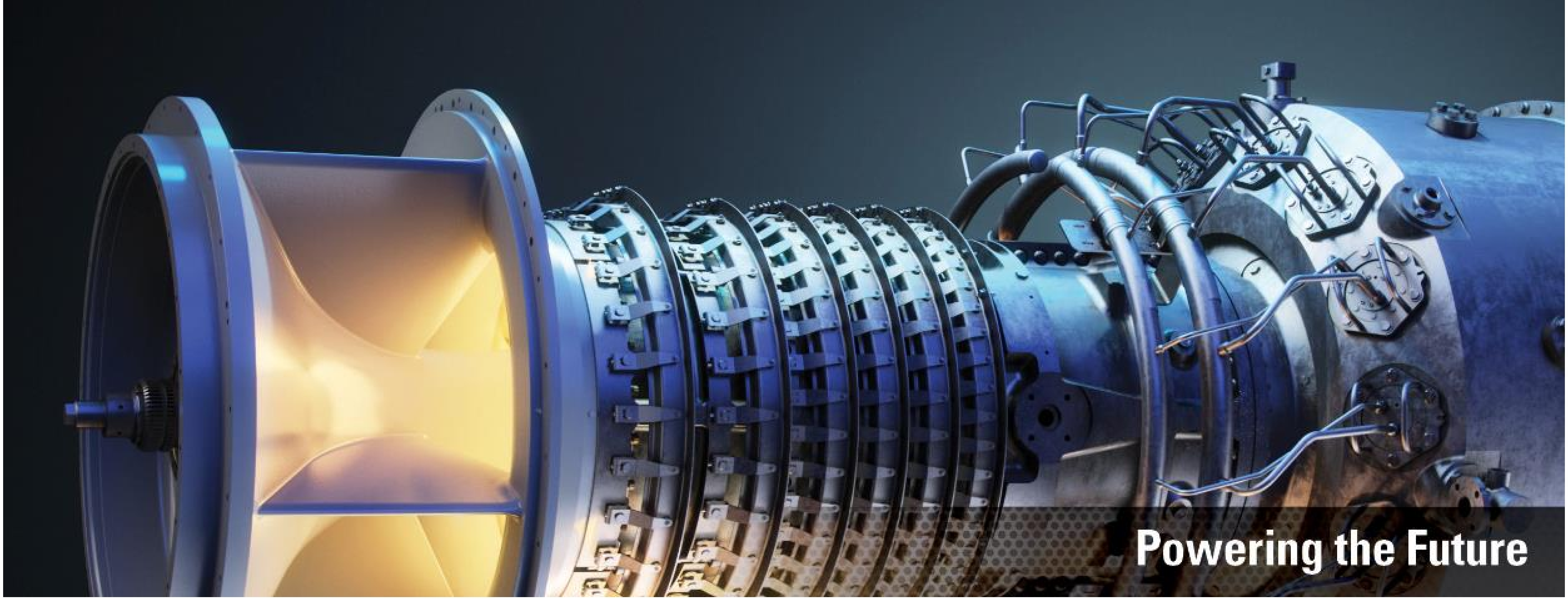
How End Users/Utilities Can Benefit Using CHP in Micro-Grid Applications



Solar Turbines
A Caterpillar Company

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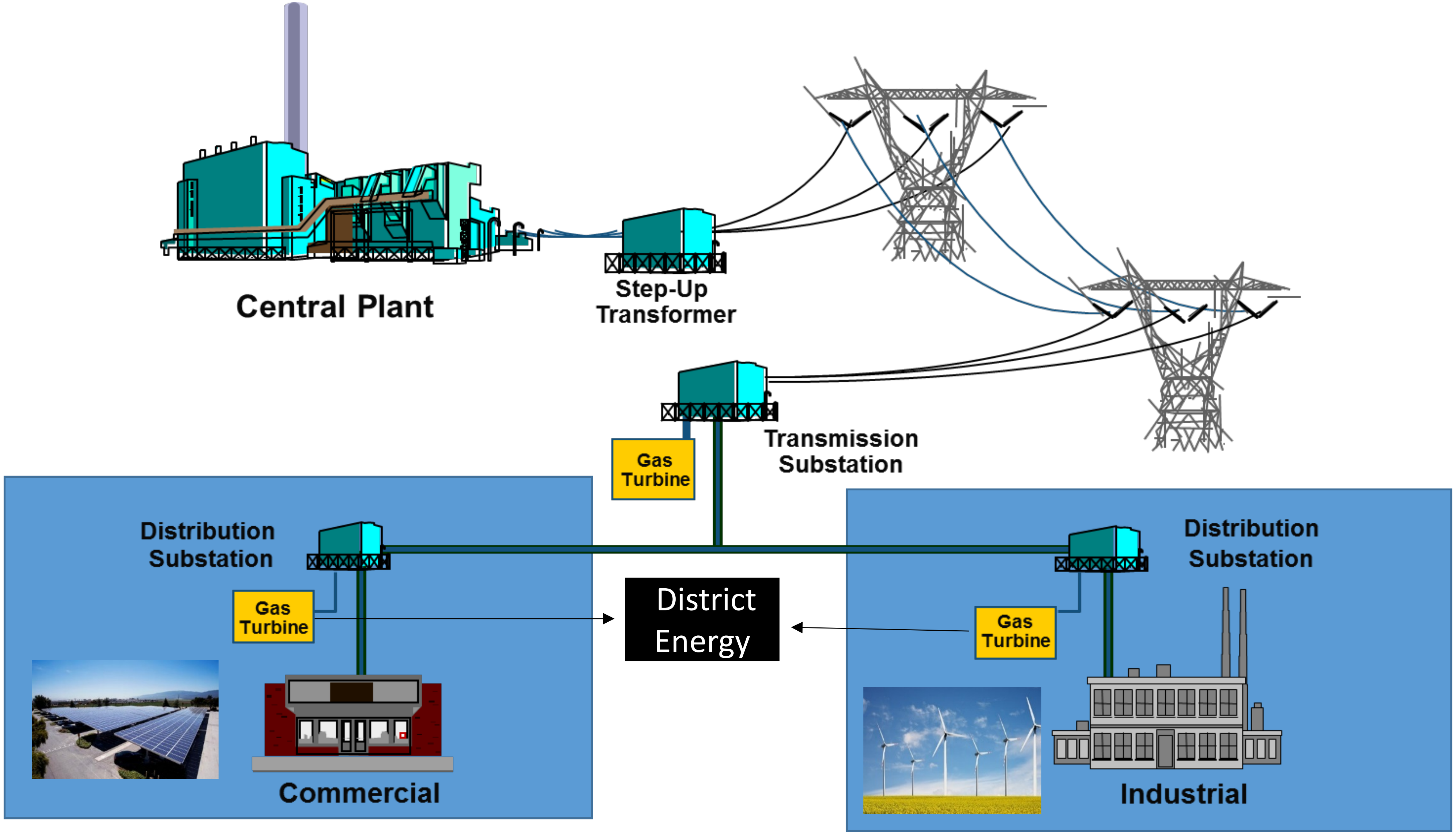
- CHP can improve reliability

What Will the Future Micro-Grid look Like?



