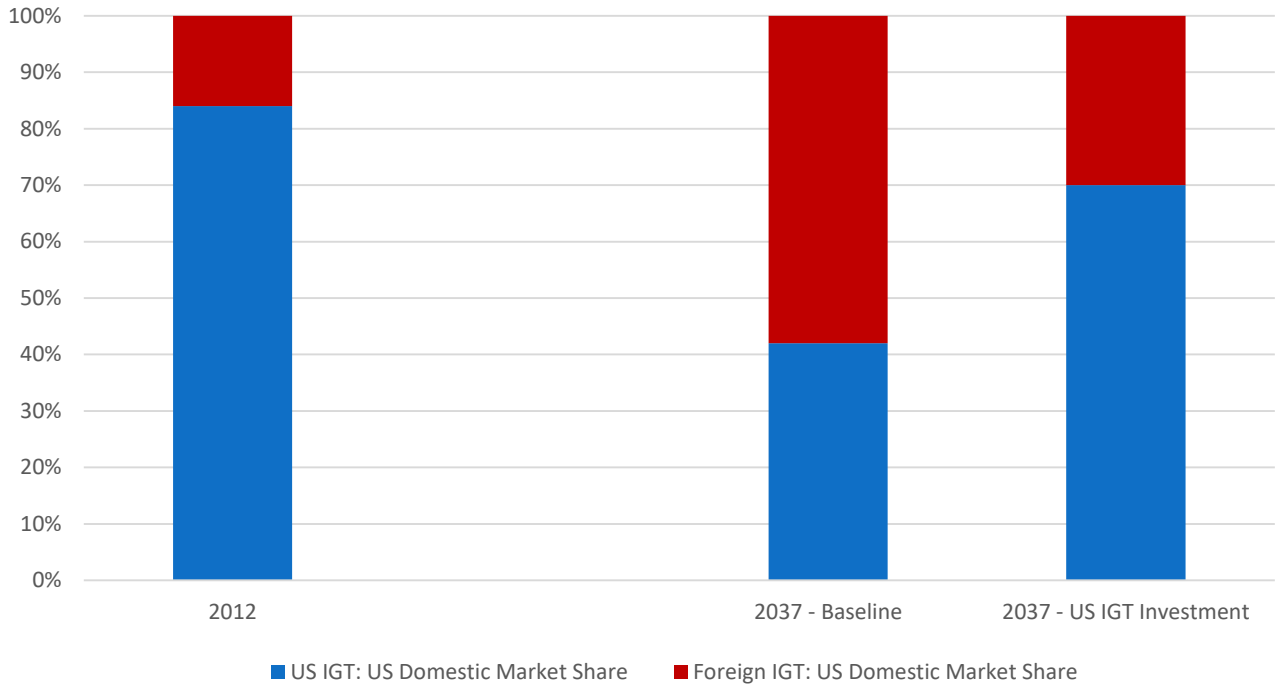
Energy Florida and Gas Turbine Association
NIST AMTech Consortium for Advanced Production and Engineering of Gas Turbines & Rotating Machinery (CAPE)

