Utility Ownership of Combined Heating & Power (CHP) as a Base Load Supply Resource

The Most Efficient Power Generation Resource on the Planet !
Yet, which Few Utilities Evaluate or Deploy as a Supply Resource

Seven Questions Addressing Why this is Changing . . .

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Some Introductory Thoughts

- The Distinguished Audience at the Louisiana Stakeholder Forum means -
- No Need to Introduce You to CHP or the Types of CHP & DG
  - This presentation presents views from 'both sides of the meter'
- Our Industry often Lumps all types of CHP & even DG together into one big pot . . . Even through the MW potential and economics are <u>not the same</u> for all types – especially as it relates to Utility ownership
- Today, my comments and economics discussed regarding utility ownership of CHP are *directed toward Topping Cycle, Industrial Gas Turbine Based CHP which provides the greatest MW potential and the lowest cost of energy*
  - All other forms of CHP/DG have value and key roles to play, but the majority of CHP MW's available are for Industrial /Institutional Power Generation, which is the focus today
  - Louisiana and the Gulf Region are unique with O&G, Chemicals – comments are not directed toward any specific industry or customer segment

Seven Questions Regarding CHP Today . . .

- We keep talking about CHP year after year after year – is it a threat or an (untapped) opportunity for the electric industry?
- Is CHP really more Efficient & Cost Effective than Other Supply Alternatives?
- How does the Electric Utility Industry Evaluate and Deploy CHP?
- What does Utility-Owned CHP look like – Structurally?
- Can Utility-Owned CHP have a Material Impact on the Electric Utility Industry Now and over the next Decade?
- Is Utility-Owned CHP just a Concept, or can CHP be Deployed as an IRP Resource?
- How should Utility Executives and Regulators View CHP?

We keep talking about CHP year after year – is it a threat or an (untapped) opportunity for the electric industry?

Properly Applied CHP is the Most Efficient Method of Generating Power on the Planet. Period !

- CHP based upon long proven gas turbine & recip engine technology – the same technology the industry relies on daily
- In addition to efficiency, CHP provides other benefits, such as operational flexibility, equipment reliability / redundancy, and resiliency from grid disturbances
- For Decades, Utilities pushed the Technology Curve Up to larger, higher pressure, more complex technologies – has the curve turned to recognize more value for smaller, faster, cleaner sources?
- **Wider Deployment of CHP is not a *Technology* issue but a *Structural* Issue – Utility development of CHP eliminates the win/lose dynamic and turns it in to a win/win**

Thomas Edison in 1882 introduced the 1st commercial power grid by the name of "The Pearl Street Station" in lower Manhattan.

Utility Industry – Traditional View of CHP

- Fact: most Utilities have considered CHP as a **Customer-owned** resource for decades thus competitive to utility supply
  - Customer builds and owns CHP – Utility loses load, revenue and income
  - Due to ratemaking process, losses are *on the margin*
  - 25 year NPV of lost 'contribution to fixed costs' from customer installing 15 MW CHP can be over $35MM (more than cost of building CHP)
  - CHP is seldom evaluated as a base load supply resource in IRP process – even though CHP is the most efficient method of generating power available
- Understandably, most Utilities support CHP intellectually, but most still take a NIMBY (not in my back yard) position, not evaluating CHP in their resource planning
- **This is changing with Duke Energy, FPU and others now actively incorporating CHP into their Resource Planning, developing Portfolios of CHP capacity to meet customer base load requirements**

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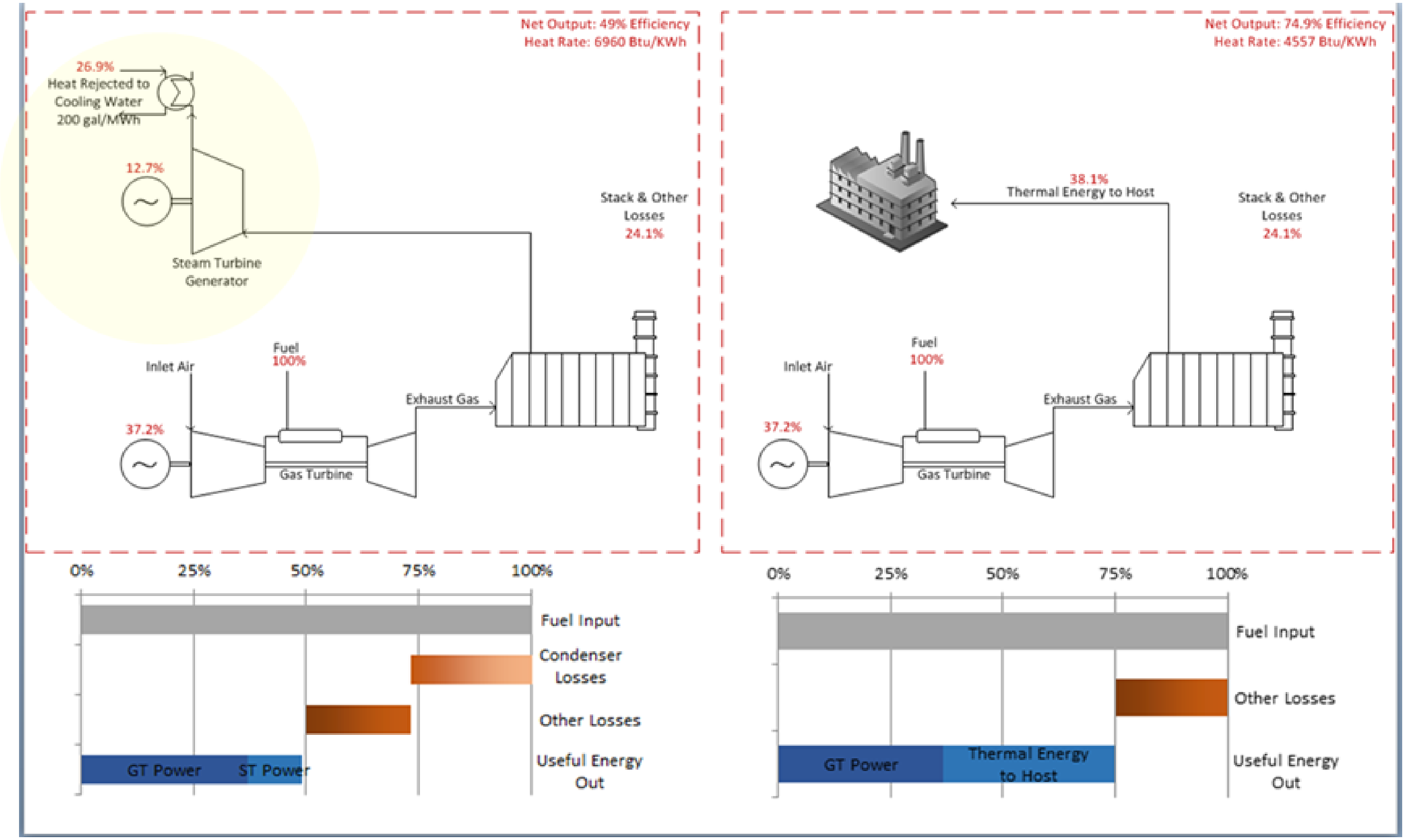
Utility Industry – Newer (Changing) View of CHP

- When Utilities Develop & Own CHP as a Rate Based Supply Asset . . .
  - Utility continues to serve full customer electric load, thus there is <u>no lost load & no lost revenue for utility</u>
  - Utility 'retains' customer via long term agreement - selling electricity plus steam/thermal energy – credited back to fuel, making CHP lowest cost resource
- Host customer and all customers can benefit due to -
  - 20-40% Higher efficiency meaning lower net heat rate and LCOE
  - Retaining customer & load means no need to spread lost contribution to margin to all other customers
    - Customer are less likely to close or leave utility system when under agreement as a CHP host
  - Substantially reduced T&D losses (particularly peak hours when I^2R losses are highest from heat, equipment loading & congestion)
  - Greater system resiliency provided by CHP (both steam and electric)
  - Substantially reduced emissions and low/no water use
  - Avoided future T&D capital investment – site specific
  - Much faster planning and development cycle – helps utilities fine tune expansion plans and avoid over/under building capacity

Is CHP really more Efficient & Cost Effective than Other Supply Alternatives?