The Issue, What will the Future Utility Do?

Does your company plan to develop, own and/or operate distributed generation resources, including microgrids?

Column % by Utility Type	Which of the following best describes your organization?			
	Investor-owned utility	Publicly-owned utility	Cooperative	Independent/ industrial power producer
Already developed, owns, and/or operates	28.4%	34.0%	28.0%	32.4%
Next 5 years	9.5%	4.3%	8.0%	27.0%
Yes, in the next 6-10 years	5.4%	10.6%	.0%	2.7%
Yes, in more than 10 years	.0%	2.1%	.0%	.0%
None planned, but is a possibility for future discussion/planning	24.3%	31.9%	44.0%	21.6%
No, never	2.7%	4.3%	8.0%	10.8%

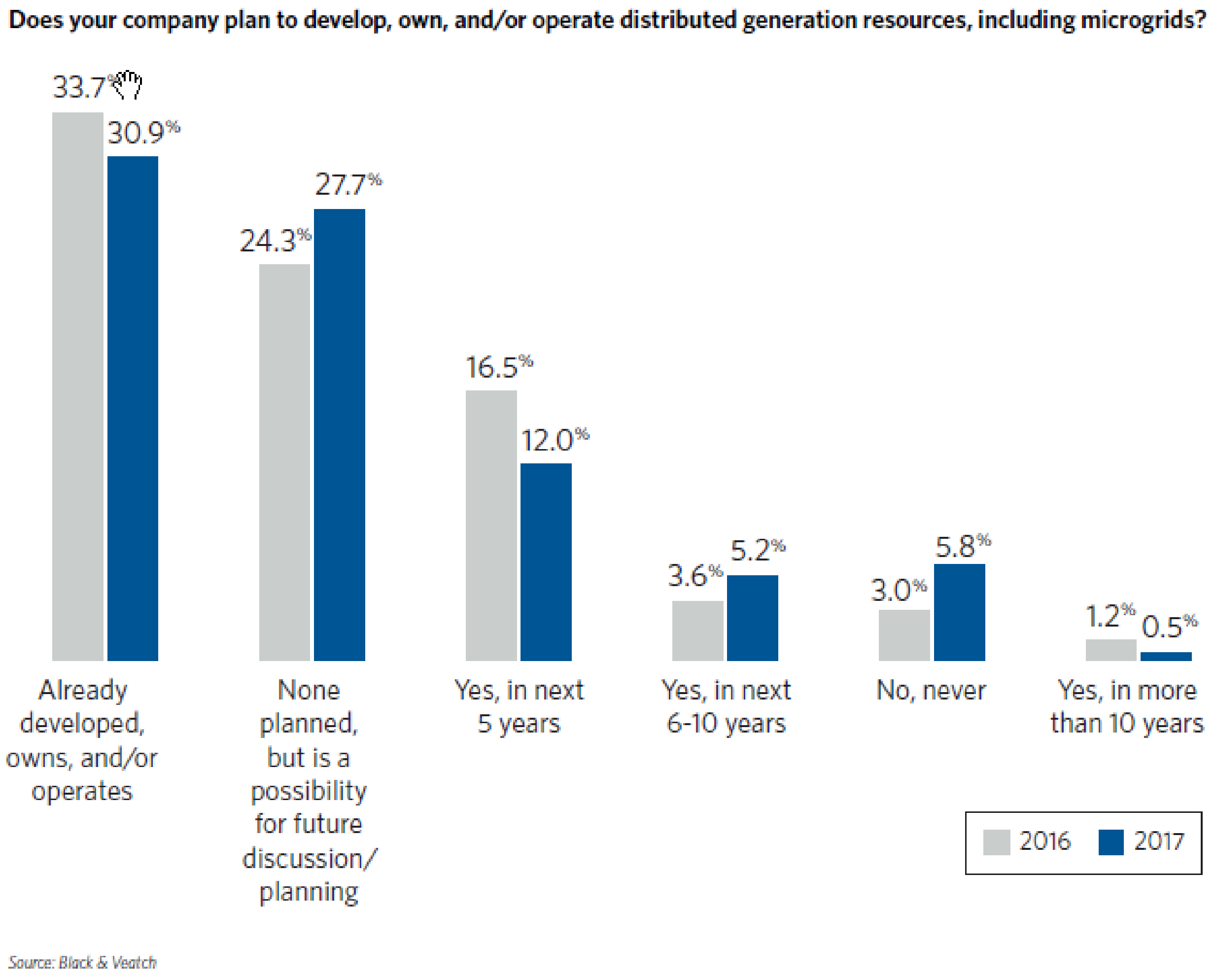
Source: Black & Veatch


E.E.
M.E.
HEY.. This turbine came with a GENERATOR!
So..uh..Where do ya plug it in?