- **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**

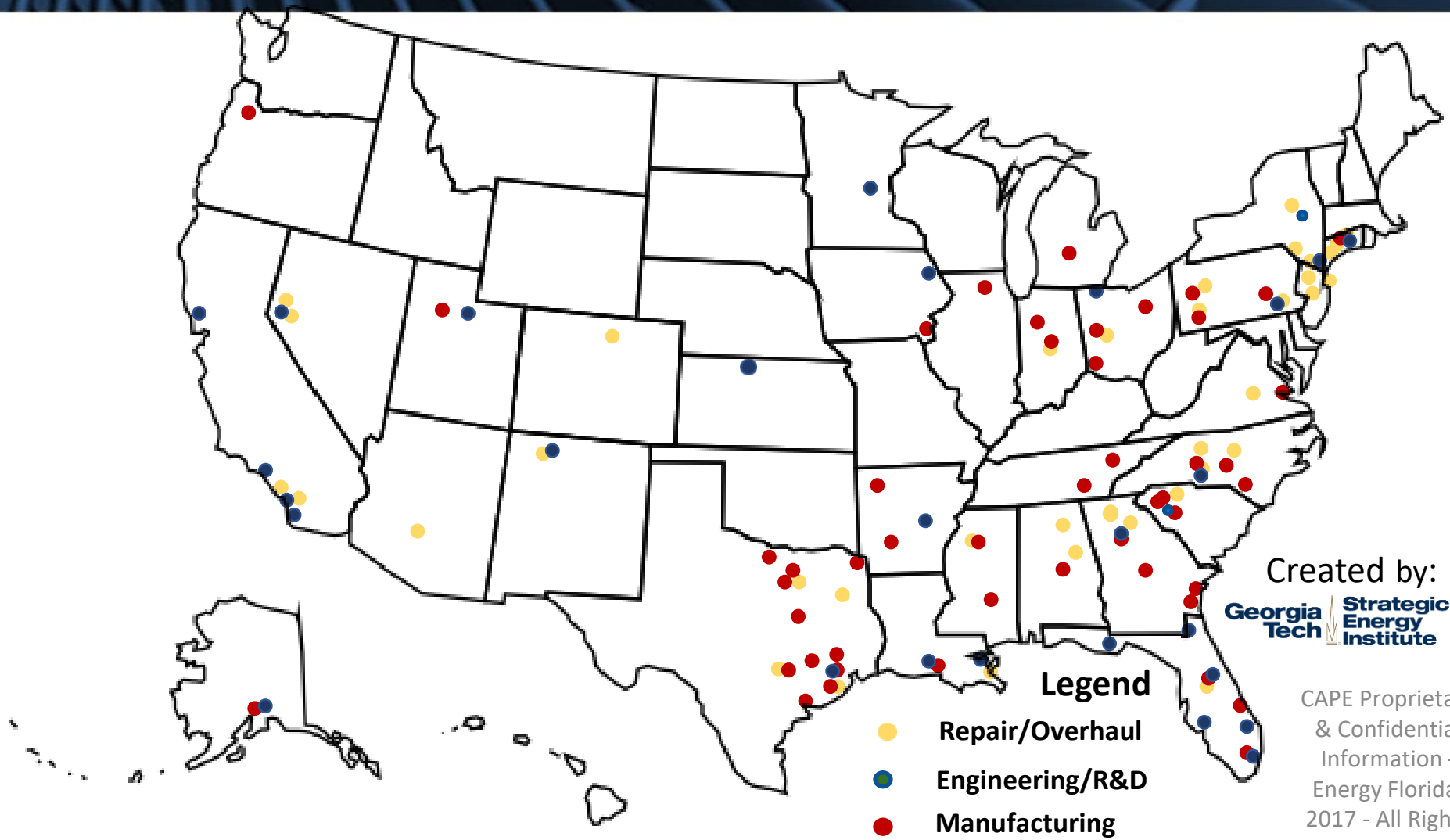
- **Enormous market opportunity as demand for turbines and related parts and components expands around the world**
  - **$1 trillion market in power generation by 2035**
  - **$3 trillion in aviation gas turbine engines by 2035**

Impact of U.S. Investment in Next-Generation Gas Turbines on U.S. Industry Competitiveness, 2012-2037



- 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



Created by:

Georgia Tech Strategic Energy Institute

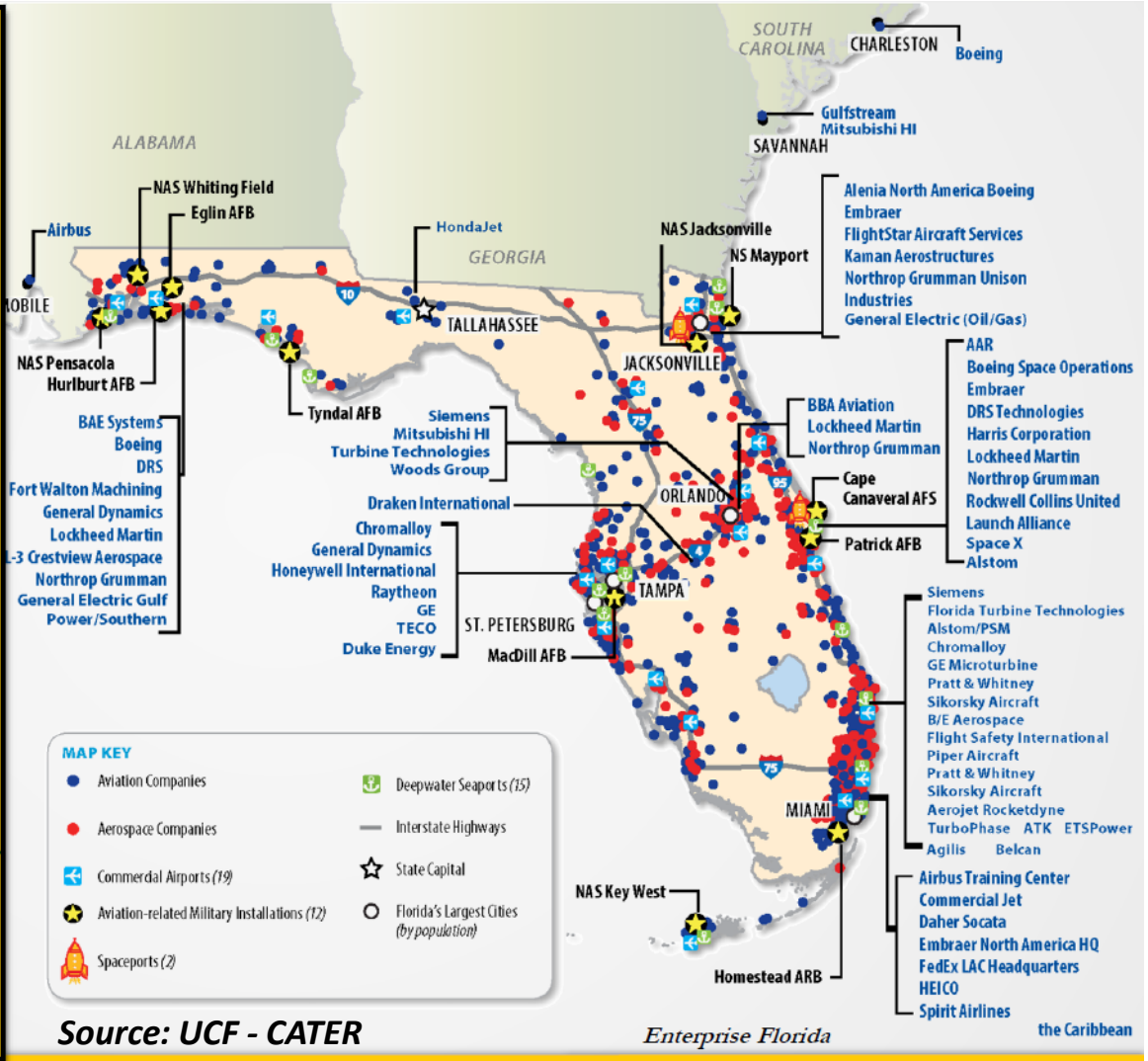
Florida is a Turbine Industry Hotspot

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