- Yes - **Properly applied** CHP is consistently more efficient & lower on a levelized cost of energy basis than any base-load resource including advanced CCCT

CCCT efficiency 50-55% 6960 Btu/kwh **CHP Efficiency 75-80% net 4560 Btu/kwh**



So, how can a 15 to 20 MW CHP be More Cost Effective than an 800 MW Advanced CCCT?

The Answer is Efficiency . . .

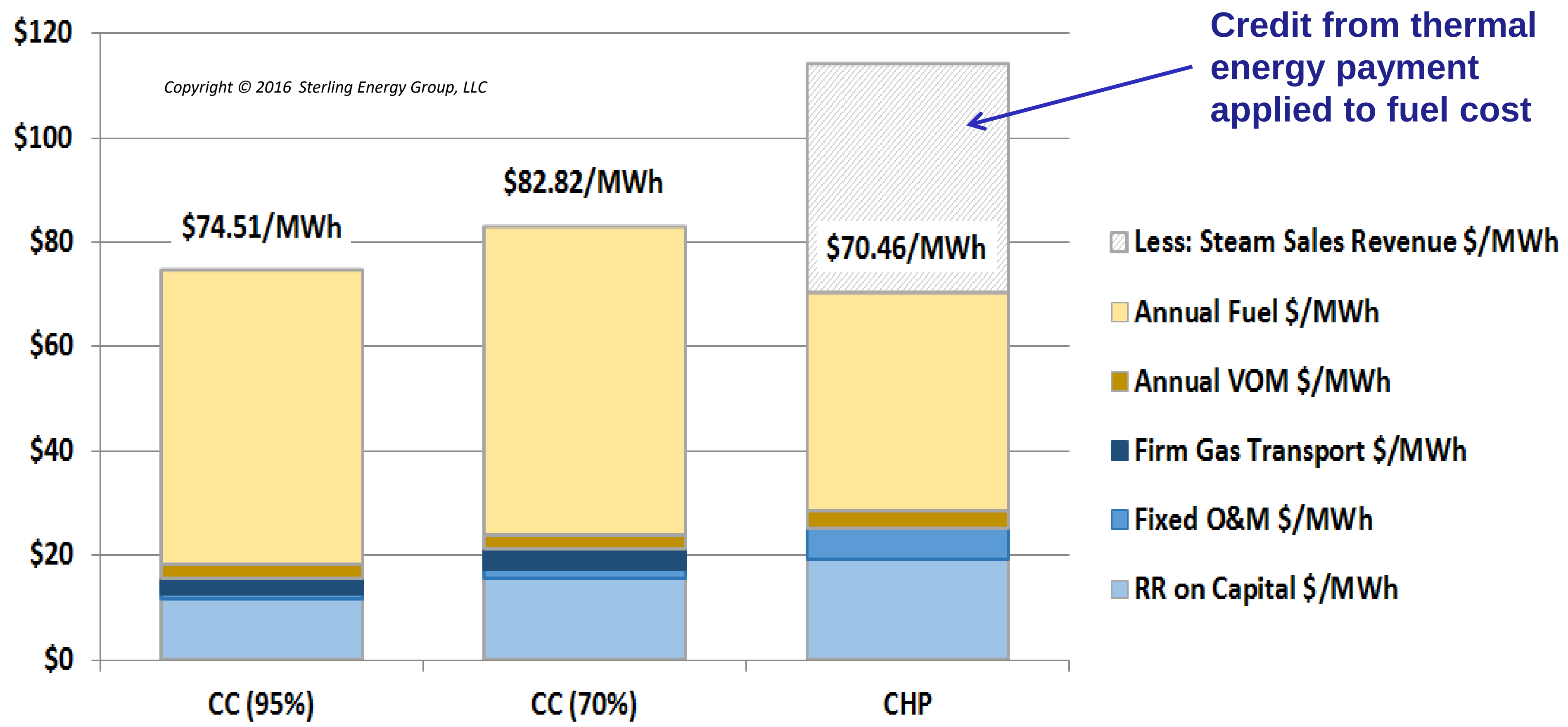
- Well applied Gas Turbine based CHP can achieve 75-80% Efficiency (HHV)
- Advanced CCCT Efficiency can only achieve 50-55% efficiency (HHV) and also incurs T&D losses mostly avoided by CHP (note: HHV = higher heating value)
- Even though cost /kW is more for CHP, 80% of *life cycle* cost is fuel - natural gas. Thus greater efficiency and reduced T&D losses consistently drives the LCOE of well-applied CHP below CCCT
- CHP can operate at full output @ 95-97% capacity where most CCCTs must cycle
  - Average Capacity factor for CCCT in 2015 was 56% with actual operating heat rate up 2-8% above design heat rate

Why is CCCT capped at 55% efficiency while CHP can achieve 80% efficiency?

- In CCCT, steam produced must be condensed to make more power in a Rankine Cycle steam turbine generator system which requires the latent heat (~ 72% of total) in steam be exhausted to atmosphere (wasted)
- In CHP applications, up to 100% of the latent heat in steam can be productively used in process drying or heating thus pushing cycle efficiency to 80%