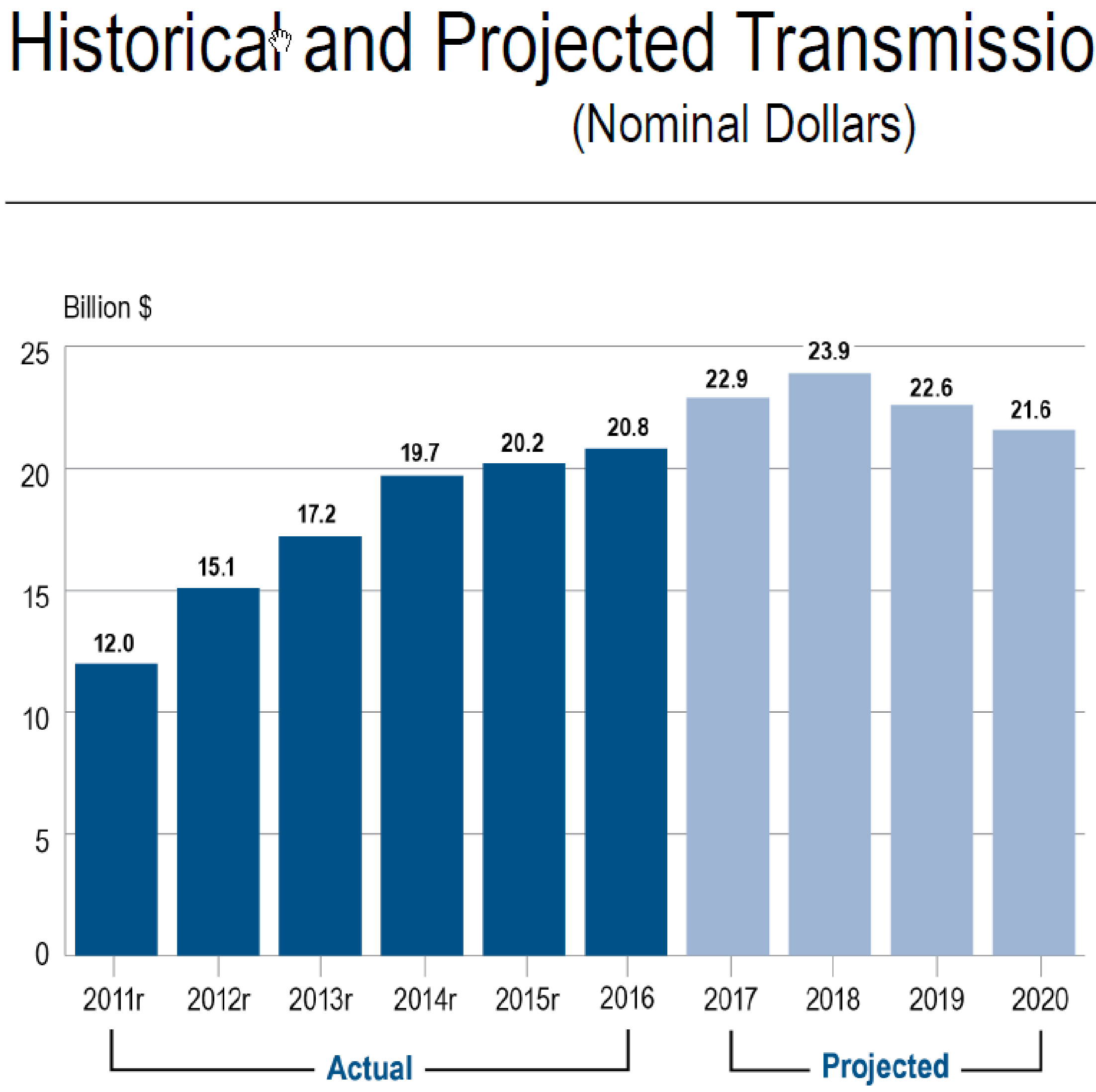
Why Working with Utilities is a Preferred Option

- Utilities are in the energy business, and understand the business and its risks
- Utilities require a lower ROI than industrial companies installing CHP
- Utilities can vastly increase the number of potential opportunities
- Utilities can take advantage of all of the potential benefits
- Utilities can benefit from economies of scale
- Utilities can reduce a number of the obstacles (interconnection, standby fees, etc.)
- Utilities have better customer contact and understanding of needs

Let 's Hope DG/CHP/DE and Micro-Grids are Valued



Transmission Investment is High, But is it Enough?



r = revised

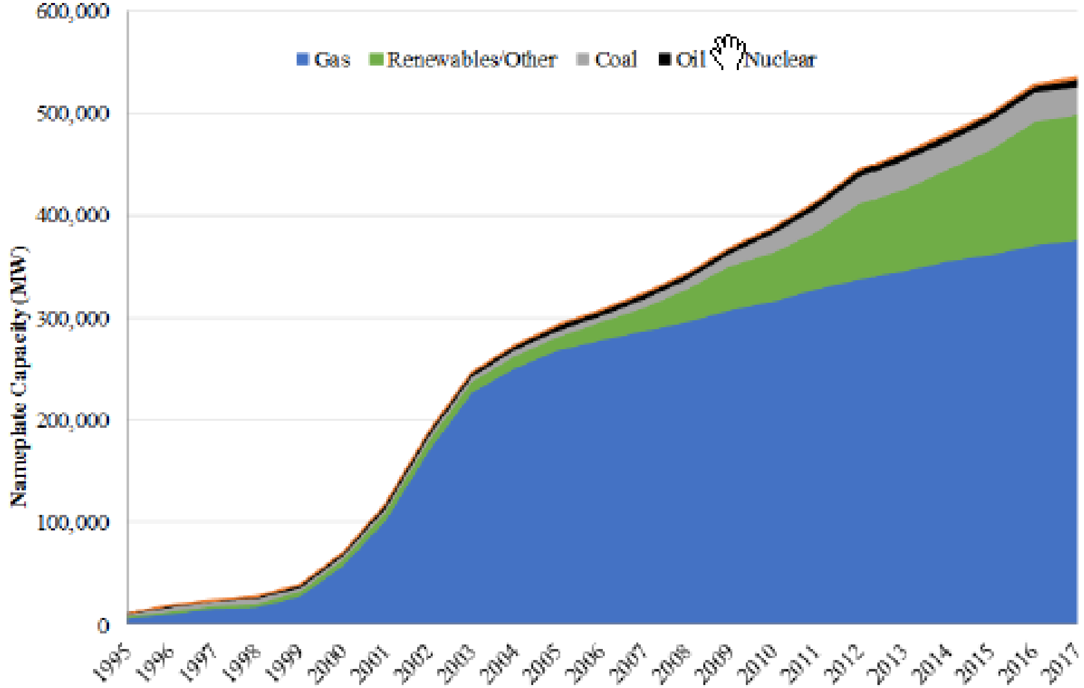
Investment of investor-owned electric companies and stand-alone transmission companies. Actual Investment figures were obtained from the EEI Property & Plant Capital Investment Survey supplemented with FERC Form 1 data. Projected investment figures were obtained from the EEI Transmission Capital Budget & Forecast Survey supplemented with data obtained from company 10-k reports and investor presentations.

Source: Edison Electric Institute Economics, Statistics and Industry Research Group.

Updated September 2017.

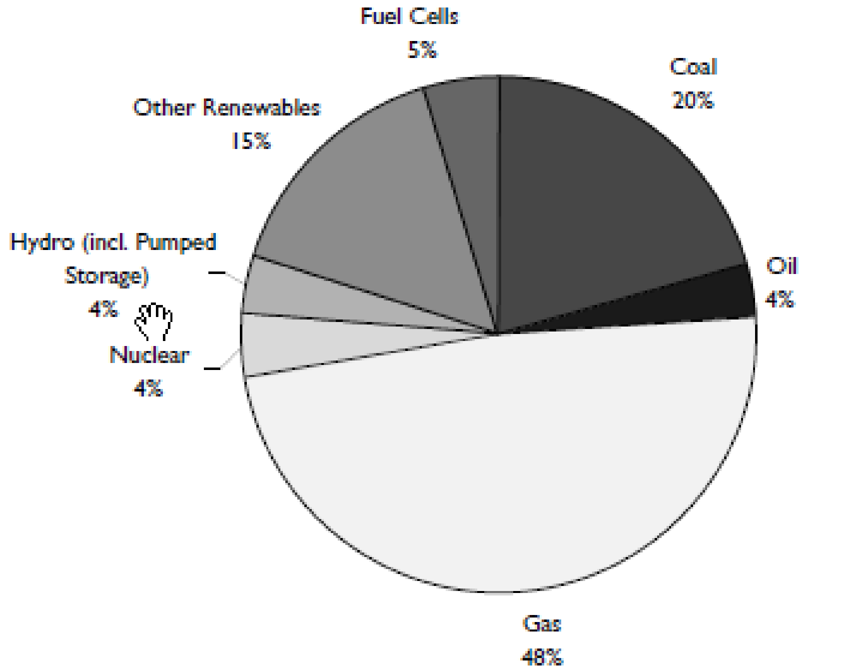
Renewables are Growing, but Natural Gas is Also!