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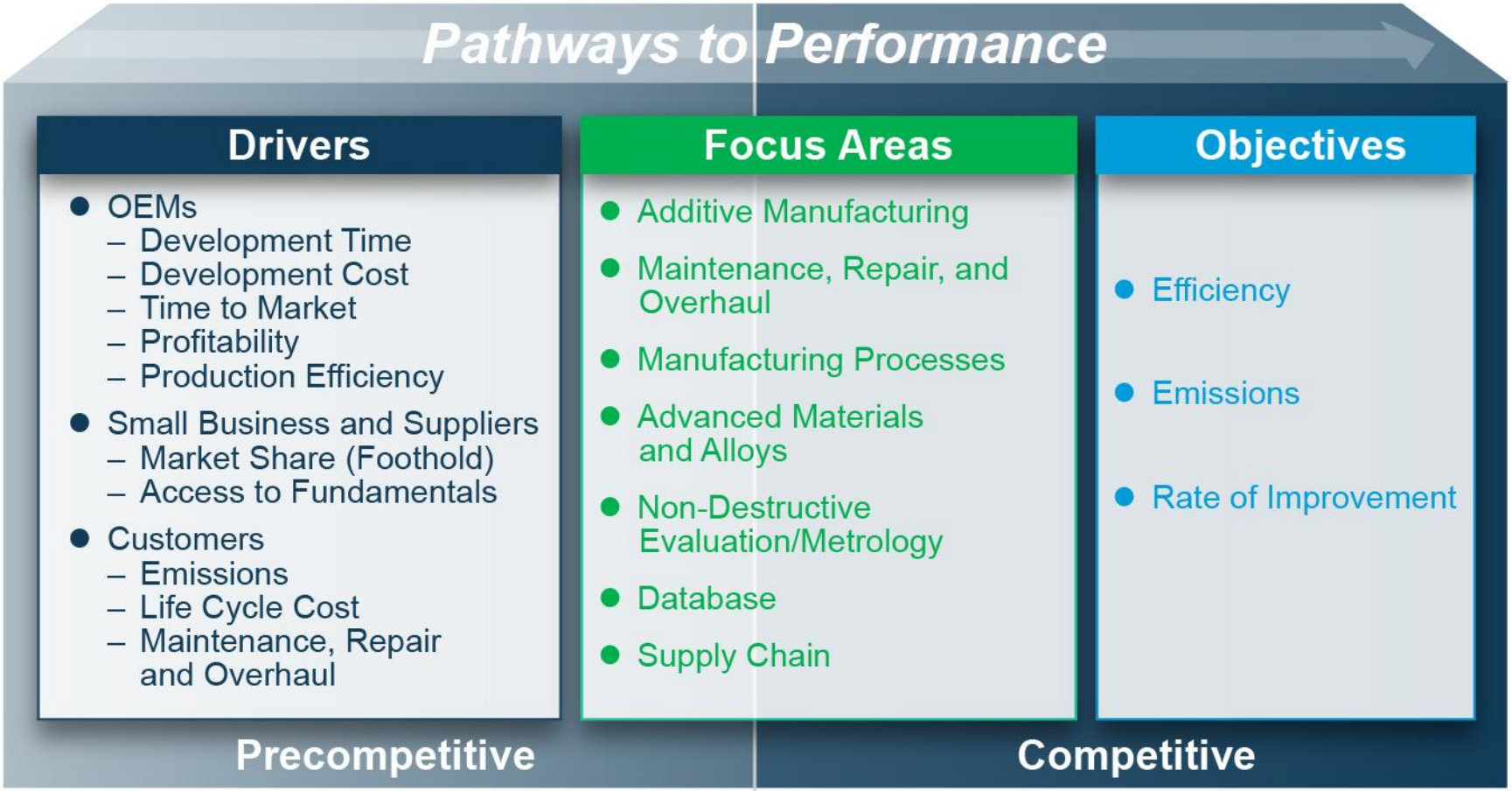
CAPE Technical Focus Areas: Next-Generation Gas Turbine Manufacturing