Levelized Cost of Energy Comparison

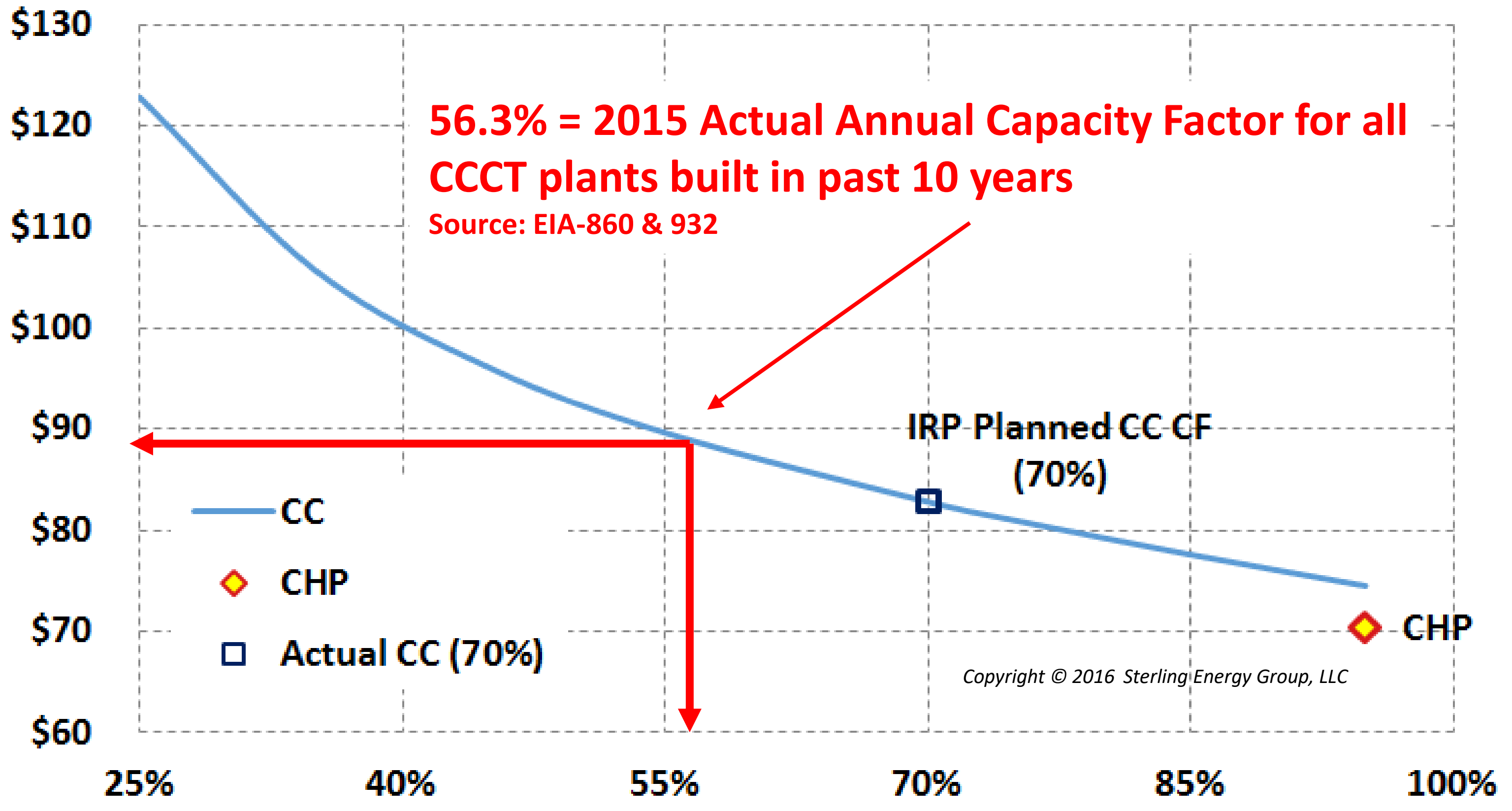
800 MW Advanced CCCT vs 21 MW CHP - with thermal credit to fuel



Notes: LCOE calculations are based upon standard IRP life cycle methodology, for cost of capital, depreciation F & V O&M taken from actual Utility IRP data and cost to construct CCCT and CHP plants. Capacity factors for CC are 95% and 70% with CHP 95%

Levelized Cost of Energy Comparison

800 MW Advanced CCCT vs 21 MW CHP - with thermal credit to fuel



Notes: LCOE calculations are based upon standard IRP life cycle methodology, for cost of capital, depreciation F & V O&M taken from actual Utility IRP data and cost to construct CCCT and CHP plants. Capacity factors for CC are 95% and 70% with CHP 95% Actual CCCT capacity factor of 56.3% from EIA-860 for 2015

How Do Electric Utilities Evaluate CHP in Resource Planning?

- **Most Haven't . . . But this is Changing**
- Duke Energy has included plans in IRP to develop and Own a portfolio of CHP resources in NC, SC and Indiana
- Several other utilities are beginning following a similar path

Technologies Evaluated
TVA 2015 Final IRP are same as most utilities IRP

A study of 20 Public IRP's showed CHP was not evaluated in any, except one which considered it a customer-owned load reduction

INTEGRATED RESOURCE PLAN – 2015 FINAL REPORT

Chapter 5: Energy Resource Options

Nuclear
- Pressurized water reactor (PWR)
- Advanced pressurized water reactor (APWR)
- Small modular reactor (SMR)

Coal fired
- Integrated gas combined cycle (IGCC)
- Supercritical pulverized coal 1x8 (SCPC1x8)
- Supercritical pulverized coal 2x8 (SCPC2x8)
- Integrated gas combined cycle with carbon capture and sequestration (IGCC CCS)
- Supercritical pulverized coal 1x8 with carbon capture and sequestration (SCPC1x8 CCS)
- Supercritical pulverized coal 2x8 with carbon capture and sequestration (SCPC2x8 CCS)

Natural Gas fired
- Simple cycle combustion turbine 3x (CT 3x)
- Simple cycle combustion turbine 4x (CT 4x)
- Combined cycle two on one (CC 2 by 1)
- Combined cycle three on one (CC 3 by 1)

Hydro
- Hydro expansion project where spill permits
- Hydro expansion project where space permits
- Small-head or low-head (run of river) hydro project

Utility-scale Storage
- Pumped-hydro storage
- Compressed air energy storage (CAES)

Wind
- Midcontinent Independent System Operator (MISO)
- Southwest Power Pool (SPP)
- In Valley
- High voltage direct current (HVDC)

Solar
- Utility-scale one-axis tracking photovoltaic
- Utility-scale fixed-axis photovoltaic
- Commercial-scale large photovoltaic
- Commercial-scale small photovoltaic