Figure 15: U.S. Capacity Additions by Fuel Type
Cumulative, 1995 - 2017



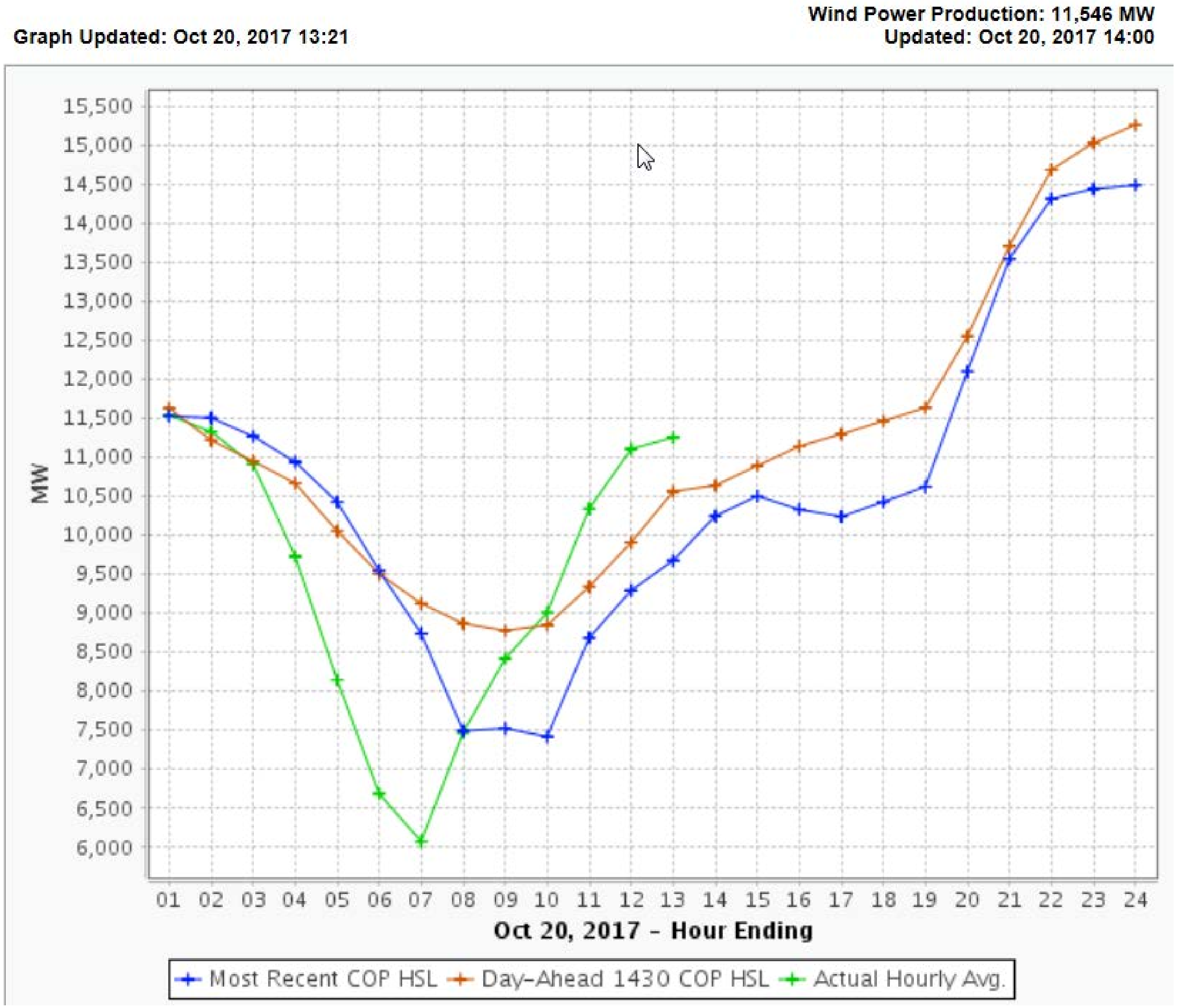
Notes:
[1] Only additions beginning in 1996 forward are displayed.
[2] The Renewables/Other category is made up of the following fuel types: Biomass, Geothermal, Solar, Wind, Water, and Other Nonrenewable. As of 2017, this category collectively represents 122,913.3 MW of cumulative nameplate capacity additions. The cumulative nameplate capacities added for each fuel type respectively as of 2017 are as follows: Biomass (6,368.3 MW), Geothermal (1,032.7 MW), Solar (23,633.7 MW), Wind (83,927.7 MW), Water (4,236.0 MW), and Other Nonrenewable (3,715.0 MW).
Source: SNL Financial.

Share of Projected Capacity Additions in OECD Generating Capacity by Fuel (1999-2030)



Note: Fuel cells are accounted separately but are assumed to use natural gas.
Source: IEA, 2002b.

However, Solar and Wind are Intermittent!



Why CHP Should be Considered in Micro-Grid Applications

- **Provides key anchor and end user benefits, (Power, heat & chilling)**
- Most CHP technologies have multiple fuel capabilities
- CHP technologies can use renewable fuels
- CHP is very efficient, reducing GHG emissions
- CHP can run 24 hours or less, your choice
- CHP can integrate with Energy Storage
- CHP Systems can provide significant cost savings
- CHP can improve reliability

The CHP Anchor at UCSD

- 47 MW Peak Load
- 30 MW of Natural Gas Fired Cogeneration
  - Two, 13.5 MW gas turbines
  - 3 MW steam turbine
- 5.8 MW of Renewable Generation
  - 3 MW of Solar PV
  - 2.8 MW of Bio-gas Fuel Cell
- 2.5 MW/5 MWhr Energy Storage