- **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



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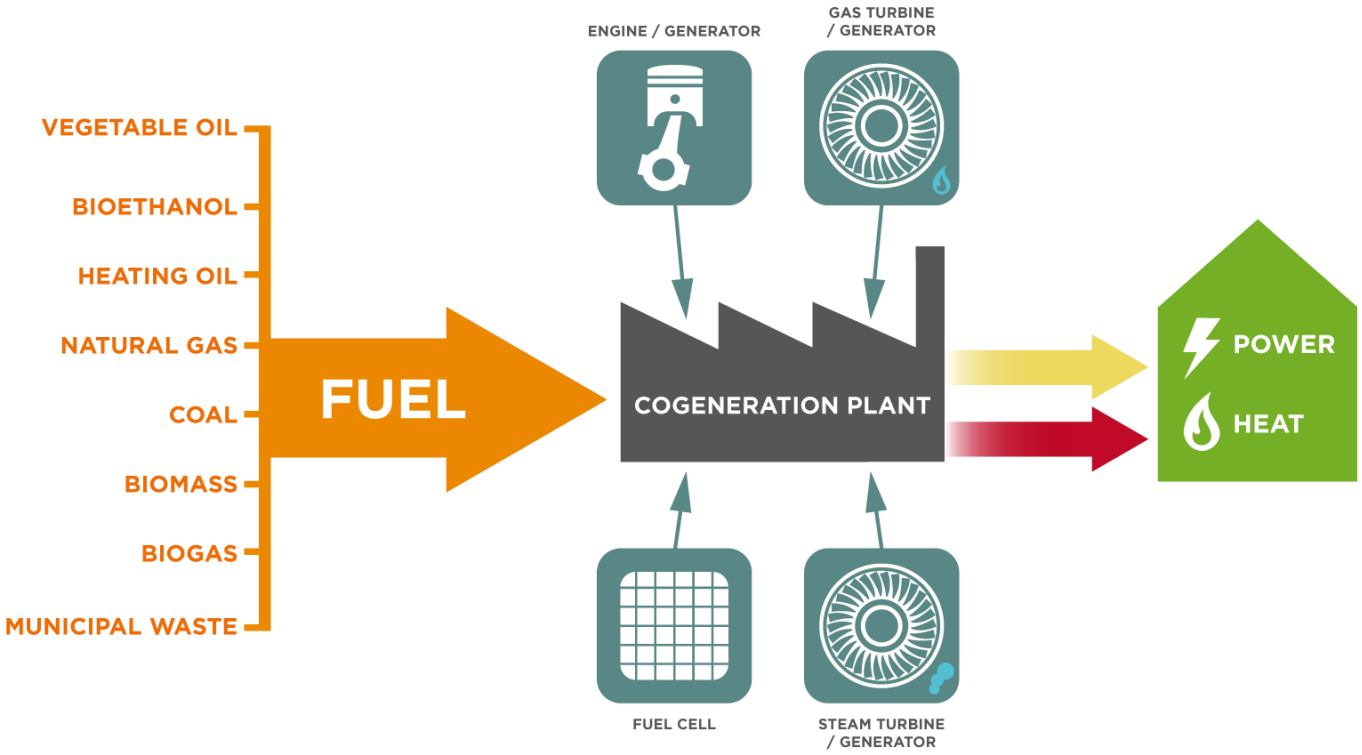
What Is Combined Heat & Power?