Biomass
- New direct combustion
- Repowering

Energy Efficiency (EE)
- Residential EE
- Commercial EE
- Industrial EE

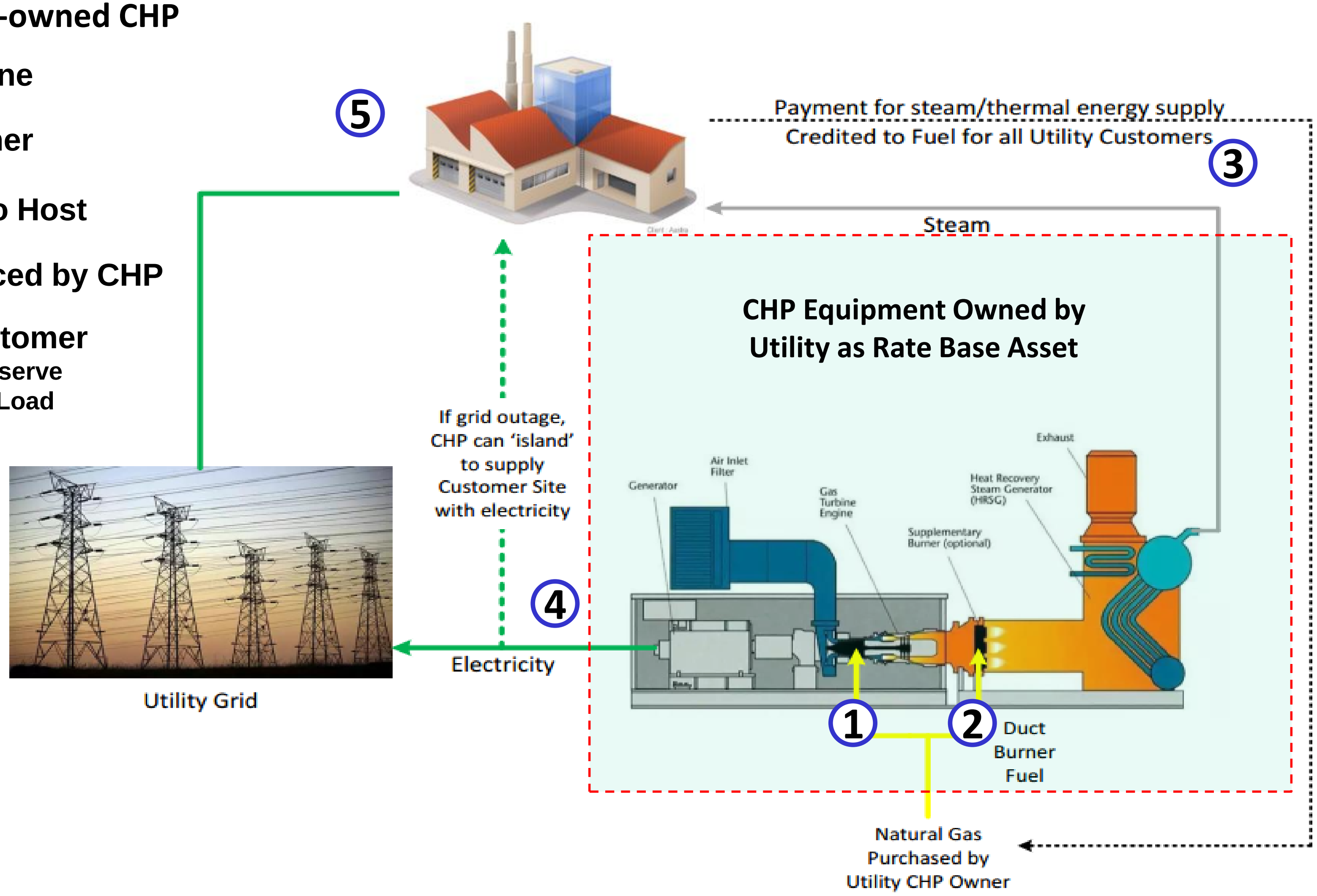
Demand Response

What does Utility-Owned CHP look like – Structurally?

Simplified Structure for Utility-Owned CHP

Meter Points for Utility-owned CHP

1. **Fuel to Gas Turbine**
2. **Fuel to Duct Burner**
3. **Steam/Thermal to Host**
4. **Electricity Produced by CHP**
5. **Electricity to Customer**
   Utility continues to serve Customer Electric Load



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Utility Owned CHP Structure Simplified

1. Utility owns CHP investment as a rate based asset just like all other power generation & T&D investments
   - Utility continues to serve host customer's full electric load – thus no loss of revenue & load to utility
   - Customer makes no capital investment but benefits by having modernized and redundant steam and electric supply on site with zero investment
2. Customer/host contracts to purchase all 'unfired' steam from gas turbine / CHP at price = < customer's cost to produce equivalent steam themselves – Price must assure CHP is a competitive resource
   - Utility credits steam payment back to fuel costs so all customers benefit from a levelized cost of energy below other fossil fueled resources
3. Utility and host Customer execute long term steam, electric and site agreements thus guaranteeing a long term service relationship
   - Should customer close before end of term, must pay 'exit fee' and GT can continue to produce full capacity MW's in simple cycle (as a peaker instead of base load dispatch)

Can Utility-Owned CHP have a Material Impact on the Electric Utility Industry Now and over the next Decade?

Hurdles to Increased Use of CHP

- Financial uncertainty
- CHP cost and performance uncertainty
- Regulatory uncertainty
- Electric utility uncertainty
  - Utility goal is affordable and reliable power
  - Generally neutral to negative on CHP
  - CHP represents a loss of revenue to the utility and can result in the deferral of investment
  - This often results in unfavorable tariffs, drawn out interconnect and other roadblocks to CHP

Institute for Industrial Productivity

Policy actions can reduce perceived risks of CHP and expand the economic potential

- Possible federal policies
  - Continuation of investment tax credit
  - Include CHP as a qualified compliance option under the CPP
  - Federal procurement requirements
  - Encourage CHP participation in ancillary services markets
- Possible state policies
  - Include CHP as a qualified resource in energy efficiency resource standards and rate-payer efficiency programs
  - Standardized interconnection requirements
  - Reasonable standby rates
  - Consider utility ownership
  - Include as a CPP compliance option in state plans

Institute for Industrial Productivity

- **Expanding Deployment of CHP is a National Objective widely supported at the Federal and State Level by both Political Parties**
- **Structural & investment hurdles will continue to keep great sites from being developed**
  - Industrial sector requires 30+% IRR after tax for non core business investment
  - Concern over spark spread over life cycle
  - Unfamiliarity and technology and O&M risks
  - Interconnection and Regulatory policies
- **Utility Ownership Overcomes ALL hurdles**
  - Utilities want to expand rate base investment for allowed ROE 10-12%
  - Utilities have no fuel or spark spread risk
  - Benefit from partnerships with key customers
  - No incentives, decoupling or lost revenue

Can Utility-Owned CHP have a Material Impact on the Electric Utility Industry Now and over the next Decade?

- Currently 82 GW of CHP capacity is installed in US at 8000 sites
  - Some 24% of Louisiana's Generating Capacity is CHP based (1)
- 150,000 MW of 'technical potential' in 4000 sites per DOE
  - Assuming only 15% can be developed a over decade => 20,000 MW

Table III-1: Total CHP Technical Potential across All Facility Types

Business Type	50-500kW		0.5 - 1 MW		1-5 MW		5-20 MW		>20 MW		Total Sites	Total Capacity (MW)
	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)	# Sites	Capacity (MW)		
On-site Industrial CHP	34,502	6,281	6,069	4,341	7,424	15,56[illegible]	1,901	17,036	479	22,157	50,375	65,381
On-site Commercial CHP	185,625	20,068	37,939	18,100	15,535	20,284	1,084	9,452	174	8,026	240,358	75,930
On-site WHP CHP	332	73	132	95	341	868	204	2,003	96	4,585	1,105	7,624
Export Industrial CHP	na	0	na	7	na	3,929	na	11,535	na	65,578	na	81,048
Export District Energy CHP	0	0	0	0	5	18	8	75	51	10,567	64	10,660
Total	**220,459**	**26,422**	**44,140**	**22,543**	**23,305**	**40,666**	**3,197**	**40,101**	**800**	**110,913**	**291,902**	**240,644**

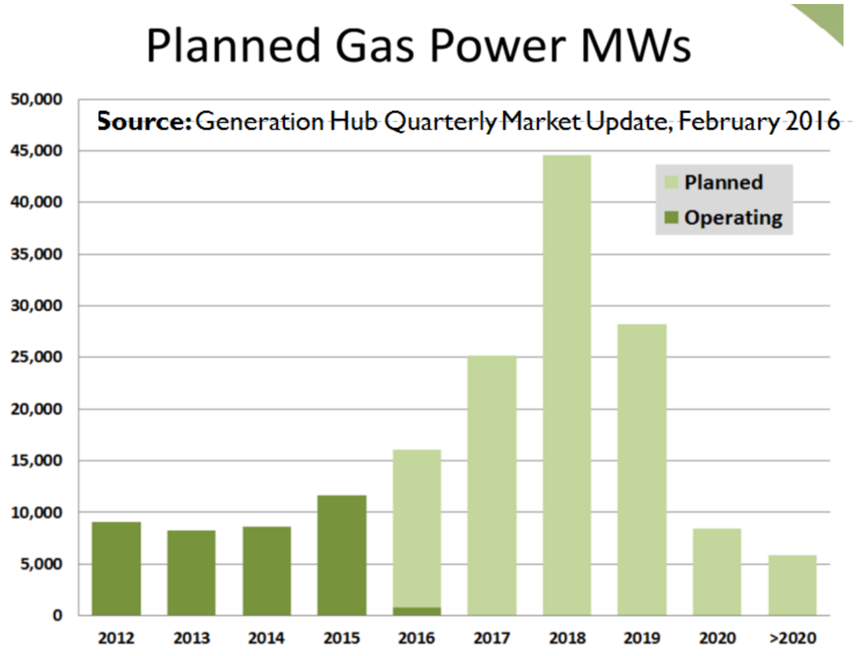
U.S. DOE CHP Deployment Program, 2016.