Significant Operating Savings $$$$

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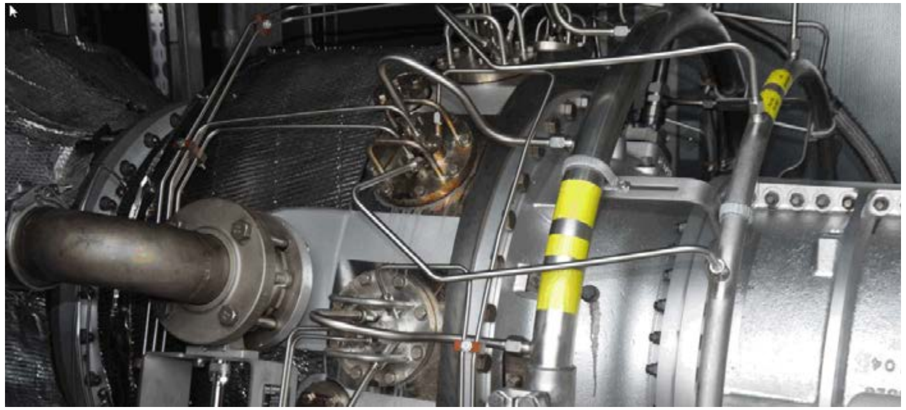
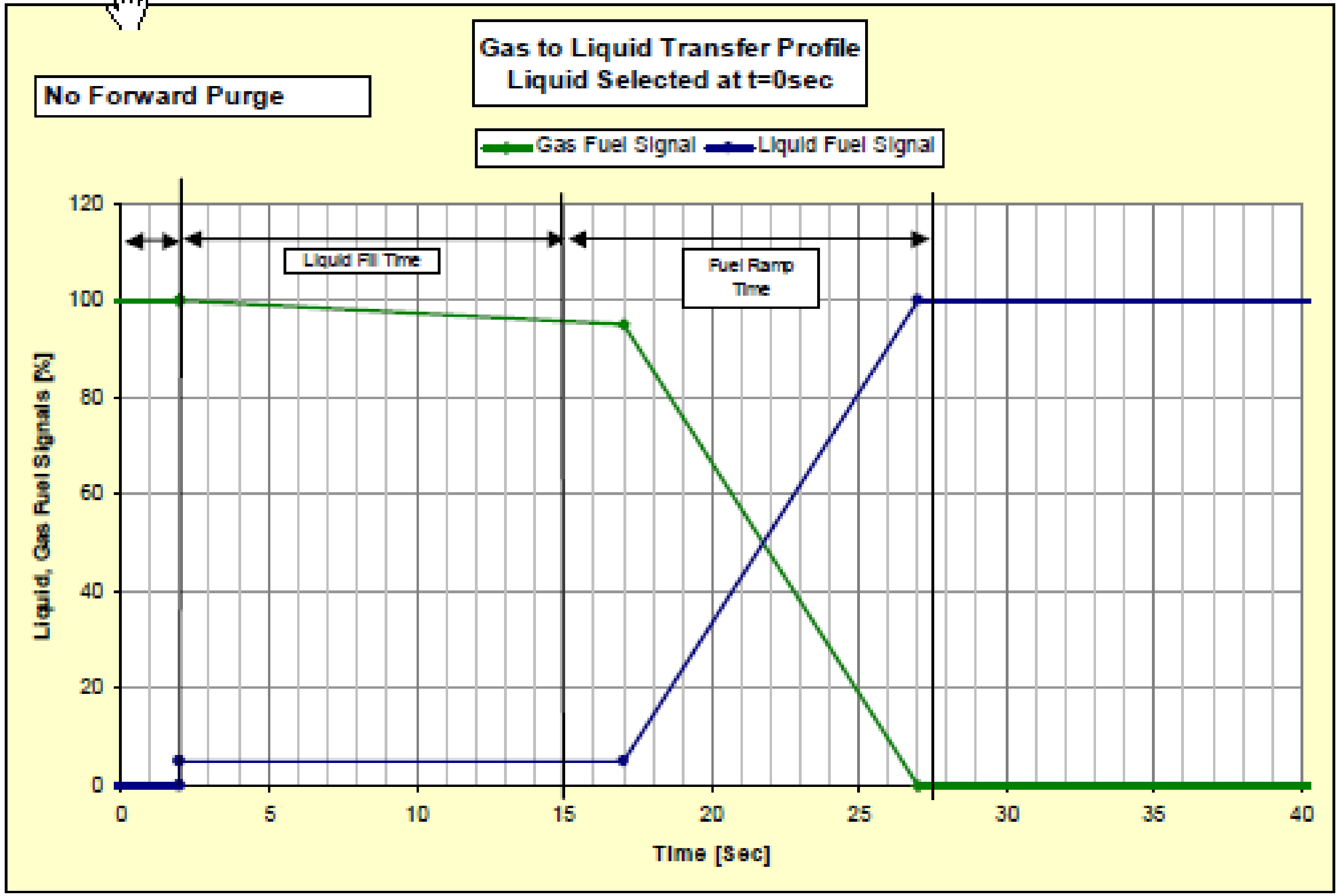
Gas Turbines Have Great Fuel Flexibility

Typical backup fuels

- Kerosene
- Naptha
- Diesel
- LPG
- Bio-diesel





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10 MWe LFG CHP Plant

Coke Oven Gas in China

Hydrogen Refinery Gas in Utah

Digester Gas In Los Angeles

Gasified Municipal Waste in UK

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CHP as a GHG Emission Strategy

The results generated by the CHP Emissions Calculator are intended for educational and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

Annual Emissions Analysis

	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	59.49	97.27	53.25	91.02	60%
SO2 (tons/year)	2.22	166.54	0.26	164.58	99%
CO2 (metric tons/year)	112,661	104,552	57,481	49,372	30%
Carbon (metric tons/year)	30,726	28,514	15,677	13,465	30%
Fuel Consumption (MMBtu/year)	2,087,178	1,338,931	1,064,908	316,661	13%
Acres of Forest Equivalent				13,465	
Number of Cars Removed				8,416	

Displaced Electricity Generation Profile: eGRID State Average All Sources 2014

Region Selected: US Average

This CHP project will reduce emissions of Carbon Dioxide (CO2) by 49,372 metric tons per year

This is equal to 13,465 metric tons of carbon equivalent (MTCE) per year

This reduction is equal to removing the carbon that would be absorbed by 13,465 acres of forest