The Cogeneration Principle



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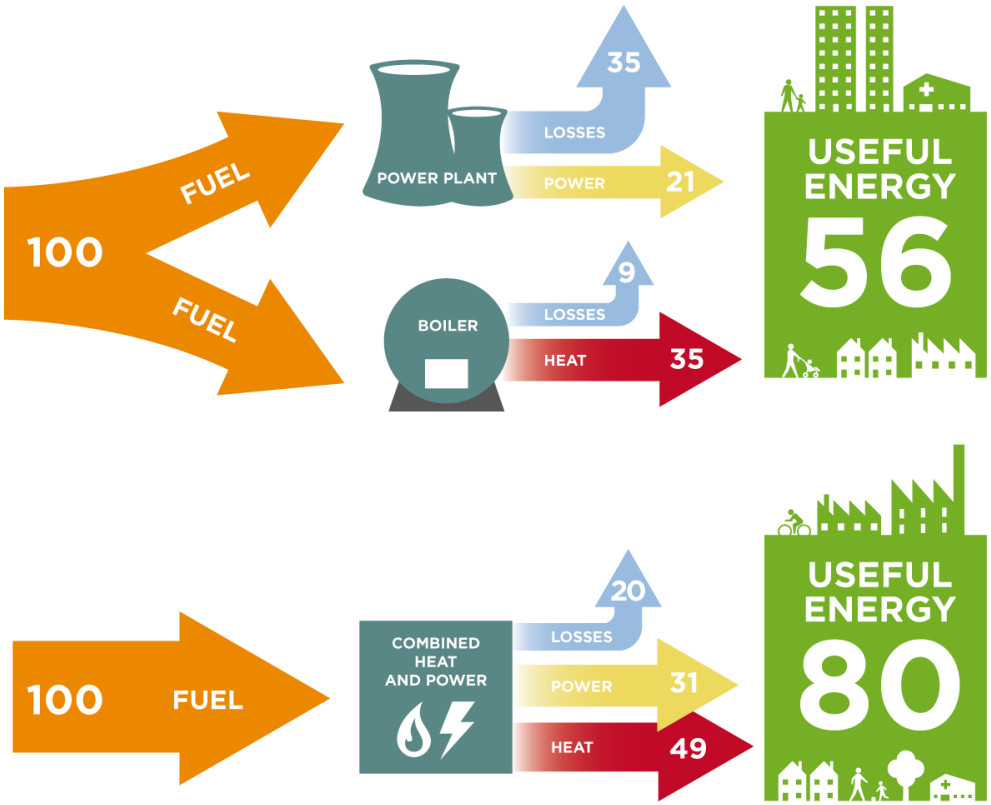
Combined Heat & Power = Greater Efficiency



- Combined Heat and Power (or Combined Cooling, Heat & Power) harnesses a larger proportion of the energy consumed for useful work

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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 CO_2 each year
- 80% of capacity – industrial

  70% of capacity – natural gas fired

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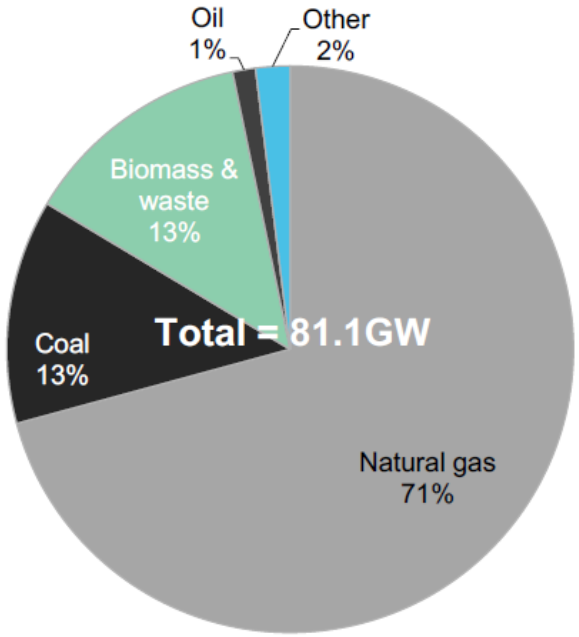
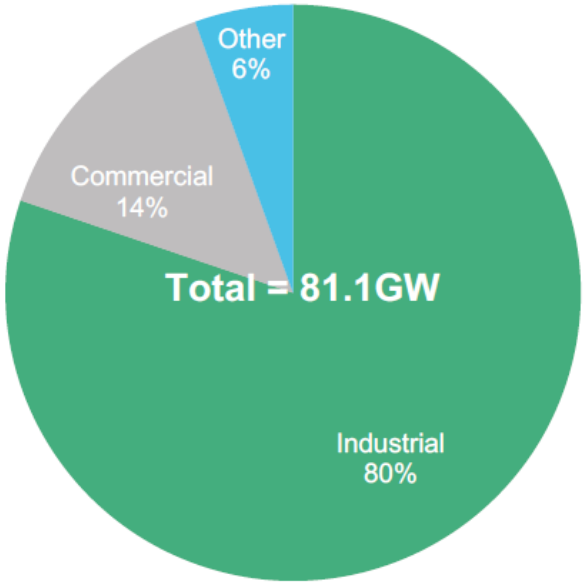
CHP installations are primarily powered by gas turbines