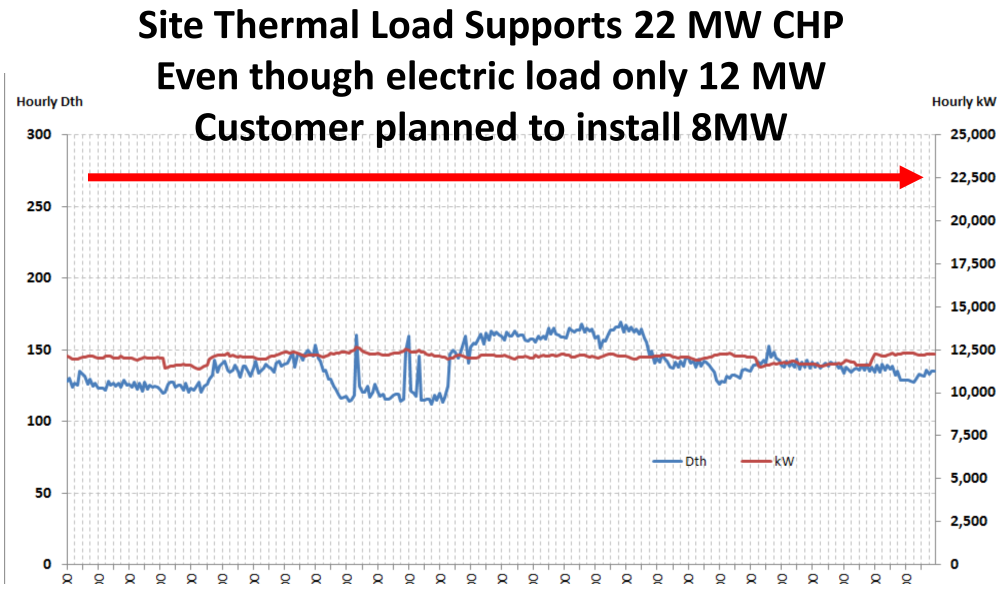
- Sterling Energy has performed detailed engineering heat and power balance analyses for over two dozen utility customer sites for several utilities
  - Over 80% are solid CHP host candidates
  - All were positive and interested in exploring being a CHP 'host' with many being enthusiastic to help facilitate and accelerate projects

1) LSU Center for Energy Studies

Other Factors Support Expanding CHP MW Potential . . .

- With Utility ownership, CHP can be sized to the Thermal load instead of electric load – often increasing MWs by a factor of 2 or 3 times more than what a customer would install
- Some 90% of base load capacity built and to be built in Industry is gas turbine combined cycle – CHP is the same technology just co-located where there are continuous thermal loads and can serve a percentage of future growth



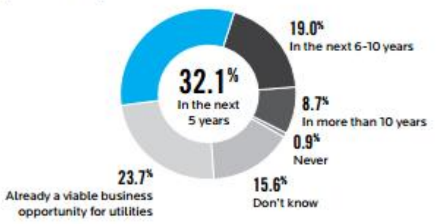


Why Should Utility Executives & Regulators Evaluate CHP?

- **The Electric Utility Industry is Rapidly Changing**
  - Faster, Smarter, Cheaper, Cleaner, Closer to Customer Resources make sense in the Changing Industry Environment
  - CHP has Significant Untapped Potential for Most Utilities and Views are Changing

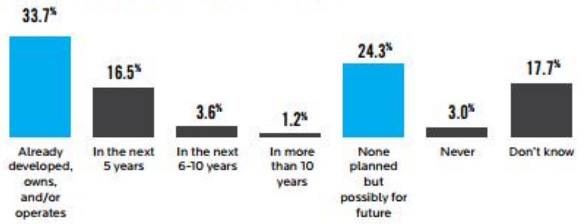
B&V Electric Utility Industry Survey Summer 2016 shows Industry Changing Positon on CHP, Microgrids and DG

Figure 6
When will distributed generation and microgrids become a viable business opportunity for electric utilities? (Select one choice.)



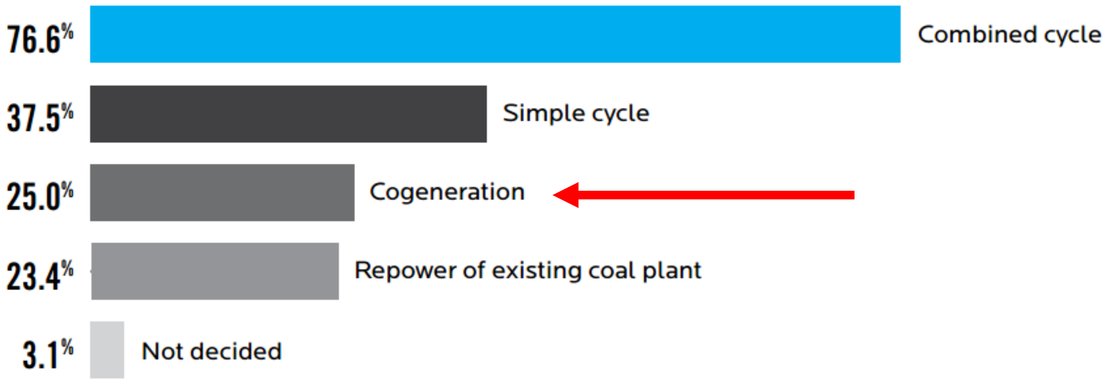
Source: Black & Veatch

Figure 7
[Electric Services Providers] When does your company plan to develop, own and/or operate distributed generation resources, including microgrids? (Select one choice.)



Source: Black & Veatch

Figure 19
What types of configurations are being considered for your natural gas-fired power generation additions? (Select all that apply.)



Source: Black & Veatch

Building in Larger Increments Mean Higher Uncertainty & Greater Risks

INTEGRATED RESOURCE PLAN – 2015 FINAL REPORT

Chapter 6: Resource Plan Development and Analysis

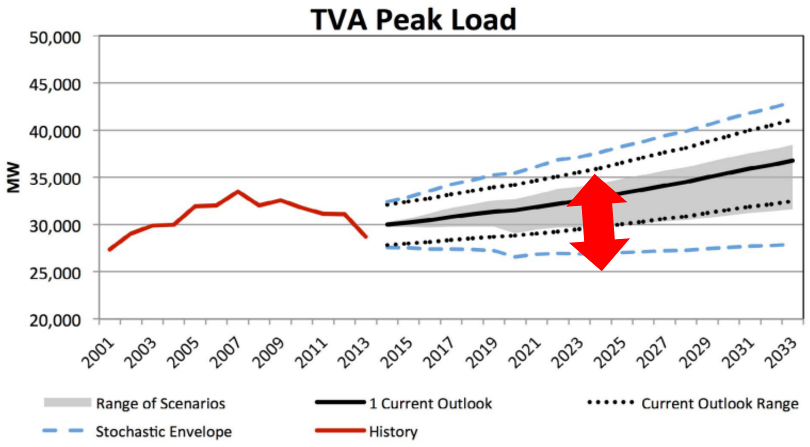


Table 6: TYSP Utilities - Accuracy of Retail Energy Sales Forecasts - Annual Analysis