or

This reduction is equal to removing the carbon emissions from 8,416 cars

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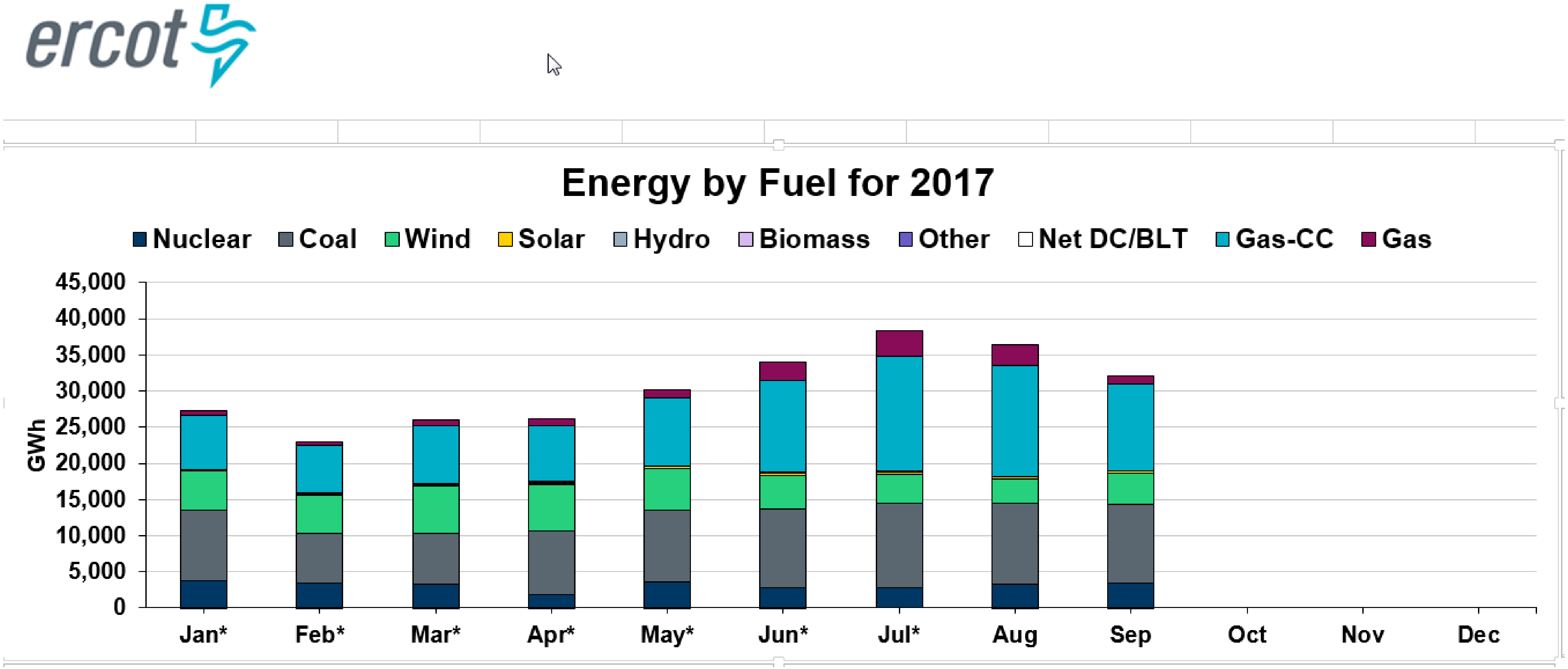
CHP Base Loaded or Dispatchable



Flexible Operating Profile w/ NG Fired CHP

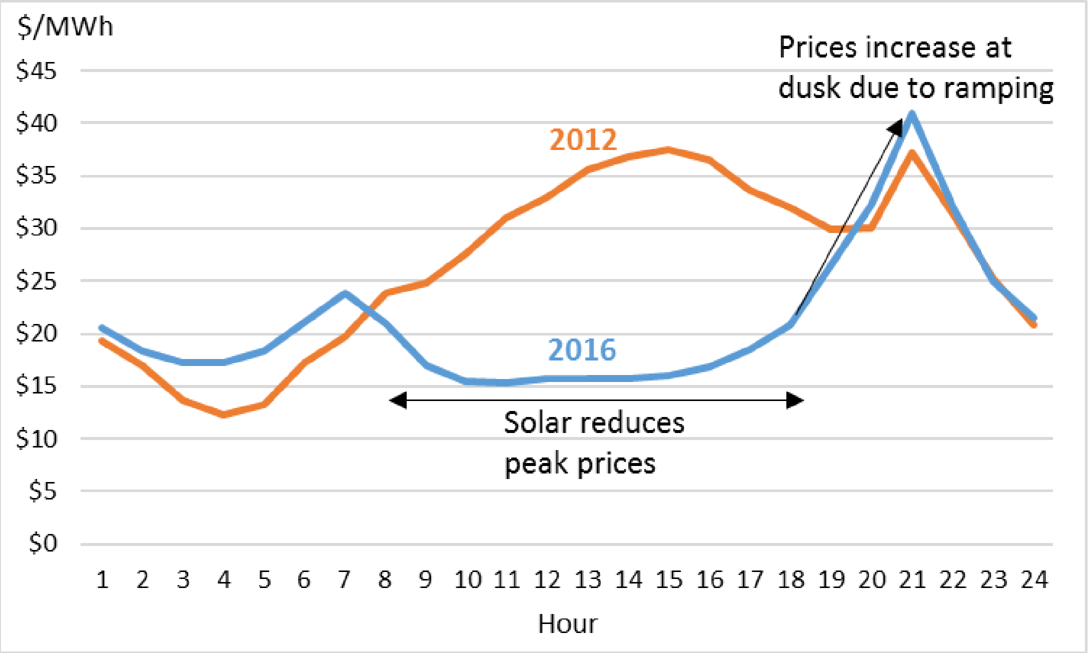
Gas Turbine Load %	Full Load (100%)	85%	70%	55%	50%
Power Output* (MWe)	22.3 MWe	18.9 MWe	15.6 MWe	12.2 MWe	11.1 MWe
Steam Production (kLb/h)	100k pph	100k pph	100k pph	100k pph	60k pph
Efficiency (%) LHV	80.7%	80.8%	81.1%	81.7%	76.3%
Spinning Reserve (MWe)	Overfiring possible	3.4 MWe	6.7 MWe	10.1 MWe	11.2 MWe

*Solar Turbines Model Titan 250
150 psig process steam

"What will the value of instantaneous spinning reserve be worth??"

The ISO Wholesale Energy Market

- Real time market
  - 5 min
  - 15 min
- Day ahead market
- Ancillary services
- Congestion revenue rights (CRRs)
- Convergence bidding