US CHP deployment by fuel source



US CHP deployment by sector



- 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

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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

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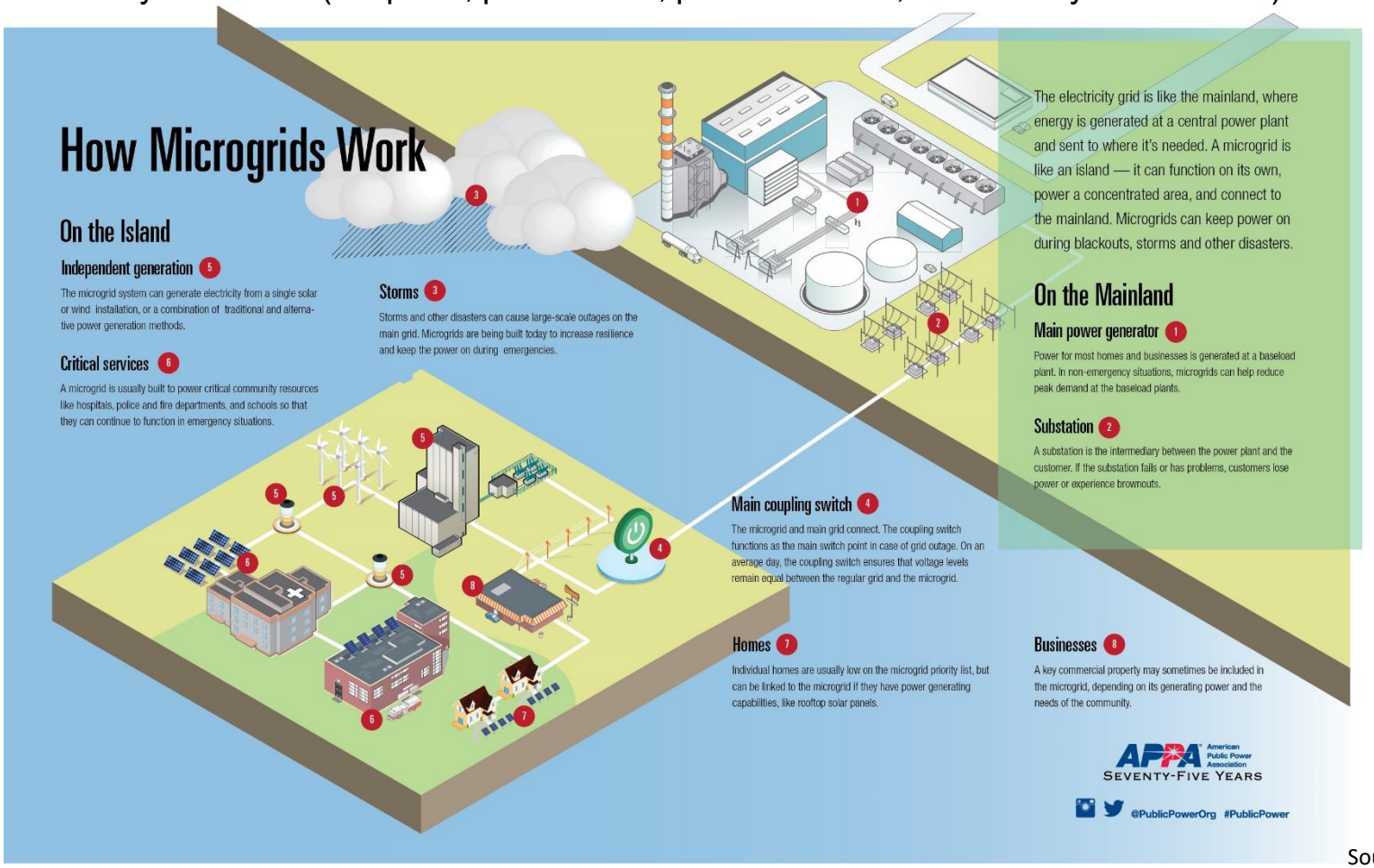
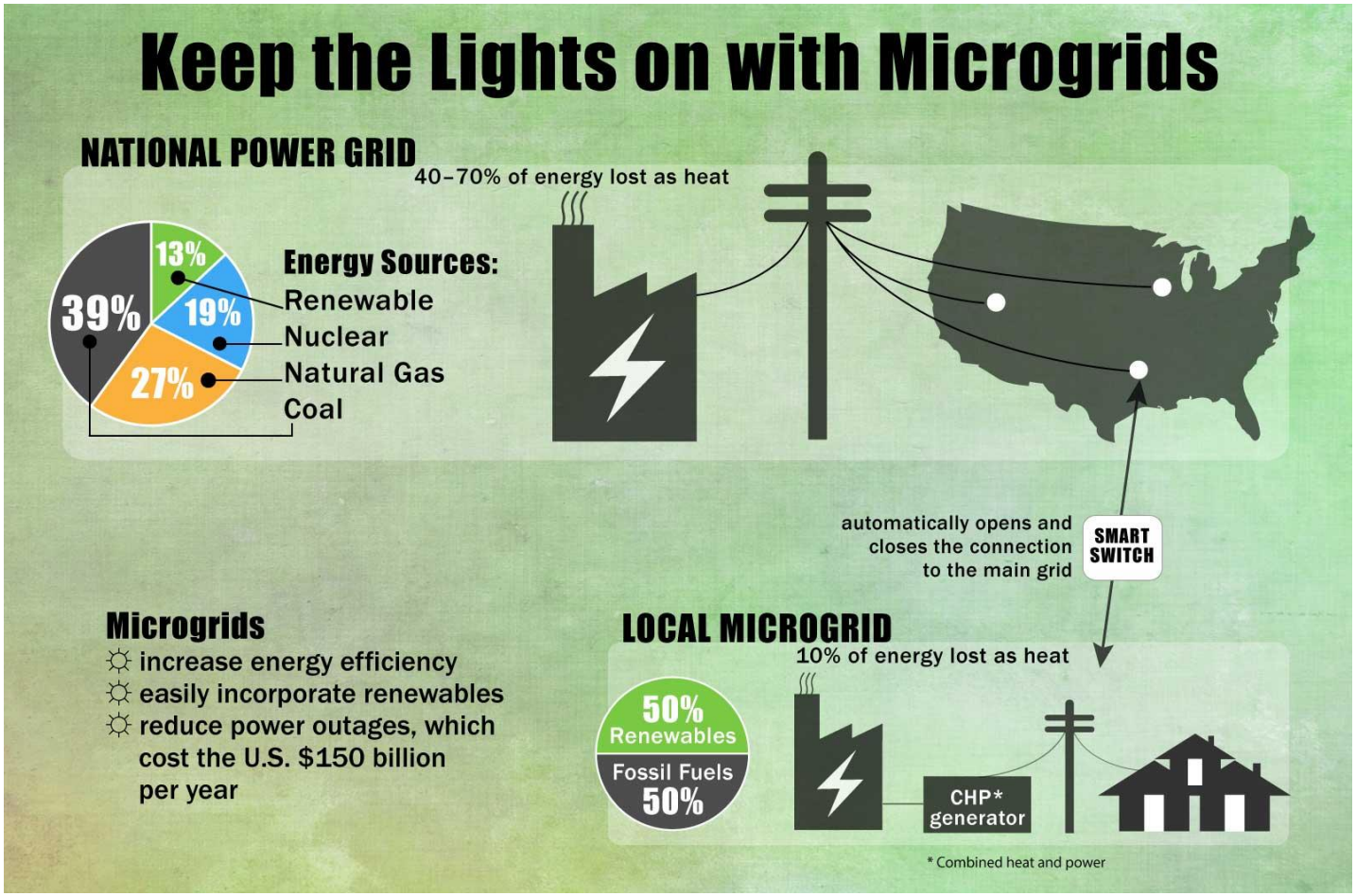
CHP and Microgrids