Year	Years Prior						Average Error	Absolute Average Error
	6	5	4	3	2	1		
2004	-	-4.96%	-3.06%	0.31%	-0.47%	1.05%	**-2.57%**	**2.78%**
2005	-5.79%	-4.00%	-0.66%	-0.60%	0.75%	0.93%	**-1.75%**	**1.75%**
2006	-3.24%	0.02%	1.08%	2.35%	2.48%	2.42%	**1.15%**	**1.15%**
2007	0.61%	2.31%	3.54%	3.63%	4.25%	3.09%	**3.16%**	**3.16%**
2008	7.02%	8.40%	8.55%	9.97%	9.24%	8.34%	**8.97%**	**8.97%**
2009	11.97%	12.17%	14.50%	13.93%	12.70%	10.19%	**13.53%**	**13.53%**
2010	12.94%	15.58%	14.89%	13.70%	10.56%	-0.73%	**14.72%**	**14.72%**
2011	21.39%	20.63%	19.92%	16.86%	3.65%	-0.06%	**19.14%**	**19.14%**
2012	26.30%	25.97%	23.03%	8.47%	3.90%	3.70%	**19.15%**	**19.15%**

Source: 2004 - 2013 TYSPs

As indicated by this high error rate, utilities projected increased need for energy that has not materialized due to the recession. The TYSP utilities have responded to changing circumstances by delaying or cancelling new generation and taking opportunities to modernize existing plants, as discussed in previous annual reviews of the TYSPs.

- Planning horizons for new Resources and Transmission can take a decade or longer which drive greater error in forecasting and greater difficulty maintaining reserve levels at ~ 15% targets
- In TVA forecast at left, there is > 6-8,000 MW swing in only 6-8 years out – if you believe lower forecast, need to be permitting & building more supply today
- If you believe the low forecast, will have soaring reserves
- Longer forecast and planning horizons mean greater uncertainty - evident in the Florida 'forecasting error' analysis
- CHP can be used to refine supply, permitted and built in smaller and faster increments

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Regulators in Florida demonstrate strong support for utility-owned CHP at customer sites

"To see the two economic drivers in this area decide to come together and form this synergy, I think is a fantastic idea and is something that is great to do.

I know there are a lot more opportunities to do this in the Southeast. I would encourage you guys to move forward and drive hard ahead. I'd be more than happy to go to other regulators to let them know what this means for their states."

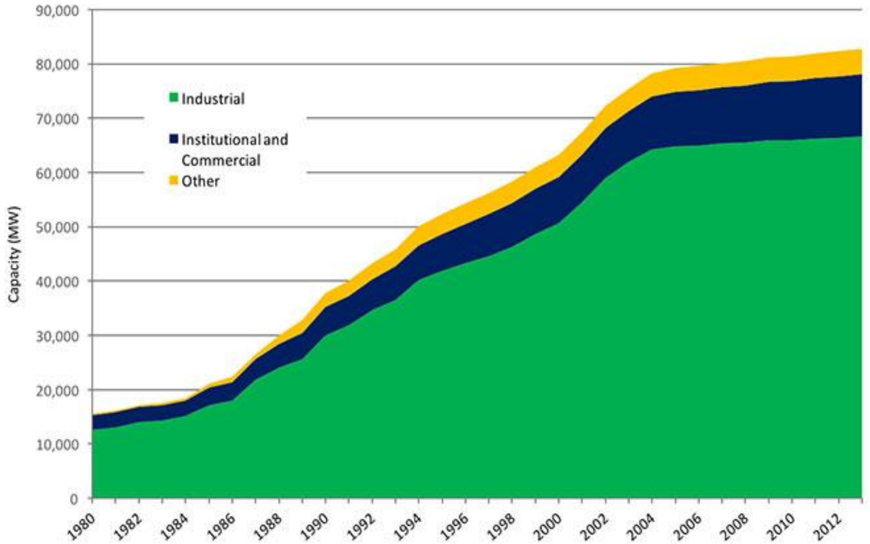
Source: https://www.youtube.com/watch?v=K2LSkEMKn70

CHP is Win/Win for Utility, Host & All Customers

Summary / Next Steps

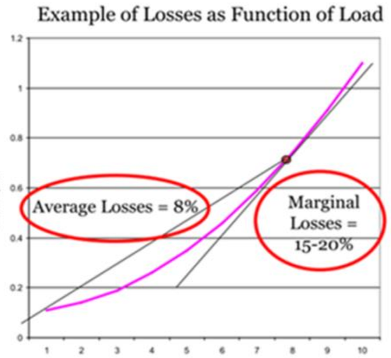
- Today, the US has 82 GW of CHP installed about 8% of all US generation – minimal utility owned
- **This level can be doubled in a Decade with Active Utility Development & Ownership & Active State Regulatory Support**
- Utility owned CHP should be evaluated in every IRP just like EE, CCCT, and other viable supply & demand technologies
- IRP evaluations should include all hard, documentable benefits, not only bus-bar economics
    - Reduced T&D impacts, lower environmental impact, faster planning in smaller increments = lower risk, customer retention, avoidance of lost revenue and other factors

CHP Growth has Slowed



T&D Impact Along Can Justify Some Projects

- Average T&D losses 7-8% based on EPRI studies
- Average system losses typically used in utility ratemaking to recover
- Marginal losses are the change in losses due to change in load
- Marginal losses are highest when load and heat is highest on feeder typically when system costs is highest
- CHP directly reduces load on feeder, reducing losses for host customer but also marginal losses on feeder due to constant lower load



Examples of Utility Ownership

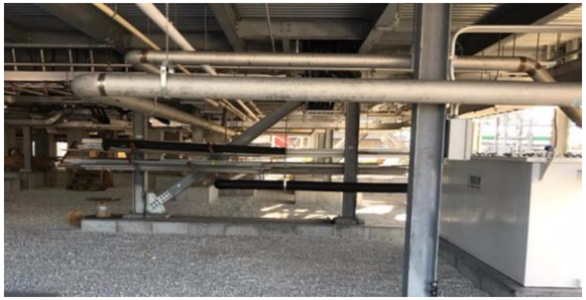
Current Case Examples of Utility CHP and Benefits

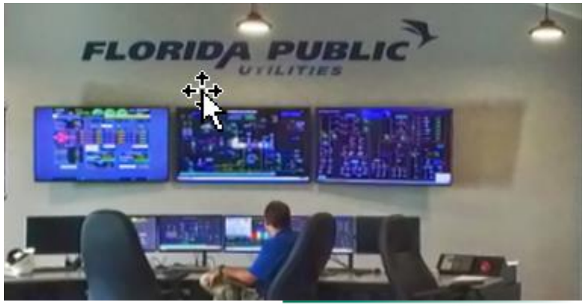
- FPU/Chesapeake – Rayonier 21 MW / 200 kpph Amelia Island, FL
- Operating since July 2016

- Duke University 21 MW /80 kpph under development by Duke Energy

Florida Public Utilities / Rayonier
21 MW CHP Overview – Eight Flags CHP

- FPU/Chesapeake Built, Owns $40MM, 21 MW CHP at Rayonier Advanced Materials (fiber mill) Amelia Is, FL
- CHP provides 21 MW to FPU creating Microgrid for Amelia Island supplying 50% of electricity used versus all power from 40 mile Transmission line
- CHP provides up to 200 kpph steam (75 unfired plus 500 gallons/minute of hot water from waste heat) - Rayonier must 'take or pay' for all unfired steam