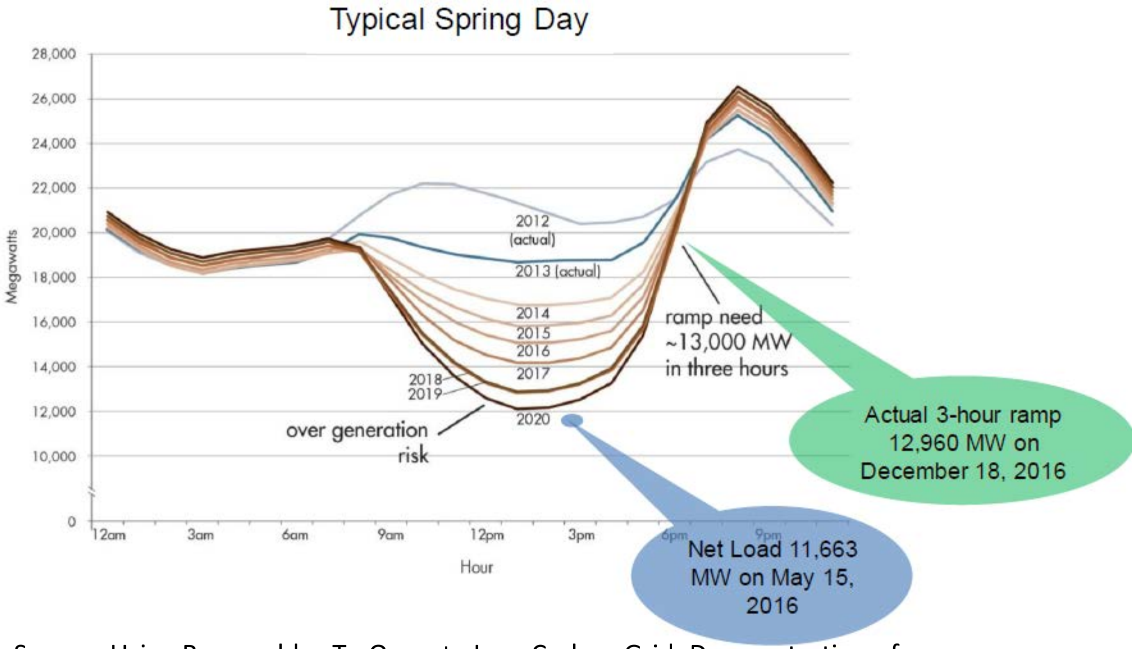


Day-Ahead Average Hourly Electricity Prices at SP-15 (CAISO), May 2012 versus May 2016 Difference in electricity prices between 2012 and 2016 closely resembles the net load duck curve

Source: SparkLibrary, based on data from CAISO

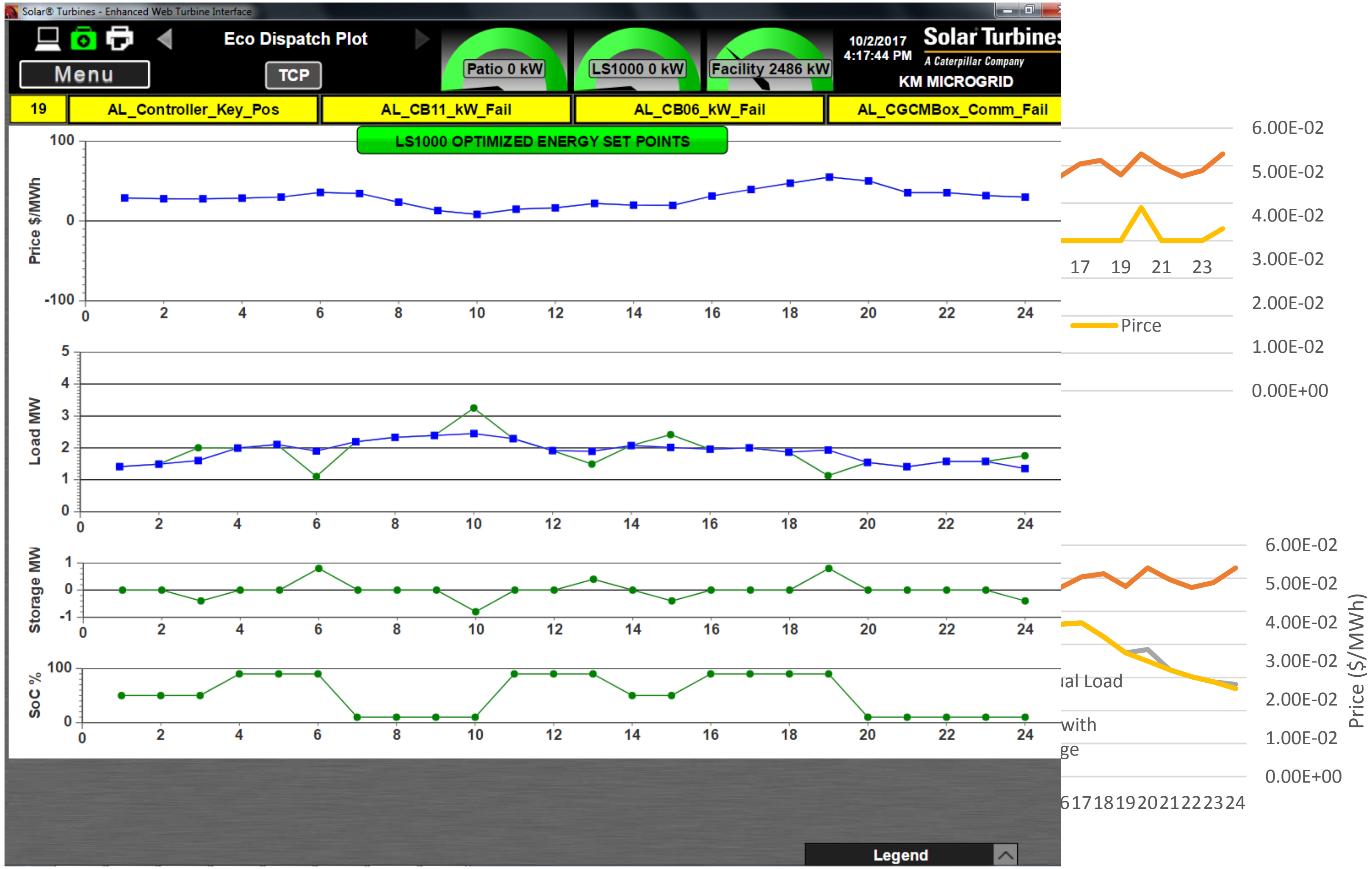
Market is Changing Faster than Anticipated

- The duck curve is more challenging than expected
- Ramp rate is growing
- Potential for microgrid and storage to supplement



Source: Using Renewables To Operate Low-Carbon Grid: Demonstration of Advance Reliability Services from a Utility-Scale Solar PV Plant, California ISO