- Microgrids provide resiliency and flexibility for power supply and demand, protecting critical community resources (hospitals, police & fire, public services, and military installations)



Source: APPA

Benefits of Microgrids



Source: PBS

Microgrids can improve the resiliency of power supplies (storm hardening) and allow communities to integrate renewables and energy storage at the local level

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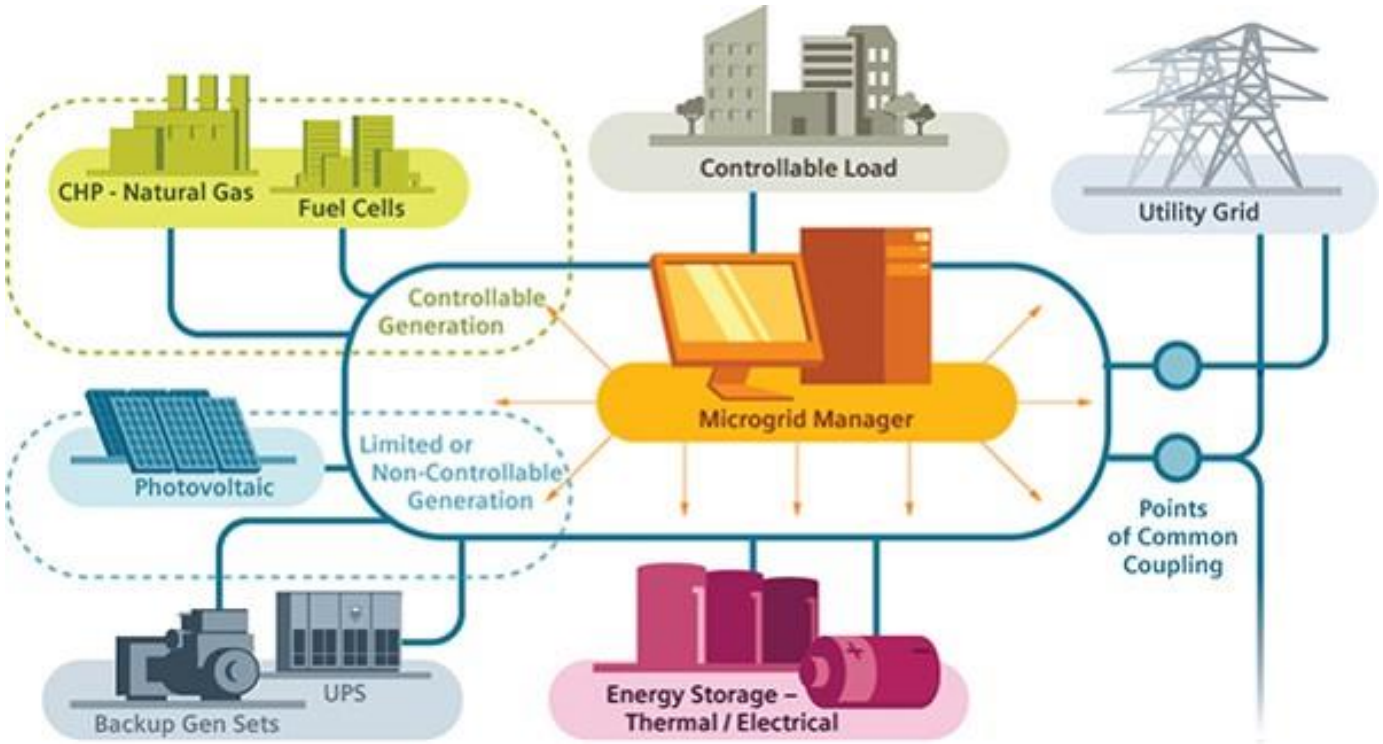
Elements of a Microgrid



- 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)

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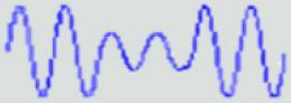
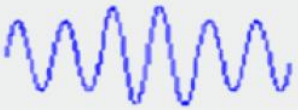
Power Modulation Challenges Faced by Grid Operators

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

Source: NYSERDA

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

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Resources to Learn More

- US Department of Energy – CHP Technical Assistance Partnerships (CHP-TAP)
  - https://energy.gov/eere/amo/chp-deployment
- US Environmental Protection Agency – CHP Partnership
  - https://www.epa.gov/chp
- Alliance for Industrial Efficiency
  - http://alliance4industrialefficiency.org
- Energy Florida
  - https://energyflorida.org/consulting
  - https://energyflorida.org/programs
- Florida State University System - Florida Solar Energy Center (UCF) & FESC (UF)

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Energy Florida Can Help!

Energy Florida Consulting

Your Value Opportunity
Consulting Connection

- **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

Michael Aller

Executive Director & CEO

Focus Areas:

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Government Relations

Grants

Public Private Partnerships

Bennett Boucher

COO/CFO

Focus Areas:

Business Planning

Entrepeneurship

Finance

Government Relations

Robert Burrows

Entrepreneur in Residence

Focus Areas:

Aerospace

Finance

Manufacturing

Publishing

Software

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Tim Franta

Director of Special Projects

Focus Areas:

Economic Development

Infrastructure

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Project Management

Supply Chain

Helge Von Helldorff-Garn

Project Associate

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Emission Testing

Systems Engineering

Systems Testing

Rory McEllin

Renewable Energy Specialist

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Renewable Energy

Quality Control

Mark Robinson

Director of Research & Mapping

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Competitive Intelligence

Lead Development

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John Van Zyl

Strategic Sourcing Consulting Manager

Focus Areas:

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Procurement

Strategic Sourcing

Supply Chain

How to Contact Energy Florida Consulting

Energy Florida Consulting

For more info call : 321-613-2973

www.energyflorida.org/consulting

Or contact:

Mike Aller, Executive Director

michael.aller @ energyflorida.org

Henriette Schoen, Director of Program Development

henriette.schoen @ energyflorida.org

Thank You!

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Thank You!

Michael Aller, Executive Director
166 Center Street, Suite 200, Cape Canaveral, FL
Email: michael.aller @ energyflorida.org
Phone: 321-613-2973 (office)

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