CHP Benefits to FPU & their Customers & Rayonier as steam host

For FPU & their Customers

- 20% Lower electric cost to customers than alternatives
- Increased reliability by regional generation forming microgrid on Amelia Island (vs 40 mi radial line)
- Increased local tax base and employment
- 76% efficiency = 80% lower NO_X & 38% lower CO_2

For Rayonier & Community

- Increased steam capacity and electric reliability
- Projected 5-7 days more production /revenue /year
- Ability to expand mill
  - **just announced $125 MM expansion at site - would not have happened without CHP**

Steam, feedwater & hot water lines from CHP to Rayonier under construction

FPU – Rayonier CHP Heat Balance

21 MW / 200kpph 160 psig 420F steam & 550 gpm heated water

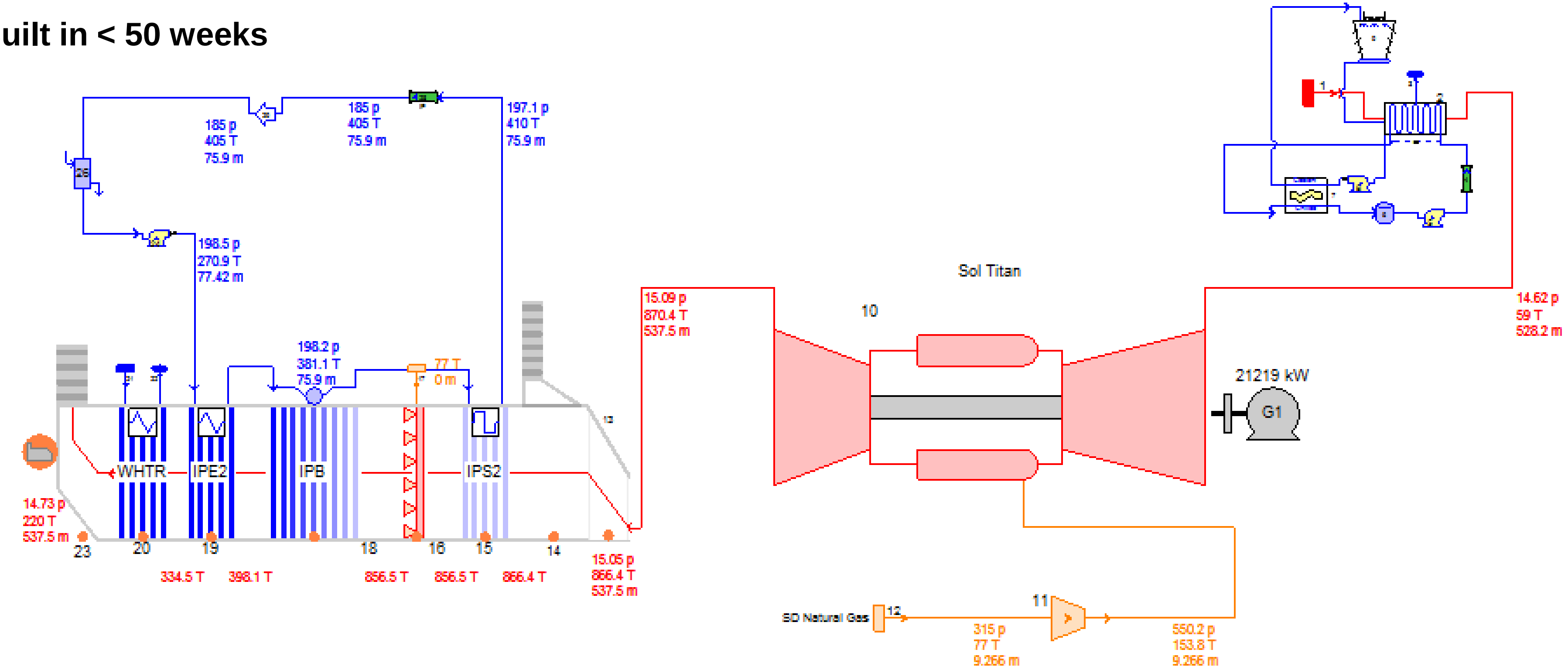
Designed for Resiliency to Survive CAT 4 Storm Surge

Critical equipment Elevated 10' above 8' island grade

800' steam, demin and feedwater lines to Rayonier with low temp economizer

Built in < 50 weeks

Total Efficiency:	**75.6% (HHV) / 83.8% (LHV)**	
Fuel input:	**62 MW**	**211.6 MMBtu/hr**
(Net) Power output:	**20.7 MW**	**70.5 MMBtu/hr**
Total Thermal output:	**26.2 MW**	**89.6 MMBtu/hr**
Steam:	21.7 MW	74.1 MMBtu/hr
Heated Water:	4.5 MW	15.4 MMBtu/hr



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First Test only 3 months after startup

Site Overview

Piling installation

Turbine platform pour

Setting the Titan 250 gas turbine next to generator

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Control and Electric Rooms going up on platform

Pipe Bridge to Rayonier – steam, FW, Demin loop

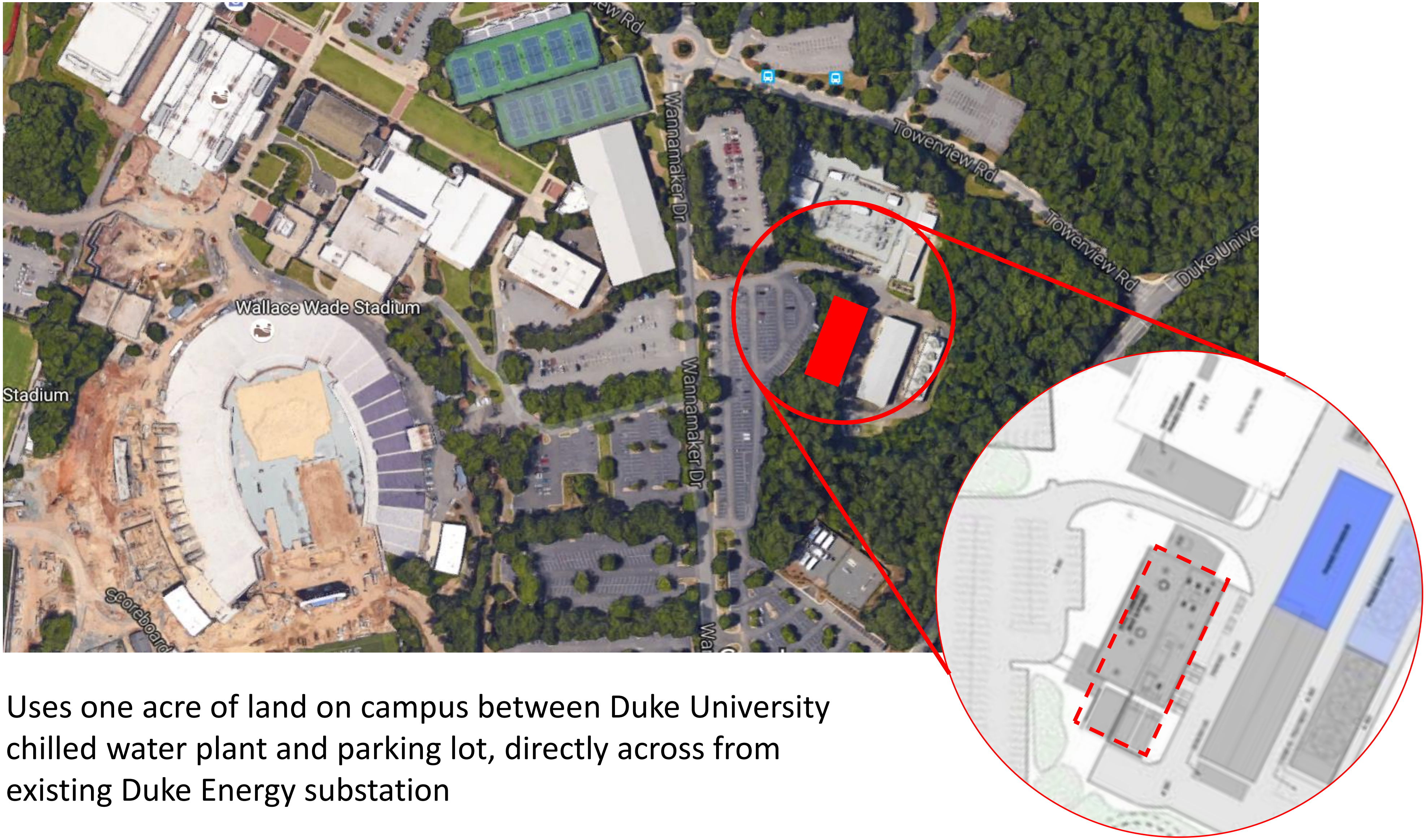
Solar Turbines Titan 250   21.7 MW gas turbine