Economic Dispatch Model



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E_b is the to
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P_s and P_b i
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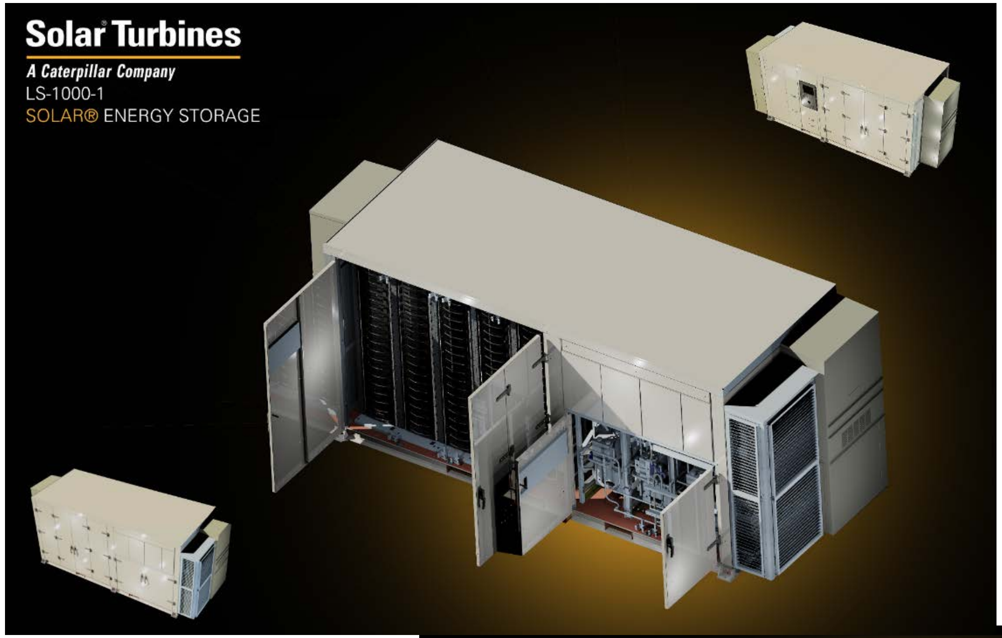
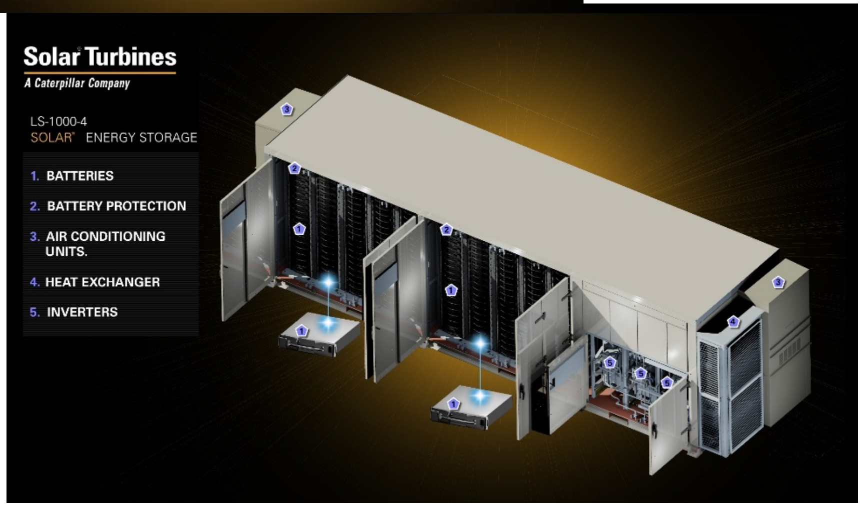
Solar Turbines 1 MWh Energy Storage System

Solar® Energy Storage Product Offerings

- LS1000-1
  - Li-Ion Storage Technology
  - 1000 kW inverter
  - 1 HR Duration
  - 6.875 kWh/ft^2
- LS375-4
  - Li-Ion Storage Technology
  - 375 kW inverter
  - 4 HR Duration
  - 12.25 kWh/ft^2
- LS1000-4
  - Li-Ion Storage Technology
  - 1000 kW inverter
  - 4 HR Duration
  - 17.55 kWh/ft^2





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Cost of Generation w/ CHP

Net Heat Rate Chargeable to Power	3910 BTU/kWh (LHV)
Natural Gas Cost	$5/MMBTU
COE	$0.044/kWh
Capital Cost	$1,507/kW
Annual Maintenance	$1,500,000/y
Steam Production	$6.77/kpph
CHP Plant Assumptions	15,000 kWe
Steam Production Capability	140,000 pph (150 psig, saturated)
Chilling Capacity	4000 tons
Standby Charge	$562,300/y

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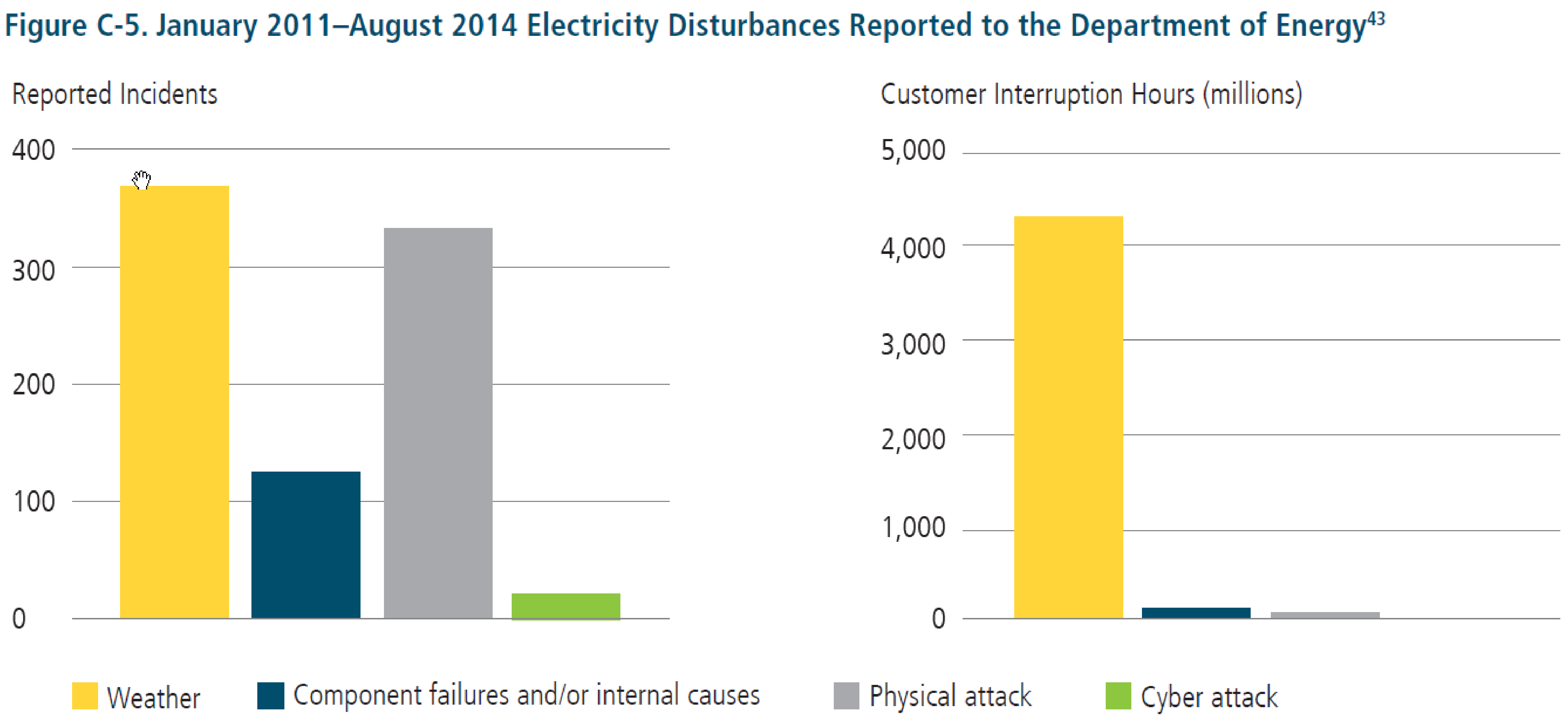
Reliability is a Major Concern



I Hope You Agree, Use CHP !!

Chris Lyons
+1-858-694-6586
clyons@solarturbines.com