Control Room

Amelia Island CHP Overview

https://youtu.be/mMuaJfLiAJo

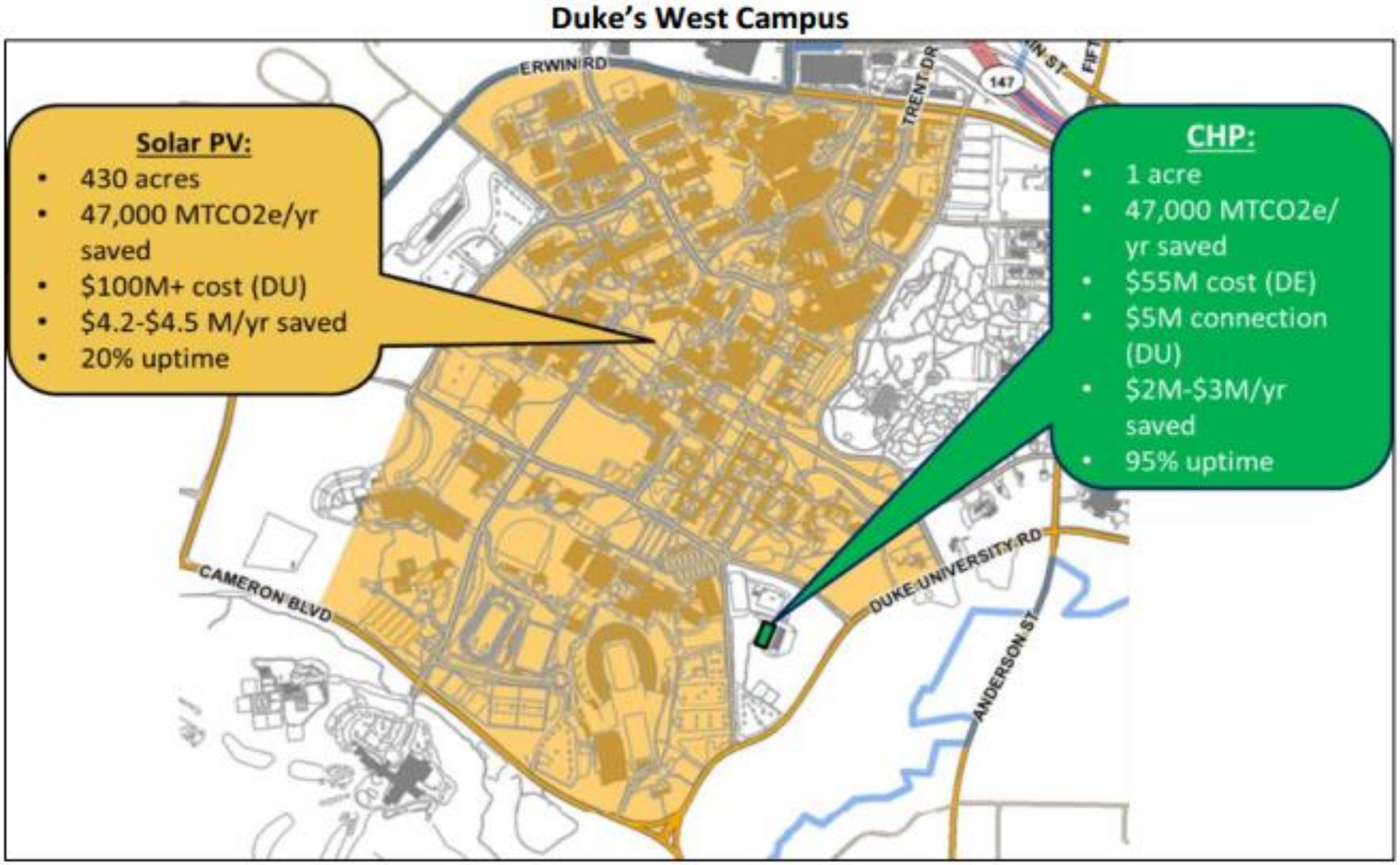
Duke University 21 MW CHP site under development to be owned by Duke Energy



Uses one acre of land on campus between Duke University chilled water plant and parking lot, directly across from existing Duke Energy substation

Duke Energy 21 MW CHP on Duke University Campus Rendering

Comparison of Emission Benefits of 21 MW CHP vs equivalent PV



Source: Duke University Facility Management Group Climate Action Plan Study of Duke Energy proposed 21 MW CHP on campus, October 2016

Benefits: Documented by Duke University

- Increased capacity and resiliency for campus steam system
- Lower cost of steam production
- Increase energy security & resiliency of power supply
  - 20 MW CHP on campus capable of serving all 'critical' loads if grid outage occurs (hospital, life safety, etc)
- Reduces campus emissions 18%
  - Largest reduction identified of all options available in campus CAP

Source: report by Duke University Facilities Management Group, October 2016

Proposed Combined Heat & Power - Building a More Sustainable Duke

Conclusions

As currently proposed, the University views the CHP as having a positive impact on our emissions, North Carolina's emissions and the campus' energy security. However, since this project is contingent on N.C. Utilities Commission approval and agreement of both parties on acceptable contract terms, much could change before a deal is finalized.

- University CAP emissions: **Reduced by 18%**
- Total source energy in NC: **Reduced by 23% - 49%**
- University energy security: **Increased by 20MW**

Duke University infrastructure needs are complex and widespread. The university has commitment to become climate neutral. The CHP coupled with the ability to burn biogas will further reduce CAP emissions and total energy source emissions. The CHP has the potential to be one of the major steps in Duke's goal to become carbon neutral by 2024. But even with its positive impact, the University has substantial work to do to meet the CAP goal of climate neutrality.

So, what's the Risk?

- CHP can be a cleaner and cost effective base load resource totaling thousands of MW's to help meet electric industry growth and clean air goals
- To realize, we must rethink the structure and evaluate the full range of benefits from CHP in Resource Planning - just like the industry has done with EE, DR and traditional supply options